COPY

RECEIVED
SEP 11 2017
WQCC

STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

In the Matter of:

PROPOSED AMENDMENTS TO
GROUND AND SURFACE WATER
***PROTECTION* REGULATIONS,**
20.6.2 NMAC

No. WQCC 17-03 (R)

NEW MEXICO ENVIRONMENT DEPARTMENT'S NOTICE OF INTENT TO PRESENT TECHNICAL TESTIMONY

Pursuant to 20.1.6.202 NMAC and the Revised Procedural Order issued June 2, 2017, the New Mexico Environment Department ("NMED" or "Department") submits this Notice of Intent to Present Technical Testimony for the hearing in this matter currently scheduled for November 14, 2017.

1. Entity for whom the witnesses will testify

The Ground Water Quality Bureau of the Water Protection Division of the Department.

2. Identity of witnesses

The Department will call the following witnesses to present technical testimony at the hearing:

Michelle Hunter is the Chief of the Department's Ground Water Quality Bureau. Her resume describing her educational and professional background is attached as NMED Exhibit 1. A copy of Ms. Hunter's written direct testimony is attached as Exhibit 2.

Dennis McQuillan is the Chief Scientist of the Department. His resume detailing his background and qualifications is attached as NMED Exhibit 4. A copy of Mr. McQuillan's written direct testimony is attached as NMED Exhibit 5.

Blayne Hartman is founder of Hartman Environmental Geoscience in Solana Beach, California. His resume detailing his background and qualifications is attached as NMED Exhibit 5. A copy of Mr. Hartman's written direct testimony is attached as NMED Exhibit 6.

Kurt Vollbrecht is the Program Manager of the Mining Environmental Compliance Section of the Department's Ground Water Quality Bureau. His resume is attached as NMED Exhibit 7. A copy of Mr. Vollbrecht's written direct testimony is attached as NMED Exhibit 8.

3. Estimated duration of direct oral testimony of witnesses

Ms. Hunter	60 minutes
Mr. McQuillan	60 minutes
Mr. Hartman	30 minutes
Mr. Vollbrecht	60 minutes

4. List of exhibits to be offered by the Department at the hearing

A complete list of exhibits that the Department intends to offer into evidence in this matter is attached to this Notice. The Department reserves the right to introduce and move for admission of any other exhibit in support of rebuttal testimony at the hearing.

Respectfully submitted,

NEW MEXICO ENVIRONMENT DEPARTMENT
OFFICE OF GENERAL COUNSEL

By: Lara Katz
John Verheul
Lara Katz
Assistants General Counsel
Post Office Box 5469
Santa Fe, New Mexico 87502
Telephone (505) 383-2063
Fax: (505) 383-2064
Email: John.Verheul@state.nm.us
Lara.Katz@state.nm.us

CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing *The New Mexico Environment Department's Notice of Intent to Present Technical Testimony* was filed with the WQCC Administrator and served on the following via electronic mail on September 11, 2017:

John T. Grubesic
Office of the Attorney General
P.O. Box 1508
Santa Fe, New Mexico 87504-1508
jgrubesic@nmag.gov
Counsel for the Water Quality Control Commission

Jaimie Park
Doug Meiklejohn
New Mexico Environmental Law Center
1405 Luisa St. #5
Santa Fe, New Mexico 87505-4074
jpark@nmelc.org
Counsel for Amigos Bravos and Gila Resources Information Project

Dalva L. Moellenberg
Gallagher & Kennedy, P.A.
1239 Paseo de Peralta
Santa Fe, New Mexico 87501
DLM@gknet.com
Counsel for Dairy Producers of New Mexico and Dairy Industry Group for a Clean Environment

Pete Domenici
Lorraine Hollingsworth
Reed Easterwood
Domenici Law Firm, P.C.
320 Gold Avenue SW, suite 1000
Albuquerque, New Mexico 87102
pdomenici@domenicilaw.com
lhollingsworth@domenicilaw.com
reasterwood@domenicilaw.com
Counsel for City of Roswell and Laun Dry

Louis W Rose
Kari Olson
Montgomery & Andrews, P.A.
P.O. Box 2307
Santa Fe, New Mexico 87504-2307
lrose@montand.com
kolson@montand.com

Timothy A. Dolan
Pranava Upadrashta
Office of Laboratory Counsel
Los Alamos National Laboratory
P.O. Box 1663, MS A187
Los Alamos, New Mexico 87545
tdolan@lanl.gov
Counsel for Los Alamos National Security, LLC

Michael L. Casillo
AFLOA/JACE
1500 W. Perimeter Rd, Suite 1500
Joint Base Andrews, Maryland 20762
michael.l.casillo2.civ@mail.mil
Counsel for United States Air Force

Bill Brancard
Cheryl Bada
1220 South St. Francis Drive
Santa Fe, New Mexico 87505
Bill.Brancard@state.nm.us
Cheryl.Bada@state.nm.us
Counsel for Energy, Minerals and Natural Resources Department

William Olson
14 Cosmic Way
Lamy, New Mexico 87540
billjeanie.olson@gmail.com

Michael Bowen
New Mexico Mining Association
1470 St. Francis Drive
Santa Fe, New Mexico 87505
nmma@comcast.net

Russell Church, President
NMML EQA Subsection
New Mexico Municipal League
P.O. Box 846
Santa Fe, NM 87504
rchurch@redriver.org

Stuart R. Butzier
Christina Sheehan
Modrall, Sperling, Roehl, Harris & Sisk, PA
P.O. Box 2168
Albuquerque, New Mexico 87103-2168
stuart.butzier@modrall.com
christina.sheehan@modrall.com
Counsel for American Magnesium, LLC; Rio Grande Resources Corp.; and New Mexico Copper Corp.

Lara Katz

Lara Katz

WQCC 17-03 (R) Exhibit List

NMED Exhibit 1	Resume – Michelle Hunter
NMED Exhibit 2	Written Direct Testimony – Michelle Hunter
NMED Exhibit 3	EPA Final Guidance on Vapor Intrusion (2015)
NMED Exhibit 4	Resume – Dennis McQuillan
NMED Exhibit 5	Written Direct Testimony – Dennis McQuillan
NMED Exhibit 6	History of Ground Water Protection in New Mexico
NMED Exhibit 7	Comparison chart of existing and proposed groundwater standards
NMED Exhibit 8	Summary of pesticide detections in New Mexico
NMED Exhibit 9	Transcript of WQCC 1985 Rulemaking Proceedings – Testimony of Victor Zalma, M.D.
NMED Exhibit 10	Resume – Blayne Hartman, Ph.D.
NMED Exhibit 11	Written Direct Testimony – Blayne Hartman, Ph.D.
NMED Exhibit 12	Resume – Kurt Vollbrecht
NMED Exhibit 13	Written Direct Testimony – Kurt Vollbrecht
NMED Exhibit 14	WQCC 1967 Regulations
NMED Exhibit 15	WQCC 1977 Regulations
NMED Exhibit 16	WQCC 1991 Regulations - Fees
NMED Exhibit 17	Transcript of April 1991 rulemaking hearing – Testimony of Ernest Rebuck
NMED Exhibit 18	WQCC 2001 Regulations – Definitions Section
NMED Exhibit 19	NMSA 1978, Section 74-6-4 (2004)
NMED Exhibit 20	NMSA 1978, Section 74-6-4 (2005)
NMED Exhibit 21	Discharge Permit Amendment, DP-1055, Chevron Questa Mine (February 23, 2015)
NMED Exhibit 22	Discharge Permit Amendment 06-12, DP-526, Chino Mine (June 8, 2016)

NMED Exhibit 23	Discharge Permit Amendment, Ghost Ranch Conference Center, DP-869 (December 30, 2009)
NMED Exhibit 24	Discharge Permit Amendment Rio Algom Mining, DP-71 (December 12, 2013)
NMED Exhibit 25	Discharge Permit Amendment Delta Person GP, DP-1260 (August 1, 2000)

Michelle Hunter

CHIEF, GROUND WATER QUALITY BUREAU

PROFESSIONAL EXPERIENCE

Ms. Hunter currently serves as the Chief of the Ground Water Quality Bureau for the New Mexico Environment Department. She has over 20 years of experience in the environmental industry, including experience working on groundwater discharge permits and remediation of contaminated groundwater under New Mexico Water Quality Control Comission rules and regulations. In addition to her work with the NMED, she has 15 years of experience in the environmental industry working as a consultant. As Bureau Chief, she is responsible for supervising and managing environmental regulatory personnel of the Ground Water Quality Bureau's Pollution Prevention Section, Remediation Oversight Section, Superfund Oversight Section, Agricultural Compliance Section, and Grants and Planning Section. Her duties include directing and approving the permitting and enforcement of discharge plans, and the investigation and abatement of contaminated soil and ground water pursuant to the New Mexico Water Quality Act and New Mexico Water Quality Control Commission regulations; investigation and remediation of contaminated properties pursuant to the Voluntary Remediation Act and Voluntary Remediation Regulations; investigation and investigation and remediation of abandoned sites in support of the U.S. Environmental Protection Agency (EPA) Superfund Program, and implementation of the new Dairy Rule, 20.6.6 NMAC in permitting Concentrated Animal Feed Operations (CAFOs).

As the Brownfield/Voluntary Remediation Team Lead at the NMED, her duties included project management, workplan and budget review, outreach, and supervision of contractors (environmental consultants) for both large and small environmental projects. Other significant responsibilities included advising municipalities, non-profits, and for-profit developers on cost effective redevelopment strategies and developing inventories of brownfields for future projects. In addition to these technical duties, grant applications and grant reporting, marketing and outreach that include workshops and public presentations were also among her responsbilities. In the Brownfields program, Ms. Hunter gained extensive experience working with 12 of the 22 tribal governments in New Mexico.

As a consultant, Ms. Hunter performed more than 250 Phase I and Phase II environmental site assessments (ESAs), asbestos surveys, lead-based paint surveys, and indoor air quality surveys in anticipation of real estate transactions. She has experience with projects ranging from due diligence for small commercial properties to permitting large industrial manufacturing facilities. She has managed multimillion dollar brownfield redevelopments that included demolition of hexavalent chromium impacted building materials, air quality monitoring, NPDES permitting, POTW permitting, dewatering for subsurface structures, managing hazardous waste, and performing risk assessments for future property use. Her experience includes managing environmental projects at Leaking Petroleum Storage Tank facilities, refinery and gas plant facilities, RCRA hazardous waste generator facilities, and due diligence and redevelopment of former Superfund sites. In addition, as a consultant, Ms. Hunter enrolled and managed sites in the Voluntary Cleanup/Remediation Programs (VRP and SCP) and the Pollution Prevention Section (PPS) of the Ground Water Quality Bureau. One of her areas of expertise includes evaluation of the vapor intrusion pathway for environmental due diligence and redevelopment projects.

EDUCATION

Bachelor of Science, Biological Sciences, 1995, University of New Mexico, Albuquerque, NM

Master's Degree Candidate, Water Resources, 2011-Present, University of New Mexico, Albuquerque, NM

Course work in geology, hydrogeology, engineering, natural resource planning, water and environmental law, environmental chemistry, and water resources

PROFESSIONAL EDUCATION & CERTIFICATIONS

ASTM, Phase I and II ESA Course, 2006 and 2012

40 Hour OSHA Hazardous Waste Site & Waste Management Training

Princeton Groundwater, Hydrogeology

Princeton Grounwater, Groundwater Modeling

WORK HISTORY

NMED-Ground Water Quality Bureau Chief 2015-present

NMED –GWQB-Brownfields Team Leader, 2014-2015

Terracon Consultants, Senior Project Manager, 2014

NMED-GWQB– Santa Fe, NM, Senior Environmental Scientist, 2012-2014

Environmental Partners, LLC–Albuquerque,

PROJECT EXPERIENCE

- Plaza Maya – Voluntary Remediation Program
  Ms. Hunter guided the New Mexico General Services Department (GSD) in a high profile acquisition of an office building in downtown Albuquerque. This building is in the middle of the Fruit Avenue Plume Superfund Site and is the location of a former bus repair facility with a diesel fuel impact. After a review of old site characterization data and newly collected data, Ms. Hunter negotiated with the current owner to enroll the site in the Voluntary Remediation Program and wrote several memos and other documents regarding the environmental risk associated with the acquisition for GSD. In addition, she appeared before the New Mexico Board of Finance, to explain the various environmental issues associated with acquiring the property. After Ms. Hunter's testimony, the Board voted unanamously to purchase the building.

- Santa Fe River Assessment - Downtown Segment, 2012-present
  Ms. Hunter is the project manager for a large Brownfield Community Wide Targeted Brownfield Assessment that evaluates the hydrogeology and geomorphology of 400 acres in downtown Santa Fe. This area of Santa Fe has a very long industrial history and is the home to both state government and the most valuable real estate in New Mexico. The Santa Fe County Judicial Complex remediation and construction were the redevelopment drivers for the study. This Brownfield project used the services of Dr. John Hawley, the foremost expert in the geology of this area, to create a conceptual model of the 400 acre site. This conceptual model allowed us to select locations within the study area to drill four wells for both geomorphological study and ground water quality sampling. The study is on-going and will continue through the Summer of 2015.

- Various Redevelopment Projects, 2012-Present
  As a regulator, Ms. Hunter has reviewed, commented, and guided, with respect to regulatory requirements and budgetary constraints, more than one hundred proposals, workplans, Phase I, Phase IIs, and other submissions from consultants that include: former manufacturing facilities, dry cleaners, former hotels, indian day schools, landfills, and many other environmentally impacted sites slated for redevelopment efforts.

- Review of old Targeted Brownfield Assessment Regulatory files, 2012-Present
  As a regulator, Ms. Hunter reviewed several closed sites with historic soil vapor data to determine the current risk these sites pose to the public. Ms. Hunter found several sites that were closed by the agency, but that require further investigation to ensure that vapor intrusion is not a current problem at these sites. She is spearheading an EPA funded study on nine of these sites to compare historic subsurface data to current screening levels to determine their current risk profile.

- Various Permitting and Due Diligence Projects, 2009-2012
  Ms. Hunter has applied for and received for clients, NPDES permits and Ground Water Discharge Permits. In addition, she has conducted HUD environmental reviews for two Bernalillo County redevelopment projects. Ms.

NM, Senior Scientist/Principal, 2009-2012

ARSA Environmental Laboratory– Albuquerque, NM, Senior Project Manager, 2009-2010

RT Hicks Consultants– Albuquerque, NM, Senior Scientist, 2006-2009

RT Hicks Consultants– Albuquerque, NM, Project Scientist, 2001-2006

RT Hicks Consultants– Albuquerque, NM, Staff Scientist,1998-2001

Assaigai Laboratory – Albuquerque, NM, QA/QC Officer/Project Manager Assistant, 1996-1997

Assaigai Laboratory – Albuquerque, NM, Organics Lab Analyst, 1995-1996

Geoscience Consultants, Albuquerque, NM, Intern Co-op Student, 1990-1991

Hunter entered two sites into the Voluntary Remediation Program during this timeframe, one site had a trespassing chlorinated solvents plume with vapor intrusion (the first VI site for the NMED VRP), and the other was a former concentrated animal feed operation in the South Valley of Albuquerque where nitrogen contamination is ubiquitous.

- Icon Emeryville – Emeryville, CA, 1999-2009
  Ms. Hunter conducted a Phase I ESA for the acquistion of a former chrome plating facility for purchase by a developer. The property had a thirty year environmental regulatory history with approximately one year of post remediation monitoring. Ms. Hunter completed the Phase I, conducted a Phase II that included identification of asbestos in the former facility and successfully closed the ground water environmental file with the San Francisco Bay Regional Water Quality Control Board. She developed a demolition and environmental redevelopment plan that included air monitoring in a high profile section of Emeryville (2000 feet from San Francisco Bay), a soil management plan, and a vapor barrier for protection of indoor air quality. The dot com crash in 2000 necessitated a re-evaluation of the development plan and the new plan required a residential scenario at the site. Ms. Hunter performed a risk assessment and after a third party peer review by the City of Emeryville's consultant and the state regulatory agency, presented the results at a planning meeting with the city of Emeryville. The residential scenario was accepted and redevelopment continued at the site. Additional bioremediation was required and Ms. Hunter managed the project through additional remediation, the worst flooding in recent Bay Area history, which required an ion exchange treatment system for stormwater, an NPDES permitting effort, and off-haul of both California Hazardous Waste and RCRA Hazardous Waste from soil excavation activites at the site. Ultimately, the site went to litigation (between the developer and the Responsible Party) and Ms. Hunter served as an expert witness during the arbitration.

- ICON - San Diego 2002-2008
  Ms. Hunter conducted two years of environmental due diligence including a Phase I and Phase II ESA at the future site of a four tower condominium complex adjacent to the new Petco Park Stadium in downtown San Diego. The site was the former location of a Carnation dairy and ice cream plant that had eight leaking underground storage tanks. The redevelopment included saving a historic façade and a 40-foot underground parking garage which required a large dewatering effort. The dewatering included treatment of the ground water and subsuequent

permits with the City of San Diego and the State Water Resources Control Board. Ms. Hunter's scope included characterization and off-haul of impacted soil and total demolition of the structures at the site.

- Various Ground Water Monitoring Sites
  As a staff and project scientist, Ms. Hunter was responsible for the planning and execution of large scale ground water sampling events at many types of environmental sites that include, commercial and manufacturing facilities, refineries, gas plants, and industrial sites. She has a broad knowledge of analytical methodologies and laboratory protocols for environmental characterization, abatement, groundwater and surface water permitting, and RCRA characterization and disposal.

STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

In the Matter of:

PROPOSED AMENDMENTS TO **No. WQCC 17-03 (R)**
GROUND AND SURFACE WATER
***PROTECTION* REGULATIONS,**
20.6.2 NMAC

DIRECT TESTIMONY OF MICHELLE HUNTER

My name is Michelle Hunter, and I am the Chief of the Ground Water Quality Bureau ("Bureau") within the Water Protection Division of the New Mexico Environment Department ("Department" or "NMED"). I am presenting this written testimony on behalf of the Department in this proceeding on proposed revisions to the Water Quality Control Commission's ("Commission's") Ground and Surface Water Protection Regulations at 20.6.2 NMAC ("Groundwater Regulations" or "Part 20.6.2").

I. QUALIFICATIONS

I hold a Bachelor's of Science degree in Biology from the University of New Mexico, and have recently completed all course work for a Masters of Water Resources Hydroscience degree, also from the University of New Mexico. I have approximately 20 years of experience working on ground water discharge permits and remediation of contaminated ground water under the New Mexico Water Quality Act, NMSA 1978, §§ 74-6-1 to -17 ("WQA"), and the Ground Water Regulations. In addition to my experience working with New Mexico's statutes and regulations, I spent ten years working as an environmental consultant in the State of California under that state's various environmental regulatory frameworks for protection of groundwater, the generation and disposal of hazardous waste, surface water protection, air quality protection, and underground storage tank cleanups.

I have held the position of Chief of the Bureau since May of 2015. As Bureau Chief, I am responsible for supervising and managing environmental regulatory personnel of the Bureau's Pollution Prevention Section, Remediation Oversight Section, Superfund Oversight Section, Agricultural Compliance Section, and Grants and Planning Section. My duties include directing and approving the permitting and enforcement of discharge plans; investigation and abatement of contaminated soil and ground water pursuant to the WQA and the Regulations; investigation and remediation of contaminated properties pursuant to the Voluntary Remediation Act and Voluntary Remediation Regulations; investigation and remediation of abandoned sites in support of the U.S. Environmental Protection Agency ("EPA") Superfund Program; and implementation of the Commission's Dairy Rule, 20.6.6 NMAC in permitting Concentrated Animal Feed Operations ("CAFOs").

After working as an environmental consultant for fifteen years, I joined the Bureau as senior technical staff on the Remediation Oversight Section Brownfields team in January 2012 and then served as the Brownfield/Voluntary Remediation Program Team Leader from June 2014 until May 2015, when I became the Bureau Chief.

A copy of my resume is attached as NMED Exhibit 1. It is current and accurate.

II. INTRODUCTION

Part 20.6.2 has not been updated or substantially amended in over 22 years. Thus, while New Mexico was the first state to adopt numerical standards for the protection of groundwater, many of the numerical standards listed in 20.6.62.3103 NMAC are woefully out of date. In fact, several of the 20.6.62.3103 NMAC organic chemical standards are orders of magnitude higher – meaning less stringent – than the federal drinking water standards adopted by EPA. The 3103 standards, along with other areas of Part 20.6.2, need to be brought up to current practices and standards.

As is the case with the Groundwater Regulations generally, the Department's Petition in this matter is fundamentally about protection of all ground water resources in New Mexico. New Mexico is an arid state, with limited water resources. As the State's population and economy grow and develop, a greater demand is placed on these limited resources. Groundwater serves as a source of drinking water for approximately 95 percent of New Mexicans, and is the sole drinking water resource for approximately 70 percent. To protect these resources, the Legislature enacted the WQA in 1967, and the Commission adopted the first regulations to protect all surface and subsurface waters in New Mexico in that same year, with substantial revisions 1977. These regulations have undergone a number of significant revisions over the years, 1982, 1983, 1986, 1995, 2001, 2004, and 2006.

In addition to protection of potential drinking water, the protection of subsurface waters includes all subsurface water in the vadose zone. The vadose zone, or the unsaturated zone, contains water that becomes groundwater, which can migrate along with chemicals that end up volatilizing from liquid to gas phase, creating contaminated soil gas that can either migrate downward to groundwater or upward into the indoor air of buildings and into utility corridors, exposing people to toxic air. EPA's realization that migration of chlorinated solvents into indoor air through groundwater and soil pollution into Silicon Valley homes ultimately became the driver to include vapor intrusion into the Superfund Hazard Ranking System. This is a glaring example of how our understanding of environmental issues has come a long way since the Commission added the abatement regulations to Part 20.6.2 in 1995, which is also the last time the Groundwater Regulations were substantially amended. This 2017 petition is our attempt to reestablish New Mexico as a leader in the regulatory protection of groundwater.

III. DEVELOPMENT OF PROPOSED AMENDMENTS AND PUBLIC OUTREACH

On May 1, 2017, the Department submitted its Petition with its proposed changes to Part 20.6.2 to the Commission and requested that the Commission set a hearing on the Petition. The Petition was the culmination of a process that began in 2015, when the Bureau first set out to identify areas within 20.6.2 NMAC that required updating, and develop regulatory language to implement those changes. In May of 2016, the Department held a public meeting in Santa Fe to discuss the proposed changes that had been developed, which at that time included changes to clarify abatement language, changes to three organic solvent standards, adding provisions to address vapor intrusion, raising permit fees, adding geothermal regulatory oversight language, and adding email notification to the regulations. In June of 2016, the Department issued a "Public Discussion Draft" of the proposed amendments for a 60-day public comment period. Following receipt of comments on that initial draft, the Department revised the proposed amendments and issued a second "Public Discussion Draft" for a 30-day comment period. The Department then held five additional public meetings comprised of meetings in Roswell, Las Cruces, Farmington, Albuquerque in September of 2016, and a "web-ex" online listening session in November of 2016. In addition to these public meetings, the Department reached out to numerous stakeholders including the Municipal League, the Dairy and Mining Industries, the U.S Departments of Energy and Defense, Amigos Bravos, the Gila Resources Information Project ("GRIP"), and others to engage these organizations in dialog regarding their suggestions and comments on the revised rules. The Bureau continued to engage, meet, and discuss potential edits to the language with stakeholder groups up through July 2017, when the Department submitted its final revised petition to the Commission.

IV. PROPOSED AMENDMENTS

My testimony will address the proposed amendments to the rules that are administrative or general in nature, as well as the issue of vapor intrusion. Dennis McQuillan will testify regarding changes to the definition of and standard for Toxic Pollutants and the numeric standards in 20.6.2.3103 NMAC, along with some exemptions to the discharge permit requirement in 20.6.2.3105 NMAC. Blayne Hartman, Ph.D., will testify regarding the need for regulation of vapor intrusion. Kurt Vollbrecht will address changes associated with discharge permit amendments, variance petitions, alternative abatement standards.

I will briefly discuss the reasons for the proposed amendments that are not being addressed in the testimony of Mr. McQuillan, Mr. Hartman, and Mr. Vollbrecht.

Section 20.6.2.7

The Department proposes to re-format the definitions numbering system to simplify future edits and to add a definition for “discharge permit amendment.” Mr. Vollbrecht’s testimony discusses the basis for the proposed definition of “discharge permit amendment.”

Section 20.6.2.1201

The Department proposes changes that incorporate the recently enacted Geothermal Resources Development Act, NMSA 1978 Sections 71-9-1 to -11. That statute defines geothermal energy as a resource in excess of 250°F which is subject to regulation by the Energy Conservation Management Division of the Energy, Minerals and Natural Resources Department. The proposed changes to Section 20.6.2.1201 would therefore require that notices of intent to discharge geothermal resources as defined in the Geothermal Resources Development Act be submitted to the Energy Minerals and Natural Resources Department.

Section 20.6.2.3108

Subsection A – The Department proposes to add 75 days to the response period for receipt of a discharge permit application that requires additional information. The reason for the additional time is associated with the work load, staffing issues, resource constraints, and the required collaboration between the permit reviewer (permit writer) and the staff member who sends out the administratively incomplete/complete letter to the permittee. The additional time will allow the processing of higher quality PN1 and PN2 administratively complete documents for review by the public while not imposing a great hardship on the regulated community. No additional fees are proposed under this rulemaking that could otherwise be used to offset this need for additional time.

Subsection B – The Department proposes to add electronic mail to the provision addressing written notice to surrounding properties. Regular United States Postal Service mail is used less frequently than in the past, and many people now prefer correspondence via email. Thus, the Department is adding electronic mail to the rule to codify that electronic mail is an acceptable way to provide notice.

Section 20.6.2.3109

Subsection C – The Department proposes to add language to meet the statutory threshold of the Water Quality Act with respect to notifying those who participated in the discharge permitting action. The Water Quality Act was amended in 2009 to provide for notice of any action taken with respect to a discharge permit to be provided to persons who participated in the permitting action, in addition to the applicant or permittee. NMSA 1978, Section 74-6-5.N. The Department proposes updating 20.6.2.3109 to align with the Act.

Subsection F – The Department proposes to delete language regarding the location of the definition of toxic pollutants within the regulations.

Section 20.6.2.4101

The Department proposes to amend the language in the regulation to include the oversight of volatilization of vapor phase pollution from subsurface impacts.

The regulatory framework for the protection of groundwater should include the protection of indoor air from pollution originating in the groundwater or vadose zone beneath that building or utility corridor. The remediation efforts at these sites must clean up the pollution in the soil and groundwater. The purpose of an environmental cleanup is to stop the exposures and potential exposures that result from that pollution. Surprisingly, groundwater and soil contamination can also result in toxic impacts to indoor air as the result of environmental pollution present beneath a property. EPA has recently addressed such impacts in its newly published Superfund Hazard Ranking System ("HRS") criteria amendment; specifically, potential vapor intrusion exposure is now included as a highly weighted exposure pathway for inclusion of a site on the CERCLA National Priority List.

It took 22 years for EPA to codify Vapor Intrusion as criteria to rank a Superfund site. As early as the late 1990's, several Silicon Valley Superfund sites began to evaluate the risks associated with the migration of the chlorinated solvents from semi-conductor facilities into homes near these facilities. By 2002, EPA had developed a draft guidance document, followed by final guidance document in 2015, *Assessing and Mitigating the* Vapor Intrusion *Pathway from Subsurface Vapor Sources to Indoor Air* (June 2015). A copy of this guidance document is attached hereto as NMED Exhibit 3. In addition, recent concern over malformation of hearts in fetuses due to short-term exposures of trichloroethylene (“TCE”) vapors to pregnant mothers has resulted in recent (within the past 3 years) policies/memos by many EPA regional offices, including Regions 3, 6, 7, 9, and 10, as well as numerous states, such as California, Ohio, and Massachusetts, regulating the upward migration of TCE vapors from contaminated groundwater and soil.

The regulatory oversight of groundwater includes the vadose zone and contamination in that medium. Indoor air impacts attributable to vadose zone or groundwater impacts should be regulated and cleaned up as part of the environmental cleanup abatement efforts.

Mr. Hartman’s testimony also addresses vapor intrusion.

Section 20.6.2.4103

The Department proposes to amend the language in the regulation to allow the Department to require deed restrictions or other institutional controls on properties where groundwater does not meet standards required for unrestricted use. The Department believes these controls may be needed as part of post-closure care to protect sites from undue injury from avoidable construction that would disturb affected soils and groundwater (e.g., utility line construction), or to protect public health by preventing new well installation.

Section 20.6.2.4104

Subsection C – The Department proposes to amend the language in the regulations to expressly provide that the Department may require financial assurance from responsible parties that are cleaning up groundwater under the abatement regulations, so that the State is not left with the responsibility of cleaning-up a site or plugging and abandoning monitoring wells. The proposed revision recognizes that the need for financial assurance is not limited to those sites that may, for one reason or another, have once been issued a discharge permit. Because groundwater protection must extend to all areas of the state regardless of prior regulated activity, abatement extends to all sites, whether they have been issued a discharge permit or not. In short, this proposal expressly allows the Secretary to require a responsible party to provide financial assurance for abatement of groundwater pollution at a site even if no discharge permit was ever issued for that particular site or responsible party.

Subsection D – The Department is proposing language to include funding agreements for large complex abatement sites to pay for the regulatory oversight of facilities that take significant staff hours. This type of funding has been utilized by the Department with several responsible parties including BNSF, LANL, KAFB, Hewlett Packard and others. Given current funding and resource constraints faced by the Department, allowing for compensation for oversight actions provided by NMED staff is prudent.

Section 20.6.2.4105

Subsection C – The Department proposes to delete language that is no longer needed due to the change in location within the regulations of the Toxic Pollutant definition.

Section 20.6.2.5003

The Department proposes to add language to include the new Geothermal Resources Development Act, NMSA 1978, §§ 71-9-1 to -11, in the Underground Injection Control (“UIC”) regulations.

Section 20.6.2.5004

Subsection A – The Department proposes to add language to the UIC regulations to include geochemical and physical parameters in the requirements for an Aquifer Storage Recharge (“ASR”) project. These parameters are important components of water quality that must be reviewed and likely modeled prior to an injection into an Underground Source of Drinking Water. The proposed changes expand on the term additional “contaminants,” as currently used in this subsection, incorporating both an additional constituent (i.e., contaminant), along with a physical parameter that would not readily be identified as a contaminant, such as pH, oxidation or reduction potential, or temperature.

Section 20.6.5005

The Department proposes to include a provision that requires permittees and responsible parties to provide a copy of their well plugging and abandonment plan. These plans are provided to and approved by the Office of the State Engineer. The proposed change would simply require that a copy of the OSE submission be provided to the Department.

Section 20.6.5006

The Department proposes to include language that eliminates any perceived exemptions from the UIC permitting requirements. The current language could be interpreted as containing an exemption from a UIC permit for ASR projects. The federal UIC regulations, for which New Mexico has primacy, does not exempt aquifers designated as Underground Sources of Drinking Water. ASR projects, by definition, inject into such aquifers, and thus, those projects cannot be exempt from the UIC regulations as a matter of federal law.

Section 20.6.2.5101

The Department proposes to add language in this section to include the Surface Mining Act, NMSA 1978, §§ 69-25A-1 to -36; the Oil and Gas Act, NMSA 1978, §§ 70-2-1 to -38; the new Geothermal Resources Development Act, NMSA 1978, §§ 71-9-1 to -11, in the Underground Injection Control regulations for permit applications that should be sent to Energy Minerals and Natural Resources Department (see above discussion on Section 20.6.2.1201).

This concludes my written direct testimony.

OSWER Publication 9200.2-154

OSWER TECHNICAL GUIDE FOR ASSESSING AND MITIGATING THE VAPOR INTRUSION PATHWAY FROM SUBSURFACE VAPOR SOURCES TO INDOOR AIR

U.S. Environmental Protection Agency

Office of Solid Waste and Emergency Response

June 2015

NMED EXHIBIT 3

DISCLAIMER

This document presents current technical recommendations of the U.S. Environmental Protection Agency (EPA) based on our current understanding of vapor intrusion into indoor air from subsurface vapor sources. This guidance document does not impose any requirements or obligations on the EPA, the states or tribal governments, or the regulated community. Rather, the sources of authority and requirements for addressing subsurface vapor intrusion are the relevant statutes and regulations. Decisions regarding a particular situation should be made based upon statutory and regulatory authority. EPA decision-makers retain the discretion to adopt or approve approaches on a case-by-case basis that differ from this guidance document, where appropriate, as long as the administrative record supporting its decision provides an adequate basis and reasoned explanation for doing so.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

ACH	air changes per hour (air exchanges per hour)
ADT	active depressurization technology
AER	air exchange rate
ANSI	American National Standards Institute
ASQ	American Society for Quality
ASTM	American Society for Testing and Materials
ASTSWMO	Association of State and Territorial Solid Waste Management Officials
ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	benzene, toluene, ethylbenzene, xylenes
BWD	block-wall depressurization
CalEPA	California Environmental Protection Agency
CASRN	Chemical Abstracts Service Registry Number
CEI	Community Engagement Initiative
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHC	chlorinated hydrocarbon
CIC	Community Involvement Coordinator
CIO	Chief Information Officer
CIP	community involvement plan
CMS	corrective measures study
CSM	conceptual site model
DCE	dichloroethylene, or equivalently dichloroethene
DNAPL	dense non-aqueous-phase liquid
DoD	U.S. Department of Defense
DoN	U.S. Department of Navy
DQO	data quality objective
DTD	drain-tile depressurization
EI	environmental indicator
EPA	U.S. Environmental Protection Agency
ERT	Environmental Response Team
FR	Federal Register
FS	feasibility study

FYR	five-year review
HI	Hazard Index
HQ	Hazard Quotient
HVAC	heating, ventilation and air conditioning
IC	institutional control
ICIAP	Institutional Controls Implementation and Assurance Plan
IDLH	immediately dangerous to life or health
ITRC	Interstate Technology and Regulatory Council
LCR	lifetime cancer risk
LEL	lower explosive limit
LEP	limited English proficiency
LNAPL	light non-aqueous-phase liquid
LTS	long-term stewardship
MADEP	Massachusetts Department of Environmental Protection
NAPL	non-aqueous-phase liquid
NAS	National Academy of Sciences
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFA	No Further Action
NIST	National Institute of Standards and Technology
NPL	National Priorities List
NRC	National Research Council
NIOSH	National Institute for Occupational Safety and Health
NYSDOH	New York State Department of Health
O&M	operation and maintenance
OIG	Office of the Inspector General
OSC	on-scene coordinator
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OUST	Office of Underground Storage Tanks
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene, or equivalently tetrachloroethene
PEM	preemptive mitigation
PID	photoionization detector

P.E.	Professional Engineer
ppbv	parts per billion by volume
PRP	potentially responsible party
QAPP	quality assurance project plan
QMP	quality management plan
RCRA	Resource Conservation and Recovery Act
RfC	inhalation reference concentration
RFI	RCRA facility investigation
RI	remedial investigation
RME	reasonable maximum exposure
ROD	Record of Decision
RPM	remedial project manager
SMD	sub-membrane depressurization
SSD	sub-slab depressurization
TAGA	trace atmospheric gas analyzer
TCE	trichloroethylene, or equivalently trichloroethene
UFP-QAPP	Uniform Federal Policy for Quality Assurance Project Plans
UECA	Uniform Environmental Covenants Act
USPS	U.S. Postal Service
UST	underground storage tank
UU/UE	unlimited use/unrestricted exposure
VI	vapor intrusion
VISL	vapor intrusion screening level
VOC	volatile organic compound

EXECUTIVE SUMMARY

Definition and Description of Vapor Intrusion

Vapor intrusion is the general term given to migration of hazardous vapors from any subsurface vapor source, such as contaminated soil or groundwater, through the soil and into an overlying building or structure. These vapors can enter buildings through cracks in `basements and foundations, as well as through conduits and other openings in the building envelope. Vapors can also enter structures that are not intended for human occupancy (e.g., sewers, drain lines, access vaults, storage sheds, pump houses) through cracks and other openings.

All types of buildings, regardless of foundation type (e.g., basement, crawl space, slab-on-grade), have openings that render them potentially vulnerable to vapor intrusion. Buildings subject to vapor intrusion include, but are not limited to, residential buildings (e.g., detached single-family homes, trailer or 'mobile' homes, multi-unit apartments and condominiums), commercial workplaces (e.g., office buildings, retail establishments), educational and recreational buildings (e.g., schools and gyms), and industrial facilities (e.g., manufacturing plants).

Vapor intrusion is a potential human exposure pathway -- a way that people may come into contact with hazardous vapors while performing their day-to-day indoor activities. For purposes of this Technical Guide, the vapor intrusion pathway is referred to as "complete" for a specific building or collection of buildings when the following five conditions are met under current conditions:

1) A subsurface source of vapor-forming chemicals is present (e.g., in the soil or in groundwater) underneath or near the building(s) (see Sections 2.1, 5.3, 6.2.1, and 6.3.1);

2) Vapors form and have a route along which to migrate (be transported) toward the building (see Sections 2.2 and 6.3.2);

3) The building(s) is(are) susceptible to soil gas entry, which means openings exist for the vapors to enter the building and driving 'forces' (e.g., air pressure differences between the building and the subsurface environment) exist to draw the vapors from the subsurface through the openings into the building(s) (see Sections 2.3 and 6.3.3);

4) One or more vapor-forming chemicals comprising the subsurface vapor source(s) is(are) present in the indoor environment (see Sections 6.3.4 and 6.4.1); and

5) The building(s)[1] is(are) occupied by one or more individuals when the vapor-forming chemical(s) is(are) present indoors.

---

[1] For purposes of this Technical Guide and its recommendations for evaluating human health risk posed by vapor-forming chemicals, "building" refers to a structure that is intended for occupancy and use by humans. This would include, for instance, homes, offices, stores, commercial and industrial buildings, etc., but would not normally include sheds, carports, pump houses, or other structures that are not intended for human occupancy.

A complete vapor intrusion pathway indicates that there is an opportunity for human exposure, which warrants further analysis (see Section 7.4) to determine whether there is a basis for undertaking a response action(s) (see Section 7.7). Depending upon building- and site-specific circumstances, concentrations of chemical vapors indoors arising from a complete vapor intrusion pathway may threaten the health of building occupants (e.g., residents, workers, etc.), which may warrant a response action(s).

On the other hand and for purposes of this Technical Guide, if one (or more) of the five foregoing conditions is currently absent and is reasonably expected to be absent in the future (e.g., vapor migration is significantly and persistently impeded by natural geologic, hydrologic, or biochemical (e.g., biodegradation) processes and conditions), the vapor intrusion pathway is referred to as "incomplete." EPA recommends that any determination that the vapor intrusion pathway is incomplete be supported by site-specific evidence to demonstrate that the nature and extent of vapor-forming chemical contamination in the subsurface has been well characterized (Section 6.3.1) and the types of vapor sources and the conditions of the vadose zone and surrounding infrastructure do not present opportunities for unattenuated or enhanced transport of vapors (Sections 5.4 and 6.5.2) toward and into any building (see Section 7.3 for further discussion). When the vapor intrusion pathway is determined to be incomplete, then vapor intrusion mitigation is not generally warranted.

EPA recommends that site managers also evaluate whether subsurface vapor sources that remain have the potential to pose unacceptable human health risks due to vapor intrusion in the future[2] if site conditions were to change. The vapor intrusion pathway is referred to as 'potentially complete' for a building when:

- a subsurface source of vapor-forming chemicals is present underneath or near an existing building or a building that is reasonably expected to be constructed in the future;
- vapors can form from this source(s) and have a route along which to migrate (be transported) toward the building; and
- three additional conditions are reasonably expected to all be met in the future, which may not all be met currently; i.e.,
    - the building is susceptible to soil gas entry, which means openings exist for the vapors to enter the building and driving forces exist to draw the vapors from the subsurface through the openings into the building;
    - one or more vapor-forming chemicals comprising the subsurface vapor source(s) is (or will be) present in the indoor environment; and
    - the building is or will be occupied by one or more individuals when the vapor-forming chemical(s) is (or are) present indoors.

---

[2] "Both current and reasonably likely future risks need to be considered in order to demonstrate that a site does not present an unacceptable risk to human health and the environment." (EPA 1991a).

In addition to their toxicity threats, methane and certain other vapor-forming chemicals can also pose explosion hazards depending upon structure-, building-, and site-specific circumstances. Explosion hazards may pose an imminent and substantial danger to human health and public welfare.

Technical Guide Development and Recommended Uses

To help assess the subsurface vapor intrusion pathway, the Office of Solid Waste and Emergency Response (OSWER) released in November 2002 for comment EPA's *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* ("Draft VI Guidance"). Since the Draft VI Guidance was released, EPA's knowledge of and experience with assessment and mitigation of the vapor intrusion pathway has increased considerably, leading to an improved understanding of and enhanced approaches for evaluating and managing vapor intrusion. In addition, EPA received hundreds of comments from the public since 2002 on the Draft VI Guidance, on a public review draft issued in April 2013, and on emerging practices and science considerations.

This Technical Guide presents current technical recommendations of the EPA based on our current understanding of vapor intrusion into indoor air from subsurface vapor sources. One of its main purposes is to promote national consistency in assessing the vapor intrusion pathway.[3] At the same time, it provides a flexible science-based approach to assessment that accommodates the different circumstances (e.g., stage of the cleanup process) in which vapor intrusion is first considered at a site and differences among pertinent EPA programs. This Technical Guide is intended for use at any site (and any building or structure on a site) being evaluated by EPA pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or the corrective action provisions of the Resource Conservation and Recovery Act (RCRA), EPA's brownfield grantees, or state agencies acting pursuant to CERCLA or an authorized RCRA corrective action program where vapor intrusion may be of potential concern. This document and the accompanying *Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites* (EPA 2015b)[4] supersede and replace the Draft VI Guidance.

Although this Technical Guide is intended for use at any site subject to federal statutes, regulations, and rules, it is not intended to alter existing requirements, guidance, or practices among OSWER's programs about development, selection, or documentation of final remediation[5] plans (addressing subsurface vapor sources, for example).

---

[3] If EPA staff wish to consider using any specific guidance that is not explicitly recommended in this Technical Guide, they should consult with Headquarters.

[4] For petroleum hydrocarbons that arise from petroleum that has been released from Subtitle I UST systems, EPA has developed a companion to this Technical Guide (*Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites* (EPA 2015b)), which provides information and guidance about how EPA recommends vapor intrusion be assessed for petroleum hydrocarbons in these settings.

[5] For purposes of this Technical Guide, "remediation" is intended to apply to interim and final cleanups, whether conducted pursuant to RCRA corrective action, the CERCLA removal or remedial programs, or using EPA brownfield grant funds with oversight by state and tribal response programs. In addition to permanent remedies for subsurface vapor sources, site remediation may also entail implementation of institutional controls and construction and operation of engineered systems for exposure control.

Document Content and Key Recommendations

This document is comprised of eleven sections and three appendices, including a list of acronyms, which precedes this summary, and a glossary of terms in Section 10. Section 3 provides an overview of the entire Technical Guide and can be further summarized as follows:

- Broadly speaking, two general levels of vapor intrusion assessments can be distinguished:

  1) A <u>preliminary analysis</u>, which utilizes available and readily ascertainable information to develop an *initial* understanding of the potential for human health risks to be posed by vapor intrusion, which would typically be performed as part of an initial site assessment (Section 5).

  2) A <u>detailed investigation</u> (Section 6), which is generally recommended when the preliminary analysis (e.g., Section 5.3) indicates that subsurface contamination with vapor-forming chemicals may be present underlying or near buildings. A detailed investigation of the vapor intrusion pathway is typically performed as part of the site investigation stage.

  The approach for assessing vapor intrusion will vary from site to site, because each site will differ in the available data when vapor intrusion is being evaluated. This Technical Guide, therefore, recommends a framework for planning and conducting vapor intrusion investigations, rather than a prescriptive step-by-step approach to be applied at every site.

- Response actions to address vapor intrusion when it poses unacceptable human health risks (Sections 7.7 and 8) typically entail a combination of:

  - remediation to reduce or eliminate subsurface vapor sources (Section 8.1);
  - engineered exposure controls for specific buildings to reduce vapor intrusion or reduce concentrations of vapor-forming chemicals that have already entered the building (Section 8.2);
  - monitoring to assess and verify the performance and effectiveness of the remediation systems and engineered exposure controls (Section 8.4); and
  - institutional controls (ICs) to restrict land use and/or to alert parties (e.g., prospective developers, owners, and municipalities) of the presence of subsurface sources of vapor-forming chemicals and to foster operation, maintenance, and monitoring of the remediation systems and engineered exposure controls (Section 8.6).

  Additional response actions to avoid or reduce human exposure may also warrant consideration in circumstances where “early” or prompt response action is appropriate to address indoor air exposure conditions or a potential for explosion hazards.

Additional key recommendations and policies comprising this document include the following:

Planning, Scoping and Conducting Investigations (see Sections 5.4 and 6.2 for further information)

- Consider site and building access agreements, equipment security, and locations of underground utilities and piping, such as storm and sewer lines within buildings, when planning vapor intrusion investigations (Section 6.2).

- Develop an initial conceptual site model, use this model to guide planning and scoping of the investigation, and update this model as additional information and insights are generated (Sections 5.4, 7.1, and 7.2).

- Generally limit chemical analyses to those vapor-forming chemicals known or reasonably expected to be present in the subsurface environment.

- Consider a “worst first” approach to prioritize buildings for investigation at sites where numerous buildings are potentially subject to vapor intrusion (Section 6.2.2).

- To the extent practical, plan and implement investigations within buildings and on individual properties with the goal of limiting return visits, which can cause disruption and inconvenience for building occupants and owners (Section 6.2).

- Generally assess the vapor intrusion pathway by collecting, weighing, and evaluating multiple lines of evidence (Sections 6.3, 7.1, and 7.2).

- Utilize 100 feet to define an initial lateral inclusion zone for vapor intrusion assessment (i.e., for identifying buildings that are ‘near’ a subsurface vapor source and generally warrant assessment) for purposes of a preliminary analysis). Investigate soil vapor migration distance (e.g., define inclusion zone(s) for assessing vapor intrusion in specific buildings) on a site-specific basis. That is, distances larger or smaller than 100 feet (i.e., beyond or within an initial 100-foot inclusion zone) may need to be considered when developing objectives for detailed vapor intrusion investigations and interpreting the resulting data (Section 6.2.1).

- To support evaluations of sources of indoor air concentrations, identify in individual buildings known or suspected indoor sources of the vapor-forming chemicals also found in the subsurface and characterize ambient air quality in the site vicinity for these same chemicals (Sections 6.3.5 and 6.4).

- Select sampling and analytical methods that are capable of obtaining reliable analytical detections of concentrations less than project-appropriate, risk-based screening levels (e.g., vapor intrusion screening levels, or VISLs).

- When groundwater is a subsurface source of vapors, collect groundwater samples from wells screened across the top of the water table to characterize the source strength for vapor intrusion (Sections 6.3.1 and 6.4.5).

- Collect indoor air samples to characterize exposure levels in indoor air, account for seasonal variations in climate and the habits of building occupants, and ensure that related risk management decisions are based upon a consideration of a reasonable maximum vapor intrusion condition for a given building (Sections 6.3.4 and 6.4.1).

- When sampling indoor air,
  - employ time-integrated sampling methods (e.g., evacuated canisters, sorbent-based sampling devices). Indoor air concentrations can be temporally variable and time-integrated exposure estimates over appropriate exposure durations (e.g., chronic typically; less-than-chronic in some cases) are generally most useful for exposure and human health risk assessment (Sections 6.4.1 and 7.4);
  - remove potential indoor sources[6] of vapor-forming chemicals from the building to strive to ensure that the concentrations measured in the indoor air samples are attributable to the vapor intrusion pathway (Sections 6.3.5 and 6.4.1); and
  - measure the pressure difference between the indoors and the subsurface, which provides a complementary line of evidence to support data evaluation and interpretation (Section 6.4.1) and is a more direct means of assessing building under-pressurization than is monitoring weather/climate factors (e.g., air temperature, wind speed).
- Mathematical modeling of vapor intrusion is most appropriately used in conjunction with other lines of evidence (Section 6.6).
- Confirm the reliability of modeling results, especially when limited site-specific data are available as inputs (Section 6.6).
- Collect and evaluate appropriate site-specific information to demonstrate that the property fulfills the conditions and assumptions of the generic conceptual model underlying the vapor intrusion screening levels (Section 6.5.2).

Data Evaluation and Decision-making

- Assess (and seek) concordance among the lines of evidence to more confidently support decision-making (Sections 7.1, 7.2, and 7.3).[7] Multiple lines of evidence are generally recommended for supporting conclusions, such as the following:
  - The subsurface vapor source(s) at a specific site has the potential to pose an unacceptable vapor intrusion exposure under current or reasonably expected future conditions, due to its vapor strength (Section 6.5) and proximity relative to one or more existing buildings or a building that may be constructed in the future (Section 6.2.1).

---

[6] As mentioned in Section 6.3.5, indoor sources can sometimes be identified and located using portable instruments.

[7] Confidence in the assessment and risk management decisions is expected to be higher when multiple independent lines of evidence come together to provide mutually supporting evidence for a common understanding of the site conditions/scenarios and the potential for vapor intrusion (EPA 2010b).

  - The vapor intrusion pathway is complete for one or more buildings under current or reasonably expected future conditions (Section 7.3).

  - The vapor intrusion pathway is incomplete for one or more buildings near a subsurface source of vapor-forming chemicals (Section 7.3), due to

    - inadequate source strength (i.e., chemicals comprising subsurface contamination and/or their potential vapor concentrations cannot pose an unacceptable human health risk via the vapor intrusion pathway) (Section 6.5); or

    - geologic, hydrologic, and/or biochemical (e.g., biodegradation) processes that provide substantial and persistent attenuation of vapors extending laterally over large distances relative to the footprint of the building(s) and the extent of the vapor source (Section 6.3.2).

  - Indoor air concentrations attributable to vapor intrusion pose (or, alternatively, are unlikely to pose) an unacceptable human health risk in one or more existing buildings under current or reasonably expected future conditions, based upon currently available information about a chemical's toxicity (Section 7.4).

  - Indoor air concentrations measured in one or more buildings can (or alternatively, cannot) be reasonably attributed to indoor or ambient air sources (i.e., background – see Glossary) (Sections 6.3.5 and 7.4.2).

  Multiple lines of evidence are particularly important for supporting "no-further-action" decisions regarding the vapor intrusion pathway (e.g., pathway incomplete determinations) to reduce the chance of reaching a false-negative conclusion (i.e., concluding vapor intrusion does not pose unacceptable human health risk, when it actually poses an unacceptable human health risk). Collecting and weighing multiple lines of evidence can also reduce the chance of reaching a false-positive conclusion (i.e., concluding vapor intrusion poses unacceptable human health risk, when it does not). On the other hand, parties may implement engineered exposure controls for vapor intrusion, even though only limited lines of evidence or measurements may be available to characterize the overall vapor intrusion pathway.

- Consider reasonably expected future conditions, in addition to current conditions, when reaching conclusions about the vapor intrusion pathway (Sections 3.2 and 7.3). For example, EPA recommends that vapor intrusion be evaluated for reasonably expected future land use conditions, including new building construction and new uses and occupants for uninhabited buildings.

- Identify any conditions that warrant prompt action (Section 7.5) and respond, consistent with applicable statutes and regulations and considering EPA guidance, with actions that eliminate, avoid, reduce or otherwise address the human health risk posed by vapor intrusion (Sections 7.7 and 8.2):

  - <u>Explosive conditions and threats</u> that warrant prompt action (Section 7.5.1) are reasonably suspected to exist when measured concentrations of vapors in the building, utility conduits, sumps, subsurface drains, or other structure directly connected to the building exceed one-tenth (10%) of the lower explosive limit (LEL).[8] EPA recommends evacuation of buildings with potential explosion and fire hazards, along with notification to the local fire department about the situation.

  - o <u>Conditions posing health concerns</u> that warrant prompt action are reasonably suspected to exist when estimated exposure concentrations of vapors in the building exceed health-protective concentrations for short-term or acute exposure (Section 7.5.2).

- When making decisions pertaining to the assessment of vapor intrusion at nonresidential buildings, consider the characteristics of the populations potentially exposed to vapor-forming chemicals in the indoor air, the relative contributions of vapors from background (including anthropogenic background), and any existing or planned engineering or institutional controls for the building, in addition to the potential for vapor intrusion (Sections 4, 6.3.5, 6.4.1 and 7.4.2).

- When evaluating environmental sampling results to assess the vapor intrusion pathway, first determine that the samples were collected appropriately (Sections 5.5 and 6.4).

- Before conducting risk-based screening, verify that the site fulfills the conditions and assumptions of the generic conceptual model underlying the VISLs (Section 6.5.2).

- Compare groundwater concentrations to the VISLs (Section 6.5) for groundwater to estimate the boundaries of the plume, when contaminated groundwater is the subsurface vapor source for vapor intrusion (Section 6.2.1).

- Generally support the decision to collect indoor air data (Section 6.4.1) by lines of site- or building-specific evidence that demonstrate vapor intrusion has the potential to pose a significant human exposure [e.g., data on strength and proximity of subsurface vapor source(s) (Sections 6.2.1, 6.3.1, and 6.5), or preferential vapor migration in the vadose zone or into buildings (Sections 5.4, 6.3.2, and 6.3.3)].

- Consider variability in laboratory analyses when evaluating sampling data.

- Generally conduct a human health risk assessment to determine whether the potential human health risks posed to building occupants are within or exceed acceptable levels consistent with applicable statutes and considering EPA guidance (Section 7.4).

- Consider the potential for adverse non-cancer health effects from short-duration exposures (i.e., acute, short-term, or subchronic exposure durations), as well as longer term exposure (i.e., chronic exposure) conditions, and select toxicity values considering OSWER's preferred hierarchy of sources (EPA 2003) (Sections 7.4 and 7.5.2).

---

[8] The Occupational Safety and Health Administration of the U.S. Department of Labor (OSHA) considers concentrations in excess of one-tenth of the LEL to be a hazardous atmosphere in confined spaces [29 CFR 1910.146(b)]. The National Institute for Occupational Safety and Health (NIOSH) has designated such concentrations as immediately dangerous to life or health (IDLH).

- Consider collecting multiple rounds of indoor air samples,[9] using time-integrated measurements (Section 6.4.1) to estimate exposure concentrations appropriate for the exposure (occupancy) scenario being evaluated (e.g., residential versus commercial), when the risk assessment for an existing building would support a conclusion that the human health risks are acceptable (Section 7.4).[10]

- In the risk characterization of the human health risk assessment, discuss 'background' contributions to indoor air exposure and associated human health risks (Section 7.4.2). (For purposes of this Guide, 'background' refers to a vapor-forming chemical(s) or location(s) that is(are) not influenced by the releases from a site – see Glossary). Information on 'background' contributions of site-related, vapor-forming chemicals in indoor air is important to risk managers because generally EPA does not clean up to concentrations below natural or anthropogenic background levels[11] (EPA 2002e).

- If data are available, distinguish the contribution of 'background' to total exposure concentration(s). With such information, EPA can help advise affected individuals about the environmental and human health risks they face. Other parties, including building owners and operators, may help with risk communication.

- If background vapor sources (see Glossary) are found to be primarily responsible for indoor air concentrations (see Section 6.3.5), then response actions for vapor intrusion would generally not be warranted for current conditions.

Engineered Exposure Controls and Building Mitigation

- When vapor intrusion has been determined to pose unacceptable human health risks,
  - Aim to achieve a permanent remedy by eliminating or substantially reducing the level(s) of vapor-forming chemical(s) in the subsurface source medium (e.g., groundwater, subsurface soil, sewer lines) (Sections 7.7 and 8.1); and
  - o In cases where subsurface vapor sources cannot be remediated quickly, implement engineered exposure controls to reduce or eliminate vapor intrusion in buildings (i.e., "mitigate" vapor intrusion) or reduce indoor air exposure levels (Sections 7.7 and 8.2).

---

[9] Because weather conditions and building operations can lead to time-variable contributions from vapor intrusion and ambient air infiltration, indoor air concentrations of vapor-forming chemicals can be expected to vary over time (see, for example, Section 2.6). An individual sample (or single round of sampling) would be insufficient to characterize seasonal variability, or variability at any other time scale.

[10] EPA recommends basing the decision about whether to undertake response action for vapor intrusion (i.e., a component of risk management; see Section 7.4) on a consideration of a reasonable maximum exposure (e.g., EPA 1989, 1991a), which is a semi-quantitative term, referring to the lower portion of the high end of the exposure distribution (see Glossary).

[11] With respect to vapor intrusion mitigation (see Sections 3.5 and 8.2), some options for reducing indoor air exposure levels (e.g., ventilation, indoor air treatment) unavoidably act on background concentrations arising from indoor or outdoor sources, as well as vapor concentrations arising from vapor intrusion. Most options for interrupting the vapor intrusion pathway (e.g., active depressurization technologies – see Section 8.2) unavoidably interrupt the intrusion of naturally occurring radon also. It should also be noted that some EPA regulations (e.g., indoor radon standards under 40 CFR 192.12) are inclusive of background.

- When developing monitoring programs to assess effectiveness of building mitigation, consider the degree of human health risk or hazard being mitigated, the building use, the technology used to mitigate vapor intrusion, and coordination with site remediation efforts.

- Establish cleanup levels and criteria for terminating engineered exposure controls and other building mitigation methods, institutional controls, and remediation systems for subsurface vapor sources (Sections 7.6 and 8.7).

Document Activities and Decisions

- Document objectives and methods of vapor intrusion investigations, preferably in a vapor intrusion work plan (Section 6.2).

- Base decisions upon data and information in the administrative record.

- Base decisions to undertake response actions on lines of site- or building-specific evidence (e.g., characterization of subsurface vapor source(s) strength and proximity to building(s); building conditions) that demonstrate that vapor intrusion has the potential to pose an unacceptable human health risk (Section 7).

- Document, consistent with statutory requirements and considering prevailing guidance for the respective land restoration program (e.g., CERCLA, RCRA corrective action, brownfields, etc.), any and all decisions pertaining to vapor intrusion, including decisions to undertake (or not to undertake) investigation or mitigation of specific buildings at a contaminated site.

- Prepare and publish system manuals to document building mitigation and remediation systems (Section 8.5).

- Prepare and implement operations and maintenance manuals and practices to foster continued effective operation and performance of engineered exposure controls and remediation systems for subsurface vapor sources (Section 8.5).

- Document monitoring programs that assess the performance and effectiveness of remediation and mitigation systems.

Community Outreach and Involvement (Section 9)

- Develop or refine a community involvement or public participation plan while planning a vapor intrusion investigation and implement this plan throughout the assessment, remediation, and mitigation phases.

- Conduct building-by-building contact and communication as means of educating the community and obtaining access needed to assess, mitigate, and monitor the vapor intrusion pathway. Personal contact is further recommended to establish a good working relationship with each building owner or occupant and to build trust.

- Generally provide validated results and interpretations (e.g., chemicals of concern, associated risk assessment implications) to property owners and occupants in a timely manner (e.g., within approximately 30 days of receiving these results).

- Provide adequate opportunities for public participation (including potentially affected landowners and communities) when considering appropriate use of ICs.

The science and technology to assess and mitigate vapor intrusion have evolved significantly over the past decade. EPA will continue to monitor these evolving developments and will update these recommendations in the future, if and as appropriate.

1.0 INTRODUCTION

This technical guide was prepared by the U.S. Environmental Protection Agency (EPA) through the cooperative efforts of a team of EPA Headquarters and Regional staff, known as the Vapor Intrusion Intra-Agency Workgroup (Workgroup). Drafts of this document were subjected to a comprehensive, consultative peer-input process in 2012, as described in EPA's *Peer Review Handbook* (EPA-SPC 2006), which included comments and other contributions from Workgroup members representing several EPA offices and the EPA's Vapor Intrusion Forum.[12] Public comments submitted from 2002 through 2013 and recommendations of the Office of Inspector General (OIG) were also considered in developing this document.

This document comprises EPA's 'final' vapor intrusion technical guide[13] and is referred to herein as "this Technical Guide." It describes a recommended framework for assessing vapor intrusion that relies upon collecting and evaluating multiple lines of evidence to support risk management decisions. It also provides technical recommendations about monitoring and terminating building mitigation systems.

This Technical Guide relied upon a large body of scientific information found in the peer-reviewed literature. Additionally, EPA developed three technical support documents that were externally peer reviewed (EPA 2011a, 2012a, 2012b). This approach is consistent with EPA's peer review handbook and policy (EPA-SPC 2006). Peer-reviewed literature, peer-reviewed technical reports, existing and relevant EPA guidance (e.g., for conducting human health risk assessment; for planning and conducting investigations of environmental contamination), and other pertinent information that support development or implementation of this Technical Guide are cited within.

This introductory section: defines the term "vapor intrusion"; summarizes EPA's statutory authorities to protect human health from vapor intrusion; summarizes the intended uses of this Technical Guide, including its applicability to petroleum hydrocarbons and other potentially biodegradable chemicals and to nonresidential buildings; identifies key technical resources that facilitate consideration of its recommendations; provides a concise historical accounting of its development; describes how the public was involved in its development; and provides an overview of its organization.

1.1 Definition of Vapor Intrusion

Certain chemicals that are released into the subsurface[14] as liquids or solids may form hazardous vapors that migrate or are transported through the vadose zone[15] and eventually

---

[12] The EPA Vapor Intrusion Forum is an intra-Agency group engaged in sharing information, technical resources, and perspectives pertaining to vapor intrusion assessment and mitigation.

[13] This document is intended to fulfill EPA's commitment to the OIG to issue "updated, revised, and finalized" vapor intrusion guidance (EPA 2009a, Appendix B; EPA 2010b).

[14] For purposes of this Technical Guide, the phrases 'released into the subsurface' and 'release to the subsurface' are intended to encompass any and all mechanisms by which chemical contamination arises in the subsurface, including, for example, spills and releases above the ground surface that result in subsurface (e.g., soil and groundwater) contamination.

enter buildings as a component of a gas[16] by migrating (being transported) through cracks, seams, interstices, and gaps in basement floors, walls, or foundations ("adventitious openings"), through intentional openings (e.g., perforations due to utility conduits, sump pits), and/or within conduits (e.g., drain and sewer lines). Vapor intrusion is the general term given to migration of hazardous vapors from any subsurface contaminant source, such as contaminated soil or groundwater or contaminated conduit(s), into an overlying building or unoccupied structure via any opening or conduit.

Recognition of soil vapor intrusion to buildings and other enclosed spaces occurred in the 1980s with concerns over radon intrusion.[17] Subsequently, there was an increasing awareness that anthropogenic chemicals (e.g., petroleum hydrocarbons and chlorinated solvents) in soil and ground water could also pose threats to indoor air quality via the vapor intrusion pathway (Little et al. 1992; Moseley and Meyer 1992).

Vapor intrusion can occur in a broad range of land use settings, including residential, commercial, and industrial, and affect buildings with virtually any foundation type (e.g., basement, crawl space(s), or slab on grade). In the last 20 years, vapor intrusion impacts have been demonstrated in occupied buildings at a number of sites across the country (e.g., Little et al. 1992). As a result, vapor intrusion is widely recognized as a potential pathway of human exposure to "volatile" hazardous chemicals in indoor spaces. When and where vapor intrusion occurs, concentrations of vapors can increase gradually in amount in buildings or structures as time passes (i.e., "accumulate"). Depending upon site- and building-specific circumstances, vapors of potentially toxic chemicals may accumulate to a point where the health of the occupants (e.g., residents, workers, etc.) in those buildings could be threatened.

In addition to their toxicity threats, methane and certain other vapor-forming chemicals can pose explosion hazards depending upon structure-, building-, and site-specific circumstances. Explosion hazards may pose an imminent and substantial danger to human health and public welfare.

Careful consideration of the vapor intrusion pathway is warranted at all sites where vapor-forming chemicals are present in the soil or groundwater aquifer (NRC 2013).

Section 2.0 describes the vapor intrusion pathway in greater detail.

---

[15] The 'vadose zone' is the soil zone between land surface and the groundwater table within which the moisture content is less than saturation (except in the capillary fringe). It is also referred to as the "unsaturated zone."

[16] The terms 'gas' and 'vapor' refer the gaseous state, as distinguished from the liquid or solid state, of matter. Whereas "vapor' refers to a volatile chemical that may comprise only a portion of the total volume, 'gas' refers to the entire volume. For economy of words, this Technical Guide refers to vapor concentrations in soil gas as "soil gas concentrations."

[17] Radon is a colorless, odorless, radioactive gas that is formed from the decay of radium, a radioactive element that occurs naturally in the soil and bedrock in many areas of the United States. Radon can also be emitted from certain uranium- or radium-containing products and wastes. For more information about radon, see: http://www.epa.gov/radon/index.html.

1.2 Statutory Authorities

Protection of human health is a critical mandate underlying several federal statutes, including the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended,[18] and the Resource Conservation and Recovery Act (RCRA), as amended.[19] Protection of human health is also a critical objective of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), which is the federal government's blueprint for responding to oil spills and releases of hazardous substances, pollutants, or contaminants.

The sources of authority and requirements for addressing subsurface vapor intrusion are the relevant statutes and regulations. On this basis, the EPA has broad authority and distinct responsibilities[20] to assess and, if warranted, mitigate vapor intrusion in residential and nonresidential[21] settings arising from a chemical release that causes subsurface contamination by volatile hazardous chemicals.[22] These actions may include sampling indoor air to assess exposure levels of building occupants to subsurface vapors and implementing interim mitigation measures to control, reduce, or eliminate exposure indoors to vapors emanating from subsurface vapor sources. Where such subsurface contamination includes vapor-forming chemicals (see Section 3.1) and underlies or is near buildings, EPA recommends that the potential for human health risk from vapor intrusion be evaluated throughout the cleanup life

---

[18] Amendments to CERCLA include the Small Business Liability Relief and Brownfields Revitalization Act.

[19] Application of these statutory authorities to a particular situation generally entails site- and fact-specific analysis.

[20] On January 23, 1987, the President of the United States signed Executive Order 12580 entitled, "Superfund Implementation," which delegates to a number of Federal departments and agencies the authority and responsibility to implement certain provisions of CERCLA. The policies and procedures for implementing these provisions (e.g., carrying out response actions) are spelled out in the NCP. The provisions of Executive Order 12580 appear at 52 *Federal Register* 2923.

[21] The EPA and the Occupational Safety and Health Administration (OSHA) of the Department of Labor each have a distinct statutory responsibility to ensure the safety and health of America's workforce through the timely and effective implementation of a number of federal laws and implementing regulations. On November 23, 1990, the Secretary of the Department of Labor and Administration of the EPA signed a Memorandum of Understanding (MOU) with the goal of establishing a program for improved environmental and workplace health and safety, which continues in effect. Implementation of the MOU is intended "to improve the combined efforts of the agencies to achieve protection of workers, the public, and the environment at facilities subject to EPA and OSHA jurisdiction; to delineate the general areas of responsibility of each agency; and to provide guidelines for coordination of interface activities between the two agencies with the overall goal of identifying and minimizing environmental or workplace hazards." An additional MOU was signed in February 1991 to establish a process and framework for notification, consultation and coordination between EPA and OSHA to aid both agencies in identifying environmental and workplace health and safety problems and to more effectively implement enforcement of their respective national environmental and workplace statutes. For additional information, see https://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=MOU&p_toc_level=1&p_keyvalue=Agency&p_status=CURRENT.

EPA's recommended approach for evaluating vapor intrusion exposures is based upon its existing risk assessment guidance, as summarized in Section 7.4.

[22] Section 3.1 of this Technical Guide describes technical criteria for identifying which specific chemicals are sufficiently volatile and hazardous to generally warrant routine evaluation during vapor intrusion assessments, when they are present as subsurface contaminants. These sufficiently volatile and hazardous chemicals are referred to as "vapor-forming chemicals" for purposes of this Technical Guide.

cycle (i.e., initial site assessment, site investigation, interim and final response actions,[23] and periodic reviews of the selected remedy), as described in Sections 5 and 6 of this Guide.

Although this Technical Guide is intended for use at any site subject to federal statutes, regulations, and rules, it is not intended to alter existing requirements, guidance, or practices among OSWER's programs about development, selection, or documentation of final remediation[24] plans (addressing subsurface vapor sources, for example).

EPA may need access to private property to conduct investigations, studies and response actions pursuant to CERCLA and RCRA, as amended. The Superfund Amendments and Reauthorization Act of 1986 and RCRA explicitly grant EPA the authority to enter property for these purposes (EPA 1986, 1987, 2010a). EPA generally prefers to obtain access through consent and cooperation. If consent is denied, however, EPA can use the judicial process or an administrative order to gain access. Application of legal doctrines to a particular access situation warrants site- and fact-specific analysis.

Provisions under CERCLA, RCRA, federal regulations, and federal guidance also provide authority and support for taking early actions to mitigate actual and potential human health risks, as discussed below. In the context of vapor intrusion, "early action" may include response measures such as engineered exposure controls to reduce or eliminate vapor intrusion in buildings (i.e., "mitigate" vapor intrusion) or reduce indoor air exposure levels (see Sections 7.8 and 8.2) and 'prompt' response actions to address more urgent threats to human health or public welfare (see Section 7.5).

1.2.1 Taking Action with Limited Data under CERCLA and the NCP

CERCLA and the NCP both contain provisions that support and encourage taking early actions to mitigate actual and potential threats to human health associated with vapor intrusion. For example, CERCLA sections 104 and 106 provide the federal government with broad authority to take response action(s) to address a release or threatened release of hazardous substances that "may present" a human health risk. Similarly, the preamble to the final NCP issued in the *Federal Register* on March 8, 1990 (55 FR 8704), states, "EPA expects to take early action at sites where appropriate, and to remediate sites in phases using operable units as early actions to eliminate, reduce or control the hazards posed by a site or to expedite the completion of total site cleanup. In deciding whether to take early actions, EPA balances a number of considerations, including the desire to definitively characterize site risks and analyze alternative remedial approaches for addressing those threats in great detail with the desire to implement protective measures quickly. EPA intends to perform this balancing with a bias for initiating

---

[23] The words "response action" or "response" are used generically in this Technical Guide to include remedial and removal actions under CERCLA as amended and similar actions under RCRA as amended.

[24] For purposes of this Technical Guide, "remediation" is intended to apply to interim and final cleanups, whether conducted pursuant to RCRA corrective action, the CERCLA removal or remedial programs, or using EPA brownfield grant funds with oversight by state and tribal response programs. In addition to permanent remedies for subsurface vapor sources, site remediation may also entail implementation of institutional controls and construction and operation of engineered systems.

response actions necessary or appropriate to eliminate, reduce, or control hazards posed by a site as early as possible."[25]

For sites that are not on the National Priorities List (NPL), EPA may use its removal authority under CERCLA to undertake early action to mitigate vapor intrusion threats. For sites that are on the NPL, EPA's Superfund program may use its remedial or removal authority under CERCLA to undertake early action to ensure the protection of human health during existing or future property uses that could be affected by vapor intrusion. Building mitigation, control of subsurface vapor source(s), and associated ICs could be part of a final remedy selected for the site, or where appropriate, could represent an early action that (1) is evaluated and selected on a faster track and (2) complements the anticipated final remedial action for the site.

Because of state cost-share consequences, EPA recommends that state concurrence be sought for any Fund-lead mitigation under CERCLA where there is a reasonable expectation that the state will need to take over responsibility for operations and maintenance (O&M) as part of a long-term, final remedy.

EPA's guidance for preparing Superfund decision documents states: "An interim action is limited in scope and only addresses areas/media that also will be addressed by a final site/operable unit ROD [Record of Decision]….Early actions can be taken throughout the RI/FS [remedial investigation/feasibility study] process to initiate risk reduction activities…. "Early" in this case is simply a description of when the action is taken in the Superfund process. Thus, an early action is one that is taken before the RI/FS for the site or operable unit has been completed. Hence, early actions may be either interim or final" (EPA 1999b). The primary goals of an early action are to "achieve prompt risk reduction and increase the efficiency of the overall site response" (EPA 1992b). Although preparation of an RI/FS Report is not essential for an early action, documentation that supports the rationale for the action and becomes part of Administrative Record is recommended, consistent with the NCP and CERCLA. For interim actions, EPA's guidance for preparing Superfund decision documents states: "A summary of site data collected during field investigations should be sufficient to document a problem in need of response. In addition, a short analysis of remedial alternatives considered, those rejected, and the basis for the evaluation (as is done in a focused FS) should be summarized to support the selected action" (EPA 1999b).

For response actions selected in an Action Memorandum or Record of Decision which are carried out by potentially responsible parties (PRPs), and where the PRP(s) agree to implement preemptive mitigation (PEM) for vapor intrusion, EPA recommends that PRP commitments to proceed with response action (including early action) be obtained through settlements or other enforcement documents (for example, administrative orders). Such response action commitments could include performance of O&M and monitoring. EPA recommends that settlement with PRPs concerning PEM/early action response actions specify that PRPs agree not to challenge the basis of the response based on inadequate characterization.

---

[25] So, for example, EPA cited the NCP in its *Compilation of Information Relating to Early/Interim Actions at Superfund Sites and the TCE IRIS Assessment* (EPA 2014b).

1.2.2 Taking Action with Limited Data under RCRA Corrective Action

EPA has emphasized the importance of interim actions and site stabilization in the RCRA corrective action program to control or abate “ongoing risks” to human health and the environment while site characterization is underway or before a final remedy is selected (see the *Federal Register* of May 1, 1996 [61 FR 19446]). Interim actions encompass a wide range of institutional and physical corrective action activities to achieve stabilization and can be implemented at any time during the corrective action process. EPA recommends that interim actions, including PEM, be employed as early in the corrective action process as possible, consistent with the human health and environmental protection objectives and priorities for the site. EPA recommends that, as further information is collected, program implementers continue to look for opportunities to conduct additional interim response actions.

1.3 Scope and Recommended Uses of this Technical Guide

This Technical Guide presents EPA’s current recommendations for how to identify and consider key factors when assessing vapor intrusion, making risk management decisions, and implementing mitigation pertaining to this potential human exposure pathway. This Technical Guide and the accompanying *Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites* (EPA 2015b) supersede and replace EPA’s *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (EPA 2002c) (“Draft VI Guidance”). One of the main purposes of this Technical Guide is to promote national consistency in assessing the vapor intrusion pathway.[26] At the same time, it provides a flexible science-based approach to assessment that accommodates the different circumstances (e.g., stage of the cleanup process) at a site and differences among pertinent EPA programs.

This Technical Guide is intended for use at any site[27] being evaluated by EPA pursuant to CERCLA or RCRA corrective action, EPA’s brownfield grantees, or state agencies acting

---

[26] If EPA staff wish to consider using any specific guidance that is not explicitly recommended in this Technical Guide, they should consult with Headquarters.

[27] The term “site” is used generically in this Technical Guide to represent areas of contamination managed in a cleanup project under CERCLA as amended, under RCRA as amended, at a federal facility, or pursuant to an EPA Brownfields grant.

pursuant to CERCLA or an authorized RCRA corrective action program[28] where vapor intrusion may be of potential concern. EPA recommends consideration of this Technical Guide when:

- Making "Current Human Exposures Under Control" environmental indicator (EI) determinations at RCRA corrective action facilities (EPA 1999a, 2002b)[29] and National Priorities List (NPL) sites under CERCLA (EPA 2008b);
- Undertaking removal actions, remedial actions, pre-remedial investigations,[30] remedial investigations, and five-year reviews (FYRs)[31] and selecting remedies under CERCLA; and
- Undertaking RCRA facility investigations and corrective actions and site investigations and cleanups at federal facilities and brownfield sites.

This Technical Guide addresses both residential and nonresidential buildings that may be impacted by vapor intrusion from subsurface vapor sources.

The broad concepts of this Technical Guide generally may be appropriate when evaluating any of a large number and broad range of vapor-forming chemicals— described in Section 3.1 — that potentially can provide subsurface sources for vapor intrusion into buildings. These chemicals include, for example, chlorinated hydrocarbons (CHCs), petroleum hydrocarbons, other types of both halogenated and non-halogenated volatile organic compounds (VOCs),

---

[28] EPA believes that states, tribes, and local governments will find this Technical Guide useful for their respective programs. EPA recommends that state agencies that have delegated authority to implement CERCLA or RCRA consider this Technical Guide when implementing their state-specific guidance for vapor intrusion assessment and mitigation, if any, (e.g., ensure they incorporate features such as: using multiple lines of evidence to support pathway-incomplete determinations and "no-further-action" decisions; collecting multiple rounds of indoor air sampling to characterize exposure levels in indoor air in existing buildings and reduce the chance of reaching a false-negative conclusion (i.e., concluding exposure is at an acceptable risk level when it is not) or a false-positive conclusion (i.e., concluding vapor intrusion poses unacceptable human health risk, when it does not); focusing lab analyses of indoor air, ambient air, and sub-slab soil gas samples on vapor-forming chemicals known or suspected to be released to the subsurface environment; invoking the recommended criteria described in Section 6.5.2 as a condition for using risk-based screening levels for vapor intrusion; assessing human health risk posed by less-than-chronic exposure durations; and considering reasonably expected future conditions, as well as current conditions, when making risk management decisions and selecting cleanup and building mitigation plans).

[29] Also see http://www.epa.gov/osw/hazard/correctiveaction/eis/faqs.htm.

[30] CERCLA authorizes the EPA to identify and prioritize which sites warrant further investigation to ascertain whether remedial action is needed. The Hazard Ranking System (HRS) is the statutorily required method for evaluating and identifying sites for placement on the NPL.

[31] Section 121 of CERCLA specifies that remedial actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be re-evaluated every five years to ensure that the remedy is and will continue to be protective of human health and the environment. OSWER Directive 9200.2-84 (*Assessing Protectiveness at Sites for Vapor Intrusion: Supplemental Guidance to the Comprehensive Five-Year Review Guidance* (EPA 2012c)) provides supplemental guidance for considering vapor intrusion while evaluating remedy protectiveness in the context of the Superfund five-year review process (even if vapor intrusion was not addressed as part of the original remedial action).

elemental mercury, and radon when it arises from uranium- or radium-bearing solid wastes in the subsurface.[32]

This Technical Guide addresses risk management (e.g., exposure control or avoidance methods) for indoor air contamination that arises from vapor intrusion from subsurface sources of these vapor-forming chemicals. It is not intended as a guide for assessing or mitigating indoor air exposures that arise solely from other sources (e.g., indoor use and storage of certain consumer products[33]).

The exposure route of general interest for vapor intrusion is inhalation[34] of vapors present in indoor air that have entered via soil gas entry from the subsurface.[35] Other human exposure routes that may warrant consideration during site investigations of subsurface contamination (e.g., ingestion of soil or water, dermal contact with soil or water, inhalation of particulate material, inhalation of vapors while outdoors, and inhalation of vapors while showering or washing with contaminated groundwater while indoors) are not addressed in this Technical Guide.

EPA recommends that risk management and response action decisions for the vapor intrusion pathway generally consider reasonably expected future conditions, which may differ from current conditions due to changes in land use, building and infrastructure construction and conditions, and vadose zone hydrology and oxygenation, among other factors. This Technical Guide provides general information regarding how these factors may enhance or impede vapor intrusion. It also provides recommendations for institutional controls and monitoring where a subsurface vapor source(s) is(are) present and has the potential to pose unacceptable human health risks.

Although this Technical Guide is intended for use at any site subject to federal statutes, regulations, and rules, it is not intended to alter existing requirements, guidance, or practices among OSWER's programs about circumstances for reviewing past risk management and cleanup decisions. As noted, remedy reviews are required by Section 121 of CERCLA when

---

[32] Radon emanating from natural geological materials may also affect indoor air quality in occupied buildings, but is not a subject of this Technical Guide. According to EPA estimates, inhalation of toxic radon decay products is the leading cause of lung cancer among non-smokers. For more information about radon emanating from natural geological materials, see: http://www.epa.gov/radon/index.html.

[33] Indoor air in most buildings will contain detectable levels of a number of volatile compounds, whether or not the building overlies a subsurface source of vapor-forming chemicals (EPA 2011a). As discussed further in Section 2.7 of this Technical Guide, these chemicals originate from indoor uses of chemical-containing products (e.g., household or consumer products) and from outdoor (ambient) air. EPA's indoor air quality program provides useful advice for control of indoor air exposures (see http://www.epa.gov/iaq/).

[34] Among human exposure pathways involving contamination of land and water, vapor intrusion is distinct. Whereas contact with contaminated surface soil, contaminated fish, and contaminated drinking water generally can be readily avoided for prolonged periods, breathing cannot.

[35] In addition, certain hazardous chemicals (e.g., methane) can pose explosion hazards when they gradually increase in amount in structures (e.g., confined spaces) or buildings as time passes to a point where there is an imminent and substantial danger to human health and public welfare.

hazardous substances remain on site.[36] EPA's other land restoration programs (e.g., RCRA corrective action, brownfield redevelopment) will continue to rely upon their existing, respective practices to address the need, if any, for periodic reviews of cleanup decisions, including consideration of the vapor intrusion pathway.

Finally, this Technical Guide does not aim or intend to:

- Offer recommendations for vapor intrusion assessments that private parties choose to conduct as part of real estate transactions;
- Modify existing guidance regarding landowner liability protection (e.g., all appropriate inquiries, the *bona fide* prospective purchaser provision); or
- Offer recommendations for responding to leaks from natural gas transmission lines.

1.3.1 Petroleum Hydrocarbons

The approaches in this Technical Guide are recommended for evaluating the vapor intrusion pathway pursuant to CERCLA or RCRA corrective action for petroleum hydrocarbons that are mixed with other types of volatile hazardous chemicals or are the result of releases from sources other than Subtitle I underground storage tank (UST) systems.[37] For petroleum hydrocarbons that arise from petroleum that has been released from Subtitle I UST systems, EPA has developed a companion to this Technical Guide (*Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites* (EPA 2015b)), which provides information and guidance about assessing vapor intrusion from petroleum hydrocarbons in these settings and may also be useful in informing decisions about vapor intrusion and petroleum hydrocarbons at non-UST sites that are similar in size to a typical Subtitle I UST release.

Many petroleum hydrocarbons may naturally biodegrade in the vadose zone through the actions of microorganisms found naturally in soil. When oxygen supply from the atmosphere is sufficient, biodegradation of petroleum hydrocarbons can occur relatively quickly, will generally produce less harmful compounds (i.e., biodegradation products), and can result in substantial attenuation of petroleum hydrocarbon vapors over relatively short distances in the vadose zone.

Numerous site-specific factors can influence the biodegradation rate of petroleum hydrocarbons (and other biodegradable vapor-forming chemicals) in the vadose zone. These factors include quantities, distribution, types, and mixtures of vapor-forming chemicals, which can differ substantially among sites where petroleum hydrocarbons are released to the subsurface

---

[36] The NCP states [40 *CFR* 300.430(f)(4)(ii)]: "If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after initiation of the selected remedial action." For further information, see, for example, http://www.epa.gov/superfund/cleanup/postconstruction/5yr.htm

[37] For example, the approaches in this Technical Guide are recommended for evaluating the vapor intrusion pathway associated with subsurface releases of petroleum, petroleum derivatives, and petroleum hydrocarbons from refineries, bulk storage facilities, oil exploration and production sites, pipelines and transportation, chemical manufacturing facilities, former manufactured gas plants, creosote (wood-treating) facilities, large-scale fueling and storage operations at federal facilities, and dry cleaners that use petroleum solvents.

environment. This Technical Guide allows site-specific observations of the effects of biodegradation to be considered in its approach for petroleum hydrocarbons (and any other biodegradable, vapor-forming chemical). Sections 6.3.2 and 7.3 expand on EPA's recommended approach to evaluating biodegradation of vapor-forming chemicals in the vadose zone at sites with subsurface contamination.

1.3.2 Nonresidential Buildings

EPA has broad authority and distinct responsibilities to assess and, if warranted, mitigate vapor intrusion in nonresidential settings arising from a chemical release that causes subsurface contamination by volatile hazardous chemicals (see Section 1.2). EPA[38] is authorized to take all appropriate actions to protect human health and the environment from subsurface vapor sources of chemical exposure consistent with applicable federal statutes[39,40] and regulations and considering EPA guidance,[41] taking into account the nonresidential setting. These actions may include sampling indoor air to assess exposure levels of building occupants to subsurface vapor sources and implementing interim mitigation measures to control, reduce, or eliminate exposure indoors to vapors emanating from a subsurface vapor source(s).

As used in this Technical Guide, the phrase "nonresidential buildings" may include, but is not limited to, institutional buildings (e.g., schools, libraries, hospitals, community centers and other enclosed structures for gathering, gyms and other enclosed structures for recreation); commercial buildings (e.g., hotels, office buildings, many (but not all) day care facilities, and retail establishments); and industrial buildings where vapor-forming chemicals may or may not be routinely used or stored. Section 4.0 expands on EPA's recommended approach to evaluating and mitigating vapor intrusion in nonresidential buildings.

1.4 Companion Documents and Technical Resources

Technical information pertaining to vapor intrusion has also been prepared to support development of and facilitate implementation of the technical approaches and recommendations in this Technical Guide. Key technical information is described in this section and can be found on OSWER's vapor intrusion website (see Section 11.0 for citations and internet links).

---

[38] On January 23, 1987, the President of the United States signed Executive Order 12580 entitled, "Superfund Implementation," which delegates to a number of Federal departments and agencies the authority and responsibility to implement certain provisions of CERCLA. The policies and procedures for implementing these provisions (e.g., carrying out response actions) are spelled out in the NCP. The provisions of Executive Order 12580 appear at 52 *Federal Register* 2923. At federal facilities on the NPL, EPA may not be the lead agency, but does have oversight responsibilities pursuant to CERCLA Section 120.

[39] CERCLA and RCRA authorize EPA to protect human health and the environment, as summarized in Section 1.2 of this Technical Guide. The NCP also addresses protection of human health and the environment.

[40] See, for example, CERCLA Section 101(22).

[41] See, for example, OSWER Directive 9355.0-30 (*Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*) (EPA 1991a) and *Rules of Thumb for Superfund Remedy Selection,* OSWER Directive 9355.0-69, August 1997 (EPA 1997).

.

1.4.1 Vapor Intrusion Screening Level Calculator

The Vapor Intrusion Screening Level (VISL) Calculator (2015a) is a technical resource, developed by EPA that:

(1) Identifies chemicals considered to be typically vapor-forming and known to pose a potential cancer risk or noncancer hazard through the inhalation pathway (as described further in Section 3.1 herein);

(2) Provides generally recommended screening-level concentrations for groundwater, near-source soil gas (exterior to buildings), sub-slab soil gas, and indoor air based upon default residential or nonresidential exposure scenarios, a target cancer risk level of one per million (10^{-6}), and a target hazard quotient of one for potential non-cancer effects; and

(3) Facilitates calculation of site-specific screening levels (see Section 6.5) and/or candidate cleanup levels (see Section 7.6) based on user-defined target risk levels, exposure scenarios, and semi-site-specific (Appendix A) or site-specific (Section 7.6) attenuation factors.

The VISL Calculator is comprised of an MS Excel workbook. It can be used in evaluating whether the vapor intrusion pathway has the potential to pose a human health risk by helping to:

(1) Identify whether volatile hazardous chemicals that can pose a threat through vapor intrusion are present;

(2) Determine if those volatile hazardous chemicals are present at potentially explosive levels;

(3) Compare subsurface or indoor data against recommended screening levels provided in the VISL Calculator; and

(4) Prioritize buildings and sites for investigation and response action.

The recommended screening-level concentrations in the spreadsheet are calculated using the recommended approaches in existing EPA guidance for human health risk assessment, as described further in Sections 6.5.2 and 6.5.3 herein, and are based on current understanding of the vapor intrusion pathway.

1.4.2 Technical Support Documents

Key technical documents supporting development of the technical approaches and recommendations in this Technical Guide include:

Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990-2005): A Compilation of Statistics for Assessing Vapor Intrusion (EPA 2011a): This technical report presents (1) a summary of indoor air studies that measured background concentrations of VOCs in the indoor air of thousands of North American residences and (2) an evaluation and compilation of the statistical information reported in these studies. The objective of this compilation is to illustrate the ranges and variability of

VOC concentrations in indoor air during the study period (1990-2005), resulting from sources other than vapor intrusion. This technical report was externally peer reviewed, consistent with EPA's peer review policy (EPA-SPC 2006) for scientific and technically based work products that are intended to inform Agency decisions.

EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings (EPA 2012a): This technical report presents technical information about sites in the U.S. that have been investigated for vapor intrusion. The primary focus of the report is the evaluation of concentrations of chlorinated VOCs in and underneath residential buildings based upon the EPA's vapor intrusion database as of 2010. This report provides the technical basis for the generic and semi-site-specific attenuation factors recommended in this Technical Guide to calculate vapor intrusion screening levels (see Section 6.5 and Appendix A). This technical report was externally peer reviewed, consistent with EPA's peer review policy (EPA-SPC 2006) for scientific and technically based work products that are intended to inform Agency decisions.

Conceptual Model Scenarios for the Vapor Intrusion Pathway (EPA 2012b): This technical report provides simplified simulation examples to illustrate graphically how subsurface conditions and building-specific characteristics determine: (1) the distribution of vapor-forming chemicals in the subsurface; and (2) the indoor air concentration relative to a source concentration. It was prepared to help environmental practitioners gain insights into the processes and variables involved in the vapor intrusion pathway and to provide a theoretical framework with which to draw inferences about and better understand the complex vapor fate and transport conditions typically encountered at actual, contaminated sites. This technical report was externally peer reviewed, consistent with EPA's peer review policy (EPA-SPC 2006) for scientific and technically based work products that are intended to inform Agency decisions.

These technical tools and documents, as well as others, can be found at http://www.epa.gov/oswer/vaporintrusion, a website developed to support the development of this Technical Guide and enhance public communication about the topic. This website also allows certain sections of this Technical Guide to be more dynamic and facilitates updates to information.

Technical documents intended to facilitate consideration of the recommendations in the *Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites* (EPA 2015b) can be found at http://www.epa.gov/oust/cat/pvi/.

1.5 Historical Context

To help assess the subsurface vapor intrusion pathway, the Office of Solid Waste and Emergency Response (OSWER) released in November 2002 for comment EPA's Draft VI Guidance, which presents EPA's technical information and recommendations for evaluating subsurface vapor intrusion, based on the understanding of vapor intrusion at that time (EPA 2002c). This Technical Guide and the accompanying *Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites* (EPA 2015b) supersede and replace the Draft VI Guidance.

Since the Draft VI Guidance was released, EPA's knowledge of and experience with assessment and mitigation of the vapor intrusion pathway has increased considerably, leading to an improved understanding of and enhanced approaches for evaluating and managing vapor intrusion. In addition:

- Other federal agencies with responsibilities and obligations for environmental cleanup or for response to reports of vapor intrusion have developed vapor intrusion guides for their respective programs (e.g., ATSDR 2008; DoD 2009; DoN 2011a; USPS 2009).
- A number of state agencies involved with environmental quality or public health protection have developed vapor intrusion guides for their programs, which they may continue to implement under their respective statutory authorities (e.g., see ASTSWMO [2009], a compilation).
- The Interstate Technology & Regulatory Council (ITRC), a state-led coalition of environmental regulatory professionals, prepared three guidelines for assessing the vapor intrusion pathway (ITRC 2007ab, 2014).

EPA has considered these guides in developing this Technical Guide.

In addition, in December 2009, the OIG made recommendations regarding EPA's Draft VI Guidance, which are documented in the evaluation report *Lack of Final Guidance on Vapor Intrusion Impedes Efforts to Address Indoor Air Risks* (Report No. 10-P-042; EPA 2009a). Among other things, the OIG recommended that the final guidance incorporate:

- Updated toxicity values.
- A recommendation(s) to collect and weigh multiple lines of evidence in evaluating and making decisions about human health risks posed by vapor intrusion.
- How risks from petroleum hydrocarbon vapors should be addressed.
- How the guidance applies to Superfund FYRs.
- When or whether preemptive mitigation is appropriate.
- Operations, maintenance, and termination of mitigation systems.
- When institutional controls are appropriate.

In its response letter dated March 11, 2010, OSWER generally agreed with OIG's recommendations to finalize guidance on vapor intrusion. In addition, the OIG recommended that EPA identify and publicly report the portions of its Draft VI Guidance that remain valid and the portions that would be updated.[42]

This Technical Guide and the companion documents identified in Sections 1.3 and 1.4 fulfill EPA's commitment to address the OIG's recommendations. Table 1-1 identifies specific updates prepared by EPA in response to OIG's specific recommendations. Table 1-2 describes additional updates identified and publicly announced by EPA (EPA 2010b).

TABLE 1-1
DIRECTORY TO UPDATES IN THIS TECHNICAL GUIDE ADDRESSING RECOMMENDATIONS OF EPA OFFICE OF INSPECTOR GENERAL (EPA 2009A)

Topics to Be Addressed	Location Within This Technical Guide	Companion Documents
Update toxicity values		*VISL Calculator* (EPA 2015a)
Use of multiple lines of evidence in evaluating and making decisions about risks from vapor intrusion	Sections 5, 6, and 7	
How risks from petroleum hydrocarbon vapors should be addressed	Sections 1.3.1, 6.3.2 and 7.3	*Technical Guide for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites* (EPA 2015b)
How this Technical Guide applies to Superfund Five-year Reviews (FYRs)		*Assessing Protectiveness at Sites for Vapor Intrusion: Supplemental Guidance to the Comprehensive Five-Year Review Guidance* (EPA 2012c)
When or whether preemptive mitigation/early action is appropriate	Sections 3.3 and 7.8	
Operations and maintenance of mitigation systems	Section 8.3	
Termination of mitigation systems	Section 8.7	
When ICs and deed restrictions are appropriate.	Section 8.6	

---

[42] OSWER carried out this recommendation by issuing a memorandum in August 2010, entitled *Review of the Draft 2002 Subsurface Vapor Intrusion Guidance* (EPA 2010b). The guidance reflected in this memorandum is incorporated in this Technical Guide.

TABLE 1-2
DIRECTORY TO ADDITIONAL UPDATES IN THIS TECHNICAL GUIDE PUBLICLY IDENTIFIED BY OSWER (EPA 2010B)

Topics to Be Updated, Including References to the Draft VI Guidance	**Location Within This Technical Guide**	**Companion Technical Document or Resource**
Updated a few chemical-specific physical parameters used for identifying the vapor-forming chemicals of concern.	Section 3.1	VISL Calculator (EPA 2015a)
Updated the toxicity-based criteria in Table D-1 in the draft guidance.	Section 3.1	VISL Calculator (EPA 2015a)
Observation-based conservative attenuation factors have been updated with a larger database. The generic attenuation factor for external soil gas has been updated, as well as the Reliability Assessment, using the newer available data.	Section 6.5.3 and Appendix A	*U.S. EPA's Vapor Intrusion Database: Evaluation of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings* (EPA 2012a)
Observational data since 2002 indicates that the "single line of evidence" approach with site-estimated attenuation factors is generally not appropriate for external soil gas samples.	Section 6.4.4 and Appendix A	
Experiences since 2002 illustrate the value of collecting indoor air samples earlier in the investigations. The "indoor air last" approach has been updated, which will allow more flexibility in the sequencing of subsurface and interior/indoor sample collection.	Sections 6.3.4 and 6.3.6	
The portions addressing background contamination have been updated. EPA also updated with more specific methodologies for evaluating and/or decision-making and managing background contamination.	Sections 6.3.5, 7.4 and 7.6	*Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990-2005): A Compilation of Statistics for Assessing Vapor Intrusion* (EPA 2011a)
The portion of this Technical Guide focusing on testing indoor air has been updated to allow more flexibility in the duration of sampling to take advantage of other sampling durations and methods.	Section 6.4.1	
The Draft VI Guidance allows site-specific decisions to be made based on indoor air concentrations in a relatively few representative buildings. This portion of this Technical Guide has been updated to increase the confidence that the approach fully addresses building-by-building variability.	Sections 6.2.2 and 7.8	
Updated and expanded the community involvement information to be more specific to vapor intrusion sites, including guidelines for effective risk communication and available resources, outreach products and tools for outreach.	Section 9	

1.6 Public Involvement in Developing this Vapor Intrusion Technical Guide

On November 29, 2002, EPA published a notice in the *Federal Register* (67 FR 71169) announcing and soliciting comment on its Draft VI Guidance. Since that time, EPA continued to gather information and learn more about vapor intrusion, in part by convening periodic forums where practitioners, regulated parties, and regulators could discuss the emerging science and engineering pertaining to vapor intrusion assessment and mitigation. In addition, on March 17, 2011, EPA published a notice in the *Federal Register* (76 FR 14660) re-opening the docket and soliciting additional comment on its development efforts for this Technical Guide. The docket was re-opened again in March 2012 to receive comments about specific technical documents that were prepared to support development of this Technical Guide; these technical documents are listed in Section 1.4. Finally, another review draft was released on April 16, 2013 for public comment. In developing and refining this Technical Guide, EPA considered all public comments and input received since 2002.

EPA also proactively engaged communities beyond the traditional outreach practices, especially environmental justice communities and communities subject to multiple stressors.[43] Aspects of this engagement have included:

- Conducting public listening sessions in communities impacted by vapor intrusion to solicit input on developing this Technical Guide.
- Using Internet sites and other communication tools to update stakeholders on the progress of developing this Technical Guide.

Table 1-3 identifies specific vapor intrusion topics that have received substantive public comment as a result of EPA's outreach efforts.

1.7 Organization

The next nine sections of this Technical Guide are as follows:

- Section 2.0 Conceptual Model of Vapor Intrusion further describes vapor intrusion and identifies many of the variables that influence vapor migration in the vadose zone and soil gas entry into buildings.
- Section 3.0 Overview of this Vapor Intrusion Technical Guide provides an overview of this Technical Guide and the general recommended framework for vapor intrusion assessment and response action.
- Section 4.0 Considerations for Nonresidential Buildings provides information regarding EPA roles, responsibilities, and risk management decision-making in nonresidential settings, including those (e.g., manufacturing facilities) where workers handle volatile hazardous chemicals similar to or different from those contaminating the subsurface.

---

[43] For more information about the Community Engagement Initiative visit: http://www.epa.gov/oswer/engagementinitiative/

TABLE 1-3
VAPOR INTRUSION TOPICS RECEIVING SUBSTANTIVE PUBLIC COMMENT

Topics	Location Within This Technical Guide	Companion Document(s)
Applicability to petroleum hydrocarbons	Sections 1.3.1, 6.3.2 and 7.3	*Technical Guide for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites* (EPA 2015b)
Applicability to nonresidential buildings	Sections 1.3.2, 4.0 and 7.4.3	
Conditions warranting prompt response action	Sections 5.2, 7.5 and 8.2.1	
Planning investigations and applying data quality objectives	Section 6.2 and Appendix B	
Sampling and monitoring methods for indoor air	Section 6.4.1	
Attenuation factors and risk-based screening	Section 6.5 and Appendix A	*U.S. EPA's Vapor Intrusion Database: Evaluation of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings* (EPA 2012a)
Semi-site-specific screening and application of mathematical models	Sections 6.5 and 6.6	
Use of conceptual site models and multiple lines of evidence in evaluating risks posed by vapor intrusion	Sections 2, 3.2, 5.4, 6.3 and 7	
Risk management benchmarks and decision-making	Section 7	
Use of institutional controls for building mitigation	Section 8.6	
Monitoring and termination of mitigation systems	Sections 8.4 and 8.7	
Risk communication	Section 7.4 and 9	

- <u>Section 5.0 Preliminary Analysis of Vapor Intrusion</u> provides technical information for situations where only limited site-specific data may be available (e.g., initial site assessment).

- <u>Section 6.0 Detailed Investigation of Vapor Intrusion</u> provides technical information for conducting site-specific vapor intrusion assessments emphasizing multiple lines of evidence, including consideration of background concentrations.

- <u>Section 7.0 Risk Assessment and Management Framework</u> provides general recommendations about data evaluations and risk-informed decision-making pertaining to vapor intrusion, including consideration of background concentrations.

- <u>Section 8.0 Building Mitigation and Subsurface Remediation</u> provides technical information for mitigating vapor intrusion and describes how subsurface vapor source remediation and other final cleanup actions are combined with engineered and non-engineered exposure controls to ensure protection of human health.

- <u>Section 9.0 Planning for Community Involvement</u> provides information and describes available resources for engaging affected communities and communicating risk-related information.

- <u>Section 10.0 Glossary</u> provides definitions and descriptions of key terms used in this document.

This Technical Guide concludes with Section 11.0, Citations and References, and three supporting appendices:

- Appendix A: Recommended Subsurface-to-Indoor-Air Attenuation Factors.

- Appendix B: Data Quality Assurance Considerations.

- Appendix C: Calculating Vapor Source Concentration from Groundwater Sampling Data.

2.0 CONCEPTUAL MODEL OF VAPOR INTRUSION

This section presents a general (i.e., not site-specific) conceptual model of vapor intrusion, borrowing from published depictions (EPA 2008a; EPA 2012b; ITRC 2007a; McAlary et al. 2011; DoD 2009). It identifies and describes the 'what', 'where', 'how' and 'why' of vapor intrusion, to provide insights about the many of the lines of evidence pertinent to evaluating vapor intrusion on a site-specific basis, which are discussed further in Sections 5, 6, and 7 of this Technical Guide.[44] It concludes with several general observations that may assist practitioners when planning and conducting detailed vapor intrusion investigations at specific sites, which is the subject of Section 6 of this Technical Guide.

Vapor intrusion is a potential human exposure pathway – a way that people may come into contact with hazardous vapors while performing day-to-day indoor activities. Figure 2-1 summarizes the vapor intrusion pathway for soil gas entry. For purposes of this Technical Guide, the vapor intrusion pathway is referred to as "complete" [45] for a specific building or collection of buildings when the following five conditions are met under current conditions:

1. A subsurface source of vapor-forming chemicals is present (e.g., in the soil or in groundwater) underneath or near the building(s);
2. Vapors form and have a route along which to migrate (be transported) toward the building(s);
3. The building(s) is(are) susceptible to soil gas entry, which means openings exist for the vapors to enter the building and driving 'forces' exist to draw the vapors from the subsurface through the openings into the building(s);
4. One or more vapor-forming chemicals comprising the subsurface vapor source(s) is (or are) also present in the indoor environment; and
5. The building(s) is (or are) occupied by one or more individuals when the vapor-forming chemical(s) is (or are) present indoors.[46]

If one (or more) of these conditions is currently absent and is reasonably expected to be absent in the future (e.g., vapor migration is significantly and persistently impeded by natural geologic, hydrologic, or biochemical (e.g., biodegradation) processes and conditions), the vapor intrusion pathway is referred to as "incomplete."

---

[44] In general, a conceptual site model integrates all lines of site-specific evidence into a three-dimensional conceptualization of site conditions that includes contaminant sources, release mechanisms, vapor migration route(s), and potential receptors. Section 5.4 provides additional information about developing conceptual site models.

[45] A complete vapor intrusion pathw ay indicates that there is an opportunity for human exposure in the subject building(s), w hereas an incomplete pathw ay w ould not provide an opportunity for human exposure,

[46] The exposure route of general interest for vapor intrusion is inhalation of toxic vapors present in indoor air. Because breathing is not avoidable for prolonged periods, individuals in occupied buildings are presumed to be exposed by the inhalation route to any hazardous vapors present in indoor air. Hence, the presence of a human exposure route is implied in the fifth condition.

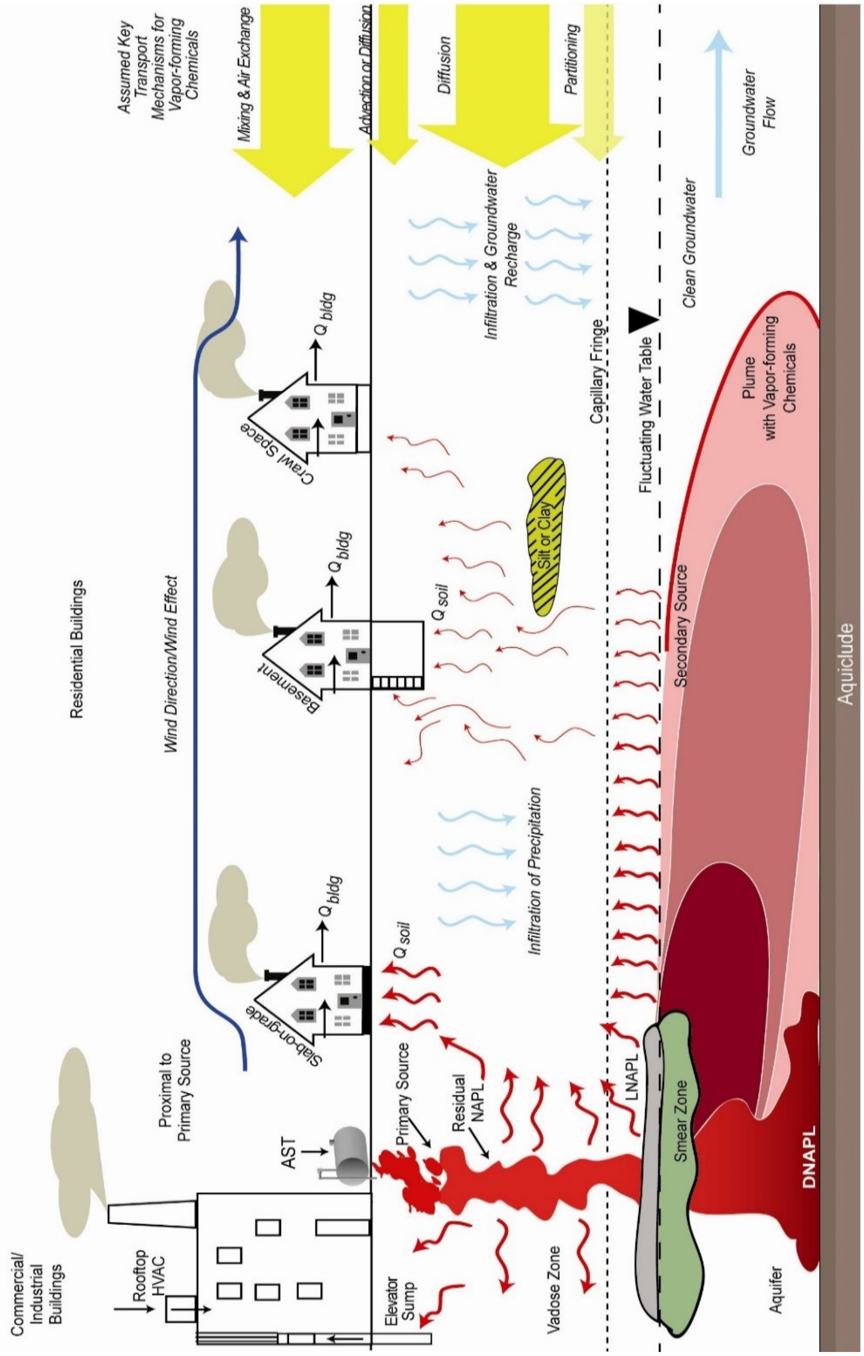


Figure 2-1 Illustration of Key Elements of the Conceptual Model of Soil Vapor Intrusion
Note: Q_{soil} represents soil gas entry; Q_{bldg} represents air exchange.

The first three of these five conditions are further discussed in the next three subsections. Knowledge of potential vapor sources and vapor fate and transport mechanisms is essential for interpreting the data collected during a site-specific investigation of vapor intrusion. Knowledge of the factors that influence the vapor intrusion pathway is also invaluable for identifying, prioritizing, and sequencing data collection activities, which allows a phased and efficient overall investigation plan to be developed. Practitioners are encouraged to refer to quantitative discussions of these subjects, which are provided in *Conceptual Model Scenarios for the Vapor Intrusion Pathway* (EPA 2012b).

The human population of primary interest is comprised of individuals living in, working in, or otherwise occupying a building subject to vapor intrusion. All types of buildings have openings and conduits that render them potentially vulnerable to vapor intrusion. This includes residential buildings (e.g., single-family homes, trailer or 'mobile' homes, multi-unit apartments and condominiums), commercial workplaces (e.g., office buildings, retail establishments), industrial facilities (e.g., manufacturing plants), and educational and recreational buildings (e.g., schools and gyms). Vapor intrusion can occur in buildings with any foundation type (e.g., basement, crawl space, slab-on-grade).

As noted previously, methane and certain other vapor-forming chemicals can also pose explosion hazards in buildings and unoccupied structures,[47] depending upon building-, structure-, and site-specific circumstances. The discussion in the next three sections pertains also to methane and other vapor-forming chemicals that can pose explosion hazards, because similar processes and conditions are involved in explosive vapors migrating towards the interior of buildings or non-occupied structures from the subsurface environment; i.e.,

1) A subsurface source of vapor-forming chemicals is present (i.e., in the soil or in groundwater) underneath or near the structure(s) or building(s).

2) Vapors form and have a route along which to migrate (be transported) toward the structure(s) or building(s).

3) The structure(s) or building(s) is (or are) susceptible to soil gas entry, which means openings exist for the vapors to enter the structure(s) or building(s) and driving 'forces' exist to draw the vapors from the subsurface through the openings into the structure(s) or building(s).

---

[47] For purposes of evaluating potential explosion hazards, non-occupied structures, in addition to buildings, are relevant structures for intrusion and accumulation of vapors.

2.1 Subsurface Vapor Sources

The originating (i.e., primary) source(s) of subsurface contamination may include, but are not limited to, leaking tanks (above or below ground), discharges to sewer lines[48], septic tanks, and floor drains, landfills and other land disposal management units, fire-training areas, spills, discharge areas, and vapor leaks from pressurized tanks and pipelines. The resulting subsurface contamination may be comprised of non-aqueous-phase liquids (NAPLs) [49] (e.g., solvents; petroleum-related products, such as gasoline) and contaminated soil. These are often referred to as the source zone(s). Groundwater and sewer lines[50] flowing through or underneath[51] the source zone(s) can become contaminated and in turn become a (secondary or derivative) subsurface vapor source of contaminant vapors at locations distant from the source zone.

Contaminants in soil, NAPLs, and groundwater can become sources for vapor intrusion if they are likely to volatilize under normal temperature and pressure conditions. Water solubility is also a factor for chemicals in source zones that come into contact with migrating groundwater. Common classes of chemicals of concern for vapor intrusion that exhibit the foregoing characteristics are VOCs, such as tetrachloroethylene (PCE), trichloroethylene (TCE), vinyl chloride, carbon tetrachloride, and benzene, toluene, ethylbenzene and xylenes (collectively, BTEX). Other compounds that are not as volatile as these VOCs (e.g., so-called semi-volatile organic compounds), but that may be cause for concern, include some polycyclic aromatic hydrocarbons (PAHs) (e.g., naphthalene), some polychlorinated biphenyl (PCB) congeners, and elemental mercury, a dense NAPL (DNAPL).[52]

---

[48] Historically, sanitary sewers and septic tanks have been common disposal points for aqueous and chemical wastes from commercial and industrial operations. Contaminated water, non-aqueous phase liquid (NAPL), and VOC vapors can leak from sewer lines through cracks, joints, or breaks. A study of solvent contamination in California arising from dry cleaning operations concluded that discharges to and leakage from sewer lines is an important source of PCE contamination of soil and groundwater: "Where a source investigation has been done in connection with PCE contamination, the … data strongly indicate that leakage through the sewer lines is the major avenue through which PCE is introduced to the subsurface." (Izzo 1992). In the South Weber neighborhood near the Hill Air Force Base in Utah, sewer lines carrying discharged contaminated groundwater to the municipal treatment system were identified as a source of vapor intrusion in homes [Source: *EnviroNews* - Updating environmental issues and activities at Hill Air Force Base, Utah (March 2011); Currently available on-line at: http://www.hillrab.org/news.aspx]

[49] EPA's Contaminated Site Cleanup Information website (http://www.clu-in.org/) provides information describing NAPLs that are denser than water (DNAPLs) or less dense than water (LNAPLs), and methods for their detection and remediation in the subsurface environment.

[50] In addition to receiving direct discharges, sewers can be indirect receptacles of subsurface contamination via infiltration of NAPL, soil gas, or contaminated groundwater through cracks in piping and manholes. For example, Vroblesky et al (2011) found that infiltration of contaminated groundwater into sewers and its transport via and exfiltration from sewers caused complex and unanticipated patterns of groundwater contamination at a site in South Carolina.

[51] Figure 2-1 illustrates a NAPL release/source (near the commercial/industrial building on the left) that fully penetrates the vadose zone. A partially penetrating NAPL release/source may also cause groundwater contamination, however, as infiltrating water passes through the source zone and migrates to the groundwater table.

[52] Once volatilized into soil or sewer gas from a subsurface vapor source(s), these less volatile chemicals will migrate under the influence of diffusion and advection (see Section 2.2) as do more volatile chemicals, although there may be chemical-specific differences in their susceptibility to biodegradation in the vadose zone.

Landfill gases, such as methane and hydrogen sulfide, also can be associated with the vapor intrusion pathway for buildings located near current or former landfills or other degrading wastes. These gases are actively produced as a result of anaerobic biodegradation processes. Methane can also be associated with the vapor intrusion pathway for buildings located near degrading petroleum hydrocarbons or fuel-grade ethanol released into the subsurface environment (Ma et al. 2014, 2012; Sihota et al. 2013).

Properties with potential contamination by vapor-forming chemicals can be found in many industrial and commercial areas. These properties include current and former manufacturing and chemical processing plants, warehouses, landfills and other land disposal units, coal gasification plants, chemical handling or transfer facilities and areas (e.g., train yards), dry cleaners, and retail fueling outlets (also known as gas stations). Use, storage, or transport of chemicals at these facilities may have resulted in a release of vapor-forming chemicals to the environment creating the potential for future vapor intrusion issues. In addition to industrial and commercial activities, roadside dumping, pesticide spraying, or even disposal of household chemicals via a septic field may also release volatile chemicals that may eventually migrate to the subsurface environment.

The primary contamination source need not, however, be on the property of interest to pose a vapor intrusion problem.[53] As illustrated in Figure 2-1, the primary source(s) of vapor intrusion (e.g., contaminated soil, or leaked tanks) may be present on a neighboring property or on a property some distance away. Even “greenspace” properties that have not previously been occupied or developed may contain contamination by vapor-forming chemicals due to migrating plumes of contaminated groundwater or migrating soil gases.[54]

In the case of groundwater as a subsurface vapor source for vapor intrusion, the source strength will be influenced by the vertical distribution of contaminant concentrations in the upper reaches (e.g., top foot) of the water table and by seasonal fluctuations in the groundwater table groundmass flux of vapors. If vapor-forming chemicals are not present in the upper reaches (e.g., within the uppermost foot) of the groundwater table (e.g., due to the presence of an overlying zone of clean water from recharge; i.e., “fresh water lens”),[55] vapor transport to the overlying vadose zone will be impeded due to the slower diffusion of volatile chemicals in water

---

[53] Depending on the geology and amount and form of contamination in the source zone(s), contaminated groundwater plumes can be long and narrow and can flow beneath a property located a mile or more away from the primary source. Soil gas plumes tend to extend in both lateral directions and can be larger in lateral extent relative to groundwater plumes.

[54] See Section 6.2.1 for further discussion on which buildings and non-occupied structures are considered “near” for purposes of a preliminary analysis.

[55] Infiltrating precipitation is important in recharging aquifers with fresh water, as well as in wetting vadose zone soils. At locations distant from “source zones,” infiltrated water that reaches the upper surface of a plume of contaminated groundwater (i.e., recharges groundwater) in an unconfined aquifer will tend to dilute concentrations of vapor-forming chemicals and may form a lens of relatively “clean” water at the groundwater table, which overlies the plume. Because diffusion of dissolved-phase volatile chemicals will tend to control the mass transfer of vapors into the soil gas at the groundwater table, the presence of a lens of clean water as little as a foot in thickness overlying a plume may be sufficient to impede vapor flux to the vadose zone (McAlary et al. 2011). This condition is less likely to occur where fluctuations of the groundwater table are large, relative to local recharge, and would not generally be expected in arid climates.

than in soil gas. For this reason, Figure 2-1 does not show vapors emanating from the leading (i.e., right-most) edge of the plume.

If the vapor-forming chemicals are present in the upper reaches of the groundwater table (i.e., volatile chemicals are in the uppermost reaches of an unconfined – “water table” – aquifer), fluctuations in the water table will tend to transport the volatile chemicals upward (during periods of rising water table) or expose impacted water above the water table to soil gas (during periods of falling water table). The latter will facilitate the episodic formation of vapors in the vadose zone. Rising water tables also will bring the vapor source closer to the building(s).

2.2 Subsurface Vapor Migration

At many sites, the subsurface vapor source (e.g., in soil or groundwater) is not in contact with the bottom of the subject building. Under these circumstances, vapors emanating from the source medium enter the pore space around and between the subsurface soil particles in the soil column above the groundwater table, which is called the unsaturated soil zone or vadose zone. If the subsurface vapor source is in the vadose zone, the vapors have the potential to migrate radially in all directions from the source via diffusion (i.e., upward toward the atmosphere, laterally outward, and downward toward the water table; downward migration may eventually lead to groundwater contamination). If the subsurface vapor source is in the upper-most zone of groundwater, the vapors have the potential to migrate upwards toward the atmosphere via diffusion. Figure 2-1 illustrates these conditions and this process.

Regardless of source type, soil gas concentrations emanating from a subsurface vapor source generally attenuate, or decrease, as the volatile chemicals move from the source through the soil and into indoor air. If and when soil vapor monitoring data at a given site are not consistent with this trend, the conceptual site model may be incomplete (e.g., additional, unrecognized sources or a preferential migration route(s) may exist at the site) and/or bias or error may have been imparted by the sampling and analysis techniques.

Diffusion, which is caused by the random motion of molecules, affects the distribution of soil vapors when there are spatial differences in chemical concentrations in the soil gas. The net direction of diffusive transport is toward the direction of lower concentrations.

Advection occurs in the vadose zone when there is bulk movement of soil gas induced by spatial differences in soil gas pressure. The direction of advective vapor transport is always toward the direction of lower air pressure. Advection is generally expected to occur in the vicinity of buildings, because differences in temperature between the building interior and the subsurface environment or the operation of combustion units or fans within the building can create driving forces for soil gas entry (See Section 2.3). Advection of soil gas may also occur:

- near the ground surface due to fluctuations in barometric (atmospheric) pressure, which can either release soil gas into the atmosphere (Clements and Wilkening 1974) or introduce ambient air into the subsurface environment (the latter process may be important in oxygenating surface soil horizons);[56]

- wherever methane generation from anaerobic degradation is sufficiently high (e.g., near some landfills, some locations with degrading fuels).

Advection may be hindered where extensive surface barriers, such as asphalt, concrete, or frozen soil are present.

Vapors also can migrate via advection (and diffusion) along a preferential subsurface pathway, such as a utility corridor or more porous zones of soil or rock, or beneath surface barriers that limit the direction(s) of vapor migration, such as frozen ground or asphalt.[57]

Vapor migration in the vadose zone can be impeded by several factors, including high soil moisture, low-permeability (generally fine-grained) soil, and biodegradation:

- High moisture levels in the vadose zone can significantly reduce the effective rate of diffusive transport, owing to the substantially smaller diffusion coefficient of vapor-forming chemicals in water compared to air. Where ground covers, such as asphalt or concrete, are absent, soil cores taken external to building structures can reasonably be expected to show greater soil moisture than underneath buildings (Tillman and Weaver 2007), particularly after episodes of precipitation and infiltration. Fluctuations in the elevation of the groundwater table can also contribute to temporal changes in soil moisture profiles, in addition to changing the thickness of the vadose zone.

- A low-permeability layer in the vadose zone, particularly one with high moisture content or perched water, may impede or prevent upward migration of vapors from deeper sources in the vadose zone. Figure 2-1 illustrates partial impedance due to a silty or clay layer of limited lateral extent.[58] In some cases, soil or rock can impose sufficient resistance to vapor migration to make the vapor intrusion pathway insignificant, because low-permeability layers are laterally extensive over distances that are large compared to the size of the building(s) or the extent of subsurface contamination with vapor-forming chemicals.

---

[56] Under certain conditions, such as periods during which indoor−outdoor pressure differences are small, atmospheric pressure fluctuations may contribute to the vapor flux into a building (Robinson and Sextro, 1997).

[57] Whether the subsurface vapor source is contaminated soil or groundwater, soil gas concentrations emanating from a subsurface source generally attenuate, or decrease, as the vapors move from the source through the soil and into indoor air due to diffusion and advection and are subject to any degradation. If and when soil vapor monitoring data at a given site are not consistent with this trend, the possible existence of a preferential migration route(s) warrants consideration. Sewer lines also warrant consideration as potential sources of vapors, as well as conduits for preferential (e.g., unattenuated) transport of vapors towards buildings. Preferential migration routes are discussed further throughout this Technical Guide, including in Sections 5.4, 6.3.2, and 6.5.2.

[58] Low-permeability layer(s) overlying contaminated groundwater (i.e., “aquicludes”) can, likewise, impede the flux of vapors from the contaminated plume to the vadose zone. The aquiclude shown at the base of Figure 2-1 would not impede the flux of vapors from the contaminated plume to the vadose zone, however, because the aquiclude is below both. The aquiclude would impede vapor flux from any additional contaminated plume located below it.

- Some chemicals (e.g., benzene, methane, and other petroleum hydrocarbons; vinyl chloride (Patterson et al. 2013) and some other chlorinated hydrocarbons) may experience reductions in their soil gas concentrations due to biodegradation in the vadose zone under certain conditions. Depending upon the potential for oxygen to migrate into the subsurface and underneath buildings from the ambient air, biodegradation may be anaerobic or aerobic. The rate of biodegradation *in situ* will be chemical-specific (i.e., chemicals have different degradation rates even within a similar microbial environment), will be site-specific (i.e., the microbial environment will depend upon soil moisture, nutrient and oxygen levels, and the chemical mixture,[59] among other factors (Holden and Fierer 2005)), and may be location-specific (i.e., the microbial environment can change over time and space due to variations in soil moisture,[60] nutrient and oxygen[61] levels). In some cases, biodegradation in the vadose zone can impede vapor migration significantly.

Demonstrating the extent, if any, to which these processes act as a barrier to vapor transport at specific sites may entail intensive testing or investigative methods that are very different from the sampling and analysis techniques for indoor air and soil gas (see, for example, Sections 6.3.2 and 6.4). Where and when it occurs, biodegradation may result in the formation of by-products that are potentially hazardous (e.g., methane from ethanol, vinyl chloride from PCE or TCE).

The distribution and magnitude of soil gas concentrations immediately beneath a building are expected to reflect the interplay between vapor transport toward the building (via diffusion and advection) in the vadose zone and vapor withdrawal due to soil gas entry into the building (in the case where the building is under-pressurized), which may be spatially and temporally variable (Section 2.3). Likewise, soil vapor may become contaminated as a result of over-pressurized buildings forcing contaminated indoor air through openings in the foundation into nearby soil.

2.3 Openings and Driving Forces for Soil Gas Entry into Buildings

Hazardous vapors in the vadose zone may eventually enter buildings as a component of a gas by migrating through cracks, seams, interstices, and gaps in basement floors, walls, or foundations (“adventitious openings”) or through intentional openings, such as perforations due to utility conduits and sump pits. Figure 2-2 illustrates some of these types of openings. Buildings can be expected to vary, even within a single community, in the amount of opening

---

[59] For example, aerobic biodegradation of benzene may be impeded by the presence of methane, due to competition for oxygen by methane-oxidizing (“methanotrophic”) bacteria, depending upon site-specific conditions (Ma et al. 2012).

[60] Moisture plays a particularly important role for microorganisms in the vadose zone. Microbial growth and activity can decrease rapidly with depth, coincident with the soil moisture profile, and increase again in the capillary fringe (Holden and Fierer 2005).

[61] Site-specific infrastructure and soil conditions, climate, and other factors will determine the extent to which oxygen levels underneath a building will be different compared to locations outside the building footprint. In addition to buildings, surface covers, such as asphalt or concrete, can impede oxygenation of the vadose zone, relative to the case where the ground surface is in contact with the atmosphere, all other factors being equal.

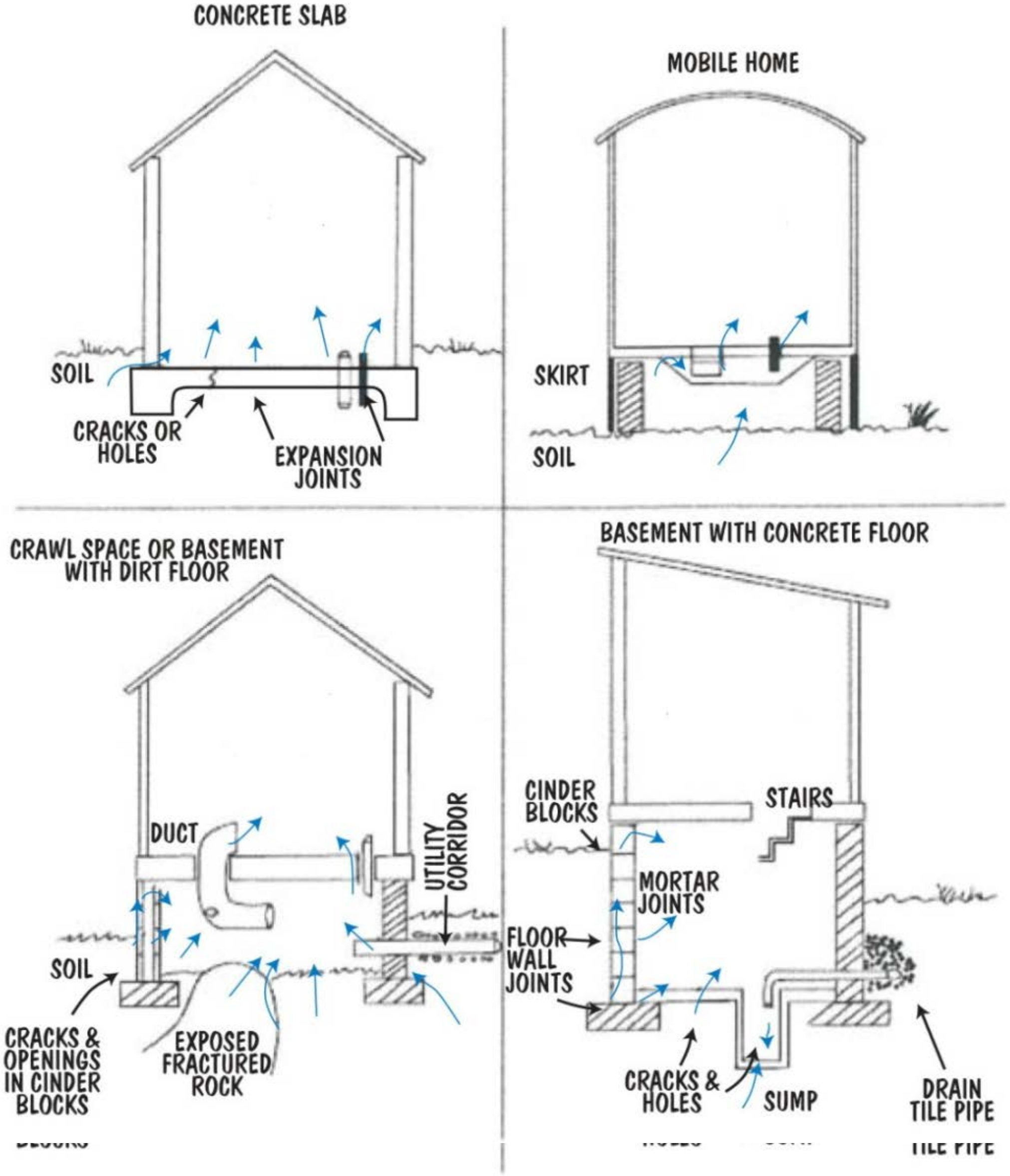


Figure 2-2 Illustration of Potential Openings in Various Building Types
Note: Blue arrows represent soil gas migration or entry. Source: EPA (2008)

area available for soil gas entry; for example, buildings with deteriorating basements and foundations or dirt floors are more susceptible to soil gas entry.

As mentioned in Section 2.2, advection in the vadose zone can arise in the vicinity of buildings whenever there is a difference between the air pressure within a building and the subsurface environment. The air pressure within a building can be lower than in the subsurface due to:

- Temperature differences between indoor and subsurface locations (e.g., the winter-time "stack effect," when buildings are commonly heated, leading to convection cells driven by heated air that rises to upper levels and leaks through roofs and upper-floor windows).
- The operation of mechanical devices, such as exhaust fans for ventilation, air conditioners, and clothes dryers, with vents to the outdoors.
- The operation of fireplaces that vent combustion (exhaust) gases to the outdoors.
- The operation of furnaces in basements of centrally heated buildings, which can incrementally depressurize the basement (EPA 1993a).
- Wind load on the building walls.[62]

Even small pressure differences may cause advective flow of soil gas into or out of the building through pores, cracks, or openings in the building floor or basement walls[63] or gas present in drain lines, sumps, and sewer lines that do not have adequate vapor traps.[64]

---

[62] The wind effect is caused by differences in building pressure on a building's surfaces. The outdoor air pressure will be higher on the windward side of the building, than on the leeward side, as ambient air flows around the building. The net effect of this pressure difference will vary from building to building, depending upon the location of the primary openings for soil gas entry (and the primary opening for air infiltration through the building envelope –see Section 2.4) (EPA 1993a, Section 2.3 therein).

[63] As a result of the construction of foundation walls and floor slabs, a perimeter crack (i.e., space between the floor slab and walls) may be created and serve as an entry location for soil vapors. This perimeter crack is often obscured by wall coverings, and may not be accessible for inspection or direct testing. Vapors have been observed to migrate through what appears to be intact concrete floors and walls, which may, in fact, have small unobserved fractures or porous areas from improper curing. In addition, conduits may be present that facilitate soil gas entry into buildings. These conduits may include utility (e.g., sewer, water, or electrical) penetrations and floor drains

[64] Where sewers or other conduits contain volatile contaminants, lateral lines connecting buildings to these conduits may facilitate vapor intrusion into indoor air. Although floor drains are designed to allow water to drain away from the building, they are usually not designed or constructed to eliminate gas entry. At a test house in Indianapolis, elevated levels of PCE and chloroform were found in gas in a laundry drain line, which was suspected of serving as a source of vapors found in indoor air (EPA 2012f). Although building construction codes and toilet designs are intended to prevent sewer gas from entering homes, inadequate maintenance (e.g., plumbing fixture seals) can result in loss of the intended protection. Pennell et al (2013), for example, found sewer gas entry to be a significant source of PCE in indoor air at a home in Massachusetts. In addition, sewer gas was a suspected source of benzene in indoor air in many buildings near a gasoline spill site in Hazleton, Pennsylvania (www.epa.gov/reg3hwmd/npl/PA0001409671.htm), where sewer vent traps were subsequently installed to mitigate intrusion of gasoline vapors into homes.

To date, most analytical and computational models of vapor intrusion have been predicated on the assumption that residences and other small buildings experience a constant under-pressurization (i.e., lower pressure in the building than in the subsurface), which fosters vapor intrusion. Whereas this assumption facilitates analyses and may be reasonable for some purposes (see, for example, Section 2.5), it is highly idealized. To illustrate: fluctuations in subslab-to-building pressure difference (and, hence, soil gas entry rates) over time can be reasonably expected due to:

- diurnal (daily) and seasonal changes in the temperature of ambient air, whereas indoor temperatures may be more stable, particularly during periods when mechanical heating and cooling systems are in use;
- changes in ambient air pressure;
- non-instantaneous response (i.e., lag or delay in response) of subsurface soil gas to changes in ambient air pressure (EPA 1993a, Section 2.3 therein), particularly where low-permeability soil is in direct contact with a building foundation (e.g., basement) below the ground surface;[65]
- changes in wind direction and speed; and
- intermittent operation of mechanical ventilation systems and combustion devices that vent exhaust gases to the outside.

Theoretically, these processes and variables suggest that soil gas entry rates can be expected:

- to vary over different time scales (e.g., within an day, and between seasons);
- to differ geographically due to differences in ambient air temperature, pressure, wind, and building conditions (e.g., leakage area and its distribution over the building envelope); and
- to be discontinuous over some time periods.

---

[65] On the other hand, where granular fill is present underneath a building, there is potential for preferential soil gas flow through the fill, especially in locations where the gas permeability of the surrounding soil is low. Where granular materials have differentially settled, air voids (also highly permeable to soil gas flow) may form beneath the foundation. Utility penetrations and other conduits may be connected to the granular fill, accentuating the potential pathway for soil gas entry into a building. Adding to the complexity, pressure differentials caused by wind flows conceivably could create a cross-flow through granular fill underneath the foundation, which may episodically dilute vapor concentrations (and oxygenate soil gas) in the building vicinity.

2.4 Air Exchange and Mixing

Air exchange refers to the flows into and out of a building, which are generally in balance, and is composed of three processes:

1) infiltration—air leakage through random cracks, interstices, and other unintentional openings in the building envelope;

2) natural ventilation—airflows through open windows, doors, and other designed (intentional) openings in the building envelope; and

3) mechanical ventilation—air movement controlled and driven by fans.

For the vapor intrusion exposure scenario, air exchange by each of these processes will generally tend to mitigate the effects of vapor intrusion (i.e., reduce indoor air concentrations) via dilution, while air inflows will also transport indoors any vapor-forming chemicals in ambient air (see Section 2.7).[66]

The air exchange rate is conventionally defined as the ratio of the airflow rate (e.g., cubic meters per second) to the building volume (e.g., cubic meters) and is generally expressed in terms of exchanges per hour (i.e., overall units of hour^{-1}). Values for residential air exchange rates are typically on the order of approximately 0.18 to 1.26 air changes per hour (ACH) (EPA 2011b, see Table 19-24 therein, 10th and 90th percentiles).[67,68] Values for non-residential buildings are highly-dependent upon building use and can range widely (on the order of approximately 0.3 to 4.1 ACH) (EPA 2011b, see Table 19-27 therein, 10th and 90th percentiles).

---

[66] The potential diluting effect of air exchange arises when ambient air has negligible presence of the volatile chemicals found in site-related contamination in the subsurface environment. In some situations, site-related contamination has the potential to impact ambient air with the same vapor-forming chemicals that pose a threat from vapor intrusion. For example, contamination of shallow soil or groundwater may release site-related vapor-forming chemicals to ambient air. In such situations, air exchange would contribute to the presence of site-related contamination in indoor air, rather than only dilute any impacts from vapor intrusion.

[67] EPA's Office of Research and Development evaluated eight studies of air exchange rate for residential buildings and selected a 1995 EPA study as the basis for recommending values for risk assessment (EPA 2011b, Table 19-24). The key study analyzed almost 3,000 time-averaged measurements of exchange rate in occupied homes in the United States, which were generally obtained using a tracer-release method. Median values ranged from 0.35 hour^{-1} in the mid-western region to 0.49 hour^{-1} in the northeast and southern regions. Tenth percentile values ranged from 0.16 hour^{-1} in the mid-western and southern regions of the U.S. to 0.23 hour^{-1} in the northeast region. Regional differences in exchange rate reflect differences in weather (e.g., temperature and wind speed), prevailing building conditions (e.g., house 'leakiness'), and the time periods (e.g., season) in which measurements were made.

[68] EPA's Office of Research and Development (EPA 2011b, Section 19.5.1.2.7) also summarized a study that conducted approximately 500 indoor-outdoor air exchange rate (AER) calculations based on residences in three urban locations (metropolitan Elizabeth, NJ; Houston, TX; and Los Angeles, CA). This study highlights how climate and season can influence air exchange rate. In Texas, the measured AERs were lower in the summer cooling season (median = 0.37 ACH) than in the winter heating season (median = 0.63 ACH), likely because windows were closed while air conditioners were in use. The measured AERs in California were higher in summer (median = 1.13 ACH) than in winter (median = 0.61 ACH), because summers in Los Angeles County are less humid than NJ or TX and residents are more likely to utilize natural ventilation through open windows and screened doors. In New Jersey, air exchange rates in the heating and cooling seasons were similar.

To date, most analytical and computational models of vapor intrusion have been predicated on the assumption that residences and other small buildings are well mixed spaces throughout which concentrations of vapor-forming chemicals are uniform. Whereas this assumption facilitates analyses and may be reasonable for some purposes (see Section 2.5), it is highly idealized. To illustrate: airflow within a building (i.e., inter-zonal airflow) can be impeded by doors, walls, and other partitions that separate rooms and other building areas. Whereas airflows within a building can be facilitated by mechanical means, spatial variation of temperature and humidity suggest that air mixing is not necessarily complete even in buildings that benefit from centralized systems for heating, air condition, and ventilation. Furthermore, many residences do not have such mechanical systems. Therefore, buildings subject to vapor intrusion may exhibit differences in concentration of vapor-forming chemicals among building areas (e.g., rooms) as a result of the differential proximity to openings for soil gas entry (see Section 2.3) and openings for air leakage and ventilation and the magnitude and balance of inter-zonal airflows. For example, rooms with perforations through the foundation (e.g., bathrooms or utility rooms) may have greater concentrations of vapor-forming chemicals in air compared to rooms that do not. Generally, basements can reasonably be expected to exhibit greater concentrations of vapor-forming chemicals than upper occupied levels.

Buildings constructed over a crawl space with a dirt floor may benefit from the dilution of soil gas by any ventilation of crawl space air, but would not have the impedance to vapor intrusion that concrete slabs can provide. Trailers enclosed at the bottom by a skirt are expected to have greater potential for vapor intrusion than would non-enclosed trailers. Wind movement between the ground surface and the bottom of the non-enclosed trailer would tend to minimize vapor buildup and associated potential for vapor flux into the building. Similarly, the existence of underground parking for a multi-story building (or other modifications to the foundation that enhance subsurface ventilation) would tend to minimize the potential for vapor intrusion.

2.5 Conceptual Model Scenarios

Based upon the foregoing conceptual model, numerous factors can influence the potential indoor air concentration arising from vapor intrusion. Some of these significant factors are illustrated in Figure 2-3.

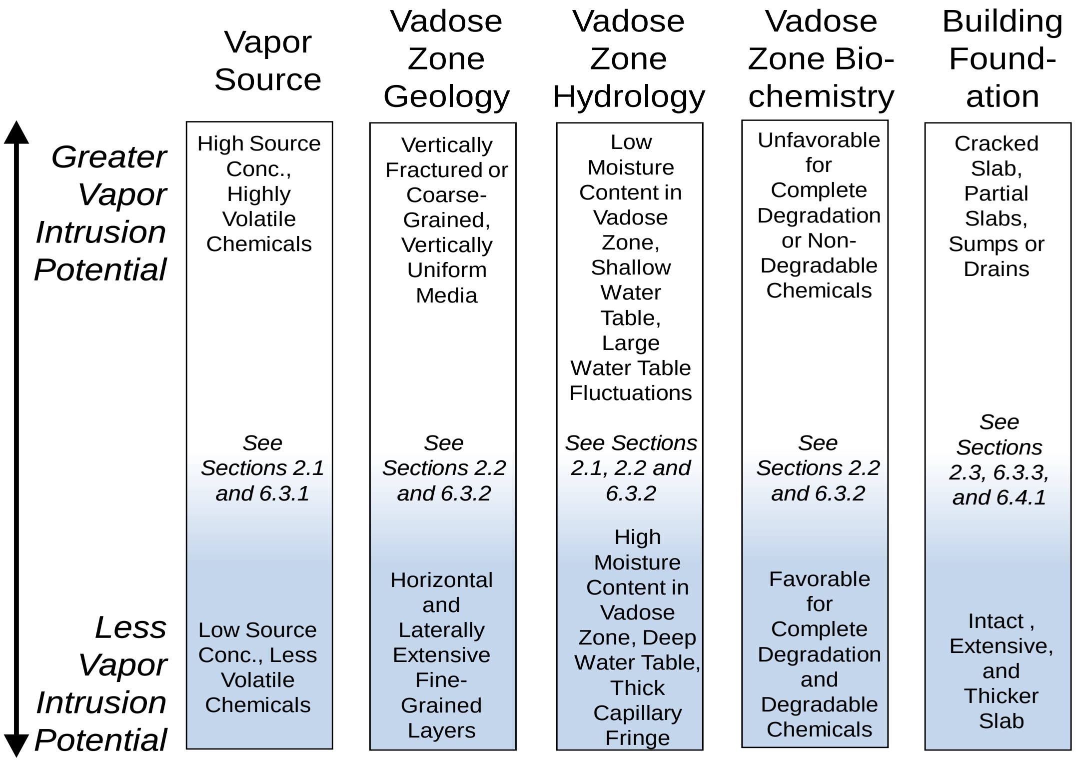


Figure 2-3 Some Factors That Affect Vapor Intrusion

The document *Conceptual Model Scenarios for the Vapor Intrusion Pathway* (EPA 2012b) provides simplified simulation examples[69] to illustrate graphically how several of the subsurface and building-specific factors work together to determine the distribution of volatile contaminants in the subsurface and the indoor air concentration relative to a source concentration. The conceptual model scenarios document offers insights into the factors influencing the vapor intrusion pathway. It provides a theoretical framework with which to draw inferences about and better understand the complex vapor fate and transport conditions typically encountered at actual, non-idealized contaminated sites. The following general observations can be made from these simplified simulation examples, and may be useful when considering the vapor intrusion pathway at a particular site:

- The horizontal and vertical distance over which vapors may migrate in the subsurface depends on the source concentration, source depth, soil matrix properties (e.g., porosity and moisture content), and time since the contaminant release to the environment occurred. Months or years of volatilization and vapor migration may be required to fully develop vapor distributions in the vadose zone at sites with deep vapor sources or with impedances to vapor migration arising from hydrologic or geologic conditions.

- Vapor concentrations, including oxygen, in the vadose zone (i.e., soil gas concentrations) may not be uniform in sub-slab soil gas or in soil gas at similar depths exterior to the building of interest. Therefore, soil gas concentrations at exterior locations (i.e., outside a building's footprint) may be substantially different from the concentration underneath the building (e.g., the sub-slab concentration), depending on site-specific conditions and the location and depth of the exterior soil gas sample.

- Simulations assuming an idealized, constructed ground cover suggest that shallow soil gas concentrations can be greater under low-permeability ground covers (e.g., asphalt) than under soil open to the atmosphere.

- The soil gas distribution beneath a building is not the only factor that determines the indoor air concentration. The indoor air concentration is also influenced by building conditions, including the presence of openings (e.g., cracks, utility penetrations) in the foundation, building pressurization, and the air exchange rate.

- Advective flow into buildings, which is presumed to occur predominantly near cracks and openings in the foundation slab, may affect the distribution of vapor-forming chemicals directly beneath the structure. Heterogeneities in the permeability of geologic materials and backfill, along with wind effects and building and atmospheric pressure temporal variation, may also contribute to the spatial and temporal variability of vapor concentrations in sub-slab soil gas and indoor air.

---

[69] Two important simplifications are the assumptions of constant values for the driving force for vapor intrusion (i.e., subslab to indoor air pressure difference) and air exchange rate, whereas time-variable values are reasonably expected as a result of changing weather and other conditions (as summarized in Sections 2.3 and 2.4, respectively).

- Subsurface heterogeneities in site geology, such as layering and moisture content, can influence the extent and rate of vapor migration from a contaminant source towards overlying or adjacent buildings.

- The soil gas distribution of aerobically biodegradable chemicals (e.g., BTEX) can be significantly different than that of other chemicals that are not biodegradable (i.e., are recalcitrant) in similar settings. Specifically, the soil gas concentrations of aerobically biodegradable chemicals exhibit greater attenuation than those of recalcitrant chemicals when the subsurface availability of oxygen is adequate.

2.6 Variability in Exposure Levels

Given the foregoing conceptual model of vapor intrusion and summary of modeled scenarios (EPA 2012b), the degree to which vapor intrusion is a pathway of concern can vary widely from site to site and from building to building within a site. Adding to the complexity, theoretical considerations (i.e., soil gas entry rates, air exchange rates, interior compartmentalization and inter-zonal airflows) suggest that indoor air concentrations arising from vapor intrusion can be expected to vary over time and within a building. Field observations and measurements demonstrate that indoor air concentrations can exhibit significant temporal variation within a day and between days and seasons in an individual residential building (EPA 2012a; Holton et al. 2013ab).

2.7 Consideration of Indoor and Outdoor Sources of VOCs

Indoor air in many buildings will contain detectable levels of a number of vapor-forming chemicals whether or not the building overlies a subsurface source of vapors (EPA 2011a), because indoor air can be impacted by a variety of indoor and outdoor sources. Indoor sources of volatile contaminants include the use and storage of consumer products (e.g., cleaners, air fresheners, aerosols, mothballs, scented candles, insect repellants, or other household products), combustion processes (e.g., smoking, cooking, and home heating), occupant activities (e.g., craft hobbies, home improvements, automotive repairs), and releases from interior building materials (e.g., carpets, insulation, paint, and wood-finishing products). Outdoor sources of volatile chemicals may arise due to releases from nearby sources such as industrial facilities, vehicles, yard maintenance equipment, fuel storage tanks, and paint or pesticide applications; regional sources such as air emissions from regional industry, vehicle exhaust, agricultural activities, and fires; or global sources, such as distant air emissions. The outdoor air surrounding a building is referred to as “ambient air” throughout this Technical Guide.

The contribution of indoor and outdoor sources of vapors (or both) to indoor air concentrations, which do not arise from site-related contamination,[70] is referred to as “background” throughout this Technical Guide (see, for example, Sections 2.7, 6.3.5, and 7.4.2 and the Glossary). In

---

[70] In some situations, site-related contamination has the potential to impact indoor or ambient air (EPA 1993c) with the same vapor-forming chemicals that pose a threat from vapor intrusion. For example, contaminated groundwater in building sumps or intruding into the building via groundwater seepage could provide an indoor source of site-related contamination. Contamination of shallow soil or groundwater may also release site-related vapor-forming chemicals to ambient air. In such situations, neither of these sources of indoor air contamination would be considered ‘background.’

some buildings, “background” sources by themselves can cause building occupants and visitors to experience significant exposures to vapor-forming chemicals.

In contrast to “background” concentrations in soil arising from naturally occurring minerals, “background” concentrations in indoor air often are not uniform in time. For example, concentrations of vapor-forming chemicals in ambient air may exhibit temporal variation over several time scales (e.g., daily, seasonal, longer term) and spatial differences across urban, suburban, and rural land use areas, reflecting differences in emission sources and rates and environmental factors that transport, disperse, and remove these pollutants (Jia et al. 2012 and citations therein). Concentrations of vapor-forming chemicals arising in indoor air in residential buildings due to indoor sources have been observed to depend upon season and other factors. Available studies suggest complex (e.g., patchy) spatial patterns in exposure concentration, which has led some researchers to refer to “microplumes” in the indoor air environment (McBride et al., 1999 and citations therein).

3.0 OVERVIEW OF THIS VAPOR INTRUSION TECHNICAL GUIDE

This section provides an overview of this Technical Guide and the general recommended framework for vapor intrusion assessment and response action, which is illustrated in Figure 3-1. This section opens with a description of subsurface contaminants that have the greatest potential to pose a health concern via vapor intrusion, based upon their volatility and potential hazards.

3.1 Contaminants of Potential Concern

Several physicochemical criteria may be considered for defining and screening for volatility.[71] For purposes of this Technical Guide, a chemical generally is considered to be “volatile” if:

1) Vapor pressure is greater than 1 millimeter of mercury (mm Hg), or

2) Henry’s law constant (ratio of a chemical’s vapor pressure in air to its solubility in water) is greater than 10^{-5} atmosphere-meter cubed per mole (atm m^3 mol^{-1}) (EPA 1991b, Section 3.1.1; EPA 2002c, Appendix D).

Various other criteria may be considered for identifying when volatile chemicals are present at levels of potential health concern. For purposes of this Technical Guide, a volatile chemical generally is considered to be “potentially toxic” via vapor intrusion if:

1) the vapor concentration of the pure component exceeds the indoor air target risk level, when the subsurface vapor source is in soil, or

2) the saturated vapor concentration exceeds the target indoor air risk level, when the subsurface vapor source is in groundwater.

Each of the chemicals with one or more toxicity values used to derive Regional Screening Levels (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm) were evaluated for volatility and toxicity, according to the foregoing recommended criteria. These criteria do not include a consideration of whether these chemicals are regulated pursuant to CERCLA, as amended, or RCRA, as amended. The universe of chemicals evaluated and the results of the evaluation are provided in EPA’s on-line VISL Calculator (EPA 2015a), which is described further in Sections 1.4.1 and 6.5.2 of this Technical Guide.

Chemicals which satisfy the foregoing screening criteria for volatility and toxicity are designated as “vapor-forming chemicals” for purposes of this Technical Guide. In addition:

---

[71] In chemistry and physics, volatility refers to the tendency of a substance to form vapors, which are molecules in a gaseous state, and escape from a liquid or solid. Volatility is directly related to a substance’s vapor pressure and Henry’s law constant. EPA (1991b) also cites molecular weight as a necessary criterion for assessing volatility. Molecular weight is not retained for this Technical Guide as a volatility criterion, because it is a relatively weak predictor of volatility.

- cis-1,2-dichloroethylene, a volatile chemical that lacks sufficient toxicity information (to apply the toxicity criteria above), is identified as a vapor-forming chemical due to its potential use as an indicator of vapor intrusion when it is present as a subsurface contaminant;[72]

- methane is identified as a vapor-forming chemical due to its potential to pose an explosion hazard and to be formed via anaerobic biodegradation processes in the subsurface environment;[73] and

- radon is identified as a vapor-forming chemical when it arises from uranium- or radium-bearing solid wastes in the subsurface.[74]

Chemicals that meet these recommended screening criteria are referred hereafter in this Technical Guide as "vapor-forming chemicals." EPA recommends that these chemicals be evaluated during vapor intrusion assessments, when they are present as subsurface contaminants due to a site-related release(s). EPA recommends that chemical analyses be limited to those vapor-forming chemicals known or reasonably expected to be present in the subsurface environment due to a site-related release(s). The list of vapor-forming substances warranting consideration for potential vapor intrusion may be modified in the future.[75]

3.2 Vapor Intrusion Assessment

The approach for assessing vapor intrusion will vary from site to site, due to site-specific factors. For example, the information available for evaluating vapor intrusion potential will vary depending upon when vapor intrusion is first considered during a site's investigation-and-cleanup life cycle. Many sites can be evaluated for potential vapor intrusion during the normal course of an initial site assessment. Examples include brownfield sites that are intended for redevelopment and buildings where chemical odors have been reported. The data available for evaluating vapor intrusion may be very limited at the outset for these situations. At the other end of the investigation and cleanup life cycle, certain sites with long- term cleanups underway for contaminated groundwater may be evaluated for vapor intrusion during periodic reviews, if any,

---

[72] EPA (2011a) and DoN (2011a) report that cis-1,2-dichloroethylene (cis-1,2-DCE) is "rarely detected in background indoor air." When they are subsurface contaminants, volatile chemicals, such as cis-1,2-DCE, that are rarely or never present in indoor sources can be inferred to arise in indoor air via vapor intrusion "without further explanation" (DoN 2011a). Brenner (2010), for example, employed this principle to identify buildings susceptible to vapor intrusion and to diagnose the relative contributions of vapor intrusion and infiltration to indoor air concentrations.

[73] As noted previously, methane in soil gas may produce two other undesirable consequences: (1) it can exacerbate migration and intrusion of other vapors if it is generated at rates sufficient to foster advective flow of soil gas (see Section 2.3); and (2) its biodegradation in the vadose zone can reduce the oxygen available for biodegradation of other hydrocarbons (Ma et al. 2012).

[74] Radon emanating from natural geological materials may also affect indoor air quality in occupied buildings, but is not a subject of this Technical Guide. For more information about radon emanating from natural geological materials, see: http://www.epa.gov/radon/index.html.

[75] For example, inhalation toxicity values for additional volatile chemicals may become available in the future.

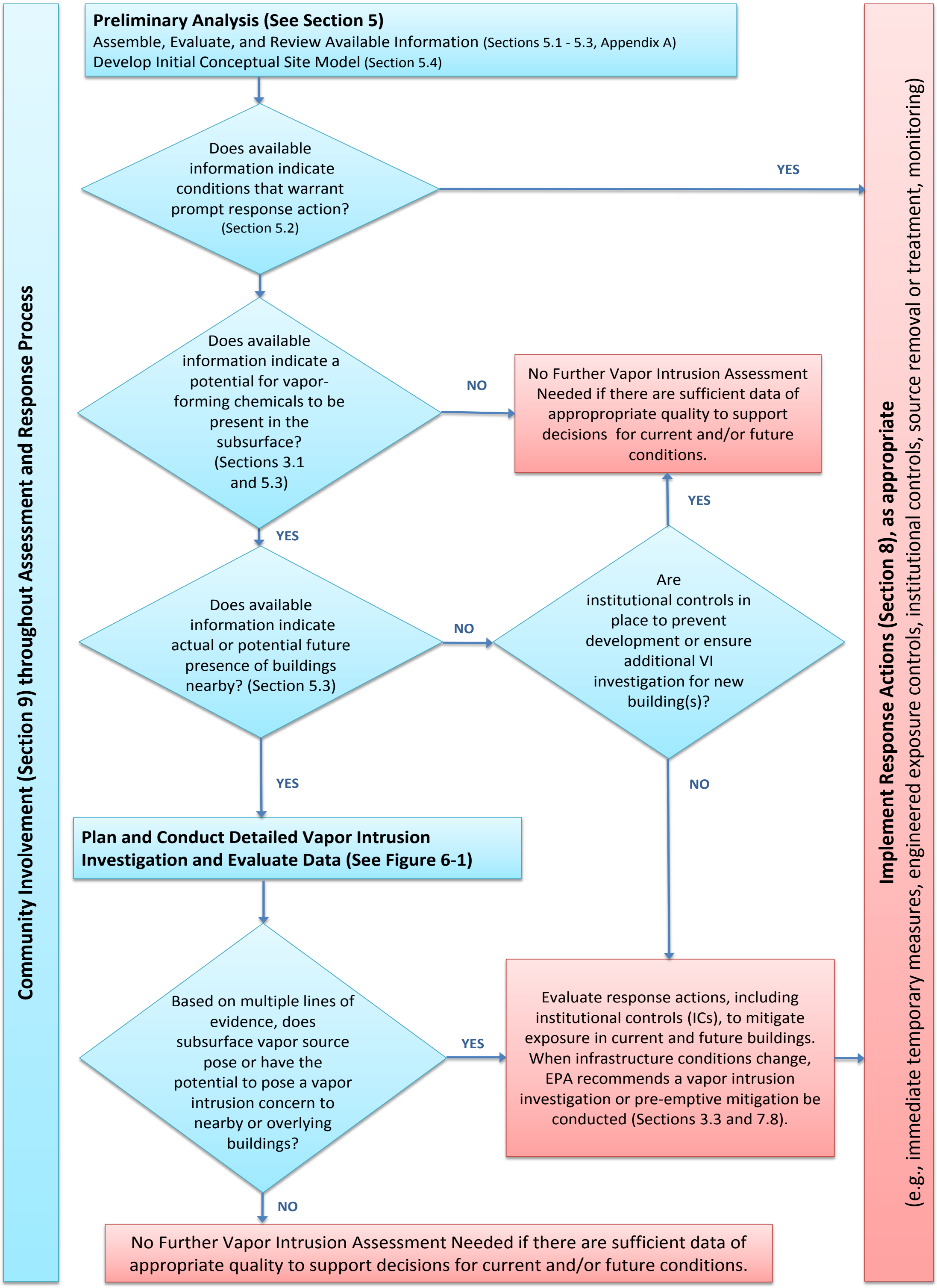


Figure 3-1 Overview of Recommended Framework for Vapor Intrusion Assessment and Response Action

of remedy performance and groundwater monitoring data.[76] In such situations, detailed information about the nature and extent of subsurface contamination and the relevant hydrogeologic conditions may already exist. In addition, there are different scenarios for vapor intrusion (EPA 2012b), depending on characteristics of the source (e.g., types, chemicals of concern, mass, distribution, and distance from building(s)), subsurface conditions and vapor migration routes (e.g., soil types and layering, existence of preferential migration routes due to geology or infrastructure, and existence of any impediments to vapor migration), building susceptibility (e.g., age, design, construction, condition), lifestyle factors (e.g., keeping windows open or closed), and regional climate. For these reasons, every site (and every building) will not warrant the same approach to or intensity of assessment for vapor intrusion. This Technical Guide, therefore, recommends a framework for planning and conducting vapor intrusion investigations, rather than a prescriptive step-by-step approach to be applied at each and every site.

Broadly speaking, two general levels of vapor intrusion assessments can be distinguished:

1) A preliminary analysis utilizes available and readily ascertainable information to develop an *initial* understanding of the potential for human health risk that are or may be posed by vapor intrusion, which would typically be performed as part of an initial site assessment. The recommended information, approaches, and practices for conducting a preliminary analysis and its potential outcomes are described in Section 5.0.

2) A detailed investigation is generally recommended when the preliminary analysis indicates that subsurface contamination with vapor-forming chemicals may be present underlying or near buildings. A detailed investigation of the vapor intrusion pathway is typically performed as part of the site investigation stage. The recommended approaches and practices for conducting detailed vapor intrusion investigations are described in Section 6.0.

Considerable information, primarily empirical, has been generated regarding evaluation of the vapor intrusion pathway since the pathway emerged as a national issue in the late 1990s and especially in the past ten years. Broadly speaking, this information demonstrates that the vapor intrusion pathway can be complex. (The conceptual model of vapor intrusion provided in Section 2.0 identifies many of the factors, variables, and conditions that warrant consideration on a site-specific basis.) As a result, current practice suggests that the vapor intrusion pathway generally be assessed using multiple lines of evidence.[77]

Specific conclusions that EPA recommends be based upon multiple lines of evidence include:

---

[76] These situations can arise, for example, if the groundwater remedy was selected in the 1980s (long before vapor intrusion became recognized as a potentially significant exposure pathway), or if supplemental groundwater data indicate that the plume is migrating toward new inhabited areas.

[77] As discussed further in Section 7.2, confidence in the assessment and risk management decisions is expected to be higher when multiple independent lines of appropriate site- or building-specific evidence from, for example, multiple types samples of environmental media (e.g., groundwater, soil-gas, sub-slab vapor, crawlspace, and indoor air) and/or other data come together to provide mutually supporting evidence for a common understanding of the site conditions/scenarios and the potential for vapor intrusion (EPA 2010b) (i.e., the various lines of evidence are in agreement with each other).

- The subsurface vapor source(s) at a specific site has (or, alternatively, does not have) the potential to pose an unacceptable vapor intrusion exposure under current or reasonably expected future conditions, due to its strength (e.g., concentration and mass of vapor-forming chemicals) and proximity relative to one or more existing buildings or a building that may be constructed in the future.

- The vapor intrusion pathway is complete for one or more buildings under current conditions or is potentially complete under reasonably expected future conditions.

- The vapor intrusion pathway is incomplete for one or more buildings near a subsurface source of vapor-forming chemicals, due to geologic, hydrologic, and/or biochemical (e.g., biodegradation) processes that provide substantial and persistent attenuation of vapors extending laterally over large distances relative to the footprint of the building(s) and the extent of the vapor source.

- Indoor air concentrations attributable to vapor intrusion pose (or, alternatively, are unlikely to pose) an unacceptable human health risk in one or more existing buildings under current or reasonably expected future conditions.

- Indoor air concentrations measured in one or more buildings can (or alternatively, cannot) be reasonably attributed to indoor or ambient air sources (i.e., background).

Multiple lines of evidence are particularly important for supporting “no-further-action” decisions regarding the vapor intrusion pathway (e.g., pathway incomplete determinations) to reduce the chance of reaching a false-negative conclusion (i.e., concluding vapor intrusion does not pose unacceptable human health risk, when it actually poses an unacceptable human health risk). Collecting and weighing multiple lines of evidence can also help avoid reaching a false-positive conclusion (i.e., concluding vapor intrusion poses an unacceptable human health risk, when it does not.

In summary, EPA recommends that site assessors generally collect and weigh multiple lines of evidence, including qualitative information, to support decision-making regarding the vapor intrusion pathway. Lines of appropriate evidence to evaluate the vapor intrusion pathway were identified in Section 2 and are discussed further in Sections 5 through 7.

As noted in Section 1.3, Figure 3-1, and the preceding discussion of lines of evidence, EPA recommends that site assessors consider reasonably expected future conditions, in addition to current conditions, when reaching conclusions about the vapor intrusion pathway.[78] For this reason, this Technical Guide includes recommendations for evaluating whether subsurface vapor sources that remain have the potential to pose unacceptable human health risks in the future if current conditions were to change. For example:

- Section 6.3.3 recommends that site assessors consider investigating vapor intrusion in non-residential buildings under conditions when the heating, ventilation, and air-conditioning system is not operating; and

---

[78] “Both current and reasonably likely future risks need to be considered in order to demonstrate that a site does not present an unacceptable risk to human health and the environment.” (EPA 1991a).

- Section 7.3 identifies some factors and processes that can make the characteristics of the vadose zone (e.g., soil moisture) transitory.

EPA also recommends that vapor intrusion be evaluated for reasonably expected future land use conditions, including new building construction and new uses and occupants for any uninhabited buildings.

3.3 Building Mitigation and Subsurface Remediation

The NCP expresses the preference for response actions that eliminate or substantially reduce the level of contamination in the source medium to acceptable levels, thereby achieving a permanent remedy. In the case of vapor intrusion, such a response action would generally entail eliminating or substantially reducing the level of vapor-forming chemicals in the subsurface (e.g., in contaminated groundwater, soil, and/or sewer lines) via treatment or removal (i.e., “remediation”). Section 8 discusses source remediation to achieve a permanent remedy and associated institutional controls (ICs) and monitoring for vapor intrusion mitigation, including criteria for their termination.

Comprehensive remediation[79] of the subsurface environment often occurs over a prolonged period (e.g., several years) to attain cleanup levels. In the interim, problems of unacceptable vapor intrusion are often addressed by also installing engineered exposure controls to reduce or eliminate vapor intrusion in buildings (i.e., “mitigate” vapor intrusion) or reduce indoor air exposure levels. Engineered exposure controls can generally be deployed and generally become effective relatively quickly. They can be considered as “interim” or “early” response actions, which are also authorized by the NCP (Section 1.2), as necessary and appropriate to promptly reduce threats to human health. Section 8 summarizes technical information about specific exposure controls and provides information about their operation, maintenance and monitoring and associated ICs, including criteria for their termination.

Functionally, engineered exposure controls can be categorized into two basic strategies:

- Those that seek to prevent or reduce vapor entry into a building (e.g., active depressurization technologies). These methods are more commonly implemented when response actions are needed.[80]

- Those that seek to reduce or eliminate vapors that have entered into a building (e.g., indoor air treatment, ventilation).

---

[79] For purposes of this Technical Guide, "remediation" is intended to apply to interim and final cleanups, whether conducted pursuant to RCRA corrective action, the CERCLA removal or remedial programs, or using EPA brownfield grant funds with oversight by state and tribal response programs. In addition to permanent remedies for subsurface vapor sources, site remediation may also entail implementation of ICs and construction and operation of engineered systems to reduce risks to human health and the environment posed by environmental pathways other than vapor intrusion. Although this Technical Guide is intended for use at any site subject to federal statutes, regulations, and rules, it is not intended to alter existing requirements, guidance, or practices in OSWER’s programs about development, selection, or documentation of final “remediation” plans (addressing subsurface vapor sources, for example) – see, for example, Sections 7.6 and 7.7.

[80] Mitigation methods that prevent or reduce vapor entry into a building from subsurface vapor sources would generally also be expected to reduce radon entry.

Neither strategy entails reducing the level of vapor-forming contamination in the subsurface source medium.[81]

As reflected in the foregoing conceptual model of vapor intrusion (Section 2.0), entry of the vapors into a building may be prevented or reduced by any of several techniques, which have the following objectives:

- Remove or reverse the driving forces for vapor intrusion into the building (e.g., install and operate an active depressurization technology to mitigate vapor intrusion from contaminated soil or groundwater; establish over-pressurization within and throughout the footprint of a nonresidential building).

- Eliminate or minimize identified openings for vapor entry into the building (e.g., caulking, grouting, or otherwise sealing all holes, cracks, sumps and other foundational openings or creating a barrier between the soil and the building that blocks openings for entry of soil gas into the building; install, repair, and/or maintain vapor traps in sewer and drain lines).

Engineered exposure controls that entail mechanical systems and forces (e.g., sub-slab depressurization or ventilation systems; building over-pressurization) are often referred to as “active.” Engineered exposure controls that do not involve mechanical operations (e.g., installing a sub-slab barrier to chemical vapor entry) are often referred to as “passive.” Many building mitigation systems rely on both active and passive strategies.

Engineered exposure controls that seek to reduce or eliminate vapors that have entered into a building can also be effective. In some instances, they can be implemented more readily than engineered exposure controls that reduce or eliminate entry of the vapors into a building. Typically, the simplest approach to limiting the concentration levels in occupied indoor spaces is to increase building ventilation (i.e., increase the rate at which indoor air is replaced with outdoor air), thereby diluting indoor air concentrations (see Section 2.4).[82] Alternatively, vapor-forming chemicals are removed from indoor air using an adsorbing material (such as activated carbon) that can be either properly disposed of or recycled. Building mitigation methods that act upon vapor-forming chemicals in indoor air (i.e., rely upon enhanced ventilation or treatment) are generally capable of reducing background levels of chemicals, in addition to reducing indoor levels of vapor-forming chemicals that intrude from subsurface sources.

---

[81] Even when operated for prolonged periods, engineered exposure controls are considered ‘interim’ remedies for purposes of this Technical Guide, because their implementation does not substitute for remediation of the subsurface source(s) of vapor-forming chemicals. Engineered exposure controls may, nevertheless, become part of a final cleanup plan.

[82] It can be difficult to establish a ventilation rate that mitigates vapor intrusion and yields an environment conducive to human occupancy (e.g., considering air temperature or moisture). In addition, ventilation may affect the driving forces for vapor intrusion. For example, mechanically exhausting air from the building will generally contribute to building under-pressurization (see Section 2.3), which may result in increased intrusion of soil gas into the building, which may offset the intended dilution effect of ventilation. On the other hand, introducing outdoor air at a rate slightly greater than the exhaust rate can create over-pressurization, which opposes the primary driving force for vapor intrusion.

Selection of an interim response action from these options may depend upon building- and site-specific factors (EPA 2008). For example, building-specific factors may include:

- Use (e.g., single-family residential, multi-family residential, commercial, educational, recreational, governmental, religious, industrial)
- Type of foundation/basement (e.g., basements with concrete slab floors or dirt floors, slab on grade, slab below grade) and other construction features
- Type of heating/cooling/ventilation systems (e.g., some systems will tend to increase pressure, whereas others will tend to decrease pressure, inside the building).

Each of these characteristics can influence the choice of mitigation methodology and, therefore, they are commonly identified during building surveys during a site-specific vapor intrusion investigation. Site-specific considerations may include the degree of risk or hazard being addressed and whether the subsurface vapor source(s) is stable in extent and concentration or is undergoing remediation.

Temporary relocation may warrant consideration in instances where explosion hazards are present (see Section 7.5.1), which may pose an imminent and substantial danger to human health and public welfare. Prompt response action may also be warranted where short-term or acute exposures may pose unacceptable human health risk (see Section 7.5.2) that cannot be addressed timely or feasibly by implementing engineered exposure controls. Section 8.2 discusses various prompt response actions for such situations, which may include temporary relocation.

There may be situations where a party may wish to implement mitigation or control measures for vapor intrusion, even though only limited lines of evidence or measurements may be available to characterize the overall vapor intrusion pathway. For example, a party may be aware that vapor intrusion has been documented at neighboring structures, where measures are being implemented to mitigate the vapor intrusion pathway. A party may conclude there is a reasonable basis to take action, but each building presents a fact-specific situation that calls for its own individual judgment. Likewise, it may be appropriate and cost-effective to design, install, operate, and monitor engineered exposure controls for individual buildings to mitigate vapor intrusion in newly constructed buildings, or in buildings to be constructed in the future, that are located in areas of vapor-forming subsurface contamination, rather than potentially allow vapor intrusion to occur later and assess vapor intrusion after the fact. The term “preemptive mitigation/early action” is used in this Technical Guide to describe these situations.[83]

The decision for preemptive mitigation/early action arises from precaution and from recognizing that:

- Installing engineered exposure controls in buildings is typically a cost-effective means of protecting human health and normally can be implemented relatively quickly in many buildings while subsurface contamination is being delineated or remediated.

---

[83] The term ‘preemptive’ has been used to describe the use of various types of controls that can prevent vapor intrusion from occurring prior to having fully demonstrated that unacceptable vapor intrusion currently exists in specific buildings being considered (EPA 2010a).

- Conventional vapor intrusion investigations can be disruptive for building occupants (residents, workers, etc.) and owners.

- Comprehensive subsurface characterization and investigation of vapor intrusion can entail prolonged study periods, during which time building occupants and owners and others may have questions and concerns about human health risk that are or may be posed via vapor intrusion.

Early action and interim action are allowed by federal environmental protection statutes, regulations, and guidance, including CERCLA, as amended, and RCRA, as amended – see Section 1.2 of this Technical Guide, for example. Other aspects of preemptive mitigation/early action are also discussed in Section 7.8, including situations and criteria for decision-makers to consider.

As noted in Figure 3-1, EPA recommends that risk managers consider reasonably expected future conditions, in addition to current conditions, when making risk management decisions about the vapor intrusion pathway. For this reason, this Technical Guide includes recommendations for response actions at sites where subsurface vapor sources remain into the future, but do not pose unacceptable human health risk under current conditions (e.g., no building is present nearby). For example, institutional control s are generally recommended to restrict land use and/or alert parties (e.g., prospective developers, owners, and municipalities) of the presence of subsurface sources of vapor-forming chemicals at levels that pose a continuing threat via vapor intrusion (see Sections 7.3, 7.4, and 8.6). When infrastructure conditions change above or near an area of known contamination with vapor-forming chemicals, EPA recommends a vapor intrusion investigation or pre-emptive mitigation be conducted, particularly if a building is constructed for human occupancy (see Section 8.2.3).

3.4 Community Outreach and Involvement

EPA is committed to transparency and upfront collaboration with community stakeholders regarding land cleanup, emergency preparedness and response, and management of hazardous chemicals and wastes. OSWER's Community Engagement Initiative (CEI), in particular, is designed to enhance OSWER's and the Regional offices' engagement with local communities and stakeholders (e.g., state and local governments, tribes, academia, private industry, other federal agencies, and nonprofit organizations) to help them participate meaningfully in government decisions regarding OSWER's nationwide programs.

Meaningful and sustained community outreach and engagement efforts are critical to the implementation of work plans for site-specific vapor intrusion assessment and mitigation. Because assessing the vapor intrusion pathway may involve sampling in a home or workplace, as well as other temporary inconveniences (e.g., assisting in reducing indoor sources of contaminants), individual, one-on-one communication with each property owner or renter generally warrants consideration. Building-by-building contact and communication are recommended as the most effective means of educating the community and obtaining access needed to assess, mitigate, and monitor the vapor intrusion pathway. Personal contact is further recommended to establish a good working relationship with each building owner or occupant and to build trust. In many instances, local religious and cultural organizations, and other community groups can be sought for assistance in reaching out to affected community members.

Vapor intrusion education and training are important components of meaningful community outreach and engagement efforts. Informing stakeholders about the vapor intrusion pathway and the cleanup process can help to build trust and can foster community participation in the overall assessment and risk management process.

Recognizing the importance of community outreach and engagement efforts, EPA staff are highly encouraged to consult with colleagues experienced in community outreach and utilize available EPA planning resources, including those discussed in Section 9, which provides OSWER's community involvement planning guide for vapor intrusion projects. Like EPA, the ITRC also recommends implementing a community outreach program that provides timely information to concerned community members and property owners.

4.0 CONSIDERATIONS FOR NONRESIDENTIAL BUILDINGS

The approach for investigating and, if necessary, mitigating vapor intrusion can vary from site to site, and from building to building, due to site- and building-specific factors and circumstances, including: the nature (e.g., mixture of vapor-forming chemicals and form), locations, and extent of subsurface contamination; geologic, hydrologic, and biochemical factors in the vadose zone; and the size, structural conditions and uses of buildings and background levels of vapor-forming chemicals in the building. Information on 'background' contributions of site-related, vapor-forming chemicals in indoor air is important to risk managers because generally EPA does not clean up to concentrations below natural or anthropogenic background levels (EPA 2003e). These statements hold true for residential and non-residential buildings.

Section 6.3.5 of this Technical Guide provides specific recommendations about how to evaluate background concentrations. Section 7.4 of this Technical Guide provides clarifications and recommendations about applying the methods in Section 6.3.5 to informing risk management decisions and recommendations. The Glossary in this Technical Guide defines various terms and types of vapor sources to foster a common understanding of EPA's approach and recommendations.

This section summarizes EPA's general recommendations to consider in making decisions about evaluating and addressing potential vapor intrusion for nonresidential buildings[84] pursuant to CERCLA and RCRA, including decisions that a response action or corrective action is not currently warranted.

When evaluating nonresidential buildings at sites that have subsurface contamination with vapor-forming chemicals, EPA generally recommends that building owners or operators (e.g., lessees) be contacted for information about vapor-forming chemicals used or stored or otherwise present in the building, the types of building occupants potentially exposed to subsurface vapor intrusion, as well as any training, equipment, or engineering controls to mitigate inhalation exposures. EPA recommends that information be provided to building owners concerning the potential for vapor intrusion so that this information can be communicated to building employees, tenants, and other occupants. Building occupants include, but are not limited to, facility employees, visitors, customers, suppliers, and building maintenance personnel.

Generally, EPA recommends the following factors be considered when making decisions pertaining to vapor intrusion at nonresidential buildings, including as to whether indoor air sampling, soil gas sampling underneath the building, or interim measures to mitigate vapor intrusion to reduce associated indoor air exposures for a nonresidential building may be warranted:

---

[84] As used in this Technical Guide, the phrase "nonresidential buildings" may include, but is not limited to, institutional buildings (e.g., schools, libraries, hospitals, community centers and other enclosed structures for gathering, gyms and other enclosed structures for recreation), commercial buildings (e.g., hotels, office buildings, many (but not all) day care facilities, and retail establishments); and industrial buildings where vapor-forming substances may or may not be routinely used or stored.

1) The types of populations potentially exposed to vapor-forming chemicals in the indoor air of the nonresidential building, including, for example, whether:

    a) Individuals are or may be present under current or reasonably expected future conditions who would not likely anticipate any chemical exposures (e.g., office workers, visitors, customers, suppliers, and other members of the general public) and may not benefit fully from hazard communication programs and other work practices in place to foster protection of workers who use chemicals, if any.

    b) Sensitive populations are or may be present under current or reasonably expected future conditions, who may have increased susceptibility or vulnerability.

2) The potential for vapor intrusion versus background vapor sources (See Glossary) to contribute to indoor air concentrations of vapor-forming chemicals found in the subsurface. Questions to consider include, for example:

    a) Can subsurface vapor intrusion be identified as a potential cause of unacceptable human health risk to building occupants (see Section 5 for further discussion about the preliminary analysis stage and Section 7 for further discussion and definition of acceptable versus unacceptable human health risk)? [85]

    b) Can subsurface remediation (e.g., excavation of contaminated soil or soil vapor extraction beneath the subject building) that is planned or underway reduce human health risk from vapor intrusion within a time frame that is protective for any potential current or near-term exposures in the building?

    c) Is there a known source(s) of one or more vapor-forming chemical(s) – see Section 3.1 – in indoor air in the nonresidential building other than vapor intrusion (e.g., indoor use and storage of chemicals, which would constitute a 'background' vapor source(s) and contribute to indoor air exposure concentrations; see Sections 2.7 and 6.3.5 for further discussion and recommendations about background sources and concentrations)? If such a vapor-forming chemical(s) is (or are) present:

        i. Is(are) it the same as the vapor-forming chemical(s) found in the subsurface?

        ii. How does the indoor air exposure concentration(s) arising from the indoor vapor source(s) compare to the indoor air concentration(s) estimated or reasonably expected to arise from vapor intrusion? [86]

    Information on 'background' contributions of site-related, vapor-forming chemicals in indoor air is important to risk managers because generally EPA does not clean up to concentrations below natural or anthropogenic background levels (EPA 2002e).

---

[85] EPA's recommended approaches to human health risk assessment are provided in Sections 7.4 and 7.5 of this Technical Guide.

[86] EPA's recommended approaches to distinguishing and considering 'background' are provided in Sections 6.3.5 and 7.4.2 of this Technical Guide.

3) Any existing or planned engineering or institutional control(s) in the building or any industrial hygiene/occupational health program that addresses workplace inhalation exposures and its scope. Questions to consider include, for example:

    a) Do work practices and engineering controls currently in place ensure protection[87] of all building occupants who may be exposed via the vapor intrusion pathway?

    b) Are enforceable institutional controls (ICs) or other control mechanisms in place to ensure that current land use and workplace practices will be sustained and will remain protective regarding indoor air exposures from vapor intrusion to all building occupants? Have these ICs and control mechanisms been communicated to all appropriate parties and documented to EPA? Can they be readily monitored and, if necessary, be enforced?

EPA recommends documenting any decision not to undertake investigation or mitigation for vapor intrusion in a nonresidential building, as well as any decision to pursue such activities. EPA may consider reviewing these decisions, as appropriate and consistent with applicable statutes and regulations and considering EPA guidance,[88] if the land use changes or new information becomes available that suggests circumstances supporting past risk management decisions have changed and prompt the need to revisit those decisions. It is recommended that EPA request from property owners and building tenants/operators timely notification of significant changes in building ownership, uses, access by the general public, or building construction (e.g., renovations), which may affect exposure of occupants and related risk management decisions pertaining to potential vapor intrusion assessment and mitigation, subsurface remediation, or ICs.

Regardless of decisions about indoor air sampling, soil gas sampling underneath the building, or interim measures to mitigate vapor intrusion, EPA[89] may proceed, consistent with applicable federal statutes and regulations (see Section 1.2) and considering EPA guidance, with activities such as the following, where appropriate:

- Subsurface investigation to delineate the areal extent of a subsurface vapor plume.

- Subsurface remediation to reduce or eliminate subsurface sources of vapors-forming chemicals to protect human health and the environment.

---

[87] EPA's recommended approaches to risk management are provided in Sections 7.4 and 7.5 of this Technical Guide.

[88] For the Superfund five-year review process, OSWER Directive 9200.2-84 (EPA 2012c) provides a recommended framework for considering vapor intrusion while evaluating remedy protectiveness.

[89] On January 23, 1987, the President of the United States signed Executive Order 12580 entitled, "Superfund Implementation," which delegates to a number of Federal departments and agencies the authority and responsibility to implement certain provisions of CERCLA. The policies and procedures for implementing these provisions (e.g., carrying out response actions) are spelled out in the NCP. The provisions of Executive Order 12580 appear at 52 *Federal Register* 2923. At federal facilities on the NPL, EPA may not be the lead agency, but does have oversight responsibilities pursuant to CERCLA Section 120.

5.0 PRELIMINARY ANALYSIS OF VAPOR INTRUSION

When a site is first identified and evaluated for vapor intrusion,[90] the amount, utility, and reliability of available information may be limited. A preliminary analysis utilizes available and readily ascertainable information to develop an *initial* understanding of the potential for human health risk to be posed by vapor intrusion, which would typically be performed as part of an initial site assessment.

This section describes EPA's recommended information, approaches, and practices for conducting preliminary analyses for vapor intrusion using pre-existing and readily ascertainable information to develop an initial understanding of the vapor intrusion potential at a site. This section:

- Explains the recommended types of information that generally can be obtained when a site is first considered for vapor intrusion (see Sections 5.1, 5.3, 5.4, and 5.5).
- Identifies some of the site conditions for which prompt action is generally warranted (see Section 5.2).
- Illustrates some of the site conditions for which further evaluation of the vapor intrusion pathway might be warranted (see Sections 5.3, 5.4, and 5.5).
- Describes the recommended approaches to evaluating the reliability of pre-existing information, including any sampling data (see Sections 5.1 and 5.5).

Depending upon the nature and reliability of the available information, it may be possible to determine whether a vapor intrusion investigation (see Section 6) or a response action (see Sections 7 and 8) is warranted. If the available information is not reliable or adequate for these purposes, however, additional data collection generally is recommended.

5.1 Assemble, Evaluate, and Review Available Information

The recommended first step in a preliminary analysis generally entails assembling and reviewing relevant information that is available at the time for the site. At a minimum, EPA recommends that information about potential subsurface sources of vapors and the presence and current use(s) of nearby buildings be developed and evaluated. For some sites, such as sites being evaluated for redevelopment (EPA 2008a), information about contiguous or nearby facilities also may be relevant, because vapors can encroach from nearby facilities due to migration of contaminated groundwater or soil gas, even though vapor-forming chemicals may not have been used at the subject site.

The following recommended types of information are often available through documents (e.g., federal, state, tribal and local government records) or through interviews with individuals

---

[90] A site may be identified, for example, based on reports to the National Response Center, citizen complaints or inquiries, state agency referrals, or other information (e.g., site history, land use, site inspections) obtained by EPA. At a brownfield site subject to an EPA grant, subsurface contamination may be discovered as a result of pre-acquisition investigation by prospective purchasers, during site redevelopment, or at other project stages.

knowledgeable about the facility or site and surrounding area (e.g., past and present owners, operators and occupants; area residents or workers):

- History and descriptions of the types of operations and activities that occurred on or near the site and nearby properties.
- Information or records about the types of chemicals that may have been used or disposed of at the site and nearby properties or are currently used and disposed at the site.
- Information about the site and nearby properties, such as the occurrence of odors, reports of dumping liquids, observations of unreported waste disposal practices, or other indications of chemical presence and release.
- Adverse physiological effects reported by building occupants (e.g., dizziness, nausea, vomiting, confusion).
- Evidence of subsurface intrusion of groundwater (e.g., wet basements) reported by building owners or occupants.

Such information usually can be reviewed and weighed together to assess whether vapor-forming chemicals (see Section 3.1) were or are being used, stored, or handled at or near the site and were or may have been released to the subsurface environment.

In addition, the following types of information may be available through documents, interviews with individuals knowledgeable about the facility or site, or reconnaissance and site inspection:

- Locations, ownership, occupancy, and intended and actual use(s) of buildings on or near the site.
- Current and reasonably anticipated future land use on and near the site.
- Location of subsurface utility corridors.

Evaluation of such information usually can help determine whether humans are present currently or are reasonably expected to be present in the future, and who may become exposed to any intrusion of vapors from the subsurface into a building(s). Zoning, land use planning, and related information may also need to be consulted to identify reasonably anticipated future land use and building types in areas where buildings do not exist or to ascertain whether reasonably anticipated uses of existing buildings are likely to change (EPA 2010c).

EPA recommends evaluating the available data to identify any data gaps for purposes of the preliminary analysis. For example, has the history of operations and primary activities been established for the site and all contiguous properties, including currently vacant land? To the extent that there are significant data gaps, EPA recommends that additional data gathering (e.g., interviews, records review) generally be planned and conducted.

EPA also recommends evaluating the available data to assess its reliability and internal consistency. For example, if the available information about operations and activities at a specific property comes only from area residents, EPA recommends additional efforts to identify, contact, and interview current and past owners to obtain and corroborate this information. Also, if anecdotal information about current activities at a specific property is in conflict with common knowledge about local zoning, EPA recommends that additional data gathering and evaluation be identified (e.g., contact property owner), planned, and conducted to resolve the inconsistency.

Section 5.5.1 describes additional considerations for evaluating the reliability of sampling data that may be available for some sites at the preliminary analysis stage.

5.2 Identify and Respond to Conditions that Warrant Prompt Action

The following conditions may indicate a need for prompt action, including follow-up evaluations to determine whether urgent intervention is warranted to eliminate, avoid, reduce, or otherwise address a human health hazard:

- Odors reported by occupants, particularly if described as "chemical," "solvent," or "gasoline." The presence of odors does not necessarily correspond to an unacceptable human health risk due to vapor intrusion, and the odors could be the exclusive result of indoor vapor sources; however, it is generally prudent to investigate any reports of odors as the odor threshold for some vapor-forming chemicals exceeds their respective lower explosive limit (LEL) or health-protective concentrations for short-term or acute exposure.

- Physiological effects reported by occupants (e.g., dizziness, nausea, vomiting, confusion, etc.). These effects may or may not be due to subsurface vapor intrusion (or even indoor vapor sources); however, it is generally prudent to investigate any such reports.

- Wet basements in areas where groundwater is known to contain vapor-forming chemicals (see Section 3.1) and the associated water table is shallow enough that the basements are prone to groundwater intrusion or flooding. This condition is particularly important where there is evidence of light NAPL (LNAPL) on the water table directly below the building or direct evidence of intrusion of liquid-phase contamination (i.e., liquid chemical or dissolved in water) inside the building.

EPA generally recommends testing of indoor air (see Sections 6.4.1 and 6.3.4) as soon as practical in buildings where:

- chemical odors or physiologic effects are reported and there is a credible information to suggest that a release to the subsurface environment may be a contributing factor, or

- intruding contaminated groundwater is reported and observed.

Likewise, EPA generally recommends testing of unoccupied structures for explosive gases as soon as practical where chemical odors are reported and there is a credible information to suggest that a release to the subsurface environment may be a contributing factor.

Section 7.4 provides EPA's approach and recommendations for identifying when human health risks are "unacceptable." Section 7.5.2 describes EPA's recommended approaches to identifying concentration levels indicating a potential need for prompt response action. Section

8.2.1 identifies potential response actions to reduce or avoid these threats promptly, when the results of testing reveal threats or potential threats warranting prompt response action.

EPA recommends health and safety planning for all building- or site-specific actions, as discussed further in Section 6.2, which considers expected work conditions and anticipated hazards.

5.3 Determine Presence of Structures and Vapor-forming Chemicals

For purposes of this Technical Guide and as reflected in the conceptual model of vapor intrusion (Section 2), the vapor intrusion pathway is referred to as "complete" for a specific building or collection of buildings when the following five conditions are met under current conditions:

1) A subsurface source of vapor-forming chemicals is present underneath or near the building(s) (see Sections 2.1, 6.2.1, and 6.3.1);

2) Vapors form and have a route along which to migrate (be transported) toward the building(s) (see Sections 2.2 and 6.3.2);

3) The building(s) is (or are) susceptible to soil gas entry, which means openings exist for the vapors to enter the building(s) and driving 'forces' exist to draw the vapors from the subsurface through the openings into the building(s) (see Sections 2.3 and 6.3.3);

4) One or more vapor-forming chemicals comprising the subsurface vapor source(s) is (or are) present in the indoor environment (see Sections 6.3.4 and 6.4.1); and

5) The building(s) is (or are) occupied by one or more individuals when the vapor forming chemical(s) is (or are) present indoors.

EPA recommends that site managers also evaluate whether subsurface vapor sources that remain have the potential to pose a complete vapor intrusion pathway in the future if site conditions were to change (e.g., reasonably expected occupancy or construction in the future of a building above or near a subsurface vapor source). A complete vapor intrusion pathway indicates that there is an opportunity for human exposure, which warrants further analysis (see Section 7.4) to determine whether there is a basis for undertaking a response action(s) (see Section 7.7).

At the preliminary assessment stage, the available information may not be sufficient to evaluate whether all five conditions are present under current or reasonably expected future conditions. EPA recommends, however, that readily ascertainable information be reviewed for purposes of assessing whether the first and fifth conditions are present; that is:

- A subsurface source of vapor-forming chemicals is present or is reasonably expected to be present (e.g., in contaminated groundwater, soil, or sewer lines or from a primary vapor release).[91] Section 3.1 describes chemicals that have the potential to pose an unacceptable human health risk through the vapor intrusion pathway. In the absence of environmental sampling data, the potential presence of vapor-forming chemicals in the subsurface may be inferred from site information, as identified in Section 5.1 (e.g., site history).

- At least one building is present or is reasonably expected to be constructed in the future above or "near" the subsurface vapor source(s), which is or could be occupied by humans. For purposes of this Technical Guide and its recommendations for evaluating human health risk posed by vapor-forming chemicals, "building" refers to a structure that is intended for occupancy and use by humans. This would include, for instance, homes, offices, stores, commercial and industrial buildings, etc., but would not normally include sheds, carports, pump houses, or other structures that are not intended for human occupancy. However, where the assessment identifies the potential for methane or other potentially explosive vapors to be present in the subsurface, EPA recommends reviewing readily ascertainable information for purposes of assessing whether non-occupied structures (including, but not limited to, sewers, pits, and subsurface drains) are present, which may also accumulate vapors, in addition to occupied and non-occupied buildings. Existing buildings (and non-occupied structures) can be identified during inspections of the land areas overlying and near subsurface vapor sources. The potential presence of buildings in the future may be inferred from site information, such as identified in Section 5.1. See Section 6.2.1 for further discussion on which buildings and non-occupied structures are considered "near" for purposes of a preliminary analysis.

If the available information is deemed reliable, well documented, and sufficient (see Section 5.1) and indicates that neither of these conditions is met, then further vapor intrusion assessments are not generally warranted.[92]

> *Example: From 1920 to 1931, the ABC Mining Company obtained and shipped iron ore from a local deposit. Ore from the mine was shipped by rail to a different location where it was milled and processed to extract the metal. Although no company records are available for the mine, a review of mining techniques indicates that solvents and other vapor-forming chemicals were not used in the mining process during the 1920s and 1930s. Former mining structures have been removed, and the site is currently vacant. The city has proposed redeveloping the site with bike and hiking trails but no buildings or other structures for storage or site maintenance support. Based on the information and*

---

[91] As noted in Section 2.1, the primary contamination source need not be on the property of interest to pose a vapor intrusion problem. The primary source(s) of vapor-forming chemicals (e.g., contaminated soil, leaking tanks) may be present on a neighboring property or on a property some distance away. Even "greenspace" properties that have not previously been occupied or developed may contain subsurface contamination by vapor-forming chemicals due to migrating plumes of contaminated groundwater or migrating soil gases. Therefore, EPA recommends that the potential for vapor intrusion be considered at all properties being considered for redevelopment (EPA 2008a) or proximate to industrial and commercial use areas.

[92] Consistent with federal environmental protection statutes, regulations, and OSWER guidance, a subsurface investigation may still be warranted for non-volatile substances or for other potential exposure pathways such as those identified in Section 1.3.

> *findings, the need for further assessment of the vapor intrusion pathway due to mining-related contamination is not indicated.*

If, on the other hand, there is reliable evidence to indicate that a release of vapor-forming chemicals to the subsurface has occurred (e.g., environmental sampling data indicate detectable levels of a vapor-forming chemical(s) in potential source media)[93] or may have occurred underneath or near a property, then EPA recommends further vapor intrusion assessment in areas where buildings are present or future buildings could be constructed, including development of a conceptual site model (see Section 5.4) and investigation of site-specific conditions (see Section 6).

> *Example: The XYZ Recycling Center site was used from 1963 to 1984 for the collection and recycling of industrial solvents and other fluids. The site was repeatedly cited by the state and city for improper handling and disposal of solvents, and was closed in 1985. Groundwater data indicate the presence of multiple chlorinated hydrocarbons. Buildings overlying the contaminated groundwater are currently used mainly for storage of non-chemical goods, but the site has been proposed for future residential or commercial redevelopment. Based on the foregoing information and findings, further assessment of the potential for vapor intrusion is warranted, possibly including risk-based screening of the groundwater data (see Section 6.5).*

If a release of vapor-forming chemicals to the subsurface is known or suspected to have occurred at or near the site, but buildings are not present and none are reasonably anticipated in the future (e.g., the contaminated source underlies an open space, recreational area, or wildlife refuge), then further vapor intrusion assessments may not be appropriate under current conditions. It may be appropriate, however, to establish an institutional control (IC) requiring a vapor intrusion investigation or building mitigation[94] in the future, in case land use changes. ICs for building mitigation and subsurface vapor source remediation are discussed further in Sections 3.3 and 8.6 of this Technical Guide.

Existing guidance and practice pursuant to CERCLA and RCRA corrective action (CA) recognize and entail various phases of subsurface or site characterization, including a site investigation to determine the full nature and extent of contamination at a site, quantify risks posed to human health and the environment, and gather information to support the selection and implementation of appropriate remedies. On this basis, a subsurface investigation may be warranted at some point to characterize subsurface contamination and assess the need for subsurface remediation to protect the environment and human health for potential exposure pathways other than vapor intrusion (such as those identified in Section 1.3). For example, site investigations to characterize the nature and extent of groundwater contamination and support assessments of risk to human health through the ingestion pathway are typically conducted, consistent with federal statutes and regulations (e.g., CERCLA and RCRA) and considering EPA guidance.

---

[93] Section 6.5 provides information on how such data may be used in a quantitative fashion to screen the site further.

[94] If, for example, a developer is considering acquiring and building on land that contains subsurface contamination with vapor-forming chemicals, the developer could retrofit existing buildings or build new buildings with vapor mitigation systems without first conducting an extensive vapor intrusion investigation (see Sections 3.3 and 7.8). Section 8.2.3 identifies additional approaches and considerations for new buildings.

5.4 Develop Initial Conceptual Site Model

EPA recommends that the planning and data review team develop an initial conceptual site model (CSM) for vapor intrusion when the preliminary analysis indicates the presence of subsurface contamination with vapor-forming chemicals underlying or near buildings. The initial CSM (and any subsequent refined CSM) can be used to support evaluations of the adequacy of the available site-specific information, to guide any vapor intrusion investigations (see Sections 6.2 and 6.3), and to support data selection for risk-based screening (see Section 6.5). The CSM can also provide useful information for supporting prompt development of a strategy for early/interim response actions (see Sections 7.8 and 8.2).

The remainder of this section discusses recommended information that can be useful for developing a CSM. Note that some of the recommended information may not be readily available when a site is first considered for vapor intrusion. Although the CSM may be updated iteratively (and interim mitigation measures may be undertaken) as the vapor intrusion investigation unfolds, EPA recommends completing the CSM before making final risk management decisions for a given site (see Section 7).

As discussed in Section 5.3, the available information may not be sufficient at the preliminary analysis stage to evaluate whether the vapor intrusion pathway is complete under current or future conditions. Therefore, the initial CSM for vapor intrusion is likely to be incomplete. EPA recommends, however, that the initial CSM for vapor intrusion portray the current understanding of site-specific conditions pertaining to the vapor intrusion pathway. Ideally, at a minimum, the initial CSM will address:

- Nature (i.e., type, chemical composition), location, and spatial extent of the source(s) of vapor-forming chemicals in the subsurface (see Sections 2.1 and 6.3.1, for example). For example, it is useful to know which vapor-forming chemical(s) primarily comprise the subsurface vapor source[95] and whether it is also capable of posing explosion hazards. It is also useful to know whether vapor-forming chemicals are present in groundwater, vadose zone soils, sewer lines, and/or some other source underneath or near buildings.

- Location, use, occupancy, and basic construction (e.g., foundation type) of existing buildings.

The CSM can be updated as additional information is obtained through investigation (Section 6) and building surveys (Section 6.4.1).

EPA recommends the CSM also portray the current understanding of the hydrologic and geologic setting in and around the subsurface vapor source(s) and the buildings, which is expected to influence vapor migration and attenuation in the vadose zone (see Sections 2.2 and 6.3.2, for example). When these conditions are not well established from existing information, and the preliminary analysis indicates the presence of subsurface contamination with vapor-

---

[95] EPA also recommends that the CSM identify any site-specific chemicals of concern that may be biodegradable and identify and summarize information and data pertaining to the possible role of biodegradation *in situ* in limiting vapor migration in the vadose zone (see Section 6.3.2) or generating hazardous, volatile degradation products (e.g., methane from anaerobic biodegradation, vinyl chloride as a byproduct of PCE or TCE biodegradation).

forming chemicals underlying or near buildings, EPA recommends that a detailed vapor intrusion investigation be scoped and conducted to address these data gaps (see Section 6.3).

Furthermore, EPA recommends the CSM identify known or suspected preferential migration routes that could facilitate vapor migration to greater distances and at higher concentrations than otherwise expected. EPA recommends that buildings with significant preferential migration routes be evaluated closely. For the purposes of this Technical Guide, a preferential migration route is a naturally occurring subsurface feature or anthropogenic (human-made) subsurface conduit that is expected to exhibit little resistance to vapor flow in the vadose zone (i.e., exhibits a relatively high gas permeability) or groundwater flow (i.e., exhibits a relatively high hydraulic conductivity), depending upon its location and orientation relative to the water table and ground surface, thereby facilitating the migration of vapor-forming chemicals in the subsurface and/or into buildings.[96] Naturally occurring examples include fractures and macropores, which may facilitate a preferential route for either the vertical or horizontal migration of source materials and/or vapors. Anthropogenic examples include sewer lines and manholes,[97] utility vaults and corridors, elevator shafts, subsurface drains, permeable fill, and underground mine workings that intersect subsurface vapor sources or vapor migration routes. In highly developed residential areas, extensive networks of subsurface utility corridors may be present, which can significantly influence the migration of contaminants. A preferential migration route can be a “significant” influence on vapor intrusion when it is of sufficient volume and proximity to a building that it may be reasonably anticipated to influence vapor migration towards or vapor intrusion into the building. Significant vertical routes of preferential migration may result in higher than anticipated concentrations in the overlying near-surface soils, whereas significant horizontal routes of preferential migration may result in elevated concentrations in areas on the periphery of subsurface contamination (see Section 6.2.1).

CSMs for vapor intrusion assessments often need to consider two distinct exposure situations:

1) At some sites and contaminated locations, there are concerns as to whether vapor intrusion may pose a human health risk to current occupants of an existing building(s). For this situation, EPA recommends that building-specific information be available to support the CSM, which may be obtained through a building survey (see Section 6.4.1, for example) .

2) At other sites and contaminated locations, buildings are not present, but are expected to be constructed, and building-specific information may not be available to support the CSM. For this situation, the CSM may need to consider a hypothetical building constructed anywhere over (or near) the subsurface vapor source.

---

[96] For purposes of this Technical Guide, preferential migration routes are distinguished from adventitious and intentional openings in a building that may also facilitate vapor entry from the subsurface (see Section 2.3), but which are expected to typically be present in all buildings (e.g., cracks, seams, interstices, and gaps in basement floors and walls or foundations; perforations due to utility conduits).

[97] In addition to receiving direct discharges of aqueous and chemical wastes from commercial and industrial operations, sewers can be indirect receptacles of subsurface contamination via infiltration of NAPL, soil gas, or contaminated groundwater through cracks in piping and manholes (see Section 2 of this Technical Guide, for example, for further discussion).

In general, CSMs identify the potentially exposed populations, potential exposure routes, and potential adverse health effects (i.e., toxicity) arising from these exposures. As such, EPA recommends the CSM also identify and consider sensitive populations, including but not limited to:

- Elderly,
- Women of child-bearing age,
- Infants and children,
- People suffering from chronic illness, or
- Disadvantaged populations (i.e., an environmental justice situation).

By definition and as noted in Section 2, the exposure route of general interest for vapor intrusion is inhalation of vapors in indoor air and the human population of primary interest is comprised of individuals living or working in or otherwise occupying a building subject to vapor intrusion. However, EPA also recommends that the CSM identify any site-specific chemicals of concern that have potential for explosion hazards (e.g., methane) or for posing other routes of exposure (e.g., dermal exposure to shallow contaminated groundwater seeping into a basement).

EPA recommends that the CSM also identify and characterize suspected sources of site-related, vapor-forming chemicals that are also found in ambient air in the site vicinity. In some situations, site-related contamination has the potential to impact ambient air with the same vapor-forming chemicals that pose a threat from vapor intrusion. For example, contamination of shallow soil or groundwater may release site-related vapor-forming chemicals to ambient air. EPA recommends the CSM identify any such conditions, which have implications for the scope and objectives of the overall site investigation, as well as for data evaluation and the human health risk assessment.

To document current site conditions, EPA recommends that a CSM be supported by maps, cross sections, and site diagrams, to the extent practical, and that the narrative description clearly distinguish what aspects are known or determined and what assumptions have been made in its development.

EPA generally recommends that developing a CSM be incorporated into the first step in EPA's data quality objective (DQO) process (EPA 2006a). It is rare for a site to have readily available sources of sufficient information to develop a complete CSM when the vapor intrusion potential is first considered. For example, a detailed site-specific investigation may be necessary to characterize the full extent of subsurface vapor sources and geologic conditions underlying nearby buildings (see Sections 6.3.1 and 6.3.2) and to demonstrate the absence of preferential routes for vapor migration and intrusion. The CSM normally warrants updating as new information is developed and new questions are framed and answered. A well-defined, detailed CSM may also facilitate the identification of additional data needs and development of appropriate detection limits for laboratory and field analyses, which can support planning of the detailed vapor intrusion investigation (see Section 6.2) and site-specific human health risk assessment, if any (see Section 7.4). Sections 6.3, 6.4, 7.1, and 7.2 provide additional information about data collection and evaluation for purposes of supporting the CSM.

5.5 Evaluating Pre-Existing and Readily Ascertainable Sampling Data

Sites and adjacent facilities that have been the subject of previous environmental investigations or regulatory actions may already have data on contaminant concentrations in site media (i.e., sampling data) when the vapor intrusion pathway is first considered and evaluated. Some of these sites and facilities may be undergoing remediation but warrant a vapor intrusion assessment as a result, for example, of changing toxicity information for vapor-forming chemicals, as part of a periodic review of remediation effectiveness and protectiveness (if any), or for other reasons.

If the pre-existing environmental data are deemed reliable and other conditions are met (as described in the remainder of this subsection and in Section 6.5.2), the sampling data may be compared to recommended generic vapor intrusion screening criteria (see Section 6.5) for purposes of developing some preliminary insights about the potential level of exposure and risk posed by vapor intrusion. Such a screening can, for example, help focus a subsequent vapor intrusion investigation (see Section 6) or provide support for considering building mitigation as an early action (see Section 7.8.2), depending upon building- and site-specific circumstances. Note that some of the site-specific information generally recommended for supporting a risk-based screening (see Section 6.5.2) may not be available when a site is first considered for vapor intrusion.

5.5.1 Evaluate Sampling Data Reliability and Quality

To the extent that environmental sampling data are identified for the site or nearby properties, EPA recommends that these data be evaluated to determine whether they are of sufficient quality and reliability to support a comparison to recommended generic vapor intrusion screening criteria (see Section 6.5). Some questions that could be considered when reviewing historical sampling data include:

- How were the samples collected and analyzed? EPA recommends using pre-existing data when they have been collected and analyzed by methods considered reliable by today’s standards.

- How old are the data? Were analyses conducted for all vapor-forming chemicals known or suspected to be present and reasonably expected degradation products? EPA recommends using pre-existing data when they can be considered representative of current conditions.

- Were the reporting limits sufficiently low for comparison with vapor intrusion screening criteria? EPA recommends use of pre-existing data with non-detect results only when they can be considered reliable on this basis.

- Were multiple locations sampled to assess spatial variability of the results? Were multiple sampling events conducted to assess temporal variability of the results? EPA recommends characterizing spatial and temporal variability to increase confidence in data evaluation and decision-making and ensure consideration of a reasonable maximum vapor intrusion condition.[98]

EPA also recommends that the reliability of any historical sampling data be assessed by considering the principles for collecting subsurface and indoor air samples that are described in Sections 6.3.1 and 6.4 of this Technical Guide. In addition, the EPA's *Guidance for Data Usability in Risk Assessment, Part A* (EPA 1992a) outlines a recommended approach for evaluating whether the data are useable for the human health risk assessment. As such, its recommended approach is also worthwhile and complementary for evaluating the quality and usefulness of historical data collected at a site.

5.5.2 Evaluate Applicability of the VISLs and Adequacy of the Initial CSM

Before performing any comparison of existing sampling data to recommended generic vapor intrusion screening levels (VISLs) (see Section 6.5), it is important to verify that site-specific conditions reflect the conditions and assumptions of the generic model underlying the VISLs, which are summarized in Section 6.5.2. To verify that the generic vapor intrusion model applies, there is a need for basic knowledge of the subsurface source of vapors (e.g., location, form, and extent of site-specific vapor-forming chemicals) and subsurface conditions (e.g., soil type in the vadose zone, depth to groundwater for groundwater sources), which are important elements of the CSM (see Section 5.4). When these subsurface data are not available, EPA recommends they be collected (i.e., initiate a vapor intrusion investigation; see Section 6.3.2, for example) before relying upon risk-based screening using pre-existing sampling data.

5.5.3 Preliminary Risk-based Screening

If reliable pre-existing sampling data are available and an adequate CSM has been developed (i.e., sufficient subsurface characterization information exists to adequately characterize the locations, forms, and extent of site-specific vapor-forming chemicals and general subsurface conditions (e.g., hydrologic and geologic setting in and around the source(s) and the buildings)), then a risk-based screening may be useful to obtain some preliminary insights about the potential level of exposure and risk posed by vapor intrusion.

> *Example: A prospective developer of a vacant lot with no history of onsite chemical use is interested in evaluating the potential for vapor intrusion in the future due to potential migration onto the lot of a plume of contaminated groundwater emanating from another property. The extent and nature of this off-property plume have been adequately and recently characterized and geologic conditions near (but not on) the lot have been characterized, as documented in a publicly available report(s). In this circumstance, it may be possible to support a preliminary screening and obtain some useful insights. For example, if the maximum concentration of each chemical of concern in the off-property plume of contaminated groundwater currently and in the future is less than the generic chemical-specific screening level for groundwater, then vapor intrusion may not be a future*

---

[98] EPA recommends basing the decision about whether to undertake response action for vapor intrusion (i.e., a component of risk management; see Section 7.4) on a consideration of a reasonable maximum exposure (e.g., EPA 1989, 1991a), which is intended to be a semi-quantitative phrase, referring to the lower portion of the high end of the exposure distribution (see Glossary).

> *concern on the vacant lot, provided there are sufficient data to document that conditions on the vacant lot are consistent with the generic model behind the vapor intrusion screening levels, as described in Section 6.5.2.*
>
> *Depending upon lot-specific circumstances, additional data collection or evaluation, possibly including on-lot site characterization, may be warranted (i.e., proceed to a detailed vapor intrusion investigation) to verify that the expected conditions hold true (e.g., hydrogeologic conditions on the vacant lot are consistent with the generic model behind the vapor intrusion screening levels). EPA generally also recommends consideration of the vapor intrusion pathway during the development planning or initial post-construction stage (e.g., pre-emptive mitigation – Sections 3.3 and 7.8; mathematical modeling, where parameters are chosen to represent conditions that give a high-impact case – Section 6.6; indoor air testing – Section 6.4.1 -- to confirm the screening results based upon the groundwater source data) before making final risk management decisions.*

This example reinforces the following general recommended guidelines:

- EPA generally recommends that site-specific data be collected and evaluated to verify that the subject property reflects the conditions and assumptions of the generic model underlying the VISLs (see Section 6.5.2).

- EPA generally recommends that multiple lines of evidence (e.g., hydrogeologic information in addition to sampling data) be collected and weighed together in supporting assessments of the vapor intrusion pathway (see Sections 7.1, 7.2, and 7.3 for further information).

- Multiple rounds of groundwater (or soil gas) sampling results can be useful in supporting conclusions that a specific vapor source is stable or shrinking and/or is not expected to pose a vapor intrusion concern (see Sections 6.3.1 and 6.4.5) under reasonably expected future, as well as current, conditions.

Similar recommended guidelines may be appropriate in situations where vapor intrusion potential is being evaluated as part of a periodic review of an existing remedy (prompted, for example, by recent construction of a new building over a contaminated plume that is undergoing remediation) (EPA 2002b, 2012c).

6.0 DETAILED INVESTIGATION OF VAPOR INTRUSION

EPA recommends that the planning and data review team plan and conduct a site investigation for vapor intrusion when the preliminary analysis (Section 5.3) indicates the presence of subsurface contamination with vapor-forming chemicals underlying or near buildings.

This section describes EPA's generally recommended approaches and practices for conducting detailed vapor intrusion investigations, which typically entail collecting and weighing multiple lines of evidence to characterize the vapor intrusion pathway. Specifically, this section:

- Identifies that a wide variety of scenarios may be encountered among sites investigated for potential vapor intrusion, which necessitates site-specific approaches to scoping investigations and sequencing investigation phases and objectives (Section 6.1);
- Provides EPA's recommendations for planning, scoping, and conducting vapor intrusion investigations (Sections 6.2, 6.3, and 6.4);
- Presents EPA's recommended screening levels for vapor intrusion and describes EPA's recommended uses of risk-based screening and suggested interpretation of the results (Section 6.5); and
- Provides recommendations for developing and using mathematical models in vapor intrusion assessments (Section 6.6).

Section 7 describes EPA's generally recommended approaches and practices for determining, on the basis of the investigation results, whether the vapor intrusion pathway poses a potential human health risk to building occupants under current and reasonably expected future conditions and whether response actions are warranted for vapor intrusion mitigation at individual facilities, buildings, or sites.

6.1 Common Vapor Intrusion Scenarios

Vapor intrusion scenarios can be quite varied, owing to the possible combinations of:

- Multiple hazardous chemicals that can form vapors.
- Multiple forms in which these chemicals may be released to or present as contaminants in the subsurface, for example:
    - Residual NAPL and adsorbed-phase chemicals, including LNAPLs that are less dense than water and DNAPLs that are denser than water.
    - Dissolved-phase chemicals in groundwater or soil moisture.
    - Primary vapor releases (e.g., from chemical vapor transmission lines).
- The variety of geologic and hydrologic characteristics and conditions in the subsurface environment in which this contamination may occur.

- The variety of buildings (in terms of size, age, condition, and use) and current or expected land use settings (e.g., residential, commercial, industrial) that may be subject to vapor intrusion from such subsurface contamination.

- Circumstances under which subsurface contamination is found or suspected and investigated (e.g., brownfield redevelopment, citizen reports/complaints, reported release)

- The variety of sources that may contribute to vapor concentrations in ambient air and may serve as indoor vapor sources unrelated to vapor intrusion.

A few of the possible scenarios are illustrated in Figure 2-1. Many more can be inferred from the conceptual model of vapor intrusion discussed in Section 2. Some of the common scenarios where vapor intrusion has been documented to occur include:

- Groundwater contaminant plumes in shallow aquifers underlying residential and nonresidential buildings. Many well-known vapor intrusion sites are in this category, in part because there is generally a greater opportunity to have multiple buildings overlying the vapor source. Specific sites and buildings normally can be prioritized and distinguished based upon their potential for vapor intrusion, which generally would depend upon a number of site-specific factors, such as:

    - strength, proximity, and extent of the vapor source emanating from shallow groundwater (see Sections 2.1 and 5.4);

    - the potential for significant attenuation of vapor migration due to geologic, hydrologic, or biochemical conditions in the vadose zone (see Sections 2.2 and 5.4);

    - the potential for significant attenuation of the contaminant plume due to geologic, hydrologic, or biochemical conditions in the saturated zone; and

    - type(s), characteristics and structural condition of the overlying building(s) (see Sections 2.3, 2.4, and 5.4).

- Soil contamination in the vadose zone underlying commercial or industrial buildings. Typically, one or a few buildings may be threatened by potential vapor intrusion. Specific buildings and sites normally can be prioritized and distinguished based upon their potential for vapor intrusion, which generally would depend upon a number of site-specific factors, such as:

    - strength, proximity, and extent of the vadose zone source (see Sections 2.1 and 5.4);

    - the potential for attenuation of vapor migration due to geologic, hydrologic, or biochemical conditions in the vadose zone (see Sections 2.2 and 5.4); and

    - type(s), characteristics and structural condition of the overlying building(s) (see Sections 2.3, 2.4, and 5.4).

- Sites with residual wastes (e.g., landfills, former manufactured gas plants, former oil production fields) underlying or near buildings. The potential for methane formation may more frequently warrant additional consideration for sites with residual wastes than for contaminated groundwater plumes.

EPA's recommended approaches and practices for vapor intrusion investigations aim to be flexible and adaptable to a wide range of reasonably expected scenarios and are not intended to be prescriptive or exhaustive for any specific scenario.

6.2 Planning and Scoping

Before information or data are collected, EPA generally recommends conducting systematic and thorough planning during which performance or acceptance criteria are developed for the collection, evaluation, or use of these data (EPA 2006a).[99] EPA recommends the data quality objective (DQO) process as the appropriate systematic planning process for its decision-making and has issued guidance for its application to hazardous waste site investigations pursuant to CERCLA and RCRA (EPA 2000a).[100] When appropriately conducted, planning provides greater assurance that the data collected will fulfill specific project needs and that mitigation and subsurface remediation options will be considered early in the process.[101] A clear and logical plan will often facilitate communication with building owners, occupants, and other stakeholders.

Given these considerations, a thorough planning process, guided by a CSM, is usually advisable for detailed vapor intrusion investigations. Figure 6-1 provides a diagram to illustrate such planning and scoping. The initial stages of planning would typically entail gathering readily available existing information and formulating an initial CSM, as described in Section 5.4. The CSM portrays the current understanding of site-specific conditions, including the nature and extent of contamination, contaminant fate and transport routes, potential "receptors" and contaminant exposure pathways. The term "conceptual" merely reflects that the model need not be entirely quantitative and mathematical; it does not, however, denote a simplistic or incomplete understanding of site conditions. The CSM normally warrants updating as new information is developed and new investigatory questions are framed and answered.

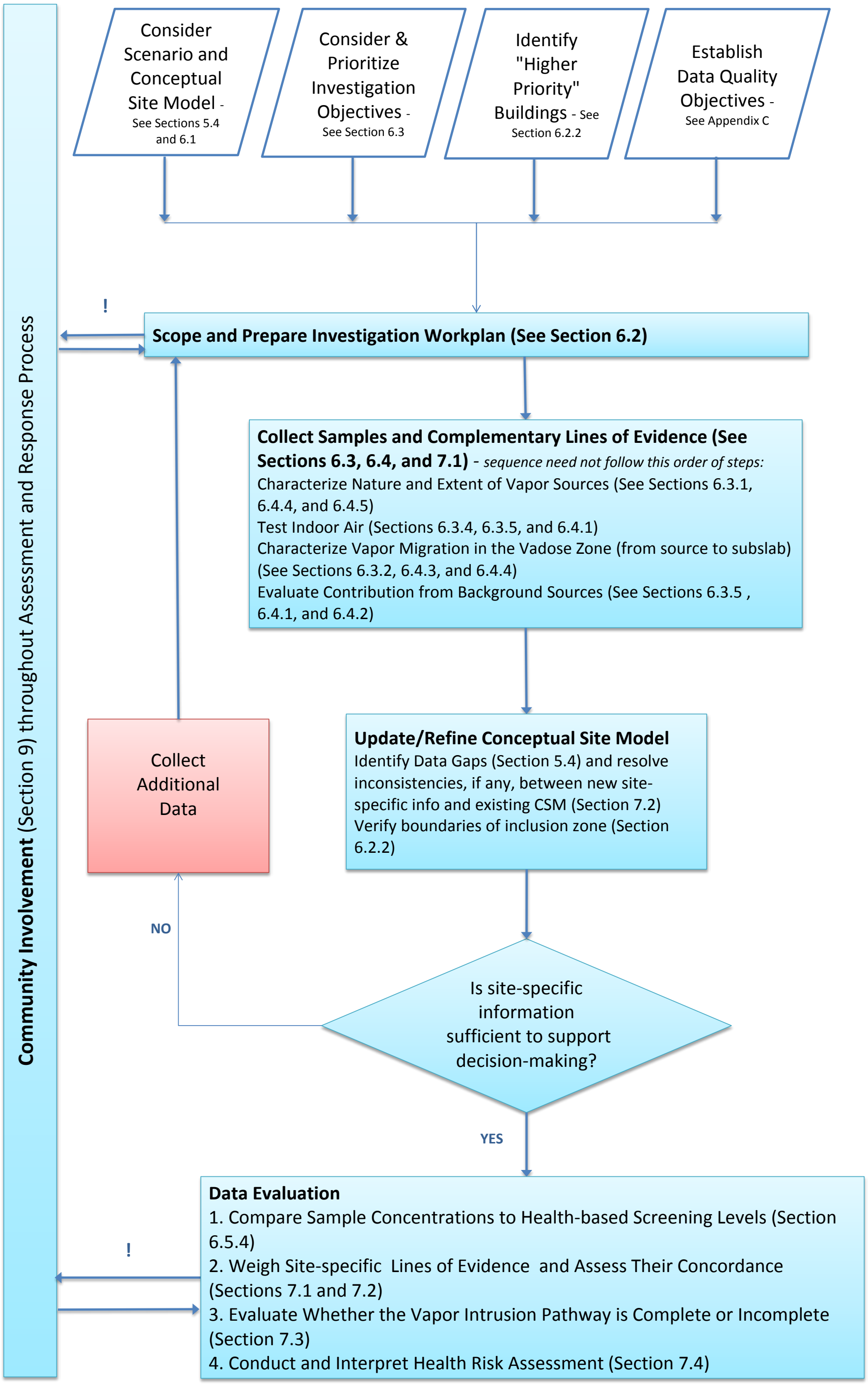
Subsequent to formulating an initial CSM based on readily available information, the scope for an initial phase of vapor intrusion investigation would be developed, preferably along with a logical plan for future directions in response to the reasonably expected outcomes of the initial investigatory phases and in coordination with the objectives and phasing of the broader site

---

[99] In situations where imminent threats (see Section 5.2) are known or reasonably expected, the initial planning process may be more truncated and focused, but careful and thoughtful planning is still recommended.

[100] Appendix B provides additional information about EPA's quality system and DQO process.

[101] *Science and Decisions: Advancing Risk Assessment* was prepared by the National Academy of Sciences (NAS) Committee on Improving Risk Analysis Approaches Used by the U.S. EPA (NRC 2009) and is commonly referred to as the "Silver Book." Among other recommendations, the NAS Committee encouraged EPA to focus greater attention on design in the formative stages of risk assessment, specifically on planning and scoping and problem formulation, and to view risk assessments as a method for evaluating the relative merits of various options for managing risk, rather than as an end in itself. Consistent with these recommendations, plausible mitigation and subsurface remediation options (see Section 8) may warrant consideration during development of vapor intrusion investigation plans.



Exclamation point (!) indicates important milestone for communication and engagement efforts with affected building occupants and owners.

Figure 6-1 Overview of Planning, Scoping, and Conducting Vapor Intrusion Investigations

characterization. Initial plans may warrant periodic updates and refinements, particularly when data outcomes are unexpected and prompt the need to reevaluate the CSM. In each case, EPA recommends that the investigation work plan include the identification of and basis for the indoor air screening levels (such as the vapor intrusion screening levels (VISLs)) and/or indoor air action levels (i.e., level of each vapor-forming chemical of potential concern that would trigger a response action if exceeded), which would dictate the DQOs for the sampling and analysis methods. In general, EPA recommends the plan also include a rationale or logic for where and how the data will be collected and over what duration(s), how the data will be interpreted (e.g., weighed with other lines of evidence, compared to risk-based benchmarks), whether confirmatory sampling will be needed if all sample concentrations are less than the action levels, whether response action(s) would be triggered if sample concentrations exceed the target levels, and similar considerations. EPA recommends considering potential health effects and relevant exposure periods (e.g., chronic versus short-term effects and exposure durations and scenarios; see Section 7.4) for site-related, vapor-forming chemicals when developing DQOs and sampling plans for indoor air (see Section 6.4.1, for example). Sections 6.3 through 6.6 below provide additional information for planning and scoping site-specific investigations for vapor intrusion assessment.

EPA's fundamental approach to evaluating contaminated sites calls for proceeding in a stepwise fashion with early data collection efforts usually limited to developing a basic understanding of the site, as reflected in the CSM.[102] Subsequent data collection efforts focus on filling gaps in the understanding of the CSM and gathering information necessary to evaluate the relative merits of various options for managing risk. Therefore, EPA generally recommends developing and implementing an overall vapor intrusion investigation plan in multiple stages or phases. Such a phased approach encourages the identification of key data needs early in the process to better ensure that data collection provides information relevant to decision-making (e.g., interim action to mitigate vapor intrusion and selection of a cleanup plan for subsurface contamination). In this way, the overall site characterization effort can be scoped to prioritize data collection and minimize the collection of unnecessary data and maximize data quality.

EPA recommends that the objectives and methods of the investigation be documented, preferably in a vapor intrusion work plan. An individual work plan may address a single phase or stage or may address the overall investigation. The vapor intrusion work plan(s) may be

---

[102] Investigations under CERCLA and RCRA corrective action (CA) explicitly recognize phasing. In these cleanup programs, the first investigatory phase is an *initial site assessment*. The purpose of this activity is to gather information on site conditions (current and historical), releases, potential releases, and exposure pathways. Investigators use this information to determine whether a response action (e.g., removal action or interim cleanup measure) may be needed or to identify areas of concern for further study. Information collected during this phase usually forms the basis for determining whether the next stage, site investigation, is warranted. In the RCRA CA program, the initial site assessment is called the RCRA facility assessment. Under CERCLA, this phase is called the preliminary assessment/site inspection. The purpose of the second phase, site investigation, is to determine the nature and extent of contamination at a site, quantify risks posed to human health and the environment, and gather information to support the selection and implementation of appropriate remedies. In the RCRA CA program, this phase is known as the RCRA facility investigation. Under the CERCLA remedial program, this phase is referred to as the remedial investigation. In addition, the site investigation may itself be conducted in multiple stages (or phases).

incorporated as part of a comprehensive site investigation work plan or as a stand-alone document, depending upon site-specific circumstances.[103]

At a minimum, EPA recommends that the components of the work plan(s) include or reference:

- Narrative description of the rationale, objective(s), and scope of the investigation.
- Summary of the CSM, based upon the current understanding of site conditions.
- Scaled map(s) illustrating known extent of subsurface contamination and readily identifiable landmarks (e.g., streets and buildings).
- Media to be sampled.
- Number, type, and location of and rationale for proposed sampling locations.
- Sampling methods and procedures for each medium.
- Analytic method(s) to be used to obtain chemical concentrations and a statement about whether a stationary or mobile laboratory will be used.
- Standard operating procedures of the laboratory and for field instruments.
- Quality assurance project plan (QAPP).
- Health and safety plan.[104]

EPA recommends that planning for vapor intrusion investigations also consider site and building access agreements, equipment security, and locations of underground utilities.

EPA recommends that the planning, data collection, and data review team(s) for vapor intrusion investigations generally include:

- Individuals with expertise in characterizing subsurface environmental conditions and interpreting and communicating environmental data.
- On-site (field) personnel with appropriate training and experience in hazard identification, workplace practices to foster health and safety, and recommended sampling protocols.

---

[103] EPA recommends that monitoring programs (see Section 8.4) that assess the performance and effectiveness of remediation and mitigation systems (see Sections 8.1 and 8.2, respectively) also be documented, preferably in work plans similar to those recommended herein for characterizing and assessing the vapor intrusion pathway.

[104] All governmental agencies and private employers are directly responsible for the health and safety of their employees. This general rule applies to many parties involved in the assessment and cleanup of Superfund sites, RCRA corrective action sites, and brownfield redevelopment sites. Standards established pursuant to the Occupational Safety and Health Act are found in Title 29 of the Code of Federal Regulations (29 CFR), which include standards for training, hazard communication, and site-specific health and safety plans.

- Individuals with expertise in human health risk assessment to characterize risks posed by the vapor intrusion pathway.

- Individuals with expertise in community involvement and outreach.

Depending upon the complexity of the CSM (see Section 5.4) and site-specific data evaluations, decision-makers may also find valuable input from individuals with expertise in hydrogeology, inferential statistics, laboratory analysis methods, and building construction, ventilation, and operations and individuals knowledgeable about land use planning, zoning, and land development.

EPA recommends that the scope of investigations within buildings and on individual properties be contemplated, planned, and implemented with the goal of limiting, to the extent practical, return visits, which can cause disruption and inconvenience for building occupants and owners. For example, it may be preferable to collect a comprehensive set of data (e.g., indoor air, sub-slab soil gas, and ambient air samples; pressure readings; see Section 6.4) and confirm information about building occupancy, building usage, heating, cooling, and ventilation (see Section 6.4.1) in a single mobilization, rather than over separate visits, when the investigation objectives include indoor air sampling (see Section 6.3.4) or evaluating contributions of 'background' sources on levels of vapor-forming chemicals in indoor air (see Section 6.3.5).

6.2.1 Vapor Intrusion Inclusion Zones

Soil gas concentrations generally decrease with increasing distance from a subsurface vapor source, and eventually at some distance the concentrations become negligible. The distance at which soil gas concentrations become negligible is a function of the strength and dimensions of the vapor source, the type of vapor source, the soil types and layering in the vadose zone, the presence of physical barriers (e.g., asphalt covers or ice) at the ground surface, and the presence of preferential migration routes, among other factors (see, for example, EPA 2012b). The extent of the site-specific "inclusion zone" for vapor intrusion may also expand in the future, depending upon:

- The age of the chemical release and whether sufficient time has elapsed to allow soil gas to migrate from the source to its maximum potential extent.[105]

- Whether the subsurface vapor source is expanding (i.e., is migrating) or rising in concentration, including hazardous byproducts of any biodegradation.

Because these factors vary among sites, the distance beyond which structures will not be affected by vapor intrusion should be a site-specific determination.

<u>Recommended Distance for Initial Evaluation</u>. There are limited published empirical data relating observed indoor air concentrations of subsurface contaminants to distance from a well-

---

[105] EPA (2012b, Section 6.1) presents some information about transient vapor migration after a subsurface vapor source is released. Sites with shallow vapor sources (e.g., less than one meter deep) may take only a few hours to a few days for soil gas to migrate to its maximum potential extent. Sites with deeper vapor sources (e.g., greater than 10 meters deep) may take months or years for soil gas to migrate to its maximum potential extent.

defined source boundary. However, a buffer zone of approximately 100 feet (laterally or vertically from the "boundary" of subsurface vapor concentrations of potential concern) generally has been used in determining which buildings to include in vapor intrusion investigations (i.e., which buildings are 'near' a subsurface vapor source for purposes of a preliminary analysis) when significant surface covers are not present, under the assumption that preferential vapor migration routes are absent.[106] Specifically, a buffer zone of 100 feet (or approximately two houses wide) has been suggested by several states for initial evaluation and is supported, in general, by:

- theoretical analyses that assume the absence of a preferential vapor migration route(s) and that diffusion is the predominant mechanism of vapor migration in the vadose zone (Lowell and Eklund 2004); and
- reports that vapor intrusion impacts generally have not been observed "at distances greater than one or two houses beyond the estimated extent of the groundwater plume" , at sites where contaminated groundwater is the subsurface vapor source (Folkes et al. 2009).

However, we would note that vapor source types for which use of a 100-foot buffer would typically be inappropriate include:

- Landfills where methane is generated in sufficient quantities to induce advective transport in the vadose zone.[107]
- Commercial or industrial settings where a vapor-forming chemical(s) has been released within an enclosed space at a density that may result in significant advective transport of the vapor(s) downward through cracks or openings in floors and into the vadose zone.
- Leaking vapors from pressurized gas transmission lines.

In each of these cases, the diffusive transport of vapors may be overridden by advective transport and the vapors may be transported in the vadose zone several hundred feet from the source of contamination.[108]

Moreover, we would also note that anecdotal evidence indicates that in some settings buildings greater than 100 feet from a plume "boundary" are affected by vapor intrusion, even when

---

[106] Preferential migration routes are defined and discussed in Section 5.4. When present, they may facilitate subsurface vapor migration over distances greater than 100 feet.

[107] EPA has also published *Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities* (EPA 2005), which provides procedures and a set of tools for evaluating landfill gas emissions to ambient air and soil gas migration due to pressure gradients.

[108] For example, Little et al (1992) describe a landfill in southern California, where methane was detected in enclosed spaces in nearby homes at concentrations approaching 1% by volume and chlorinated hydrocarbons had migrated into a house 180 meters from the landfill.

diffusion is the presumed mechanism of vapor migration.[109] Furthermore, the presence of conduits (e.g., sewer and drain lines that intercept and carry subsurface contamination (Vroblesky et al. 2011), as well as permeable bedding for sewer lines or other utilities) or preferential hydrogeologic pathways that facilitate unattenuated vapor migration in the vadose zone, and other factors (e.g., presence of extensive surface covers, uncertainties in delineating the boundaries) may extend the recommended inclusion distance for a vapor intrusion investigation. For these reasons, EPA recommends investigating soil vapor migration distance on a site-specific basis. That is, larger or smaller distances may need to be considered when developing objectives for detailed vapor intrusion investigations and interpreting the resulting data. Data from sub-slab and exterior soil gas sampling (see, for example, Sections 6.4.3, and 6.4.4, respectively)[110] and indoor air testing (see, for example, Sections 6.3.4 and 6.4.1) can be collected and evaluated to delineate or confirm areas at specific sites within which buildings are potentially subject to vapor intrusion.

Criteria for Establishing "Boundaries" of the Plumes that Contain Vapor-forming Chemicals. This Technical Guide is intended to be applied to existing groundwater plumes as they are currently defined (e.g., Maximum Contaminant Levels, state standards, or risk-based concentrations). However, it is important to recognize that some non-potable aquifers may have plumes that have been defined by threshold concentrations significantly higher than drinking-water concentrations. In these cases, contamination that is not technically considered part of the plume may still have the potential to pose unacceptable human health risk via the vapor intrusion pathway. Consequently, the plume definition may need to be expanded for purposes of defining an inclusion zone for a vapor intrusion investigation. When groundwater is the subsurface vapor source, EPA generally recommends comparing groundwater concentrations to the VISLs to estimate the boundaries of the plume, when contaminated groundwater is a subsurface vapor source, for purposes of establishing the boundaries of the vapor intrusion inclusion zone.

Criteria for Establishing "Boundaries" of NAPL Plumes that Contain Vapor-forming Chemicals. EPA generally recommends comparing soil gas concentrations to the respective VISLs to estimate the boundaries of the vapor plume, when residual or free-phase NAPL is a subsurface vapor source, for purposes of establishing the boundaries of the vapor intrusion inclusion zone.

6.2.2 Prioritizing Investigations with Multiple Buildings

At sites where numerous buildings are potentially subject to vapor intrusion (e.g., developed areas with an extensive plume of contaminated groundwater), it may not be feasible or practical at the outset to sample indoor air in each building or soil gas underneath or near each building. In such circumstances, EPA generally recommends a "worst first" approach to prioritize

---

[109] Among other possibilities, vapor intrusion impacts observed to occur at distances greater than 100 feet in the absence of a preferential migration route(s) may reflect imprecision in the interpolated edge of a plume, based upon sampling data from sparse monitoring wells, and/or use of screening levels for drinking water, rather than for vapor intrusion (i.e., VISLs), to delineate a plume's extent.

[110] For assessing the extent of soil gas migration from the subsurface vapor source, EPA generally recommends measuring soil gas concentrations, either sub-slab soil gas (preferably) or exterior soil gas, with a sufficient density to characterize and understand spatial variability (Section 6.3.2).

buildings for investigation. Factors that, if known, may warrant consideration in prioritizing buildings for investigation include:

- Source strength and proximity. Buildings overlying and near a source of vapors in the vadose zone would generally be expected to have a greater potential for vapor intrusion than buildings that do not overlie this same vapor source. Where the subsurface vapor source is groundwater, buildings located over higher concentrations or shallower water levels would generally be expected to have a greater potential for vapor intrusion than buildings located over lower concentrations and deeper groundwater plumes.

- Building types and conditions. Buildings that are continuously occupied may pose a more immediate concern than buildings that are not currently occupied, if all other factors (e.g., source strength and proximity) are equivalent. Nonresidential buildings with bay-style doors that are routinely open may be better ventilated than other types of nonresidential buildings, providing greater potential for dilution of vapor-forming chemicals that enter the building via vapor intrusion.

- Vapor migration ease. Buildings overlying vadose zones comprised of coarse geological materials (e.g., gravel, boulders) generally would be expected to have a greater potential for vapor intrusion than buildings overlying vadose zones comprised of fine-grained materials (e.g., silts, clays), provided significant preferential migration routes (e.g., geologic fractures, utility corridors) are not present in the fine-grained layers.

Interviews and building surveys during development of the investigation work plan (or during the preliminary analysis – see Section 5) also can provide useful information for prioritizing buildings, when phased testing is chosen or indicated. Sections 6.3 and 6.4 provide additional examples of survey information that can support planning, in addition to supporting data interpretation.

In situations where “higher-priority” buildings and locations are investigated initially, investigation of locations of other buildings may still be warranted, for example, to ensure that the CSM is complete and accurate and that variability in the subsurface conditions and building conditions is understood. There usually is substantial spatial variability in the concentrations of subsurface vapors, caused by heterogeneities in the subsurface materials and other factors, that can result in variability among buildings in vapor flux and indoor air concentrations arising from vapor intrusion. Additionally, building construction, building age and maintenance, and occupants’ activities that affect soil gas entry and air exchange rate will vary from building to building, further adding to the variability in indoor air concentrations between buildings. Therefore, it may be difficult to identify *a priori* either a “representative” or “reasonable worst case”[111] building or group of buildings, when it is determined that sampling all buildings is not practical.

---

[111] For purposes of this Technical Guide, “reasonable worst case” is intended to be a semi-quantitative phrase, referring to the upper portion of the high end of the exposure distribution, but less than the absolute maximum exposure (see Glossary). Because EPA generally recommends a “worst first” approach to prioritize buildings for investigation of the vapor intrusion pathway, “reasonable worst case” buildings would warrant a “higher priority” than “representative” or typical buildings.

When sampling all buildings is not practical, but other lines of evidence suggest that vapor intrusion may be occurring, the site management team may wish to consider installing engineered exposure controls for vapor intrusion mitigation in buildings without baseline indoor air data (i.e., building mitigation as an early action – see Sections 3.3 and 7.8).

6.2.3 Planning for Community Involvement

Community involvement is an important component of any vapor intrusion investigation. EPA recommends that a community involvement or public participation plan (see Section 9.1) be developed or refined while planning a vapor intrusion investigation. Proper and sustained community outreach and engagement efforts are critical to effectively implementing work plans for vapor intrusion investigations, particularly when they involve sampling in a home or workplace or on private property. Resuming and conducting community involvement at legacy sites (i.e., sites that have a past history of agency involvement; see Section 9.6) can be particularly complex. The site planning team is encouraged to consult with appropriate EPA colleagues experienced in community outreach and involvement efforts and utilize available EPA planning resources, including those discussed in Section 9.

6.3 Characterize the Vapor Intrusion Pathway

As discussed in Section 2, the vapor intrusion pathway entails emanation of volatile chemicals from a subsurface source(s) in a vapor form that migrates in the vadose zone, gradually increases in amount underneath buildings as time passes, and enters buildings through openings and conduits. As a result, detailed vapor intrusion investigations designed to develop or enhance the CSM for a specific site will typically address one or more of the following objectives, often in phases:[112]

- Characterize the nature and extent of subsurface sources of vapors.
- Characterize the subsurface migration paths between vapor sources and buildings (potential "receptors").
- Assess building(s) for their susceptibility to soil gas entry.
- Evaluate the presence and concentration of a site-related subsurface contaminant(s) in indoor air.
- Identify and evaluate contributions of indoor and ambient air sources to concentrations of hazardous vapors in indoor air.

---

[112] The order of presentation is not intended to convey a suggested sequencing of objectives; rather, it follows the presentation of the conceptual model of vapor intrusion in Section 2.

These objectives are described in the following subsections for purposes of identifying the primary lines of evidence typically developed and evaluated for each objective and describing how the objectives fit together in developing and enhancing the CSM for a specific site an characterizing vapor intrusion potential. This information is provided to assist the site planning team in selecting and sequencing objectives for vapor intrusion investigations.

6.3.1 Characterize Nature and Extent of Subsurface Vapor Sources

Where the preliminary analysis indicates that subsurface contamination with vapor-forming chemicals may be underlying or near buildings, EPA recommends that the nature and extent of such contamination be well characterized. Source characterization data are critical to developing a sound CSM and supporting confident, final decisions about the vapor intrusion pathway.

Investigations to characterize the nature and delineate the extent of potential sources of vapors may rely upon the results of groundwater sampling, soil sampling, or soil gas sampling, as dictated by the site-specific source(s) and subsurface conditions.

Groundwater Sources:

Where contaminated groundwater is a vapor source located near buildings, EPA recommends that groundwater observation wells (i.e., monitoring wells) be installed at strategic locations and used to assess groundwater flow and contaminant concentrations; i.e., verify the nature and extent of groundwater contamination through groundwater sampling and analysis.[113] Groundwater samples obtained from the uppermost portion of the aquifer[114] that underlies the study area of interest (i.e., where buildings are located) are recommended for characterizing representative vapor source concentrations for vapor intrusion assessment. For this purpose, wells (or multi-level samplers) that are screened across the water table interface are preferred and EPA recommends samples be collected as close as possible to the top of the water table using approved sampling methods designed to minimize loss of volatiles while sampling (EPA 2002a, EPA-ERT 2001a).[115] Ideally, the plume can be shown as stable or shrinking (i.e., is not migrating or rising in concentration, including hazardous byproducts of any biodegradation), through multiple rounds of sampling, so that vapor source concentrations can be confidently evaluated under reasonably expected future, as well as current, conditions. Otherwise, the inclusion zone for vapor intrusion (see Section 6.2.1) may expand over time and/or current sample concentrations in or beneath a given building may under-estimate the reasonable maximum vapor intrusion condition in the future.

For purposes of assessing vapor intrusion for specific buildings, groundwater samples from wells nearer to buildings are generally recommended over those from more distant wells. Interpolation of the results obtained from two or more wells in the uppermost portion of the aquifer may be warranted for these purposes when the spatial pattern suggests significant lateral gradients in contaminant concentrations within the area of interest. However, for purposes of determining whether contaminated groundwater poses acceptable human health risk from vapor intrusion on an area-wide basis, it may be more appropriate to utilize sampling results for the most greatly impacted well within the area of interest.

In addition, EPA generally recommends that a soil gas sample be collected immediately above the groundwater table (and above the capillary fringe) (i.e., "near-source" soil gas sample)[116] to help characterize the subsurface vapor source. The results of such "near

---

[113] Although a soil gas survey can also be employed as a screening tool to assist with the delineation of a plume of contaminated groundwater, EPA recommends that plume delineation ultimately be supported by the collection and analysis of confirmatory groundwater samples at appropriate locations.

[114] EPA recommends that, to the extent practical, groundwater samples be collected over a narrow interval (e.g., a few feet or less) just below the water table when the data are to be used for assessing the potential for vapor intrusion. Of course, the broader objectives of a site characterization will generally necessitate installation and sampling of additional wells, from other depth intervals, to accurately characterize the full nature and extent of groundwater contamination. Such wells and the broader topic of site characterization are not discussed in this Technical Guide, which is focused instead on recommended guidelines that are pertinent specifically to vapor intrusion.

[115] If available groundwater data do not meet these criteria, the site data review team may consider whether they are nevertheless representative of potential vapor source concentrations emanating from groundwater.

[116] In this context and for purposes of this Technical Guide, "near" means "within a practically short distance." Site- and location-specific circumstances and project-specific objectives typically will influence the quantitative definition of "near" for purposes of collecting "near-source" soil gas samples.

source" soil gas samples can be compared to calculations of the vapor concentration expected when the soil gas is in equilibrium with the concentrations measured in shallow groundwater (see Appendix C). A favorable comparison (i.e., the two concentrations are equivalent for each vapor-forming chemical in groundwater) would help to support the results of the groundwater characterization. On the other hand, a "fresh water lens" (or other site-specific conditions; see, for example, Section 6.3.2) could account for measured soil gas concentration(s) being significantly lower than the calculated equilibrium concentration(s).

Because fluctuations in water table elevation can lead to elevated vapor concentrations in the vadose zone, EPA also recommends that "near source" soil gas sampling (and possibly a soil gas survey) be considered in different seasons that coincide with groundwater fluctuations.

Vadose Zone Sources:

Where contaminated soil or non-aqueous-phase liquid (NAPL) in the vadose zone is a subsurface vapor source, soil sampling using coring techniques for sample retrieval or using sensors, such as a membrane interface probe, can be used to characterize the chemical composition and general location of contamination; that is, bulk soil concentration data can be used in a qualitative sense for this purpose. For example, high soil concentrations generally would indicate impacted soil. Unfortunately, the converse is not always true. Non-detect results for soil samples cannot be interpreted to indicate the absence of a subsurface vapor source, because of the potential for vapor loss due to volatilization during soil sampling, preservation, and chemical analysis.

Alternatively or in addition, a soil gas survey can be used to locate the primary source zone and delineate the areal and vertical extent of the vapor-affected area. Generally, EPA recommends that the soil gas survey include a soil gas sample collected immediately above each contaminant source in the vadose zone (i.e., "near-source" soil gas samples) to help characterize the vapor source.

Although a soil gas survey can generally be used to characterize many other subsurface vapor sources (e.g., sewer and drain lines; landfills and other land-based disposal units; impoundments and other land-based storage and/or treatment units, pressurized tanks and pipelines), additional approaches tailored to the specific source type may also warrant consideration.

These sampling options are generally coupled with an understanding of the site-specific subsurface conditions that control the location and extent of contamination (e.g., geologic properties, including stratigraphy and level of heterogeneity; hydrogeologic conditions; sewers, drains, and other conduits that lie underneath or intersect areas of groundwater and soil contamination). Such understanding is generally developed by interpreting the data obtained through borehole logging (i.e., visually inspecting soil cores and determining soil texture) or geophysical tools.

EPA generally recommends sample locations be of sufficient density to adequately account for spatial variability and heterogeneity in subsurface conditions. EPA generally recommends consulting with individuals who have expertise in characterizing subsurface environmental conditions (e.g., a geologist) when determining appropriate sampling locations and spacing.

When combined with the data demonstrating that the property reflects the conditions and assumptions of the generic model invoked in the VISLs (see Section 6.5.2), groundwater and “near-source” soil gas samples can be compared to medium-specific screening levels to develop an initial quantitative perspective about the potential level of exposure and human health risk posed by vapor intrusion. Section 6.5 provides additional information about risk-based screening of vapor source concentrations.

6.3.2 Characterize Vapor Migration in the Vadose Zone

As described in Section 2, geologic, hydrologic, biochemical factors in the vadose zone, as well as elapsed time since the environmental release, can influence vapor migration and attenuation in soil gas concentrations between subsurface vapor sources and nearby building(s).[117] As noted in Section 5.4, EPA recommends the CSM portray the current understanding of these vadose zone conditions in and around the subsurface vapor source(s) and nearby building(s). Furthermore, EPA recommends the CSM identify known or suspected preferential migration routes that could facilitate vapor migration to greater distances and at higher concentrations than otherwise expected. When these conditions are not well established from existing information, EPA recommends that a detailed investigation be scoped to address these data gaps.

When combined with other data, as discussed further in Section 7.3, information about subsurface vapor migration can support determinations that the vapor intrusion pathway is complete under current conditions or may be complete under future conditions. In some cases, vadose zone conditions may impose sufficient resistance to vapor migration to make the vapor intrusion pathway insignificant. In these circumstances, information about subsurface vapor migration, combined with other lines of evidence, can support determinations that the vapor intrusion pathway is incomplete under current conditions, as discussed further in Section 7.3.

Investigations seeking to characterize vapor migration in the vadose zone generally entail, at a minimum, a soil gas survey. Because soil gas concentrations can exhibit considerable spatial variability, due to a variety of factors,[118] EPA generally recommends that soil gas surveys collect soil gas samples at multiple locations and depth intervals between the vapor source and building(s) (potential “receptors”). As a result, the soil gas survey may include samples collected immediately outside the building (“exterior soil gas”) at various depths or several depth intervals,

---

[117] The horizontal and vertical distance over which vapors may migrate in the subsurface depends on the source concentration, source depth, soil matrix properties (e.g., porosity and moisture content), and time since the release occurred. For example, months or years of volatilization and vapor migration may be required to fully develop vapor distributions in the vadose zone at sites with deep vapor sources or with impedances to vapor migration arising from hydrologic or geologic conditions (Section 2.5; EPA 2012b). Under such circumstances, soil gas surveys conducted soon after an environmental release may not yield data indicating the maximum extent of vapor migration.

[118] Modeling of idealized scenarios provides additional demonstrations about spatial variability of soil gas concentrations. For example, vertical profiles of soil gas concentration(s) can be very different underneath buildings compared to locations exterior to the building and soil gas concentrations may not be uniform laterally, particularly in the vicinity of the building, even when the vapor source is a laterally extensive plume of contaminated groundwater (EPA 2012b). These simulation results indicate why EPA recommends that soil gas generally be sampled in multiple sampling locations, when assessing subsurface vapor migration routes.

as well as immediately beneath it (e.g., sub-slab soil gas sampling).[119] If any shallow soil gas samples are collected, EPA recommends they be collected as close as possible to the building and at depths below the respective building foundation and no less than five feet below ground surface, depending on site-specific conditions. Where crawl spaces are present, crawl space air sampling may also be conducted.

Generally, EPA recommends that the soil gas survey include a "near-source" soil gas sample collected immediately above each source of contamination to help characterize the subsurface vapor source (see Section 6.3.1). The results of such "near source" soil gas samples can be compared to calculations of the vapor concentration expected when the soil gas is in equilibrium with the concentrations measured in shallow groundwater (see Appendix C), when the subsurface vapor source is in the groundwater. Geologic, hydrologic, or biologic impedances to vapor migration may be indicated if the measured "near source" soil gas concentrations are significantly lower than the calculated equilibrium concentrations.

To characterize subsurface migration in the vadose zone, soil gas survey data are generally coupled with an understanding of the site-specific subsurface conditions that influence vapor migration and attenuation (e.g., geologic properties, including stratigraphy and level of heterogeneity; hydrologic conditions, including groundwater elevation and soil moisture;[120] and biological properties, including availability of oxygen to support aerobic biodegradation).[121] Such geologic understanding is generally developed by interpreting the data obtained through borehole logging and geophysical tools. Soil permeability to air flow can be measured in the field (McHugh et al. 2013) and would be used to corroborate inferences based upon borehole logging data. Hydrologic conditions can be characterized by analyzing soil samples for porosity and moisture content and by hydrologic modeling. For potentially biodegradable contaminants, an intensive soil gas survey to establish current vertical profiles for contaminant vapors and oxygen (and, in some cases, biodegradation products, such as carbon dioxide or methane)[122] may be able to demonstrate that biodegradation is responsible for attenuating vapor migration

---

[119] EPA recommends that spacing of soil gas sampling locations generally consider the extent and location of the subsurface vapor source, distance between the building and the source, and other site-specific factors.

[120] Tillman and Weaver (2007) conducted hydrologic modeling and collected field data, which showed that moisture content determined from soil cores taken external to a building may over-estimate soil moisture underneath the building. They inferred that vapor intrusion assessments based upon moisture content in soil from open areas between buildings may under-estimate vapor intrusion potential.

[121] As noted in Section 2, vapor migration in the vadose zone can be impeded by several factors, including soil moisture, low-permeability (generally fine-grained) soils, and biodegradation. Significant characterization of the vadose zone may be needed to demonstrate that such geologic, hydrologic, and biologic features are laterally extensive over distances that are large compared to the footprint of the building and the extent of the subsurface vapor source at a specific site.

[122] Interpretation of profiles for carbon dioxide and methane can be challenging, due to the presence of natural sources unrelated to contaminant biodegradation (Holden and Fierer 2005).

to a greater extent than can be attributed to advection and diffusion in the vadose zone.[123, 124] For both purposes, samples collected directly underneath the building will tend to be more representative of conditions influencing vapor intrusion potential than samples collected outside the building footprint, all else being equal.

When conducted contemporaneously for multiple buildings, a soil gas survey and characterization of the vadose zone can help identify distances from subsurface vapor sources beyond which threats from vapor intrusion are not reasonably expected, as mentioned in Section 6.2.1. At sites with a limited number of potentially affected buildings, it may be feasible to characterize the subsurface vapor migration near and surrounding all of them. However, at sites where a large number of buildings may be affected, this approach is not likely to be feasible; in these cases, EPA generally recommends that the site manager seek the advice of an individual familiar with the site-specific subsurface conditions (typically a geologist) to help guide selection of appropriate sampling locations and assess whether “representative” or “reasonable worst case” locations can be identified, as appropriate to the objectives of the investigation. Because there usually is substantial spatial variability in the concentrations of subsurface vapors, caused partially by heterogeneities in the subsurface materials, it may be difficult to identify *a priori* locations that are either “representative” or are “reasonable worst case” subsurface conditions.

Subsurface investigations of vapor intrusion also generally warrant an evaluation of utility corridors, which can facilitate unattenuated vapor transport over longer-than-anticipated distances and/or vapor migration towards and into buildings that are serviced by the utility. EPA also recommends subsurface investigations of vapor intrusion consider whether sewers and other man-made conduits have the potential to transport NAPLs, contaminated groundwater, and/or vapors (through soil) towards and/or directly into buildings. Public and facility records may be useful sources of information about utility and sewer locations, which may provide maps, “as built diagrams,” or construction specifications. Depending upon the CSM, sampling of vapors within the utility corridor (or within a sewer, if present) may be warranted to characterize vapor migration in the subsurface (or characterize a secondary source of vapors – see Sections 6.3.1 and Section 2.1).

Reasonably expected future risks posed by the subsurface vapor source(s) warrant consideration, in addition to risks posed under current conditions, “in order to demonstrate that a site does not present an unacceptable risk to human health and the environment” (EPA 1991a). For example, when evaluating subsurface vapor migration and attenuation in locations where buildings do not exist, it is important to recognize that the conditions in the vadose zone and soil

---

[123] At sites where aerobic biodegradation is limiting the upward migration of petroleum hydrocarbon vapors, for example, the vertical concentration profile will typically show higher concentrations of petroleum hydrocarbons and lower (or non-detect) concentrations of oxygen in deeper soil gas samples. At these same sites, the vertical concentration profile will typically show lower (or non-detect) concentrations of petroleum hydrocarbons and higher concentrations of oxygen in shallower soil gas samples. Because weather events can affect rates of oxygen replenishment in the vadose zone (Lundegard et al. 2008), multiple rounds of such sampling are recommended to demonstrate that biodegradation consistently poses a significant impedance to upward vapor migration. This recommendation is particularly apt where the subsurface vapor source is strong (e.g., unweathered NAPL in the vadose zone) relative to time-variable processes supplying oxygen to the vadose zone.

[124] In this context, mathematical modeling (see Section 6.6) can be employed to characterize vapor migration attributable to advection and diffusion in the vadose zone.

gas concentrations may be changed as a result of constructing a new building and/or supporting infrastructure. The moisture content may decrease and the moisture profile change in the vadose zone as a result of reduced infiltration of rainwater below a building footprint (Tilman and Weaver 2007). The permeability to vapor flow in the vadose zone may be altered in the foundation vicinity due to construction. Finally, the future presence of extensive surface covers and/or utility corridors may also modify the vertical and horizontal profile of soil gas concentrations in the subsurface (EPA 2012b). As a result, EPA recommends that appropriate lines of evidence in addition to a soil gas survey (e.g., mathematical modeling, where parameters are chosen to represent conditions that give a high-impact case – Section 6.6) be developed and considered to support any determination that a future building will not be subject to vapor intrusion or will not pose unacceptable human health risk for occupants. Owing to the potentially unpredictable plans for building construction and site redevelopment, as well as potentially unpredictable changes in the transitory soil characteristics (e.g., soil moisture) and soil gas concentrations, institutional controls may be warranted (e.g., to inform the need for a confirmatory evaluation of the vapor intrusion pathway) when new buildings are constructed in areas where the subsurface vapor source(s) has(have) significant potential to pose a vapor intrusion threat.

6.3.3 Assess Building Susceptibility to Soil Gas Entry

When elevated concentrations of vapor-forming chemicals accumulate in the soil gas immediately underneath the foundation, surrounding the basement, or within the crawl space of a vulnerable building, then soil gas entry (i.e., vapor intrusion) can lead to unacceptable levels of subsurface contaminants in indoor air, depending upon building- and site-specific circumstances. As discussed in Section 2.3, soil gas can enter a building when openings are present and driving ‘forces’ exist to draw the vapors from the subsurface through the openings into the indoor environment.

Single-family detached homes can generally be presumed to have openings for soil gas entry; as such, they will generally be susceptible to soil gas entry unless a mitigation system (e.g., radon mitigation system) is present and operating as intended. Some buildings are more susceptible to soil gas entry than others. For example, buildings with significant openings, such as:

- buildings with deteriorating basements or dirt floors, which generally provide poor barriers to vapor (soil gas) entry; and
- buildings with sumps (or other openings to the subsurface) that can facilitate transport of vapors via soil gas entry.

EPA recommends that appropriate lines of evidence be employed to assess susceptibility to soil gas entry, when this objective is selected as part of a site-specific investigation plan for vapor intrusion assessment. Vulnerability to soil gas entry can be assessed for a specific building by using any of several methods, including:

- Concurrently monitoring indoor air samples for presence of radon and finding radon in indoor air at levels greater than in ambient air.[125]

- Concurrently monitoring indoor air and ambient air (see Section 6.3.5) and finding cis-1,2-dichloroethylene, vinyl chloride, 1,1-dichloroethylene, or 1,1-dichloroethane in indoor air at levels greater than in ambient air, when and where they are present in the subsurface vapor source(s), but are not used indoors.[126]

- Employing a photoionization detector (PID) or other real-time in-field device, capable of detecting parts per billion by volume (ppbv) levels, to directly survey suspected locations of soil gas entry (e.g., utility penetrations, sumps) and finding elevated readings of vapors.

- Conducting a visual inspection for cracks and holes in concrete foundation slabs, basement walls, or any floor drain(s). (Openings for soil gas entry will not necessarily be visible or accessible for inspection, so the absence of visible openings, by itself, is insufficient to demonstrate that a building is not susceptible to soil gas entry.)

- Monitoring pressure differences between the building and subsurface environment to characterize the 'driving force' for soil gas entry and the effects of the heating, ventilation, and air-conditioning (HVAC) systems.

- Injecting tracers into the subsurface at selected concentrations and subsequently finding it in indoor air samples.

Certain complementary information obtained for the building, as identified in Section 6.4.1, can also support such assessments. Relevant information includes the operating characteristics of HVAC systems.

In many commercial buildings, the HVAC system brings outdoor air into the building, potentially creating building over-pressurization relative to the outdoor environment. When the building is

---

[125] Because vapor intrusion and radon intrusion entail similar mechanisms for subsurface vapor migration and gas entry into buildings and structures (Section 2.3), naturally occurring radon may serve as a tracer to help identify those buildings that are more susceptible to soil gas entry than others. Buildings with radon concentrations greater than levels in ambient air are likely susceptible to soil gas intrusion and would likely be susceptible to intrusion of any chemical vapors in the subsurface. On the other hand, the radon concentration in a building is <u>not</u> generally expected to be a good <u>quantitative</u> indicator of indoor air exposure concentrations of vapor-forming chemicals arising from sub-surface contamination. Hence, radon measurement is not generally recommended as a proxy for directly measuring vapor-forming chemicals in indoor air. Among other factors, the distribution of radon-emanating rock and soil and the spatial and temporal variability of their source strength are generally expected to be very different (e.g., tending to be broader and more uniform) than the distribution and source strength variability for subsurface sources of chemical vapors.

[126] EPA (2011a) reports that "vinyl chloride, 1,1-dichoroethylene, cis-1,2-dichloroethylene, and 1,1-dichloroethane are rarely detected in background indoor air." DoN (2011a) also reports that vinyl chloride and cis-1,2-dichloroethylene "are rarely detected in background indoor air." When they are subsurface contaminants, volatile chemicals that are rarely or never present in indoor sources can be inferred to arise in indoor air via vapor intrusion "without further explanation" (DoN 2011a). Brenner (2010), for example, employed this principle (and cis-1,2-dichloroethylene) to identify buildings susceptible to vapor intrusion and to diagnose the relative contributions of vapor intrusion and infiltration to indoor air concentrations.

over-pressurized sufficiently to eliminate the driving force for soil gas entry over at least a portion of the building foundation, vapor intrusion potential is diminished.[127]

Reasonably expected future risks posed by subsurface contamination warrant consideration, in addition to risks posed under current conditions, "in order to demonstrate that a site does not present an unacceptable risk to human health and the environment" (EPA 1991a). For example, current building use and HVAC systems might not be sustained perpetually. Therefore, when the subsurface vapor source(s) underneath or near a building with an over-pressurizing HVAC system has(have) significant potential to pose a vapor intrusion threat, it may be useful to assess susceptibility to soil gas entry and diagnose vapor intrusion (also see Sections 6.3.4 and 6.4.1) in such buildings under conditions when the HVAC system is not operating. (In addition, indoor air testing could be conducted during periods when the HVAC system operates with diminished flows, such as weekends or evenings.) The results of such testing can be used to support determinations about whether the vapor intrusion pathway is "potentially complete" and is reasonably expected to pose unacceptable human health risk (see Section 7.4) in the future,[128] in which case a response action(s) may be warranted (see Section 7.7). For example, if the results indicate susceptibility to soil gas entry when the HVAC system is not in operation and vapor intrusion under these conditions has the potential to pose a health concern, then the building may warrant future monitoring (e.g., continuous monitoring of the pressure gradient across the foundation or indoor air testing) and/or engineered exposure controls, which may be enforceable through an institutional control (IC) (see Section 8.6).

Likewise, well-designed and operated radon mitigation systems generally should diminish vapor intrusion via soil gas entry under current conditions. Therefore, buildings with pre-existing radon mitigation systems, which overlie or are near subsurface vapor sources, could be tested under conditions where the radon mitigation system is temporarily not operated to support decisions about monitoring and ICs as part of a vapor intrusion remedy.[129]

6.3.4 Evaluate Presence and Concentration of Subsurface Contaminants in Indoor Air

Indoor air sampling (see Section 6.4.1) using time-integrated sampling methods or grab samples can confirm the presence, if any, of a site-related vapor-forming chemical (i.e., one comprising the subsurface vapor source(s)) in the indoor environment. When combined with data characterizing subsurface vapor migration and demonstrating the building is (or is not) susceptible to soil gas entry, indoor air sampling data can support determinations that the vapor intrusion pathway is (or is not) complete for a given building, as discussed further in Section 7.3. When conducted contemporaneously in multiple buildings, indoor air sampling can, in concert with soil gas survey data and data delineating subsurface vapor sources, help identify the boundaries of the land area(s) within which buildings are known or suspected to have indoor air concentrations of subsurface contaminants arising from vapor intrusion (also see Section 6.2.1).

---

[127] Over-pressurization may not be uniform throughout a building, particularly in large buildings. Over-pressurization in portions of a building will not necessarily mitigate all openings for soil gas entry.

[128] "Both current and reasonably likely future risks need to be considered in order to demonstrate that a site does not present an unacceptable risk to human health and the environment." (EPA 1991a).

[129] EPA recommends that state and local laws be researched before any such testing is conducted. Some areas have local ordinances governing operation and maintenance of radon mitigation systems.

Indoor air sampling is most commonly conducted using time-integrated sampling methods, when characterizing exposure concentrations for building occupants (see Section 6.4.1), which may include contributions from "indoor" or ambient air sources of these chemicals (see Section 2.7). For example, time-integrated concentrations of hazardous vapors in samples of indoor air can be compared to appropriate, risk-based screening criteria (see Section 6.5) to obtain some preliminary insights about the potential level of exposure and risk posed by vapor intrusion or can be used to support a human health risk assessment (Section 7.4) about vapor-forming chemicals found in the subsurface environment.[130]

When sampling indoor air (or sub-slab soil gas) to characterize exposure concentrations arising from vapor intrusion, EPA recommends removing potential indoor sources of vapor-forming chemicals (see Section 2.7 and 6.4.1) from the building to strive to ensure that the concentrations measured in the indoor air samples are attributable to the vapor intrusion pathway. However, even after removing indoor sources, their effects may linger depending on source strength, relative humidity in the building, the extent to which the contaminants have been absorbed by carpets and other fabrics or "sinks," and air exchange rate. In addition, field experience suggests that it may not be possible to remove all indoor sources. It may be particularly impractical to do so in industrial settings where vapor-forming materials are used or stored.

6.3.5 Identify and Evaluate Contributions from Indoor and Ambient Air Sources

As noted in Section 2.7 herein, indoor air is likely to contain detectable levels of a number of vapor-forming chemicals regardless of whether the building overlies a subsurface vapor source, because indoor air can be impacted by a variety of indoor and outdoor vapor sources unrelated to site contamination. The contribution of indoor and outdoor vapor sources (or both) to indoor air concentrations is referred to as "background" throughout this Technical Guide, when they do not arise from site-related contamination (see Glossary). Information on 'background' contributions of site-related, vapor-forming chemicals in indoor air is important to risk managers because generally EPA does not clean up to concentrations below natural or anthropogenic background levels (EPA 2002e).

To determine if a subsurface vapor source(s) is (or are) responsible for indoor air contamination, EPA recommends that such background sources of site-specific analytes be identified and distinguished from vapor-forming chemicals arising from vapor intrusion. A comprehensive investigation of all background substances found in the environment is usually not recommended. For example, sub-slab soil gas and ambient air samples typically would not be analyzed for radon for purposes of characterizing 'background' exposures *per se*, whereas EPA would recommend analyzing for radon if its precursor was part of a regulated release to the subsurface environment (EPA 2002e).[131] Generally, EPA recommends the site planning and

---

[130] In certain cases, depending in part on the results (e.g., concentrations exceed risk-based screening levels), indoor air sampling data may be a sufficient basis for supporting decisions to undertake pre-emptive mitigation/early action (see Sections 3.3 and 7.8) in lieu of additional rounds of sampling and analysis or an evaluation of the contribution of background sources to indoor air concentrations.

[131] Sub-slab soil gas and indoor air samples might also be analyzed for radon, where its precursor was not part of a release to the subsurface environment, for purposes of diagnosing vulnerability to soil gas entry (see, for example, Section 6.3.3), depending upon the objectives of the vapor intrusion investigation.

data evaluation team limit chemical analyses to those vapor-forming chemicals known (based upon subsurface contaminant characterization) or reasonably expected (based upon site history) to be present as a result of a release to the subsurface environment.

To support evaluations of sources of indoor air concentrations, EPA recommends conducting a building survey (see Section 6.4.1) that identifies in individual buildings known or suspected indoor sources of the vapor-forming chemicals also found in the subsurface (see Section 2.7) and characterizing ambient air quality (see Section 6.4.2) in the site vicinity for these same chemicals. Key supporting information includes: (1) the locations and types of known or potential indoor vapor sources; (2) information about outdoor vapor sources related to the site (e.g., locations of chemical storage, use, and/or release to the environment); (3) information about outdoor vapor sources un-related to the site, such as nearby commercial or industrial facilities and mobile sources (e.g., cars, trucks, and other equipment); and (4) data on the local ambient air quality.

Interviews of building occupants and inspections of buildings can be helpful initial sources of information about indoor uses and storage of vapor-forming consumer and commercial products.[132] In addition, vapor-detecting field instruments and in-field gas chromatographs[133] can be used to locate indoor vapor sources. Grab (essentially short-duration) samples of indoor air, as described in Section 6.4.1, can be useful for identifying specific vapor-forming chemicals emanating from indoor vapor sources of consumer or commercial products. When the objective is to quantitatively distinguish contributions to indoor air concentrations from vapor intrusion versus contributions from indoor and ambient air sources, as described below, EPA recommends obtaining indoor air concentrations using time-integrated sampling methods (see Section 6.4.1) instead of grab samples.

If the subsurface vapor source(s) is (or are) comprised of multiple vapor-forming chemicals and the subsurface source medium (e.g., soil, groundwater) and location are identical for these chemicals, then contemporaneous samples of sub-slab soil gas (see Section 6.4.3) and indoor air (see Section 6.4.1) can be compared, potentially supporting one of the following conclusions:

> Results indicating vapor intrusion as solely responsible for vapor concentrations in indoor air. The predominant vapor-forming chemicals in the sub-slab soil gas and their relative proportions in indoor air and sub-slab vapor samples would be expected to be similar, whereas their concentrations in sub-slab soil gas would be expected to be substantially higher than in indoor air,[134] if vapor intrusion is solely responsible for indoor air

---

[132] Information about the chemical composition of commonly encountered products is provided by the U.S. Navy (DoN 2011a, Appendix A) in its guidance for background analysis for the vapor intrusion pathway.

[133] Gorder and Dettenmaier (2011) reported on the use of a field-portable gas chromatograph and mass spectrometer to identify specific sources of vapor-forming chemicals and estimate their mass emission rate(s). EPA's Environmental Response Team has employed the Trace Atmospheric Gas Analyzer (TAGA) mobile laboratory for similar purposes.

[134] Based upon the generic sub-slab attenuation factor identified in Section 6.5.3 herein, sub-slab soil gas concentrations can be expected to typically exceed indoor air concentrations by 33 times or more in residences that are impacted by vapor intrusion (i.e., 33 is the inverse of an attenuation factor of 0.03), when background sources are negligible and the building is under-pressurized relative to the subsurface during indoor air sampling.

concentrations.[135] If recalcitrant (i.e., not subject to biodegradation in the vadose zone), the predominant vapor-forming chemicals and their relative proportions in the subsurface vapor source would likewise tend to be similar to those in indoor air if vapor intrusion is solely responsible for indoor air concentrations.[136]

Results indicating indoor vapor sources as primarily responsible for indoor air concentrations. If a vapor-forming chemical is present with an elevated concentration in indoor air, but is not present or is negligibly present in sub-slab soil gas samples (or representative samples of the subsurface vapor source), then the presence of this contaminant in indoor air may not arise from the vapor intrusion pathway, but rather from indoor sources or other background sources (e.g., ambient air). In these circumstances, EPA recommends considering additional attempts to identify and temporarily eliminate indoor sources, where practical, and re-sample indoor air and sub-slab soil gas after doing so.

Likewise, outdoor (ambient) air samples can be collected (see Section 6.4.2) contemporaneously with indoor air (see Section 6.4.1) and sub-slab soil gas (see Section 6.4.3) samples, as recommended in Section 6.4.

Results indicating outdoor vapor sources as primarily responsible for indoor air concentrations. If a vapor-forming chemical(s) is(are) detected in outdoor air and indoor air at similar concentrations, but is(are) not present in sub-slab soil gas samples (or representative samples of the subsurface vapor source) or is present in the subsurface samples at concentration(s) similar to indoor air),[137] then the presence of this contaminant(s) in indoor air may not arise from the vapor intrusion pathway, but rather from outdoor sources (i.e., ambient air).

Concentrations of vapor-forming chemicals in indoor air, sub-slab soil gas, and ambient air can be compared, as described above, using an individual time-integrated sample for each medium. Recognizing that weather conditions and building operations can lead to variable contributions from vapor intrusion and ambient air infiltration over time, EPA recommends, however, that such

---

[135] Conversely, if there is an interior source of a vapor-forming chemical in indoor air samples, the relative proportion of this chemical in indoor air will be greater than its respective proportion in the sub-slab soil gas, even where vapor intrusion is occurring, assuming that the other vapor-forming chemicals in the sub-slab soil gas do not have 'background' sources.

[136] Conversely, if there is an interior source of a vapor-forming chemical in indoor air samples, the relative proportion of this chemical in indoor air will be greater than its respective proportion in the subsurface vapor source or in "near-source" soil gas samples (see Section 6.3.1), even where vapor intrusion is occurring, assuming that the other vapor-forming chemicals in the sub-surface do not have 'background' sources.

[137] Sample concentrations of vapor-forming chemicals in indoor air and sub-slab soil gas can be compared to conservative, risk-based screening levels to provide a complementary line of evidence. Generally, vapor-forming chemicals with concentrations that consistently fall below screening levels (see Section 6.5) through multiple sampling events (see Section 6.4) warrant no further action or study, so long as the exposure assumptions match those taken into account by the calculations and the site fulfills the conditions and assumptions of the generic conceptual model underlying the screening levels (see Section 6.5.2).

comparisons be made for multiple sets of paired samples, collected in different seasons,[138] to support any conclusion that vapor intrusion is not a significant contributor to indoor air concentrations, which can instead be attributed to indoor and outdoor sources unrelated to the subject site. Even with a few sets of such samples, rigorous statistical tests may not be feasible. Nevertheless, comparing contemporaneously measured concentrations and proportions of vapor-forming chemicals in indoor air, subsurface media, and ambient air can be effective for this investigation objective, particularly when one (or more) of the analytes is known to be present only in the subsurface or in ambient air.

The following hypothetical example illustrates how site-specific sampling data might inform conclusions about the relative contributions of indoor versus subsurface vapor sources in a building overlying contaminated groundwater:

> *Example: Time-integrated samples of indoor air, outdoor air, and subslab soil gas were collected contemporaneously for a building that overlies shallow groundwater that is contaminated with a suite of vapor-forming chemicals (designated as VFCA, VFCB, VFCC, and VFCD). The sampling results are summarized as follows:*

Vapor-forming Chemical in Groundwater	***Time-weighted Sample Concentrations (µg/m^3)***			***Ratio of Subslab Concentration to Indoor Air Concentration***
	Subslab Soil Gas	***Indoor Air***	***Outdoor Air***	
VFCA	*1*	*0.65*	*0.75*	*3*
VFCB	*33,000*	*26*	*0.18*	*1,300*
VFCC	*5,200*	*5.8*	*0.14*	*900*
VFCD	*15,000*	*15*	*0.51*	*1,000*

> *Based upon the conceptual site model, the presence of these vapor-forming chemicals in outdoor (ambient) air is believed to be due to anthropogenic sources that are not associated with the environmental release responsible for the subsurface contamination. The building is presumed to be susceptible to vapor intrusion, as indicated by pressure monitoring data that indicate building under-pressurization, relative to the subsurface environment, during the sampling event (as discussed further in Section 6.4.1).*
>
> *Based upon these findings, the presence of VFCB, VFCC, and VFCD in indoor air appears to be solely or primarily attributable to vapor intrusion. The relative proportions*

---

[138] A goal of collecting multiple samples is to observe and characterize a reasonable maximum vapor intrusion condition for the respective building. Because weather conditions and building operations can lead to time-variable contributions from vapor intrusion (e.g., driving forces for vapor intrusion; see Section 2.3) and ambient air infiltration (see Sections 2.4), indoor air concentrations of vapor-forming chemicals can be expected to vary over time. An individual sample, collected at a randomly chosen time, may under-estimate or over-estimate average and reasonable maximum exposure conditions (see Section 6.4.1) to different degrees, depending upon the season of sample collection and other factors.

> *of these subsurface contaminants in indoor air and sub-slab vapor samples are similar, as indicated by a similar ratio of subslab to indoor air concentration, considering analytical uncertainty. In addition, their indoor air concentrations exceed those found in the paired sample of ambient air.*
>
> *By contrast, the presence of VFCA in indoor air may be entirely attributable to infiltration of ambient air, as the sample concentrations in indoor air and outdoor are similar, considering analytical uncertainty.*
>
> *Recommended next steps in the investigation might include a human health risk assessment (see Section 7.4) and a review of the conceptual site model (see Section 5.4) to evaluate whether the different conclusion for VFCA can be reasonably explained (e.g., by vapor attenuation in the vadose zone that is expected to be substantially greater than for VFCB, VFCC, and VFCD).*

EPA has compiled and published an evaluation of studies pertaining to indoor air concentrations of volatile organic compounds in North American residences in 1990-2005 (EPA 2011a), which can be employed to identify whether measured indoor air concentrations in residences exceed the historical range of background concentrations. Specifically, if measured indoor air concentrations are found to greatly exceed the historical range of background levels, there is a greater likelihood that the indoor air concentrations are the result of vapor intrusion. This conclusion is supported by the expectation that current levels of vapor-forming chemicals in ambient air and in indoor air due to indoor and ambient air sources are likely to be lower than those observed historically,[139] due to regulations and business practices fostering less use of toxic chemicals in consumer products and industrial processes and reduced emissions from mobile and stationary sources. As a result of this expectation, EPA does not recommend the use of generic values of historical background concentrations, even those cited in peer-reviewed publications or available from databases maintained by regulatory agencies, to characterize current levels in any building, for purposes of supporting conclusions that indoor air concentrations are due to ‘background’ sources. Rather, EPA recommends that site-specific data (e.g., sub-slab, indoor air and ambient air sampling data) be obtained (as described in Sections 6.4.1, 6.4.2, and 6.4.3), and evaluated, as described above, when the investigation objectives include determining whether indoor air concentrations arise from indoor or ambient air sources.

The following additional approaches for identifying and characterizing ‘background’ sources may warrant consideration in special situations:

- McHugh et al. (2012) have demonstrated the principle that building over-pressurization can be employed temporarily to minimize vapor intrusion and facilitate measuring indoor

---

[139] McCarthy et al. (2007), for example, analyzed ambient air data for 25 toxic substances collected in the United States from 1990 through 2005 and found that concentrations of many halogenated volatile organic compounds were declining at most sites and evaluation periods (i.e., 1990-2005, 1995-2005, and 2000-2005). They found that concentrations of petroleum hydrocarbons, such as benzene, associated with mobile sources were all consistently decreasing over the three evaluation periods at most sites.

air concentrations under conditions where only indoor sources may be contributing.[140] At this time, however, there are no standard practices for using over-pressurization to assess 'background' contributions, which is a research and development need (SERDP-ESTCP 2014).

- Forensic and multi-variate statistical methods have been described and illustrated by the U.S. Navy (DoN 2011a) in its guidance for background analysis for the vapor intrusion pathway.

6.3.6 Select, Prioritize, and Sequence Investigation Objectives

Site-specific investigations of potential vapor intrusion frequently begin with pursuing one or more of the objectives presented in Sections 6.3.1 through 6.3.5. Criteria potentially warranting consideration by the site planning team when making decisions about prioritizing and sequencing investigation objectives include, but are not limited to: site scenario (see Section 6.1); building occupants who may be particularly sensitive to the potentially toxic effects of vapors; buildings that are more susceptible to soil gas entry (e.g., buildings with deteriorating basements or dirt floors; whether there are any significant data gaps in the CSM (see Section 5.4); and relationships with and perspectives of the owners and occupants of potentially impacted buildings.

Characterizing subsurface vapor sources (Section 6.3.1), characterizing subsurface vapor migration (Section 6.3.2), and evaluating the presence of subsurface contaminants in indoor air (Section 6.3.4) – are frequently candidates for an initial objective and each can be pursued separately. For example, characterizing subsurface vapor sources (Section 6.3.1) may be a useful initial choice when responding to an initial report about a release of hazardous, vapor-forming chemicals to the subsurface from a commercial or industrial operation or when buildings do not exist currently, but are expected in the future. Characterizing subsurface vapor sources may also be a useful initial choice when building owners or occupants are reluctant to grant access for indoor air testing. In this situation, the site planning team may need to pursue subsurface investigations more intensely to characterize vapor intrusion potential before being granted building access. On the other hand, testing indoor air is recommended as an initial objective when responding to reports of odors in buildings or clusters of inhalation-related symptoms and there is credible information to suggest that a subsurface environmental release may be a contributing factor (see Section 5.2).

In a different scenario, characterizing subsurface vapor migration (Section 6.3.2) may be a useful starting point when addressing sources that are comprised of potentially biodegradable chemicals or that are suspected to occur below an extensive geologic layer that might impede upward diffusive migration. For large buildings with HVAC systems that may over-pressurize the interior relative to the subsurface environment, EPA generally recommends: a building assessment early in the investigation, which obtains and weighs the complementary information

---

[140] Indoor air concentrations measured after sufficient periods of over-pressurization may be indicative of 'background' levels, whereas indoor air concentrations detected before and after a sufficient period of "rebound" from temporary over-pressurization may be indicative of joint contributions from 'background' sources and any vapor intrusion from the subsurface.

identified in Section 6.4.1, to support investigation planning; and an evaluation of susceptibility to soil gas entry under conditions when the HVAC system is not operating (see Section 6.3.3).

Each of the investigation objectives described in Sections 6.3.1 through 6.3.5 may, in some cases, be conducted iteratively with increasing complexity as the investigation proceeds and the CSM is refined. For example, field instruments can be useful for locating potential background sources (e.g., household or commercial cleaning products) (see Section 6.3.5) and grab (essentially short-duration) samples of indoor air, as described in Section 6.4.1, can be useful for characterizing the chemical composition of identified indoor sources of vapors during an initial building reconnaissance while potential background sources are surveyed. These activities might be followed by indoor air and sub-slab soil gas sampling, using time-integrated sampling methods as described in Section 6.4.1 and 6.4.2, to distinguish subsurface contributions from indoor sources. More advanced methods of distinguishing the various potential contributions to indoor air might be utilized, if warranted, in intermediate phases of the investigation under such an iterative approach.

6.4 General Principles and Recommendations for Sampling

Sampling of indoor air, outdoor air, soil gas, and groundwater and analysis for vapor-forming chemicals can play an important role in vapor intrusion investigations for one or more of the objectives identified in Section 6.3. This subsection summarizes for indoor air, outdoor air, sub-slab soil gas, exterior soil gas, and groundwater the following:

- Principal methods for collecting samples.
- Potential uses of the resulting sampling data.
- Recommended practices for sample collection.
- Unique or frequently encountered logistical issues.

We would note that soil and NAPL sampling has been and may be used to characterize the nature (e.g., chemical composition) and general location of subsurface vapor sources (see Section 6.3.1). Information about soil sampling can be found in *Standard Operating Procedures, Soil Sampling* (EPA-ERT 2001b). However, bulk soil (as opposed to soil gas) sampling and analysis is not currently recommended for estimating the potential for vapor intrusion to pose unacceptable human health risk in indoor air, because of the potential for vapor loss due to volatilization during soil sampling, preservation, and chemical analysis. In addition, there are uncertainties associated with soil partitioning calculations.

To ensure that the sampling data will meet the site-specific data quality needs, EPA recommends that the sampling and analytical methods selected by the site planning team be capable of obtaining reliable analytical detections of concentrations less than project-appropriate, risk-based screening levels (e.g., VISLs). Towards that end, EPA recommends that, as part of establishing site-specific data quality objectives (DQOs), the planning and data collection team(s) consult with a laboratory skilled in the analysis of air and soil gas samples and choose sampling and analytical methods capable of routinely attaining the desired detection sensitivity for each medium.

EPA also recommends that the site planning team identify and utilize appropriate sampling locations and durations and address spatial and temporal variability to fulfill the specific objectives of the investigation, which may include obtaining data to characterize the potential human exposure in a building(s). EPA recommends the CSM, the objective(s) of the investigation, and other site-specific information be considered in determining the number and types of samples used at a specific site.

The sampling duration depends on the type of medium being sampled (for example, soil gas, sub-slab soil gas, and indoor or outdoor air) and analytical methods (for example, Method TO-15). Some of the key recommended considerations are provided in the following subsections. Several rounds of sampling are recommended to develop an understanding of temporal variability[141] to ensure that final risk management decisions are based upon a consideration of a reasonable maximum vapor intrusion condition.[142]

6.4.1 Indoor Air Sampling

Indoor air sampling results are used to assess the presence of and level of human health risk posed by vapor-forming chemicals in indoor air (see Sections 6.3.4 and 7.4), and to diagnose whether vapor intrusion is occurring (see Sections 6.3.3, 6.3.5, and 7.3). These two uses of indoor air sampling in vapor intrusion investigations are discussed further below with recommended methods for each. As discussed further in Sections 8.4 and 8.7, indoor air sampling may also be useful for supporting performance evaluations of vapor intrusion mitigation systems and verifying the health protectiveness of subsurface remediation systems.

EPA recommends that the decision to collect indoor air data be supported by lines of site- or building-specific evidence (e.g., characterization of subsurface vapor source(s) strength and proximity to building(s), vadose zone conditions, and building conditions) that demonstrate that vapor intrusion has the potential to pose a significant human exposure. Confidence in the assessment is expected to be higher when multiple lines of site- or building-specific evidence, in addition to indoor air data, come together to provide mutually supporting evidence for a common understanding of the site conditions/scenarios and the potential for vapor intrusion (i.e., the various lines of evidence are in agreement with each other).

A potential shortcoming of indoor air testing is that indoor sources and outdoor sources unrelated to subsurface contamination and to releases from the subject site – “background” (see Glossary) – may contribute to the presence of volatile chemicals in occupied buildings (see Section 2.7), particularly if these sources cannot be removed from the building prior to and throughout the duration of sampling indoors. This shortcoming of indoor air testing is

---

[141] Seasonally variable conditions (e.g., moisture levels, depth to groundwater) can lead to seasonally variable concentrations and distributions of vapors n the vadose zone. Likewise, weather conditions and building operations can lead to time-variable contributions from vapor intrusion (e.g., driving forces for vapor intrusion; see Section 2.3) and ambient air infiltration (see Sections 2.4). Collectively, these processes cause indoor air concentrations of vapor-forming chemicals to vary over time (see Section 2.6). An individual sample (or single round of sampling) would be insufficient to characterize seasonal variability, or variability at any other time scale.

[142] EPA recommends basing the decision about whether to undertake response action for vapor intrusion (i.e., a component of risk management; see Section 7.4) on a consideration of a reasonable maximum exposure (e.g., EPA 1989, 1991a), which is intended to be a semi-quantitative phrase, referring to the lower portion of the high end of the exposure distribution (see Glossary).

unavoidable when the subsurface environment contains the very same volatile chemicals that contemporaneously arise in indoor air due to background sources, which is common for some chemicals and relatively rare for others (EPA 2011a). In this circumstance, additional lines of evidence, possibly including special procedures and analyses, may warrant evaluation to distinguish background contributions from those originating from vapor intrusion (see Section 6.3.5).

After discussing recommended sampling methods and practices for the primary uses of indoor air sampling data, this sub-section concludes by discussing:

- Recommended measures to reduce the impact of indoor sources of vapor-forming chemicals.
- Recommended approach to establishing analyte lists for indoor air samples.
- Complementary, building-specific data (i.e., additional lines of evidence) that can be collected contemporaneously while indoors.

Characterize Human Exposure Levels. Indoor air sampling and analysis provide a direct approach to obtaining concentrations of vapor-forming chemicals in indoor air to which building occupants can be exposed. For this purpose, EPA generally recommends time-integrated sampling methods, since indoor air concentrations can be temporally variable[143] and time-integrated exposure estimates over appropriate exposure durations (e.g., chronic typically; less-than-chronic in some cases) are generally most useful for assessing human exposure and human health risk (see Section 7.4).

Because of variability, a single indoor air sample, collected at a randomly chosen time, is insufficient information to estimate an average exposure. On the other hand, it is impractical to collect indoor air samples continuously over a chronic exposure period (i.e., up to 30 years for a reasonable maximum exposure duration in a residence (EPA 2014a)), which would also entail deferring risk management decisions for a prolonged period while human exposures from vapor intrusion could occur unabated. Hence, current and past practice has generally relied upon collecting multiple indoor air samples for purposes of estimating long-term average (i.e., chronic) exposures and assessing human health risk (see Section 7.4). All else being equal, a longer collection period for each individual sample would be expected to yield a more reliable basis for estimating long-term, time-average exposure than would a one-day sample collection period.

When investigating short-term exposure conditions that might warrant prompt response action to protect human health (see, for example, Sections 5.2 and 7.5.2), time-integrated indoor air samples can provide useful estimates of exposure for the location and time period of sample collection. (A short-term exposure is defined as a “repeated exposure for more than 24 hours,

---

[143] Because weather conditions and building operations can lead to time-variable contributions from vapor intrusion (e.g., driving forces for vapor intrusion; see Section 2.3) and ambient air infiltration (see Sections 2.4), indoor air concentrations of vapor-forming chemicals can be expected to vary over time (see Section 2.6). Field observations indicate that indoor air concentrations arising from vapor intrusion can be temporally variable within a day and between days and seasons in an individual residential building (EPA 2012f; Holton et al., 2013ab).

up to 30 days" – see Glossary.) All else being equal, a longer collection period for an individual sample would be expected to yield a more reliable basis for estimating time-average short-term exposure than a one-day sample.

As noted above, EPA also recommends considering potential health effects and relevant exposure periods for site-related, vapor-forming chemicals when developing DQOs and sampling plans for indoor air.

Variability in laboratory analyses can be considered when evaluating these data in support of risk management decisions.[144]

Time-integrated samples provide a direct measurement of the average chemical concentration over a fixed period of time (e.g., ranging from 8 hours to several weeks, depending upon the sampling method, its capabilities, and its deployment). Time-integrated samples can be collected using either evacuated canisters, which collect gas in a container, or sorbent samplers, which collect vapor-forming chemicals on a sorbent material.

Evacuated canisters

Evacuated canisters are spherical- or cylindrical-shaped stainless steel or silica-lined containers that are prepared to be under negative pressure relative to the environment and certified by the laboratory to be clean and leak-free.[145] As described in EPA Method TO-14A (EPA 1999c), evacuated canisters can be used as passive (sub-atmospheric pressure sampling) or active (pressurized sampling) samplers. In both cases, the canister is initially evacuated to a standard vacuum in preparation for sampling. For sub-atmospheric sampling, when the canister is opened for sample collection, the differential pressure causes air to flow into the canister without use of a pump. In this case, sampling must end before the vacuum is fully dissipated, else the sample collection period will be unknown. For pressurized sampling, a pump is used to pass air into the canister until a specified pressure (up to two atmospheres) is reached. In both cases, a flow-control device is used to maintain a constant flow into the canister over the desired sample period. To ensure that the canisters are filling at the proper rate, EPA recommends checking the flow rate periodically during sample collection. EPA Methods TO-14A and TO-15 provide further information on measuring and controlling flow rates into canister-type samplers.

---

[144] For a recently published study, EPA's ORD determined "The acceptance criterion to demonstrate equivalency is ±30% … based on what is defined as acceptable reproducibility in vapor intrusion field studies" (EPA 2012f).

[145] Canisters are cleaned and re-used because they are too expensive to dispose routinely. The certification process entails cleaning the interior of the container using a combination of dilution, heat, and high vacuum. Canisters are then analyzed for a large suite of vapor-forming chemicals to establish that they are free of detectable chemicals at a suitably low (sensitive) detection level. The cleanliness of canisters can be certified individually (i.e., direct testing of each canister, or 100% certification), which is generally desirable in instances where the data are to be used for exposure/risk assessment purposes. Alternatively, canisters can be certified by batch (or lot), in which a subset of the canisters are tested directly (e.g., 10%) and results are extrapolated to the remainder of the batch. Batch-certified canisters may be sufficient when concentrations of target analytes are expected to be high, relative to potential levels of residual contamination in the canister after cleaning. EPA recommends that flow controllers also be cleaned between uses to avoid artificial contamination.

Typically, for vapor intrusion investigations, indoor air samples are collected using six-liter canisters using sub-atmospheric pressure sampling over a 24-hour period in residences or over an 8-hour period (or workday equivalent) in commercial and industrial settings, when using these devices. Larger canisters (i.e., 15-liter) allow higher flow rates and may be preferable for longer sampling events or to collect a larger volume of sample.[146] A capillary flow controller has been developed and demonstrated for use in industrial hygiene applications (Rossner et al. 2002; Rossner and Wick 2005), which may hold promise for extending sampling time periods for indoor air with standard-sized canisters.

Details for selecting and utilizing sampling canisters are provided in EPA Methods TO-14A (EPA 1999c) and TO-15 (EPA 1999d). EPA's Environmental Response Team has developed a standard operating procedure for sampling air with evacuated canisters (EPA-ERT 1995).

An advantage of using evacuated canisters for sample collection is the capability of analyzing multiple sub-samples from the same canister (because these canisters obtain a "whole air" sample). They are also reasonably easy to deploy and retrieve. However, sample recovery and representativeness can be affected by ambient conditions; for example, low humidity conditions in the sample may lead to losses of certain volatile compounds on the canister walls (EPA 1999c).

Fourteen days is the most commonly cited hold time for air samples in canisters. Some analytes, however, may be stable in canisters for up to 30 days.

Sorbent Samplers

Sorbent sampling devices are hollow containers that hold one or more adsorbent media that can bind vapor-forming chemicals. They have been developed and tested over several decades for industrial hygiene monitoring and have more recently been employed for other purposes, including vapor intrusion investigations. Sorbent samplers can be used in an active or passive mode.

In the active mode, a pump is used to draw air at a known rate through the device. The flow rate and sampling volume are determined based on the type of sorbent used, the target constituent(s), and the amount of sorbent contained in the device. Care must be taken to ensure that the volume of air drawn through the tube does not exceed the "breakthrough" volume[147] (i.e., the volume of air which may be passed through the sorbent tube before a detectable level of the analyte concentration elutes from the non-sampling end), else the time-weighted average concentration will be biased low by an unknown amount.

In the passive mode, no pump is used, and vapor-forming chemicals enter the device due to diffusion. Consequently, passive (diffusion) samplers may be placed in locations of interest without consideration of power availability.

---

[146] Alternatively, two (or more) large canisters can be connected together to allow collection of time-integrated samples over longer durations, which is generally desirable for characterizing long-term average exposure levels.

[147] For this reason, sample volumes in the one- to four-liter range are generally recommended for this method (EPA 1999e).

Although passive (diffusion) samplers have been less commonly used to quantify indoor air concentrations, their use may grow as a result of recent demonstrations that they can yield results comparable to those obtained using evacuated canisters (EPA-Region 9 2010; EPA 2012f; Odencrantz et al. 2009; Odencrantz et al. 2008),[148] and a recognition that they may be less intrusive for some building owners and occupants and more convenient for field staff (EPA-Region 9 2010). Passive samplers are also capable of being deployed for longer durations than evacuated canisters, thereby providing a more economic means of obtaining average indoor air concentrations over longer periods of exposure. Time-integrated samples of indoor air over longer periods than one day are also indicated by field observations demonstrating that indoor air concentrations arising from vapor intrusion can be temporally variable within a day and between days and seasons (EPA 2012f; Holton et al., 2013a).

The basic configuration of a passive sampler is a solid, typically granular, sorbent contained in a metal, glass of plastic container with openings of known dimensions. Several different containers and a wide range of adsorptive media are commercially available, which function similarly. After sample collection, adsorbed mass is measured in a laboratory for each analyte; the two most common analytical methods involve thermal desorption or solvent extraction combined with gas chromatography/mass spectrometry. The air concentration for each analyte is calculated from the adsorbed mass, the duration of sampling, and the uptake rate.

The uptake rate is dependent upon the geometry of the sampling device and the diffusion coefficient of the analyte. The uptake rate is the most critical variable for accurately measuring air concentrations with passive samplers, since the sampling duration and adsorbed mass can generally be measured very accurately. Fortunately, most commercially available passive samplers have published uptake rates for several compounds, which collectively address many of the vapor-forming chemicals described in Section 3.1.[149] Once the target analyte(s) and uptake rate(s) are known, the sample duration needed to attain data quality objectives (i.e., reporting limit equal to or lower than the risk-based screening level or risk-based action level) can be calculated for each analyte.

Uptake rates of deployed samplers can be affected by ambient conditions (e.g., temperature, because chemical-specific diffusion rates are temperature-dependent; and humidity, which influences the uptake of water vapor, which may interfere with retention and stability of the analyte and/or with laboratory analysis). EPA, therefore, recommends that ambient conditions be recorded during deployment of passive samplers.

One potential advantage of passive samplers is that they can be left unattended for relatively longer durations, thereby conveniently providing estimates of longer-term time-

---

[148] For example, EPA's National Exposure Research Laboratory found that Radiello™ charcoal passive samplers performed well for sampling periods up to 28 days for TCE (EPA 2012f). In that study, one-week (7-day) Radiello™ passive samplers were utilized as a primary measurement tool and the resulting data were used as a basis of comparison to longer-duration samples (e.g., two-week, four-week (monthly), and 13-week (quarterly) samples).

[149] Standard methods for determining uptake rates have been published by a few organizations. Ideally, the selected passive sampling device will have vendor-supplied uptake rates supported by controlled chamber tests or a considerable body of field-calibrated uptake rates for most, if not all, of the target compounds.

weighted average concentrations. However, similar to active sorbent sampling, the duration of passive sampling must be such that the adsorptive capacity of the media is not approached or exceeded, else the time-weighted average concentration will be biased low by an unknown amount.

One potential disadvantage of sorbent sampling, compared to canister sampling, is that only one analysis is possible from an individual device, because it does not collect a "whole air" sample. Thus, if an error occurs in laboratory handling or there is an instrument malfunction, the sample is lost. Such errors generally are not common. Therefore, this potential disadvantage will not generally offset the benefits of sorbent sampling, the foremost of which is the ability to obtain time-integrated samples over longer periods (i.e., up to a few months for some compounds) than with evacuated canisters.

For a typical-size residential building or a commercial building less than 1,500 square feet, EPA recommends that the site teams generally collect one time-integrated sample in the area directly above the foundation floor (basement or crawl space) and one from the first floor living or occupied area, at least for the initial sampling round.[150] In general, EPA recommends samples be collected at the breathing zone level for the most sensitive exposed population.[151]

EPA recommends the site planning and data evaluation team discuss the number of sample locations per building for atypical situations, which include: (1) very large homes or buildings;[152] (2) multi-use buildings, particularly ones with segmented areas that are occupied by different populations (e.g., day care with young children versus office with adult workers) or have different occupancy patterns over time. Additional samples may also be warranted, depending on internal building partitions, HVAC layout, contaminant distribution in the subsurface, and occurrence of observable locations of potential soil gas entry (e.g., basement sumps or drains, relatively large holes or spaces in the foundation floor, entry points for utilities). Closed rooms located below ground may have appreciably higher contaminant concentrations originating from vapor intrusion. Closed rooms may warrant sampling to characterize the reasonably maximum exposure levels, if occupied, or to diagnose vapor intrusion (e.g., see below), even if not occupied.

---

[150] Placement of indoor air sampling devices may entail compromises. Whereas the ideal location may be a central location that is unobstructed and representative of the actual used area of a room, placement at breathing zone height in a heavily used area well away from any wall is likely to interfere with normal occupant activities.

[151] The "most sensitive" exposed population may be identifiable by combining information about the types of human occupants in a given building and the types of potential toxic effects for vapor-forming chemicals found in the subsurface environment. For example, the 'most sensitive' exposed population could be children, pregnant women, or elderly adults, depending upon building- and chemical-specific characteristics.

[152] Larger commercial and residential buildings (e.g., multi-family residences) may warrant additional discussion with the site planning team and perhaps a statistician to select the appropriate number and placement of indoor air samples to meet DQOs.

Indoor air concentrations vary over time, due to time-dependent changes in soil gas entry rates, exchange rates, intra-building mixing, among other factors (see Section 2).[153] Therefore, multiple rounds (and often several rounds) of indoor air sampling is generally recommended in order to reduce the chance of reaching a false-negative conclusion (i.e., concluding exposure is at an acceptable risk level when it is not) or reaching a false-positive conclusion (i.e., concluding exposure is at an unacceptable risk level when it is not).[154] Also, multiple sampling events generally are considered necessary to account for seasonal variations in climate and the habits of building occupants and ensure that related risk management decisions are based upon a consideration of a reasonable maximum vapor intrusion condition.[155] In many geographic areas in the continental United States, indoor air sampling during the heating season may yield higher indoor air concentrations than at other periods, because stack effects are generally more significant and, therefore, higher rates of soil gas entry are reasonably expected. Another scenario that may yield higher indoor air concentrations is when a building is sealed and the ventilation system is not operating.

When sampling indoor air (or sub-slab soil gas), EPA generally recommends removing potential indoor sources of vapor-forming chemicals (see Section 2.7) from the building to strive to ensure that the concentrations measured in the indoor air samples are attributable to the vapor intrusion pathway.[156] After removal of indoor sources, their effects may linger longer depending on source strength, relative humidity inside the building, the extent to which the contaminants have been absorbed by carpets and other fabrics or “sinks,” and air exchange rate of the building. In residential settings, EPA generally recommends that potential indoor sources be removed from the structure and stored in a secure location at least 24 to 72 hours prior to the start of sampling, based on an approximate air exchange rate of 0.25 to 1.0 per hour in

---

[153] Because weather conditions and building operations can lead to time-variable contributions from vapor intrusion (e.g., driving forces for vapor intrusion; see Section 2.3) and ambient air infiltration (see Sections 2.4), indoor air concentrations of vapor-forming chemicals can be expected to vary over time. Holton et al. (2013ab) obtained and reported a set of long-term, high-frequency, indoor air data for an unoccupied house (except for periodic visits by researchers) in Utah overlying a plume of chlorinated hydrocarbons. TCE concentrations in indoor air varied by approximately two to three orders of magnitude, exceeding variations in measured air exchange rate.

[154] An individual sample, collected at a randomly chosen time, may under-estimate average and reasonable maximum exposure conditions. From their high-frequency, measured data, Holton et al. formulated a synthetic data set (simulating one-day-average concentrations), which they used to estimate that a single, randomly drawn, one-day sample had a forty percent chance of being less than the true mean (Holton et al. 2013b; see Table 1 therein). When the true mean was assumed to exceed the risk-based action level (“target concentration” in their parlance) by two or five times, they estimated that a single, randomly drawn, one-day sample had a twenty percent or six percent chance, respectively, of not detecting the exceedance. These data support EPA’s recommendation to collect multiple rounds of indoor air sampling to reduce the chance of reaching a false-negative conclusion. Collecting multiple rounds of indoor air sampling can also reduce the chance of reaching a false-positive conclusion (i.e., concluding that vapor intrusion poses unacceptable human health risk when it does not), because an individual sample, collected at a randomly chosen time, may over-estimate the average exposure condition.

[155] Given EPA’s over-arching duty to protect human health and recognizing the disruption to building owners and occupants caused by indoor air sampling, risk managers may choose to pursue pre-emptive mitigation (i.e., early action) at some buildings (see Sections 3.3 and 7.8) rather than, for example, conduct multiple rounds of sampling over a few years to establish an estimate of long-term average exposure concentration and characterize temporal variability.

[156] Vapor-detecting field instruments and in-field gas chromatographs can be used to locate indoor sources of vapors. For example, Gorder and Dettenmaier (2011) reported on the use of a field-portable gas chromatograph and mass spectrometer to identify specific sources of vapor-forming chemicals. EPA’s Environmental Response Team has employed the Trace Atmospheric Gas Analyzer (TAGA) mobile laboratory for similar purposes.

residential buildings. In residences with attached garages, keeping the door(s) between the garage and the living space closed prior to and during indoor air sampling may also be warranted, in situations where the site-specific chemicals of potential concern include petroleum hydrocarbons or are components of products stored in the garage.

Diagnose Vapor Intrusion and Background Sources. When access is granted for indoor air sampling, EPA generally recommends concurrently collecting samples of sub-slab soil gas (see Section 6.4.3) and outdoor (ambient) air (see Section 6.4.4) over similar durations using the same methods. Comparing these results to each other and to results for subsurface vapor sources can foster insights and support findings about the relative contribution of vapor intrusion and background sources to indoor air concentrations (as described in Section 6.3.5). In this case, time-integrated sampling methods are recommended for indoor air, because concentrations of vapor-forming chemicals can vary significantly over time (see Section 2.6).

Grab (essentially short-duration) samples can, however, be useful for:

- confirming the presence of a subsurface contaminant in indoor air[157] (see Section 6.3.4) or in gas in a drain line or sewer lateral that enters a building,
- identifying specific vapor-forming chemicals emanating from indoor sources of consumer or commercial products[158] (see Section 6.3.5), and
- identifying specific vapor-forming chemicals emanating from suspected openings for soil gas entry into buildings (see Section 6.3.3).

Grab samples can provide a convenient and less intrusive means of confirming the presence, if any, of a site-related subsurface contaminant(s) in the indoor environment. However, an individual grab sample is not reliable for purposes of demonstrating that vapor intrusion is not occurring in a specific building; among other considerations, vapor intrusion and indoor air concentrations can exhibit significant temporal variability (EPA 2012f, Holton et al., 2013ab). Consequently, EPA recommends collecting multiple time-integrated samples to support any such building-specific determination.

Indoor air samples can also be concurrently collected for radon testing, which may be useful in evaluating building susceptibility to soil gas entry (see Section 6.3.3).

Evaluate and Develop Analyte Lists. EPA recommends the site planning and data evaluation team generally limit chemical analyses to those vapor-forming chemicals known (based upon subsurface contaminant characterization) or reasonably expected (based upon site history) to be present in the subsurface environment. For example, if the site history and reliable subsurface sampling data do not identify benzene as a subsurface contaminant, it would be appropriate for site managers to exclude benzene as a target analyte for indoor air samples. Benzene could originate indoors as a result of a car, lawnmower, or snow blower in a garage. In

---

[157] For this purpose, EPA generally recommends collecting one sample directly above the foundation floor (e.g., basement or crawl space) and one from the first floor living or occupied area.

[158] For characterizing indoor sources or openings for soil gas entry, one round of grab sampling of indoor air may be sufficient.

this hypothetical case, benzene would not typically be amenable to reduction by vapor mitigation systems or subsurface remediation efforts. In fact, requesting an extensive list of analytes that are not related to subsurface contamination may unnecessarily complicate risk communication if indoor air testing reveals volatile chemicals unrelated to vapor intrusion.

Collect Complementary Data While Indoors. A variety of useful information can be gathered during a building survey conducted in advance of or during indoor air sampling. EPA recommends that the following complementary data be gathered by observation, interviews, or reports (e.g., mechanical test-and-balance reports) when buildings are to be sampled to analyze indoor air:

- Building Occupancy
    - Characteristics and locations of building occupants (e.g., residents, including children or other sensitive populations; expectations for presence of general public in commercial or industrial settings; presence of multiple exposure units – due to different uses or activities and occupants – within a building other than a single-family residence).
    - Hours of building occupancy under current conditions (and reasonably expected future conditions, as appropriate), particularly for a nonresidential setting. Because this information is pertinent to the human health risk assessment and data evaluation, EPA recommends considering hours of building occupancy when establishing the sampling duration for characterizing indoor air exposure levels.
- Susceptibility to Soil Gas Entry Under Current Conditions
    - EPA recommends that the pressure difference between the indoors and the subsurface be measured whenever indoor air samples are collected. Ideally, differential pressure data would be collected continuously starting several days before sampling and throughout the sample collection period.[159] The magnitude and direction of the pressure difference during sampling can support insights about whether a 'driving force' for vapor intrusion is present during indoor air sampling; if not, then the resulting sampling data are unlikely to characterize a reasonable maximum vapor intrusion exposure condition. Differences in driving forces (direction or magnitude) among indoor air sampling events may help to explain any significant differences in observed indoor air concentrations over time.[160] Measuring pressure difference between the indoors and the subsurface

---

[159] These data can be collected using portable pressure monitors installed in a dedicated sub-slab probe at one or more locations. Pressure transducers were employed for this purpose during high-frequency sampling as part of a research study in Indianapolis (EPA 2012f, see Section 3.6.6 therein); readings were recorded every 15 minutes. Technical information about pressure-measuring instruments (e.g., description, operation, and calibration) can be found in Section 4 of *Technical Guidance Document: Compliance Assurance Monitoring* (EPA 1998).

[160] Pre-mitigation measurements of the pressure difference between indoors and the subsurface may also be useful for supporting design of active depressurization technologies to reduce vapor intrusion (EPA 1993a, see Section 3 therein).

is a more direct means of assessing building under-pressurization than is monitoring weather/climate factors (e.g., air temperature, wind speed). Pressure difference monitoring in large buildings can help identify any areas with significant under-pressurization.

  - Presence and operation of a mitigation system, which would generally be expected to mitigate intrusion of vapor-forming chemicals even if designed for radon.

  - Physical conditions that indicate potential openings to soil gas entry (e.g., potential conduits, such as cracks or floor drains; presence of structures such as utility pits, sumps, and elevators; basements or crawl spaces; modifications to the original foundation).

- Building Heating, Ventilation, and Cooling

  - Building ventilation, including zones of mechanical influence and stagnation. As noted in Section 2.4, greater ventilation is intended to result in smaller vapor concentrations in indoor air. Any non-ventilated or passively ventilated rooms (such as mechanical rooms) may be subject to greater accumulation of vapors. For commercial and industrial buildings, each distinct zone of influence may warrant sampling, when indoor air testing is selected as part of a site-specific investigation plan for vapor intrusion assessment.

  - Operating characteristics of HVAC systems. In many commercial buildings, the HVAC system brings outdoor air into the building, potentially creating building over-pressurization relative to the outdoor environment. EPA recommends noting any areas with significant over-pressurization, relative to the outdoors.

- Indoor and Outdoor Sources of Vapor-Forming Chemicals

  - Chemicals and consumer products used or stored within the building that can act as potential sources of toxic vapors. Vapor-forming chemicals are used in many commercial and most industrial buildings.[161] As noted in Section 2.7, consumer products that can emit vapors may be common in residential buildings. In some circumstances, a photoionization detector (PID) can be used to directly screen the building for locations with vapor-forming chemicals and materials; however, the PID may not be sensitive enough for very low concentration sources. More sensitive options include use of the HAPSITE gas chromatograph/mass spectrometer (Gorder and Dettenmaier 2011) or the TAGA Mobile Laboratory (EPA-ERT 2012).

  - HVAC systems that bring outdoor air into the building potentially bring contaminated outdoor air into the building, depending on the location of the vent and exhaust with regard to other spaces. For example, HVAC intakes adjacent to

---

[161] Depending upon it history of uses and operations, buildings undergoing renovation, redevelopment or reuse may have lingering presence of vapor-forming chemicals due to a past release(s) also.

or near a dry-cleaning facility may introduce vapors of the dry-cleaning solvent into the building.

- In some cases, contaminated groundwater seeps into or actively collects in the building (for example, in sumps), possibly serving as a direct source of vapors. It may be appropriate to collect water samples concurrently with indoor air (and any sub-slab) samples in these circumstances.
- Presence and operation of any indoor air treatment system (e.g., in-line carbon adsorption) that can reduce indoor exposure levels of vapor-forming chemicals.

In general, EPA recommends that the foregoing complementary information be collected during investigation planning and scoping to help determine where to sample and prioritize or sequence buildings for testing. Then, the information can be confirmed during indoor sampling.

Field experience in residential settings suggests that it may not be possible to remove all indoor sources of vapor-forming chemicals. It may be particularly impractical to do so in industrial settings where vapor-forming materials are used or stored. It may also be impractical when deploying passive samplers, owing to their longer deployment period. Therefore, EPA recommends asking building occupants to document indoor sources (and relevant building operations) during indoor air sampling, using an activity log or questionnaire.

6.4.2 Outdoor Air Sampling

Outdoor air concentration data can be useful in identifying potential contributions to indoor air concentrations from ambient air sources (see Section 6.3.5). Therefore, EPA generally recommends collecting ambient air samples using similar sampling and analysis methods, whenever indoor air samples are collected. Normally, EPA recommends one or two outdoor air sample locations to characterize the conditions surrounding a single or a few buildings.[162] Additional outdoor air samples may be warranted if the investigation is assessing multiple buildings over a wide area. EPA also recommends that sample locations be designed to characterize representative conditions in the absence of site-related subsurface contamination (e.g., avoid collecting ambient air samples near locations of known or suspected chemical release(s), including any atmospheric releases from remediation equipment). It also is suggested that observable potential outdoor sources of pollutants (e.g., air emissions from nearby commercial or industrial facilities) be recorded during all building surveys.

Because concentrations of vapor-forming chemicals in ambient air can vary with time, EPA recommends that ambient air samples generally be collected over the same sampling period as indoor air, which will facilitate data evaluations when contaminant concentrations are compared between media. For residential buildings, EPA generally recommends beginning ambient air sampling at least one hour, but preferably two hours, before indoor air monitoring begins and continuing to sample until at least 30 minutes before indoor monitoring is complete. EPA recommends this practice because most residential buildings have an hourly air exchange rate in the range of 0.25 to 1.0, causing air that enters the building before indoor air sampling to

---

[162] For buildings where outdoor air is mechanically brought into the building, an outdoor sample may be co-located near the HVAC intake.

remain in the building for a long time (for example, see Section D.10, ITRC 2007a). Recommended lag times may warrant adjusting for nonresidential buildings.

Evaluate and Develop Analyte Lists. To characterize potential concentrations entering a building via ambient air, EPA generally recommends that chemical analyses for ambient air samples be limited to those vapor-forming chemicals known (based upon subsurface testing) or suspected (based upon site history) to be present in the subsurface environment. Requesting an extensive list of analytes that are not related to subsurface contamination, as discussed previously, may unnecessarily complicate risk communication.

Consider Collecting Complementary Data. Monitoring air exchange during ambient air sampling events can provide useful complementary data. Ideally, these data would be collected continuously starting before sampling and throughout the sample collection period. Information about air exchange can support insights about the amount of ambient air infiltration during sampling.

6.4.3 Sub-slab Soil Gas Sampling

Sub-slab sampling is intended to draw soil gas from the air space immediately below the floor slab of a building. Depending upon building construction and condition, this air space may be an air gap that forms beneath a concrete foundation due to differential settlement over time or a pore space within a granular layer that may have been placed below the concrete slab. Access to this air space is generally provided by drilling or coring through the concrete and inserting a probe, which is sealed into the floor. EPA's Environmental Response Team has developed a standard operating procedure for constructing and installing sub-slab soil gas sampling probes (EPA-ERT 2007).

Sub-slab soil gas samples can provide useful data for characterizing the levels of hazardous, vapor-forming chemicals that can enter a building via soil gas intrusion. When combined with other soil gas data, sub-slab soil gas data can be used to assess whether the subsurface vapor migration route is complete (i.e., subsurface vapor migration is capable of transporting hazardous vapors from the source to building; see Section 6.3.2). When combined with an appropriate attenuation factor (e.g., a conservative generic value – see Section 6.5.3), sub-slab soil gas data can be used to estimate a potential upper-bound indoor air concentration[163] that may arise from vapor intrusion. In this way, sub-slab data can be used to assess the potential for the vapor intrusion pathway to pose a health concern.[164]

---

[163] For purposes of this Technical Guide, the term "upper bound indoor air concentration" is intended to be a semi-quantitative phrase, referring to the high end of the exposure distribution. EPA recommends basing the decision about whether to undertake response action for vapor intrusion (i.e., a component of risk management) on a consideration of a "reasonable maximum exposure" (e.g., EPA 1989, 1991a), which is intended to be a semi-quantitative phrase, referring to the lower portion of the high end of the exposure distribution (see Glossary). Alternatively, a "worst case" or "reasonable worst case" (see Glossary) indoor air concentration would refer to the upper portion of the exposure distribution. Section 6.6, which discusses mathematical modeling of vapor intrusion, notes that consideration of a "worst case" exposure condition may be particularly useful where the predicted "worst case" indoor air concentrations can be shown to pose acceptable human health risk.

[164] The sub-slab soil gas concentration provides only half of the information for estimating vapor flux into a building. The other information needed is the soil gas flow rate (Q_{soil}), which is embodied in the attenuation factor. The soil gas flow rate can also be explicitly calculated using a model.

Field experience indicates there may be substantial spatial variability in sub-slab soil gas concentrations even over an average-sized footprint of a residential building. EPA, therefore, recommends site planning and data review teams consider collecting multiple samples per building when sub-slab soil gas sampling is conducted.[165] Three sub-slab samples have been collected in a number of EPA investigations of a typical size residential building or commercial building less than 1,500 square feet in area. EPA recommends the site planning and data evaluation team discuss the number of sample locations per building for atypical situations, which include: (1) very large or small homes or buildings;[166] (2) buildings with more than one foundation floor type;[167] (3) subsurface structures or conditions that might facilitate or mitigate vapor intrusion; and 4) multi-use buildings with distinct segmented areas that differ significantly by occupying population or exposure frequency. In addition, EPA recommends multi-point sub-slab samples be considered to support data interpretation and resolve uncertainties that may arise when:

- There are fewer surrounding buildings that are being sampled (that could have helped the understanding of typical sub-slab values and variability).[168]
- The indoor and sub-slab concentrations for a specific building(s) are out of line with expectations based on data from neighboring homes and other information.

EPA generally recommends that sub-slab sampling include centrally located sub-slab samples in buildings identified for testing when the subsurface vapor source is laterally extensive relative to the building footprint (e.g., a broad plume of contaminated groundwater).[169] In addition, EPA recommends that site teams consider internal building partitions, HVAC layout, contaminant distribution, utility conduits, and openings for preferential soil gas entry in selecting any additional locations for collecting sub-slab samples.

Several rounds of sampling are generally recommended to develop an understanding of temporal variability of sub-slab soil gas concentrations, particularly when these data are used with the recommended attenuation factor (see Section 6.5.3) to estimate a potential upper-bound indoor air concentration that may arise from vapor intrusion.

---

[165] An individual sample, collected at a randomly chosen time, may under-estimate or over-estimate average subslab conditions. Collecting multiple subslab soil gas samples can, therefore, reduce the chance of reaching a false-negative conclusion (i.e., concluding subsurface vapor source strength is limited, when vapor intrusion actually poses an unacceptable human health risk) or a false-positive conclusion (i.e., concluding subsurface vapor source strength is unacceptably elevated, when vapor intrusion actually poses an acceptable human health risk).

[166] For larger structures, a statistician may assist in identifying the number and placement of sampling ports to meet the desired DQOs.

[167] In basements with a partial slab, but one large enough to allow vapors to accumulate (for example, if the slab covers more than 50 percent of the building footprint), EPA generally recommends that one sub-slab port be installed on the slab portion and an indoor air sample be collected directly over the dirt portion.

[168] In these cases, EPA recommends multiple ports be installed in a specific percentage (e.g., more than 10 percent) of the buildings sampled to provide a check for variability in the study area.

[169] Based on work conducted in New York as of the spring of 2010, it appears that the sub-slab concentrations beneath the central area of a home are usually (75 percent of the time) higher than (or as high as) the concentrations closer to the perimeter of the home. This field observation is supported by modeling results for idealized scenarios, which show greater sub-slab soil gas concentrations near foundation centers in under-pressurized residential buildings when the vapor source is laterally extensive relative to the building footprint (EPA 2012b).

If a site team decides to proceed with sub-slab sampling, EPA recommends that leak-testing be performed to ensure the hole is properly sealed, for example through the use of a helium tracer gas shroud. Because installing soil gas probes can disturb subsurface conditions, EPA recommends that the site team allow some time after the sampling probe has been installed for the subsurface to return to equilibrium conditions. An EPA study of the time needed for the subsurface conditions to come back to equilibrium (equilibration rate) after they have been disturbed by installation of the soil gas probes found that an equilibration time of two hours generally was sufficient because most sub-slab material consists of sand or a sand-gravel mixture—even for buildings built directly on clay (Section 5.0, EPA 2006b).

There also may be special considerations for sub-slab soil gas samples because of either a unique construction (for example, pretension concrete slab) or environmental situation. Key EPA recommendations include, but are not limited to:

- Identify the location of cables in post-tensioned concrete (e.g., using ground-penetrating radar) before sub-slab sampling, as drilling through a cable poses a significant health and safety concern and may damage the slab.

- Avoid locating sub-slab samples in areas where groundwater might intersect the slab.

- Identify and avoid the location(s) of underground utilities and structures (for example, electric, gas, water, or sewer lines) to prevent damage to these lines; however, sample collection in close proximity to these lines may be warranted as building penetrations for these lines may pose openings for soil gas entry.

- Consider whether to augment sub-slab samples with samples through the basement walls, as the primary entry points for vapors in basements might be through the sidewalls rather than from below the floor slab.

<u>Evaluate and Develop Analyte Lists.</u> To characterize potential concentrations entering a building via soil gas, EPA generally recommends that chemical analyses for sub-slab soil gas samples be limited to those vapor-forming chemicals known (based upon subsurface testing) or suspected (based upon site history) to be present in the subsurface environment. Requesting an extensive list of analytes that are not related to subsurface contamination, as discussed previously, may unnecessarily complicate risk communication.

<u>Collect Complementary Data While Indoors</u>. When sub-slab soil gas samples are collected, EPA recommends that the following complementary information be gathered by observation or interviews:

- Physical conditions and characteristics that are pertinent to assessing the building's susceptibility to soil gas entry, if any (e.g., potential conduits, such as cracks or floor drains; presence of structures, such as utility pits and elevators; basements or crawl spaces). Such information may help interpret spatial differences in sub-slab or indoor air concentrations within a building.

- Areas with potentially significant over- or under-pressurization relative to the outdoors. Such information may assist in interpreting spatial differences in sub-slab or indoor air concentrations within a building.

- Where outdoor air is mechanically brought into the building by the HVAC system and building(s) interiors are over-pressurized, it may be helpful to also collect ambient air samples to support interpretations of the sub-slab sampling results. If the predominant vapor-forming substances and their respective concentrations in sub-slab soil gas and outdoor air samples are similar, then ambient air may be influencing sub-slab soil gas conditions.

EPA recommends that the pressure difference between the indoors and the subsurface be measured whenever sub-slab soil gas samples are collected. Ideally, differential pressure data would be collected continuously starting several days before sampling and throughout the sample collection period.[170] EPA recommends measuring pressure at locations away from where sub-slab sampling probes are installed to avoid any pressure artifacts caused during purging and sampling. The magnitude and direction of the pressure difference during sampling can support insights about whether a driving force for vapor intrusion is present during sampling.

When any sub-slab soil gas sample is collected, EPA recommends that relevant meteorological data that can influence soil gas concentration patterns at the time of sampling, such as wind speed, snow or ice cover, significant recent precipitation, and changes in barometric pressure, be recorded, using direct observation (e.g., for snow or ice cover) or readily available data sources (e.g., regional weather stations). These data may be helpful qualitatively in data interpretation; for example, in reconciling soil gas data collected on multiple occasions.

A potential shortcoming of sub-slab soil gas testing is that gaining access may be difficult (or, in some cases, infeasible). This difficulty can often be overcome by implementing a program of community outreach and engagement that fosters trust and good relationships (see Section 9.0).

When access is granted for indoor sampling, EPA recommends collecting sub-slab and indoor air samples contemporaneously using similar sampling and analysis methods and sampling durations to allow for data comparison. The sub-slab sampling ports can be installed after the indoor air sample is deployed and collected (8 - 24 hours later) to avoid biasing the indoor air concentrations with potentially higher sub-slab gas infiltration rates during port installation. Alternatively, the sub-slab ports may be installed prior to indoor air sampling and sampled concurrently with the indoor air samples, provided sufficient time is allowed for the indoor air concentrations to return to “normal” after installation of the sub-slab port.[171]

---

[170] These data can be collected using portable pressure monitors installed in a dedicated sub-slab probe at one or more locations. Pressure transducers were employed for this purpose during high-frequency sampling as part of a research study in Indianapolis (EPA 2012f, see Section 3.6.6 therein); readings were recorded every 15 minutes. Technical information about pressure-measuring instruments (e.g., description, operation, and calibration) can be found in Section 4 of *Technical Guidance Document: Compliance Assurance Monitoring* (EPA 1998).

[171] EPA generally recommends delaying indoor air testing for at least 24 to 72 hours based on an approximate air exchange rate of 0.25 to 1.0 per hour. Note that the effects of any ‘spike’ in indoor air concentration may linger depending on source strength, relative humidity inside the building, and the extent to which the contaminants have been absorbed by carpets and other fabrics or “sinks.”

6.4.4 Soil Gas Sampling

Data obtained from a soil gas survey can be used to identify, locate, and characterize subsurface vapor sources (see Section 6.3.1) and characterize subsurface vapor migration routes, including any impedances from geologic, hydrologic, or biochemical conditions (see Section 6.3.2). Soil gas survey data can also be useful in supporting the design of soil vapor extraction systems and other subsurface remediation systems and the performance assessment of these systems (see Section 8.1). For each of these purposes, EPA recommends that soil gas survey data be supported by site-specific geologic information (i.e., site geology and subsurface lithology).

Soil gas sampling generally consists of installing a probe into the ground, drawing gas out of the probe, and collecting the gas for transport to a location for analysis. Inert materials (e.g., stainless steel, copper, brass, polyvinyl chloride, high-density polyethylene) are recommended for constructing soil gas probes. To ensure that data collected are representative of conditions *in situ* (e.g., are not adversely impacted by artificial infiltration of ambient air), a reliable seal of the annulus between the probe and the probe housing and leak testing for the seal are generally recommended. In addition, purging of the probe before collecting the soil gas sample is recommended, analogous to purging of monitoring wells before collecting groundwater samples. EPA's Environmental Response Team has developed a standard operating procedure for soil gas sampling, including constructing and installing sampling probes (EPA-ERT 2001c).

Typically, grab (rather than time-integrated) samples are collected when sampling soil gas. EPA recommends that the site team allow some time after the sampler has been installed for the subsurface to return to equilibrium conditions because installing temporary or permanent soil gas probes can disturb subsurface conditions. The equilibration time may depend on the degree of soil disturbance during installation, which is influenced by the type of drilling techniques used to install the soil gas probes (e.g., with more time needed for auger drilling compared with hand drilling). For example, the California Environmental Protection Agency recommends an equilibration time of two hours for temporary driven probes and 48 hours for probes installed using augered borings (CalEPA 2012).

EPA recommends documenting wind direction, precipitation information, temperature, and other site-specific information that can influence soil gas concentration patterns at the time of sampling, using readily available data sources. These data may be helpful qualitatively in data interpretation; for example, in reconciling soil gas data collected on multiple occasions or assessing concordance of sampling data from various media, when not collected contemporaneously.

EPA recommends that soil gas samples be taken as close to the areas of interest as possible and preferably from directly beneath the building structure. As vapors are likely to migrate upward through the coarsest or driest material in the vadose zone, EPA recommends that soil gas samples be collected from these materials.

Using vertical boring or drilling techniques, it is generally practical to collect soil gas samples only in locations exterior or adjacent to a building's footprint ("exterior" soil gas samples). Modeling results for idealized scenarios show that, in homogeneous soil, soil gas concentrations tend to be greater beneath the building than at the same depth in adjacent open areas when the vapor source is underneath the building, even if the source is laterally extensive relative to the building footprint (e.g., broad plume of contaminated groundwater) (EPA 2012b). Given these predictions and supporting field evidence (EPA 2012a, see Figure 6; Luo et al. 2009; Patterson and Davis 2009, see Figure 1), individual exterior soil gas samples cannot generally be expected to accurately estimate sub-slab or indoor air concentrations. This potential limitation may be particularly valid for shallow soil gas samples collected exterior or adjacent to a building footprint. On the other hand, when the subsurface vapor source is not underneath the building, ”exterior” soil gas samples collected from depths below a building’s foundation and along the side of the building closest to the source may be useful for characterizing a reasonable worst case condition underneath the building in the absence of routes for preferential vapor migration or soil gas entry.

Deeper soil gas samples collected in the vadose zone immediately above the source of vapor contamination (i.e., “near-source” soil gas samples; see Section 6.3.1) can reasonably be expected to be less susceptible to the diluting effects of ambient air, compared to shallow soil gas samples. On this basis, deeper soil gas samples collected in the vadose zone immediately above the source of vapor contamination will tend to be more suitable than will be shallow soil gas samples for assessing vapor concentrations that may be in contact with the building’s sub-slab.[172] Several rounds of sampling are generally recommended to develop an understanding of temporal variability of “near-source” soil gas concentrations, particularly when these data are used with the recommended attenuation factor (e.g., a conservative generic value – see Section 6.5.3) to estimate a potential upper-bound indoor air concentration that may arise from vapor intrusion.[173]

6.4.5 Groundwater Sampling

Groundwater sampling and analysis also feature prominently in many vapor intrusion investigations, for example, to help characterize plumes that can serve as vapor sources. Groundwater sampling methods are not discussed here because practitioners typically are relatively experienced and trained to collect samples that meet site-specific data quality needs (see, for example, EPA-ERT 2001a). However, Section 6.3.1 provides a few recommended guidelines for groundwater sampling that are pertinent for characterizing representative vapor source concentrations for vapor intrusion assessment. One key consideration in sampling groundwater for vapor intrusion investigations is focusing on characterizing water table

---

[172] Luo et al. (2009) also point to the shortcomings of relying on exterior sampling data, citing significant differences in vapor concentrations and soil gas composition between interior and exterior sampling locations at a maintenance warehouse located at a former refinery. They also observed that the spatial variability in the soil-gas distribution was smaller for soil-gas samples drawn from the source zone, suggesting greater confidence in the assessment of source zone or “near source” vapor concentrations.

[173] For purposes of this Technical Guide, the term “upper bound indoor air concentration” is intended to be a semi-quantitative phrase, referring to the high end of the exposure distribution. EPA recommends basing decisions about whether to undertake response action for vapor intrusion (i.e., a component of risk management) on a consideration of a reasonable maximum exposure (e.g., EPA 1989, 1991a), which is intended to be a semi-quantitative phrase, referring to the lower portion of the high end of the exposure distribution (see Glossary). Alternatively, a “worst case” or “reasonable worst case” (see Glossary) indoor air concentration would refer to the upper portion of the exposure distribution. Section 6.6, which discusses mathematical modeling of vapor intrusion, notes that consideration of a “worst case” exposure condition may be particularly useful where the predicted “worst case” indoor air concentrations can be shown to pose acceptable human health risk.

concentrations. EPA recommends that groundwater samples be taken from wells screened (preferably over short intervals) across the top of the water table.[174]

Groundwater data can be compared to the groundwater VISLs (see Section 6.5).[175] When combined with an appropriate attenuation factor (see Section 6.5.3), groundwater data can be used to estimate a potential upper-bound indoor air concentration that may arise from vapor intrusion.[176] In these ways, groundwater data can be used to assess the potential for vapor intrusion from groundwater sources to pose a health concern.

6.4.6 Planning for Building and Property Access

Vapor intrusion investigations generally entail gaining legal access to buildings and properties to conduct sampling. To address this practical and logistical concern during the planning stage, EPA recommends that an access agreement be executed between the property owner, any occupants, and the investigating entity. Section 9.3 provides additional information for addressing building and property access for sampling.

Obtaining and scheduling access to a property and building can be difficult, whether the structure is a commercial or institutional building or a private residence. This potential difficulty can often be overcome by implementing a program of community outreach and engagement that fosters trust and good relationships. EPA recommends conducting public outreach and communication for this purpose considering the site-specific community involvement plan (See Section 9.1).

6.5 Overview of Risk-Based Screening

Risk screening for vapor intrusion generally is performed using site-specific data collected via appropriate methods, as described in Section 6.4. In some cases, pre-existing data identified during a preliminary analysis can be deemed reliable and adequate for use in risk-based screening (see Section 5.5).

6.5.1 Objectives of Screening

The primary objective of risk-based screening is to identify sites or buildings unlikely to pose a health concern through the vapor intrusion pathway. Generally, at properties where subsurface concentrations of vapor-forming chemicals (e.g., groundwater or "near source" soil gas concentrations) fall below screening levels (i.e., VISLs), no further action or study is warranted, so long as the exposure assumptions match those taken into account by the calculations and the site fulfills the conditions and assumptions of the generic conceptual model underlying the

---

[174] EPA recommends that, to the extent practical, groundwater samples be collected over a narrow interval (e.g., a few feet or less) just below the water table when the data are to be used for assessing the potential for vapor intrusion.

[175] If available groundwater data do not meet the criteria set forth in Section 6.4.5, the site data review team may judge whether they are nevertheless representative of potential vapor source concentrations emanating from groundwater.

[176] EPA recommends basing decisions about whether to undertake response action for vapor intrusion (i.e., a component of risk management) on a consideration of a reasonable maximum exposure (e.g., EPA 1989, 1991a).

screening levels. In a similar fashion, the results of risk-based screening can help the data review team identify areas, buildings, and/or chemicals that can be eliminated from further assessment.

Subsurface concentrations of vapor-forming chemicals that exceed the VISL for the respective medium (e.g., groundwater, soil gas, subslab soil gas) would not automatically trigger mitigation or subsurface remediation (i.e., they are not offered as response action levels or cleanup levels). Exceeding a subsurface screening level generally suggests, however, that further evaluation of the vapor intrusion pathway is appropriate. In this way, risk-based screening, along with other lines of evidence, can help focus a subsequent site-specific investigation, the results of which would provide support for considering building mitigation and other risk management options (see Section 8.0). For example, the results of vapor source strength screening can help identify and prioritize buildings for indoor testing.

Finally, risk-based screening can also support:

- a preliminary evaluation of human health risk using individual building data (e.g., indoor air concentrations), which would consider the magnitude of the concentration exceedance of the indoor air screening level and site-specific risk management benchmarks (see Section 7.4.1); and
- identification of buildings and structures that may warrant prompt action due to potential explosion threats (see Section 7.5.1).

6.5.2 Scope and Basis for Health-based, Vapor Intrusion Screening Levels

EPA developed VISLs for human health protection that are generally recommended, medium-specific, risk-based screening-level concentrations intended for use in identifying areas or buildings that may warrant further investigation of the vapor intrusion pathway. These VISLs are calculated and documented in the VISL Calculator and are based on:

- Current toxicity values selected considering OSWER’s hierarchy of sources for toxicity values (EPA 2003).
- Physical-chemical parameters for vapor-forming chemicals.
- EPA-recommended approaches for human health risk assessment (e.g., EPA 2009c, 2014a).

The VISLs for human health protection include indoor air screening levels for long-term (i.e., chronic) exposures, which consider the potential for cancer and noncancer effects of vapor-forming chemicals.[177] The VISLs for human health protection also include subsurface screening levels for comparison to sub-slab soil gas, “near-source” soil gas, and groundwater sampling

---

[177] The VISL Calculator does not include information about radon. Information about characterizing the human health risk posed by radon can be found on-line at: http://epa-prgs.ornl.gov/radionuclides/

results. These screening levels are derived from the indoor air screening levels for chronic exposures using medium-specific, generic attenuation factors described further in Section 6.5.3 and Appendix A. The user's guide for the VISL Calculator provides additional information about derivation of the indoor air and subsurface screening levels (EPA 2015a).

The medium-specific VISLs for human health protection are intended to be compared to:

- Building-specific data, such as results from sub-slab soil gas samples, crawl space samples, or indoor air samples; or
- Site- or building-specific data that characterize subsurface vapor sources (e.g., groundwater samples, "near-source" soil gas concentrations)

to determine if there is a potential for the vapor intrusion pathway to pose a health concern to building occupants.

The medium-specific VISLs for health protection are developed considering a generic conceptual model for vapor intrusion consisting of:

- A source of vapors underneath the building(s) either in the vadose zone or in the uppermost, continuous zone of groundwater.
- Vapor migration via diffusion upwards through unsaturated soils from these sources toward the ground surface and overlying buildings.
- Buildings with poured concrete foundations (e.g., basement or slab-on-grade foundations) that are susceptible to soil gas entry.

A critical assumption for this generic model is that site-specific subsurface characteristics will tend to reduce or attenuate soil gas concentrations as vapors migrate upward from the source and into overlying structures. Specific factors that may result in relatively unattenuated or enhanced transport of vapors into a building include the following:

- Significant openings to the subsurface that facilitate soil gas entry into the building (e.g., sumps, unlined crawl spaces, earthen floors) other than typical utility penetrations.[178]
- Very shallow groundwater sources (e.g., depths to water less than five feet below foundation level) (see, for example, EPA (2012a), Section 5.2).
- Significant routes for preferential, subsurface vapor migration whether naturally-occurring (e.g., fractured bedrock) or anthropogenic (see Sections 5.4 and 6.3.2).

---

[178] For purposes of this Technical Guide, the term "significant openings" is intended to refer to forms and amounts of openings, other than adventitious and intentional openings in a building that are expected to typically be present in all buildings (e.g., cracks, seams, interstices, and gaps in basement floors and walls or foundations; perforations due to utility conduits). Such an atypical opening would be "significant" when it is of sufficient volume and proximity to a building that it may be reasonably anticipated to influence vapor migration towards or soil gas entry into the building.

These specific factors are likely to render inappropriate the use of the recommended attenuation factors and the sub-slab, groundwater, and soil gas VISLs for purposes of identifying sites or buildings unlikely to pose a health concern through the vapor intrusion pathway. On the other hand, further evaluation of the vapor intrusion pathway is still appropriate when the sub-slab, groundwater, and soil gas VISLs are exceeded for samples from a building or site where these specific factors are present.

Vapor source types that typically make the use of the recommended attenuation factors and health-based VISLs for groundwater and soil gas inappropriate include:

- Those originating in landfills where methane is generated in sufficient quantities to induce advective transport in the vadose zone.

- Those originating in commercial or industrial settings where vapor-forming chemicals can be released within an enclosed space and the density of the chemicals' vapor may result in significant advective transport of the vapors downward through cracks and openings in floors and into the vadose zone.

- Leaking vapors from pressurized gas transmission lines.

In each case, the diffusive transport of vapors may be overridden by advective transport, and the vapors may be transported in the vadose zone several hundred feet from the source of contamination with little attenuation in concentration.

In general, EPA recommends considering whether the assumptions underlying the generic conceptual model are attained at a given site. If they are not attained, then EPA recommends that the medium-specific VISLs not be relied upon as a line of evidence for identifying sites or buildings unlikely to pose a health concern through the vapor intrusion pathway. Where the assumptions regarding the subsurface attenuation factors do not or may not apply, EPA generally recommends collecting indoor air samples.

As noted in Section 6.5.1, these VISLs are not automatically response action levels, although EPA recommends that similar calculation algorithms be employed to derive cleanup levels (see Section 7.6)**.** Comparison of sample concentrations to the VISLs is only one factor recommended for use in determining the need for a response action at a site. As discussed further in Section 6.5.4, an individual subsurface sampling result that exceeds the respective, chronic screening level does <u>not</u> establish that vapor intrusion will pose an unacceptable human health risk to building occupants. Conversely, these generic, single-chemical VISLs do not account for the cumulative effect of all vapor-forming chemicals that may be present. Thus, if multiple chemicals that have a common, non-cancer toxic effect are present, a significant health threat may exist at a specific building or site even if none of the individual substances exceeds its VISL (see discussion of non-cancer hazard index in Section 7.4.1).

6.5.3 Recommended Attenuation Factors for Health-based Screening

Vapor attenuation refers to the reduction in volatile chemical concentrations that occurs during vapor migration in the subsurface, coupled with the dilution that can occur when the vapors enter a building and mix with indoor air (Johnson and Ettinger 1991). The aggregate effect of these physical and chemical attenuation mechanisms can be quantified through the use of a vapor intrusion attenuation factor, which is defined as the ratio of the indoor air concentration arising from vapor intrusion to the soil gas concentration at the source or a depth of interest in the vapor migration route (EPA 2012a).[179]

EPA compiled a database of empirical attenuation factors for chlorinated VOCs and residential buildings through review of data from 913 buildings at 41 sites with indoor air concentrations paired with sub-slab soil gas, groundwater, exterior soil gas, or crawl space concentrations (EPA 2012a). After removing data that do not meet quality criteria and data likely to be influenced by background sources, the distributions of the remaining attenuation factors were analyzed graphically and statistically.[180] Based upon these analyses, the attenuation factors in Table 6-1 are recommended by EPA to derive the VISLs for health protection.

With the exception of the "near-source" exterior soil gas attenuation factor, the recommended values for residential buildings are the estimated 95th percentile values, rounded to one significant figure.[181] The rationale for these recommendations and related analyses are provided in Appendix A. These recommended values are proposed to apply to all vapor-forming chemicals for use in estimating potential upper-bound concentrations in indoor air that may arise from vapor intrusion.[182] The recommended groundwater and "near-source" soil gas attenuation factors do not, however, include the effects of biodegradation.[183] On the other hand, because biodegradation is not expected to occur indoors (i.e., in indoor air in the absence of an air treatment system), the sub-slab soil gas and crawl space attenuation factors are expected to apply equally to vapor-forming chemicals that biodegrade in the vadose zone and those that do not.

As with the medium-specific VISLs, EPA recommends considering whether there are site- or building-specific factors that may result in unattenuated or enhanced transport of vapors toward and into a building, such as the presence of preferential migration route(s) as described in Sections 5.4 and 6.3.2. The presence of such factors is likely to render inappropriate the use of any of these generic attenuation factors.

---

[179] As defined here, the vapor attenuation factor is an inverse measurement of the overall dilution that occurs as vapors migrate from a subsurface vapor source into a building; i.e., lower attenuation factor values indicate lower vapor intrusion impacts and greater dilution; higher values indicate greater vapor intrusion impacts and less dilution (EPA 2012a, b). Johnson and Ettinger (1991) utilized the symbol α for the vapor intrusion attenuation factor. For example, the subslab soil gas attenuation factor is intended to account for concentration dilution arising during migration through openings in the foundation and from mixing of subsurface contaminants inside the building. The groundwater attenuation factor is intended to account for concentration dilution arising during vapor migration from the groundwater table through the vadose zone, in addition to concentration dilution arising during migration through openings in the foundation and from mixing of subsurface contaminants inside the building.

[180] A summary of the resulting distributions is provided in Appendix A of this document.

[181] The recommended "near-source" exterior soil gas attenuation factor corresponds to approximately the estimated 75th percentile value.

[182] EPA recommends basing decisions about whether to undertake response action for vapor intrusion (i.e., a component of risk management) on a consideration of a reasonable maximum exposure (e.g., EPA 1989, 1991a).

[183] Appropriate data can be collected and evaluated, as described in Section 6.3.2, to characterize and document the occurrence of biodegradation in the vadose zone and its effects in attenuating vapor concentrations of biodegradable vapor-forming chemicals.

TABLE 6-1
RECOMMENDED VAPOR ATTENUATION FACTORS FOR RISK-BASED SCREENING OF THE VAPOR INTRUSION PATHWAY[184]

Sampling Medium	**Medium-specific Attenuation Factor for Residential Buildings**
Groundwater, generic value, except for shallow water tables (less than five feet below foundation) or presence of preferential vapor migration routes in vadose zone soils	1E-03 (0.001)
Groundwater, specific value for fine-grained vadose zone soils, when laterally extensive layers are present[185]	5E-04 (0.0005)
Sub-slab soil gas, generic value	3E-02 (0.03)
"Near-source" exterior soil gas, generic value except for sources in the vadose zone (less than five feet below foundation) or presence of routes for preferential vapor migration in vadose zone soils	3E-02 (0.03)
Crawl space air, generic value	1E-00 (1.0)

The VISL Calculator (http://www.epa.gov/oswer/vaporintrusion/guidance.html) also facilitates calculation of groundwater screening levels based on the recommended attenuation factor for fine-grained soil. EPA recommends that any use and application of this semi-site-specific groundwater attenuation factor be supported by site-specific geologic information (i.e., site geology and subsurface lithology). Significant characterization of the vadose zone may be needed to demonstrate that fine-grained layers are laterally extensive over distances that are large compared to the size of the building(s) or the extent of vapor contamination at a specific site, which is the recommended support for using the semi-site-specific attenuation factor for

---

[184] Use of these attenuation factors for estimating indoor air concentrations is contingent upon site conditions fitting the generic model of vapor intrusion described in Section 6.5.2 and subsurface conditions being characterized considering the recommendations in Sections 6.3 and 6.4.

[185] The Draft VI Guidance allowed for the modification of VISLs for groundwater by incorporating a lower attenuation factor, based upon "some site-specific inputs", which estimates a greater reduction in vapor concentrations in the vadose zone than the generic value (EPA 2002c, 2010b). In the Draft VI Guidance, graphs were provided from which such "semi-site-specific" attenuation factors could be selected and justified based upon site-specific soil type and depth to the water table. Based upon analysis of EPA's expanded database, a single groundwater attenuation factor is provided in this Technical Guide for fine-grained soils.

fine-grained soil.[186] For purposes of applying the groundwater attenuation factors, EPA recommends the depth to groundwater be estimated relative to the bottom of the building foundation and be based upon the seasonal high groundwater table.

6.5.4 Comparing Sample Concentrations to Health-based Screening Levels

When evaluating environmental sampling results to assess the vapor intrusion pathway, it is important to first determine that the samples were collected appropriately. Section 6.4 provides information about recommended sampling locations and procedures for vapor intrusion investigations. In addition, EPA recommends collecting and evaluating appropriate site-specific information to demonstrate that the property fulfills the conditions and assumptions of the generic conceptual model underlying the VISLs, as described in Section 6.5.2.

After verifying that the CSM justifies the use of the VISLs, the individual sample concentrations may be compared to the appropriate medium-specific screening levels. In order to select the appropriate target media concentrations for comparison, it generally is important to identify whether a source of vapors for a building or a developed area occurs in the unsaturated zone, which is an important aspect of the CSM. This allows the site data to be segregated into two categories:

- Data representing areas where contaminated groundwater is the only source of contaminant vapors.

  In this first case, groundwater VISLs are generally appropriate to use to evaluate groundwater concentrations (also see sampling recommendations in Sections 6.3.1 and 6.4.5). Under these circumstances, EPA recommends that the plume be shown to be stable or shrinking (i.e., is not migrating or rising in concentration, including hazardous byproducts of any biodegradation) to establish that the potential for vapor intrusion to pose a human health risk from vapor intrusion will not increase in the future. “Near-source” soil gas data (i.e., soil gas samples collected immediately above the water table) could also be compared to the soil gas VISLs to obtain a corroborating line of evidence (see recommendations in Section 6.3.1).

  When the anticipated outcome of the screening is a finding that groundwater poses acceptable human health risk from vapor intrusion on an area-wide basis, it may be appropriate to compare sampling results for the most greatly impacted well within the area of interest and show that these results are less than the groundwater VISLs.

- Data representing areas where the underlying vadose zone soil contains a source of vapors (e.g., residual NAPL).

  In this second case, EPA recommends that only soil gas VISLs be used and compared to results from “near-source” soil gas samples collected near the vapor source zone

---

[186] The general soil type assigned to paired vapor intrusion data in the EPA’s database “generally represents the coarsest soil described in the vadose zone near the sample location” unless “sufficient stratigraphic information was available to indicate finer sediments are laterally continuous” (EPA 2012a). EPA recommends that similar criteria be applied to justifying the use of the semi-site-specific attenuation factor for groundwater (or selection of soil-related parameters for modeling); see Section 6.6. For these purposes, soil classified as clay, silty clay, silty clay loam, or silt consistent with the U.S. Soil Conservation Service classification system can be considered to be “fine-grained.”

(also see sampling recommendations in Sections 6.3.1 and 6.4.4). In this situation, the groundwater VISLs (and vapor attenuation factors for groundwater) are not recommended for estimating potential upper-bound indoor air concentrations, because they have been derived assuming no other vapor sources exist between the water table and the building foundation.

In both cases, because of the complexity of the vapor intrusion pathway, EPA recommends that professional judgment be used when applying the VISLs.

Generally, if all subsurface sample concentrations for a given building or area are less than the respective medium-specific screening level, then vapor intrusion is less likely to pose an unacceptable human health risk to building occupants. On the other hand, when individual sample concentrations exceed the respective screening level, additional assessments may be warranted. So, for example, if a groundwater or "near-source" soil gas concentration exceeds the respective screening level, it is recommended that sub-slab soil gas testing and indoor air testing be conducted.

However, we would note that any individual subsurface sampling result that exceeds the respective, chronic screening level does not establish that vapor intrusion will pose an unacceptable human health risk to building occupants. For one, the subsurface screening levels are expected to be conservative (i.e., are likely to over-estimate the contribution to indoor air levels arising from vapor intrusion) for many buildings due to the use of a high-end attenuation factor (see Section 6.5.3). In many cases, indoor air concentrations arising from vapor intrusion would be expected to be lower than those estimated using the recommended generic attenuation factors. For carcinogens, the screening levels are set using a one-per-million lifetime cancer risk (i.e., 10^{-6}), whereas EPA recommends consideration of a cancer risk range when making risk management decisions (see Section 7.4.1). Finally, sampling results can be expected to be variable spatially and temporally and these screening levels assume a long period of exposure at the stated concentration.

Owing to the temporal variability in building-specific data and the potential temporal and spatial variability in soil gas vapor concentrations, EPA generally recommends multiple samples be collected (see Section 6.4) and compared to the respective medium-specific screening level. In addition, the results of risk-based screening are generally most useful when they can be evaluated for indoor air and subsurface vapor sources concurrently and in the context of the CSM. EPA, therefore, generally recommends that multiple lines of evidence be developed and their results weighed together when evaluating and making risk-informed decisions pertaining to vapor intrusion. EPA generally recommends that concordance among the multiple lines of evidence be obtained, particularly when considering a determination that the vapor intrusion pathway is incomplete or does not pose an unacceptable human health risk. Sections 7.1, 7.2, and 7.3 provide additional information and recommendations about developing and using multiple lines of evidence and risk management decision-making.

6.5.5 Planning for Communication of Sampling Results

EPA recommends the community involvement or public participation plan (See Section 9.1) describe and address community questions, concerns, and preferences for participation regarding sampling results. Generally, EPA recommends that the site planning team provide validated results to property owners and occupants. These results can be transmitted to relevant parties in a letter, along with a description of what future actions, if any, may be warranted. In addition, the site planning team may choose to hold a community meeting to discuss the sampling results in general terms and EPA's plans, if any, for response actions. Section 9.4 provides additional information for communicating sampling results.

6.6 General Principles and Recommendations for Mathematical Modeling

When suitably constructed, documented, and verified, mathematical models can provide an acceptable line of evidence supporting risk management decisions pertaining to vapor intrusion. In certain situations (e.g., for future construction on vacant properties), it is particularly useful to employ mathematical modeling to predict reasonable maximum indoor air concentrations, because indoor air testing is not possible.

Mathematical modeling is most appropriately used in conjunction with other lines of evidence. For example, in the brownfield development case (i.e., yet-to-be-constructed building), EPA generally recommends these additional lines of evidence include, at a minimum, data that characterize potential subsurface vapor sources and associated geologic and hydrologic conditions in the vadose zone (see Sections 6.3.1 and 6.3.2).

Generally, mathematical models transform empirical values of input parameters into predictions of chemical concentrations in environmental media. The model input parameters are equally as important to the results as the mathematical components of the model (i.e., governing equations and solution algorithms). As a consequence, the results critically depend on the choices for the inputs.

Historically, to assure confidence in predictions of mathematical models, they have been compared to measured, site-specific values. When measured and predicted values do not reasonably match, model input parameters are adjusted through calibration. For example, calibration is commonly used in groundwater flow modeling, in which model-predicted groundwater levels are matched to measured groundwater levels for a baseline condition to gain insight into hydrogeologic properties. The calibrated input parameters must reasonably represent the underlying phenomena and the characteristics of the model must reasonably match the field situation. Calibration of mathematical models is known to be non-unique, so that different sets of parameters can be used to fit the same observed data. This means that calibration does not produce a theoretically correct set of parameters. Because various values of input parameters could be used in the calibrated model, there will always be uncertainty as to the actual values.

Three approaches exist for applying mathematical models in these circumstances:

1) Calibrating the mathematical model to the measured indoor air concentration (and, possibly, the sub-slab soil gas concentration) considered to be representative of vapor intrusion (i.e., background vapor sources have been identified and removed prior to sampling and data evaluation indicates that the concentration is reasonably attributable to vapor intrusion). Calibration entails adjusting the input parameters within plausible and realistic ranges so that the predicted indoor air concentrations (or sub-slab soil gas concentrations) are similar to the measured vapor concentrations. The adjusted input parameters can then be compared to site-specific conditions and data to verify that the CSM and calibrated model are coherent and sound.

2) Conducting an uncertainty analysis (perhaps using an automated uncertainty analysis (see http://www.epa.gov/athens/learn2model/part-two/onsite/uncertainty-vi.html as only one example)) to understand where, within the probability distribution of results, model results with pre-selected default parameters lie. This approach may be particularly useful where indoor air concentrations have not been measured or non-site-specific inputs have been used.

3) Using a bounding case analysis, where parameters are chosen to represent conditions that give a high-impact (e.g., "reasonable worst") case – see Glossary – or "worst" (maximum plausible)[187] case. This approach may be particularly useful where the predicted indoor air concentrations for the bounding case can be shown to pose acceptable human health risk.[188] The range of predicted indoor air concentrations can be established if the analysis also includes a low-impact ("best") case.

Unless site-specific parameter values are obtained for input parameters and the mathematical model is calibrated to field data, use of default input parameter values will generate model results that lie at an unknown point within an uncertainty band of the model outcomes. Because the combined effect of parameter uncertainty is large, a one- or two-order of magnitude error might be made unknowingly. To reduce these errors, sub-slab vapor sampling could be used to characterize the vapor concentration(s) beneath a building. Model results (i.e., predicted sub-slab soil gas concentrations) that match measured values would have increased confidence. Alternately, using bounding estimates of parameter values could provide a conservative model result that would be expected to represent the reasonable worst case of potential exposure.

Three examples follow where differing applications of mathematical models would be useful in vapor intrusion assessment:

- Verify General Magnitude. Modeling using site-specific inputs can be useful for verifying the general magnitude of measured indoor air sample concentrations, which may allow risk managers to reach supportable conclusions not to conduct additional indoor air testing. In this situation, the model could be calibrated to indoor air measurements and the plausibility of the calibrated input parameters evaluated. If the calibrated model input parameters are plausible, then they can be considered an additional line of evidence supporting risk management decisions.

- Explore Range of Outcomes through Uncertainty Analysis. In certain situations, indoor air testing is not possible (e.g., for future construction on vacant properties) or feasible.

---

[187] For purposes of this Technical Guide, the phrase "worst case indoor air concentration" is intended to be a semi-quantitative phrase, referring to the high end of the exposure distribution. "No-further-action" decisions can normally be supported more confidently when the "worst case indoor air concentration" can be shown to pose acceptable health risks. Under these conditions, the "reasonable maximum exposure" (see Glossary) typically would also pose acceptable health risks.

[188] "Bounding estimates" purposely overestimate the exposure or dose in an actual population for the purpose of developing a statement that the risk is "not greater than..." (EPA 1992c).

Here the range of possible outcomes could be explored with the model through an uncertainty analysis. For example, model input parameters, including building and vadose zone soil properties, could be varied within plausible ranges to determine the parameters to which the model is most sensitive to guide field investigations. Uncertainty analyses can also be used to ascertain whether the subsurface vapor source concentrations are such that indoor air samples would not be expected to contain detectable levels of vapor-forming chemicals arising from vapor intrusion.

- Generate Bounding Estimates. If the range of parameter values is known with confidence for the site, then parameters can be chosen to represent the bounding case of maximum plausible vapor intrusion (i.e., worst case).

In each of these examples, model parameters might vary in space and time because of subsurface heterogeneity, transient hydrologic conditions, or variation in building operation. Thus, there is a need for characterizing spatial and temporal variability.

Mathematical models provide opportunities to predict conditions that cannot be observed directly, but the reliability of the results need to be confirmed, especially when limited site-specific data are available and the model is not calibrated to observed indoor air concentrations. Use of a generic, conservative attenuation factor (see Section 6.5.3) to predict potential, upper-bound indoor air concentrations (based upon soil gas concentrations – see Sections 6.4.3 and 6.4.4) implicitly represents use of a mathematical model, even when the attenuation factor is selected from an empirical data set. Whether the mathematical model is implicit (e.g., generic, conservative attenuation factor) or explicit (e.g., mathematical model that generates a bounding estimate), both analytic approaches make the assumption that site-specific attenuation is likely to be greater and the indoor air concentration(s) is (are) likely to be lower than predicted value(s).

The use of extreme and non-representative assumptions or parameter values is the most common weakness of mathematical modeling for environmental assessments. Mathematical modeling typically yields more reliable results when used with high-quality, site-specific data inputs (that is, representative groundwater or soil gas concentrations, depth to groundwater, soil type and moisture content underneath the building, and the building conditions (e.g., air exchange rate, building mixing height), for example); in these cases, the site-specific data inputs and CSM provide additional lines of evidence supporting the use of mathematical modeling as a line of evidence.

Whenever mathematical modeling is used to make predictions pertaining to vapor intrusion, EPA recommends that the site planning and data team:

- Identify the underlying mathematical model and include appropriate references to document that it has been peer-reviewed.
- Verify that the selected model fits the CSM and is appropriate for the chosen purpose.
- Document all inputs and outputs in a readily recognizable and understandable format.
- Identify the critical parameters and conduct a sensitivity analysis for the most critical parameters.

- Determine and document the appropriate modeling approach (e.g., calibration, uncertainty analysis, bounding case analysis).

- Perform new individual measurements (i.e., field sampling) to confirm one or more results of the modeling.

A critical assumption underlying almost all mathematical models of vapor intrusion is that site-specific subsurface characteristics will tend to reduce or attenuate soil gas concentrations as vapors migrate upward from the source and into overlying structures. Mathematical modeling of vapor intrusion is, therefore, not generally recommended for sites and buildings where unattenuated or enhanced transport of vapors toward and into a building is reasonably expected. Sections 5.4, 6.3.2, and 6.5.2 identify several factors that may result in unattenuated or enhanced transport of vapors toward and into a building.

7.0 RISK ASSESSMENT AND MANAGEMENT FRAMEWORK

This section provides general recommendations about risk-informed decision-making pertaining to vapor intrusion. The risk management information described herein presumes that a sound CSM has been developed (see Sections 5.4 and 6.3), which is supported by multiple lines of evidence, and that subsurface vapor sources have been characterized (see Section 6.3.1) sufficiently to support the risk management decisions for the site. EPA also notes that temporal and spatial variability of sampling data can span at least an order of magnitude and often more.

Site-specific decisions potentially supported by the information described in this section include:

- Whether to install engineered exposure controls to prevent or reduce the impacts of vapor intrusion in specific buildings.
- Whether to remediate subsurface vapor sources for the site to reduce risks posed by vapor intrusion.
- Whether the vapor intrusion pathway is incomplete and there is no potential for unacceptable human exposure under current or future conditions.
- Whether to collect additional information as part of the detailed vapor intrusion investigation or monitor indoor air as part of an overall vapor intrusion remedy.

As conditions warrant and resources allow, EPA generally recommends that officials responsible for overseeing cleanups pursuant to RCRA and CERCLA ensure that past decisions pertaining to vapor intrusion continue to be supported by current conditions (EPA 2002b).

Finally, EPA encourages systematic approaches to decision-making, which can foster scientific rigor, consistency, and transparency.

7.1 Collect Site-specific Lines of Evidence

Current practice suggests that the vapor intrusion pathway generally be assessed using multiple lines of evidence. As discussed in Sections 5.1, 5.4, 5.5.2, 6.3, 6.4, and 6.5, appropriate lines of evidence to support development of the CSM and evaluate the vapor intrusion pathway may include, but are not limited to:

<u>Subsurface Vapor Sources</u>

- Site history and source of the contaminants to demonstrate that vapor-forming chemicals have been or may have been released to the underlying and surrounding subsurface environment and identify the type of vapor source (e.g., vapor-forming chemicals dissolved in groundwater or present in a NAPL).
- Groundwater data (generally recommended from more than one sampling event), as appropriate, to confirm the presence of a water-table aquifer, if present, as a source of vapors and establish its chemical and hydrogeologic characteristics.

- Soil gas data, bulk soil sampling data,[189] and/or NAPL sampling data to confirm the presence of contamination in the vadose zone, if present, as a source of vapors and establish its chemical and physical characteristics.

- Sub-slab (or crawl space) soil gas data to assess concentrations potentially available for entry with any intruding soil gas (generally recommended from multiple sampling events and in multiple locations to reduce the chance of reaching a false-negative conclusion (i.e., concluding subsurface vapor source strength is limited when vapor intrusion actually poses an unacceptable human health risk) or a false-positive conclusion.

- Comparison of groundwater and/or soil gas concentrations to VISLs to evaluate source strength and potential for a health concern if the vapor intrusion pathway is complete.

Vapor Migration and Attenuation in the Vadose Zone

- Soil gas survey data, including some level of vertical and spatial profiling, as appropriate, to confirm soil gas migration and attenuation along anticipated routes in the vadose zone between sources and buildings.

- Data on site geology and hydrology (e.g., soil moisture and porosity) to support the interpretation of soil gas profiles, the characterization of gas permeability, and the identification of anticipated soil gas migration routes in the vadose zone or the identification and characterization of impeded migration.

- Vertical profiles of chemical vapors, electron acceptors for microbial transformations (e.g., oxygen), and degradation products (e.g., methane, vinyl chloride) to characterize attenuation due to biochemical (e.g., biodegradation) processes.

- Utility corridor assessment to identify preferential migration routes, if any, that facilitate subsurface vapor migration between sources and towards and into buildings

Building Foundation Assessment, Including Susceptibility to Soil Gas Entry

- Building construction and current conditions, including utility conduits or other preferential routes or openings for soil gas entry, heating and cooling systems in use, and any segmentation of ventilation and air handling.

- Instrumental (e.g., PID) readings to locate and identify potential openings for soil gas entry into buildings.

---

[189] As noted in Section 6.4, bulk soil sampling and analysis can be used to characterize the chemical composition and general location of contamination; for example, high soil concentrations generally would indicate impacted soil. On the other hand, non-detect results for soil samples cannot be interpreted to indicate the absence of a subsurface vapor source, because of the potential for vapor loss due to volatilization during soil sampling, preservation, and chemical analysis. Therefore, bulk soil (as opposed to soil gas) sampling and analysis is not currently recommended for estimating the potential for vapor intrusion to pose unacceptable human health risk in indoor air.

- Grab samples of soil gas or indoor air near openings to characterize the composition of presumptive soil gas entering buildings.

- Pressure data to assess the driving force for soil gas entry into building(s) via advection.

- Tracer-release data to verify openings in building foundations for soil gas entry or assess fresh air exchange within buildings.

Interior Assessment

- Indoor air sampling data (Section 6.4.1) to assess the presence of subsurface contaminants in indoor air (Section 6.3.4), estimate potential exposure levels to building occupants to support site-specific human exposure and human health risk assessments (see Section 7.4), and otherwise diagnose vapor intrusion and characterize background concentrations (Section 6.3.5).[190]

Indoor and Outdoor Sources of Vapor-forming Chemicals Found in the Subsurface

- Building-specific indoor sources of volatile chemicals (Section 2.7).

- Concurrent outdoor air data to assess potential contributions of ambient air to indoor air concentrations (Sections 6.3.5 and 6.4.2).

- Comparative evaluations of indoor air and sub-slab soil gas data (e.g., Section 6.3.5), including calculation and comparison of building-specific, empirical attenuation factors (EPA 2012a, Section 3.0) (e.g., to assess their consistency among subsurface contaminants to assist in identifying indoor vapors arising from vapor intrusion).

Additional Supporting Lines

- Results of statistical analyses (e.g., data trends, contaminant ratios) to support data interpretation.

- Results of mathematical modeling that rely upon site-specific inputs (Section 6.6).

The relative utility of these and other individual lines of evidence will depend on site-specific factors, as described and documented in the CSM (Section 5.4), and the objectives of the investigation (Section 6.3). For example:

- When the primary subsurface vapor source is residual NAPL in the vadose zone, bulk soil data would typically be collected to characterize the chemical composition and general location of contamination; for example, high soil concentrations generally would

---

[190] In certain cases, depending in part on the results (e.g., concentrations exceed risk-based screening levels), indoor air sampling data may be a sufficient basis for supporting decisions and recommendations to undertake pre-emptive mitigation (see Sections 3.3 and 7.8) in lieu of additional rounds of sampling and analysis or an evaluation of the contribution of background sources to indoor air concentrations.

indicate impacted soil in the vadose zone, as discussed in Sections 6.3.1 and 6.4.[191] In this situation, "near source" soil gas data, rather than groundwater data, would be recommended for assessing the potential for vapor intrusion to pose an unacceptable human health risk to occupants of any building overlying the NAPL zone. On the other hand, when the subsurface vapor source underneath a building is shallow groundwater, groundwater sampling data from the uppermost hydrogeologic unit would be an appropriate line of evidence for purposes of assessing the potential for vapor intrusion to pose an unacceptable human health risk, unlike the previous example.

- In both of the preceding cases, information about the soil conditions (e.g., soil type and moisture) *underlying the buildings* would be useful for characterizing the subsurface vapor migration route between the subsurface vapor source and the building. Sub-slab soil gas samples and indoor air samples (if background sources are removed or accounted for), in concert with other lines of evidence, can provide a strong line of evidence regarding whether the vapor intrusion pathway is complete.

- For an industrial building, indoor air testing while the HVAC system is not operating (see Section 6.3.3) could be useful for diagnosing vapor intrusion. On the other hand, single-family detached homes can generally be presumed susceptible to soil gas entry when heating or cooling systems are operating.

7.2 Weigh and Assess Concordance Among the Lines of Evidence

To the risk manager, the ideal outcome from collecting multiple lines of appropriate evidence is a concordant set of site-specific information that unambiguously supports decisions that can be made confidently. However, based upon observations at many buildings and sites, the vapor intrusion site where all available information is in agreement and is unambiguous may be the exception rather than the rule. Some lines of evidence may not be definitive (e.g., indoor air and subsurface concentrations can be greatly variable temporally and spatially). At worse, some individual lines of evidence may be inconsistent with other lines of evidence. In general, when lines of evidence are not concordant and the weight of evidence does not support a confident decision, EPA recommends re-evaluating the CSM, which may warrant adjusting the CSM to better represent the weight of the available evidence.

> *For example, a building overlying contaminated shallow groundwater may have high concentrations of vapor-forming chemicals in the sub-slab soil gas samples, but lower concentrations in soil gas samples collected exterior to the building at intermediate depths. In this example, the exterior soil gas data suggest there may not be a connected vapor migration path between the groundwater source and the building that exhibits continuous attenuation along the path. Nevertheless, the data review team may conclude that vapor migration is capable of transporting hazardous vapors from the source to building(s) if the groundwater and sub-slab soil gas samples share common contaminants that are known or suspected to have been released at the site (for example, samples of both groundwater and*

---

[191] Because of the large uncertainties associated with measuring concentrations of volatile contaminants introduced during soil sampling, preservation, and chemical analysis, bulk soil (as opposed to soil gas) sampling and analysis is not currently recommended for estimating the potential for vapor intrusion to pose unacceptable human health risk in indoor air. In addition, there are uncertainties associated with soil partitioning calculations.

> *the sub-slab soil gas contain TCE). In this circumstance, the data review team may wish to consider whether the occurrence of a higher TCE concentration in the sub-slab soil gas than in the exterior soil gas sample(s) can be explained by: (1) a previously unknown or unrecognized utility corridor or other preferential migration route that provides relatively unattenuated vapor transport between the groundwater and the building; (2) a previously unknown or unrecognized source of TCE in the vadose zone; or (3) the possibility that the exterior soil gas samples were not well located for purposes of characterizing subsurface vapor migration. This example also underscores the importance of developing an adequate CSM (e.g., identify all sources and preferential routes of subsurface vapor migration) and illustrates why EPA generally recommends that the vapor intrusion pathway not be deemed incomplete based upon any single line of evidence (EPA 2010b), such as exterior soil gas in this example.*

When lines of evidence are not concordant and the weight of evidence does not support a confident decision, it may also be appropriate to collect additional lines of evidence, possibly including additional samples, depending upon the CSM. For example:

- Appropriate site-specific testing (see Section 6.3.5) can be conducted to assess the contribution of background sources of vapor-forming chemicals, including comparisons among chemicals of their relative concentrations in indoor air, outdoor air, and soil gas. Background sources of vapor-forming chemicals may help to explain situations where the indoor air concentration is higher than can be accounted for by the subsurface vapor source or the sub-slab soil gas data.

- Diagnostic testing of indoor air (see Section 6.4.1), building condition assessments or utility surveys, or supplemental hydrogeologic characterization (see Section 6.3.2) can be used to investigate the suspected presence of preferential migration routes, such as those described in Sections 5.4 and 6.3.2. Such investigations may help to explain situations where the sub-slab or indoor air concentration appears to reflect unattenuated vapor transport from the subsurface vapor source.

- Building susceptibility to vapor intrusion can be tested (see Section 6.3.3), which may help to explain situations where the indoor air concentration is significantly lower than expected based upon the sub-slab soil gas data.

- Vapor migration in the vadose zone can be further characterized to identify impedances to vapor migration (see Section 6.3.2), appropriate semi-site specific attenuation factors can be considered (see Section 6.5.3), and appropriate modeling can be conducted (see Section 6.6) to investigate site-specific vapor attenuation. Such data and analyses may help to explain situations where the sub-slab soil gas concentration is significantly lower than expected based upon groundwater source or "near-source" soil gas concentrations and the respective medium-specific attenuation factor (Section 6.5.2 and Appendix A). In some of these situations, the vapor intrusion pathway may be impeded, or perhaps even incomplete, due to geologic, hydrologic, or microbial characteristics in the vadose zone (see Sections 6.3.2 and 7.3).

Recognizing the temporal and spatial variability of indoor air and subsurface concentrations and the potentially episodic nature of vapor intrusion at some sites (Section 2), EPA generally recommends collecting multiple rounds of sampling in the respective media from multiple locations (see Section 6.4) to reduce the chance of reaching a false-negative or false-positive conclusion. Considerable judgment may be necessary when evaluating multiple data sets from individual sampling events to support decision-making.

In summary, EPA recommends the appropriate use and evaluation ("weighing") of multiple lines of evidence for determining whether the vapor intrusion pathway is complete or not, whether any elevated levels of contaminants in indoor air are likely caused by subsurface vapor intrusion versus an indoor source or an ambient (outdoor) air source, whether concentrations of subsurface contaminants in indoor air may pose a health concern, and whether interim response measures to mitigate vapor intrusion are warranted.

7.3 Evaluate Whether the Vapor Intrusion Pathway is Complete or Incomplete

For purposes of this Technical Guide, and as reflected in the conceptual model of vapor intrusion (see Section 2), the vapor intrusion pathway is referred to as "complete" for a specific building or collection of buildings when the following five conditions are met under current conditions:

1) A subsurface source of vapor-forming chemicals is present underneath or near the building(s) (see Sections 2.1, 5.3, 6.2.1, and 6.3.1);

2) Vapors form and have a route along which to migrate (be transported) toward the building(s) (see Sections 2.2 and 6.3.2);

3) The buildings are susceptible to soil gas entry, which means openings exist for the vapors to enter the building and driving 'forces' exist to draw the vapors from the subsurface through the openings into the building(s) (see Sections 2.3 and 6.3.3);

4) One or more vapor-forming chemicals comprising the subsurface vapor source(s) is (or are) present in the indoor environment (see Sections 6.3.4 and 6.4.1); and

5) The building is occupied by one or more individuals when the vapor-forming chemical(s) is (or are) present indoors.

Considerable scientific and professional judgment will likely be needed when weighing lines of evidence to determine whether the vapor intrusion pathway is complete or incomplete. Each of the first four conditions generally entails obtaining and weighing multiple lines of evidence, whereas the fifth condition generally can be confidently determined by direct observation. EPA recommends considering and evaluating together the various lines of evidence in determining completeness of the vapor intrusion pathway under current conditions.

As noted previously (e.g., Section 3.2), EPA recommends that risk management decisions also consider whether the vapor intrusion pathway is 'potentially complete' under reasonably expected future conditions. The vapor intrusion pathway is referred to as 'potentially complete' for a building when:

- a subsurface source of vapor-forming chemicals is present underneath or near an existing building or a building that is reasonably expected to be constructed in the future;

- vapors can form from this source(s) and have a route along which to migrate (be transported) toward the building; and

- three additional conditions are reasonably expected to all be met in the future, which may not all be met currently; i.e.,
    - the building is susceptible to soil gas entry, which means openings exist for the vapors to enter the building and driving forces exist to draw the vapors from the subsurface through the openings into the building;
    - one or more vapor-forming chemicals comprising the subsurface vapor source(s) is (or will be) present in the indoor environment (see Sections 6.3.4 and 6.4.1); and
    - the building is or will be occupied by one or more individuals when the vapor-forming chemical(s) is (or are) present indoors.

This determination also generally entails obtaining and weighing multiple lines of evidence.

A complete pathway indicates that there is an opportunity for human exposure, which warrants further analysis to determine whether there is a basis for undertaking a response action(s). Specifically, a complete exposure pathway does not necessarily mean that an unacceptable human health risk exists due to vapor intrusion. Rather, specific exposure conditions, such as the magnitude, frequency, and duration of exposures, and the contribution from background concentrations warrant examination; hence, EPA recommends additional analyses be conducted to assess and characterize human health risk to building occupants where the vapor intrusion pathway is determined to be complete (see, for example, Sections 7.4 and 6.3.5). On the other hand, human exposure, and hence human health risk, from the vapor intrusion pathway would not exist if the pathway is incomplete.

The conceptual model described in Section 2 identifies the characteristics of the vadose zone that could render the vapor intrusion pathway incomplete under current and future conditions. These individual characteristics include, but are not limited to:

- Soil layers that significantly and persistently impede vapor transport due to geologic or hydrologic conditions (e.g., fine-grained soil, soil with high moisture content) and are laterally extensive over distances that are large compared to the size of the building(s) or the extent of subsurface contamination with vapor-forming chemicals; and

- A biologically active vadose zone that can significantly and persistently attenuate soil gas concentrations due to biodegradation, in which all appropriate conditions (e.g., nutrients, moisture, and electron acceptors, such as dissolved oxygen in the case of aerobic biodegradation) are readily available over a laterally extensive area.

EPA recommends demonstrating these characteristics, when present, by collecting, evaluating, and documenting multiple lines of evidence, as identified in Section 6.3.2. In addition, EPA recommends that any determination that the vapor intrusion pathway is incomplete be supported by site-specific evidence to demonstrate that:

- The nature and extent of vapor-forming chemical contamination in the subsurface has been well characterized, as discussed in Sections 6.3.1 and 6.4. Ideally, where groundwater is the source of vapors, the plume has been shown to be stable or shrinking to establish that the potential for vapor intrusion to pose a health concern will not increase in the future.

- The types of vapor sources and the conditions of the vadose zone and surrounding infrastructure do not present opportunities for unattenuated or enhanced transport of vapors toward and into any building (e.g., via a preferential migration route(s)), as discussed in Sections 5.4, 6.2.1, 6.3.2, and 6.5.2.

When the vapor intrusion pathway is determined to be incomplete, then vapor intrusion mitigation is not generally warranted under current conditions. EPA recommends that site managers also evaluate whether subsurface vapor sources that remain have the potential to pose a complete vapor intrusion pathway and unacceptable human health risk due to vapor intrusion in the future if site conditions were to change. For example, potentially unpredictable changes in the transitory soil characteristics (e.g., soil moisture) and soil gas concentrations may occur as a result of constructing a new building or supporting infrastructure. Either type of change could result in the potential for unacceptable human health risk due to vapor intrusion in the future.

Response actions may, therefore, be warranted to protect human health wherever and as long as subsurface vapor sources remain that have the potential to pose unacceptable human health risk in the future due to vapor intrusion. These response actions (see Section 7.7) may include institutional controls (see Section 8.6) (e.g., to record and alert parties about the presence of subsurface vapor sources and/or to inform the need for a confirmatory vapor intrusion investigation in case infrastructure or geologic conditions are modified in the future). In addition, subsurface remediation may be warranted to protect human health or the environment via other exposure pathways (e.g., groundwater discharge to surface water bodies), consistent with applicable statutes and considering EPA guidance.

7.4 Conduct and Interpret Human Health Risk Assessment

EPA generally recommends that a human health risk assessment be conducted to determine whether the potential human health risk posed to building occupants by a complete or potentially complete vapor intrusion pathway are within or exceed acceptable levels, consistent with applicable statutes[192] and considering EPA guidance (EPA 1991a, 2009c). The primary purpose of this risk assessment is to provide risk managers with an understanding of the actual and potential risks to human health posed by vapor intrusion under current and reasonably expected future conditions. This information may be useful in determining whether a current or potential future threat to human health exists, as described in Sections 7.4.1, 7.4.2, and 7.5.2,[193] which warrants response action(s), as described in Sections 7.7 and 8.

---

[192] In the RCRA corrective action program, any human health risk assessment would typically be conducted during the RCRA facility investigation, if a release to the environment is identified. Under the CERCLA remedial program, a human health risk assessment would typically be conducted during the remedial investigation and is generally referred to as a baseline (i.e., pre-cleanup) risk assessment.

[193] In appropriate circumstances (e.g., where time is of the essence to ensure protection of human health; see, for example, Section 7.5.2), a formal human health risk assessment need not be completed and documented before taking a response action, but a preliminary evaluation of human health risk using individual building data or aggregated community data is generally recommended (also see Section 7.8).

The human health risk posed to building occupants by intrusion of a given vapor-forming chemical will depend upon its toxicity, its concentration in indoor air, the amount of time the occupants spend in the building, and other variables (e.g., human life stage (e.g., child) can matter for some chemicals (e.g., those with a mutagenic mode of action for carcinogenicity)). EPA recommends that its risk assessment guidance (e.g., EPA 2009c, EPA 2003) be used to identify, develop, and combine information about these variables and characterize human health risk due to vapor intrusion from subsurface contaminant sources.

For the vapor intrusion pathway, the inhalation route is the primary means of human exposure. Therefore, the human health risk assessment uses estimates of indoor air exposure concentrations, exposure duration and frequency for building occupants, and the potential toxicity of the vapor-forming chemicals found in the subsurface (e.g., inhalation unit risk and noncancer reference concentration) to characterize risks of cancer and noncancer effects (EPA 2009c). Generally, exposure concentrations in existing buildings can be estimated using direct measurements of indoor air (see Sections 6.3.4 and 6.4.1). EPA recommends that time-integrated measurements from multiple sampling events be used to estimate exposure concentrations appropriate for the exposure (occupancy) scenario being evaluated (e.g., residential versus commercial), when the risk assessment for an existing building would support a conclusion that the human health risk is acceptable (see Section 7.4.1).[194,195] Generally, modeling would be used to conservatively estimate exposure concentrations under future conditions in buildings yet to be constructed in areas with subsurface contamination by vapor-forming chemicals (see Section 6.6). EPA recommends the noncancer assessment consider the potential for adverse health effects from short-duration inhalation exposures (i.e., acute, short-term, or subchronic exposure durations),[196] as well as longer term inhalation exposure (i.e., chronic exposure) conditions. EPA recommends that inhalation toxicity values be selected

---

[194] An individual sample, collected at a randomly chosen time, may under-estimate (or over-estimate) average and reasonable maximum exposure conditions. From their high-frequency, measured data, Holton et al. formulated a synthetic data set (simulating one-day-average concentrations), which they used to estimate that a single, randomly drawn, one-day sample had a forty percent chance of being less than the true mean (Holton et al. 2013b; see Table 1 therein). When the true mean was assumed to exceed the risk-based action level ("target concentration" in their parlance) by two or five times, they estimated that a single, randomly drawn, one-day sample had a twenty percent or six percent chance, respectively, of not detecting the exceedance. These data support EPA's recommendation to collect multiple rounds of indoor air sampling data to reduce the chance of reaching a false-negative conclusion (i.e., concluding exposure is at an acceptable risk level when it is not). Collecting multiple rounds of indoor air sampling can also reduce the chance of reaching a false-positive conclusion (i.e., concluding that vapor intrusion poses unacceptable human health risk when it does not), because an individual sample, collected at a randomly chosen time, may over-estimate the average and reasonable maximum exposure conditions.

[195] Given EPA's assigned mission to protect human health from environmental contamination and recognizing the disruption to building owners and occupants caused by indoor air sampling, risk managers may choose to pursue pre-emptive mitigation (i.e., early action) at some buildings (see Sections 3.3 and 7.8) rather than, for example, conduct multiple rounds of sampling over a few years to establish an estimate of long-term average exposure concentration and characterize temporal variability.

[196] The inhalation reference concentration (RfC) (expressed in units of mass concentration in air) is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Reference values may be derived for acute (≤24 hours), short-term (>24 hours, up to 30 days), subchronic (>30 days, up to approximately 10% of the life span), and chronic (greater than 10% of the life span) exposure durations, all of which are derived based on an assumption of continuous exposure throughout the duration specified. See http://www.epa.gov/ncea/iris/help_ques.htm#whatiris

considering OSWER's hierarchy of sources (EPA 2003) and that relevant existing guidance (e.g., EPA 2009c) be followed in situations where a desired toxicity value is not available.

When a single vapor-forming chemical is present in the subsurface and intrudes as a vapor into occupied building spaces, the noncancer human health risk can be characterized by calculating the noncancer hazard quotient (HQ) (EPA 2009c,Chapter 8). When multiple vapor-forming chemicals are present in the subsurface and intrude as vapors into occupied building spaces, the HQ estimates for each chemical are aggregated (as a simple sum, which is the Hazard Index (HI)), based upon the assumption that each chemical acts independently (i.e., there are no synergistic or antagonistic toxicity interactions among the chemicals). If the HI exceeds one, there may be concern for potential adverse non-cancer effects and risk assessors should consider segregating the chemicals by target organ or toxic effect to derive separate hazard index (HI) values for each (EPA 2009c, Chapter 8). EPA recommends that noncancer HQ and HI values be estimated for each type of exposure period identified in the conceptual site model or indicated by measurements of indoor air levels of vapor-forming chemicals (e.g., chronic, subchronic, short-term, acute), evaluating inhalation reference concentrations that "match the characterization of the exposure scenario" (EPA 2009c, Chapter 4).[197]

The carcinogenic risks can be characterized by calculating the excess cancer risk over a lifetime (LCR) and, if multiple vapor-forming chemicals are present, aggregating the LCR estimates for each carcinogen (as a simple sum), based upon the assumption that each chemical acts independently (EPA 2009c, Chapter 8).

A well-crafted risk characterization section (EPA 1992c, 1995ab, 2000b, 2009c) puts risk calculations into context for risk managers, so that they may effectively weigh and interpret risk assessment results and recognize key uncertainties (e.g., in the exposure and dose-response assessments and risk estimation).[198] Additional recommendations for promoting and increasing the utility and transparency of human health risk assessments can be found in *Framework for Human Health Risk Assessment to Inform Decision Making* (EPA-RAF, 2014).

---

[197] For example, when evaluating situations in which vapor concentrations in indoor air exceed the chronic reference concentration (see Section 7.4.1), and there are shorter periods of significantly higher vapor intrusion exposure, EPA recommends that noncancer risks for the shorter periods also be characterized using toxicity values appropriate for the respective period(s). On the other hand, if vapor concentrations in indoor air are consistently less than benchmarks for acceptable chronic exposure, then exposures for less-than-chronic scenarios are unlikely to pose unacceptable human health risk.

[198] For example, EPA recommends that the risk characterization for existing buildings describe the uncertainty in the exposure assessment arising from: (i) inherent variability of indoor air exposures over time and space; (ii) the match between the sampling data [e.g., sampling frequency (i.e., number of samples and time intervals between samples); and time period over which each sample was collected] and the exposure period represented by the selected toxicity value (e.g., chronic); and (iii) the ability to distinguish and apportion the contribution to indoor air concentrations arising from vapor intrusion versus background sources. EPA recommends that the risk characterization for future buildings describe the principal uncertainties in the exposure assessment, which may be associated with the type(s) of building use, building construction and operations (e.g., HVAC system), frequency and duration of occupancy, vapor concentrations in indoor air, or other factors.

EPA recommends that any human health risk assessment be documented; a summary in a decision document is also generally warranted.[199] EPA also recommends that human health risk information for individual buildings be communicated to building occupant(s) and owners. Section 9.4 provides additional information for communicating sampling results.

7.4.1 Risk Management Benchmarks

EPA recommends that OSWER programs make the risk management determination to take response action consistent with their statutes and regulations and considering existing program guidance.[200] The carcinogenic risk and non-cancer HI values used in this determination generally are the "cumulative risks" that include all exposure pathways that a given population may consistently face.[201] In making such risk management determinations, EPA generally recommends reporting the HQ and HI to one significant figure.

EPA generally uses a cancer risk range of 10^{-6} to 10^{-4} as a "target range" within which to manage human health risk as part of site cleanup. For judging whether indoor air exposures may pose acceptable health risk based upon potential non-cancer effects, EPA generally recommends that the target HQ or HI not exceed 1.

Once a decision has been made to undertake a response action, EPA has expressed a preference for cleanups that are at the more protective end of the cancer risk range. Thus, EPA recommends using an individual lifetime cancer risk of 10^{-6} as a point of departure for establishing cleanup levels based upon potential cancer effects (see Section 7.6).[202] The EPA risk manager may determine that a response action achieving reductions in human health risk

---

[199] Devices that have been found to improve comprehension and retention of textual materials include a table of contents, clear section headings, and a summary (Morgan et al. 1992). It is most helpful to provide a summary that translates the risk assessment into relatively simple language that non-expert risk managers, stakeholders, and wider audiences can understand (Lundgren and McMakin, 2013). Hazards and risks posed by vapor intrusion are more likely to be misunderstood or misinterpreted if they are not explained in simple terms.

[200] See, for example: *The Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*, OSWER Directive 9355.0-30, April 22, 1991 (EPA 1991a); *Rules of Thumb for Superfund Remedy Selection,* OSWER Directive 9355.0-69, August 1997 (EPA 1997); and Advanced Notice of Proposed Rulemaking: Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities (61 *Federal Register* 19432, May 1, 1996). So, for example, EPA cited OSWER Directive 9355.0-30 (EPA 1991a) in its *Compilation of Information Relating to Early/Interim Actions at Superfund Sites and the TCE IRIS Assessment* (EPA 2014b).

[201] In some site-specific situations, a population might be exposed to a substance or combination of substances through several exposure pathways (i.e., not only the vapor intrusion pathway). For example, individuals might be exposed to substance(s) from a contaminated site by consuming contaminated drinking water from a groundwater supply, as well as from vapor intrusion. Once reasonably expected exposure pathways have been identified, EPA recommends examining whether it is likely that the same individuals would consistently face the reasonable maximum exposure for each pathway or a combination of some of these pathways. Under such circumstances, the total exposure to each chemical would equal the sum of the exposures by all consistently faced pathways (EPA 1989, Section 8.3) and EPA recommends that the risk assessor clearly identify those exposure pathway combinations for which a total risk estimate or hazard index is being developed. When characterizing human health risk arising from multiple pathways and posed by a vapor-forming chemical(s) with potential adverse noncancer effects, EPA recommends that the toxicity values for each pathway "match the characterization of the exposure scenario" (EPA 2009c, Chapter 4).

[202] See: National Oil and Hazardous Substances Pollution Contingency Plan (55 *Federal Register* 8717); and Advanced Notice of Proposed Rulemaking: Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities (61 *Federal Register* 19432, May 1, 1996).

within the 10^{-6} to 10^{-4} cancer risk range is acceptable, however, depending on site-specific conditions or remedial factors.

For establishing cleanup levels based upon potential non-cancer effects, EPA generally recommends that the target HI not exceed 1 (see Section 7.6).

7.4.2 Accounting for Background Contributions

As noted previously, EPA recommends including in the human health risk assessment vapor-forming chemicals that are related to releases to the subsurface environment. Some of these vapor-forming chemicals may be present in indoor air due to 'background' sources (see Section 2.7). If data are available, EPA recommends that the contribution of 'background' to total exposure concentration(s) be distinguished in the human health risk assessment (EPA 2002e). If background vapor sources (see Glossary) are found to be primarily responsible for indoor air concentrations (see Section 6.3.5), then response actions for vapor intrusion would generally not be warranted for current conditions. In any event, EPA recommends that the risk characterization include a discussion of 'background' contributions to indoor air exposure and associated human health risk. With such information, EPA can help advise affected individuals about the environmental and public health risks they face that are within their control (e.g., indoor sources of vapor-forming chemicals in residences).[203] Other parties, including building owners and operators, may help with risk communication.

If 'background' contributions are unknown and such data are sought to support risk management decisions, EPA recommends that additional data be collected (see, for example, Section 6.3.5). Information on 'background' contributions of site-related, vapor-forming chemicals in indoor air is also important to risk managers because generally EPA does not clean up to concentrations below natural or anthropogenic background levels (EPA 2002e).

7.4.3 Occupational Exposure Limits

Permissible exposure limits (PELs) are enforceable occupational exposure standards developed by the Occupational Safety and Health Administration (OSHA) in the U.S. Department of Labor. Most of OSHA's PELs were adopted in 1971 from then-existing secondary guidance levels, such as Threshold Limit Values (TLVs) developed by the American Conference of Governmental Industrial Hygienists (ACGIH) to protect workers from adverse effects of occupational exposure to airborne chemicals. They were intended to protect workers against catastrophic effects (such as cardiovascular, liver, kidney, and lung damage), as well as more subtle effects (such as narcosis, central liver system damage, and sensory irritation).

PELs (and TLVs), however, are not intended to protect sensitive workers, may not incorporate the most recent toxicological data, and may differ from EPA derivations of toxicity values with respect to weight-of-evidence considerations and use of uncertainty factors. For these and other

---

[203] In cases where 'background' contamination (e.g., due to indoor use of a consumer product or household chemical in a residence) may pose a human health risk, but its remediation is beyond the authority of the applicable statute, risk communication to the public may be most effective when coordinated with public health agencies (EPA 2002e).

reasons,[204] EPA does not recommend using OSHA's PELs (or TLVs) for purposes of assessing human health risk posed to workers (EPA 1991c, Appendix C) by the vapor intrusion pathway or supporting final "no-further-action" determinations for vapor intrusion arising in nonresidential buildings. Rather, EPA's recommendations for assessing human health risk posed by vapor intrusion are set forth herein in Sections 7.4.1 and 7.4.2.

7.5 Concentration Levels Indicating Potential Need for Prompt Response Action

In some circumstances, human health risk arises from vapor intrusion, which warrants prompt response action. This Section provides some recommendations for identifying such circumstances.

7.5.1 Potential Explosion Hazards

EPA recommends using the chemical-specific LELs[205] to identify potential explosion hazards (e.g., for methane and other petroleum hydrocarbons). Whenever building-specific data (such as results from sub-slab soil gas samples and crawl space samples for any building type, indoor air samples from sheds or pump houses, or gas samples from confined or semi-confined spaces (e.g., sewers)) exceed one-tenth (10%) of the LEL for any chemical, a hazard is indicated that generally warrants prompt action.[206,207] EPA recommends to building owners and occupants the evacuation of buildings with potential explosion and fire hazards, along with immediate notification to the local fire department about the threat. Construction and operation of engineered systems that can reduce or eliminate intrusion of explosive vapors into existing buildings or unoccupied structures may also warrant consideration to reduce the potential for future explosion hazards.

7.5.2 Considering Short-term and Acute Exposures

EPA may identify health-protective concentration levels for vapor-forming chemicals based upon potential noncancer health effects that can be posed by air exposures over short-term or acute exposure durations, considering EPA guidance for human health risk assessment (e.g., EPA

---

[204] OSHA's website (May 2015) currently states: "OSHA recognizes that many of its permissible exposure limits (PELs) are outdated and inadequate for ensuring protection of worker health. Most of OSHA's PELs were issued shortly after adoption of the Occupational Safety and Health (OSH) Act in 1970, and have not been updated since that time. Since 1970, OSHA promulgated … new PELs for 16 agents, and standards without PELs for 13 carcinogens. Industrial experience, new developments in technology, and scientific data clearly indicate that in many instances these adopted limits are [also] not sufficiently protective of worker health. This has been demonstrated by the reduction in allowable exposure limits recommended by many technical, professional, industrial, and government organizations, both inside and outside the United States." [On-line source: https://www.osha.gov/dsg/annotated-pels/] On October 10, 2014, OSHA issued a Chemical Management Request for Information (79 FR 61384), in which it acknowledges many of its PELs are not sufficiently protective and seeks comment on strategies to address this problem; available on-line at: https://www.osha.gov/FedReg_osha_pdf/FED20141010.pdf

[205] The Vapor Intrusion Screening Level Calculator (EPA 2015a) provides LELs for vapor-forming chemicals to facilitate identification of potential explosion hazards.

[206] NIOSH has designated such concentrations as immediately dangerous to life or health (IDLH).

[207] Although the building-specific data may vary temporally, any short-term exceedance of one-tenth of the LEL indicates vapor concentrations that, given an ignition source and available oxygen, may be capable of causing an explosion.

2009c) and using sources of toxicity information considering OSWER's hierarchy (EPA 2003). For example, subchronic reference concentrations, developed by the EPA Office of Research and Development/National Center for Environmental Assessment/ Superfund Health Risk Technical Support Center (STSC), are currently available for some vapor-forming chemicals as Provisional Peer Reviewed Toxicity Values (PPRTVs), which are designated as a Tier 2 source of toxicity values by OSWER (EPA 2003). Acute and intermediate Minimal Risk Levels (MRLs)[208] adopted by the Agency for Toxic Substances and Disease Registry (ATSDR) are currently available for some vapor-forming chemicals and are designated as a Tier 3 source of toxicity values by OSWER (EPA 2003). PPRTVs and ATSDR MRLs are peer reviewed and are publicly available (see, http://hhpprtv.ornl.gov/ and http://www.atsdr.cdc.gov/mrls.html).

Historically, toxicity values for short-term or acute exposure durations have not been derived or published in EPA's IRIS, which otherwise is EPA's preferred source of toxicity values (EPA 2003). EPA, under its authority, will work to develop expanded science policy direction to address short-term exposures and develop and identify appropriate toxicity values for additional chemicals for consideration for vapor intrusion assessment and related OSWER regulatory frameworks. EPA recommends that relevant existing guidance (e.g., EPA 2009c) be followed in situations where a desired toxicity value is not available, using sources of toxicity information considering OSWER's hierarchy (EPA 2003).

Although the indoor air concentrations may vary temporally, an appropriate exposure concentration estimate (e.g., time-integrated or time-averaged indoor air concentration measurement in an occupied space – see Section 6.4.1) that exceeds the health-protective concentration levels for acute or short-term exposure (i.e., generally considered to be a hazard quotient (HQ) greater than one for an acute or short-term exposure period)[209] indicates vapor concentrations that are generally considered to pose an unacceptable human health risk.[210]

As noted in Section 7.4 of this Technical Guide, a well-crafted risk characterization section (EPA 1992c, 1995ab, 2000b, 2009c) puts risk calculations into context for risk managers, so that they may effectively weigh and interpret risk assessment results and recognize key uncertainties (e.g., in the exposure and dose-response assessments and risk estimation). Uncertainties include the derivation of an RfC, which is defined as "…an estimate (with uncertainty spanning perhaps an order of magnitude)…" (See http://www.epa.gov/ncea/iris/help_ques.htm#whatiris). Sections 3.3 and 7.7 identify other EPA-recommended considerations for risk managers.

When indoor air concentrations in an occupied space exceed health-protective concentration levels for short-term or acute inhalation exposures arising from a complete vapor intrusion

---

[208] Minimal Risk Levels (MRLs) published by ATSDR are estimates of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure. The ATSDR MRLs are peer reviewed and are publicly available (http://www.atsdr.cdc.gov/mrls.html).

[209] See Glossary for definitions of "acute" and "short-term" exposure durations.

[210] See, for example: *The Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*, OSWER Directive 9355.0-30, April 22, 1991 (EPA 1991a); and *Rules of Thumb for Superfund Remedy Selection,* OSWER Directive 9355.0-69, August 1997 (EPA 1997). In addition, the NCP states "For systemic toxicants, acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety" [40 *CFR* 300.430(e)(2)(i)(1)].

pathway, ventilation, indoor air treatment, temporary relocation, and other response actions may be implemented to reduce or avoid these threats promptly (see Section 8.2.1). Construction and operation of engineered systems that can reduce or eliminate vapor intrusion into existing buildings (see Section 8.2) may also warrant consideration after urgent threats to human health have been addressed.

7.6 Risk-based Cleanup Levels

When response action is determined to be warranted to reduce or eliminate indoor air exposures from vapor intrusion (see Sections 7.4 and 7.5), EPA recommends that cleanup levels be established and documented consistent with statutes and regulations and considering guidance for the respective OSWER program.[211] These cleanup levels would be used to evaluate when building mitigation measures, subsurface remediation, and associated monitoring can be terminated and to assess cleanup progress in the meantime (see Section 8.7).

Candidate risk-based cleanup levels can be calculated using information from the risk assessment (Section 7.4). Results of the human health risk assessment indicate, for example, which site-related vapor-forming chemicals warrant building mitigation and subsurface remediation. The exposure factors and toxicity values used in the human health risk assessment can be used to calculate chemical-specific cleanup levels, considering EPA risk assessment methods (e.g., EPA 2009c, EPA 2003). Candidate cleanup levels are usually developed for potential cancer and non-cancer effects. The lower (or lowest if there are multiple potential non-cancer effects) of the candidate values, based upon cancer risk and non-cancer HQ/HI targets, is generally recommended for selection as the cleanup level (EPA 1991c, Section 3.4 therein).[212] The VISL Calculator (http://www.epa.gov/oswer/vaporintrusion/guidance.html) can be used to support these calculations, including input of alternative attenuation factor(s) based upon site- or building-specific information.

Calculating candidate cleanup levels based upon potential cancer effects entails selecting a target cancer risk. As noted above (Section 7.4.1), once a decision has been made to undertake a response action, EPA has expressed a preference for cleanups achieving the lower end of the cancer risk range (i.e., 10^{-6}) (EPA 1991a). Response actions achieving reductions in human health risk anywhere within the cancer risk range may be deemed acceptable by the EPA risk manager, however.

To protect human health from potential noncancer effects, EPA generally recommends using a target value of one for the non-cancer HQ (if there is a single vapor-forming chemical of health concern for vapor intrusion) or for the non-cancer HI (if there are multiple vapor-forming chemicals of health concern for vapor intrusion acting by a common effect).

---

[211] See, for example: *RCRA Corrective Action Plan (Final),* OSWER Directive 9902.3-2A (EPA 1994); and *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents,* OSWER Directive 9200.1-23P (EPA 1999b).

[212] An exception arises when 'background' sources pose elevated exposures, because generally EPA does not clean up to concentrations below natural or anthropogenic background levels (EPA 2002e).

Cleanup levels for indoor air can be readily calculated, as described above, without additional assumptions or modeling about vapor intrusion processes. On the other hand, cleanup levels for groundwater and/or soil gas in the vadose zone will entail developing a medium-specific vapor attenuation factor, which EPA recommends be conservatively estimated based upon site-specific information. The cleanup level for soil gas can be calculated by dividing the chemical-specific indoor air cleanup level by the site-specific soil gas vapor attenuation factor. The cleanup level for groundwater can be calculated by dividing the chemical-specific indoor air cleanup level by the site-specific vapor attenuation factor for groundwater vapors and assuming equilibrium between the aqueous and vapor phases at the groundwater table. EPA recommends that site-specific attenuation factors intended to be protective of chronic exposure conditions: be conservatively estimated when based upon mathematical models; and be based upon multiple measurements of indoor air concentration in different seasons, which have negligible influences from ‘background’ sources, when based upon site-specific measurements.

EPA recommends that cleanup levels be documented with at most two significant figures, even though some of the input values may carry additional significant figures (EPA 1991b, see page 19).

7.7 Options for Response Action

When response action is determined to be warranted to reduce or eliminate indoor air exposures from vapor intrusion (see Sections 7.4 and 7.5), EPA recommends that OSWER programs select, recommend, and document response action(s) consistent with statutes and regulations and considering their existing program guidance.[213]

The selection of a health-protective interim response action(s) for existing buildings will generally depend on site-specific considerations, which can include: nature of subsurface vapor source (e.g., groundwater, vadose zone soils, sewer lines), magnitude of the exposure above cleanup levels; the severity of the potential adverse health effects or health hazard; building features and conditions (e.g., construction; heating, ventilation, and air conditioning equipment); climate and season (which influence the feasibility of ventilation, for example); the quality of ambient air in the vicinity; and the feasibility of implementing a given option quickly.[214] In general, EPA recommends that response actions limit the amount of time individuals are exposed to concentrations that correspond to unacceptable human health risk, as described in Sections 7.4 and 7.5.

---

[213] See, for example: *RCRA Corrective Action Plan (Final),* OSWER Directive 9902.3-2A (EPA 1994); and *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents,* OSWER Directive 9200.1-23P (EPA 1999b).

[214] Most response actions cannot be implemented immediately upon determining that a response is warranted. For example, engineered exposure controls ordinarily entail from two to four weeks of lead time (at a minimum) for planning, design, any permit acquisition, material acquisition and construction. In many circumstances, ventilation measures to reduce exposure can be implemented more quickly, but local climate or air quality may render this option less attractive during some seasons.

TABLE 7-1
MATRIX OF OPTIONS TO RESPOND TO HUMAN HEALTH RISK POSED BY THE VAPOR INTRUSION PATHWAY

Option for Response Action	Applicability of Response Action for Common Sources of Sub-surface Vapors		
	Groundwater	Vadose Zone Soil	Sewer & Drain Lines
Remediation of Source*	•	•	•
Removal of contaminated soil via excavation	#	•	
Treatment of contaminated soil *in situ*	#	•	
Treatment of contaminated groundwater *in situ*	•		
Removal of contaminated groundwater (e.g., pump-and-treat)	•		
Decontaminating and/or rehabilitating sewer and drain lines			•
Interim Measures to Reduce or Eliminate Vapor Intrusion*	•	•	•
Subslab de-pressurization and ventilation systems	•	•	
Sealing major openings for soil gas entry, where known and identified+	•	•	
Building over-pressurization	•	•	
Installing, repairing, or maintaining vapor traps			•
Interim Measures to Reduce or Avoid Exposure to Vapors	•	•	•
Notification to local fire department about potential explosion hazards+	•	•	•
Notification and risk communication to building occupants and owners, including institutional controls (e.g., deed notices)	•	•	•
Increasing building ventilation*	•	•	•
Treating indoor air*	•	•	•
Temporary relocation+	•	•	•
Monitoring Indoor Air to Characterize Human Exposure	•	•	•

KEY: • designates potentially appropriate response action for indicated vapor source

FOOTNOTES:

* includes: associated institutional controls to maintain operations and provide public notification of residual contamination; and associated monitoring to assess effectiveness and protectiveness of the response action

remediation of soil may also be warranted for purposes of protecting groundwater from further contamination, even if contaminated soil in the vadose zone is not a source for vapor intrusion directly (e.g., due to the absence of an existing building near the contaminated soil)

\+ response option primarily applies to existing buildings

Table 7-1 presents an overview of key candidate response options for the vapor intrusion pathway, which are discussed further in Section 8. Response actions that may be recommended for and implemented in existing buildings include:

- Interim measures that can be implemented relatively quickly (see Section 8.2.1), if prompt action is warranted to reduce or eliminate exposures to vapor-forming chemicals (see Sections 5.2 and 7.5.2) or to mitigate explosion hazards (see Section 7.5.1);
- Engineered exposure controls (see Section 8.2.2) with associated monitoring and institutional controls (see Section 8.6), as an interim (but potentially long-term) measure to reduce or eliminate vapor intrusion into buildings; and
- Remediation of the subsurface vapor source (see Section 8.1) with associated monitoring and institutional controls (see Section 8.6).

Response actions that may be warranted in buildings that may be constructed in the future include:

- Remediation of the subsurface vapor source (see Section 8.1) with associated monitoring and institutional controls (see Section 8.6); and
- Institutional controls (see Section 8.6) to inform the need for building mitigation (see Section 8.2.2) and/or a confirmatory vapor intrusion investigation before the building is occupied, in case the building is to be or may be constructed before subsurface vapor sources are remediated to cleanup levels.

Indoor air monitoring has frequently been selected as a response action in circumstances where subsurface vapor sources are present and the vapor intrusion pathway has not been shown to be incomplete. Indoor air monitoring may be deemed warranted, for example:

- To better characterize spatial or temporal variability;
- To address uncertainty in the characterization of the vapor intrusion pathway when subsurface vapor sources have the potential to pose a health concern in overlying or nearby buildings (e.g., incomplete pathway characterization, concern about the potential for changes in building conditions, discordant lines of evidence); or
- For other site-specific or situation-specific reasons.

EPA generally prefers to obtain building access and undertake response actions through consent and cooperation from building owners, tenants, and other stakeholders (see Section 1.2).

7.8 Pre-emptive Mitigation/Early Action

It may be appropriate to implement mitigation of the vapor intrusion pathway as an early action, even though all pertinent lines of evidence have not yet been completely developed to characterize the vapor intrusion pathway for the subject building(s), when sufficient site-specific data indicate that vapor intrusion: (1) is occurring or may occur due to subsurface contamination that is being addressed by federal statutes, regulations, or guidance for environmental protection; and (2) is posing or may pose a health concern to occupants of an existing building(s). Likewise, it may be appropriate and cost-effective to design, install, operate, and monitor mitigation systems (including passive barrier systems) in newly constructed buildings (or buildings planned for future construction) that are located in areas of vapor-forming subsurface contamination, rather than allow vapor intrusion (if any) to occur and address vapor intrusion after the fact. As described in Section 3.3, preemptive mitigation/early action is the term used to describe both situations.

Preemptive mitigation (PEM) is recognized as an early action that is intended to ensure protectiveness of human health. In this context and as described further in Section 8.2, mitigation refers to methods that seek to:

- Prevent or reduce vapor entry into a building.
- Reduce or eliminate vapors that have entered a building.

Note that the selection and implementation of PEM, when it occurs, is not necessarily intended to pre-judge final decisions about remediation of subsurface vapor sources; however, EPA generally recommends that decision-making about PEM include a consideration of the O&M and monitoring obligations. In addition, EPA recommends that the selection of PEM be based upon data and information in the administrative record and be documented in the administrative record, consistent with statutes and regulations and considering EPA guidance for the respective land restoration program (e.g., CERCLA, RCRA corrective action, brownfields, etc.), in order to provide an adequate basis for actions undertaken.

7.8.1 Rationale

In ensuring protectiveness of human health, PEM generally may be an appropriate approach to consider for buildings with potential vapor intrusion for a number of reasons, including:

- Building mitigation typically is an effective means of protecting human health and is cost effective for many buildings.
- The potential exposure scenario (e.g., inhalation of potentially toxic vapors) cannot generally be readily avoided by building occupants.
- Involuntary and unavoidable exposures and hazards are generally sources of anxiety and concern for affected building occupants and the general public, particularly when they occur in homes and in the workplace.
- Comprehensive subsurface characterization and investigations of vapor intrusion (to conclusively characterize unacceptable, but variable, levels of vapor-forming chemicals in soil, groundwater, and indoor air, as described in Section 6) can entail prolonged study periods, during which building occupants may be exposed and owners and environmental stewardship groups may remain anxious and concerned about potential indoor air exposures to subsurface vapors in the absence of mitigation.
- Conventional vapor intrusion investigations in and of themselves can be disruptive, particularly when indoor access is sought to acquire interior samples and assess interior building conditions.

- Mitigation can typically be implemented relatively quickly, while subsurface contamination is being more fully delineated or remediated.

- EPA's experience with residential communities suggests that many affected residents seek and prefer that mitigation systems be installed when vapor intrusion is suspected.

- Mitigation can be a cost-effective approach to help ensure protectiveness of human health during ongoing vapor intrusion investigations to acquire multiple lines of evidence and characterize spatial and temporal variability in subsurface and indoor air concentrations, as well as while subsurface remediation is being planned and conducted to reduce or eliminate subsurface vapor sources.

In summary, PEM, based on limited but credible subsurface and building data, can be an appropriate approach to begin to implement response actions quickly and ensure protectiveness of current building occupants. In such circumstances, resources can be used appropriately to focus first on mitigation of buildings and subsurface remediation, rather than site and building characterization efforts, which may be prolonged. Although PEM may be an effective tool to reduce the human exposure and human health risk, building mitigation is not generally intended to address the subsurface vapor source; as such, EPA recommends that it typically be used in conjunction with remediation of the subsurface source of vapor-forming chemicals (e.g., source removal or treatment), as discussed in Section 8.1.

7.8.2 General Decision Framework

To consider PEM, EPA recommends that reliable data supporting a preliminary analysis, as described in Section 5.0, and risk-based screening, as described in Section 6.5, be obtained and documented in the administrative record. In appropriate circumstances (e.g., where time is of the essence to ensure protection of human health; see, for example, Section 7.5.2), a formal human health risk assessment need not be conducted and documented before selecting PEM, but a preliminary evaluation of human health risk using individual building data or aggregated community data is generally recommended. If there are insufficient data to perform a preliminary risk analysis, but subsurface vapor sources are known to be present near buildings (see Section 5.3), EPA recommends that an appropriate vapor intrusion investigation (see Section 6) be conducted to obtain sufficient data.

EPA generally recommends that the decision to undertake building mitigation be supported by appropriate lines of site- or building-specific evidence (e.g., characterization of subsurface vapor source(s) strength and proximity to building(s); building conditions) that demonstrate that vapor intrusion has the potential to pose an unacceptable human health risk. Sections 5, 6, and 7 herein provide information about the types of evidence obtained and relied upon in assessing vapor intrusion potential and the types of analyses that can support determinations of whether the vapor intrusion pathway is complete for a specific building or collection of buildings and poses or has the potential to pose a health concern to building occupants. This information is equally pertinent for supporting final remediation and mitigation decisions and for supporting PEM consistent with applicable statutes and regulations. The premise of PEM, however, is to protect human health first without necessarily waiting to collect all lines of pertinent evidence or multiple rounds of sampling data.

Certain types of subsurface conditions may have greater potential to facilitate vapor intrusion when subsurface sources of vapors are present. These conditions include, but are not limited to:

- Shallow aquifers (for example, five feet or less from the building foundation to the seasonal high water table).
- High-permeability (e.g., gravelly) vadose zone soils that are fairly dry, which are favorable to upward migration of gases.
- Preferential migration routes, such as fractured sediments or bedrock, buried streambeds, subsurface drains, and utility conduits, as they can facilitate vertical or lateral migration of vapor with limited attenuation of chemical concentrations.

Under these conditions, it may be easier to determine that PEM may be warranted if a structure is located near a subsurface vapor source that has the potential to pose an unacceptable human health risk. Other factors to consider include the following:

- Susceptibility to soil gas entry. Some buildings have greater potential for vapor intrusion (i.e., are more susceptible to soil gas entry; see Section 2.3) than others. For example, buildings with deteriorating basements or dirt floors generally provide poor barriers to vapor (soil gas) entry. Buildings with sumps or other openings to the subsurface that can facilitate soil gas entry are also more susceptible to vapor intrusion.
- Actions undertaken or planned to address the subsurface source of vapors. For example, if the source of vapors (e.g., contaminated soil in the vadose zone) is being removed (e.g., excavation of contaminated soil or soil vapor extraction underneath the building) or is to be removed within a time frame that is protective for any potential current or near-term exposures in the overlying or nearby building, then PEM may not be warranted.

7.8.3 Some General Scenarios Where Pre-emptive Mitigation May be Warranted

Three general scenarios where PEM may be warranted are summarized below. The first two scenarios address situations where building(s) currently exist, while the third scenario addresses a situation where building(s) may be constructed in the future.

Site with High Potential to Facilitate Vapor Intrusion. In this scenario, indoor air concentration data have not been collected, but other lines of evidence support a conclusion that the vapor intrusion pathway is likely complete and may pose an unacceptable human health risk. Figure 7-1 shows a hypothetical residential area located near a shopping center that contains an active dry-cleaning facility. In this hypothetical example, a sufficient number of appropriately screened monitoring wells have been installed throughout the neighborhood to characterize a historical groundwater plume emanating from the dry cleaner that has migrated under eight homes and continues to migrate. Groundwater is encountered at approximately five feet below ground surface, and site geology consists of dry gravel and sands. "Near-source" soil gas samples have also been collected from several locations throughout the neighborhood and found to corroborate a high-strength vapor source near the buildings. All homes have crawl spaces with dirt floors. In this hypothetical example, PEM may be warranted for the eight buildings located above, near, or downgradient of the groundwater plume, based on the groundwater concentration and soil gas data available (i.e., PCE concentrations significantly exceeding screening levels in this example),[215] and the likelihood that the proximity of the groundwater table, characteristics of the vadose zone, and building conditions will collectively facilitate vapor migration and intrusion.

Note that if a groundwater restoration system is constructed and operated and plume migration is thereby controlled, additional buildings downgradient of the plume may not warrant PEM in the future. In the meantime, an IC may be appropriate for the undeveloped parcel hydraulically down-gradient of the current leading edge of the plume.

<u>Site with Indoor Air Data for Some Buildings but Not for All Buildings</u>. Depending on individual owners and occupants in the affected community, it may be difficult to obtain adequate data for all buildings within a specified area. Challenges include gaining timely access into each building and other practical considerations. In such circumstances, it may be appropriate to characterize a limited number of buildings under a reasonable maximum vapor intrusion condition,[216] by collecting and weighing multiple lines of evidence, and then extrapolating those findings to similar buildings nearby. The following hypothetical scenario describes one such situation, which is represented in Figure 7-2. In this hypothetical example, a sufficient number of appropriately screened monitoring wells have been installed throughout the neighborhood to characterize a historical groundwater plume. “Near-source” soil gas samples have also been collected from several locations throughout the neighborhood and found to corroborate the measured groundwater concentrations. Indoor air has been sampled and analyzed for a few homes and found to exhibit concentrations that pose an unacceptable human health risk. In this scenario, the assumption can be made that buildings with similar construction and built about the same time may have similar susceptibility to soil gas entry. As a result, it may be determined to use a PEM approach to offer mitigation systems to all buildings within a specified area of subsurface contamination.

---

[215] Several site-specific factors render inappropriate the use of the recommended attenuation factors and groundwater and soil gas VISLs for purposes of identifying sites or buildings unlikely to pose a health concern through the vapor intrusion pathway, as discussed in Section 6.5.2. Nevertheless, response actions for vapor intrusion can be supported when the groundwater and soil gas VISLs are exceeded for samples from a building or site where these specific factors are present.

[216] EPA recommends basing decisions about whether to undertake response action for vapor intrusion (i.e., a component of risk management) on a consideration of a reasonable maximum exposure (e.g., EPA 1989, 1991a), which is intended to be a semi-quantitative phrase, referring to the lower portion of the high end of the exposure distribution (see Glossary).

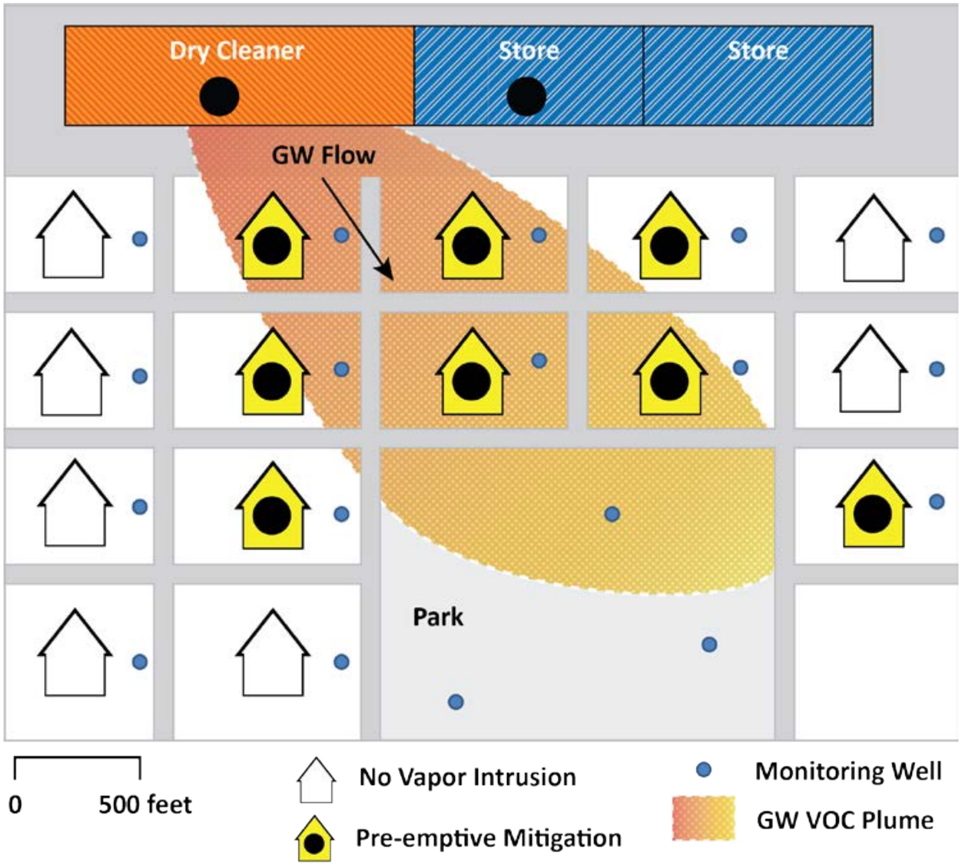


Figure 7-1 Sample Depiction of Subsurface Vapor Source and Data to Support Pre-emptive Mitigation/Early Action for Multiple Buildings, Each with Limited Data

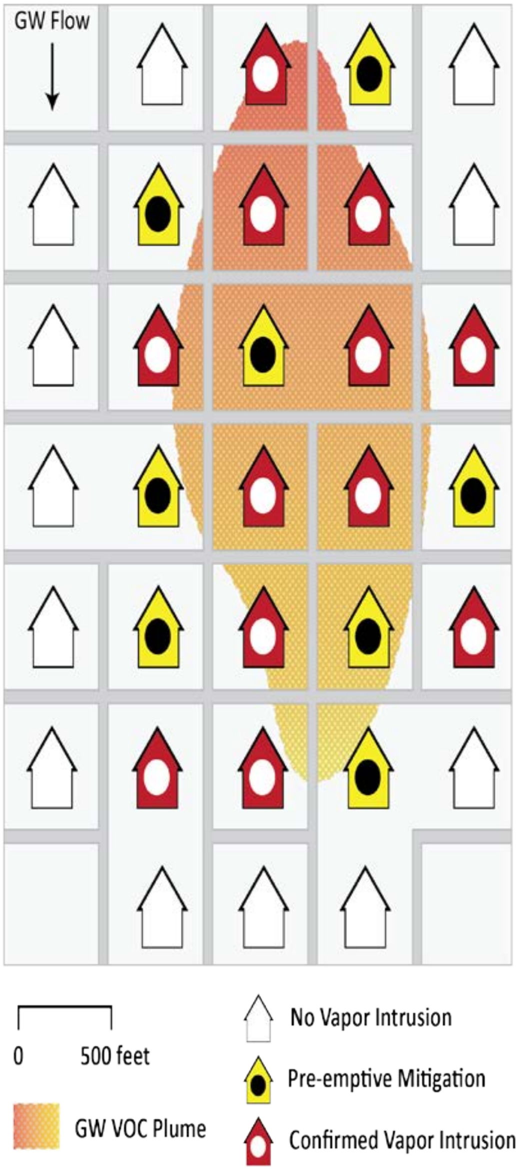


Figure 7-2 Sample Depiction of Subsurface Vapor Source and Data to Support Pre-emptive Mitigation/Early Action for Multiple Buildings, Some with Only Limited or No Data

Future Construction and Development. If current data (e.g., "near-source" soil gas) indicate that there is potential for unacceptable human health risk arising from vapor intrusion in an area where a building(s) is expected to be constructed in the future, EPA recommends that the remediation decision document record the known facts and data analyses and clearly state that vapor intrusion mitigation or site re-evaluation may be needed when the property is developed or occupied. EPA generally recommends appropriate ICs to ensure enforcement of such remediation decisions.[217]

Prior site use (see Section 5) can be particularly relevant where residential development is planned or occurring on property formerly used for commercial or industrial purposes. In these situations, it is not uncommon for residual NAPLs or shallow plumes to remain. Under this circumstance, PEM may be warranted for new construction as a precautionary measure without direct evidence of a vapor intrusion pathway. Incorporating mitigation systems into newly constructed buildings is generally easier to implement and incurs lower cost when compared with retrofitting existing structures.

On the other hand, if response actions to treat or remove the subsurface vapor source(s) are being conducted or will be conducted before a building is constructed and occupied, then building mitigation for the vapor intrusion pathway may not be warranted in the future.

7.8.4 Additional Considerations

EPA recommends that the following factors also be considered in evaluating PEM and determining whether to implement it.

Weighing Relative Costs of Characterization versus Engineered Exposure Controls. EPA recommends that cost not be the primary criterion for deciding whether or how to mitigate vapor intrusion because protection of human health could be compromised. On the other hand, cost effectiveness is addressed by CERCLA and the NCP and can be an important consideration when evaluating response alternatives. Cost can be a factor in deciding when and whether to pursue PEM, in relation to continuing to investigate and assess actual or potential vapor intrusion, and in ensuring effective human health protection through installing and operating a vapor intrusion mitigation system. At PRP-lead sites, for example, PEM may be viewed favorably where the costs associated with a complete site characterization or continued monitoring are estimated to easily exceed the cost of installing a mitigation system (and associated system monitoring). The number of buildings that would need to be characterized, or the order of priority, may be a factor in considering whether to implement PEM.

Institutional Controls. For existing vapor intrusion mitigation systems, ICs may be warranted to ensure that the system is operated, maintained, and monitored. Maintenance and monitoring of the mitigation system, which are discussed in Sections 8.3 and 8.4 of this document, are generally appropriate to ensure that the system is performing as intended. In addition, ICs may facilitate access to property to conduct routine maintenance and monitoring activities, although

---

[217] At undeveloped sites, or at sites where land use may change in the future, ICs may be important to ensure that the vapor intrusion pathway is effectively addressed in the future. ICs at undeveloped sites could include mechanisms to inform the need for PEM in new buildings. Selecting and implementing PEM for new buildings avoids some of the difficulties associated with attempting to predict the potential for vapor intrusion prior to building construction.

separate access agreements also warrant consideration. Additional information regarding ICs is provided in Section 8.6 of this document.

Community Input and Preferences. Community acceptance of early action may vary widely, depending on the human health risk to building occupants and past experiences at the site, including interaction with site stakeholders and regulators and perceptions of the site. Some owners and occupants may view PEM as a precautionary measure and be willing to have mitigation systems installed; some may even request them before characterization is completed. On the other hand, some home owners may not agree to have a mitigation system installed unless the pathway is demonstrated to be complete.

Others may be reluctant to install mitigation systems because of the operation costs or the inconvenience associated with the installation and subsequent monitoring. Although some owners may view mitigation systems as an advantage when they sell a property, others may be concerned with the possible negative effect on property values.

Issues and concerns about equity and fairness can also arise when some homes within a neighborhood receive mitigation systems and others do not. In some situations, it may be easier to persuade property owners to install vapor intrusion mitigation systems if the entire street, block, or neighborhood is found to warrant early action.

Public meetings and one-on-one meetings provide opportunities to discuss PEM with affected property owners and building occupants and obtain information and input. Section 9.0 of this document provides additional information about community involvement and engagement.

Refined Conceptual Site Model

Decisions to undertake pre-emptive mitigation may warrant re-evaluation as additional monitoring and/or site and/or building characterization data become available and are evaluated in the context of the conceptual site model. If and when such data shift the weight of evidence towards a conclusion that the vapor intrusion pathway is incomplete or otherwise does not pose unacceptable health risk, then EPA recommends re-considering whether continued operation, maintenance, and monitoring of the interim response action (Section 8.2) is warranted.

8.0 BUILDING MITIGATION AND SUBSURFACE REMEDIATION

This section summarizes information and recommendations on potential response options to mitigate and manage vapor intrusion. It is organized as follows:

- Section 8.1 summarizes the role of subsurface remediation in mitigating vapor intrusion.
- Section 8.2 provides an overview of engineered exposure controls (i.e., building mitigation technologies) for existing and new buildings.
- Sections 8.3 and 8.4 summarize information about operating and monitoring building mitigation systems, respectively.
- Section 8.5 summarizes information about documenting building mitigation systems.
- Section 8.6 describes and provides information about institutional controls (ICs).
- Section 8.7 provides information about exit strategies (e.g., termination of: subsurface remediation for vapor source control; building mitigation system operation; and associated ICs).

Sections 5.2, 7, and 9 discuss potential bases for deciding to implement response options for vapor intrusion. Sections 3.3 and 7.7 introduced some of the response options and policies discussed in the remainder of this Section regarding components and development of cleanup plans.

8.1 Subsurface Remediation for Vapor Source Control

The preferred long-term response to the intrusion of vapors into buildings is to eliminate or substantially reduce the level of contamination in the subsurface vapor source (e.g., groundwater, subsurface soil, sewer lines) by vapor-forming chemicals to acceptable-risk levels, thereby achieving a permanent remedy. Remediation of the groundwater plume or a source of vapor-forming chemicals in the vadose zone will eventually eliminate potential exposure pathways and can include the following actions, among others:

- Removal of contaminated soil via excavation;
- Removal of contaminated groundwater with pump-and-treat approaches;
- Decontaminating and/or rehabilitating sewer lines that harbor vapor-forming chemicals; and
- Treatment of contaminated soil and groundwater *in situ*, using technologies such as soil vapor extraction, multiphase extraction, and bioremediation, or natural attenuation.

Because there is a substantial body of EPA and other guidance on selection, design, construction, and operation of technologies for remediation of subsurface vapor sources (e.g., EPA 1993b, 2006c; NRC 2004), these topics are not discussed further here.

When monitoring to assess the performance and effectiveness of remediation technologies for subsurface vapors, EPA recommends employing the methods, approaches, and recommendations described in Sections 5.4, 6.2, 6.4 and 7.0 of this Technical Guide.

ICs may be necessary to help ensure the continued integrity of the cleanup. In some cases, therefore, ICs such as zoning or deed restrictions, may accompany implementation of vapor source remediation methods. Section 8.6 provides information about ICs and their application to the vapor intrusion pathway.

8.2 Building Mitigation for Vapor Intrusion

In cases where subsurface vapor sources cannot be remediated quickly, it may be appropriate to also undertake (interim) measures in individual occupied buildings (i.e., building mitigation for vapor intrusion) to reduce threats to human health more quickly. EPA recommends that building mitigation for vapor intrusion be regarded as an interim action that can provide effective human health protection, which may become part of a final cleanup plan. Mitigation of vapor intrusion in specific buildings generally is not a substitute for remediation of subsurface vapor sources. Thus, EPA recommends that building mitigation generally be conducted in conjunction with vapor source remediation where at all possible.

The purpose of this section is to provide an overview of vapor intrusion mitigation for new and existing buildings where response action is determined to be warranted. Section 8.2.1 summarizes response options that generally can be implemented relatively quickly to reduce indoor air concentrations. Section 8.2.2 identifies and summarizes the most commonly implemented engineered control methods for reducing vapor intrusion into existing buildings. Section 8.2.3 identifies and describes some approaches and considerations for addressing vapor intrusion for new buildings. Additional detailed information about technologies for reducing vapor intrusion into buildings and their selection, design, operation, and monitoring is provided in other EPA documents (EPA 1993a, 2008c). Building owners and occupants may find EPA's *Consumer's Guide to Radon Reduction* (EPA 2013b) a useful source of additional information, in light of similarities in technologies for reducing vapor intrusion and radon intrusion.

ICs may be necessary to help ensure the continued integrity of building mitigation systems. In many cases, therefore, ICs may accompany implementation of engineered exposure controls, for example to ensure that an active system remains operational and passive membranes are not disturbed (EPA 2008c). Additional information about ICs is provided in Section 8.6.

8.2.1 Prompt Response Options for Existing Buildings

For buildings with potential explosion and fire hazards, EPA recommends evacuation, along with notification of the local fire department about the threat. If, on the other hand, prompt action is warranted to reduce or eliminate vapor intrusion exposures in an existing building (e.g., measured indoor air concentrations pose an unacceptable human health risk for an acute or short-term exposure scenario (see Section 7.5.2)), it may be appropriate to implement response options such as the following:

- Sealing major openings for soil gas entry, where known and identified;
- Over-pressurizing nonresidential buildings by adjusting the HVAC system;

- Installing, repairing, or maintaining vapor traps for sewer or drain lines that are sources of vapor intrusion;

- Increasing building ventilation, for example using fans or natural ventilation;

- Treating indoor air (e.g., adsorption using activated carbon); and

- Temporary relocation

The fore-going response actions may take several days to a few weeks to plan (e.g., arrange, design) and implement, which generally is quicker than other interim response actions (e.g., active depressurization technologies). The first three options seek to reduce or eliminate vapor entry into the building. The last three options seek to reduce, eliminate, or avoid vapors that have entered the building by vapor intrusion. Specifically:

- Vapor intrusion into the building via soil gas entry from vadose zones soils can be reduced by sealing foundational openings using products such as synthetic rubbers, acrylics, oil-based sealants, asphalt/bituminous products, swelling cement, silicon, epoxy or elastomeric polymers. EPA recommends screening the selected sealant(s) (e.g., checking the composition, relying upon manufacturer's data) to ensure they do not contain or emit vapor-forming chemicals that might pose a human health risk to building occupants. This interim mitigation approach is among the easiest and least expensive to implement; however, its effectiveness relies upon being able to identify and access openings for soil gas entry. EPA recommends appropriate monitoring of indoor air concentrations be conducted to ensure that sealing attains and sustains sufficient reduction in vapor intrusion. In some cases, however, sealing openings may not be capable of reducing indoor air concentrations to acceptable levels and/or some openings may not be visible and accessible. EPA recommends that this response option generally be supplemented by installing, operating, and maintaining an engineered exposure control (e.g., an active depressurization technology) that reduces or eliminates vapor entry into the building until remediation of subsurface vapor sources is complete and terminated.

- For commercial and industrial buildings where HVAC units blow air into the building and are well maintained, it may be advantageous to increase pressurization in the building to prevent or reduce vapor intrusion. In some cases (e.g., buildings with few doors and other openings), relatively small increases in building pressure may be sufficient, which may be accomplished by increasing the air flow rate and using specialized equipment to monitor and balance air flow rates. EPA recommends appropriate monitoring of pressure and other indicators (e.g., indoor air monitoring) be conducted to ensure that adequate pressurization is sustained throughout areas of the building that could be subject to vapor intrusion. In some climates and for some buildings, this response option may be impractical or prohibitively expensive.

- Vapor intrusion into the building via gas entry from sewer and drain lines can be reduced or eliminated by installing, repairing, and maintaining vapor traps.

- Increasing building ventilation (i.e., increasing the rate at which indoor air is replaced with outdoor air) can reduce the buildup of indoor air contaminants within a structure. Natural ventilation may be accomplished by opening windows, doors, and vents. Forced or mechanical ventilation may be accomplished by using a fan to blow air into or out of the building. Increased ventilation is easiest and least costly to implement in locations where the air is not conditioned (heated or cooled). If indoor air is conditioned, increased ventilation can be a costly option because the conditioned air is ventilated to the outdoors. This drawback can be partly overcome by use of heat exchangers, but they are also costly. Another concern is that exhausting air from the building will generally contribute to under-pressurization of the building, relative to the subsurface, thereby potentially resulting in an increased rate of soil gas entry (i.e., vapor intrusion) unless ambient air entry into the building is increased equivalently. EPA recommends appropriate monitoring of indoor air concentrations be conducted to ensure that ventilation attains and sustains sufficient reduction in exposures to vapor-forming chemicals. In some cases, ventilation may not be capable of reducing indoor air concentrations to acceptable levels. In addition, building occupants may find it uncomfortable to increase the air exchange rate by more than a factor of three or four. EPA generally recommends that this response option be supplanted, when feasible, by installing, operating, and maintaining an engineered exposure control that reduces or eliminates vapor entry into the building until remediation of subsurface vapor sources is complete and terminated.

- Commercially available indoor air cleaners, which include both in-duct models and portable air cleaners, is another response option. These devices operate on various principles, including zeolite and carbon sorption and photocatalytic oxidation. Methods that rely on adsorption generate a waste that must be disposed of appropriately or regenerated and warrant periodic replacement of the adsorption medium. EPA recommends appropriate monitoring of indoor air concentrations be conducted to ensure that adequate treatment is sustained throughout the building. EPA generally recommends that this response option be supplanted, when feasible, by installing, operating, and maintaining an engineered exposure control that reduces or eliminates vapor entry into the building until remediation of subsurface vapor sources is complete and terminated.

- Temporary relocation may be implemented for buildings where conditions warranting prompt response action (see Section 7.5) and cannot be adequately addressed by other means.[218]

None of these options entails reducing the level of vapor-forming contamination in the subsurface medium (see Section 8.1). EPA generally recommends that these response options be supplanted, when feasible, by installing, operating, and maintaining an engineered exposure

---

[218] For response actions carried out under Sections 104(a) and 106(a) of CERCLA, OSWER Directive 9230.0-97 (*Superfund Response Actions: Temporary Relocations Implementation Guidance* (EPA 2002d)) states: "Temporary relocation should not be selected if health and safety risks or circumstances that pose an unreasonable inconvenience can be adequately addressed by other means without significantly increasing the overall cost or duration of the response action." Similarly, OSWER Directive 9355.0-71P (*Interim Policy on the Use of Permanent Relocations as Part of Superfund Remedial Actions* (EPA 1999f)) states: "EPA's preference is to address the risks posed by the contamination by using well-designed methods of cleanup which allow people to remain safely in their homes and business." OSWER Directive 9230.0-97 provides recommended procedures and other policies for temporarily relocating residents when this response action is selected and implemented under Sections 104(a) and 106(a) of CERCLA.

control that reduces or eliminates vapor entry into the building (see Section 8.2.2), until remediation of subsurface vapor sources is complete and terminated.

8.2.2 Active Depressurization Technologies for Existing Buildings

This section provides a brief overview of engineered systems that can be used to reduce or eliminate soil vapor intrusion in existing buildings, along with a summary of steps and considerations for selecting an appropriate technology for a given building. The focus is on active depressurization technologies most commonly employed for reducing soil vapor intrusion into buildings. This focus does not mean, however, that active depressurization technologies are always preferred over other mitigation methods or that they will be the best option for every site. More detailed information on vapor intrusion mitigation systems for existing buildings, including sub-membrane ventilation systems and passive technologies,[219] can be found in several EPA publications (e.g., EPA 2008c).

Active depressurization technologies (ADT) have been used successfully to mitigate the intrusion of radon into buildings and have also been successfully installed and operated in residential, commercial, and school buildings to control vapor intrusion from subsurface vapor-forming chemicals. ADT systems are widely considered the most practical vapor intrusion mitigation strategy for most existing buildings, including those with basement slabs or slab-on-grade foundations. ADT systems are generally recommended for consideration for vapor intrusion mitigation because of their demonstrated capability to achieve significant concentration reductions in a wide variety of buildings[220] and their moderate cost.

Sub-slab depressurization (SSD) systems, a common type of ADT system, function by creating a pressure difference across the building slab to prevent soil gas entry into the building (i.e., overcoming the building's natural under-pressurization, which is the 'driving force' for vapor intrusion; see Section 2.3). Creating this pressure difference is accomplished by extracting soil gas from beneath the slab and venting it to the atmosphere.[221] For the system to be effective by this mechanism,[222] this soil depressurization must be established and maintained at least near the primary openings for soil gas entry (EPA 1993a). Construction of SSD systems entails opening one or more holes in the existing slab, removing soil from beneath the slab to create a "suction pit" (6–18 inch radius), placing vertical suction pipes into the holes, and sealing the

---

[219] As noted in Section 3.3, engineered exposure controls that do not involve mechanical operations (e.g., creating a barrier between the soil and the building that blocks openings from soil gas entry into the building) are referred to as "passive."

[220] Folkes and Kurz (2002) describe a case study of a vapor intrusion mitigation program in Denver, Colorado. Sub-slab depressurization systems and/or sub-membrane depressurization systems were installed in 337 residential homes to control indoor air concentrations of 1,1-dichloroethylene (DCE) resulting from migration of vapors from groundwater with elevated 1,1-DCE concentrations. Over three years of monitoring data for 301 homes have shown that these systems are capable of achieving the very substantial reductions in concentrations in indoor air. Approximately one quarter of the systems warranted minor adjustment or upgrading after initial installation in order to achieve the state standards established for indoor air exposure.

[221] Depending, in part, upon location and prevailing statutes and regulations, governmental permits or authorizations may be required for venting systems that exhaust to the atmosphere.

[222] A second mechanism by which ADT systems can function is diluting the vapor concentrations beneath the slab and foundation (EPA 1993a, 2008c). Engineered controls designed and operated to use this mechanism predominately are often referred to as sub-slab ventilation systems.

openings around the pipes. These pipes are then connected together to a fan, which draws soil gas from the sub-slab area through the piping and vents it to the outdoors.[223] Sealing known and accessible openings in the slab and foundation can reduce the flow rate of conditioned indoor air that can be pulled into the sub-slab region by the suction wells and the sub-slab depressurization (EPA 2008).

SSD systems were first developed for radon reduction (EPA 1993a) and operate under similar design principles as radon mitigation methods. Figure 8-1 illustrates such an SSD system.

When sumps and associated drain tile systems are present, they may also be depressurized to prevent soil gas entry into the building (again, overcoming the building's natural under-pressurization). This variation on active depressurization is often referred to as drain-tile depressurization (DTD). Depressurization of drain tiles located near a foundation wall can help control soil gas entry at the joint between the foundation wall and slab. Figure 8-2 illustrates such a DTD system.

If the building has hollow block walls, the usual sub-slab suction point may not adequately mitigate the wall cavities, which may be particularly important if the outside surfaces are in contact with the soil. In these situations, the void network within the wall may be depressurized by drawing air from inside the wall and venting it to the outside. This method, called "block-wall depressurization" (BWD) is often used in combination with SSD. Because uniform depressurization of block walls can be difficult, BWD is generally recommended only when sub-slab or DTD prove inadequate to control vapor intrusion. Figure 8-3 illustrates such a BWD system.

In buildings with a crawl space foundation or a basement with a dirt floor, a flexible membrane may be installed over the floor to facilitate depressurization of the soil gas beneath the membrane, which prevents vapors from intruding into the crawl space or basement air. To maximize the effectiveness of a sub-membrane depressurization (SMD) system, EPA recommends the membrane cover the entire floor area and be sealed at all seams and penetrations. Figure 8-4 illustrates such an SMD system.

Extensive guidance is available for the design, sizing, installation, and testing of ADT systems for radon control in existing and new homes and large institutional (e.g., school) and commercial buildings. EPA recommends that ADT systems be designed and installed by qualified persons, typically environmental professionals and licensed radon contractors. EPA guidance for design of ADT systems can be found in several publications (e.g., EPA 1993a, 2008c). EPA recommends documenting each constructed ADT system via a system manual, as described further in Section 8.5.

The Vapor Intrusion Mitigation Quick Guide provided in Table 8-1 summarizes a list of steps for selecting and implementing a vapor intrusion mitigation system in existing buildings.

---

[223] A central issue that determines the design and effectiveness of ADT systems is the ease with which suction at one location can extend to other subsurface areas underneath the building. Where a good and uniform layer of aggregate (e.g., gravel or crushed rock) was placed underneath a slab foundation during construction, for example, such hydraulic control and communication can generally be expected to be good (EPA 1993a). Where the layer of aggregate under a slab is interrupted or uneven to a significant degree, additional suction pipes will generally be needed and their location will be increasingly important.

TABLE 8-1
VAPOR INTRUSION MITIGATION QUICK GUIDE FOR EXISTING BUILDINGS

Step 1: Consider Prompt Response Actions

It may be appropriate to implement certain interim measures before engineered controls are constructed and operated, as warranted and feasible. For example, building ventilation can be increased, cracks and other openings in the floor or foundation (that otherwise allow soil gas entry) can be sealed, or indoor air treatment can be conducted (refer to Section 8.2.1).

Step 2: Select a Building Mitigation System

The initial step in selecting the appropriate vapor intrusion mitigation technology is to conduct a visual inspection of an existing building. The selection of a vapor intrusion mitigation system primarily depends on building characteristics and contaminant concentrations. In the majority of cases, a type of active depressurization technology (ADT) can be an efficient, reliable, and cost-effective vapor intrusion mitigation technique. In some cases, however, other approaches may be preferable.

Factors that may prompt consideration of vapor intrusion mitigation approaches other than ADT include foundation conditions that prevent development and extension of a suction field below the building.

If there are no factors that would rule out an ADT technology, appropriate systems that can be considered include:

- Sub-slab depressurization (SSD) systems, particularly in houses having slabs (basements and slabs on grade) where drain tiles are not present.
- Drain-tile depressurization (sump/DTD or remote discharge/DTD) when drain tiles are present.
- Sub-membrane depressurization (SMD) in buildings with a crawlspace foundation or a basement with a dirt floor,
- Block-wall depressurization (BWD), usually used only as a supplement to SSD, DTD, or SMD to better mitigate vapors found to be migrating through the wall.

Step 3: Design Building Mitigation System

EPA recommends the final detailed design of the selected vapor intrusion mitigation technology specify the number and location of suction points, location and size of piping, suction fan, piping network and exhaust system, and sealing options to be used in conjunction with the ADT technology. Pre-mitigation diagnostic testing can provide information about the suction field underneath a building and pressure differences that will need to be overcome (EPA 1993a) if the ADT system is to be effective. Diagnostic testing during installation can also help verify the adequacy of the design.

Step 4: Install Building Mitigation System

EPA recommends that the vapor intrusion mitigation system be installed consistent with design specifications by equipment manufacturers, local permit conditions and regulations, and relevant industry standards.

Step 5: Confirm the Installed System is Operating Properly

EPA recommends a visual inspection of the installed system as a routine quality assurance step to confirm that all construction details have been completed. Post-construction monitoring is recommended (refer to Section 8.4) to demonstrate the ADT system is operating appropriately and effectively. Where a vapor intrusion mitigation system is not performing adequately, post-construction diagnostic tests can be helpful in trouble-shooting (EPA 1993a).

Step 6: Ensure Proper Operation and Maintenance of Vapor Intrusion Mitigation System (refer to Sections 8.3 and 8.4)

EPA recommends proper system maintenance and periodic inspections and monitoring to ensure the system is operating as designed and is effective at reducing indoor air concentrations to (or below) target levels. EPA recommends that site managers provide the building owner/occupant with information to help ensure proper operation and maintenance of the system.

EPA recommends that periodic inspections include periodic measurements to confirm that the building mitigation system is continuing to perform adequately.

The U.S. Navy has issued a concise fact sheet that contains useful technical information (DoN 2011b).

8.2.3 Approaches and Considerations for New Buildings

The ADT systems described above are generally available for new buildings also. However, a wider array of approaches and technical options is typically available to mitigate or avoid vapor intrusion for new buildings, compared to existing buildings. These options potentially include the choice of building location and opportunities to modify the building design and construction, which are not available for existing buildings. For example:

- At some sites, contaminated areas most likely to produce unacceptable vapor intrusion exposures can be avoided and designated for another purpose, such as recreational space or undeveloped landscape.

- Mitigation needs can also be considered in the selection of heating and cooling systems, which are normally selected based only on economics, aesthetics, preference, and custom. A system design that avoids creating under-pressurization inside the structure and maintains over-pressurization inside the structure may be effective in mitigating vapor intrusion.

- Passive barriers, such as a low-permeability membrane, can be more readily installed between the soil and the building during new building construction. Passive barriers are intended to reduce vapor intrusion by limiting openings for soil gas entry. However, passive barriers as stand-alone technologies may not adequately reduce vapor intrusion owing to difficulties in their installation and the potential for perforations of the barrier during or after installation. They are commonly combined with ADT systems or with sub-membrane ventilation systems to help improve their efficiency.

- Venting layers can be more readily installed between the soil and the building during new building construction.[224]

- New buildings may be designed to include a highly ventilated, low-occupancy area at ground level, such as an open parking garage.

Steps 2-6 of the Vapor Intrusion Mitigation Quick Guide provided in Table 8-1 are also pertinent to newly constructed buildings. EPA guidance for selecting, designing, and installing vapor intrusion mitigation systems for new buildings can be found in several publications (e.g., EPA 2008c). The U.S. Navy has issued a concise fact sheet that contains useful technical information (DoN 2011c).

---

[224] Constructed sub-slab ventilation systems typically consist of: a venting layer (e.g., filled with porous media such as sand or pea gravel; or suitably fabricated with continuous voids) below a floor slab to allow soil gas to move laterally to a collection piping system for discharge to the atmosphere; and a sub-slab liner that is installed on top of the venting layer to reduce entry points for vapor intrusion. These and other sub-slab ventilation systems function by drawing outside air into and through the sub-slab area, which dilutes and reduces concentrations of vapor-forming chemicals, and provides a route for soil gas to vent to the atmosphere or migrate outside the building footprint, rather than into a building.

8.2.4 Owner/Occupant Preferences and Building Access

Building owners and occupants can initially be notified in various ways that their home or building warrants construction and operation of a building mitigation system. Section 9.5 provides information regarding such notifications and other messages pertaining to building mitigation.

Whereas EPA managers and mitigation system designers may be primarily concerned with the performance, cost-effectiveness, and reliability of any mitigation system, the building owners and occupants may have additional perspectives and opinions that warrant consideration during technology selection, design, construction, and operation. For example, owners and tenants will often have strong opinions about where fans and piping are located, what level of fan noise is acceptable, and what quality of construction craftsmanship is satisfactory. When there are multiple mitigation options (for example, at a large commercial building), EPA recommends these options be presented fairly to the building owner and tenants, explaining the advantages and disadvantages associated with each and describing the rationale for the preferred alternative.

In some cases, obtaining and scheduling access to a building can be difficult, whether the structure is a commercial or institutional building or a private residence. Commercial building tenants may not want construction activities disrupting business operations. Some homeowners/tenants may resist granting access to their home. Other homeowners/tenants may prefer to schedule tests before or after their work-day. To address these practical and logistical concerns, EPA recommends that an access agreement(s) be executed between the property owner, any tenants, and the mitigating entity to ensure appropriate access as needed to operate, maintain, and monitor the engineered exposure controls in each impacted building.

8.3 Operation and Maintenance of Vapor Intrusion Mitigation Systems

For purposes of this Technical Guide, operation and maintenance (O&M) is used generically to refer to periodic inspections, component maintenance or replacements, repairs, and related activities that are generally necessary to ensure continued operation and effectiveness of engineered exposure controls to mitigate vapor intrusion. EPA generally recommends that such O&M activities be conducted routinely, be documented in an O&M plan (as described further in Section 8.5), and consider recommendations of equipment manufacturers, if any, and site-specific factors. Additional information about ensuring continued effectiveness of systems is available in EPA (2009b).

Design specifications for vapor migration systems may include (1) a maintenance frequency that varies over the operating period of the mitigation system and/or (2) a provision to evaluate and modify the frequency based on data or information obtained during monitoring and maintenance. For example, it may be acceptable to reduce inspection or maintenance frequency once efficient system operation has been demonstrated for at least an initial year, with triggers for additional, unscheduled inspections following alarms (from warning devices) and floods, earthquakes, and building modifications, if any.

Typical O&M activities for either passive or active systems may include, but are not limited to:

- Routine inspection of all visible components of the vapor intrusion mitigation system, including fans, piping, seals, membranes and collection points, to ensure there are no signs of degradation or blockage. EPA recommends that the as-built drawing for the vapor intrusion mitigation system be examined to verify the system configuration has not been modified.

- Visual inspection of the building to evaluate whether any significant changes were made (such as remodeled basement, new furnace) that would affect the design of the vapor intrusion mitigation system or the general environment in which it is operated. A crawl space SMD membrane, for example, may warrant repair or replacement if its integrity is compromised.
- Visual inspection of the area of concern (including basement floor and wall seals, sumps, floor drains and utility penetrations) to ensure there are no significant changes in conditions that would warrant modification of the system design.
- Routine monitoring of vent risers for flow rates and pressures generated by the fan to confirm the system is working and moisture is draining correctly.
- Routine maintenance, calibration and testing of functioning components of the venting system consistent with the manufacturers' specifications.
    - Pressure readings for both active and passive depressurization systems as well as positive pressurization systems (e.g., periodic verification of measurable pressure differences across the slab).
    - Confirmation that the extraction fan is operating.
    - SSD system fans generally can function well for prolonged periods without maintenance; however, EPA recommends fans be replaced periodically throughout the operating life of the system (e.g., every 4 to 10 years) to avoid breakdowns and associated problems.
- Inspection of external electrical components to identify undesirable conditions, such as excessive noise, vibration, moisture, or corrosion, and to verify that the fan cut-off switch is operable.
    - Inspection of the fan(s) is important throughout the operating period but may be particularly important near the end of its expected lifespan. Noisy fans typically indicate problems with ball bearings and warrant replacement on that basis.
    - Confirmation of adequate operation of the warning device or indicator.
- Confirmation that building owner/occupants are knowledgeable about how to maintain system operation. Confirmation that a copy of the O&M manual is present in the building and has been updated as necessary.

EPA also recommends that the site team determine if there has been any change in ownership/occupant. If such a change has occurred, EPA recommends the site manager work with the new owner/occupant to ensure continued integrity and operation of the vapor intrusion mitigation system.

8.4 Monitoring of Vapor Intrusion Mitigation Systems

Regardless of the type of system selected for mitigating vapor intrusion in a given building, EPA recommends monitoring to demonstrate that performance standards are achieved at the time of installation and that those performance standards continue to be met throughout the operating period of the mitigation system. EPA recommends that any monitoring program developed for a building mitigation system be based upon site-specific considerations, including the degree of risk or hazard being mitigated, the building use, the technology used to mitigate vapor intrusion, whether the subsurface vapor source(s) is stable in extent and concentration, and coordination with site remediation efforts. For example:

- An older building with highly volatile chemicals at high concentrations may need a more intense level of monitoring than a new building with lower concentrations of less volatile chemicals.

- Passive systems are generally less predictable and less efficient at preventing vapor intrusion than active systems and, therefore, typically warrant more intensive monitoring, all else being equal.

- When contaminated groundwater plumes are migrating to new areas (i.e., expanding) or concentrations in shallow groundwater are increasing, increased frequency and intensity of mitigation monitoring may be warranted.

- During start-up, some remediation methods have the potential to alter soil gas conditions in ways and to a degree that may be difficult to predict. Increased frequency and intensity of mitigation monitoring may be warranted when such remediation methods are implemented near buildings undergoing mitigation.

Mitigation monitoring will generally entail two phases: (i) an initial post-construction phase, which is generally more intensive; and (ii) a subsequent phase, which may be comprised of fewer diagnostic tests to be conducted periodically. As with radon mitigation systems (EPA 1993a, Section 11.1.2), results of indoor air sampling during initial post-construction monitoring may be used to demonstrate that the occupant's exposure to vapor-forming subsurface contaminants has been reduced as anticipated. In addition, pressure field measurements in the subslab region can be used to demonstrate that the system has attained hydraulic control and communication (e.g., depressurization in the case of an ADT system) over the footprint of the building (or portion of a large building, as appropriate, considering the extent of subsurface contamination). Adjustments to the mitigation system and/or additional diagnostic testing (EPA 1993a, 1993c) may be warranted if the results of such testing do not clearly demonstrate that the system is achieving its intended performance and effectiveness. Once an adequate demonstration of effectiveness has been made for the vapor intrusion mitigation system, periodic monitoring is recommended to verify that this performance is sustained; for this purpose, monitoring may be comprised of fewer types of tests than during the immediate post-construction (i.e., start-up) phase at the discretion of EPA when the subsurface vapor source(s) is stable. Examples of various monitoring scenarios for these two phases are provided in Table 4 of CalEPA (2011), Table 6-2 of NJDEP (2012), and Table 3-1 of MADEP (2011). Additional information about ensuring continued effectiveness is available in the *Operational and Functional Determination and the Transfer of Fund-lead Vapor Intrusion Mitigation Systems to the State* (EPA 2009b).

When monitoring to assess the performance and effectiveness of building mitigation technologies, EPA recommends employing the methods, approaches described in Sections 5.4, 6.2, 6.4 and 7.0 of this Technical Guide. EPA also recommends that monitoring programs that assess the performance and effectiveness of remediation and mitigation systems be documented, preferably in work plans similar to those recommended herein for characterizing and assessing the vapor intrusion pathway (see Section 6.2). Such vapor intrusion monitoring plans may be incorporated as part of a comprehensive remedial design and operations manual or as a stand-alone document, depending upon site-specific circumstances. In addition, EPA recommends that data and other results obtained through such monitoring programs be documented (e.g., in the administrative record), as they become available.

The remainder of this section identifies and further discusses some elements commonly incorporated in monitoring programs for active depressurization technologies.

Pressure Measurements

Sub-slab probes can be used to monitor differential pressures for a direct indication of the hydraulic performance of ADT systems (i.e., the pressure difference across the slab prevents soil gas entry); see Section 2.3. For basements, the walls that are underground become part of the critical building envelope that must prevent soil gas entry. For subsurface depressurization systems, EPA recommends that the pressure gauge be monitored quarterly to verify the system is operating efficiently. A reduced monitoring frequency may be appropriate after one year of successful operation of the remedial system.

Tracer Testing

Openings within the building or leaks in the mitigation system can affect system performance. Tracers can be used either for leak detection through barriers, building materials or system components (piping, for example) or to measure the air exchange rate in the building.

Smoke testing is a qualitative form of tracer testing used to detect leaks (e.g., at seams and seals of membranes in SMD systems or at potential leakage points (openings) through floors above sealed crawl space systems or through conduits that facilitate preferential vapor migration), or to test airflow patterns. A limitation of smoke testing in existing structures is that non-noxious smokes can be expensive, and cheaper high-volume smoke sources can leave undesirable residues. The efficacy of smoke testing in some applications has been questioned on the grounds that many leaks are too small for visual detection using this method (Maupins and Hitchins 1998, Rydock 2001), and that leaks large enough to detect using smoke could be detected other ways. More quantitative methods have been recommended, such as tracer testing with instrumentation for quantitative results.

Air Sampling

Once an adequate demonstration of vapor intrusion mitigation system effectiveness has been made, indoor air quality generally will be acceptable as long as an adequate pressure difference is maintained throughout the footprint of the building. Periodic or intermittent sampling of indoor air, nevertheless, warrants consideration, since indoor air data can provide direct confirmation that the system is reducing exposure levels of vapor-forming chemicals and because depressurization technologies can be expected to alter the distribution of vapors in the vadose zone and available for soil gas entry, if any.

Weather-Related Considerations

EPA recommends that weather conditions be noted during monitoring activities (EPA 1993a). Weather conditions, such as temperature and precipitation, can affect the performance of a vapor intrusion mitigation system. For example, cold temperatures may increase the building depressurization created by the thermal stack effect and thus increase the driving force for soil gas entry, depending upon the height of the house and the temperature difference between indoors and outdoors (see Section 2.3). As a result, the ADT system may need to overcome more building depressurization than originally considered when designed. Precipitation may also increase moisture in the fill under the slab, which may affect the performance of the system, and is a factor to consider in developing a monitoring program.

Alarms

Alarms generally are used as part of a monitoring program to ensure that malfunctions of vapor intrusion mitigation systems are timely and readily detected and addressed. According to ASTM (2003), “All active radon mitigation systems shall include a mechanism to monitor system performance (air flow or pressure) and provide a visual or audible indication of system degradation and failure” (i.e., an ‘alarm’). ASTM goes on to say, “The mechanism shall be simple to read or interpret and be located where it is easily seen or heard. The monitoring device shall be capable of having its calibration quickly verified on site.” Such devices may indicate operational parameters (such as on/off or pressure indicators) or hazardous gas buildup (such as percent LEL indicators). EPA concurs with the cited advice from ASTM and recommends it be considered when monitoring and maintaining mitigation systems for vapor-forming chemicals and sites addressed by this Technical Guide.

In particular, EPA recommends that system failure alarms be installed on active depressurization systems, and appropriate responses to alarms be communicated by the building owner/occupants. EPA also recommends that alarms be placed in readily visible, frequently trafficked locations within the respective building and their proper operation be confirmed on installation and monitored periodically.

Placards

EPA also recommends that permanent placards be placed on the system to describe the system’s purpose and operational requirements (e.g., power source) and instructions on what to do if the system does not operate as designed (for example, a phone number to call for corrective action). EPA recommends the placard provide information about how to read and interpret the monitoring instruments or warning devices provided. EPA also recommends that these placards be placed as close to the monitoring/alarm part of the system as possible, as well as close to the fan or other active parts of the system.

8.5 Documentation of Engineered Exposure Controls for Vapor Intrusion Mitigation

EPA recommends that documentation be provided to building owners and occupants and appropriate regulatory agencies[225] describing the vapor intrusion mitigation system (i.e., a ‘system manual’) and its associated O&M (i.e., an ‘O&M plan’). The system manual provides a detailed record about the mitigation system, including as-built drawings, permits (if any), copies of agreements, and construction/layout plans, whereas the O&M manual describes the O&M activities to be conducted routinely and identifies which party is responsible for these O&M activities. Additional information about ensuring continued effectiveness is available in *Operational and Functional Determination and the Transfer of Fund-lead Vapor Intrusion Mitigation Systems to the State* (EPA 2009b).

O&M Plan

O&M plans generally are prepared on a site-specific basis, and they often are particularly useful at sites where:

- Monitoring is needed to verify remedial effectiveness.
- The remedial system warrants periodic adjustments and maintenance.
- Human health risk would result if the system fails or if site conditions change.
- Conditions that would trigger specific contingent response may occur sporadically or episodically.

Some site remedial systems may also warrant the use of a regulatory agency-approved contingency plan or similar corrective response document approved by the regulatory agency to identify conditions that may trigger the need for additional maintenance, collection of additional data, modifications of monitoring frequency, or other responses to ensure the remedy remains effective.

Communication with building owners and occupants about vapor intrusion and the O&M of a vapor intrusion mitigation system is critically important. For example, building owners may be concerned about some aspect of system operation and decide to turn it off. It is important to communicate that turning off the system may result in harmful indoor air concentrations inside the building.

System Manual

The specific contents of the system manual will depend on the type of system. EPA recommends, however, that the system manual generally include at least the following information or items:

- Cover/transmittal letter;

---

[225] For example, EPA recommends the potentially responsible party (PRP) provide a system manual and O&M plan to EPA at PRP-lead Superfund sites.

- Description and diagram of final as-built system layout with components labeled;
- Building permits for a vapor intrusion mitigation system;
- Pre- and post-mitigation air and gas sampling data;
- Pre- and post-mitigation diagnostic test data;
- Copies of contracts and warranties;
- Proper operating procedures of the system;
- Contact information of the contractor or installer;
- Copy of signed access agreement;
- Copy of vapor mitigation system O&M agreement;
- Copy of pre-mitigation sample result letter (see Section 9.4);
- Copy of post-construction sample result letter;
- Contact information in case of future questions; and
- Inspection and maintenance guidelines.

User's Guide

Documentation typically is also provided to the property owner and occupant in the form of a user's guide suitable to keep lay persons informed about the system and to provide a summary reference in case questions or issues arise pertaining to the system.

A user's guide is a brief summary of why a vapor intrusion mitigation system was installed at a property and how the system works, and may include the following: (1) a brief description of the system and its proper range of operation; (2) contact information for the party responsible for responding to malfunctions and ensuring the system performs properly; and (3) information about routine maintenance to be conducted by the owner/occupant, if any. EPA recommends that a user's guide be placed near the system for quick access and easy reference (e.g., into a clear protective sleeve and attached to the main extraction pipe of the ADT system). An easy-to-read user's guide may be especially helpful at rental properties because the guide informs each new tenant about what the system is and why it was installed.

8.6 Use of Institutional Controls

ICs may be used to restrict certain land uses, buildings, or activities that could otherwise pose an unacceptable human exposure via the vapor intrusion pathway.

Response actions for vapor intrusion may include ICs to restrict land use for protection of human health regardless of whether a vapor intrusion mitigation system provides interim measures to control (i.e., reduce, limit) human exposures. ICs can be used as either an interim response until site cleanup goals are reached or as part of a long-term response where vapor-forming waste remains in place.

General EPA guidance on ICs is provided in *Institutional Controls: A Guide to Planning, Implementing, Maintaining, and Enforcing Institutional Controls at Contaminated Sites* ("PIME IC Guidance") (EPA 2012d). As discussed in the PIME IC Guidance, ICs are non-engineered instruments, such as administrative or legal controls, that help to minimize the potential for human exposure to contamination and protect the integrity of a response action. ICs typically operate by imposing land or resource use restrictions at a given site or by conveying notice to stakeholders regarding subsurface contamination or the possible need to refrain from certain actions that may result in human exposure to hazardous chemicals. For example, ICs may be used to restrict the development and use of properties for certain land uses (e.g., prohibiting residential housing, hospitals, schools, and day care facilities).

In some situations, ICs can be used to restrict access to a property, facilitate response activities conducted by a responsible party or EPA, such as the installation or maintenance of vapor intrusion mitigation systems, or help ensure the integrity of vapor mitigation systems. ICs may also be used to help inform the need for vapor intrusion mitigation for future construction where vapor-forming waste remains in place and may pose unacceptable human health risk due to vapor intrusion.

As described further in Section 2.2 of the PIME IC Guidance, ICs can be described in four general categories:

- Proprietary controls.
- Governmental controls.
- Enforcement and permit tools with IC components.
- Informational devices.

The first three categories (i.e., proprietary controls, governmental controls, and enforcement and permit tools with IC components) typically memorialize and prescribe substantive use restrictions concerning the land or resource use, while informational devices generally operate to provide notice of contamination and any remedial activities to parties. Depending on the nature of the site and the particular jurisdiction in which it is located, certain instruments may not be available or feasible for a particular site. Certain ICs may help facilitate how interim response actions and subsurface remediation are carried out, such as provisions addressing access, O&M of vapor intrusion mitigation systems, and design specifications for buildings (see Example #3 box below).

8.6.1 Evaluating ICs in the Overall Context of Response Selection

As a site moves through a program's response selection process (for example, a Superfund remedial investigation/feasibility study [RI/FS] or RCRA facility investigation/corrective measures study [RFI/CMS]), EPA recommends that site managers develop information about reasonably anticipated future land uses and infer reasonably expected exposure pathways related to land use. This information may be incorporated in the conceptual site model and often can be used to evaluate whether ICs will be needed to ensure protectiveness of current and reasonably anticipated future land uses over time. EPA's land use guidance (EPA 1995a, 2010c) recommends that the site manager discuss reasonably anticipated future land uses of the site with local land use planning authorities, local officials, property owners, and the public, as appropriate, as early as possible during the scoping phase of the RI/FS, RFI/CMS, or equivalent phase under other cleanup programs.

EPA recommends that the Region's decisions to implement ICs be documented in proposed cleanup plans and in final cleanup decision documents. For example, for CERCLA cleanups, the proposed restriction, and need for ICs would normally be identified in the Proposed Plan for notice and opportunity to comment by potentially affected landowners and the public. Such use restrictions or notices typically are then selected and memorialized in the Record of Decision (ROD).

In some cases, unanticipated changes in land use may occur after the response action is implemented, which may impact the protectiveness of a completed response action and raise questions concerning the effectiveness of the ICs. As a result, vapor intrusion may be identified as a potential human exposure pathway in a subsequent periodic review. In this case, EPA recommends that site managers evaluate options for modifying the original response decision, including the need for new or additional ICs consistent with existing and reasonably anticipated future land uses and other response selection considerations.

8.6.2 Common Considerations and Scenarios Involving ICs

The evaluation of whether an IC is needed at a contaminated site, including one where the vapor intrusion pathway poses a current or potential threat to human health, is a site-specific determination. When evaluating whether an IC will be needed, EPA recommends that EPA Regional staff consider whether the site meets unlimited use and unrestricted exposure (UU/UE), among other factors. UU/UE is generally the level of cleanup at which all exposure pathways present an acceptable level of human health risk for all land uses, including reasonably anticipated future land use scenarios that are considered during response selection.

Common scenarios where ICs may be a useful instrument for fostering protectiveness at a site involving vapor intrusion threats include, but are not limited to, the following:

1. Existing buildings overlie soil or groundwater contamination, or a migrating groundwater plume that is moving toward existing buildings potentially poses a future vapor intrusion threat;

2. Future construction is planned or is reasonably anticipated on a site that overlies subsurface contamination with vapor-forming chemicals;

3. Changes to building construction/design (such as remodeling or ventilation changes) or building use (such as commercial building converted for residential use) potentially affect exposure to the vapor intrusion pathway;

4. Vapor intrusion mitigation systems are needed in buildings, or existing ventilation systems are being utilized for vapor intrusion mitigation, and continued access is sought to facilitate their O&M;

5. Response actions to reduce source contamination will not immediately meet response objectives; and

6. Response actions to reduce or eliminate source contamination will not be taken (for example, where it is technically impracticable to treat groundwater that is the source of vapor intrusion).

Informational ICs may also serve to provide notice to parties, including prospective purchasers, about what land or building uses are compatible with human health risk that may be posed by vapor intrusion at the site. For example, modifications to a building's ventilation or air conditioning system may affect building under-pressurization in a way that fosters a greater potential vapor intrusion threat. Various ICs can be tailored to address construction and design specifications of both existing and future buildings—a local ordinance, for example, may require parties to submit a building design to its building department that incorporates mitigation measures as determined appropriate by a Professional Engineer (P.E.) (see IC Example #1).

In addition to restricting land, building, or resource use, some types of ICs may provide an effective means for addressing O&M at vapor intrusion sites consistent with decision documents and enforcement documents. This could happen, for instance, when an IC specifies that mitigation systems be installed and maintained in future construction or if the use of an existing building changes (e.g., industrial building use changes to mixed commercial or residential uses). Provisions regarding access to and periodic maintenance and testing of the mitigation systems, and other site-specific obligations may be incorporated into the IC (see IC Example #2).

IC EXAMPLE 1:

City of Mandan, North Dakota Ordinance No. 1002 (City of Mandan 2006)

In 2006, the City of Mandan, North Dakota, enacted an ordinance that created an Environmental Institutional Control Zoning District to define an area of downtown Mandan impacted by petroleum contaminated soil and groundwater and to establish ICs for the protection of human health and the environment. Among other provisions, the ordinance requires any person proposing redevelopment, demolition, excavation, grading, or construction activities at properties within the District to submit to the city administrator or their appointee a contingency plan, approved by the North Dakota Department of Health, to evaluate and manage any petroleum contaminated soils or groundwater and any potential petroleum vapor impacts. The contingency plan must be prepared by a P.E. with experience in the environmental field, and the plan must consider and protect against, among other things, the vapor intrusion pathway. In addition, the ordinance also provides for restrictions on construction of new structures within the District. In pertinent part, the ordinance provides:

“Any person proposing to construct a new structure within the District shall submit a design for that structure that incorporates engineered controls to mitigate the effects of the potential presence of petroleum in the subsurface to the city administrator or their appointee. The design must be prepared by a P.E. and the design must be approved by the North Dakota Department of Health and must meet additional applicable codes and standards relative to the presence of petroleum. The design shall protect the public health and the environment by considering, at a minimum a) historic water/product intrusion; b) historic petroleum vapor/odor issues; c) potential future water/product intrusion; and d) potential future petroleum vapor/intrusion. The design shall incorporate vapor barriers, venting system, groundwater suppression/collection, and specialized HVAC as determined appropriate by a P.E.”

IC EXAMPLE 2: State IC Legislation

Some states have enacted statutes that directly authorize proprietary controls for the purpose of preventing use in conflict with environmental contamination or remedies. These state statutes divide into ones modeled after the Uniform Environmental Covenants Act (UECA)[226] and other non-UECA statutes.[227] These UECA and non-UECA state statutes tend to provide advantages over traditional common law proprietary controls by reducing certain legal and management complications associated with their use. The Model UECA, for instance, contemplates that the grantee or "holder" of the "environmental covenant" may be given specific rights or obligations with respect to future implementation of the environmental covenant.[228] This ability to oblige parties to undertake affirmative actions at a site, such as long-term maintenance of a cap or O&M of a vapor intrusion mitigation system, through a UECA environmental covenant, is different from traditional common law proprietary controls.

Proprietary controls that bind current and subsequent landowners (that is, the proprietary control "runs with the land") to use restrictions at properties, as well as oblige them to undertake affirmative obligations, may have utility at vapor intrusion sites. For instance, at a contaminated site in Bucks County, Pennsylvania, an environmental covenant executed pursuant to the Pennsylvania Uniform Environmental Covenants Act contained provisions to address vapor intrusion threats. In addition to provisions for access, annual inspections, compliance reporting, and other specifications related to cleanup activities, parties to the environmental covenant agreed to construct slab-on-grade buildings without basements and install vapor barriers as an engineered control to mitigate the potential for vapor intrusion as part of the eventual development of the property. Further, the environmental covenant provided that engineering plans for the vapor barriers first be submitted to and approved by EPA prior to construction. For examples of environmental covenants executed pursuant to the Pennsylvania Uniform Environmental Covenants Act, Act No. 68 of 2007, 27 Pa. C.S. §§ 6501-6517: http://www.depweb.state.pa.us/portal/server.pt/community/land_recycling_program/20541/uniform_environmental_covenants_act/1034860

---

[226] UECA was developed by the National Conference of Commissioners on Uniform State Laws. See: www.uniformlaws.org.

[227] See, for example, Colo. Rev. Stat. § 25-15-320 (2011); Cal. Civ. Code § 1471 (2011).

[228] "Grantee" is a traditional property law term describing a person to whom property is conveyed. States that have passed legislation based on UECA have created different legal concepts specific to those jurisdictions. For example, UECA jurisdictions typically define "holder" and "environmental covenant" to reflect, respectively, the grantee and the servitude that imposes the land or resource use restrictions. The model UECA provides that "[h]older means the grantee of an environmental covenant…" See definition 6 in Section 2.0 of the model UECA.

8.6.3 Selecting the Right Instrument(s)

When evaluating potential IC instruments, EPA recommends that site managers and site attorneys balance the relative advantages and limitations of IC instruments under consideration—for example, consider legal implementation issues, jurisdictional questions, permanence and enforceability concerns—and select those that best achieve the response objectives. (IC Example #3 describes how these factors were considered at the Middlefield-Ellis-Whisman Study Area.)

EPA guidance on ICs provides detailed considerations regarding the selection of ICs and the relative strengths of the different categories of IC instruments.[229] Ultimately, the selection of ICs is a site-specific evaluation based on the characteristics of the site (for example, the nature and extent of the vapor intrusion threat) and the particular jurisdiction in which it is located. There are times when multiple IC instruments can be "layered" to best ensure protectiveness of the response action while meeting the response objectives outlined in the decision documents.[230]

Because many ICs are created pursuant to state and other non-federal laws, the authority to implement and otherwise oversee these ICs resides with government entities other than EPA. Units of local governments, for instance, typically have jurisdiction to implement, maintain, enforce, and terminate certain governmental controls, such as zoning ordinances and building permit conditions. Therefore, it is important to evaluate the capacity (financial, technical, etc.) and willingness of the entity ultimately responsible for taking over IC responsibilities prior to IC selection.[231] Site managers and site attorneys are encouraged to coordinate early with IC stakeholders so that adequate assurances may be acquired and then subsequently maintained as necessary over time.

Given the potential role of non-EPA entities, it may be appropriate for EPA to facilitate or recommend a process by which IC stakeholders provide similar assurances or otherwise reach a common understanding[232] regarding their respective IC responsibilities to ensure that selected ICs are effectively implemented, maintained, and enforced. At a vapor intrusion site, for example, a zoning ordinance may be effective in preventing or ensuring responsible future development of properties overlying a contaminated groundwater plume that presents a vapor intrusion pathway threat. Such zoning ordinances generally are designed and enacted by the local government. Once enacted, the ordinance must be followed and enforced for it to serve as an effective IC over its lifespan. One inherent limitation of governmental controls, however, is that their implementation, modification, and termination generally follow a legislative process

---

[229] See Site Manager's IC Guide and Section 3.2 of the PIME IC Guide for a framework to consider when deciding among available ICs.

[230] See Section 3.2 of the PIME IC Guide for more discussion on layering ICs.

[231] See Section 3.8 of the PIME IC Guide on IC stakeholder capacity considerations.

[232] Parties may be able to provide assurances or otherwise reach a common understanding regarding their respective IC roles and responsibilities through various mechanisms that may be available under state law (for example, a Memorandum of Understanding, Memorandum of Agreement, Administrative Order on Consent, contract, City Resolution, or enforceable agreement, etc.). For additional discussion about obtaining or memorializing IC assurances, see Sections 3.3, 3.8, and 4.3 of the PIME IC Guide.

IC EXAMPLE 3: Efforts to Address VI at the Middlefield-Ellis-Whisman Study Area

The Middlefield-Ellis-Whisman (MEW) Study Area is composed of four separate CERCLA sites—Raytheon Corp., Intel Corp. (Mountain View Plant), Fairchild Semiconductor Corp. (Mountain View Plant), and portions of the former Naval Air Station Moffett Field Superfund site—and many distinct parcels with land uses including residential, commercial, and light industrial. In 2009, EPA finalized a Supplemental FS for the MEW Study Area that presented an evaluation of a variety of remedial alternatives that could be used to mitigate potential vapor intrusion into current and future buildings overlying the shallow plume of contaminated groundwater. The FS provided an analysis of ICs using the NCP evaluation criteria: overall protection of human health and the environment; long-term protectiveness and permanence; compliance with applicable or relevant and appropriate requirements; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. The other two NCP evaluation criteria, state acceptance and community acceptance, were evaluated in the ROD Amendment for the vapor intrusion pathway remedy at the MEW Study Area.

In 2009, EPA published the Proposed Plan for the MEW Study Area that identified EPA's preferred alternatives for the vapor intrusion remedy. The Proposed Plan identified the adoption of a municipal ordinance as EPA's preferred IC, but the City of Mountain View and concerned property owners raised concerns that this was not necessary. Instead, EPA worked with the City of Mountain View, California, to have the City formalize its permitting procedures that apply to future construction. These permitting procedures oblige those proposing new building construction within the MEW Study Area to obtain EPA approval of construction plans to ensure that, where necessary, the appropriate vapor intrusion control system is integrated into building construction. In a 2010 ROD Amendment, EPA presented its selected remedy for the vapor intrusion pathway for the MEW Study Area. The ROD Amendment identified a combination of ICs for use at the site. In place of a municipal ordinance as called for in the Proposed Plan, the ROD Amendment selected reliance upon the internally modified permitting procedures by the City of Mountain View's Building, Planning, and Permitting Departments. The City will also implement remedy requirements for projects subject to the California Environmental Quality Act through that law's procedures. With regard to existing commercial buildings where an active remedy is necessary, EPA selected the use of recorded agreements that will help provide notice to current and future owners and occupants, notice to EPA and the MEW Companies when there is a change in building ownership or configuration, and the necessary access to install, maintain and operate the vapor intrusion remedy. These agreements will be binding on and enforceable against future property owners. Additionally, EPA selected the use of a tracking service to provide notice when changes are made to properties within the MEW Study Area. Additional controls that will be implemented by the City of Mountain View include creation of a mapping database to help ensure that parties interested in properties within the MEW Study Area are informed of the appropriate construction specifications when making inquiries with the City.

For more information on the MEW Study Area, see the *Final Supplemental Feasibility Study for the Vapor Intrusion Pathway* (June 2009), *Proposed Plan for the Vapor Intrusion Pathway* (July 2009), and *Record of Decision Amendment for the Vapor Intrusion Pathway* (August 2010), available at: www.epa.gov/region9/mew outside the authority of EPA that may raise questions regarding the reliability and continued sustainability of the IC. Obtaining early and continued assurances from a local government specifying its commitment to the governmental control is recommended to help address this limitation prior to its selection as part of a final cleanup plan.

Certain IC instruments may not be available for use at a site, depending on federal, state, local, tribal, or other applicable laws. Therefore, after determining the universe of ICs available for use at a particular site, the practical and legal limitations can be evaluated. For example, large sites with widespread contamination pose unique IC challenges. These challenges could arise, for instance, where a contaminated groundwater plume underlies many distinct parcels with multiple property owners/occupants and vapor intrusion is the exposure pathway of concern. Negotiating and implementing proprietary controls with many property owners, some of whom may not be PRPs, may present legal, administrative, and other challenges.[233]

8.6.4 Long-term Stewardship

Long-term stewardship (LTS) activities are intended to help ensure that cleanups remain protective of human health and the environment over time and that reuse activities remain compatible with residual site contamination and associated human health risk potentially posed by the vapor intrusion pathway. LTS procedures vary widely, but they generally are intended to help assure compliance with the response actions at the site, including IC compliance, by providing relevant information in a timely manner to stakeholders who may use the property (e.g., owners, excavators, developers, prospective purchasers or tenants) or to parties who otherwise have IC responsibilities (i.e., an entity with enforcement authority). LTS procedures, for example, may entail provisions to monitor and then inform those responsible for the response actions of potential changes in land use, ownership, tenancy, or building construction at a site. Also, LTS procedures may facilitate monitoring IC(s) so that they remain effective and reliable over time. EPA guidance on ICs generally speaks to LTS procedures in terms of IC maintenance[234] and enforcement activities.[235]

Periodic Reviews

A key part of IC maintenance is a periodic process over the IC life cycle to critically review and evaluate the IC instrument(s). Site managers and other stakeholders can evaluate the status of IC implementation, maintenance and enforcement activities at a site and address any potential IC deficiencies during the periodic review. The CERCLA FYR process,[236] for example, allows site managers to evaluate overall protectiveness of the remedy, including ICs.[237]

---

[233] See Section 4.4 of the PIME IC Guide for strategies for implementing proprietary controls.

[234] The term "maintenance" generically refers to those activities, such as monitoring and reporting, that ensure ICs are implemented properly and functioning as intended.

[235] See Sections 8 and 9 of the PIME IC Guide discussing IC maintenance and enforcement activities.

[236] See CERCLA section 121(c).

[237] For general FYR guidance, see *Comprehensive Five-Year Review Guidance* (EPA 2001) at www.epa.gov/superfund/cleanup/postconstruction/5yr.htm. For a more detailed discussion on IC considerations during the CERCLA FYR process, see *Recommended Evaluation of Institutional Controls: Supplement to the "Comprehensive Five-Year Review Guidance,"* (EPA 2011c).

A list of possible IC-specific issues arising from any periodic review of a vapor intrusion site may include:

- ICs that are specified by the decision documents but are not yet in place;
- ICs that are in place but are not attaining compliance with the use restrictions specified by the decision documents (e.g., land use not compatible with IC-specified use restrictions);
- ICs are not identified in the decision documents but are necessary for the remedy to be protective of human health because of the vapor intrusion pathway; and
- Response selection assumptions change (e.g., toxicity values, potential exposure pathways, or land uses change) and warrant the need for new or different response actions, including additional IC(s).

IC Planning Documents

Responsibilities to monitor and report on IC compliance, among other obligations, may be documented in an Institutional Controls Implementation and Assurance Plan (ICIAP)[238] or other IC-related planning documents.[239] An ICIAP can serve to: (1) document the activities necessary to implement and ensure the long-term effectiveness and permanence of ICs (that is, the IC life cycle); and (2) identify the person(s) or organization(s) who, under state or local law, are responsible for conducting those activities. Some ICs generally fall within the jurisdiction of a particular category of stakeholders. Therefore, in addition to developing a comprehensive planning document, such as an ICIAP, it may be useful for parties who share IC responsibilities (e.g., a PRP and local government regarding the use of governmental controls, such as an ordinance or permitting system) to reach a common understanding and acknowledge various IC roles and responsibilities in a formalized manner. Where possible, EPA recommends that these types of arrangements among IC stakeholders be documented to describe commonly understood roles and responsibilities for proper and effective monitoring, reporting, and other IC maintenance and enforcement activities.

8.6.5 Community Involvement and ICs

EPA recommends that site managers and site attorneys provide adequate opportunities for public participation (including potentially affected landowners and communities) when considering appropriate use of ICs (EPA 2012e). Those opportunities may include providing appropriate notice and soliciting comments about cleanup plans. Community acceptance of the need for ICs to provide protection from residual contamination and public understanding of the legal and administrative steps for maintaining ICs often are important to the long-term effectiveness of ICs.

---

[238] For further guidance on developing ICIAPs, EPA developed *Institutional Controls: A Guide to Preparing Institutional Control Implementation and Assurance Plans at Contaminated Sites* (EPA 2012e).

[239] For example, other types of documents may address IC-related activities and responsibilities at a site, such as a ROD, O&M plan, and land use control and implementation plan for federal facility sites.

8.7 Termination/Exit Strategy

This sub-section focuses on the termination/exit strategy for vapor mitigation response actions. Termination for vapor mitigation activities implemented under CERCLA, RCRA, Brownfields, and federal facilities cleanups can occur when the objectives of these cleanup activities have been met. For purposes of this sub-section, termination refers to the cessation of all activities related to building mitigation, control of subsurface vapor source(s), ICs, and monitoring.

When mitigating vapor intrusion through subsurface source remediation, building mitigation, and ICs, it is important to develop termination criteria, including the rationale for their selection, early in the remedy planning (e.g., alternatives development) process. (Termination criteria generally refer to numeric cleanup levels for each site-specific contaminant and narrative cleanup objectives that are to be attained by the response actions.) EPA recommends that these termination criteria be recorded in decision documents, in any other planning reports, and in monitoring reports. EPA generally recommends also developing and documenting an exit strategy, which clarifies how it will be determined that the termination criteria have been attained (e.g., monitoring data and associated statistics that will be used to demonstrate attainment). This document could be developed in conjunction with the O&M plan and monitoring program so that all stakeholders are provided with a clear and comprehensive set of termination criteria for the remediation and mitigation systems and ICs. If site conditions (e.g., building usage, vapor flux) change during the cleanup activities, it may become necessary to modify the termination criteria and/or strategy.

When reviewing vapor intrusion activities, considerations for evaluating termination activities may include:

- Termination of subsurface remediation activities;
- Termination of engineered exposure controls (building mitigation);
- Termination of the associated ICs; and
- Termination of monitoring.

8.7.1 Termination of Subsurface Remediation Activities

Where feasible, the preferred response to address vapor intrusion is to eliminate or substantially reduce the level of volatile chemical contamination in the source media (e.g., groundwater and subsurface soil) to levels that eliminate the need to mitigate or monitor vapor intrusion, as noted in Section 8.1 of this Technical Guide. If subsurface remediation activities are being conducted at the site, termination of these activities will be contingent on demonstrating that the chemical-specific cleanup levels for the subsurface media have been attained. EPA recommends that the termination criteria and exit strategy for these remediation activities be documented to foster collection and evaluation of appropriate data to support eventual termination of these subsurface activities.

EPA recommends that site-specific monitoring data be evaluated to determine if the termination criteria have been met. Typically, monitoring will continue until the source(s) are remediated to cleanup levels that eliminate the need to mitigate vapor intrusion at the point of exposure. As appropriate, the exit strategy may provide criteria for phased remediation, resulting in a termination evaluation as source cleanup levels are achieved in parts of the contaminated area. If the subsurface vapor source(s) is not remediated, it is generally anticipated that remediation (and monitoring and any building mitigation) will continue.

Monitoring, in part, could be based on data similar to those that were used in a multiple-lines-of-evidence approach for characterizing the pathway and human health risk or for supporting the decision to undertake preemptive mitigation/early action (e.g., soil gas sampling, sub-slab sampling, or vapor sampling within potentially affected structures). EPA recommends identifying and documenting target concentration(s) that would allow for remediation termination, along with recommended monitoring/sampling frequencies.

If evaluation of the site-specific data indicates an increase in subsurface vapor concentrations during the monitoring period, it may be appropriate to evaluate whether the subsurface remediation plan and the CSM are adequate and appropriate.

Typically, once it is preliminarily determined that the subsurface remediation system(s) may be terminated, EPA recommends a period of attainment monitoring. During the attainment period, EPA recommends that the remediation system (e.g., reagent delivery equipment, soil vapor extraction wells) not be operated for a sufficient period to allow subsurface vapors reach equilibrium and indicate post-remediation conditions. The type and frequency of data collected during attainment monitoring entails a site-specific determination. Additionally, EPA recommends that criteria be described and documented, as part of exit strategy development, to determine when ending the attainment monitoring period is appropriate. To develop an exit termination strategy, site-specific fate and transport data may be used to identify an appropriate time period to allow the vapor concentrations to equilibrate. In addition, the termination of the attainment monitoring period may involve an evaluation of the contaminant attenuation in the vadose zone.

8.7.2 Termination of Building Mitigation

For purposes of this Technical Guide, “termination of building mitigation” refers to ending the use of an engineered exposure control(s) that reduces or eliminates human exposure via the vapor intrusion pathway. Typically, vapor mitigation is implemented when it is determined that (1) unacceptable human health risk to inhabitants is identified, or (2) the system(s) was(were) installed as part of an early action strategy (see Sections 3.3 and 7.8 for a discussion of building mitigation as an early action).

As described in Section 8.2, vapor intrusion can be mitigated in specific buildings using either an active or passive vapor mitigation system (or a combination thereof).

Active Building Mitigation

Generally, building mitigation systems are implemented in conjunction with the investigation and remediation of subsurface vapor source(s). Typically, building mitigation systems will be operated until the source(s) are remediated to attain the cleanup levels (e.g., for the subsurface vapor source(s)) that eliminate the need to mitigate vapor intrusion at the point of exposure. If subsurface vapor source(s) are not remediated, it is generally anticipated that mitigation activities will continue indefinitely. As appropriate, the termination strategy may provide criteria for phased evaluation of system cessation as source cleanup levels are achieved in parts of the contaminated area.

Generally, once the subsurface vapor source(s) is remediated to levels that meet the remedial objectives and protect human health from the vapor intrusion pathway, EPA recommends that the site-specific monitoring data be evaluated to determine if the termination criteria for the building mitigation system have been met. These monitoring data, in part, could be based on data similar to those that were used for characterizing human health risk or for supporting the decision to undertake preemptive mitigation/early action during the vapor intrusion investigation (e.g., sub-slab soil gas sampling and/or indoor air sampling). EPA recommends identifying and documenting target concentration(s) that would allow for system termination, along with recommended monitoring/sampling frequencies. In addition, certain site-specific performance assessment data (e.g., standpipe vapor sampling) may also warrant consideration to make this determination.

Typically, once it is determined that the building mitigation system may be terminated, EPA recommends a period of attainment monitoring. During the attainment period, EPA recommends that the mitigation system (e.g., subslab suction wells or ventilation fans) be offline for a sufficient period to allow vapors beneath the structure reach equilibrium and indicate post-remediation conditions. The type and frequency of data collected during attainment monitoring entails a site-specific determination. Additionally, EPA recommends that criteria be established in the exit strategy to determine when ending the attainment monitoring period is appropriate. To develop an exit termination strategy, site-specific fate and transport data may be used to identify an appropriate time period to allow the vapor concentrations to equilibrate. In addition, the termination of the attainment monitoring period may involve an evaluation of the contaminant attenuation in the vadose zone.

If the attainment criteria evaluation indicates that cleanup levels and objectives are not being met, it may be necessary to continue or resume subsurface remediation and mitigation activities. Once it is determined that the cleanup levels and objectives have been met, the active components of the system may be removed from the building; on the other hand, the building owner may elect to continue to operate the mitigation system under their own discretion and for their own purposes (e.g., radon reduction and moisture control). Once the cleanup levels and objectives have been met, all O&M and monitoring of active mitigation systems specified by EPA can cease.

Passive Building Mitigation

The termination of passive vapor mitigation systems will typically be similar to the criteria established for the termination of active mitigation systems. In summary:

- Like active mitigation systems, passive mitigation systems are typically implemented in conjunction with the investigation and remediation of subsurface vapor source(s).
- Generally, once the subsurface vapor source(s) is remediated to levels that meet the cleanup levels and objectives that will protect human health from the vapor intrusion pathway, EPA recommends that the site-specific monitoring data be evaluated to determine if the termination criteria have been met.

If the site-specific criteria evaluation indicates that cleanup levels and objectives are not being met, it may be appropriate to evaluate the current system's effectiveness or the possible application of an active mitigation system. Once it is determined that contaminant cleanup levels and objectives have been met, all O&M and monitoring specified by EPA can cease. EPA generally does not have a need to seek removal of barriers or seals that comprise a passive mitigation system as part of termination activities.

8.7.3 Termination of ICs

"Termination of ICs," as used in this Technical Guide, refers to discontinuing any and all ICs specified by EPA because restrictions on land or resource use and/or notices and other informational devices are no longer necessary to help ensure protectiveness of human health (i.e., human health risk from exposures to vapor intrusion, if any, are expected to be acceptable in the absence of all IC(s)). Generally, ICs are implemented in conjunction with the investigation and remediation of source(s). It is anticipated that ICs selected and implemented will be needed until (1) subsurface vapor source(s) are adequately remediated, or (2) restrictions on land, resource, or building use are no longer necessary based on current and reasonably anticipated future exposure scenarios. Therefore, when developing a termination strategy for ICs that have been selected as part of a response action, the strategy is typically based on data collected from the affected media.

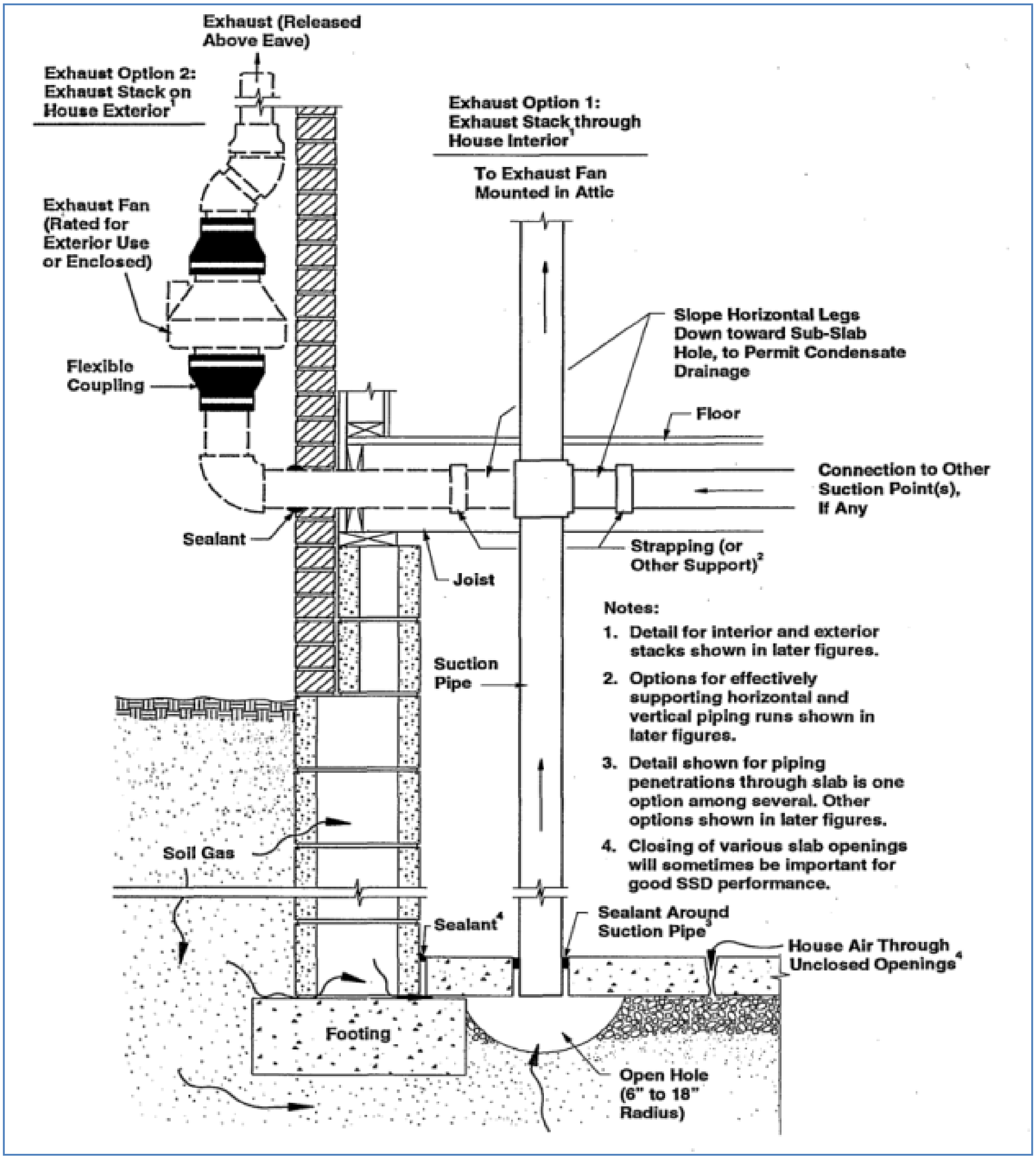
EPA recommends that the exit strategy consider and identify cleanup levels for the subsurface vapor source(s). As long as the subsurface vapor source exceeds such cleanup levels, it is generally anticipated that the associated ICs will continue. As appropriate, the termination/exit strategy may provide criteria for a phased IC termination evaluation as source cleanup levels are achieved in parts of the contaminated area.

If the site-specific criteria evaluation indicates that terminating the ICs is appropriate, EPA may conclude that site conditions no longer warrant ICs being used as part of the response action for the vapor intrusion pathway. At this point, EPA could notify the appropriate entity(s), such as local or state government, tribe, affected landowner, or responsible parties, in writing that EPA's response objectives have been met and that the IC need not be maintained. As such, EPA's oversight of the IC(s) can cease.

8.7.4 Termination of Monitoring

For purposes of this Technical Guide, monitoring includes activities conducted to verify that the vapor intrusion pathway does not pose a health concern to building inhabitants while remediation and mitigation activities are underway and in the event that the remediation and mitigation activities are terminated. "Termination of monitoring," for purposes of this Technical Guide, refers to ending any monitoring that was needed to verify that no further response action, including IC-related activity, is necessary to protect human health from indoor air exposures posed by vapor intrusion. When developing termination criteria for monitoring, the decision is generally based on data collected from all the affected media.

As noted above, monitoring is generally implemented in conjunction with the remediation of subsurface vapor sources(s). EPA recommends that the exit strategy consider cleanup levels for all contaminated media. Typically, monitoring will continue until the source(s) are remediated to cleanup levels that eliminate the need to mitigate vapor intrusion at the point of exposure (i.e., allow building mitigation systems to be terminated). If the subsurface vapor source is not remediated, it is generally anticipated that any associated monitoring will continue. As appropriate, the exit strategy may provide criteria for phased monitoring, resulting in a termination evaluation as source cleanup levels are achieved in parts of the contaminated area.

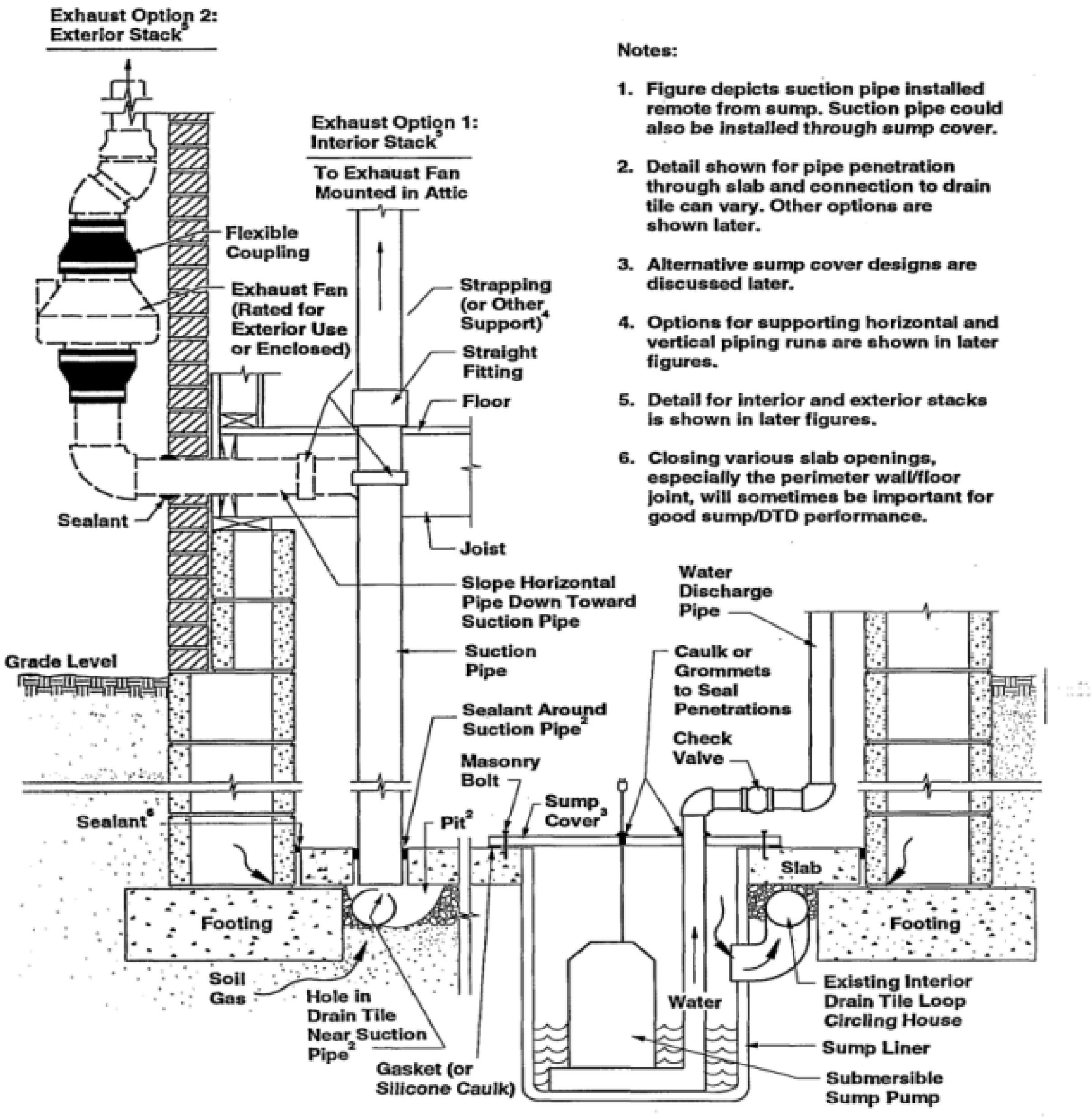


Notes:

1. Detail for interior and exterior stacks shown in later figures.
2. Options for effectively supporting horizontal and vertical piping runs shown in later figures.
3. Detail shown for piping penetrations through slab is one option among several. Other options shown in later figures.
4. Closing of various slab openings will sometimes be important for good SSD performance.

Figure 8-1 Illustration of Sub-slab Depressurization (SSD) System

Note: Shows one example of how a sub-slab depressurization system might be constructed. In this case, the example suction pipe has been inserted vertically downward through the slab from inside the house. Two options are indicated for location of the exhaust fan: one exterior to the building; and the other within an attic. In both of these cases, the exhaust gas stream is to be vented outside and above the building. Source: EPA (1993a; Figure 1)



Notes:

1. Figure depicts suction pipe installed remote from sump. Suction pipe could also be installed through sump cover.
2. Detail shown for pipe penetration through slab and connection to drain tile can vary. Other options are shown later.
3. Alternative sump cover designs are discussed later.
4. Options for supporting horizontal and vertical piping runs are shown in later figures.
5. Detail for interior and exterior stacks is shown in later figures.
6. Closing various slab openings, especially the perimeter wall/floor joint, will sometimes be important for good sump/DTD performance.

Figure 8-2 Illustration of Drain-tile Depressurization (DTD) System

Note: Shows one example of how a drain-tile depressurization system might be constructed. In this case, tiles are shown draining to a sump in the basement, to which an air-tight cover is sealed. The example suction pipe has been inserted vertically downward through the slab at a location remote from the sump. Two options are indicated for location of the exhaust fan: one exterior to the building; and the other within an attic. In both of these cases, the exhaust gas stream is to be vented outside and above the building. Source: EPA (1993a; Figure 3)

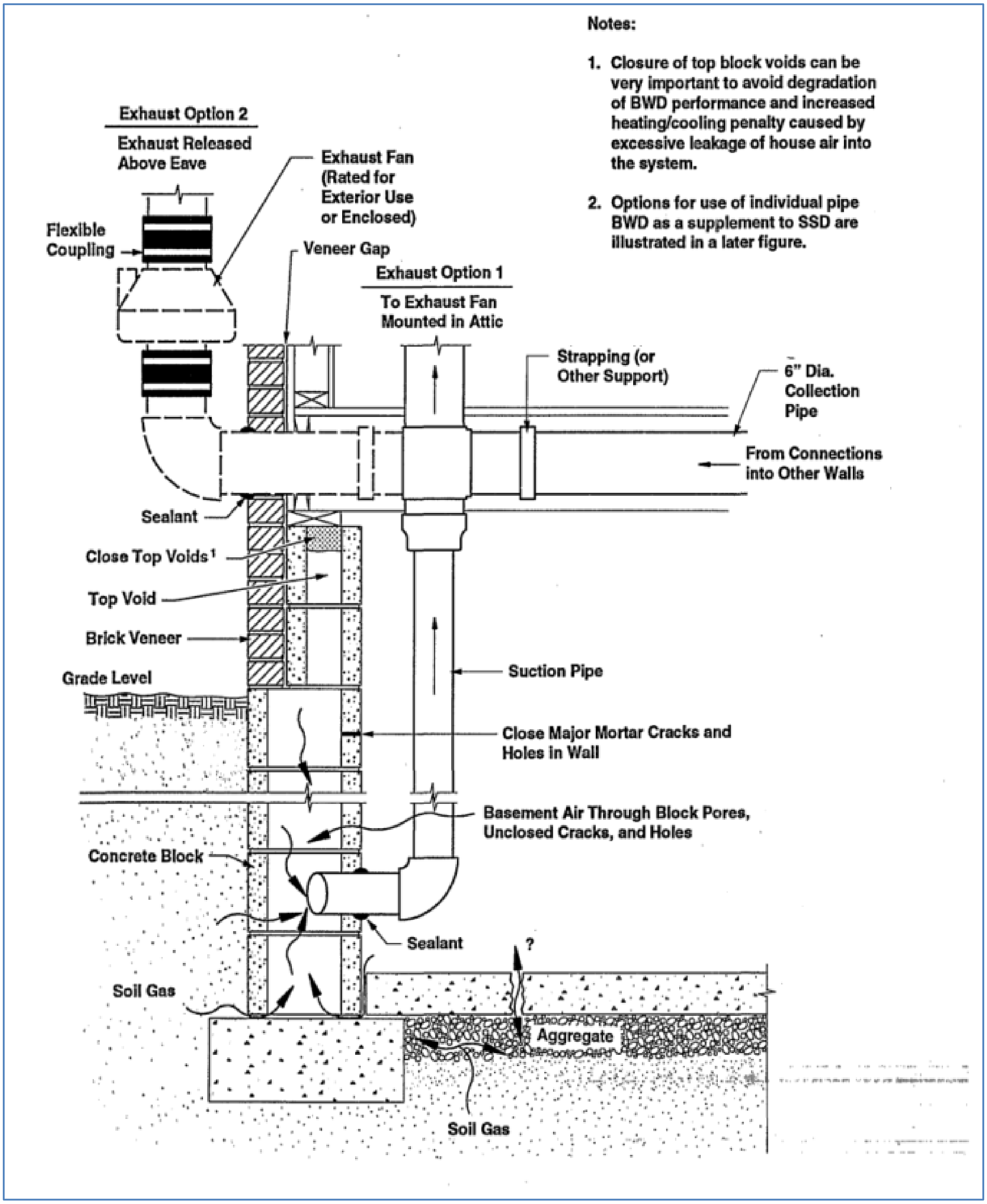
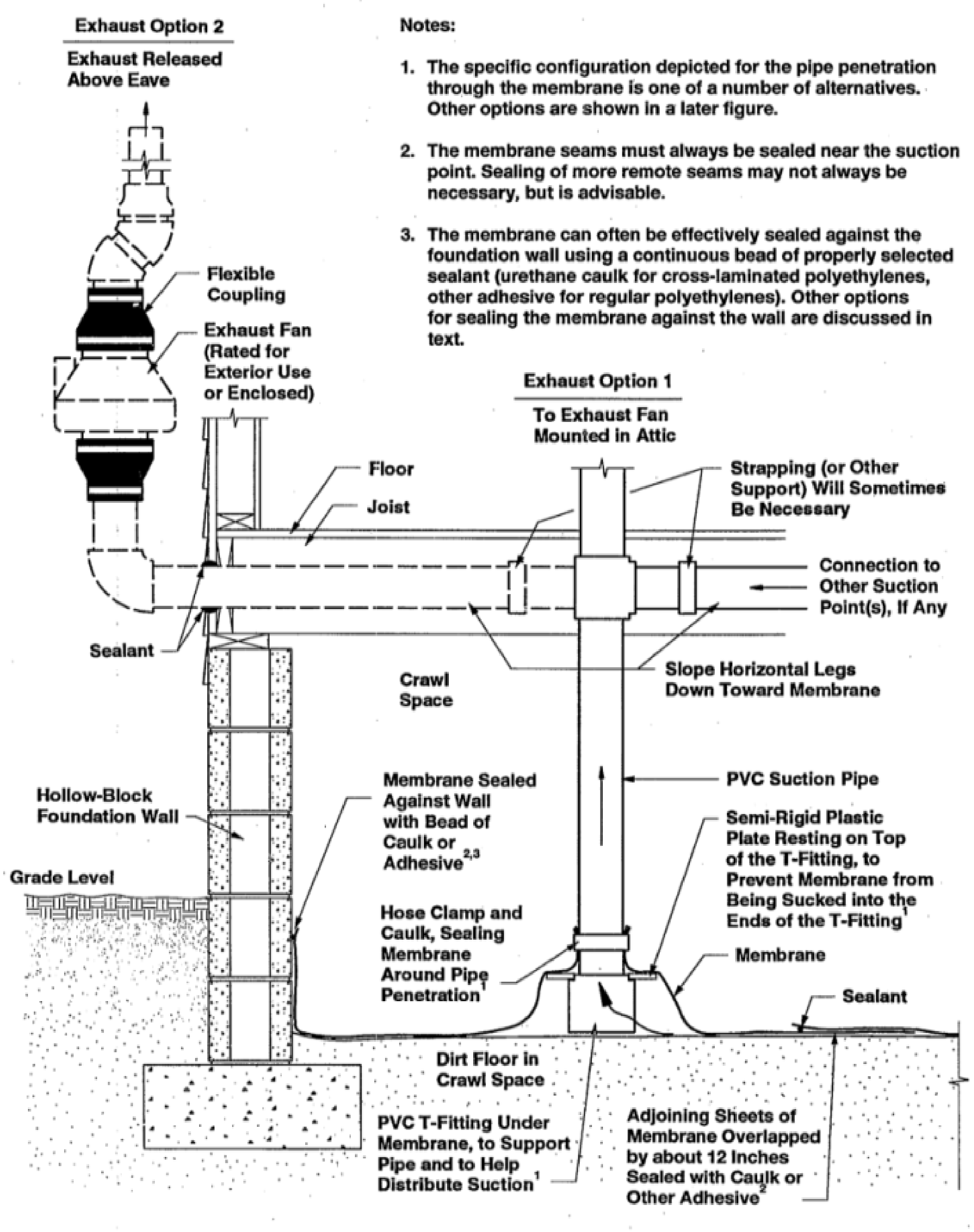


Figure 8-3 Illustration of Block-wall Depressurization (BWD) System

Note: Shows one example of how a block-wall depressurization system might be constructed. In this case, individual suction pipes are inserted into the void space in the basement wall, which are connected to one or more fans. Source: EPA (1993a; Figure 5)



Notes:

1. The specific configuration depicted for the pipe penetration through the membrane is one of a number of alternatives. Other options are shown in a later figure.
2. The membrane seams must always be sealed near the suction point. Sealing of more remote seams may not always be necessary, but is advisable.
3. The membrane can often be effectively sealed against the foundation wall using a continuous bead of properly selected sealant (urethane caulk for cross-laminated polyethylenes, other adhesive for regular polyethylenes). Other options for sealing the membrane against the wall are discussed in text.

Figure 8-4 Illustration of Sub-membrane Depressurization (SMD) System

Note: Shows one example of how a sub-membrane depressurization system might be constructed. In this case, the example suction pipe penetrates the membrane overlying a dirt floor.

Source: EPA (1993a; Figure 6)

9.0 PLANNING FOR COMMUNITY INVOLVEMENT

Communicating information about environmental risk is one of the most important responsibilities of site managers and community decision-makers. Simply stated, risk communication, whether written, verbal, or visual statements concerning risk, is the process of informing people about potential and perceived hazards to their person, property, or community.

EPA recommends that human health risk be described in context, recognizing there are personal, cultural and societal dimensions of risk. EPA also recommends providing advice about risk-reduction behavior and encouraging a dialogue between the sender and receiver of the message. The best risk communication occurs in contexts in which the participants are informed about risks they are concerned about, the process is fair, and the participants are free and able to solve whatever communication difficulties arise. *Risk Communication in Action: The Risk Communication Workgroup* (EPA 2007) is one of several resources available that explain the elements of successful risk communication and describe communication tools and techniques.

Thus, community involvement is a key component of any site investigation or other EPA response action. Members of the public affected by environmental contamination can be made aware of what EPA is doing in their community and have a say in the decision-making process. Stakeholder and community involvement is particularly important for sites with vapor intrusion issues, in part because the exposure to toxic vapors may pose a significant human health risk that is unknown to inhabitants (in the absence of mitigation systems), as they potentially arise in homes, workplaces, schools, and places of commerce and gathering. Because of the potentially intrusive nature of assessment and mitigation for vapor intrusion, stakeholder involvement is important throughout the process.

EPA generally recommends that stakeholder and community involvement be conducted from the earliest stage of the site assessment and risk assessment process, with on-going education, two-way communication, and discussion throughout the entire process to create community trust and acceptance. For example, EPA recommends initiating community involvement activities as soon as possible after determining that vapor intrusion may exist at a particular site.

Informing the community about vapor intrusion concerns and plans to conduct an assessment, including sampling, can be resource intensive. Thus, EPA recommends evaluating each project, in coordination with appropriate state and tribal officials, to assess the level of stakeholder interest and need for community involvement during various stages of the decision-making process.

Public Participation and Risk Communication

A meaningful community involvement process is founded upon knowledge of effective public participation and risk communication practices. Public participation refers to the full range of activities that EPA uses to engage communities in the Agency's decision-making process. In 2003, EPA updated its Public Involvement Policy.[240] Its foundation includes seven basic steps to support effective public participation:

---

[240] EPA Public Involvement Policy (2003): http://www.epa.gov/publicinvolvement/policy2003/index.htm.

1) Plan and budget.
2) Identify those to involve.
3) Consider providing assistance.
4) Provide information.
5) Conduct involvement.
6) Review and use input and provide feedback to the public.
7) Evaluate involvement.

To help implement the steps, EPA developed a series of brochures[241] on effective public participation that outline how to budget for, plan, conduct, and evaluate public participation.

EPA Program-Specific Community Involvement Guidance and Recommendations

CERCLA and other EPA regulations[242] identify specific community involvement activities that are appropriate at certain points throughout the cleanup process. Specifically, in 2005, OSWER published the *Community Involvement Handbook*[243] (EPA 540-K-05-003). The handbook presents legal and policy motivations for Superfund community involvement and includes additional suggestions for involving the community in the Superfund process. In addition, EPA's *Proposed Guidelines for Brownfields Grants* encourages applicants to describe their plans for involving community-based organizations in site cleanup and reuse decisions.[244] The *Grant Funding Guidelines for State and Tribal Response Programs* for brownfields funding also encourage programs to establish, at a minimum, "mechanisms and resources to provide meaningful opportunities for public participation."[245] In addition, in 1995, EPA promulgated the *RCRA Expanded Public Participation* rule (60 FR 63417-34, December 11, 1995)[246] which created additional opportunities for public involvement in the permitting process and increased access to permitting information.[247]

---

[241] EPA Public Involvement Brochures: http://www.epa.gov/publicinvolvement/brochures/index.htm

[242] 40 CFR §300.155 http://edocket.access.gpo.gov/cfr_2003/julqtr/pdf/40cfr300.155.pdf

[243] EPA *Superfund Community Involvement Handbook*: http://www.epa.gov/superfund/community/cag/pdfs/ci_handbook.pdf

[244] EPA Brownfields Grants website: http://www.epa.gov/brownfields/cleanup_grants.htm

[245] EPA Brownfields State and Tribal Response Program Grants website: http://www.epa.gov/brownfields/state_tribal/fund_guide.htm

[246] Section 7004(b) of the Resource Conservation and Recovery Act provides EPA broad authority to encourage and assist public participation in the development, revision, implementation, and enforcement of any regulation, guideline, or program under RCRA.

[247] EPA *RCRA Public Participation Manual*: http://www.epa.gov/osw/hazard/tsd/permit/pubpart/manual.htm

At sites with vapor intrusion issues, EPA recommends that the site planning team (i.e., the remedial project manager (RPM) or on-scene coordinator (OSC); community involvement coordinator (CIC); risk assessor; the enforcement case team; EPA contractor; state, tribal, or local agency staff; federal agency staff relevant to the site; or others) to consider the following:

- Develop a community involvement plan (CIP) or update the existing CIP.
- Learn about the site and the community to foster development of a CIP that highlights key community needs, concerns and expectations.
- Commit to ongoing, sustained communication activities throughout vapor mitigation and site cleanup efforts.
- Develop a communication strategy[248] and conduct outreach to inform stakeholders about the facts and findings pertaining to the site.
- Obtain written permission, if appropriate and necessary, for building/property access, and involve the property owner/occupant in identifying or removing potential indoor air contamination sources, including inspection of residence and completing an occupant survey.
- Fully communicate and interpret sampling results, and evaluate mitigation options, if any are warranted.
- Recognize preference of owners and occupants for confidentiality with regards to property-specific data.

When considering the most effective community involvement strategies, EPA recommends that its previous involvement be considered, as well as the existence of community or neighborhood groups and the phase of the regulatory process in which vapor intrusion is being addressed. Additional resources for planning and implementing effective community involvement activities are discussed in Section 9.2: Communication Strategies and Conducting Community Outreach.

9.1 Developing a Community Involvement or Public Participation Plan

A CIP is a site-specific strategy to enable meaningful community involvement throughout the cleanup process.[249] CIPs specify EPA-planned community involvement to address community needs, concerns, and expectations that are identified through community interviews and other means. A CIP will enable community members to understand the ways in which they can participate in decision-making throughout the cleanup process. That is, the CIP is a way for EPA to plan for informing and involving the community in the cleanup process and can be a powerful

---

[248] A communication strategy can be one component of a CIP, but it addresses a specific event, issue, or concern, such as an emergency response to a release, or communicating risk at a site. The CIP, on the other hand, describes an overall strategy for conveying information throughout the cleanup process at a site.

[249] Community involvement plans available at: http://www.epa.gov/superfund/community/pdfs/toolkit/ciplans.pdf

way to communicate EPA's commitment to listening and responding to community concerns, and provide timely information and opportunities for community involvement.

The CIP is intended to be a "living" document and is most effective when it is updated or revised as site conditions change. When developing the CIP document, EPA recommends that the site planning team consider the following steps:

Describe the Environmental Setting and Cleanup Process

Describe the release and affected areas (the site). This includes information about the site, its history, the key issues related to site contamination, and how vapor intrusion fits into EPA's overall cleanup effort at the site.

Describe and Learn about the Community

Describe the community. The community profile is a description of the affected community that summarizes demographic information and identifies significant subgroups in the population, languages spoken, and other important characteristics of the affected community, such as whether the site is located in an area with environmental justice concerns or includes sensitive populations. EPA recommends that the community profile also document information sources and describe how the profile was developed.

Learn about community needs, concerns and expectations: Issues of concern to residents and business owners can be identified through community interviews, informal discussions and interactions, local media reports, and other insights about the affected community. Questions may include:

- What are public perceptions and opinions of EPA and the cleanup process?
- How do people want to be kept informed (i.e., mechanisms to deliver information)?
- How do people want to be included in the decision-making process?
- What are the perceived barriers to effective public participation?
- Are there other sources of pollution that affect the community?
- Have there been past experiences of mistrust or any unique concerns?

This information can be used to recommend any special services to be provided, including technical assistance, formation of a Community Advisory Group, facilitation/conflict resolution, or translation services.

Write and Compile the CIP

Once the site planning team has learned about the community, it is time to put the information together in a way that will be useful to EPA and the community. In addition to the site description, community description, and community needs and concerns, the CIP also may include a reference listing of contacts (name, address, phone, email) useful for the community or the site planning team. EPA recommends that the contact list generally include contact information for:

- The site planning team.
- Community groups and community leaders.
- Local elected officials.
- Local, state, tribal, and federal agency staff relevant to the site.
- Media contacts (including social media outlets and community journalists).
- Others, as appropriate.

To ensure that the CIP is indeed informed by the community, EPA recommends that a draft of the CIP be shared with the community, and their input and feedback be invited as it evolves. Again, the CIP is intended to be a "living" document and is most effective when it is updated or revised as site conditions change. In some cases, particularly when the CIP is updated or revised for a FYR or where community interest is minimal, a short CIP outlining EPA's plan for community involvement may be all that is needed. For most sites, EPA recommends that the CIP be written to address the community directly, and their active involvement be invited at each stage of the cleanup process.

9.2 Communication Strategies and Conducting Community Outreach

EPA recommends that community outreach activities be initiated as soon as possible after determining that vapor intrusion may exist at a particular site. Informing and educating the community includes distributing information and providing opportunities for EPA to listen to community concerns. EPA recommends community outreach activities be tailored to the community based on information gleaned from community interviews and other methods used in developing the CIP. Public health officials from state, tribal, or local agencies may be helpful in communicating risk information and answering questions from the community.

Communication Strategies

Communication strategies are plans for communicating information related to a specific issue, event, situation, or audience. They serve as the blueprints for communicating with the public, stakeholders, or even colleagues. EPA recommends that communication strategies:

- Outline the objective and goals of the communication.
- Identify stakeholders.
- Define key messages.
- Pinpoint potential communication methods and vehicles for communicating information and obtaining information from the community for a specific purpose.

When developing a communication strategy, the first step is to determine why the communication is necessary and define its desired objectives, and then to focus on defining the audiences and how to reach them. Keep in mind that the demographics, knowledge, and concerns of the audiences play an important role in defining the key messages. Once the key messages are defined, the outreach vehicle can be determined.

Conducting Community Outreach

The site planning team likely will use several different outreach techniques during the course of the cleanup process. When planning community outreach, EPA generally recommends that the site planning team collaborate with internal and external partners, such as local, state, and tribal officials and departments of health; faith-based organizations; and community groups. It is important to accommodate hearing-impaired or limited English proficiency (LEP)[250] persons in all outreach efforts by providing spoken or sign language interpreters at meetings and translating printed outreach materials. It also is important to ensure that the community understands the concept of vapor intrusion.

Examples of community outreach techniques to consider are described below.

Public Meetings/Gatherings

Public meetings are a useful opportunity to explain environmental conditions at the site, potential health impacts, intended indoor air sampling, and remediation strategies. It may be helpful to hold meetings prior to and following key sampling events to describe sampling strategies and consequent results, respectively. EPA recommends that the meeting include a period to address specific questions from the public regarding sampling results or any other specific concerns, as well as visual aids and maps and spoken or sign language interpreters to facilitate communication and discussion. The use of a CSM, for example, is useful in public meetings to graphically reinforce the messages. It may be helpful to follow up with meeting participants to inquire about the effectiveness of the meeting and whether it met their needs. Other meeting follow-up activities could include responding to requests for information, distributing meeting notes, and creating a mailing list.

Additional opportunities for the site planning team to communicate with the community in a group setting include public availability sessions and public forums or poster sessions at community group meetings or neighborhood board meetings. These options are a more informal way of interacting with community members and they allow a casual "question and answer" or discussion format as compared to the more formal presentation at a public meeting.

Mass Media

The media can be the best means of reaching a large audience quickly. Extending invitations to the media for important meetings, providing opportunities for media questions

---

[250] Executive Order 13166, *Improving Access to Services for Persons with Limited English Proficiency*, directs federal agencies to examine the services they provide, identify any need for services to those with LEP, and develop and implement a system to provide those services so LEP persons can have meaningful access to them.

to be addressed in a timely manner, and recognizing that the media control the content of their publications all are important considerations when working with the media. The site planning team can work with the Agency's regional site press officer to foster a relationship with the media by sharing the Agency's rationale for its plans and actions. It is appropriate to use the media to publicize a site-related decision, an upcoming meeting, changes in schedule, or changes in activities or expectations. Press releases can be used to inform the media of major site-related milestones.

Fact Sheets

Communities appreciate concise, easy-to-understand, and technically accurate fact sheets on the history of the contamination, chemicals of concern, human health risk, planned cleanup activities, and the vapor intrusion assessment and response actions. Be sure to include who to contact for more information.

Because sites involving vapor intrusion can be complex, it may be useful to include additional information in the fact sheets for home owners and renters, including information about household products that may be potential sources of indoor air contamination, as well as steps that can be taken to minimize these sources. EPA recommends preparing and distributing periodic status updates and fact sheets to concerned community members throughout the cleanup process.

Letters

Whenever there are plans to conduct indoor air sampling, EPA recommends sending a letter to each building owner and renter explaining plans to conduct indoor air sampling and requesting written permission for voluntary access to do so. In addition, a one-on-one meeting with the building owner or renter is generally recommended to discuss sampling efforts and access agreements in detail (see Section 9.3).

EPA also recommends that letters be sent to each building owner and renter to report sampling results in a timely manner (see Section 9.4). These letters and meetings often are part of a larger effort that also includes use of other communication strategies, such as community meetings and in-person visits.

In-person Visits

EPA recommends individual, one-on-one communication with each property owner and renter whenever possible.

- Try to schedule in-person visits with individual property owners and renters. These visits also may include owners and renters of properties located outside the planned investigation area. The initial visit can be used to explain sampling plans in more detail, answer questions, and obtain written permission to sample.

- During the visit, the property owner or renter can be briefed about any instructions to follow during sampling activities (for example, keep doors and windows closed during sampling). A general survey of the building could be conducted to determine likely sources of indoor air contaminants.

- EPA recommends the site planning team also describe to owners and renters the sampling devices that will be used, what they look like, where they will be located, and any restrictions or impediments to daily activities that may arise from the ongoing sampling activities.

Information Repository

An information repository can be established and maintained prior to, during, and following site activities, which is generally required for sites where remedial action or removal actions (where on-site action is expected to exceed 120 days) are undertaken pursuant to CERCLA. The information repository is intended to include the administrative record, fact sheets, question-and-answer sheets, and other site-related documents and be located reasonably near the site. However, given the tremendous change in information technology, it may also be appropriate to set up an Internet-based or digital repository (webpages) to share key information. This depends on the community's ability to access and utilize this technology. EPA recommends that community members be made aware of the information repository through the other public outreach mechanisms described above (e.g., local media, newsletters, and public meetings).

Electronic Notification

It also may be useful to establish a registration capability that allows interested community members to sign up for automatic alerts to updates posted on the site website or email listserv.

9.3 Addressing Building Access for Sampling and Mitigation

EPA recommends that all requests for access, as well as provision of access, be in writing in order to document EPA's due diligence to protect human health at the site. EPA recommends that the site planning team provide building owners and occupants with information about the sampling device(s)) being used, including what they look like, where they will be located and any restrictions or impediments to daily activities that may arise due to ongoing sampling.

In the case of an initial refusal to provide access, additional attempts for access are generally recommended, although regional practices may vary. EPA recommends documenting all attempts to gain access, for example using telephone conversation records, emails, or letters sent to home or building owners.

Gaining access to owner-occupied residences for vapor intrusion sampling and mitigation may be handled differently than for commercial buildings or rental properties.

Owner-Occupied Residences: Allowing EPA to sample or install mitigation systems in an owner-occupied residence is a voluntary action. EPA generally encourages owners to take advantage of an offer for an assessment and mitigation system, if necessary.

Rental Properties: Access may be voluntary or involuntary. Site planning teams often deal with both owners and renters when there is a need to sample on, in, or under a rental property. There are different legal and communication issues for owners and renters. For example, the owner is responsible for granting access for sampling and for installation of mitigation measures, if they are necessary; however, if the owner grants access, logistics normally are arranged with the renter. EPA recommends apprising both the owner and the renter of human health risk that may be posed by vapor intrusion, which includes providing building-specific sampling results to both parties when available. If the owner of a rental property refuses access, EPA may, nevertheless, pursue access, in the interest of protecting the occupants, for determining the need for response, choosing a response action, taking a response action, or otherwise enforcing CERCLA or RCRA (EPA 1986, 1987, 2010a). Notifying the owner of a rental property of this statutory authority may help to avoid the need for legal action.

Nonresidential Buildings: Site managers also may need to sample on, in, or under nonresidential buildings, such as schools, libraries, hospitals, hotels, and stores. In these situations, broader outreach to the public may be appropriate in addition to maintaining direct contact with the property owner. Similar to rental properties, access for sampling and for implementation of mitigation methods, if they are necessary, may be voluntary or involuntary. If the owner of a nonresidential building refuses access, EPA may, nevertheless, pursue access, in the interest of protecting the occupants, for determining the need for response, choosing a response action, taking a response action, or otherwise enforcing CERCLA or RCRA (EPA 1986, 1987, 2010a).

Property Ownership Changes: For owners of homes or buildings who did not provide access for assessment sampling or installation of a mitigation system, EPA recommends that the site planning team make reasonable attempts to track ownership changes, although the appropriate state, tribal, or local agency or PRP may be in a better position to track this information. For example, reasonable attempts to make contact can be done by annually conducting drive-bys or inspections and noting homes or buildings for sale, periodically checking on-line real estate sales or title insurance listings, or using other mechanisms. Homes that were initially targeted but not sampled can be reconsidered during the review or if there are major changes to the toxicity values for the site contaminants of concern. Annually mailing notifications to buildings not previously sampled is a means to foster reconsideration of testing with a change in ownership. If ownership changes are noted, appropriate follow-up can be conducted with the new home owner or building owner.

Federal statutory authority to access private property to conduct investigations, studies and cleanups pursuant to CERCLA and RCRA is discussed in Section 1.2 of this Technical Guide.

9.4 Communication of Indoor Sampling Efforts and Results

The community involvement plan or public participation plan is intended to address community concerns and participation regarding indoor air and sub-slab sampling. In addition to the general community involvement activities occurring throughout the cleanup process (see Section 9.2), the site planning team may choose to hold a community meeting to discuss indoor sampling efforts and results. EPA recommends sending a letter to each home or building owner and renter explaining plans to conduct sampling or providing sampling results. EPA recommends that this letter be in addition to a one-on-one meeting with the building or home owner to discuss access agreements, sampling efforts, and sampling results. Prompt communication of sampling results to building or home owners is important as some people may choose to make precautionary decisions prior to regulatory decisions on remediation or mitigation measures.

EPA recommends the site planning team inquire about stakeholder preferences for confidentiality with regards to property-specific data. It may be appropriate to segregate data for private residential properties versus community properties (e.g., schools, daycare centers, commercial buildings) or provide different types of property identifiers for these respective building types in reports and maps and tables displayed at public meetings or otherwise made available to the community.

Letters Transmitting Sampling Results[251]

EPA recommends that the site planning team provide validated sampling results and interpretations (e.g., chemicals of concern, associated risk assessment implications) in plain English (and translations, if necessary) to property owners and renters in a timely manner (e.g., within approximately 30 days of receiving the results). EPA also recommends the transmittal letter indicate what future actions (e.g., mitigation options), if any, are contemplated,[252] based on the sampling results, and contain additional site-specific and possibly building-specific information, including, but not limited to:

- Site and Home/Building Information.
  - Site name and location of contamination.
  - Date of sampling.
  - Address of sampled home or building.
  - Locations sampled (both indoor and outdoor).

- Sampling Results
  - Sampling results for site-related, vapor-forming chemical(s) and for any other chemicals, if detected, including an explanation of results believed to be attributable to background sources, if known.[253]
  - Risk-based screening levels (for example, VISLs described in Section 6.5) or other risk-based benchmarks used to explain and interpret the sampling results.
  - Explanation and interpretation of sampling results, if known, which may include a summary of the human health risk assessment, if available (see Section 7.4).[254]

---

[251] Within the community of risk professionals, the phrase 'risk communication' has come to mean communication that supplies lay people with the information they need to make informed independent judgments about human health risk or public safety (Morgan et al. 1992). In this case about vapor intrusion, the ultimate goal of risk communication is to assist stakeholders and the general public in understanding the investigation data and the rationale behind any risk-informed decision, so they may arrive at a balanced judgement that reflects the factual evidence in relation to their own interests and values.

[252] This section may include an explanation of mitigation process and responsibilities and a timeline for further contact regarding system installation and options. If a building mitigation system is recommended on the basis of a human health risk assessment, EPA recommends that the site planning team explain that the risk calculation reflects conservative, health-protective factors.

[253] With such information, EPA can help advise citizens about the environmental and public health threats they face that are within their control (e.g., from indoor sources). In cases where 'background' contamination may pose a human health risk, but its remediation is beyond the authority of the applicable statute, risk communication to the public may be most effective when coordinated with public health agencies (EPA 2002e). The public may also be advised about the scope and limits of EPA's statutory authorities.

[254] Assessment uncertainty is generally an important factor in deciding how to act (Frewer 2004); i.e., whether to reduce risk through response action or reduce uncertainty (e.g., through additional monitoring and data collection). Risk professionals, therefore, generally recommend that risk communication to stakeholders and the general public characterize the sources of uncertainty, as well as the magnitude of uncertainty associated with a particular hazard (see, for example, Frewer (2004) and Markon and Lemyre 92013)).

  - Simple tabulated and color-coded results (representing exceedances of human health risk levels or no exceedance).

- Diagrams/Illustrations
  - Diagrams and illustrations of sampling devices.
  - Diagrams and illustrations of sampling locations
  - Diagrams of specific mitigation systems (e.g., how a SSD system works and looks).

- Next Steps
  - Actions that property owners and occupants can take to reduce vapor intrusion exposure until mitigation systems are in place.

- Information Sources
  - Contact information for a person who can answer questions or supply further explanations.
  - The location of the site information repository or site website can be included as a resource for public access to more detailed information and site documents.

9.5 Transmitting Messages Regarding Mitigation Systems

The initial notification to residents or building owners about mitigating vapor intrusion can be delivered in various ways. A primary mechanism is a face-to-face meeting with the building owner or occupant to explain the sampling results and discuss next steps, including installation of a vapor intrusion mitigation system. EPA recommends that this meeting include a member of the site planning team (RPM or OSC and risk assessor, for example), a representative from the local health department or the Agency for Toxic Substances and Disease Registry (ATSDR), and the mitigation contractor scheduler. This meeting could discuss topics such as:

- Sampling Results: Describe where samples were taken and the chemicals of concern, and explain the results as related to site action levels. Any questions related to human health risk can be answered by the risk assessor or public health representative at this time. For questions or concerns regarding personal health, EPA recommends that residents and building owners contact their medical professional.

- Mitigation System Details: Describe the need for a mitigation contractor to visit the residence to identify potential locations for the mitigation system. The property owner will need to be present for the visit and will have input about where the system is installed, if they agree to install such a system. Photos of a mitigation system (piping, system fan, number of holes drilled in the slab, height of the vent on the outside of the residence, etc.) may be helpful. EPA recommends that plans and schedules for periodic inspection, maintenance, and monitoring also be described.

- Access: EPA recommends advance planning to ensure building access to install, monitor and maintain any mitigation system. Arrangements could be made at this meeting to sign an additional access agreement for these activities, if needed.

- Cost of the Mitigation System: Identify which party will pay for installation of the mitigation system and anticipated property-owner costs. For example, EPA or a PRP may pay for the system installation, and the property owner or PRP may take responsibility to pay for the monthly costs associated with the mitigation system.

- Project Schedule and Next Steps: The meeting may be concluded by giving an overview of the overall project timeline, including the appointment for the mitigation contractor visit and system installation.

Notification also can be provided through the data transmittal letter. In many cases, however, the decision to install mitigation systems will not have been made prior to the transmittal of sampling results. In these situations, data transmittal letters can convey that EPA is reviewing all data results for the affected area and considering appropriate next steps. Once the decision document is signed, the site planning team can develop and mail a fact sheet to all community members in the affected area, followed by a community meeting.

In addition, if a vapor intrusion mitigation system is installed, EPA recommends that the property owner or renter be informed that the system normally is designed to protect the home or building only against vapor-forming chemicals coming from the subsurface. A vapor intrusion mitigation system generally will not protect the home against continuing indoor sources because vapor intrusion mitigation systems typically are not indoor air filtration systems.

EPA recommends that current owner-occupants be advised that if they decline or waive an offer to install a vapor mitigation system, they might be responsible for the costs of installing and maintaining their own system if they decide to do so at a later time. EPA also recommends documenting any declination or waiver.

9.6 Addressing Community Involvement at Legacy Sites

Ongoing site activities with assessment components, such as remedial investigations and monitoring, allow EPA to continually evaluate site conditions and adjust cleanup actions as warranted. During periodic reviews or conducting other site activities, such as the FYR pursuant to CERCLA, EPA has evaluated vapor intrusion where appropriate. In some instances, EPA has newly identified vapor intrusion as an exposure pathway. These mature or “legacy” sites present a unique challenge to site planning teams.

Conducting community involvement at legacy sites may be complicated by several factors including:

- A remedy for the control of exposure to volatile chemicals already has been installed, proposed, or is under construction as part of the cleanup plan.
- Ownership of properties previously exposed to VOCs has changed hands through resale, foreclosure, or assumption of the property by second-generation homeowners. These owners were not part of any original resolution of exposure issues and in many cases may not be aware that a remediation or treatment was put in place.
- Property owners and other community members who participated in prior cleanup efforts may be reluctant to fully engage with efforts to reopen lines of investigation at their properties.

In these and similar circumstances, the challenge for Agency representatives is to resume contact with communities who have put past difficulties behind them. In many cases, mailing lists are outdated, previous reliable contacts no longer are available, and elected officials may not have institutional memory of the events that prompted the remediation.

Strategies for Revitalizing Community Involvement at Legacy Sites

Every legacy re-entry will be a site-specific situation. Therefore, EPA recommends that events and activities be planned to acknowledge and accommodate the inevitable changes in the makeup of a community. In addition to the communication strategies and community involvement techniques described in Sections 9.1 through 9.5, additional suggestions to ease re-entry and revitalize community involvement at a legacy site include:

- Reassess the community and the site by revisiting the site and the surrounding areas and taking note of new construction.
- Reintroduce yourself and the Agency to current municipal staff and check previously used public venues for viability. Determine if new venues may be closer or more accessible to the community.
- If contacts within the community are still extant, reconnect; ask for updates on the growth and stability of the community. If no viable contacts exist, attempt to cultivate new ones.
- Revise and update mailing lists and fact sheets.

As with all sites affected by vapor intrusion issues, be prepared to meet with property owners door to door and to hold public meetings or forums to explain the current investigation and its importance to protecting human health.

9.7 Property Value Concerns for Current and Prospective Property Owners

EPA recognizes that vapor intrusion impacts may have implications for property values. In some instances, mitigation systems and other clean-up measures may help to restore property values.

Nevertheless, property value issues are outside the scope of Agency authority. In general, if asked, EPA recommends that regional staff suggest that prospective buyers and sellers contact real estate professionals and lenders from the local area with questions about property values. If a home owner or renter has questions about vapor intrusion mitigation systems, EPA regions can provide information that explains how vapor intrusion systems are designed to reduce exposure to chemicals found in indoor air and to avert human health-related problems.

9.8 Additional Community Involvement Resources

EPA’s Superfund Community Involvement Program:

EPA’s Superfund Community Involvement website contains many resources that may be helpful for planning community involvement activities for other cleanup programs. This resource includes a list of regional Superfund community involvement points of contact, a list of technical assistance and training resources, and descriptions and links to community involvement policies, guidance and publications (see http://www.epa.gov/superfund/community/).

EPA's Superfund Community Involvement Toolkit (CI Toolkit):

While targeted to a Superfund Program audience, the CI toolkit may be helpful to a wide variety of users because it is a practical, easy-to-use aid for designing and enhancing community involvement activities and contains tips on how to avoid some of the pitfalls common to the community involvement process. The toolkit enables users to quickly review and adapt a variety of community involvement tools to engage the community during all stages of the cleanup process. Relevant tools include tips for conducting public availability and poster sessions and public meetings, developing fact sheets, working with the media, planning communication strategies, developing a Community Involvement Plan, and establishing an information repository (see http://www.epa.gov/superfund/community/toolkit.htm).

EPA’s Community Engagement Initiative:

The OSWER CEI is designed to enhance OSWER and regional offices’ engagement with local communities and stakeholders to help them participate meaningfully in government decisions on land cleanup, emergency preparedness and response, and the management of hazardous substances and waste (see http://www.epa.gov/oswer/engagementinitiative/).

10.0 GLOSSARY

The following definitions are provided for purposes of this Technical Guide:

accumulate	Increase gradually in amount as time passes. Note that there will be a finite maximum amount, which will be determined by site- and building-specific conditions and will reflect a balance among physical processes (e.g., soil gas entry, air exchange).
active	Involving mechanical operations; Compare with *passive*.
active depressurization technology	Vapor intrusion mitigation method that creates a driving force for air flow from the building into the subsurface by lowering the pressure below the slab, thereby reducing vapor intrusion (soil gas entry into a building).
acute	Refers to repeated or single exposure for 24 hours duration or less. Compare with *short-term* and *subchronic*.
advection	As it pertains to soil gas, refers to bulk movement in the vadose zone induced by spatial differences in soil gas pressure. The direction of advective vapor transport is always toward the direction of lower air pressure.
aerobic	Describes a process or activity requiring oxygen. Compare with *anaerobic*.
air exchange rate	Rate of air infiltration into a building through windows, doorways, intakes and exhausts, 'adventitious openings' (e.g., cracks and seams that combine to form the building envelope), plus natural and mechanical ventilation.
ambient air	The outdoor air surrounding a building or site.
anaerobic	Describes a process or activity requiring the absence of oxygen. Compare with *aerobic*.
analyte	A substance for which identification (of presence) and/or quantification (of amount, such as concentration) is/are sought by instrumental measurement.
attenuation	Decrease in vapor concentration in soil gas emanating from a subsurface vapor source along the migration route towards and into a building (indoor air)
attenuation factor	The ratio of the indoor air concentration arising from vapor intrusion to the soil gas concentration at the source or a depth of interest in the vapor migration route.
background	Refers to a vapor-forming chemical(s) or location(s) that is(are) not influenced by the releases from a site, and is usually described (EPA 1989, 1995c, 2002e) as naturally occurring or anthropogenic: 1) *Anthropogenic* – natural

	and human-made substances present in the environment as a result of human activities and not specifically related to the site-related release in question; and, 2) *Naturally occurring* – substances present in the environment in forms that have not been influenced by human activity. Background may include a vapor-forming chemical(s) present in indoor air due to human activities that is(are) not related to vapor intrusion or site-related contamination.
background vapor concentration	This term may include the concentration of a vapor-forming chemical in indoor air that fits within the definition of "background" above. Information on background concentrations of vapor-forming chemicals in indoor air "is important to risk managers because generally EPA does not clean up to concentrations below natural or anthropogenic background levels" (EPA 2002e).[255]
background vapor source	The origin(s) and location(s) of a vapor-forming chemical(s), other than vapor intrusion, and not associated with or emanating from a site-related release(s) to the environment. Background vapor sources may include indoor or outdoor sources. See also *indoor vapor source, outdoor vapor source,* and *background vapor concentration;* compare to *subsurface vapor source*.
biodegradation	Decomposition or breakdown of a substance through the action of microorganisms (such as bacteria or fungi).
brownfield	A parcel of real estate that is abandoned or inactive or may not be operated at its fully beneficial use and on which expansion or redevelopment is contemplated or reasonably expected; distinguished from "greenfield" because expansion or redevelopment may be complicated by the presence of vapor-forming chemicals in the subsurface environment.
building	a structure that is intended for human occupancy and use. This would include, for instance, homes, offices, stores, commercial and industrial buildings, etc., but would not normally include sheds, carports, pump houses, or other structures that are not intended for human occupancy.
building survey	Refers generically to gathering -- by observation, interviews, reviewing documents and records or other means -- information about existing buildings, including,

---

[255] It should, however, be noted that some EPA regulations (e.g., indoor radon standards under 40 CFR 192.12) are inclusive of background.

	but not limited to, location, use, occupancy, basic construction (e.g., foundation type), heating ventilation and cooling systems, potential indoor sources of vapor-forming chemicals, and anticipated susceptibility to soil gas entry (e.g., presence of radon mitigation system).
capillary fringe	The porous material just above the ground water table which may hold water by capillarity (a property of surface tension that draws water upwards) in the smaller void spaces.
chlorinated hydrocarbon (CHC)	Compound comprised solely of the elements chlorine, hydrogen and carbon. Includes dry-cleaning solvents such as tetrachloroethylene (PCE) and degreasing solvents such as trichloroethylene (TCE) and 1,1,1-trichloroethane (TCA).
chronic	Refers to repeated exposure for more than approximately 10% of the life span (approximately seven years) in humans. Compare with *subchronic*.
concentration	Amount (mass) of a vapor-forming chemical contained in a unit quantity (e.g., volume) of a specific medium (e.g., air, soil gas).
conceptual site model (CSM)	Narrative description of the current understanding of the site-specific conditions, which, in the case of vapor intrusion, include the nature, location, and spatial extent of the source(s) of vapor-forming chemicals in the subsurface and the location, use, occupancy, and basic construction of existing buildings. A CSM represents an adaptation of a general *conceptual model* to account for and reflect site- and/or building-specific conditions. See also *model*.
crawl space	A type of basement in which one cannot stand up — the height may be as little as one foot, and the bottom surface is often bare soil.
complete (vapor intrusion) pathway	The vapor intrusion pathway is referred to as “complete” for a building or collection of buildings when five conditions are met under current conditions: (1) a subsurface source of vapor-forming chemicals is present underneath or near the building(s); (2) vapors form and have a route along which to migrate (be transported) toward the building(s); (3) the building(s) is (or are) susceptible to soil gas entry, which means openings exist for the vapors to enter the building(s) and driving forces exist to draw the vapors from the subsurface into the building(s); (4) one or more vapor-forming chemicals comprising the subsurface vapor source(s) is (or are) present in the indoor environment; and (5) the building(s)

	is (or are) occupied by one or more individuals when the vapor-forming chemical(s) is (or are) present indoors.
data objectivity	Refers to the accuracy, reliability, and absence of bias in the information; scientific information will generally attain this criterion when the original or supporting data are generated using sound research, investigatory, or statistical methods.
data quality objective (DQO)	Performance and acceptance criteria that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
data utility	Refers to the usefulness (e.g., relevance, importance) of the information to reaching a conclusion or judgment (e.g., is the vapor intrusion pathway complete or incomplete? Does the vapor-forming chemical in indoor air arise from background sources or vapor intrusion? Does vapor intrusion pose an unacceptable human health risk in a specific building?)
diffusion	Random motion that affects the distribution of molecules when there are spatial differences in chemical concentrations in the fluid (e.g., soil gas, indoor air, groundwater). The net direction of diffusive transport is toward the direction of lower concentrations.
driving force	refers to the combination of: (i) pressure differences between a building interior and the subsurface or ambient air, which foster vapor intrusion and infiltration, respectively, via advection; and (ii) concentration differences between a building interior and the subsurface or ambient air, which foster vapor transport via diffusion.
early action	Refers to a response action undertaken early in the cleanup process to achieve prompt risk reduction. Also see *response action* and *pre-emptive mitigation.*
evidence	A fact or other information (i.e., datum) ascertainable by direct observation, interviews, review of records and documents, instrumental analysis in a lab or field setting, research and testing, sampling of environmental media (e.g., indoor air, soil gas, groundwater), statistical analysis, or other means, which is useful for forming a conclusion or judgment; each distinguishable datum is referred to as a line of evidence, which may be categorized into scientific realms (e.g., geology, biology, physics) or investigatory objectives (e.g., characterization of subsurface vapor source, accounting for background sources)

exposure	Opportunity to come into contact with vapor-forming chemicals (via inhalation, in the case of vapor intrusion).
exposure assessment	Process of characterizing the magnitude, frequency, and duration of exposure to a vapor-forming chemical, along with the characteristics of the population exposed.
exposure control	Modification of a property or building intended to reduce or eliminate human exposure to hazardous vapors in buildings or explosive vapors in structures, which arise from the vapor intrusion; such controls may include engineered methods (e.g., active depressurization technologies, mechanical ventilation, indoor air treatment) or non-engineered methods (e.g., institutional controls, such as deed notices and land use restrictions)
exposure pathway	The physical course a vapor-forming chemical takes from its source (e.g., groundwater) to the individual (in a building in the case of vapor intrusion).
exposure route	The way in which a vapor-forming chemical enters a human body (i.e., inhalation in the case of vapor intrusion).
flux	The rate of movement of mass through a unit cross-sectional area per unit time in response to a concentration gradient or a driving force for advection.
gas	A fluid (as air) that has neither independent shape nor volume but tends to expand indefinitely; a state of matter in which the matter concerned occupies the whole of its container irrespective of its quantity.
grab sample	A sample of air collected over a short (practically instantaneous) duration. Compare with *time-integrated sample*.
hazard index (HI)	The sum of hazard quotients for substances that affect the same target organ or organ system. Because different pollutants can cause similar adverse health effects, it is often appropriate to combine hazard quotients associated with different substances.
hazard quotient (HQ)	The ratio of the potential exposure to the substance and the level at which no adverse effects are expected. If the HQ is calculated to be equal to or less than 1, then no adverse health effects are expected as a result of exposure. If the HQ is greater than 1, then adverse health effects are possible.
hazardous	Involving or exposing one to threat of adverse health effects (due to toxicity) or loss of loss of life or welfare (due to explosiveness).

Henry's Law Coefficient or Constant...	Ratio of a chemical's vapor pressure in air to its solubility in water. Generally reported for standard reference temperature, such as 25 °C.
human exposure pathway	A way that people may come into contact with environmental contaminants while performing their day-to-day indoor activities.
human health risk assessment	The evaluation of scientific information on the hazardous properties of vapor-forming chemicals (hazard assessment and characterization), the dose-response relationship, and the extent of human exposure to those agents. The product of the risk assessment is a statement regarding the probability that populations or individuals so exposed will be harmed and to what degree and describing the principal technical uncertainties (i.e., risk characterization).
hydrocarbon	Compound comprised solely of the elements hydrogen and carbon. See also *chlorinated hydrocarbon* and *petroleum hydrocarbon*.
inclusion zone	Land area within which EPA recommends assessing the vapor intrusion pathway, which extends beyond the aggregate boundaries of the site-specific source(s) of vapor-forming chemicals.
indoor vapor source	Refers to a vapor-forming chemical(s) in indoor air which originates within a building. Indoor sources of vapor-forming chemicals may include, but are not limited to, use and storage of consumer or household products, use or storage of industrial materials or products, combustion processes, activities or operations within a building, and releases from interior building materials (e.g., off-gases from furniture or clothing); for example, operational use or storage of chemicals in an industrial building may represent an indoor vapor source separate from a site-related release. Also see *background vapor source;* compare to *subsurface vapor source*.
infiltration	Air leakage into a building through random cracks, interstices, and other unintentional openings in the building envelope.
institutional control (IC)	Non-engineering measures intended to affect human activities in such a way as to prevent or reduce exposure to hazardous substances. For example, ICs may be used to restrict certain land uses, buildings, or activities that could otherwise result in unacceptable exposure to the vapor intrusion pathway. Generally, four categories of ICs are recognized: governmental controls; proprietary controls; enforcement tools; and informational devices. They are almost always used in conjunction with, or as a

	supplement to, other cleanup measures such as treatment or containment.
interim action	Refers to a response action that is undertaken to protect human health, but is limited in scope and objective (e.g., does not accomplish complete or final remediation of subsurface vapor sources). Also see *response action.*
interzonal air flow	Movement or transport of air through doorways, ductwork, and service chaseways that interconnect rooms or zones within a building.
lines of evidence	Data collected and weighed together in supporting assessments of the vapor intrusion pathway, which are identified and described throughout Sections 2 through 7 inclusive. See also *evidence*.
lower explosive limit (LEL)	The lowest concentration at which a gas or vapor is flammable or explosive at ambient conditions.
mitigation	Interim actions taken to reduce or eliminate human exposure to vapor-forming chemicals in a specific building arising from the vapor intrusion pathway; compare with *remediation.*
model	Refers to a description of a system. In the case of vapor intrusion the ‘system’ will generally consist of a subsurface source of vapors, one or more buildings potentially subject to soil gas entry, and the soil underlying the building(s). *Conceptual models* (i.e., models that are conceptual) are comprised of narrative descriptions that identify the primary physical elements and processes of the system and the interactions between and relationships among them; for example, Section 2 of this document provides a general conceptual model of how vapor intrusion can arise and why it may be variable over time and in space. A *mathematical model* is an expression of a conceptual model, which uses mathematical symbols and language to identify key elements (e.g., variables) and processes. Generally, mathematical models are highly idealized or simplified descriptions, compared to the complex systems they represent. For example, Johnson and Ettinger (1991) formulated an idealized mathematical model of vapor intrusion*.* In the case of a *physical model,* the description is provided using physical objects, which may or may not have full functionality; for example, a physical model of a construction project might differ from a planned system in its scale, but would necessarily show significant elements in relationship to each other.

near-source	Refers to a soil gas sample collected within a practically short distance from subsurface vapor source
nonresidential building	Refers to a building other than a home; includes, but is not limited to, institutional buildings (e.g., schools, libraries, hospitals, community centers and other enclosed structures for gathering, gyms and other enclosed structures for recreation); commercial buildings (e.g., hotels, office buildings, many (but not all) day care centers, and retail establishments); and industrial buildings where vapor-forming chemicals may or may not be routinely used or stored. Compare with *residential building*; see also *building*.
outdoor vapor source	Refers to a vapor-forming chemical(s) present in outdoor (ambient) air. Sources of vapor-forming chemicals in outdoor air may include, but are not limited to, releases from industrial facilities, vehicle exhaust, yard maintenance equipment, fuel storage tanks, paint or pesticide applications, agricultural activities, and fires, as well as site-related contamination, activities, and operations (e.g., emissions from remediation equipment). Also see *background vapor source;* compare to *subsurface vapor source*.
passive	Not involving mechanical operations; Compare with *active*.
petroleum hydrocarbon (PHC)	Hydrocarbons derived from petroleum and present in various refined products of petroleum (such as automotive gasoline, diesel fuel, lubricating oils). See also *hydrocarbon*.
potentially complete (vapor intrusion pathway)	The vapor intrusion pathway is referred to as ‘potentially complete’ for a building when: a subsurface source of vapor-forming chemicals is present underneath or near an existing building or a building that is reasonably expected to be constructed in the future; vapors can form from this source(s) and have a route along which to migrate (be transported) toward the building; and three additional conditions are reasonably expected to all be met in the future, which may not all be met currently (i.e., the building is susceptible to soil gas entry, which means openings exist for the vapors to enter the building and driving forces exist to draw the vapors from the subsurface through the openings into the building; one or more vapor-forming chemicals comprising the subsurface vapor source(s) is (or will be) present in the indoor environment; and the building is or will be occupied by one or more individuals when the vapor-forming chemical(s) is (or are) present indoors.

preemptive mitigation (PEM)	Implementation of systems or control measures to mitigate the vapor intrusion pathway as an early action, even though all pertinent lines of evidence have not yet been completely developed to characterize the vapor intrusion pathway for the subject building(s). Also see *early action* and *response action.*
preferential migration route	Naturally occurring subsurface feature (e.g., gravel lens, fractured rock) or anthropogenic (human-made) subsurface conduit (e.g., utility corridor or vault, subsurface drain) that is expected to exhibit little resistance to vapor flow in the vadose zone (i.e., exhibits a relatively high gas permeability) or groundwater flow (i.e., effectively exhibits a relatively high hydraulic conductivity), depending upon its location and orientation relative to the water table and ground surface, thereby facilitating the migration of vapor-forming chemicals in the subsurface and towards or into buildings
pressure difference/differential pressure	Difference between the air pressure within a building and the subsurface environment or ambient air. Can promote advective flow of gas into or out of a building through pores, cracks, or openings in the building foundation or envelope.
radon	A radioactive gas formed during the radioactive decay of radium, which occurs naturally in many geologic settings.
reasonable maximum exposure (RME)	A semi-quantitative term, referring to the lower portion of the high end of the exposure distribution; conceptually, above the 90th percentile exposure but less than the 98th percentile exposure.
reasonable worst case	A semi-quantitative term, referring to the upper portion of the high end of the exposure distribution, but less than the absolute maximum exposure.
reference concentration (RfC)	An estimate of the continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime.
remediation	Refers to interim and final cleanups, whether conducted pursuant to RCRA corrective action, the CERCLA removal or remedial programs, or using EPA brownfield grant funds with oversight by state and tribal response programs. In addition to permanent remedies for subsurface vapor sources, site remediation may also entail implementation of institutional controls and construction and operation of engineered systems.

residential building	refers to a building used as or intended for use as a home; includes, but is not limited to, single-family detached homes with foundations, trailer homes, multi-unit apartments an*d* condominiums. Compare with *non-residential building;* see also *building*.
response action	any action taken to reduce or eliminate human exposure to or risk posed by hazardous vapors in buildings and structures, which arise from the vapor intrusion pathway; these actions may include engineered exposure controls in a specific building(s), non-engineered exposure controls, remediation of subsurface vapor sources, and associated monitoring to assess effectiveness and protectiveness. Also see *remediation* and *mitigation.*
risk	Probability of an adverse human health effect (due to toxicity) or physical hazard (e.g., due to potential for explosion) caused under specific circumstances by a vapor-forming chemical.
risk communication	The process of exchanging information about health threats and levels or significance of human health risk.
risk management	The process of determining whether response action(s) is(are) warranted to protect human health and, if so, selecting response actions to implement.
screening	Process of comparing concentrations of vapor-forming chemicals in a specific medium (e.g., indoor air, soil gas, crawl space air, groundwater) to screening levels to identify sites, buildings, or chemicals unlikely to pose a health concern through the vapor intrusion pathway versus those warranting further investigation or analysis.
screening level	Risk-based concentrations derived from standardized equations combining exposure information and assumptions with toxicity values.
short-term	Refers to repeated exposure for more than 24 hours, up to 30 days. Compare with *acute* and *subchronic*.
significant opening	Refers to refer to an atypical form and amount of an opening in a building (e.g., a sump, an unlined crawl space, an earthen floor), which could facilitate greater amounts of soil gas entry, all else being equal. Forms of openings typically expected to be present in all buildings include cracks, seams, interstices, and gaps in basement floors and walls or foundations and perforations due to utility conduits.
site	The geographical area where investigation and evaluation of the presence of vapor-forming chemicals is desired; in many situations, it includes areas surrounding

	a facility where a release to the subsurface environment is known or suspected to have originated.
soil gas	The gas present underground in the pore spaces between soil particles.
soil gas concentration	Vapor concentration in a soil gas sample. Sub-slab soil gas is found immediately beneath a building. Near-source or exterior soil gas samples are collected at other depths and typically outside the building footprint.
source strength	Vapor concentration(s) of vapor-forming chemical(s) arising from a subsurface vapor source.
stakeholder	A person, group, community, or corporate entity with an interest in activities at a site with subsurface contamination.
subchronic	Refers to repeated exposure for more than 30 days, up to approximately 10% of the life span (approximately seven years) in humans. Compare with *short-term* and *chronic*.
subsurface remediation	Response action that eliminates or substantially reduces the level of vapor-forming chemicals in the subsurface vapor source via treatment or physical removal. Compare with *mitigation.*
subsurface vapor source	Refers to a vapor-forming chemical(s) present in the subsurface environment arising from a release(s) to the environment. A subsurface vapor source may occur as a non-aqueous-phase liquid (NAPL), adsorbed-phase contamination, or dissolved-phase contamination, which may be present in the vadose zone, in groundwater, or within sewers and other conduits. Information on subsurface vapor sources is important to risk managers because response actions are generally warranted when vapor intrusion is determined to pose unacceptable human health risks. Compare with *background vapor source* and *background vapor concentration*.
termination criteria	Refers to numeric cleanup levels for each site-specific contaminant and narrative cleanup objectives that are to be attained by the response actions.
time-integrated sample	Sample collected over an extended period of time to account for temporal variations in vapor concentrations. Compare with *grab sample*.
toxicity value	Refers to an inhalation unit risk (IUR) for potential cancer effects or an inhalation reference concentration (RfC) for potential non-cancer effects of a vapor-forming chemical.

vadose zone	The soil zone between land surface and the groundwater table within which the moisture content is less than saturation (except in the capillary fringe). Soil pore spaces not occupied by moisture contain (soil) gas. Also referred to as the "unsaturated zone."
vapor	A substance in the gaseous state as distinguished from the liquid or solid state.
vapor intrusion	The migration of potentially hazardous vapors from any subsurface contaminant source, such as contaminated soil or groundwater, through the vadose zone and into a building or structure.
vapor source	The place and form of origin of chemical vapors. Also see *background vapor source*, *indoor vapor source*, *outdoor vapor source*, and *subsurface vapor source*.
vapor-forming chemical	A volatile chemical that EPA recommends be routinely evaluated during a site-specific vapor intrusion assessment, when it is present as a subsurface contaminant.
volatile chemical	Chemical with a vapor pressure greater than 1 milliliter of mercury (mm Hg), or Henry's law constant greater than 10^{-5} atmosphere-meter cubed per mole.
volatility	The tendency of a substance to form vapors, which are molecules in a gaseous state, and escape from a liquid or solid source. This tendency is directly related to a substance's vapor pressure and Henry's law constant and is indirectly related to a substance's molecular weight (i.e., substances with lower molecular weights tend to volatilize more readily than substances with similar molecular structures that have higher molecular weights).
water table	The water surface in an unconfined aquifer at which the fluid pressure in the pore spaces is at soil gas pressure.
weight of evidence	Refers to a conceptual approach to data evaluation, in which each of several lines of evidence is critically appraised for its quality (e.g., utility, objectivity) and systematically assessed for its logical support for a particular conclusion, as well as alternative conclusions; the appraisals consider lines of evidence individually and in light of other lines of reliable evidence for purposes of determining whether a particular conclusion is supported by the preponderance of the evidence and is consistent with the conceptual site model; this 'weighing' concept does not entail a quantitative (*a priori*) scheme to score or rank the individual lines of evidence. See also *evidence*.

work plan	A site-specific document that includes a project description, project objective(s), historical information about the site.
worst case	A semi-quantitative term, referring to the absolute maximum plausible exposure (i.e., a bounding – high-impact – case).

11.0 CITATIONS AND REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). 2008. *Evaluating Vapor Intrusion Pathways at Hazardous Waste Sites.* Currently available online at: http://www.atsdr.cdc.gov/document/evaluating_vapor_intrusion.pdf

American Society for Testing and Materials (ASTM). 1995. *E 1739: Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites*.

ASTM International. 2003. *E 2121: Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings*.

Association of State and Territorial Solid Waste Management Officials (ASTSWMO). 2009. *Vapor Intrusion Pathway: A Guide for State and Territorial Federal Facilities Managers.* ASTSWMO Policy and Technology Focus Group, Washington, D.C. July.

Brenner, D. 2010. Results of a Long-Term Study of Vapor Intrusion at Four Large Buildings at the NASA Ames Research Center. *J. Air & Waste Manage. Assoc.* 60: 747–758.

California Environmental Protection Agency (CalEPA). 2011. *Vapor Intrusion Mitigation Advisory*. Department of Toxic Substances Control. Revision 1. October. Currently available online at: http://www.dtsc.ca.gov/AssessingRisk/upload/Final_VIG_Oct_2011.pdf

California Environmental Protection Agency (CalEPA). 2012. *Advisory: Active Soil Gas Investigations*. Department of Toxic Substances Control. April. Currently available online at: http://www.dtsc.ca.gov/SiteCleanup/upload/VI_ActiveSoilGasAdvisory_FINAL_043012.pdf

City of Mandan. 2006. Chapter 21-10: Environmental institutional control ordinance. *City of Mandan Municipal Code*, Title 21: Planning and Zoning. Currently available online at: www.cityofmandan.com

Clements, W.E. and M.H. Wilkening. 1974. Atmospheric pressure effects on ^{222}Rn transport across the Earth-air interface. *Journal of Geophysical Research* 79(33):5025-5029.

Folkes, D.J. and D.W. Kurz. 2002. Efficacy of sub-slab depressurization for mitigation of vapor intrusion of chlorinated organic compounds. *Proceedings of Indoor Air 2002: The 9th International Conference on Indoor Air and Climate*. June 30-July 5.

Folkes, D.J., W. Wertz, J. Kurtz, and T. Kuehster. 2009. Observed spatial and temporal distributions of CVOCs at Colorado and New York vapor intrusion sites. *Groundwater Monitoring & Remediation* 29(1):70-80.

Frewer, L. 2004. The public and effective risk communication. *Toxicology Letters* 149:391-397.

Gorder, K.A. and E.M. Dettenmaier. 2011. Portable GC/MS methods to evaluate sources of cVOC contamination in indoor air. *Groundwater Monitoring & Remediation* 31(4):113-119.

Holden, P.A. and N. Fierer. 2005. Microbial processes in the vadose zone. *Vadose Zone Journal* 4:1-21.

Holton, C., E. Luo, Y. Guo, P. Dahlen, P. C. Johnson, K. Gorder and E. Dettenmaier. 2013a. Multi-year monitoring of a house over a dilute CHC plume: Implications for pathway assessment using indoor air sampling and forced under-pressurization tests. *23rd Annual International Conference of the Association of Environmental Health Sciences, San Diego, CA, March 19*.

Holton, C., H. Luo, P. Dahlen, K. Gorder, E. Dettenmaier, and P. C. Johnson. 2013b. Temporal variability of indoor air concentrations under natural conditions in a house overlying a dilute chlorinated solvent groundwater plume. *Environmental Science & Technology* 47:13347-13354.

Interstate Technology & Regulatory Council (ITRC). 2014. *Petroleum Vapor Intrusion: Fundamentals of Screening, Investigation, and Management.* Interstate Technology and Regulatory Council, Vapor Intrusion Team, Washington, D.C. October. Currently available online at: http://itrcweb.org/PetroleumVI-Guidance

Interstate Technology & Regulatory Council (ITRC). 2007a. *Vapor Intrusion Pathway: A Practical Guideline*. ITRC Vapor Intrusion Team, Washington, D.C. VI-1. January. Currently available online at: http://www.itrcweb.org/documents/VI-1.pdf

Interstate Technology & Regulatory Council (ITRC). 2007b. *Vapor Intrusion Pathway: Investigative Approaches for Typical Scenarios*. ITRC Vapor Intrusion Team, Washington, D.C. VI-1A. January. Currently available online at: http://www.itrcweb.org/documents/VI-1A.pdf

Izzo, V. J. 1992. *Drycleaners – A Major Source of PCE in Ground Water.* Sacramento: State of California Regional Water Quality Control Board Central Valley Region. March. Currently available online at: http://www.swrcb.ca.gov/rwqcb5/water_issues/site_cleanup/dry_cleaner_rpt.pdf

Jia, C., S.A. Batterman, and G.E. Relyea. 2012. Variability of indoor and outdoor VOC measurements: An analysis using variance components. *Environmental Pollution* 169:152-159.

Johnson, P.C. and R.A. Ettinger. 1991. Heuristic model for predicting the intrusion rate of contaminant vapors into buildings. *Environmental Science & Technology* 25:1445-1452.

Little, J.C., J.M. Daisey, and W.W. Nazaroff. 1992. Transport of subsurface contaminants into buildings. *Environmental Science & Technology* 26(11): 2058 – 2066.

Lowell, P.S. and B. Eklund. 2004. VOC emission fluxes as a function of lateral distance from the source. *Environmental Progress* 23(1):52-58.

Lundegard, P.D., P.C. Johnson, and P. Dahlen. 2008. Oxygen transport from the atmosphere to soil gas beneath a slab-on-grade foundation overlying petroleum-impacted soil. *Environmental Science & Technology* 42:5534-5540.

Lundgren, R.E., and A.H. McMakin. 2013. *Risk Communication: A Handbook for Communicating Environmental, Safety, and Health Risks, Fifth Edition*. John Wiley & Sons.

Luo, H., P. Dahlen, P.C. Johnson, T. Peargin, and T. Creamer. 2009. Spatial variability of soil-gas concentrations near and beneath a building overlying shallow petroleum hydrocarbon–impacted soils. *Groundwater Monitoring & Remediation* 29(1): 81–91.

Ma, J., H. Luo, G.E. DeVaull, W.G. Rixey, and P.J.J. Alvarez. 2014. Numerical model investigation for potential methane explosion and benzene vapor intrusion associated with high-ethanol blend releases. *Environmental Science & Technology* 48:474-481.

Ma, J., W.G. Rixey, G. E. DeVaull, B.P. Stafford, and P.J.J. Alvarez. 2012. Methane bioattenuation and implications for explosion risk reduction along the groundwater to soil surface pathway above a plume of dissolved ethanol. *Environmental Science & Technology* 46: 6013-6019.

Markon, M. L. and L. Lemyre. 2013. Public reactions to risk messages communicating different sources of uncertainty: An experimental test. *Human and Ecological Risk Assessment* 19: 1102-1126.

Massachusetts Department of Environmental Protection (MADEP). 2011. *Interim Final Vapor Intrusion Guidance*. WSC#-11-435. December. Currently available online at: http://www.mass.gov/dep/cleanup/iawg.htm

Maupins, K. and D.T. Hitchins. 1998. Reducing employee exposure potential using the ANSI/ASHRAE 110 "Method of Testing Performance of Laboratory Fume Hoods" as a diagnostic tool. *American Industrial Hygiene Association Journal* 59(2):133-138.

McAlary, T.A., J. Provoost, and H.D. Dawson. 2011. Vapor intrusion. *Dealing with Contaminated Sites: From Theory Towards Practical Applications*, Chapter 10. F.A. Swartjes [ed.], Springer Science.

McBride, S.J., A.R. Ferro, W.R. Otto, P. Switzer, and L.M. Hildemann. 1999. Investigations of the proximity effect for pollutants in the indoor environment. *Journal of Exposure Analysis and Environmental Epidemiology* 9:602-621.

McCarthy, M.C., H.R. Hafner, L.R. Chinkin, and J.G. Charrier. 2007. Temporal variability of selected air toxics in the United States. *Atmospheric Environment* 41:7180-7194.

McDonald, G.J. and W.E. Wertz. 2007. PCE, TCE, and TCA vapors in subslab soil gas and indoor air: A case study in upstate New York. *Groundwater Monitoring & Remediation* 27(4):86-92.

McHugh, T.E., L. Beckley, and D. Bailey. 2013. Influence of shallow geology on volatile organic chemical attenuation from groundwater to deep soil gas. *Groundwater Monitoring & Remediation* 33(3):92-100.

McHugh, T.E., L. Beckley, D. Bailey, K. Gorder, E. Dettenmaier, I. Rivera-Duarte, S. Brock, and I.C. MacGregor. 2012. Evaluation of vapor intrusion using controlled building pressure. *Environmental Science & Technology* 46:4792-4799.

Morgan, M.G., A. Bostrom, L. Lave, and C.J. Atman. 1992. Communicating risk to the public. *Environmental Science & Technology* 26(11): 2048-2056.

Moseley, C.L. and M.R. Meyer. 1992. Petroleum contamination of an elementary school: A case history involving air, soil-gas, and groundwater monitoring. *Environmental Science & Technology* 26(11): 185-192.

National Conference of Commissioners on Uniform State Laws. 2003. *Uniform Environmental Covenants Act*. Currently available online at: http://www.epa.gov/superfund/policy/ic/pdfs/kerr_uecalang.pdf

National Research Council (NRC). 2013. *Alternatives for Managing the Nation's Complex Contaminated Groundwater Sites.* National Academies Press, Washington, D.C. Committee on Future Options for Management in the Nation's Subsurface Remediation Effort.

National Research Council (NRC). 2009. *Science and Decisions: Advancing Risk Assessment*. National Academies Press, Washington, D.C. Committee on Improving Risk Analysis Approaches Used by the U.S. EPA.

National Research Council (NRC). 2004. *Contaminants in the Subsurface: Source Zone Assessment and Remediation.* National Academies Press, Washington, D.C. Committee on Source Removal of Contaminants in the Subsurface.

New Jersey Department of Environmental Protection (NJDEP). 2012. *Vapor Intrusion Technical Guidance, Version 2.0*. Site Remediation Program. Currently available online at: http://www.state.nj.us/dep/srp/guidance/vaporintrusion/vig_main.pdf

Odencrantz, J.E., S.C. Thornley, and H. O'Neill. 2009. An evaluation of the performance of multiple passive diffusion devices for indoor air sampling of VOCs. *Remediation* 19(4):63-72.

Odencrantz, J.E., H. O'Neill, S.J. Steinmacher, J.D. Case, and P.C. Johnson. 2008. Residential vapor-intrusion evaluation: Long-duration passive sampling vs. short-duration active sampling. *Remediation* 18(4):49-54.

Patterson, B. M. and G.B. Davis. 2009. Quantification of Vapor Intrusion Pathways into a Slab-on-Ground Building under Varying Environmental Conditions. *Environmental Science & Technology* 43(3): 650-656.

Patterson, B. M., R. Aravena, G.B. Davis, A.J. Furness, T.P. Bastow, and D. Bouchard. 2013. Multiple lines of evidence to demonstrate vinyl chloride aerobic biodegradation in the vadose zone, and factors controlling rates. *J. Contaminant Hydrology* 153(1) 69−77.

Pennell, K.G., M.K. Scammell, M.D. McClean, J. Ames, B. Weldon, L. Friguglietti, E.M. Suuberg, R. Shen, P.A. Indeglia, and W.J. Heiger-Bernays. 2013. Sewer gas: An indoor air source of PCE to consider during vapor intrusion investigations. *Groundwater Monitoring & Remediation* 33(3):119-126.

Robinson, A.L. and R.G. Sextro.1997. Radon entry into buildings driven by atmospheric pressure fluctuations. *Environmental Science & Technology* 31(6):1742–1748.

Rossner, A., J.P. Farant, P. Simon, and D.P. Wick. 2002. Development of a Flow Controller for Long-Term Sampling of Gases and Vapors Using Evacuated Canisters. *Environmental Science & Technology* 36(22): 4912–4920.

Rossner, A. and D.P. Wick. 2005. A field study to assess the long-term sampling feasibility of evacuated canisters and the development of a mathematical model to analyze potential sampling bias. *J. Occupational Environmental Hygiene* 2(9): 474-480

Rydock, J.P. 2001. Reality-check your fume hoods. *Today's Chemist at Work* 10(06):19-20.

Sihota, N.J., K. U. Mayer, M.A. Toso, and J.F. Atwater. 2013. Methane emissions and contaminant degradation rates at sites affected by accidental releases of denatured fuel-grade ethanol. *Journal of Contaminant Hydrology* 151:1-5.

Strategic Environmental Research and Development Program and Environmental Security Technology Certification Program (SERDP-ESTCP). 2014. *SERDP and ESTCP Workshop on Vapor Intrusion into Indoor Air from Contaminated Groundwater (Summary Report).* March. Currently available online at: http://www.serdp-estcp.org/Featured-Initiatives/Cleanup-Initiatives/Vapor-Intrusion

Tilman, F.D. and J.W Weaver. 2007. Temporal moisture content variability beneath and external to a building and the potential effects on vapor intrusion risk assessment. *Science of the Total Environment* 379:1-15.

U.S. Department of Defense (DoD). 2009. *DoD Vapor Intrusion Handbook*. January. Currently available online at: http://www.environmental.usace.army.mil/docs/DoD%20VI%20Handbook%20Final%20Jan%2009.pdf?syspage=documents&id=129239

U.S. Department of the Navy (DoN). 2011a. *Guidance for Environmental Background Analysis, Volume IV: Vapor Intrusion Pathway*. Naval Facilities Engineering Command, Washington, D.C. April.

U.S. Department of the Navy (DoN). 2011b. *Vapor Intrusion Mitigation in Existing Buildings Fact Sheet.* Naval Facilities Engineering Command, Washington, D.C. May.

U.S. Department of the Navy (DoN). 2011c. *Vapor Intrusion Mitigation in Construction of New Buildings Fact Sheet.* Naval Facilities Engineering Command, Washington, D.C. August.

U.S. Environmental Protection Agency (EPA). 2015a. *Vapor Intrusion Screening Level (VISL) Calculator, User's Guide.* Currently available online at: http://www.epa.gov/oswer/vaporintrusion/guidance.html

U.S. Environmental Protection Agency (EPA). 2015b. *Technical Guide for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites* [EPA 510-R-15-001]. Office of Solid Waste and Emergency Response, Office of Underground Storage Tanks.

U.S. Environmental Protection Agency (EPA). 2014a. *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors.* Memorandum from Dana Stalcup. Office of Superfund Remediation and Technology Innovation, Washington, D.C. February 6. Currently available online at: http://www.epa.gov/oswer/riskassessment/pdf/superfund-hh-exposure/OSWER-Directive-9200-1-120-ExposureFactors.pdf

U.S. Environmental Protection Agency (EPA). 2014b. *Compilation of Information Relating to Early/Interim Actions at Superfund Sites and the TCE IRIS Assessment*. Memorandum from Robin Richardson. Office of Superfund Remediation and Technology Innovation, Washington, D.C. August 27. Currently available online at: http://www.epa.gov/superfund/sites/npl/TCE_compilation_final.pdf

U.S. Environmental Protection Agency (EPA). 2013a. *Evaluation of Empirical Data to Support Soil Vapor Intrusion Screening Criteria for Petroleum Hydrocarbon Compounds.* Office of Underground Storage Tanks, Washington, D.C. EPA-510-R-13-001. January. Currently available online at: http://www.epa.gov/oust/cat/pvi/PVI_Database_Report.pdf

U.S. Environmental Protection Agency (EPA). 2013b. *Consumer's Guide to Radon Reduction.* EPA 402/K-10/005. Office of Radiation and Indoor Air (ORIA), Indoor Environments Division. Washington, DC. September. Currently available online at: http://www.epa.gov/radon/pubs/consguid.html

U.S. Environmental Protection Agency (EPA). 2012a. *EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings.* EPA-530-R-10-002. March. Currently available online at: http://www.epa.gov/oswer/vaporintrusion/documents/OSWER_2010_Database_Report_03-16-2012_Final.pdf

U.S. Environmental Protection Agency (EPA). 2012b. *Conceptual Model Scenarios for the Vapor Intrusion Pathway.* EPA-530-R-10-003. February. Currently available online at: http://www.epa.gov/oswer/vaporintrusion/documents/vi-cms-v11final-2-24-2012.pdf

U.S. Environmental Protection Agency (EPA). 2012c. *Assessing Protectiveness at Sites for Vapor Intrusion: Supplement to the "Comprehensive Five-Year Review Guidance."* OSWER Directive 9200.2-84. Currently available online at: http://www.epa.gov/superfund/cleanup/postconstruction/pdfs/VI_FYR_Guidance-Final-11-14-12.pdf

U.S. Environmental Protection Agency (EPA). 2012d. *Institutional Controls: A Guide to Planning, Implementing, Maintaining, and Enforcing Institutional Controls at Contaminated Sites*. OSWER 9355.0-89, EPA-540-R-09-001. December. Currently available online at: http://www.epa.gov/superfund/policy/ic/guide/Final%20PIME%20Guidance%20December%202012.pdf

U.S. Environmental Protection Agency (EPA). 2012e. *Institutional Controls: A Guide to Preparing Institutional Control Implementation and Assurance Plans at Contaminated Sites.* OSWER #9200.0-77, EPA-540-R-09-002. December. Currently available online at: http://www.epa.gov/superfund/policy/ic/guide/ICIAP%20guidance%20(FINAL)%20-%2012.04.2012.pdf

U.S. Environmental Protection Agency (EPA). 2012f. *Fluctuation of Indoor Radon and VOC Concentrations Due to Seasonal Variations.* National Exposure Research Laboratory, Las Vegas, Nevada. EPA/600/R-12/673. September. Currently available online at: http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=247212&fed_org_id=770&SIType=PR&TIMSType=Published+Report&showCriteria=0&address=nerl/pubs.html&view=citation&sortBy=pubDateYear&count=100&dateBeginPublishedPresented=01/01/2010

U.S. Environmental Protection Agency (EPA). 2011a. *Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990-2005): A Compilation of Statistics for Assessing Vapor Intrusion.* Office of Solid Waste and Emergency Response, Washington, D.C. EPA-530-R-10-001. June. Currently available online at: http://www.epa.gov/oswer/vaporintrusion/documents/oswer-vapor-intrusion-background-Report-062411.pdf

U.S. Environmental Protection Agency (EPA). 2011b. *Exposure Factors Handbook – 2011 Edition.* Office of Research and Development, Washington, D.C. EPA/600/R-090/052F. September. Currently available online at: http://www.epa.gov/ncea/efh/pdfs/efh-complete.pdf

U.S. Environmental Protection Agency (EPA). 2011c. *Recommended Evaluation of Institutional Controls: Supplement to the "Comprehensive Five-Year Review Guidance."* OSWER Directive 9355.7-18. September. Currently available online at: http://www.epa.gov/superfund/cleanup/postconstruction/641333.pdf

U.S. Environmental Protection Agency (EPA). 2010a. *Clarification of CERCLA Entry Policy.* Office of Enforcement and Compliance Monitoring. Washington, D.C. Memorandum from Kenneth Patterson. March 3. Currently available online at: http://www2.epa.gov/sites/production/files/documents/access-clarify-10.pdf

U.S. Environmental Protection Agency (EPA). 2010b. *Review of the Draft 2002 Subsurface Vapor Intrusion Guidance.* Office of Solid Waste and Emergency Response, Washington, D.C. August.

U.S. Environmental Protection Agency (EPA). 2010c. *Considering Reasonably Anticipated Future Land Use and Reducing Barriers to Reuse at EPA-Lead Superfund Remedial Sites*. OSWER Directive 9355.7-19. March. Currently available online at: http://www.epa.gov/superfund/programs/recycle/pdf/reusedirective.pdf

U.S. Environmental Protection Agency (EPA). 2009a. *Evaluation Report: Lack of Final Guidance on Vapor Intrusion Impedes Efforts to Address Indoor Air Risks.* Report No. 10-P-0042. EPA Office of Inspector General, Washington, D.C. December. Currently available online at: http://www.epa.gov/oig/reports/2010/20091214-10-P-0042.pdf

U.S. Environmental Protection Agency (EPA). 2009b. *Operational and Functional Determination and the Transfer of Fund-Lead Vapor Intrusion Mitigation Systems to the State*. OSWER 9200.2-72. April. Currently available online at: http://www.epa.gov/superfund/policy/pdfs/VaporGuidance04092009.pdf

U.S. Environmental Protection Agency (EPA). 2009c. *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment).* Office of Superfund Remediation and Technology Innovation, Washington, D.C. OSWER 9285.7-82, EPA-540-R-070-002. January. Currently available on-line at http://www.epa.gov/oswer/riskassessment/ragsf/index.htm

U.S. Environmental Protection Agency (EPA). 2008a. *Brownfields Technology Primer: Vapor Intrusion Considerations for Redevelopment.* EPA-542-R-08-001. March. Currently available online at: www.brownfieldstsc.org/pdfs/BTSC%20Vapor%20Intrusion%20Considerations%20for%20Redevelopment%20EPA%20542-R-08-001.pdf

U.S. Environmental Protection Agency (EPA). 2008b. *Superfund Environmental Indicators Guidance: Human Exposure Revisions.* Office of Superfund Remediation and Technology Assessment, Washington, D.C. March. Currently available online at: http://www.epa.gov/superfund/accomp/ei/pdfs/final_ei_guidance_march_2008.pdf

U.S. Environmental Protection Agency (EPA). 2008c. *Engineering Issue: Indoor Air Vapor Intrusion Mitigation Approaches.* EPA/600/R-08/115. October. Currently available online at: http://www.clu-in.org/download/char/600r08115.pdf

U.S. Environmental Protection Agency (EPA). 2007. *Risk Communication in Action: The Risk Communication Workbook.* EPA/625/R-05/003. August. Currently available online at: http://nepis.epa.gov/Adobe/PDF/60000I2U.pdf

U.S. Environmental Protection Agency (EPA). 2006a. *Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4).* Office of Environmental Information. Washington, D.C. EPA-240-B-06-001. February. Currently available online at: http://www.epa.gov/quality/qs-docs/g4-final.pdf

U.S. Environmental Protection Agency (EPA). 2006b. *Assessment of Vapor Intrusion in Homes near the Raymark Superfund Site Using Basement and Subslab Air Samples*. EPA/600/R-05/147. March. Currently available online at: http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=2000D268.txt

U.S. Environmental Protection Agency (EPA). 2006c. *In Situ Treatment Technologies for Contaminated Soil.* Office of Solid Waste and Emergency Response, Washington, D.C. EPA-542-F-06-013. November. Currently available on-line at: http://www.cluin.org/download/remed/542f06013.pdf

U.S. Environmental Protection Agency (EPA). 2005. *Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities*. EPA/600/R-05/123a. September. Currently available online at: http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1000BRN.txt

U.S. Environmental Protection Agency (EPA). 2003. *Human Health Toxicity Values in Superfund Risk Assessments.* OSWER Directive 9285.7-53. December 5. Currently available online at: http://www.epa.gov/oswer/riskassessment/pdf/hhmemo.pdf

U.S. Environmental Protection Agency (EPA). 2002a. *Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers.* EPA-542-S-02-001. May. Currently available online at: http://www.epa.gov/tio/tsp/download/gw_sampling_guide.pdf

U.S. Environmental Protection Agency (EPA). 2002b. *Office of Inspector General Recommendations Concerning RCRA Corrective Action Environmental Indicators.* Office of Solid Waste, Washington, D.C. Currently available online at: http://www.epa.gov/osw/hazard/correctiveaction/pdfs/eiigmemo.pdf

U.S. Environmental Protection Agency (EPA). 2002c. *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)*. Office of Solid Waste and Emergency Response, Washington, D.C. EPA-530-D-02-004. November.

U.S. Environmental Protection Agency (EPA). 2002d. *Superfund Response Actions: Temporary Relocations Implementation Guidance.* Office of Solid Waste and Emergency Response, Washington, D.C. OSWER Directive 9230.0-97. April. Currently available online at: http://www.epa.gov/superfund/community/relocation/tempreloc.pdf

U.S. Environmental Protection Agency (EPA). 2002e. *Role of Background in the CERCLA Cleanup Program.* OSWER Directive 9285.6-07P. Office of Emergency and Remedial Response, Washington, D.C. May. Currently available online at: http://www.epa.gov/oswer/riskassessment/pdf/role.pdf

U.S. Environmental Protection Agency (EPA). 2001. *Comprehensive Five-Year Review Guidance*. OSWER 9355.7-03B-P, EPA-540-R-01-007. June. Currently available online at: http://www.epa.gov/superfund/cleanup/postconstruction/5yr.htm

U.S. Environmental Protection Agency (EPA). 2000a. *Data Quality Objectives Process for Hazardous Waste Site Investigations: EPA QA/G-4HW.* EPA/600/R-00/007. January. Currently available online at: http://www.epa.gov/quality/qs-docs/g4hw-final.pdf

U.S. Environmental Protection Agency (EPA). 2000b. *Risk Characterization Handbook*. Science Policy Council, Washington, D.C. EPA-100-B-00-002. December. Currently available online at: http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=40000006.TXT

U.S. Environmental Protection Agency (EPA). 1999a. *Interim-Final Guidance for RCRA Corrective Action Environmental Indicators.* Office of Solid Waste, Washington, D.C. February 5. Currently available online at: http://www.epa.gov/osw/hazard/correctiveaction/eis/ei_guida.pdf

U.S. Environmental Protection Agency (EPA). 1999b. *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Documents*. Office of Solid Waste and Emergency Response, Washington, D.C. EPA-540-R-98-031. July. Currently available online at: http://www.epa.gov/superfund/policy/remedy/rods/pdfs/guide_decision_documents_071999.pdf

U.S. Environmental Protection Agency (EPA). 1999c. Compendium Method TO-14A. Determination of volatile organic compounds (VOCs) in ambient air using specially prepared canisters with subsequent analysis by gas chromatography. *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition.* Center for Environmental Research Information, Office of Research and Development, Cincinnati, Ohio. EPA/625/R-96/010b. January. Available online at http://www.epa.gov/ttnamti1/airtox.html.

U.S. Environmental Protection Agency (EPA). 1999d. Compendium Method TO-15. Determination of volatile organic compounds (VOCs) in air collected in specially-prepared canisters and analyzed by gas chromatography/mass spectrometry (GC/MS). *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition.* Center for Environmental Research Information, Office of Research and Development, Cincinnati, Ohio. EPA/625/R-96/010b. January. Available online at http://www.epa.gov/ttnamti1/airtox.html.

U.S. Environmental Protection Agency (EPA). 1999e. Compendium Method TO-17. Determination of volatile organic compounds in ambient air using active sampling onto sorbent tubes. *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition.* Center for Environmental Research Information, Office of Research and Development, Cincinnati, Ohio. EPA/625/R-96/010b. January. Available online at http://www.epa.gov/ttnamti1/airtox.html.

U.S. Environmental Protection Agency (EPA). 1999f. *Interim Policy on the Use of Permanent Relocations as Part of Superfund Remedial Actions.* OSWER Directive 9355.0-71P. Office of Solid Waste and Emergency Response Washington, DC. Currently available on-line at: http://www.epa.gov/superfund/community/relocation/intpol.htm

U.S. Environmental Protection Agency (EPA). 1998. *Technical Guidance Document: Compliance Assurance Monitoring, Revised Draft.* Office of Air Quality Planning and Standards, Research Triangle Park, NC. August. Currently available online at: http://www.epa.gov/ttn/emc/cam.html

U.S. Environmental Protection Agency (EPA). 1997. *Rules of Thumb for Superfund Remedy Selection.* OSWER Directive 9355.0-69. August. Currently available online at: http://www.epa.gov/oerrpage/superfund/policy/remedy/rules/index.htm

U.S. Environmental Protection Agency (EPA). 1995a. *Land Use in CERCLA Remedy Selection Process*. OSWER Directive 9355.7-04. May. Currently available online at: http://www.epa.gov/superfund/community/relocation/landuse.pdf

U.S. Environmental Protection Agency (EPA). 1995b. *Guidance for Risk Characterization*. Science Policy Council, Washington, D.C. February. Currently available online at: http://www.epa.gov/osainter/spc/pdfs/rcguide.pdf

U.S. Environmental Protection Agency (EPA). 1995c. *Engineering Forum Issue Paper. Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites*, EPA/540/S-96/500. Office of Research and Development, Office of Solid Waste and Emergency Response, Washington, DC. Currently available online at: http://www.epa.gov/osp/hstl/tsc/Breckenridge1995.pdf

U.S. Environmental Protection Agency (EPA). 1994. *RCRA Corrective Action Plan (Final).* OSWER Directive 9902.3-2A. Office of Solid Waste, Washington, DC. Currently available online at: http://www.epa.gov/epawaste/hazard/correctiveaction/resources/guidance/gen_ca/rcracap.pdf

U.S. Environmental Protection Agency (EPA). 1993a. *Radon Reduction Techniques for Existing Detached Houses: Technical Guidance (Third Edition) for Active Soil Depressurization Systems.* EPA-625-R-93-011. October. Currently available online at: http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=30004MR2.txt

U.S. Environmental Protection Agency (EPA). 1993b. *Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with VOCs in Soils.*

U.S. Environmental Protection Agency (EPA). 1993c. *Air/Superfund National Technical Guidance Study Series: Options for Developing and Evaluating Mitigation Strategies for Indoor Air Impacts at CERCLA Sites.* Office of Air Quality Planning and Standards. EP-451/R-93-012, September. Currently available on-line at: http://www.epa.gov/nscep/index.html

U.S. Environmental Protection Agency (EPA). 1992a. *Guidance for Data Useability in Risk Assessment, Part A.* Currently available online at: http://www.epa.gov/oswer/riskassessment/datause/parta.htm

U.S. Environmental Protection Agency (EPA). 1992b. *Early Action and Long-Term Action under SACM – Interim Guidance.* Office of Solid Waste and Emergency Response, Washington, D.C. Publication 9203.1-051. December.

U.S. Environmental Protection Agency (EPA). 1992c. *Guidance on Risk Characterization for Risk Managers and Risk Assessors*. Memorandum from F. Henry Habicht II, Deputy Administrator, Washington, D.C. February 26. Currently available online at: http://www.epa.gov/oswer/riskassessment/pdf/habicht.pdf

U.S. Environmental Protection Agency (EPA). 1991a. *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions.* Office of Solid Waste and Emergency Response. Washington, D.C. OSWER Directive 9355.0-30. April. Currently available online at: http://www.epa.gov/oswer/riskassessment/pdf/baseline.pdf.

U.S. Environmental Protection Agency (EPA). 1991b. *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part B, Development of Preliminary Remediation Goals), Interim.* Office of Emergency and Remedial Response, Washington, D.C. EPA-540-R-92-003. December. Currently available on-line at http://www.epa.gov/oswer/riskassessment/ragsb/index.htm

U.S. Environmental Protection Agency (EPA). 1991c. *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part C, Risk Evaluation of Remedial Alternatives), Interim.* Office of Emergency and Remedial Response, Washington, D.C. Publication 9285.7-01C. October. Currently available on-line at http://www.epa.gov/oswer/riskassessment/ragsc/index.htm

U.S. Environmental Protection Agency (EPA). 1989. *Risk Assessment Guidance for Superfund, Volume I Human Health Evaluation Manual (Part A), Interim Final.* Office of Emergency and Remedial Response, Washington, D.C. EPA-540-1-89-002. December. Currently available online at: http://www.epa.gov/oswer/riskassessment/ragsa/index.htm.

U.S. Environmental Protection Agency (EPA). 1987. *Entry and Continued Access under CERCLA.* Office of Enforcement and Compliance Monitoring, Washington, D.C. Publication 9829.2. June 5. Currently available online at: http://www2.epa.gov/sites/production/files/2013-09/documents/cont-access-mem.pdf

U.S. Environmental Protection Agency (EPA). 1986. *Inspection Authority under Section 3007 of RCRA.* Office of General Counsel, Washington, D.C. Memorandum from Francis Blake. April 17. Currently available online at: http://www2.epa.gov/enforcement/guidance-rcra-section-3007-inspection-authority

U.S. Environmental Protection Agency, Environmental Response Team (EPA-ERT). 2012. *Standard Operating Procedures, Trace Atmospheric Gas Analyzer (TAGA) IIE Operation (SOP 1711).* October 22. Currently available online at: http://www.epaosc.org/sites/2107/files/1711-r00.pdf

U.S. Environmental Protection Agency, Environmental Response Team (EPA-ERT). 2007. *Standard Operating Procedures, Construction and Installation of Permanent Sub-Slab Soil Gas Wells (SOP 2082).* March 29. Currently available online at: http://www.epaosc.org/sites/2107/files/2082-r00.pdf

U.S. Environmental Protection Agency, Environmental Response Team (EPA-ERT). 2001a. *Standard Operating Procedures, Groundwater Well Sampling (SOP 2007).* April 16. Currently available online at: http://www.epaosc.org/sites/2107/files/2007-R00.pdf

U.S. Environmental Protection Agency, Environmental Response Team (EPA-ERT). 2001b. *Standard Operating Procedures, Soil Sampling (SOP 2012).* July 11. Currently available online at: http://www.epaosc.org/sites/2107/files/2012-r10.pdf

U.S. Environmental Protection Agency, Environmental Response Team (EPA-ERT). 2001c. *Standard Operating Procedures, Soil Gas Sampling (SOP 2042).* April 18. Currently available online at: http://www.epaosc.org/sites/2107/files/2082-r00.pdf

U.S. Environmental Protection Agency, Environmental Response Team (EPA-ERT). 1995. *Standard Operating Procedures, Summa Canister Sampling (SOP 1701).* July 27. Currently available online at: http://www.epaosc.org/sites/2107/files/1704-R01.pdf

U.S. Environmental Protection Agency, Region 9 (EPA-Region 9). 2010. R9's *"RARE"Opportunity to Improve Vapor Intrusion Indoor Air Investigations.* EPA Vapor Intrusion Forum. June 14.

U.S. Environmental Protection Agency, Risk Assessment Forum (EPA-RAF). 2014. *Framework for Human Health Risk Assessment to Inform Decision Making*. Office of Science Advisor, Washington, D.C. April. Currently available online at: http://www2.epa.gov/sites/production/files/2014-12/documents/hhra-framework-final-2014.pdf

U.S. Environmental Protection Agency (EPA-SPC). 2006. *Peer Review Handbook, 3rd Edition.* EPA/100/B-06/002. Science Policy Council, Washington DC. Currently available online at: http://www2.epa.gov/sites/production/files/2014-12/documents/peer_review_handbook_3rd_ed.pdf

U.S. Postal Service (USPS). 2009. *Vapor Intrusion Guidance, Volume 1.* September.

Vroblesky, D.A., M.D. Petkewich, M.A. Lowery, and J.E. Landmeyer. 2011. Sewers as a source and sink of chlorinated-solvent groundwater contamination, Marine Corps Recruit Depot, Parris Island, South Carolina. *Groundwater Monitoring & Remediation* 31(4):63-69.

APPENDIX A
RECOMMENDED SUBSURFACE-TO-INDOOR AIR ATTENUATION FACTORS

A.1 INTRODUCTION

This Technical Guide includes recommended medium-specific (groundwater, soil gas, and indoor air) Vapor Intrusion Screening Levels (VISLs) that are intended to help identify those sites unlikely to pose a health concern from vapor intrusion and identify areas or buildings that may warrant further investigation of the vapor intrusion pathway. These VISLs are recommended for use in evaluating the concentrations of vapor-forming chemicals measured in groundwater, "near-source" exterior soil gas, and sub-slab soil gas in residential and nonresidential settings where the potential for vapor intrusion is under investigation.

The subsurface VISLs are developed considering a generic conceptual model for vapor intrusion consisting of a groundwater or vadose zone source of vapor-forming chemicals that diffuse upwards through unsaturated soils towards the surface and enter buildings. The underlying assumption for this generic model is that subsurface characteristics will tend to reduce or attenuate soil gas concentrations as vapors migrate upward from the source and into structures. Section 6.5.2 describes this conceptual model further. In general, EPA recommends considering whether the assumptions underlying the generic conceptual model are attained at each site. The *Vapor Intrusion Screening Level (VISL) Calculator User's Guide* (EPA 2015a) provides additional information about the technical basis for deriving the VISLs.

Comparison of sampling results to medium-specific VISLs (see Section 6.5.4) comprises one line of evidence in the multiple-lines-of-evidence approach described in this Technical Guide (see, for example, Sections 7.1 and 7.2). The subsurface (groundwater and soil gas) VISLs (C_{VISL}) are calculated using risk-based, screening levels for indoor air ($C_{target,ia}$) and a medium-specific, subsurface-to-indoor air attenuation factor (α_{VI}), as follows:

$$C_{VISL} = \frac{C_{target,ia}}{\alpha_{VI}} \qquad \text{Equation A.1}$$

The risk-based, indoor air screening levels ($C_{target,ia}$) are calculated according to the guidance provided in *Risk Assessment Guidance for Superfund (RAGS) Part F* (EPA 2009) as implemented in EPA's Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/). The medium-specific, attenuation factors (α_{VI}) recommended for calculating the subsurface VISLs are derived from information in *EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings* (EPA 2012a).

This appendix describes the technical basis for the selection of the subsurface-to-indoor air attenuation factors (α_{VI}) that are recommended for use in calculating the VISLs for groundwater, sub-slab soil gas, "near-source" exterior soil gas, and crawl space air, according to Equation A.1.

A.2 DEFINITION AND DESCRIPTION OF ATTENUATION FACTOR

Vapor attenuation refers to the reduction in concentration of vapor-forming chemicals that occurs during vapor migration in the subsurface, coupled with the dilution that can occur when the vapors enter a building and mix with indoor air (Johnson and Ettinger 1991). The aggregate effect of these physical and chemical attenuation mechanisms can be quantified through the use of a subsurface-to-indoor air vapor intrusion attenuation factor (α_{VI}), which is defined as the ratio of the indoor air concentration arising from vapor intrusion ($C_{IA\text{-}VI}$) to the subsurface vapor concentration (C_{sv}) at the source or a depth of interest in the vapor migration route (EPA 2012a):

$$\alpha_{VI} = \frac{C_{IA-VI}}{C_{SV}} \alpha_{VI} = \frac{C_{IA-VI}}{C_{SV}} \qquad \text{Equation A.2}$$

As defined here, the vapor attenuation factor is an inverse measurement of the overall dilution that occurs as vapors migrate from a point of measurement in the subsurface into a building; i.e., attenuation factor values decrease with increasing dilution of vapor concentration.

Subsurface vapor concentrations (C_{SV}) may be measured directly under a building (often called sub-slab soil gas or just sub-slab), measured exterior to a building at any depth in the unsaturated zone (often called exterior soil gas), or derived from groundwater concentrations by converting the dissolved concentration to a vapor concentration assuming equilibrium conditions (i.e., by multiplying the groundwater concentration by the chemical's dimensionless Henry's law constant for the groundwater temperature *in situ*) (EPA 2001); also see Appendix C of this Technical Guide.

Subfloor vapor concentrations may also be measured in building crawl spaces. Although crawl space samples are not strictly subsurface samples, they represent the vapor concentration underlying a building's living space. Thus, crawl space samples may be evaluated in a manner similar to subsurface vapor samples.

A.3 RECOMMENDED ATTENUATION FACTORS

This section summarizes the technical basis and rationale for EPA's recommended attenuation factors for groundwater, sub-slab soil gas, exterior soil gas, and crawl space air, as follows:

- Section A.3.1 summarizes EPA's database of empirical attenuation factor values and the results of analyzing that database.
- Section A.3.2 identifies the recommended empirically based attenuation factors for groundwater.
- Section A.3.3 identifies the recommended attenuation factor for sub-slab soil gas and presents a theoretical analysis that supports the selection of the recommended empirically based value.
- Section A.3.4 recommends a generic attenuation factor for exterior soil gas and discusses its basis, justification, and limited applications.

- Section A.3.5 identifies the recommended attenuation factor for crawlspace vapor.
- Section A.3.6 presents a reliability analysis of the recommended generic attenuation factors.

A.3.1 EPA'S VAPOR INTRUSION DATABASE (EPA 2012A)

The information in *EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings* (EPA 2012a) is used to derive recommended attenuation factor values for use in evaluating subsurface sample concentrations collected as part of vapor intrusion investigations. EPA's vapor intrusion database consists of numerous pairings of concentrations in indoor air and subsurface samples (groundwater, sub-slab soil gas, exterior soil gas, and crawlspace vapor) from actual sites. It represents the most comprehensive compilation of vapor intrusion data for chlorinated hydrocarbons (CHCs) available at this time.

EPA's vapor intrusion database was analyzed and screened to reduce the impacts of background sources to indoor air concentrations. The resulting data distributions are considered representative of vapor intrusion of CHCs from subsurface vapor sources into residential buildings for most conditions. These distributions serve as the basis for identifying the high-end (conservative) attenuation factors for those media.

Table A-1 and Figure A-1 (Table 19 and Figure 34, respectively, in EPA (2012a)) present and compare the distributions of the attenuation factors (groundwater, exterior soil gas, sub-slab soil gas, and crawl space) that remain after applying the respective source strength and indoor air screens considered most effective at reducing the influence of background contributions to indoor air concentrations. These data demonstrate that the attenuation factor distributions obtained for groundwater, sub-slab soil gas, and crawl spaces for multiple buildings and sites are consistent with the conceptual model for vapor intrusion, which predicts that greater attenuation is expected with greater depths to the vapor sources or vapor samples. As shown in Table A-1 and Figure A-1, the paired groundwater–indoor air data generally exhibit greater attenuation (lower attenuation factors) than the paired sub-slab soil gas–indoor air data, which in turn exhibit greater attenuation than the paired crawl space-indoor air data.

A.3.2 RECOMMENDED ATTENUATION FACTORS FOR GROUNDWATER

To account for the inherent temporal and spatial variability in indoor air and subsurface vapor concentrations, the 95th percentile value of the "source-screened" groundwater data subset in EPA 2012a is recommended as a reasonably conservative generic attenuation factor, after considering a range of values. **Thus, for groundwater, the recommended generic attenuation factor (α_{gw}) is 0.001.** This value is considered to apply for any soil type in the vadose zone (excepting where preferential vapor pathways are present; see Section 5.4) in cases where the groundwater is greater than five feet below the ground surface. If the depth to groundwater is less than five feet below the building foundation, investigation of the indoor space is recommended, as there is potential for contaminated groundwater to contact the building foundation, either because the capillary fringe intersects the building foundation or groundwater fluctuations results in groundwater wetting the foundation.

Table A-2 (Table 13 in EPA (2012a)) provides statistics and Figure A-2 (Figure 28 in EPA (2012a)) shows box-and-whisker plots for individual sites compared with the statistics for the combined set of screened groundwater attenuation factors. This table and figure show that the 95^{th} percentile value of the combined groundwater-indoor air measurements is considered appropriate for estimating reasonable maximum indoor air concentrations that might be observed at a site due to vapor intrusion. The majority of sites and buildings would be expected to exhibit lower indoor air concentrations.

A factor that commonly results in greater attenuation (lower attenuation factors) is the presence of laterally extensive, unfractured fine-grained sediment in the vadose zone. Table A-3 (Table 14 in EPA (2012a)) provides selected statistics and Figure A-3 (Figure 29 in EPA (2012a)) shows the box-and-whisker plots for the groundwater attenuation factors for three soil types. Comparing each descriptive statistic (except for the 25th percentile values) indicates that the attenuation factor values for residences overlying soils classified as “very coarse” generally are larger than those for residences overlying soils classified as “coarse,” which are larger than those for soils classified as “fine.” This pattern is consistent with the conceptual model for vapor intrusion; smaller attenuation factors, which indicate greater reduction in vapor concentration, would be expected in vadose zones with finer-grained soils, when all other factors (e.g., depth to groundwater, biodegradability of the volatile chemicals) are the same. The 95^{th} percentile value of the coarse-grained soil is equal to the generic value, as expected, since coarse-grained soil provide low resistance to vapor transport and thus would be expected to yield high-valued attenuation factors. Where fine-grained sediments underlay buildings, however, more attenuation is expected and observed in the database. **Thus, a semi-site-specific attenuation factor of 0.0005 may be used at sites where laterally extensive fine-grained sediment has been demonstrated through site-specific sampling to underlay buildings being investigated for vapor intrusion**.

A.3.3 RECOMMENDED GENERIC ATTENUATION FACTOR FOR SUB-SLAB SOIL GAS

To account for the inherent temporal and spatial variability in indoor air and subsurface vapor concentrations, the 95^{th} percentile value of the “source-screened” sub-slab data subset in EPA (2012a) is recommended as a reasonably conservative generic attenuation factor, after considering a range of values. Thus, **for sub-slab soil gas, the recommended generic attenuation factor (α_{ss}) is 0.03.**

The selection of this value can be supported by theoretical analysis. Specifically, a simple mass balance analysis, assuming a well-mixed interior volume and steady-state conditions, indicates that the theoretical (true) sub-slab soil gas attenuation factor can be expressed as the ratio of the soil gas entry rate to the building ventilation rate (Song et al., 2011; EPA 2012a) for cases where there is no background contribution to the indoor air concentration. Using median values for residential building volume and air exchange rate (395 m^3 and 0.45 ACH, respectively) provided in the *Exposure Factors Handbook 2011 Edition* (EPA, 2011) and a mid-range value of 5 L/min for soil gas entry rate in sandy materials (EPA 2002, Appendix G), the central tendency value of the sub-slab soil gas attenuation factor (according to Equation 4a therein), is expected to be approximately 0.002. Using upper-end (10th percentile) values for residential building volume and air exchange rate (154 m^3 and 0.18 ACH, respectively (EPA 2011)) and soil gas entry rate (10 L/min), an upper-end value of 0.02 for the sub-slab soil gas attenuation factor is obtained. These values agree well with the 95^{th} percentile and 50^{th} percentile (median) values

(0.03 and 0.003, respectively) obtained from the source-screened data. These calculations buttress the conclusion that the sub-slab attenuation factor distributions summarized in EPA's vapor intrusion database report can be considered representative of vapor intrusion of CHCs into residential buildings for most conditions.

Table A-4 (Table 10 in EPA (2012a)) provides statistics and Figure A-4 (Figure 25 in EPA (2012a)) shows box-and-whisker plots for individual sites compared with the statistics for the combined set of screened sub-slab attenuation factors. This table and figure show that the 95th percentile value of the combined sub-slab-indoor air measurements is considered appropriate for estimating reasonable maximum indoor air concentrations that might be observed at a site due to vapor intrusion. The majority of sites and buildings would be expected to exhibit lower indoor air concentrations.

A.3.4 RECOMMENDED ATTENUATION FACTOR FOR "NEAR-SOURCE" EXTERIOR SOIL GAS

Based upon the conceptual model for vapor intrusion, the attenuation factors for exterior soil gas data would be expected to be less than those for sub-slab soil gas, because the former includes an additional contribution from attenuation through the vadose zone, and greater than those for groundwater vapors for a given building at a site where groundwater is the primary subsurface source of vapors. The distributions of exterior soil gas attenuation factors shown in Table A-1 and Figure A-1 do not exhibit this expected relationship. In addition, a comparison of exterior soil gas to sub-slab soil gas concentrations for buildings where both types of samples were collected, shown in Figure A-5 (see Figure 6 in EPA (2012a)), suggests that a substantial proportion of the exterior soil gas data in the database, particularly shallow soil gas data, may not be representative of soil gas concentrations directly underneath a building. On this basis, shallow exterior soil gas sampling data generally are not recommended for purposes of estimating indoor air concentrations and the exterior soil gas attenuation factors in Table A-1 are not recommended for use in deriving generic attenuation factors.

Based upon the data in Figure A-5, "deep" exterior soil gas data appear to more reliably reflect sub-slab concentrations beneath buildings. On this basis, "near-source" soil gas sampling data (i.e., collected in the vadose zone immediately above each vapor source) generally are allowed for purposes of assessing vapor concentrations that may be in contact with the building's sub-slab, as discussed further in Section 6.4.4. However, the same conservative attenuation factor value for sub-slab soil gas is recommended for use with "near-source" exterior soil gas data for this purpose. **Thus, for "near-source" exterior soil gas, the recommended generic attenuation factor is 0.03**.

A.3.5 RECOMMENDED ATTENUATION FACTOR FOR CRAWLSPACE VAPOR

The distribution of attenuation factors presented in Figure A-1 show that attenuation between building crawlspaces and living spaces is limited. To account for the inherent temporal and spatial variability in indoor air and crawlspace vapor concentrations, the 95th percentile value of the "indoor air-screened" crawlspace data subset in EPA (2012a) is recommended as a reasonably conservative generic attenuation factor, after considering a range of values. **Thus, for crawl space vapor the recommended generic attenuation factor is 1.0** (0.9 rounded up to 1.0).

A.3.6 RELIABILITY ANALYSIS OF THE RECOMMENDED SUBSURFACE-TO-INDOOR AIR GENERIC ATTENUATION FACTORS

An analysis was performed to determine the reliability of these recommended attenuation factors for screening in residences in EPA's vapor intrusion data base with measured indoor air concentrations exceeding target levels corresponding to a cancer risk of 10^{-6} and a hazard quotient of 1. The reliability analysis was performed separately for each medium by determining the number of correct assessments and the number of false negatives for a range of attenuation factors. The potential incidence of false negatives is a critical criterion, because the primary objective of risk-based screening is to identify sites or buildings unlikely to pose a health concern through the vapor intrusion pathway (see Section 6.5.1).

For the purposes of this analysis:

- A correct assessment is deemed to occur either: (1) when a chemical's measured indoor air concentration exceeds the target level and the measured subsurface vapor concentration also exceeds the appropriate medium-specific VISL calculated using the specified generic attenuation factor, or (2) when a chemical's measured indoor air concentration is below the target level and the measured subsurface vapor concentration also is below the appropriate medium-specific VISL calculated using the recommended generic attenuation factor. Correct assessments in this analysis represent a correct decision based on subsurface concentration data regarding the potential for vapor intrusion to pose indoor air concentrations that exceed target risk-based concentrations in affected buildings.

- A false negative is deemed to occur when a chemical's measured indoor air concentration exceeds the target level, but the measured subsurface vapor concentration does not exceed the appropriate medium-specific VISL calculated using the specified generic attenuation factor. False negatives in this analysis represent the potential for making an incorrect decision based on subsurface concentration data regarding the potential for vapor intrusion to pose indoor air concentrations that exceed target risk-based concentrations in affected buildings.

This assessment uses the Data Consistency Subset of the EPA's vapor intrusion database for residential buildings (i.e., before screening to minimize the impacts of background contributions to indoor air as described in EPA (2012a)). This subset was chosen to allow for the possibility that background indoor air contributions were incorrectly identified and removed from further analysis in the "source-screened" data subsets presented in EPA (2012a). Thus, false negatives may appear if indoor or ambient (outdoor) sources of VOCs are present and they exceed the indoor air target level. This choice of datasets provides a conservative estimate of the frequency of false negatives identified by this reliability analysis. Even lower rates of false negatives would be obtained when considering the "source-screened" data subsets, described in EPA (2012a), in which the impacts of background contributions to indoor air are minimized.

The results of this assessment are shown in Figures A-6 through A-8 for sub-slab soil gas, groundwater, and exterior soil gas.[256] The essential results are as follows:

- The recommended generic attenuation factors yield low rates of false negatives (< 2%) for all three media when individual pairs of samples are evaluated together.
- The recommended generic attenuation factors for groundwater, exterior soil gas, and sub-slab soil gas provide generally high rates of correct assessments when individual pairs of samples are evaluated together: 78% for groundwater; 76% for exterior soil gas; and 87% for sub-slab soil gas. Higher rates of correct assessments are expected for sub-slab soil gas than for the other subsurface media, likely due to the closer spatial correspondence of building sub-slab soil gas and indoor air samples.
- The rates of correct assessments appear to level off in Figure A-6 through A-8 at about the point on the x-axis where the recommended generic attenuation factors occur.
- The rates of false positives using the Data Consistency Subset can be inferred from Figure A-6 through A-8. This analysis indicates that use of ground water data or exterior soil gas data is more likely to incorrectly identify a site or building as warranting further investigation than is use of sub-slab soil gas data.

Compared to the values estimated in Figures A-6 through A-8, significantly higher rates of a correct assessment (and, hence, lower rates of false negatives and false positives) are reasonably anticipated to be realized by following this Technical Guide. Specifically, collecting multiple samples to characterize spatial and temporal variability (see, for example, Section 6.4), collecting multiple lines of additional evidence (see, for example, Section 6.3 and 7.1), and weighing this information together (see, for example, Sections 6.3 and 7) are reasonably expected to significantly reduce the "error rates" estimated in this reliability analysis, which are based upon comparison of individual pairs of indoor air and subsurface sample concentrations.

As previously stated, this Technical Guide includes subsurface VISLs that are intended to help identify those sites with the potential to pose a vapor intrusion concern. The reliability analysis described above suggests the recommended attenuation factors, on which the recommended VISLs are based, can reasonably be expected to provide an acceptably small probability of 'screening out' sites that pose a vapor intrusion concern and a high probability of correctly identifying sites or buildings that may pose a vapor intrusion concern.

---

[256] The reliability assessment was not conducted for crawlspace data, because the distribution of attenuation factors presented in Figure A-1 show that attenuation between building crawlspaces and living spaces is limited.

A.4 CONSIDERATIONS FOR NONRESIDENTIAL BUILDINGS

The recommended attenuation factors (see Sections B.3.2 through B.3.5) are proposed for use for nonresidential buildings as well as residential buildings. The rationale is that, in many geographic locations, some commercial enterprises have been established in converted residential buildings. Although used for commercial purposes, such buildings can reasonably be expected to exhibit similar susceptibility to vapor intrusion and similar interior mixing and dilution (and, hence, similar attenuation factors) as residential buildings represented in EPA's vapor intrusion database. In addition, McDonald and Wertz (2007) found that sub-slab attenuation factors for commercial and institutional buildings in Endicott, New York, which were not "extraordinarily large", were not substantially different than those for residential buildings in the same area.

There are theoretical considerations to support expectations that larger nonresidential buildings that are constructed on thick slabs will have lower attenuation factors than residential buildings. These considerations include:

- Given that the size (e.g., interior height and footprint area) and air exchange rate tend to be larger for many nonresidential buildings (see, for example, Table A-5), it is expected that building ventilation rates for many nonresidential buildings would be higher than those for residential buildings. A higher ventilation rate is expected to result in greater overall vapor dilution as vapors migrate from a subsurface vapor source into a building. On this basis, many nonresidential buildings would be expected to have lower attenuation factors than those for residential buildings, all else being equal.

- Comparing buildings with slab-on-grade construction, nonresidential buildings tend to have thicker slabs than residential buildings. With thicker slabs, a given amount of differential settling would be expected to lead to less cracking in the slab and would be less likely to create cracks that extend across the entire slab thickness. Buildings with thicker slabs would, therefore, be expected to exhibit lower soil gas entry rates, all else being equal.

Where appropriate, EPA may consider appropriate building-specific data, information, and analysis when evaluating vapor intrusion into large nonresidential buildings.

A.5 CITATIONS (APPENDIX A)

Johnson, P.C., and R.A. Ettinger. 1991. Heuristic model for predicting the intrusion rate of contaminant vapors into buildings. *Environmental Science & Technology* 25:1445-1452.

McDonald, G.J. and W.E. Wertz. 2007. PCE, TCE, and TCA vapors in subslab soil gas and indoor air: A case study in upstate New York. *Groundwater Monitoring & Remediation* 27(4):86-92.

Song, S., F. C. Ramacciotti, B. A. Schnorr, M. Bock, and C.M. Stubbs. 2011. Evaluation of EPA's empirical attenuation factor database. *EM: The Magazine for Environmental Managers* February:16-21. Currently available online at http://pubs.awma.org/gsearch/em/2011/2/song.pdf

U.S. Environmental Protection Agency (EPA). 2015a. *Vapor Intrusion Screening Level (VISL) Calculator, User's Guide.* Currently available online at:

http://www.epa.gov/oswer/vaporintrusion/guidance.html

U.S. Environmental Protection Agency (EPA). 2012a. *U.S. EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings*. EPA 530-R-10-002. Currently available online at http://www.epa.gov/oswer/vaporintrusion/documents/OSWER_2010_Database_Report_03-16-2012_Final.pdf

U.S. Environmental Protection Agency (EPA). 2012b. *Conceptual Model Scenarios for the Vapor Intrusion Pathway.* EPA-530-R-10-003. Currently available online at http://www.epa.gov/oswer/vaporintrusion/documents/vi-cms-v11final-2-24-2012.pdf

U.S. Environmental Protection Agency (EPA). 2011. *Exposure Factors Handbook – 2011 Edition.* Office of Research and Development, Washington, D.C. EPA/600/R-090/052. Currently available online at http://www.epa.gov/ncea/efh/pdfs/efh-complete.pdf

U.S. Environmental Protection Agency (EPA). 2009. *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment).* Office of Superfund Remediation and Technology Innovation, Washington, D.C. EPA-540-R-070-002. Currently available online at http://www.epa.gov/oswer/riskassessment/ragsf/index.htm

U.S. Environmental Protection Agency (EPA). 2002. *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)*. Office of Solid Waste and Emergency Response, Washington, D.C. EPA-530-D-02-004. November. Currently available online at: http://www.epa.gov/osw/hazard/correctiveaction/eis/vapor.htm

U.S. Environmental Protection Agency (EPA). 2001. *Fact Sheet, Correcting the Henry's Law Constant for Soil Temperature.* Office of Solid Waste and Emergency Response, Washington, D.C. Currently available online at http://www.epa.gov/oswer/riskassessment/airmodel/pdf/factsheet.pdf

TABLE A-1.

DESCRIPTIVE STATISTICS SUMMARIZING ATTENUATION FACTOR DISTRIBUTIONS FOR GROUNDWATER, EXTERIOR SOIL GAS, SUB-SLAB SOIL GAS, AND CRAWL SPACE VAPOR AFTER APPLICATION OF THE DATABASE SCREENS CONSIDERED MOST EFFECTIVE AT MINIMIZING THE INFLUENCE OF BACKGROUND SOURCES ON INDOOR AIR CONCENTRATIONS.

Statistic	Groundwater (GW > 1,000X Bkgd)	Exterior Soil Gas (SG > 50X Bkgd)	Sub-slab Soil Gas (SS > 50X Bkgd)	Crawl Space (IA > Bkgd)
Min	1.0E-07	5.0E-06	2.5E-05	5.7E-02
5%	3.6E-06	7.6E-05	3.2E-04	1.0E-01
25%	2.3E-05	6.0E-04	1.5E-03	2.2E-01
50%	7.4E-05	3.8E-03	2.7E-03	3.9E-01
75%	2.0E-04	2.7E-02	6.8E-03	6.9E-01
95%	1.2E-03	2.5E-01	2.6E-02	9.0E-01
Max	2.1E-02	1.3E+00	9.4E-01	9.2E-01
Mean	2.8E-04	5.0E-02	9.2E-03	4.6E-01
StdDev	1.0E-03	1.7E-01	5.0E-02	2.8E-01
95UCL	3.4E-04	7.8E-02	1.3E-02	5.3E-01
Count All	774	106	431	41
Count >RL	743	106	411	41
Count <RL	31	0	20	0
No. of sites	24	11	12	4

Note: The applied database screens are groundwater (vapor) concentrations > 1,000X “background,” exterior soil gas > 50X “background,” sub-slab soil gas > 50X “background,” and for crawl space, indoor air concentrations > 1X “background.” SOURCE: Table 19 in EPA (2012a).

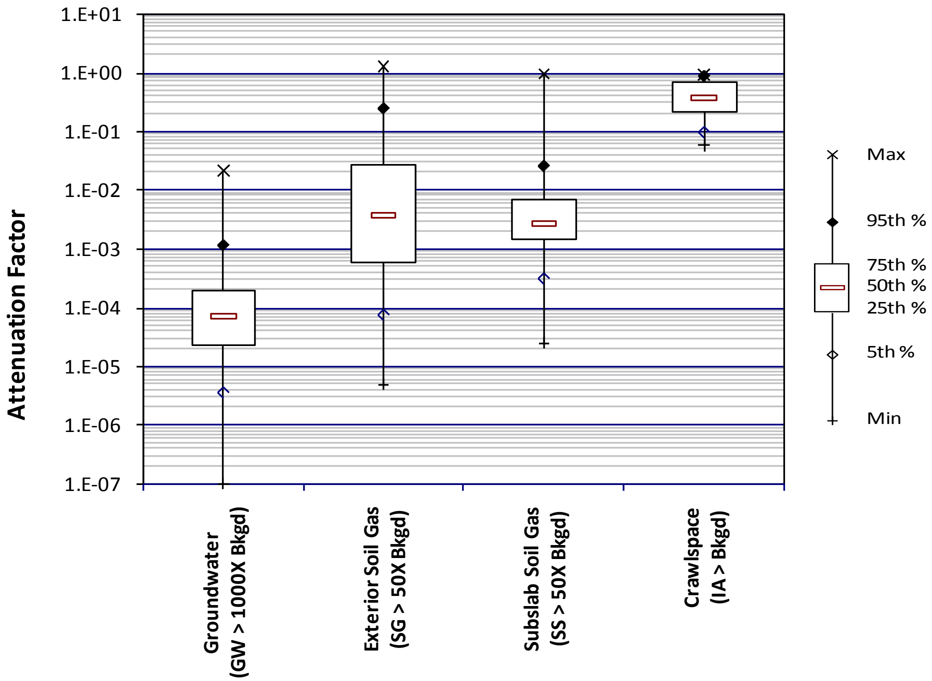


Figure A-1. Box-and-whisker plots summarizing attenuation factor distributions for groundwater, exterior soil gas, sub-slab soil gas, and crawl space vapor after application of the database screens considered most effective at minimizing the influence of background sources on indoor air concentrations. SOURCE: Figure 34 in EPA (2012a).

TABLE A-2.
DESCRIPTIVE STATISTICS SUMMARIZING GROUNDWATER ATTENUATION FACTOR DISTRIBUTIONS FOR INDIVIDUAL SITES COMPARED WITH THE COMBINED DATA SET AFTER SOURCE STRENGTH SCREEN (GROUNDWATER VAPOR CONCENTRATIONS > 1,000 TIMES "BACKGROUND").

Statistic	GW > 1,000 X Bkgd	Allepo	Alliant	BillingsPCE	CDOT	Davis	Eau Claire	Endicott	Grants	Hamilton-Sundstrand	Harcros/Tri State	Hopewell Precision	Jackson	LAFB	Lockwood	MADEP 1	MADEP 2	Moffet	Mountain View	Rapid City	Redfield	SCM - Cortlandville	Uncasville	Wall	West Side Corp.
Min	1.0E-07	9.1E-06	2.5E-06	1.0E-06	1.8E-06	4.7E-05	3.6E-06	1.9E-05	1.0E-07	9.6E-06	1.2E-06	2.5E-05		2.9E-06	8.6E-07	1.6E-04		1.3E-06	4.8E-07	9.9E-06	1.7E-06	5.9E-05	3.3E-05	1.4E-06	2.1E-06
5%	3.6E-06			1.1E-05	3.4E-06			2.8E-05	9.7E-07	1.2E-05		1.7E-04		4.0E-06	2.9E-06						7.6E-06	5.9E-05		1.7E-05	1.3E-05
25%	2.3E-05			2.1E-05	9.9E-06			2.8E-05	2.7E-06	5.8E-05		2.9E-04		1.7E-05	1.9E-05						2.8E-05	5.9E-05	3.5E-04	2.9E-05	1.5E-05
50%	7.4E-05		3.7E-06	3.9E-05	2.2E-05		2.5E-04	1.7E-04	1.2E-05	1.0E-04	2.5E-04	5.6E-04	4.7E-04	3.4E-05	8.8E-05		4.0E-05	4.0E-06	3.3E-06	3.1E-05	7.3E-05	3.1E-04	4.8E-04	8.2E-05	3.7E-05
75%	2.0E-04			8.9E-05	1.5E-04			7.0E-04	8.7E-05	1.5E-04		1.2E-03		1.4E-04	2.7E-04						1.5E-04	1.7E-03	6.5E-04	3.2E-04	2.7E-04
95%	1.2E-03			6.8E-04	5.4E-04			1.4E-03	2.9E-04	2.9E-04		7.7E-03		6.8E-04	1.3E-03						4.8E-04	4.2E-03		1.4E-03	4.3E-03
Max	2.1E-02	1.4E-05	1.1E-03	8.0E-04	5.4E-04	4.3E-04	1.9E-03	1.5E-03	2.9E-04	5.2E-04	3.7E-03	7.7E-03		2.3E-03	2.4E-03	1.0E-03		1.9E-05	3.3E-05	4.0E-05	1.8E-03	6.6E-03	1.8E-03	1.1E-02	2.1E-02
Mean	2.8E-04		1.1E-04	1.2E-04	1.1E-04	2.4E-04	7.7E-04	4.3E-04	7.5E-05	1.2E-04	7.1E-04	1.2E-03		1.6E-04	2.6E-04	6.0E-04		7.9E-06	9.7E-06	2.7E-05	1.3E-04	1.1E-03	6.0E-04	4.9E-04	1.1E-03
StdDev	1.0E-03		3.4E-04	2.1E-04	1.7E-04		8.1E-04	4.8E-04	1.1E-04	9.8E-05	1.3E-03	1.8E-03		3.6E-04	4.5E-04			9.3E-06	1.4E-05	1.6E-05	1.9E-04	1.6E-03	5.1E-04	1.7E-03	4.0E-03
95UCL	3.4E-04		2.8E-04	1.9E-04	1.8E-04		1.4E-03	5.7E-04	1.2E-04	1.5E-04	1.7E-03	2.0E-03		2.2E-04	3.5E-04			2.4E-05	2.3E-05	5.4E-05	1.5E-04	1.6E-03	9.2E-04	9.2E-04	2.3E-03
Count All	774	2	12	25	17	2	6	32	14	32	7	17	1	93	63	2	1	3	5	3	329	28	9	43	28
Count >RL	743	1	5	25	17	2	6	22	14	32	7	17	1	93	63	2	1	3	5	3	329	21	9	43	22
Count <RL	31	1	7	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	6

SOURCE: Table 13 in EPA (2012a).

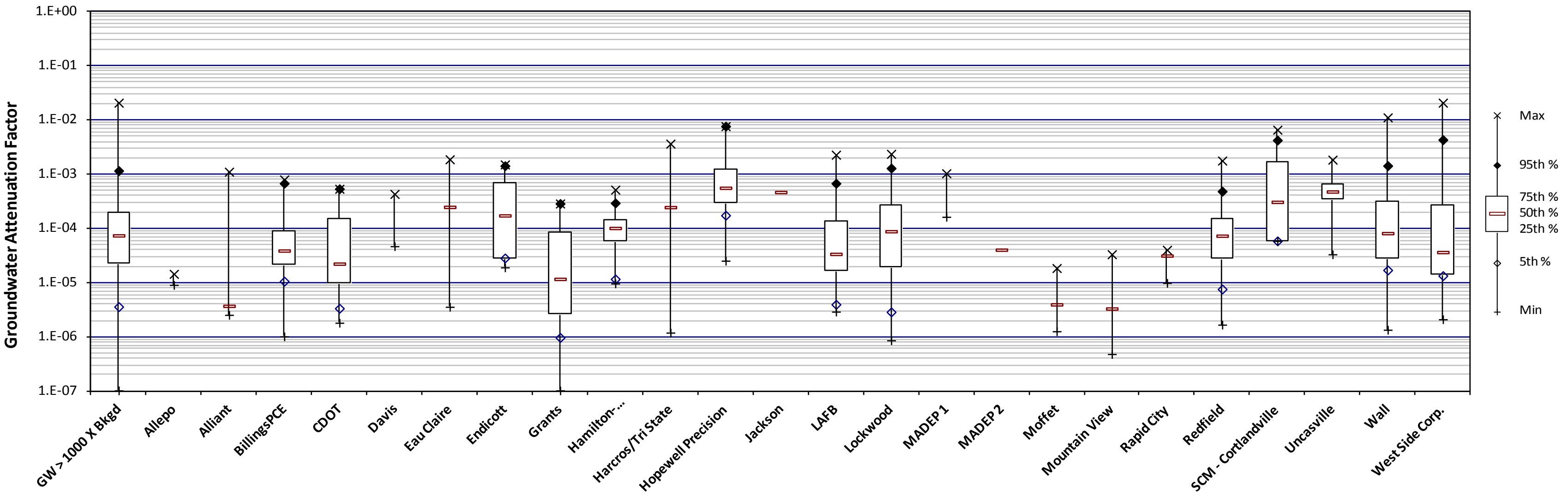


Figure A-2. Box-and-whisker plots summarizing groundwater attenuation factor distributions for individual sites compared with the combined data set after Source Strength Screen (groundwater vapor concentrations > 1,000 times "background"). SOURCE: Figure 28 in EPA (2012a).

TABLE A-3.
DESCRIPTIVE STATISTICS SUMMARIZING GROUNDWATER ATTENUATION FACTOR DISTRIBUTIONS FOR SPECIFIC SOIL TYPES AFTER SOURCE STRENGTH SCREEN.

	Soil Type Below Foundation		
Statistic	**Fine**	**Coarse**	**V.Coarse**
Min	1.0E-07	4.8E-07	2.1E-06
5%	2.3E-06	7.6E-06	1.3E-05
25%	1.9E-05	3.1E-05	2.0E-05
50%	4.6E-05	1.0E-04	1.5E-04
75%	1.4E-04	2.5E-04	6.8E-04
95%	4.5E-04	1.4E-03	4.2E-03
Max	2.4E-03	1.1E-02	2.1E-02
Mean	1.3E-04	3.3E-04	9.7E-04
StdDev	2.4E-04	8.9E-04	3.0E-03
95UCL	1.5E-04	4.1E-04	1.7E-03
Count All	353	369	52
Count >RL	344	359	40
Count <RL	9	10	12
No. of sites	10	15	3

SOURCE: Table 14 in EPA (2012a).

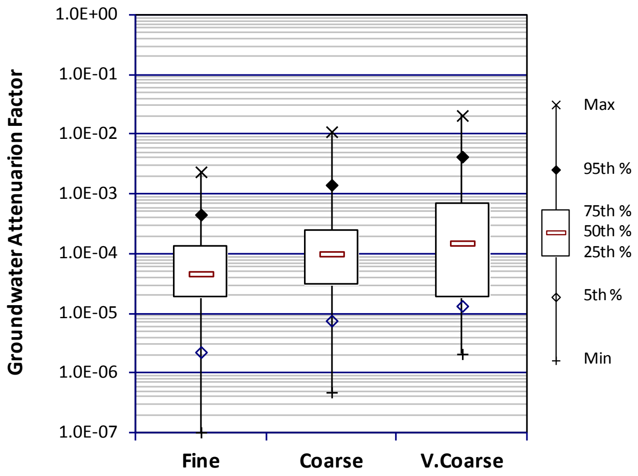


Figure A-3.Box-and-whisker plots summarizing groundwater attenuation factor distributions for specific soil types after Source Strength Screen. SOURCE: Figure 29 in EPA (2012a).

TABLE A-4.

DESCRIPTIVE STATISTICS SUMMARIZING SUB-SLAB ATTENUATION FACTOR DISTRIBUTIONS FOR INDIVIDUAL SITES COMPARED WITH THE COMBINED DATA SET AFTER SOURCE STRENGTH SCREEN (SUB-SLAB SOIL GAS CONCENTRATIONS > 50 TIMES "BACKGROUND").

Statistic	SS > 50X Bkgd	BillingsPCE	DenverPCEBB	Endicott	Georgetown	Harcros/Tri State	Hopewell Precision	Jackson	LAFB	Orion Park	Raymark	SCM-Cortlandville	West Side Corporation
Min	2.5E-05	2.5E-05	1.1E-03	2.6E-04	1.3E-03	3.8E-04	1.5E-03		3.5E-05	5.0E-04	2.5E-04	3.4E-03	2.0E-04
5%	3.2E-04	9.6E-05		6.9E-04			1.9E-03		1.4E-04		1.2E-03	3.6E-03	
25%	1.5E-03	4.6E-04		1.7E-03			5.0E-03		4.1E-04	1.8E-03	2.0E-03	7.1E-03	5.9E-04
50%	2.7E-03	7.0E-04	6.4E-03	2.6E-03	1.9E-03	4.5E-04	1.0E-02	8.4E-03	1.9E-03	2.8E-03	5.5E-03	1.8E-02	1.5E-03
75%	6.8E-03	1.5E-03		5.0E-03			1.8E-02		5.3E-03	8.8E-03	8.3E-03	4.1E-02	9.7E-03
95%	2.6E-02	2.6E-03		1.1E-02			3.4E-02		3.2E-02		2.1E-02	1.5E-01	
Max	9.4E-01	2.7E-03	4.1E-02	9.4E-01	2.9E-03	2.7E-03	3.4E-02		4.2E-02	3.3E-02	7.9E-02	1.5E-01	3.5E-01
Mean	9.2E-03	9.5E-04	1.7E-02	8.5E-03	2.0E-03	1.0E-03	1.3E-02	8.4E-03	5.0E-03	7.6E-03	7.4E-03	4.1E-02	4.3E-02
StdDev	5.0E-02	7.7E-04	1.9E-02	6.5E-02	8.4E-04	1.1E-03	1.0E-02		9.0E-03	1.1E-02	1.0E-02	5.0E-02	1.2E-01
95UCL	1.3E-02	1.2E-03	3.5E-02	1.6E-02	3.5E-03	2.3E-03	1.7E-02		7.1E-03	1.4E-02	9.2E-03	6.8E-02	1.2E-01
No. of AFs	431	27	5	207	3	4	19	1	52	9	83	12	9
No. of AFs > RL	411	27	5	188	3	4	19	1	52	9	83	12	8
No. of AFs < RL	20	0	0	19	0	0	0	0	0	0	0	0	1

SOURCE: Table 10 in EPA (2012a).

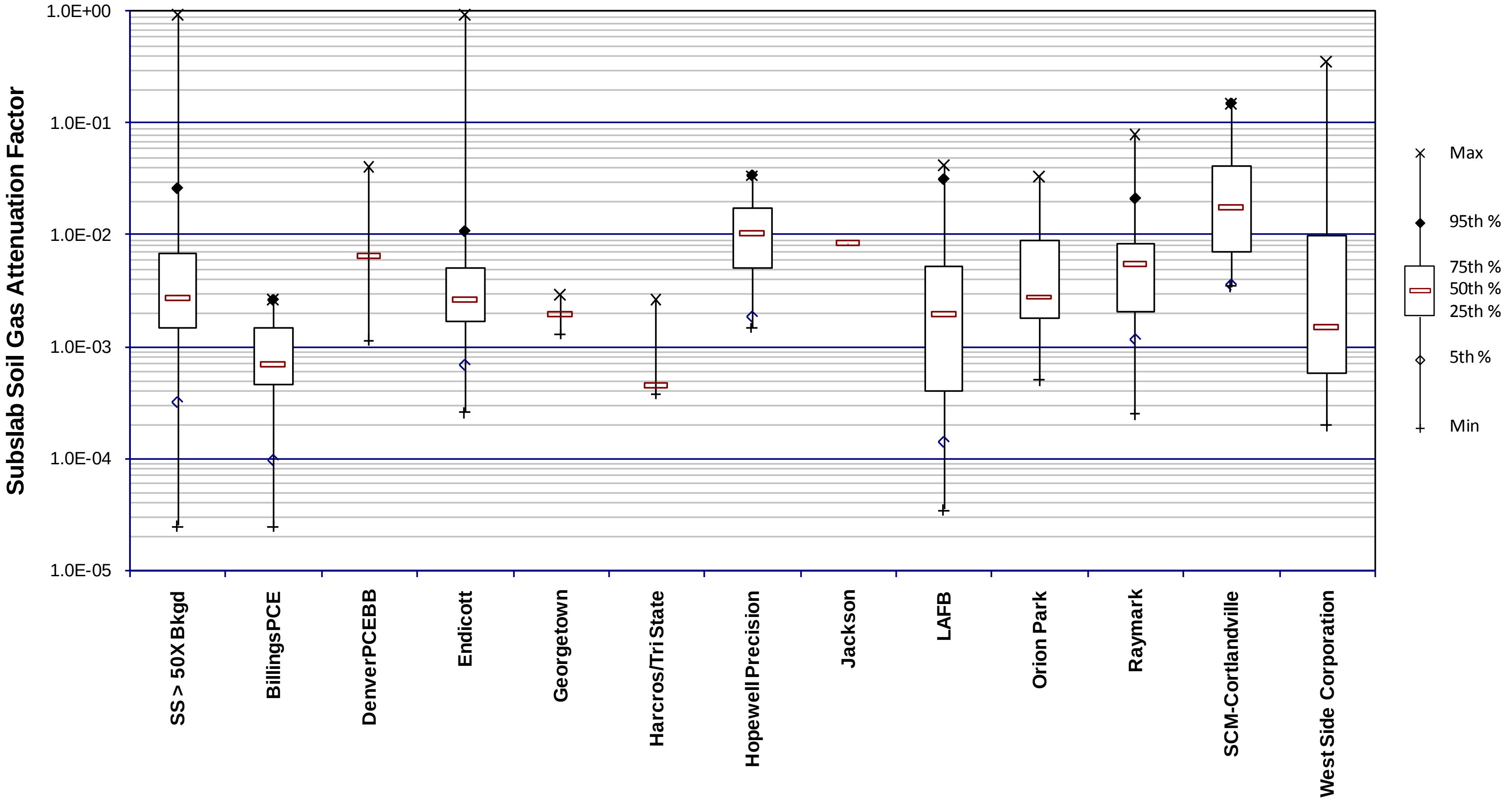


Figure A-4. Box-and-whisker plots summarizing sub-slab soil gas attenuation factor distributions for individual sites after Source Strength Screen (sub-slab soil gas concentrations > 50 times "background"). SOURCE: Figure 25 in EPA (2012a).

TABLE A-5

COMPARISON OF SIZE CHARACTERISTICS FOR RESIDENTIAL AND SOME COMMERCIAL BUILDINGS

Building Parameter and Units	Value and Source for Residential Building	Value and Source for Commercial Buildings, Other Than Warehouses and Enclosed Malls
ACH_{Bldg} (1/hr), 10th percentile	0.18 (EPA 2011, Table 19-1)	0.6 (EPA 2011, Table 19-27)
H_{Bldg} (feet)	8-feet ceiling height (EPA 2011, assumed value)	12-feet ceiling height (EPA 2011, assumed value)

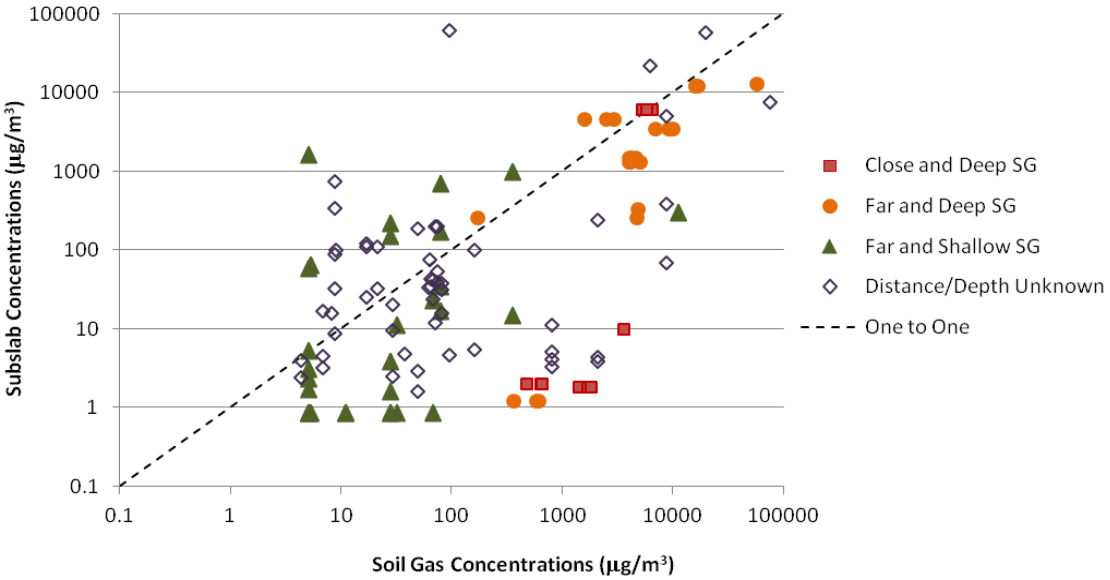


Figure A-5. Exterior soil gas versus sub-slab soil gas concentrations for buildings with both types of data in EPA's vapor intrusion database differentiated qualitatively by horizontal distance to building and depth to the exterior soil gas sample. SOURCE: Figure 6 in EPA (2012a).

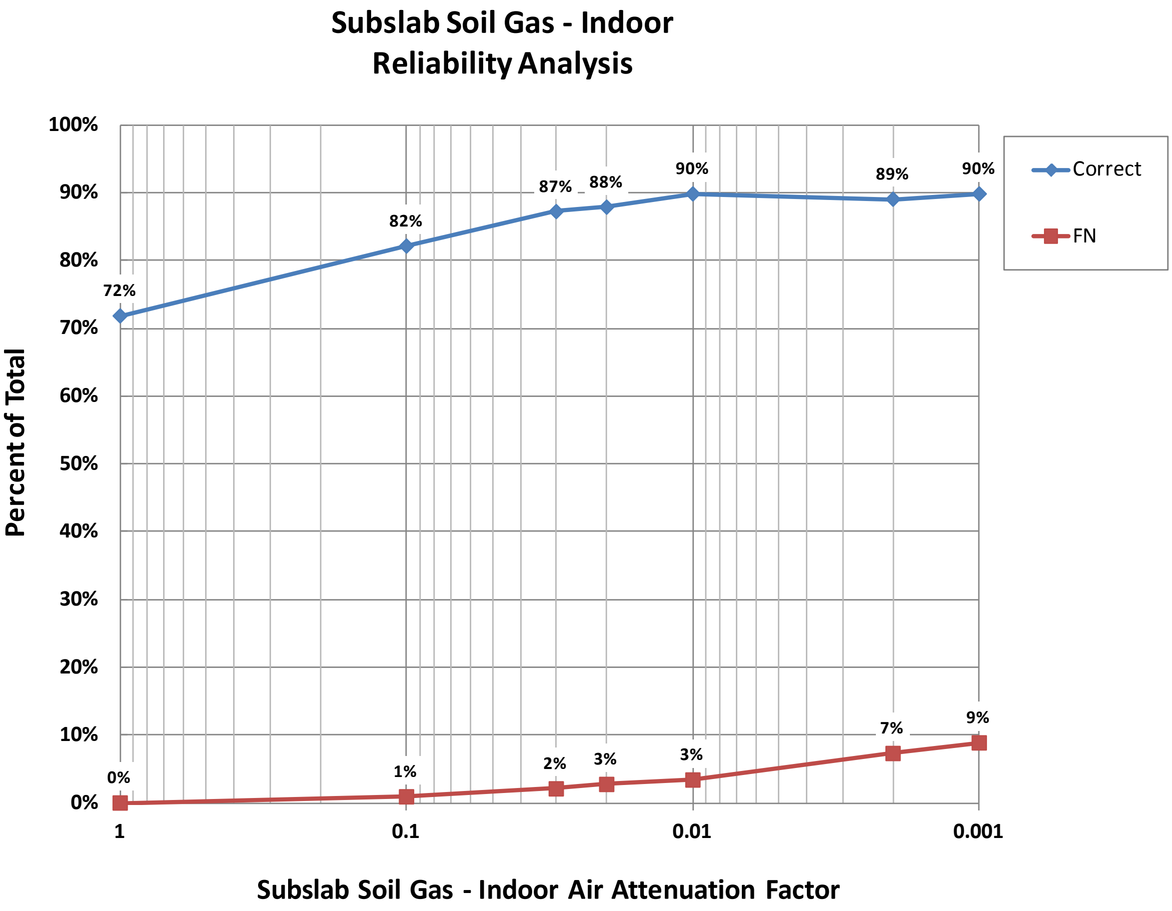


Figure A-6.Reliability Predictions for Alternative Choices of the Sub-slab Attenuation Factor Based on a Comparison of Paired Data in the Data Consistency Screen Dataset
[tabulated values shown below]

Reliability Analysis: Subslab Soil Gas - Indoor Air

Classification	SS AF = 1	SS AF = 0.1	SS AF = 0.03	SS AF = 0.02	SS AF = 0.01	SS AF = 0.002	SS AF = 0.001
Correct	**551**	**630**	**669**	**674**	**689**	**683**	**689**
FN	**0**	**7**	**16**	**21**	**26**	**56**	**68**
Total	767	767	767	767	767	767	767

SS AF	1	0.1	0.03	0.02	0.01	0.002	0.001
Correct	**72%**	**82%**	**87%**	**88%**	**90%**	**89%**	**90%**
FN	0%	1%	2%	3%	3%	7%	9%

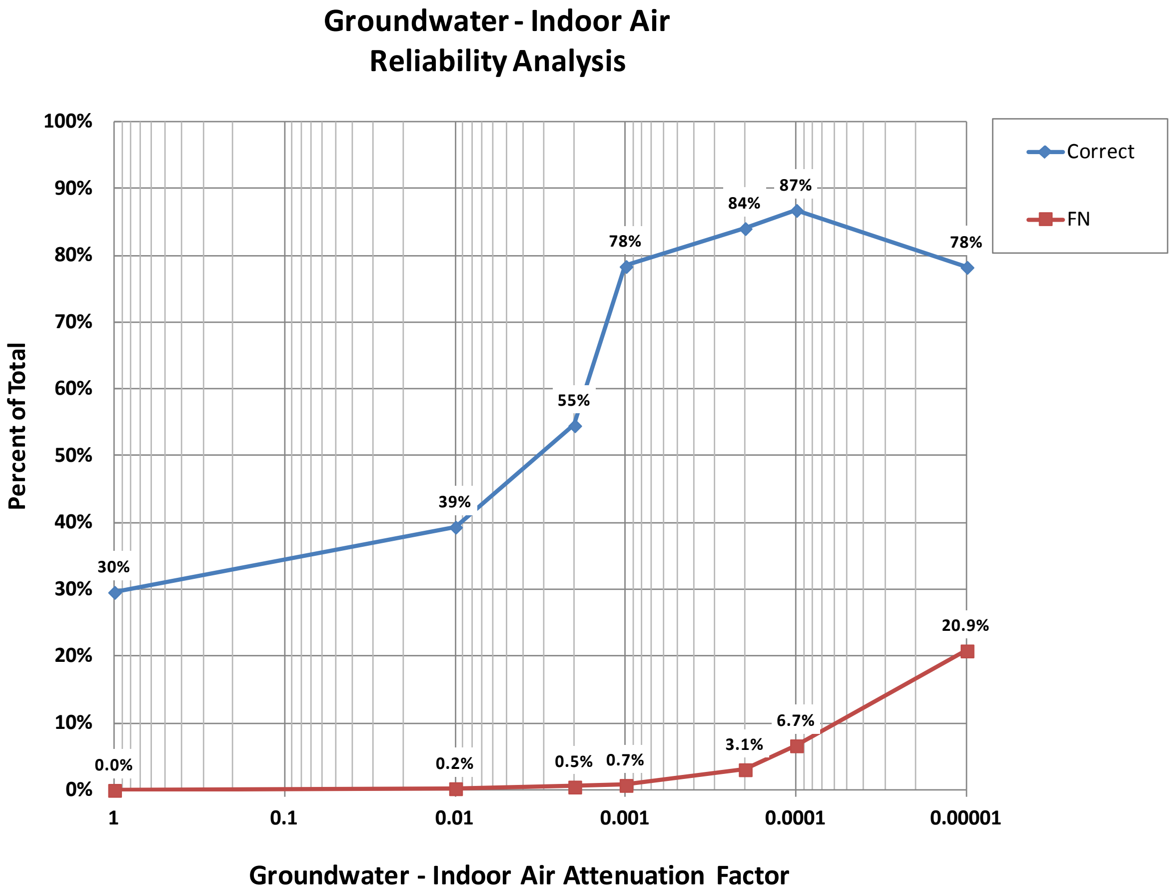


Figure A-7.Reliability Predictions for Alternative Choices of the Groundwater Attenuation Factor Based on a Comparison of Paired Data in the Data Consistency Screen Dataset [tabulated values shown below]

Reliability Analysis: Groundwater -Indoor Air

Classification	**GW AF = 1**	**GW AF = 0.01**	**GW AF = 0.002**	**GW AF = 0.001**	**GW AF = 0.0002**	**GW AF = 0.0001**	**GW AF = 0.00001**
Correct	**240**	**319**	**442**	**635**	**681**	**703**	**634**
FN	**0**	**2**	**4**	**6**	**25**	**54**	**169**
Total	810	810	810	810	810	810	810

GW AF	**1**	**0.01**	**0.002**	**0.001**	**0.0002**	**0.0001**	**0.00001**
Correct	**30%**	**39%**	**55%**	**78%**	**84%**	**87%**	**78%**
FN	**0.0%**	**0.2%**	**0.5%**	**0.7%**	**3.1%**	**6.7%**	**20.9%**

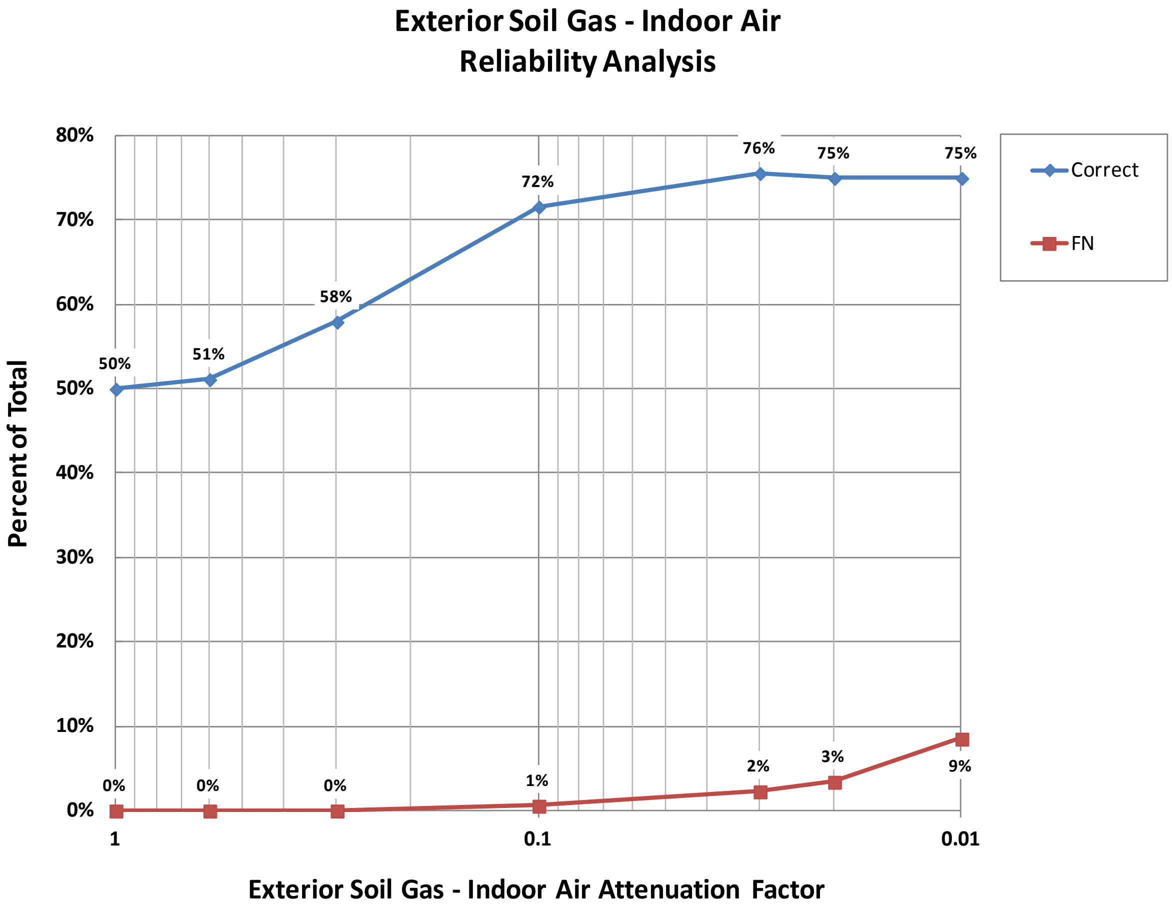


Figure A-8. **Reliability Predictions for Alternative Choices of the Exterior Soil Gas Attenuation Factor Based on a Comparison of Paired Data in the Data Consistency Screen Dataset** [tabulated values shown below]

Reliability Analysis: Exterior Soil Gas - Indoor Air

Classification	SG AF = 1	SG AF = 0.6	SG AF = 0.3	SG AF = 0.1	SG AF = 0.03	SG AF = 0.02	SG AF = 0.01
Correct	**88**	**90**	**102**	**126**	**133**	**132**	**132**
FN	**0**	**0**	**0**	**1**	**4**	**6**	**15**
Total	176	176	176	176	176	176	176

SG AF	1	0.6	0.3	0.1	0.03	0.02	0.01
Correct	**50%**	**51%**	**58%**	**72%**	**76%**	**75%**	**75%**
FN	**0%**	**0%**	**0%**	**1%**	**2%**	**3%**	**9%**

APPENDIX B
DATA QUALITY ASSURANCE CONSIDERATIONS

B.1 INTRODUCTION

Site-specific investigations of the vapor intrusion pathway will generally entail the collection and evaluation of environmental data and possibly the use of modeling. As noted in Exhibit B-1, EPA generally recommends the use of a quality assurance project plan (QAPP) for the collection of primary (and existing or secondary) data. A QAPP is a tool for project managers and planners to document the type and quality of data needed to make environmental decisions and to describe the methods for collecting and assessing the quality and integrity of those data. A QAPP is a plan or roadmap intended to help a project team document how they plan, implement, and evaluate a project. It applies the systematic planning process and the graded approach for collecting environmental data for a specific intended use. EPA standards governing the collection of data are outlined in Exhibit B-1.

Exhibit B-1. EPA Data Standards

CIO 2105 (formerly EPA Order 5360; *Policy and Program Requirements for the Agency-wide Quality System*, May 2000) is intended to promote the organization collecting or using the data to (1) establish a Quality System and prepare and approve a QAPP for each project.

For clarity, CIO 2105 will be replaced by the following two standards:

- CIO 2106-S-01 is the *Quality Standard for Environmental Data Collection, Production, and Use by EPA Organizations*, also called “Internal Standard” (EPA 2013a); and
- CIO 2106-S-02 is the *Quality Standard for Environmental Data Collection, Production, and Use by Non-EPA (External) Organizations*, also called “External Standard” (EPA 2013b).

These standards conform to *EPA Quality Policy*, CIO 2106.0, “Quality Policy” (EPA 2008a), *Procedure for Quality Policy,* CIO 2106-P-01.0, “Quality Procedure” (EPA 2008b), and the American National Standards Institute (ANSI) consensus standard, *Quality Systems for Environmental Data and Technology Programs – Requirements with Guidance for Use* (ANSI/ASQ 2004).

Two guidance documents accompany these standards:

- *EPA Guidance on Quality Management Plans* (EPA 2012b, CIO 2106-G02-QMP), documents the quality system of the organization conducting environmental data collection or using the data for EPA.
- *EPA Guidance on Quality Assurance Project Plans* (EPA 2012a, CIO 2106-G-05) focuses on projects requiring the collection of new data, projects using existing data, and projects involving modeling.

EPA also encourages the use of the *Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP)* (EPA/DoD 2005) as a collaborative approach to fulfill the purposes of a QAPP, especially for Federal Facilities. OSWER Directive 9272.0-17, *Implementation of the Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) at Federal Facility Hazardous Waste Sites* (EPA 2005a) and OSWER Directive 9272.0-20 (EPA 2005b) state that QAPPs prepared and approved under the UFP conform to EPA's quality standards and are consistent with EPA Standards CIO 2106-S-0 and CIO 2106-S-02, EPA's Quality Policy (EPA 2008a), and ANSI/ASQ 2004.

B.2 RECOMMENDATIONS

This appendix provides two recommendations concerning the key components of QAPP development. These recommendations are not exhaustive, but are included as a starting point as considerations before studying or applying EPA or UFP QAPP guidance.

Recommendation 1: Using the conceptual site model (CSM), develop the project plan and QAPP through a process that involves all key players and share these materials with interested parties in draft form so that potential study weaknesses can be addressed early. The CSM is developed to portray the current understanding of site conditions, the nature and extent of contamination, routes of contaminant transport, potential contaminant pathways, and potentially exposed human population. Developing the CSM is the first step in EPA's DQO process.

Recommendation 2: Use systematic planning in developing project documents, including the QAPP. Systematic planning is a science-based, common-sense approach designed to ensure that the level of documentation and rigor of effort in planning is commensurate with the intended use of the information and available resources. DQOs are a key component of systematic planning and play a central role in the systematic planning process. DQOs generally are addressed within the QAPP and typically are a critical element in the planning for environmental investigations. *Guidance on Systematic Planning Using the Data Quality Objectives Process (QA/G-4)* (EPA 2006) provides guidance addressing implementation of DQOs and application of systematic planning to generate performance and acceptance criteria for collecting environmental data.

Table B-1 summarizes the steps in the DQO process, the purpose of each step, and provides some examples of how plans could be structured.

TABLE B-1. EXAMPLE OF STEPS IN THE DQO PROCESS

DQO Step	**Purpose of the DQO Step**	**Example Application for Vapor Intrusion**
1. State the Problem	Summarize the problem (e.g., the monitoring hypothesis, the investigation objective(s)) for which new environmental data will be collected or modeling or analysis will be performed.	Indoor air in one or more buildings overlying a shallow plume of PCE-contaminated groundwater is (are) to be sampled to determine whether PCE is present. The original PCE release occurred at an industrial site approximately 1,000 feet away from the closest building.
2. Identify the Decision	Identify the decision that will be supported by the new data, modeling or analysis.	The data will be used to support decisions about whether additional indoor air sampling or preemptive vapor intrusion mitigation will be pursued in one or more buildings.
3. Identify the Inputs to the Decision	Identify the information needed to support the decision, including data gaps that warrant collection of new information.	Indoor air sampling data for one or more buildings, in conjunction with information about measured or interpolated concentrations in groundwater near or underneath the building(s).
4. Define the Boundaries of the Study	Specify the spatial and temporal aspects of the environmental media or endpoints that the data are to represent to support the decision.	The boundaries of this initial study area extend a prescribed distance outside the lateral extent of the plume. Eventually, the boundaries of a vapor intrusion impact zone will be defined by the extent to which indoor air contamination can be associated with site-related contamination.
5. Develop a Decision Rule	Develop a logical “if…then” statement that defines the conditions that will inform the decision-maker to choose among alternative decisions.	Buildings with detectable concentrations of PCE in indoor air samples will be considered for additional indoor air sampling or preemptive vapor intrusion mitigation.
6. Specify Tolerable Limits on Decision Errors	Specify acceptable limits on decision errors, which are used to establish performance goals for limiting uncertainty in the analysis.	EPA recommends analytical limits of detection be less than risk-based screening levels for PCE to ensure that a building’s indoor air concentration is not misidentified.
7. Optimize the Design for Obtaining Data	Identify the most resource-effective sampling and analysis design for generating the information needed to satisfy the DQOs.	Time-integrated samples will be collected in basements and in the first above-ground level of each building. The sampling and analysis plan and approach will be documented in a QAPP.

B.3 CITATIONS AND REFERENCES (APPENDIX B)

ANSI/ASQ. 2004. *Quality Systems for Environmental Data and Technology Programs – Requirements with Guidance for Use.* E4-2004. Currently available for purchase online at http://webstore.ansi.org/FindStandards.aspx?SearchString=ansi+e4&SearchOption=0&PageNum=0&SearchTermsArray=null|ansi+e4|null

U.S. Environmental Protection Agency (EPA). 2000. *Policy and Program Requirements for the Agency-wide Quality System*. CIO 2105. May. Currently available online at http://www.epa.gov/irmpoli8/policies/21050.pdf

U.S. Environmental Protection Agency (EPA). 2005a. *Implementation of the Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) at Federal Facility Hazardous Waste Sites.* OSWER Directive 9272.0-17. June 7. Currently available online at http://www.epa.gov/fedfac/pdf/oswer_qapp_directive.pdf

U.S. Environmental Protection Agency (EPA). 2005b. *Applicability of the Uniform Federal Policy for Quality Assurance project Plans.* EPA-505-04-900A, OSWER Directive 9272.0-20. December 5. Currently available online at http://www.epa.gov/fedfac/pdf/oswer_9272.0_20.pdf

U.S. Environmental Protection Agency (EPA). 2006. *Guidance on Systematic Planning Using the Data Quality Objectives Process (QA/G-4)*. EPA-240-B-06-001. February. Currently available online at http://www.epa.gov/quality/qs-docs/g4-final.pdf

U.S. Environmental Protection Agency (EPA). 2008a. *U.S. Environmental Protection Agency Quality Policy.* CIO 2106.0. Currently available online at http://www.epa.gov/irmpoli8/policies/21060.pdf

U.S. Environmental Protection Agency (EPA). 2008b. *U.S. Environmental Protection Agency Procedure for Quality Policy*. CIO 2106-P-01.0. Currently available online at http://www.epa.gov/irmpoli8/policies/21060.pdf

U.S. Environmental Protection Agency (EPA). 2012a. *U.S. Environmental Protection Agency Guidance on Quality Assurance Project Plans.* CIO 2106-G-05 QAPP. January 17.

U.S. Environmental Protection Agency (EPA), 2012b. *EPA Draft Final Guidance on Quality Management Plans.* CIO 2106-G02-QMP. January 17. Currently available online at http://www.epa.gov/oeitribalcoordination/2106-G-05%20QAPP%20Final%20Draft%2001-17-12.pdf

U.S. Environmental Protection Agency (EPA). 2013a. *Quality Standard for Environmental Data Collection, Production, and Use by EPA Organizations.* CIO 2106-S-01.

U.S. Environmental Protection Agency (EPA). 2013b. *Draft Final Quality Standard for Environmental Data Collection, Production, and Use by Non-EPA (External) Organizations.* "External Standard." CIO 2106-S-02. February 22. Currently available online at http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OEI-2012-0774-0002

U.S. Environmental Protection Agency and U.S. Department of Defense (EPA/DoD). 2005. *Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP). Part 1: UFP-QAPP Manual.* EPA-505-B-04-900A, DTIC ADA 427785. March. Currently available online at http://www2.epa.gov/fedfac/uniform-federal-policy-quality-assurance-project-plans-evaluating-assessing-and-documenting

APPENDIX C
CALCULATING VAPOR SOURCE CONCENTRATION FROM GROUNDWATER SAMPLING DATA

Correcting the Henry's Law Constant for Groundwater Temperature

In the case of groundwater as the vapor source, the subsurface source concentration (C_{sv}) is estimated assuming that the vapor and aqueous phases are in local equilibrium according to Henry's law such that:

$$C_{sv} = H'_{TS} \times C_w \qquad \text{Equation C.1}$$

where:

C_{sv} = vapor concentration at the source of contamination (g/cm^3-v),

H'_{TS} = Henry's law constant at the system (groundwater) temperature (dimensionless), and

C_w = concentration of volatile chemical in groundwater (g/cm^3-w).

The Henry's law constants generally are reported for a temperature of 25 degrees Celsius (^{o}C). **Table C-1** provides these values for the chlorinated hydrocarbons (CHCs) in the vapor intrusion database. Average groundwater temperatures, however, are typically less than 25^{o}C. In such cases, use of the Henry's law constant at 25^{o}C may over-predict the volatility of the contaminant in water.

As described in EPA's *Soil Screening Guidance* (EPA 1996), the dimensionless form of the Henry's law constant at the average groundwater temperature (H'_{gw}) may be estimated using the Clapeyron equation:

$$H'_{gw} = \frac{\exp\left[-\frac{\Delta H_{v,gw}}{R_c} \times \left(\frac{1}{T_{gw}} - \frac{1}{T_R}\right)\right] H_R}{R \times T_{gw}} \qquad \text{Equation C.2}$$

where:

$\Delta H_{v,gw}$ = enthalpy of vaporization of the specific chemical at the groundwater temperature (cal/mol),

T_{gw} = groundwater temperature (°K = ^{o}C + 273.15),

T_R = reference temperature for the Henry's law constant (298.15^{o}K),

R_C = gas constant (= 1.9872 cal/mol-^{o}K),

H_R = Henry's law constant for the specific substance at the reference temperature (atm-m^3/mol), and

R = gas constant (= 8.205 E-05 atm-m^3/mol-^{o}K).

The enthalpy of vaporization at the groundwater temperature can be approximated from the enthalpy of vaporization at the normal boiling point, as follows:

$$\Delta H_{v,gw} = \Delta H_{v,b}\left[\frac{\left(1 - T_{gw}/T_C\right)}{\left(1 - T_B/T_C\right)}\right]^{\eta} \qquad \text{Equation C.3}$$

where:

$\Delta H_{v,gw}$ = enthalpy of vaporization at the groundwater temperature (cal/mol),

$\Delta H_{v,b}$ = enthalpy of vaporization at the normal boiling point (cal/mol),

T_C = critical temperature for specific chemical (^oK),

T_B = normal boiling point for specific chemical (^oK),

η = exponent (unitless), and

all other symbols are as defined previously. **Table C-1** provides the chemical-specific property values used for temperature corrections to the Henry's law constant. **Table C-2** provides the value of η as a function of the ratio T_B/T_C. If site-specific data are not readily available for the groundwater temperature, then Figure 1 of the EPA fact sheet, *Correcting the Henry's Law Constant for Soil Temperature* (EPA 2001) can be used to generate an estimate.

Citations (Appendix C)

U.S. Environmental Protection Agency (EPA). 1996. *Soil Screening Guidance: Technical Background Document*. Office of Solid Waste and Emergency Response, Washington, D.C. EPA-540-R-95-128. Currently available online at: http://www.epa.gov/superfund/health/conmedia/soil/introtbd.htm

U.S. Environmental Protection Agency (EPA). 2001. *Fact Sheet, Correcting the Henry's Law Constant for Soil Temperature.* Office of Solid Waste and Emergency Response, Washington, D.C. Currently available online at http://www.epa.gov/oswer/riskassessment/airmodel/pdf/factsheet.pdf

U.S. Environmental Protection Agency (EPA). Regions 3, 6, and 9. 2011. *Regional Screening Levels for Chemical Contaminants at Superfund Sites*. Region 3, Philadelphia, PA. November. Currently available online at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm

Lide, D.R. (Ed.). 1998. *CRC Handbook of Chemistry and Physics, 79th Ed*. Boca Raton, FL. CRC Press.

Mallard, W.G. and P.J. Linstrom (Eds.). 1998. *NIST Chemistry WebBook: NIST Standard Reference Database Number 69.* Gaithersburg, MD. National Institute of Standards and Technology. November. Currently available online at http://webbook.nist.gov/chemistry/

Table C-1. Chemical-Specific Parameters for Adjusting Henry's Law Coefficients for Groundwater Temperature

Chemical Abstracts Service Registry Number (CASRN)	Alphabetized List of Compounds	Henry's Law Constant @25°C		Henry's Law Constant @25°C[g]	Normal Boiling Point		Critical Temperature		Enthalpy of vaporization at the normal boiling point	
		H_R		H'_R	T_b		T_c		$\Delta H_{v,b}$	
		(atm-m^3/mol)	source	(unitless)	(^oK)	source	(^oK)	source	(cal/mol)	source
56-23-5	Carbon tetrachloride	2.76E-02	a	1.13E+00	3.50E+02	b	5.57E+02	h	7.13E+03	h
75-00-3	Chloroethane (ethyl chloride)	1.11E-02	a	4.54E-01	2.85E+02	b	4.60E+02	f	5.88E+03	f
67-66-3	Chloroform	3.67E-03	a	1.50E-01	3.34E+02	b	5.36E+02	h	6.99E+03	h
75-34-3	Dichloroethane,1,1-	5.62E-03	a	2.30E-01	3.30E+02	b	5.23E+02	h	6.90E+03	h
75-35-4	Dichloroethene, 1,1-	2.61E-02	a	1.07E+00	3.05E+02	b	5.76E+02	h	6.25E+03	h
156-59-2	Dichloroethene,cis-1,2-	4.08E-03	a	1.67E-01	3.28E+02	b	5.44E+02	h	7.19E+03	h
156-60-5	Dichloroethene,trans-1,2-	4.08E-03	a	1.67E-01	3.28E+02	b	5.17E+02	h	6.72E+03	h
75-09-2	Methylene chloride	3.25E-03	a	1.33E-01	3.13E+02	b	5.10E+02	h	6.71E+03	h
127-18-4	Tetrachloroethylene	1.77E-02	a	7.23E-01	3.94E+02	b	6.20E+02	h	8.29E+03	h
76-13-1	Trichloro-1,2,2-trifluoroethane,1,1,2-	5.26E-01	a	2.15E+01	3.21E+02	b	4.87E+02	f	6.46E+03	f
71-55-6	Trichloroethane, 1,1,1-	1.72E-02	a	7.03E-01	3.47E+02	b	5.45E+02	h	7.14E+03	h
79-01-6	Trichloroethylene	9.85E-03	a	4.03E-01	3.60E+02	b	5.44E+02	h	7.51E+03	h
75-01-4	Vinyl chloride (chloroethylene)	2.78E-02	a	1.14E+00	2.60E+02	b	4.32E+02	h	5.25E+03	h

Sources and Footnotes:

a Based on values reported in the U.S. EPA Regional Screening Tables. November 2011. Available online at: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/xls/params_sl_table_run_NOV2011.xls

b Experimental values. EPA 2009. *Estimation Programs Interface Suite™ for Microsoft® Windows, v 4.00*. U.S EPA, Washington, DC, USA. Available online at: http://www.epa.gov/opptintr/exposure/pubs/episuite.htm

f *CRC Handbook of Chemistry and Physics, 76th Edition*

h EPA (2001). FACT SHEET *Correcting the Henry's Law Constant for Soil Temperature*. Attachment.

g National Institute of Standards and Technology (NIST). *Chemistry WebBook*. Available online at http://webbook.nist.gov/chemistry/

Table C-2. Values of Exponent η as a Function of T_B/T_C

Chemical-specific ratio T_B/T_C	H
< 0.57	0.30
0.57 - 0.71	0.74 (T_B/T_C) - 0.116
> 0.71	0.41

Dennis M. McQuillan

Chief Scientist
New Mexico Environment Department
1190 St. Francis Drive
P.O. Box 5469
Santa Fe, NM 87502
505-827-2140
dennis.mcquillan@state.nm.us

EDUCATION

University of New Mexico: Bachelor of Science; Geology, 1978; distributed minor in chemistry, mathematics and physics

Short Courses and Certifications: OSHA 1910.120 Hazardous Waste Operations and Emergency Response (HAZWOPER); Incident Command System; Health Homes Specialist Credential (National Environmental Health Association), Red Cross first aid and CPR/AED; geochemistry; management and supervision

WORK EXPERIENCE

New Mexico Environment Department: March 1979 to June 2005 and October 2005 to present; Environmental Scientist, Water Resource Specialist, Geologist, Health Program Manager, Natural Science Manager, Chief Scientist

Consultant, Educator and Freelance Writer: 1987 to 2005; Sites in Arizona, Colorado, New Mexico, Ireland, Nova Scotia, Scotland and Wales

DUTIES AND ACCOMPLISHMENTS

Surveillance, Investigation, Incident Response: regional environmental surveillance and mapping; 200+ site investigations; spill response; emergency response actions for hazardous materials releases, wildfires and drinking-water outages.

Negotiation, Design and Oversight of Corrective Actions: public sewer and/or safe drinking water service provided to rural communities with contaminated domestic wells; source control/removal actions; free-product recovery systems; aquifer pump-and-treat systems; sparge-and-vent systems; in-situ bioremediation systems, drinking-water treatment systems on contaminated public supply wells.

Research: ground-water quality and public health; laboratory and in-situ biodenitrification; natural attenuation of nitrate, gasoline, chlorinated solvents and high explosives; natural and anthropogenic sources of perchlorate; pharmaceutical residues in ground and surface water; stable isotope geochemistry of ground-water pollution; natural uranium in the Espanola Basin; effect of septic-tank lot size on ground-water nitrate.

NMED EXHIBIT 4

Program Development: creation of the “Water Fair” free well-testing program; promulgation and revision of numerical and narrative water-quality standards; development of comprehensive regulations to abate water pollution; design and implementation of databases and Geographic Information System; development of regulations to allow beneficial reuse of domestic gray water; development of a program to eliminate substandard onsite wastewater systems owned by indigent households.

Management and Supervision: hiring, training, supervision and mentoring of staff; preparation of job hazard analyses; development and implementation of hazard communication and safety plans; management of program budgets; acquisition and management of state and federal grants and appropriations; job hazard analysis; program audits to identify and correct inconsistencies.

Stakeholder Outreach and Involvement: negotiated rulemaking committees; training and technical assistance to the regulated community and general public; guest lectures and seminars at state universities; public presentations; conference papers; news media interviews; cooperation and partnerships with universities, activist groups, federal, tribal, county and municipal agencies.

Expert Testimony: U.S. Congress; N.M. State Legislature; N.M. District Courts; Federal District Court; N.M. Environmental Improvement Board; N.M. Water Quality Control Commission; judicially qualified as an expert in state and federal district courts.

EQUIPMENT USED

Vapor Testing Instruments: flame ionization detectors; photo-ionization detectors; combustible gas and O_2 meters.

Radiation Detection Instruments: Hand-held alpha, beta, gamma and x-ray monitor; gamma scintillometer.

Water Testing Instruments: pH meters; conductivity/temperature/salinity/dissolved oxygen meters; ion-specific electrodes; colorimeters; spectrophotometers.

Other Equipment: water level/free petroleum product sounders; continuous water-level recorders; pressure transducers; portable well pumps; electromagnetic induction (terrain conductivity) meter; hollow-stem auger; portable X-ray fluorescence spectrophotometer.

RECENT PUBLICATION EXAMPLES

McQuillan, D., Shuey, C. and P. Robinson. 2017. Let’s Not Wait for Catastrophic Spills to Happen: Holistic, Long-Term, Multi-Jurisdictional Monitoring in Legacy Mining Areas. Proceedings, New Mexico Water Resources Research Institute, 2nd Annual Conference on Environmental Conditions of the Animas and San Juan Watersheds, With Emphasis on Gold King Mine and Other Mine Waste Issues, Farmington, NM, June 22-20, 2017, https://animas.nmwrri.nmsu.edu/2017/presentations/oral-presentations/ (Abstract 20)

Agnew, D., Plank, C., Gillespie, J., Bodour, A. and D. McQuillan. 2016. Influence of Depositional Environment on Dissolved-Phase Plume Migration at the Kirtland Air Force Base Bulk Fuels Facility Leak Site. New Mexico Geological Society Annual Spring Meeting April 8, 2016, Macey Center, New Mexico Tech campus, Socorro, NM, pp. 7. http://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=428

Flynn, R., Kliphuis, T., McQuillan, D. and A. Majure. 2016. New Mexico's Response to the Gold King Mine-Water Spill. Proceedings, New Mexico Water Resources Research Institute, Environmental Conditions of the Animas and San Juan Watersheds, With Emphasis on Gold King Mine and Other Mine Waste Issues, Farmington, NM, May 17-18, 2016, https://animas.nmwrri.nmsu.edu/2016/abstracts/oral-presentations/ (Abstract 5)

Linhoff, B., Longmire, P., Rearick, M., McQuillan, D. and G. Perkins. 2016. Water Quality and Hydrogeochemistry of a Basin and Range Watershed in a Semi-Arid Region of Northern New Mexico. Environmental Earth Sciences: 75:640, http://link.springer.com/article/10.1007/s12665-015-5179-8

McQuillan, D., M. Holmes, B. Surgeon, J. Esparsen, R.Romero and J. Longworth. 2013. Sustainable Drinking Water Sources. Proceedings, New Mexico Water Resources Research Institute, 58th Annual New Mexico Water Conference, Albuquerque, New Mexico, November 21-22, 2013, https://nmwrri.nmsu.edu/water-conference-proceedings/2149-2/ (Poster Abstract 31)

McQuillan, D. and J. Vincent. 2012. Vulnerability Factors for Groundwater Contamination from Onsite Wastewater Systems. New Mexico Bureau of Geology, Open-file Report – 547, 11th Annual Espanola Basin Workshop: Espanola Basin Watersheds: Natural and anthropogenic Impacts on surface and ground water resources, p. 11. http://geoinfo.nmt.edu/publications/openfile/details.cfml?Volume=547

McQuillan, D., B. Toth, S. Wiman, P. Longmire, D. Vaniman, M. Rearick, V. McLemore and A. Simmons. 2012. Public Health Concerns of Uranium in Groundwater in New Mexico. Geological Society of America, Rocky Mountain Section - 64th Annual Meeting (9–11 May 2012), https://gsa.confex.com/gsa/2012RM/finalprogram/abstract_203276.htm

McLemore, V.T., D. Vaniman, D. McQuillan, and P. Longmire. 2011. Uranium Deposits in the Espanola Basin, Santa Fe County, New Mexico, New Mexico Geological Society, Fall Field Conference Guidebook – 62, Geology of the Tusas Mountains and Ojo Caliente, pp. 399-408. http://nmgs.nmt.edu/publications/guidebooks/62/; http://nmgs.nmt.edu/publications/guidebooks/downloads/62/62_p0399_p0408.pdf

McQuillan, D. and E. Bassett. 2009. Return Flow to Ground Water From Onsite Wastewater Systems. Proceedings, National Onsite Wastewater Recycling Association, 18th Annual Technical Conference and Expo, April 6-9, 2009, Milwaukee, WI, http://www.nmenv.state.nm.us/fod/LiquidWaste/documents/McQuillanandBassettNOWRA09.pdf

STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

In the Matter of:

PROPOSED AMENDMENTS TO
GROUND AND SURFACE WATER
***PROTECTION* REGULATIONS,**
20.6.2 NMAC

No. WQCC 17-03 (R)

WRITTEN DIRECT TESTIMONY OF DENNIS MCQUILLAN

My name is Dennis McQuillan, and I am the Chief Scientist of the New Mexico Environment Department ("Department" or "NMED"). I am presenting this written testimony on behalf of the Environment Department in this proceeding on proposed revisions to the Water Quality Control Commission's Ground and Surface Water Protection Regulations at 20.6.2 NMAC ("Regulations" or "Part 20.6.2"). My testimony will explain the intent, substance and justification for proposed amendments to the exemptions from discharge permit requirements, "Toxic Pollutant" narrative standard, amendments to numerical groundwater standards, and proposed addition of a narrative abatement standard for subsurface water.

I. QUALIFICATIONS

I hold a Bachelor's degree in Geology from the University of New Mexico, with a minor distributed in Chemistry, Mathematics, and Physics, and have more than 38 years of professional experience working in the environmental sciences. I have served in a variety of positions within NMED, and am currently employed as the NMED Chief Scientist, a position I have held since August, 2015. I have extensive experience in the prevention, investigation, and abatement of soil and groundwater pollution. I was a principle technical witness during New Mexico Water Quality Control Commission (WQCC) hearings in 1981, 1985, 1994, and 2003-04 that led to the adoption of the WQCC narrative standard of "Toxic Pollutant," numerical groundwater standards for organic contaminants, regulations for the prevention and abatement of water pollution, and amendment of the groundwater uranium standard. I was a principle technical witness during the 1990 New Mexico Environmental Improvement Board (EIB) hearing that led to the adoption of the EIB groundwater standard for methyl tertiary-butyl ether (MTBE). I have also delivered technical testimony before the United States Congress, the New Mexico Legislature, the EIB, and in State and Federal District Court. I have been judicially qualified as an expert in my field in both state and federal district court. For most of my career, I have maintained an inventory of fatalities and injuries among NMED staff and other environmental professionals working in New Mexico, including injuries caused by soil and groundwater pollution. Additionally, I have worked as a consultant, educator and freelance writer. A copy of my resume is attached as NMED Exhibit 4.

II. IMPORTANCE OF GROUNDWATER TO NEW MEXICO

Protecting groundwater is of tremendous importance to public health and welfare in New Mexico. Groundwater resources in New Mexico are utilized by public water systems, farmers, ranchers, industries, and individual homeowners for municipal, agricultural, industrial and domestic supply. Approximately 95% of New Mexico residents rely on groundwater for all or part of their drinking water supply[1].

The harmful consequences of groundwater pollution have long been known within the State of New Mexico (NMED Exhibit 6). The awareness, understanding and response to groundwater pollution has improved significantly since 1937 when the state published the first regulations to prevent pollution of water wells. The State of New Mexico continues a long history of pioneering leadership to protect the quality of its valuable groundwater resources.

---

[1] *See* EPA-Approved 2016-2018 CWA §§ 303(d)/ 305(b) Integrated Report, p. 73. Available at https://www.env.nm.gov/swqb/303d-305b/2016-2018/documents/EPA-APPROVED2016-2018IR092316.pdf.

The potential sources of the water contaminants addressed by NMED's proposed amendments are regulated by NMED and other constituent agencies of the WQCC, and include mines, mills, petroleum exploration, production, refinement facilities, petroleum product distribution and storage facilities and retail outlets, dairies, wastewater treatment plants, and a wide variety of other industrial facilities. As the WQCC is well aware, these facilities provide jobs, tax revenue, and important infrastructure, products and services for the benefit of the citizens of New Mexico.

Many of the groundwater pollution cases in New Mexico were caused by legacy discharges that are no longer allowed by current state and federal regulatory programs, or by accidental leaks and spills. One of the long-held tenets of the WQCC, and of constituent agencies that administer WQCC standards and regulations, is that prevention of groundwater pollution is far more technically achievable and cost effective than abatement of groundwater pollution and treatment of polluted water sources.

WQCC groundwater regulations and the federal Safe Drinking Water Act program share the common goals of protecting groundwater as sources of public water supply, and ensuring that these public water sources do not contain levels of contamination that are hazardous to human health. WQCC groundwater regulations are a critical component of how NMED helps public water systems develop and administer Wellhead Protection and Source Water Protection Plans, as provided for by the federal Safe Drinking Water Act. WQCC groundwater standards also play a critical role in assuring that public water systems deliver drinking water to their customers that complies with the national primary drinking water standards set by the United States Environmental Protection Agency ("EPA").

Groundwater contaminants, such as nitrogen, can discharge into New Mexico surface waters and can contribute to stream impairments that are addressed by Total Maximum Daily Loads (TMDLs) developed pursuant to the federal Clean Water Act.

Other federal programs such as the Resource Conservation and Recovery Act, administered by the NMED Hazardous Waste Bureau, make reference to WQCC groundwater standards as permit requirements and corrective action requirements.

III. PROPOSED AMENDMENTS TO NARRATIVE AND NUMERICAL GROUNDWATER STANDARDS, 20.6.2.3103 NMAC

A. Introduction and Summary

Since there is no comprehensive EPA program to prevent and abate groundwater pollution, states have had to develop groundwater protection programs on their own, with New Mexico being the first to do so. Protecting groundwater as a potential source of drinking water is a common goal of state programs, and EPA's Drinking Water Standards have often been adopted as state groundwater standards.

EPA's Drinking Water standards, however, do not include all of the chemical constituents that have been detected in groundwater in the United States. New Mexico and several other states, therefore, have adopted groundwater standards for parameters that are not included in EPA's Drinking Water Standards. NMED Exhibit 7 compares existing and proposed WQCC groundwater standards, both narrative and numerical, with NMED tap water screening levels, EPA Maximum Contaminant Levels ("MCLs"), and EPA drinking water health advisories with groundwater quality standards and criteria that have been adopted by the States of New Jersey, Wisconsin and Washington. It is noteworthy that the list of more than 400 constituents in NMED Exhibit 7 does not include all of the chemical contaminants that have been detected in groundwater in New Mexico and/or in the United States. Examples of these unregulated groundwater contaminants include pesticide degradates and pharmaceutical residues.

NMED selected chemical contaminants for addition to WQCC narrative and numerical groundwater standards on the basis of either being known pollutants of groundwater in New Mexico, or posing a credible threat of polluting groundwater in New Mexico at concentrations of concern to human health. An updated summary of pesticide detections in New Mexico groundwater (NMED Exhibit 8) was prepared to assist in the identification of constituents that pose threats to New Mexico groundwater.

NMED proposes to add 13 chemical constituents to the Toxic Pollutant narrative standard at 20.6.2.3103.A(2) NMAC:

- styrene (ethenylbenzene)
- 1,2-dichlorobenzene (ortho-dichlorobenzene)
- 1,4-dichlorobenzene (para-dichlorobenzene)
- 1,2,4-trichlorobenzene
- pentachlorophenol (PCP)
- 1,2-dichloropropane (propylene dichloride, PDC)
- 1,4-dioxane (1,4-D)
- sulfolane (thiolane 1,1-dioxide)
- perfluorinated chemicals (PFCs)
    - perfluorohexane sulfonic acid (PFHxS)
    - perfluorooctane sulfonate (PFOS)
    - perfluorooctanoic acid (PFOA)
- pesticides

    - atrazine
    - prometon

NMED proposes to add numerical groundwater health standards for 13 constituents:

- antimony
- atrazine
- beryllium
- 1,2-dichlorobenzene (1,2-DCB)
- 1,4-dichlorobenzene (1,4-DCB)
- cis-1,2,-dichloroethene (cis-1,2-DCE)
- trans-1,2-dichloroethene (trans-1,2-DCE)
- 1,2-dichloropropane (propylene dichloride, PDC)
- Nitrite
- pentachlorophenol (PCP)
- styrene
- thallium
- 1,2,4-trichlorobenzene (1,2,4-TCB)

NMED also proposes to add the numerical groundwater standard of 0.1 mg/L for methyl tertiary-butyl ether (“MTBE”) that has been set by the EIB (Petroleum Storage Tank Regulations, 20.5.12.42.A.2 NMAC), to the aesthetic groundwater standards of 20.6.2.3103.B NMAC.

The WQCC adopted numerical groundwater standards for toxic organic contaminants years before EPA set drinking water standards for the same constituents. Since some WQCC standards now differ from those of EPA, NMED proposes to adjust most standards to be equal to drinking water standards. Some WQCC standards will decrease in concentration, and others will increase. NMED is proposing to not adjust several existing WQCC standards to be equal to those of EPA at this time for reasons that are explained below.

With regard to numerical groundwater standards for inorganic constituents, NMED proposes language to give the NMED cabinet secretary the discretion to require dischargers and responsible persons to address, on a site-specific basis, the possibility that facilitated transport may be occurring and that filtration of groundwater samples through a 0.45 µm membrane may remove contaminants that have the potential to migrate in groundwater.

B. Background Information on Chemical Constituents in Proposed for Inclusion in Narrative and Numerical Standards

Inorganic Constituents

Antimony (Sb, stibium) minerals occur in New Mexico sometimes associated with deposits of copper, lead, silver and zinc[2]. Antimony can occur in discharges associated with mining and milling operations for these metals, as well as molybdenum, in sulfide ore bodies. Small amounts of antimony were mined in Grant and Hidalgo Counties. Antimony has been detected in mining and milling waste in New Mexico and has been detected in groundwater at concentrations up to 0.174 mg/L. In addition to mining and milling operations, antimony can be associated with discharges from petroleum refineries, fire retardants, ceramics, electronics, and solder. EPA has set a drinking water MCL for antimony at 0.006 mg/L. NMED proposes to add EPA's MCL for antimony to the groundwater human health standards of 20.6.2.3103.A NMAC.

Beryllium (Be) is a strategic element that is becoming more important in our increasingly technological society. In New Mexico, about 1.7 million pounds of the beryllium mineral beryl

---

[2] Mineral and Water Resources of New Mexico, 1965, NM Bureau of Mines and Mineral Resources Bulletin 87, http://geoinfo.nmt.edu/publications/monographs/bulletins/87/.

have been mined from pegmatites in Taos, Rio Arriba, Mora, San Miguel, and Grant Counties from 1950-1963, although there is currently no production in the state[3]. Beryllium has been detected in mining and milling waste in New Mexico, and has been detected in groundwater at concentrations up to 0.28 mg/L. In addition to mining and milling operations, beryllium can be associated with discharges from coal-burning facilities, and electrical, aerospace, and defense industries. EPA has set a drinking water MCL for beryllium at 0.004 mg/L. NMED proposes to add EPA's MCL for beryllium to the groundwater human health standards of 20.6.2.3103.A NMAC.

Nitrite can occur in discharges that contain nitrate and other nitrogenous compounds, particularly in human and animal waste, fertilizers and explosives. Nitrate and nitrate can occur in groundwater together and the relative amounts of each constituent will be governed by oxidation and reduction (redox) conditions. Nitrite has been detected in groundwater at numerous locations in New Mexico. EPA has set a drinking water MCL for nitrite at 1 mg/L. NMED proposes to add EPA's MCL for nitrite to the groundwater human health standards of 20.6.2.3103.A NMAC.

Thallium (Tl) can occur in discharges associated with mining and milling operations, and electronics manufacturing. Thallium has been detected in mining and milling waste in New Mexico and has been detected in groundwater at concentrations up to 0.003 mg/L. EPA has set a drinking water MCL for thallium at 0.002 mg/L. NMED proposes to add EPA's MCL for thallium to the groundwater human health standards of 20.6.2.3103.A NMAC.

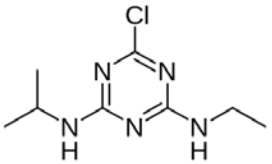
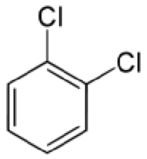
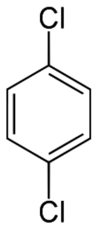
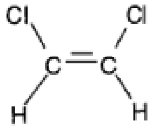
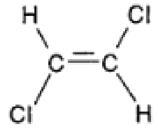
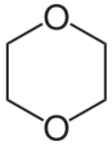
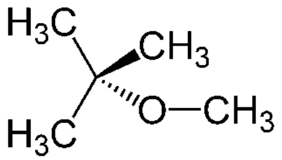
Organic Constituents

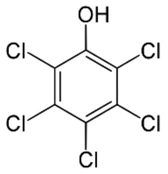
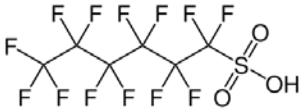
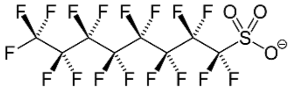
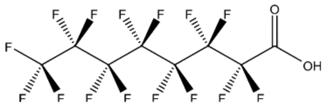
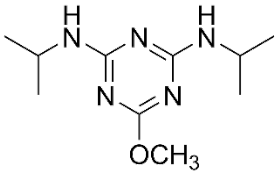
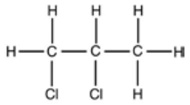
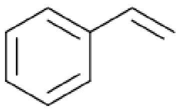
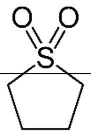
---

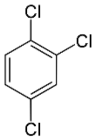
[3] McLemore, V.T., 2010, Beryllium Resources in New Mexico and Adjacent Areas: NM Bureau of Geology Open File Report OF-533, http://geoinfo.nmt.edu/publications/openfile/details.cfml?Volume=533 .

Physical and chemical information on the organic constituents proposed for inclusion in WQCC narrative and numerical groundwater standards is contained in Table 1. These physical and chemical parameters can be useful for investigations and modelling of the subsurface transport fate of organic contaminants. Laboratory test method(s) and nominal detection limit(s) are also provided.

Table 1. Physical and Chemical Background Information on Organic Constituents Proposed for Inclusion in WQCC Narrative and Numerical Standards.

Constituent	Formula	Molecular Weight (g/mol)	Water Solubility (mg/L)	Henry's Law Constant @ 25ºC (atm-m^3/mol)	Test Method(s) for Water Detection Limit(s)	Structure
Atrazine	$C_8H_{14}ClN_5$	215.69	34.7 @22ºC	2.96×10^{-9}	GC-NPD, GC-ECD, or GC-MS 2 ng/L	
1,2-DCB	$C_6H_4Cl_2$	147.00	156 @25ºC	1.92×10^{-3}	GC-PID, GC-MS 0.01 to 0.05 µg/L	
1,4-DCB	$C_6H_4Cl_2$	147.002	80 @25ºC	2.41×10^{-3}	GC-PID, GC-MS 0.01 to 0.05 µg/L	
cis-1,2-DCE	$C_2H_2Cl_2$	96.95	3,500 @25ºC	4.08×10^{-3}	GC/ECD, GC/MS 0.03 µg/L	
trans-1,2-DCE	$C_2H_2Cl_2$	96.95	6,300 @25ºC	9.39×10^{-3}	GC/ECD, GC/MS 0.01 µg/L	
1,4-D	$C_4H_8O_2$	88.11	miscible	4.8×10^{-6}	GC-MS 0.03 µg/L	
MTBE	$C_5H_{12}O$	88.15	51,000 @25ºC	5.87×10^{-5}	GC-PID, GC-MS 0.3 to .09 µg/L	

Constituent	**Formula**	**Molecular Weight (g/mol)**	**Water Solubility (mg/L)**	**Henry's Law Constant @ 25ºC (atm-m^3/mol)**	**Test Method(s) for Water Detection Limit(s)**	**Structure**
PCP	C_6HCl_5O	266.35	14 @20ºC	3.4×10^{-6}	GC-ECD 300 ng/L	
PFHxS	$C_6HF_{13}O_3S$	400.12	6.2 @25ºC	not applicable	LC/MS/MS 0.5 to 6.5 ng/L	
PFOS	$C_8HF_{17}O_3S$	500.03	570	not applicable	LC/MS/MS 0.5 to 6.5 ng/L	
PFOA	$C_8HF_{15}O_2$	414.069	9,500 @25ºC	not applicable	LC/MS/MS 0.5 to 6.5 ng/L	
Prometon	$C_{10}H_{17}N_5O$	223.2749	750 @20ºC	9.1×10^{-10}	GC-NPD 0.05 µg/L	
PDC	$C_3H_6Cl_2$	112.99	2,700 @20ºC	2.07×10^{-3}	GC-ECD 0.03 µg/L	
Styrene	C_8H_8	104.15	300 @20ºC	2.61×10^{-3}	GC-PID, GC-MS 0.01 to 0.02 µg/L	
Sulfolane	$C_4H_8O_2S$	120.17	379,000 to miscible	8.9×10^{-10}	GC-MS	

Constituent	**Formula**	**Molecular Weight (g/mol)**	**Water Solubility (mg/L)**	**Henry's Law Constant @ 25ºC (atm-m^3/mol)**	**Test Method(s) for Water Detection Limit(s)**	**Structure**
					0.01 µg/L	
1,2,4-TCB	$C_6H_3Cl_3$	181.447	49.0 @25ºC	1.42 x 10^{-3}	GC-MS 0.5 µg/L	

Test Method Abbreviations:
ECD – electron capture detector
GC – gas chromatography
LC – liquid chromatography
MS – mass spectrometry
NPD – nitrogen phosphorous detector
PID – photoionization detector

Sources of information for Table 1:
https://www.atsdr.cdc.gov/toxprofiles/index.asp#P
http://webbook.nist.gov/chemistry/
https://pubchem.ncbi.nlm.nih.gov/
https://www.epa.gov/sites/production/files/2016-05/documents/pfos_health_advisory_final_508.pdf
https://www.epa.gov/sites/production/files/2016-05/documents/pfoa_health_advisory_final_508.pdf

Atrazine is a triazine herbicide that has been widely used in some agricultural areas of the United States, including the eastern high plains of New Mexico. The U.S. Geological Survey ("USGS") modeled atrazine use rates, coupled with hydrogeologic settings that favor transport of pesticides to groundwater, to predict the occurrence of atrazine detections in groundwater in the United States (Figure 1). While the overall predicted level of groundwater atrazine detection in New Mexico was low relative to that in Midwestern corn belt states, the USGS model predicted elevated detections in the central eastern region of the state (Figure 1) where Curry and Roosevelt Counties are located. Ten of the 18 groundwater detections of atrazine in New Mexico occur in Curry and Roosevelt Counties, (NMED Exhibit 8). EPA has set a drinking water MCL for atrazine at 0.003 mg/L. NMED proposes to add atrazine to the narrative Toxic Pollutant standard, and add EPA's MCL for atrazine to the groundwater human health standards of 20.6.2.3103.A NMAC. The proposed atrazine groundwater standard of 0.003 mg/L is well within the nominal detection limit of 2 ng/L (0.000002 mg/L), Table 1.

Dichlorobenzene isomers (1,2-DCB and 1,4-DCB) have been used as disinfectants, deodorizers, insecticides and in chemical manufacturing. Dichlorobenzene isomers have been detected in groundwater in New Mexico. EPA has set drinking water MCLs for 1,2-DCB and 1,4-DCB at 0.6 mg/L and 0.075 mg/L, respectively. NMED proposes to add 1,2-DCB and 1,4-DCB to the narrative Toxic Pollutant standard at 20.6.2.3103.A(2) NMAC, and add EPA's MCLs for 1,2-DCB and 1,4-DCB to the groundwater human health standards of 20.6.2.3103.A NMAC. The proposed DCB groundwater standards of 0.6 mg/L and 0.075 mg/L are well within the nominal detection limits of 0.01 µg/L to 0.05 µg/L (0.00001 to 0.00005 mg/L), Table 1.

Dichloroethene isomers (cis-1,2-DCE and trans-1,2-DCE) have been detected in New Mexico groundwater at multiple locations, often in association with trichloroethene (TCE) and tetrachloroethene (PCE). The 1,2-DCE isomers may have been contained in commercial chlorinated solvent products that were discharged to groundwater, and also may exist in groundwater as degradation byproducts of TCE and PCE. Both 1,2-DCE isomers are already included in the narrative standard of Toxic Pollutant. NMED proposes to add EPA's MCLs for cis-1,2-DCE and trans-1,4-DCE to the groundwater human health standards of 20.6.2.3103.A NMAC. The proposed DCE groundwater standards of 0.07 mg/L (cis-1,2-DCE) and 0.1 mg/L (trans-1,2-DCE) are well within the nominal detection limits of 0.03 µg/L and 0.01 µg/L (0.00003 to 0.00001 mg/L), Table 1.

1,4-Dioxane (1,4-D) has been used as a stabilizer in chlorinated solvent products. 1,4-D is highly mobile in the subsurface and in groundwater, resistant to biodegradation, and has been detected in groundwater at multiple chlorinated-solvent contamination sites in New Mexico. NMED proposes to add 1,4-D to the narrative standard of Toxic Pollutant at 20.6.2.3103.A(2) NMAC.

Methyl tertiary-butyl ether (MTBE) is a gasoline additive that has contaminated groundwater at numerous locations in New Mexico. In 1990, the EIB adopted a groundwater standard for MTBE of 0.1 mg/L based on aesthetic concerns (Corrective Action for Storage Tank Systems Containing Petroleum Products, 20.5.12.42.A.2 NMAC). Since some of the facilities that have discharged MTBE into groundwater in New Mexico are under the authority of WQCC, rather than EIB, regulations, NMED proposes to add the EIB standard to the list of WQCC aesthetic groundwater standards in 20.6.2.3103.B NMAC. The proposed MTBE groundwater standard of 0.1 mg/L is well within the nominal detection limits of 0.3 µg/L to 0.09 µg/L (0.0003 to 0.00009 mg/L), Table 1.

Pentachlorophenol (PCP) was widely used as an insecticide for treated lumber, and is a widespread contaminant of soil and groundwater. PCP became a restricted use pesticide in the 1980’s and is no longer available to the general public. PCP has been detected in groundwater in at multiple locations in New Mexico (NMED Exhibit 8). EPA has set a drinking water MCL for PCP at 0.001 mg/L. NMED proposes to add PCP to the narrative Toxic Pollutant standard at 20.6.2.3103.A(2) NMAC, and add EPA’s MCL for PCP to the groundwater human health standards of 20.6.2.3103.A NMAC. The proposed PCP groundwater standard of 0.001 mg/L is well within the nominal detection limit of 300 ng/L (0.0003 mg/L), Table 1.

Perfluorinated chemicals (PFCs) were widely used in carpet, clothing, furniture fabric, paper packaging for food, cookware coatings, and in aqueous film-forming foam used for fire suppression. As a result of their widespread use in consumer products and food packaging, PFCs have been detected in the blood of nearly all humans that have been tested, although concentrations have been decreasing since their production and use has been largely phased out beginning in 2000. Some persons also were exposed to PFCs through contaminated drinking water. Testing thus far has not detected PFCs in New Mexico groundwater. But NMED believes there is a reasonable probability that PFCs may be detected in groundwater in the state in the future. NMED proposes to add PFCs to the narrative standard of Toxic Pollutant at 20.6.2.3103.A(2) NMAC.

Prometon is a triazine herbicide that has been widely used for total vegetation control on industrial sites, non-cropping agricultural areas, in and under asphalt, and to some extent by homeowners. Prometon is a commonly detected pesticide in urban groundwater, and has been detected in groundwater in agricultural areas less frequently. In New Mexico, prometon has been detected in groundwater at multiple locations in Bernalillo and Doña Ana Counties, the two most urbanized areas of the state. NMED proposes to add prometon to the narrative standard of Toxic Pollutant at 20.6.2.3103.A(2) NMAC.

Propylene dichloride (PDC, 1,2-Dichloropropane) has been used as an industrial solvent, for the manufacturing of various products, and as a soil fumigant. PDC has been detected in groundwater in New Mexico. EPA has set a drinking water MCL for PDC at 0.005 mg/L. NMED proposes to add PDC to the narrative Toxic Pollutant standard, and add EPA's MCL for PDC to the groundwater human health standards of 20.6.2.3103.A. The proposed PDC groundwater standard of 0.005 mg/L is well within the nominal detection limit of 0.03 µg/L (0.00003 mg/L), Table 1.

Styrene has been detected in groundwater in New Mexico associated with discharges of petrochemical fuels. EPA has set a drinking water MCL for styrene at 0.1 mg/L. NMED proposes to add styrene to the narrative Toxic Pollutant standard at 20.6.2.3103.A(2) NMAC, and add EPA's MCL for styrene to the groundwater human health standards of 20.6.2.3103.A NMAC. The proposed styrene groundwater standard of 0.1 mg/L is well within the nominal detection limits of 0.01 µg/L to 0.02 µg/L (0.00001 to 0.00002 mg/L), Table 1.

Sulfolane is an industrial solvent that has been used in oil refining and natural gas processing. Sulfolane has caused serious groundwater contamination in other states but detections of sulfolane have not been reported in New Mexico groundwater. NMED believes there is a reasonable probability that sulfolane may be detected in groundwater in the state in the future. NMED proposes to add sulfolane to the narrative standard of Toxic Pollutant at 20.6.2.3103.A(2) NMAC.

1,2,4-Trichlorobenzene (1,2,4-TCB) has been used as a termiticide, dye carrier, a herbicide intermediate, a heat-transfer medium, a dielectric fluid in transformers, a degreaser, a lubricant, in synthetic transformer oils, and as a solvent in chemical manufacturing. 1,2,4-TCB has been detected in groundwater in New Mexico. EPA has set a drinking water MCL for 1,2,4-TCB at 0.07 mg/L. NMED proposes to add 1,2,4-TCB to the narrative Toxic Pollutant standard at 20.6.2.3103.A(2) NMAC, and add EPA's MCL for 1,2,4-TCB to the groundwater human health standards of 20.6.2.3103.A NMAC. The proposed 1,2,4-TCB groundwater standard of 0.07 mg/L is well within the nominal detection limit of 0.05 µg/L (0.00005 mg/L), Table 1.

Technologies to Prevent or Abate Water Pollution

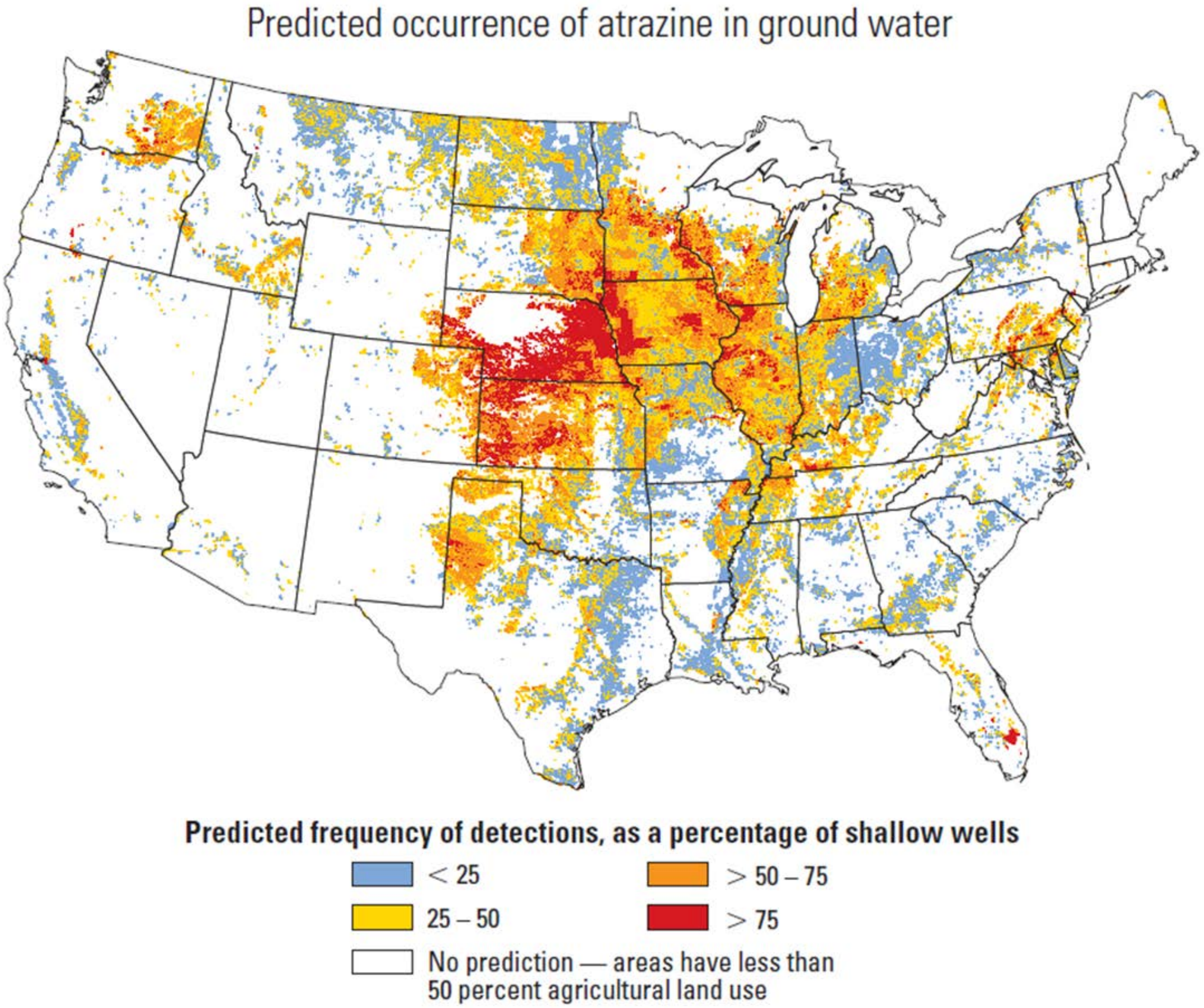
The following discussion applies to the existing chemical constituents that are addressed by WQCC groundwater regulations, as well as to the chemical constituents which NMED proposes to add to the regulations. The Water Quality Act, NMSA 1978, Section 74-6-4.D, provides that WQCC regulations, “shall not specify the method to be used to prevent or abate water pollution…” A diverse variety of technologies have been used to prevent or abate water pollution in New Mexico. Some water treatment technologies, such as carbon filtration, can and have been used to treat wastewater, groundwater and drinking water. Many technologies are capable of removing multiple contaminants or classes of contaminants. Over the past several decades, a number of new technologies have emerged and have been demonstrated to be effective.

Wastewater Treatment - Technologies that have been successfully used in New Mexico to reduce or eliminate water contaminants from regulated sources include impermeable or low hydraulic conductivity pond liners, land application areas that take advantage of natural attenuation processes, and a multitude of wastewater treatment systems some of which can produce high-quality effluent meeting all groundwater and drinking water standards.

Groundwater and Vadose Zone Treatment – At every contaminated site in New Mexico, contaminant concentrations are attenuated by multiple naturally occurring chemical, physical, and/or biological processes. The progress of natural attenuation can be monitoring using various indicator parameters. “Monitored natural attenuation” can be a viable option for abatement of vadose zone and groundwater pollution in situations where contaminant exposure pathways either do not exist, or do not threaten public health and safety. Technologies that have been successfully used in New Mexico to reduce or eliminate water contaminants from the vadose zone and groundwater include soil excavation, soil vapor extraction, bioventing, bio-slurping, recovery of non-aqueous phase liquid, groundwater pump-and-treat, groundwater sparging, non-potable beneficial use of contaminated groundwater, permeable reactive barriers, bio-stimulation, bio-augmentation, and monitored natural attenuation.

Drinking Water Treatment - In some instances of groundwater pollution in New Mexico, affected well owners have successfully installed and operated treatment systems to reduce contaminant concentrations to acceptable, sometimes non-detectable, levels. Technologies that have been used to treat contaminated sources of drinking water include aeration, carbon adsorption, ion exchange, reverse osmosis, distillation, and blending. The cost of providing water treatment, however, is an economic burden to the well owner. In other cases, water treatment has been economically or technically infeasible, and polluted water supply wells have been removed from service or abandoned.

Figure 1. Predicted occurrence of atrazine in groundwater in the United States.[4]



---

[4] Gilliom, R.J., Barbash, J.E., Crawford, C.G., Hamilton, P.A., Martin, J.D., Nakagaki, N., Nowell. L.H., Scott, J.C., Stackelberg, P.E., Thelin, G.P. and D.M. Wolock, 2007, Pesticides in the Nation's Streams and Groundwater, 1992-2001: U.S. Geological Survey Circular 1291, 173 p., https://pubs.usgs.gov/circ/2005/1291/.

C. PROPOSED AMENDMENTS TO THE “TOXIC POLLUTANT” NARRATIVE GROUNDWATER STANDARD, 20.6.2.3103.A(2) NMAC

NMED proposes to add contaminants to the list of toxic pollutant constituents; and move the narrative language for the toxic pollutant standard from the definitions section at 20.6.2.7 NMAC to the groundwater standards section at 20.6.2.3103 NMAC, while keeping the list of toxic pollutant constituents in the definitions section.

The Toxic Pollutant standard provides authority to protect groundwater from contaminants for which numerical groundwater standards do not exist. NMED must perform an evaluation of the concentration at which a contaminant becomes a Toxic Pollutant in groundwater. The Toxic Pollutant standard also provides authority to regulate combinations of contaminants where the toxic effects of the combined contaminants may be worse than that of the individual contaminants. This is why the Toxic Pollutant standard also lists constituents for which numerical groundwater standards also exist. It is impossible to predict what specific combinations of contaminants will be present in future discharges that will be required to have groundwater discharge permits, and in future groundwater contamination plumes that will need to be abated. As such, NMED must perform a case-by-case evaluation of the specific combination of contaminants that are present at a site, their respective concentrations, and whether the combination poses a greater risk than the individual contaminants.

As discussed above, NMED proposes to add the following chemical compounds to the narrative standard for Toxic Pollutant:

- styrene (ethenylbenzene)
- 1,2-dichlorobenzene (ortho-dichlorobenzene)
- 1,4-dichlorobenzene (para-dichlorobenzene)
- 1,2,4-trichlorobenzene

- pentachlorophenol (PCP)
- 1,2-dichloropropane (propylene dichloride, PDC)
- 1,4-dioxane
- sulfolane (thiolane 1,1-dioxide)
- perfluorinated chemicals (PFCs)
    - perfluorohexane sulfonic acid (PFHxS)
    - perfluorooctane sulfonate (PFOS)
    - perfluorooctanoic acid (PFOA)
- pesticides
    - atrazine
    - prometon

NMED proposes to move the narrative standard for toxic pollutant from the definitions section to the groundwater standards section at 20.6.2.3103 NMAC. This amendment is proposed for regulatory clarity since the toxic pollutant definition is a narrative groundwater standard. Doing so will eliminate the need to refer to the Toxic Pollutant standard elsewhere in the regulations when reference is also made to the groundwater standards of 20.6.2.3013 NMAC, and NMED has proposed to strike these references to Toxic Pollutant.

D. PROPOSED AMENDMENTS TO THE PREAMBLE OF 20.6.2.3103 NMAC, STANDARDS FOR GROUND WATER OF 10,000 mg/l TDS CONCENTRATION OR LESS

NMED proposes to authorize the requirement for additional testing and development of sample processing protocol for sites where facilitated transport of inorganic contaminants may be an issue. The reason for this proposed amendment is to ensure that filtration through a 0.45-micron membrane does not remove contaminants attached to colloids or organic macromolecules that actually migrate through the aquifer.

It has long been an industry standard, and required by 20.6.2.3013 NMAC, to filter groundwater samples through a 0.45-micron membrane to obtain the "dissolved" portion of most inorganic water contaminants. While the true distinction between dissolved and suspended (colloidal) particles is significantly less than 0.45 microns, the rationale for filtering has been the presumption that only contaminants that will pass through a 0.45-micron filter can actually migrate through the aquifer. Suspended contaminants larger than 0.45 microns can enter a well from the aquifer matrix near the well screen. These larger suspended contaminants originating near the well screen typically do not migrate through the aquifer, but may create artificially high test results that are not an accurate indication of ground water quality, particularly for metals such as aluminum, arsenic, iron and manganese. Additionally, biological growths containing metals can form on well screens, on pumps, and inside water pipes, and can also create artificially high test results. In practice, properly constructed, developed, and maintained water supply wells that are pumped on a daily or frequent basis typically produce only small amounts of suspended solids and the difference between filtered and unfiltered contaminant concentrations is negligible. Monitoring wells, however, can sometimes produce water with high levels of suspended solids.

Filtration through a 0.45 micron membrane, however, has been shown to sometimes create the following problems [5],[6],[7]:

---

[5] Puls, R.W. and M.J. Barcelona, 1989, Ground Water Sampling for Metals Analyses: U.S. EPA, Superfund Ground Water Issue, EPA/540/4-89/001.

[6] Horowitz, et al., 1996, Problems Associated with Using Filtration to Define Dissolved Trace element Concentrations in Water Samples: Environmental Science and Technology, 30, 854-963.

[7] Horowitz, A.J., 1997, Some Thoughts on Problems Associated with Various Sampling Media Used for Environmental Monitoring: Analyst, vol. 122 (1193-1200).

- Filtration can remove colloids and organic macromolecules larger than 0.45 microns that may be capable of facilitating the transport of other contaminants through groundwater. Removal of these materials can result in artificially low test results for contaminants that are mobile in groundwater.
- It has been demonstrated that filtration artifacts, including filter type, filter diameter, filtration method, volume of water filtered, suspended solids concentrations, and suspended solids grain-size distributions, can create substantial differences, and errors, in the reported concentrations of dissolved contaminants.

NMED proposes to amend 20.6.2.3103 NMAC as follows to provide NMED with the authority to require additional testing and development of protocol for sites where facilitated transport or improper filtration procedures may be an issue:

> **20.6.2.3103 STANDARDS FOR GROUND WATER OF 10,000 mg/l TDS CONCENTRATION OR LESS:** The following standards are the allowable pH range and the maximum allowable concentration in ground water for the contaminants specified unless the existing condition exceeds the standard or unless otherwise provided in Subsection D of Section 20.6.2.3109 NMAC. Regardless of whether there is one contaminant or more than one contaminant present in ground water, when an existing pH or concentration of any water contaminant exceeds the standard specified in Subsection A, B, or C of this section, the existing pH or concentration shall be the allowable limit, provided that the discharge at such concentrations will not result in concentrations at any place of withdrawal for present or reasonably foreseeable future use in excess of the standards of this section. These standards shall apply to the dissolved portion of the contaminants specified with a definition of dissolved being that given in the publication "*methods for chemical analysis of water and waste of the U.S. environmental protection agency*," with the exception that Standards for mercury, organic compounds and non-aqueous phase liquids shall apply to the total ~~un~~ nonfiltered concentrations of the contaminants. If the secretary determines that there is a reasonable probability of facilitated contaminant transport by colloids or organic macromolecules, or that proper filtration procedures are not being followed, the discharger may be required to test for both filtered and nonfiltered portions of inorganic contaminants to

develop appropriate protocol for monitoring contaminants that have the potential to migrate through the aquifer.

E. Proposed Amendments to WQCC Groundwater Health Standards, 20.6.2.3103.A NMAC

NMED proposes to add WQCC groundwater human-health standards for chemical constituents that: have been detected in groundwater in New Mexico, or pose a reasonable threat of contaminating groundwater in New Mexico; are discharged at facilities subject to the authority of 20.6.2.3000 to 3114 NMAC; and have EPA National Primary Drinking Water Standards.

NMED proposes to adjust the concentrations of existing WQCC groundwater human-health standards to be numerically equivalent to EPA National Primary-Drinking Water Standards for most constituents.

The WQCC groundwater human-health standards of 20.6.3.3103.A NMAC, and the EPA National Primary Drinking-Water Standards, share the common goal of protecting the health of people who drink groundwater. WQCC groundwater standards serve a critical function in protecting aquifers as sources of public and private water supply. Protecting groundwater is critical to the Wellhead Protection and Source Water Protection provisions of the federal Safe Drinking Water Act.

EPA's National Primary Drinking-Water Standards are administered to public water supply systems, and apply to the water delivered to consumers, regardless of whether the contaminants:

- occur naturally in the water source;
- result from anthropogenic contamination of the water source;
- are residues or byproducts of disinfection; or

- dissolve or dislodge from plumbing materials.

The WQCC groundwater standards are administered to persons who discharge water contaminants onto or below the surface of the ground, and apply to groundwater of present or reasonably foreseeable future use with a total dissolved solids concentration of 10,000 mg/L or less. Notwithstanding these differences in application, EPA and WQCC health standards are often set at the same, or close to the same, numerical concentration.

Historically, NMED has provided the WQCC with the advice of independent medical/toxicological experts when setting numerical groundwater standards, instead of proposing to adopt EPA drinking-water standards across the board. Consequently, the WQCC has adopted groundwater standards for constituents that do not have drinking water standards, and some WQCC standards were set at different numerical concentrations from EPA drinking water standards. In most instances where WQCC and EPA standards differ in numerical concentration, WQCC groundwater standards were adopted before EPA had promulgated drinking-water standards for the same constituents, and EPA subsequently set their standards at concentrations different from those of WQCC. In other cases, the WQCC disagreed with the numerical concentration established by EPA for drinking water.

The WQCC originally adopted a groundwater standard for uranium set at 5 mg/L in 1977. In 2000, EPA promulgated a drinking water standard for uranium set at 0.03 mg/L. NMED petitioned the WQCC in 2002 to lower the uranium standard to 0.007 mg/L in order to protect populations in New Mexico that were sensitive to the toxic effects of uranium on the kidney. In 2004 post-hearing deliberations, however, the WQCC, set the uranium standard at 0.03 mg/L, the same numerical concentration as the drinking water standard, instead. In its August 18, 2004

Statement of Reasons, the WQCC made the following conclusions as to why the groundwater standard should be set to the same number as the drinking water standard:

> 31. A drinking water numeric standard is translatable to a groundwater standard because the Act's purpose is to protect New Mexicans who consume this protectable water.
>
> 32. A drinking water numeric standard is translatable to a groundwater standard because ten percent of New Mexicans use untreated groundwater directly as drinking water.
>
> 33. A drinking water numeric standard is translatable to a groundwater standard because ninety percent of New Mexicans use groundwater as its source of drinking water.
>
> 34. Setting the groundwater standard to the same number as the drinking water standard will provide uniformity and clarity to the municipalities, counties, businesses, and the public.

For these reasons, NMED proposes to:

- add numerical groundwater standards for chemical contaminants for which EPA has established a drinking water standard to the WQCC human health standards, but only for those contaminants that have been, or might likely be, detected in New Mexico groundwater; and
- adjust existing WQCC groundwater health standards to the same numerical concentrations as the drinking water standards, with several exceptions.

Since these adjustments of and additions to WQCC groundwater standards are proposed to be numerically equivalent to established EPA drinking water standards, in accordance with the WQCC's August 18, 2004 Statement of Reasons discussed above, NMED is not providing expert toxicological testimony in support of these proposed standard adjustments and additions.

The specific groundwater standard amendments proposed by NMED, addition of new standards and adjustments to existing standards, are listed in NMED Exhibit 7.

F. Proposed Adoption of Additional WQCC Numerical Groundwater Human-Health Standards 20.6.2.3103.A

NMED reviewed EPA's National Primary Drinking-Water Standards for parameters that did not have a WQCC groundwater human-health standard to identify parameters that:

- have been detected in groundwater in New Mexico, or pose a reasonable threat of contaminating groundwater in New Mexico; and
- are discharged at facilities subject to the authority of 20.6.2.3000 – 3114 NMAC and 20.6.2.4000 – 4115 NMAC.

Based on these criteria, NMED proposes to add the following parameters to the WQCC groundwater human-health standards (20.6.2.3103.A NMAC) set at the same numerical concentration as the EPA National Primary Drinking-Water Standards: antimony, beryllium, nitrite, thallium, styrene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, pentachlorophenol, cis-1,2,-dichloroethene, trans-1,2-dichloroethene, 1,2-dichloropropane, and atrazine.

NMED does not propose to add the following EPA National Primary Drinking-Water Standard constituents to WQCC groundwater human-health standards.

Microbiological Contaminants – While microbiological contaminants have been detected in groundwater in New Mexico, the contamination often originates from sources that are not subject to the authority of 20.6.2 Subparts III and IV NMAC. These sources include onsite liquid waste systems, facilities discharging pursuant to NPDES permits, and losing streams affected by wildlife. Investigations of microbiological groundwater contamination in New Mexico have not mapped discernable plumes of microbial contaminants[8], [9]. The contamination exists, instead, as localized microbiological detections over the areas studied, and in some cases the detections were caused by unsanitary water well construction rather than by actual groundwater contamination. Indeed, the WQCC has never adopted groundwater standards for microbiological contaminants. Moreover, the adoption of groundwater microbiological standards would require a new dimension of quality assurance and quality control for the installation, construction and sampling of monitoring wells that is not presently applied to discharges permitted under 20.6.2.3000 - 3114 NMAC. For these reasons, NMED does not propose to add the EPA National Primary Drinking-Water Standards for microbiological contaminants to WQCC groundwater human-health standards at this time.

<u>Disinfectants and Disinfection Byproducts</u> – Disinfectants are chemicals added to drinking water and to treated wastewater to control microbes. Disinfectants can react with substances in drinking water and in treated wastewater, and with the water itself, resulting in the generation of chemical byproducts. EPA has established National Primary Drinking-Water Standards for disinfectants chloramines, chlorine and chlorine dioxide, and for disinfectant byproducts bromate, chlorite, haloacetic acids and trihalomethanes. The NMED Drinking Water Bureau administers these standards to public water-supply systems. Discharges of disinfected wastewater, and disinfected water injected for aquifer storage and recovery projects, also might contain disinfectants and disinfection byproducts,

---

[8] Gallaher, B.M., D.M. McQuillan, L.D. Chavez, L.D. Hull and M. Eidson. 1987. Ground-Water Quality and Public Health, Albuquerque South Valley. NMED Open-File Report EID/GWH-87/1, 240 p.

[9] Jackson, S., 2009, Seasonal Trends in Water Contamination and Cryptosporidium Infections in Households with On-site Wells and Septic Systems, University of New Mexico, Master's Thesis.

but NMED is unaware of any such detections in the state that exceed Primary Drinking Water Standards.

For these reasons, NMED is not proposing to add EPA's National Primary Drinking-Water Standards for disinfectants and disinfection byproducts to the WQCC groundwater standards at this time. It should be noted that the WQCC has already adopted a groundwater standard for chloroform, one of the trihalomethane disinfection byproducts regulated by EPA's drinking-water standard for "Total Trihalomethanes". Additionally, the trihalomethanes bromodichloromethane, bromoform, and chloroform are already listed in the narrative groundwater standard for "Toxic Pollutants".

Chloroform has been detected in groundwater in New Mexico associated with biodegrading plumes of carbon tetrachloride, widely used in the past as a solvent and grain fumigant. Carbon tetrachloride can undergo reductive dechlorination (a biodegradation process) that generates chloroform as a byproduct. Since the WQCC groundwater standard for chloroform (0.1 mg/L) is close to the EPA National Primary Drinking-Water Standard for "Total Trihalomethanes" (0.8 mg/L), NMED is not proposing to amend the WQCC groundwater standard for chloroform at this time.

Contaminants Originating from Plumbing Materials –

Asbestos is not water soluble and asbestos mineral fibers do not migrate underground to any appreciable extent. Some drinking-water pipe, however, is made of asbestos-cement and can leach asbestos fibers into drinking water, causing EPA to set a drinking water standard for asbestos.

Epichlorohydrin is used to manufacture some resins that are used to treat drinking water. These resins can leach epichlorohydrin into drinking water, causing EPA to set a drinking water standard for epichlorohydrin.

The NMED Drinking Water Bureau administers the standards for asbestos and epichlorohydrin to public water-supply systems. Discharges of drinking water injected for aquifer storage and recovery projects, also might contain asbestos and epichlorohydrin, but NMED is unaware of any such detections in the state that exceed Primary Drinking Water Standards.

For these reasons, NMED does not propose to add EPA's National Primary Drinking-Water Standards for asbestos and epichlorohydrin to the WQCC groundwater standards at this time.

Alpha Particles, Beta Particles and Photon Emitters – Naturally occurring uranium and radon are the most commonly detected radionuclides in New Mexico groundwater. Naturally occurring radium has been detected in groundwater less frequently. Uranium and radium also have contaminated groundwater as a result of uranium mining and milling operations. Many water-supply wells in New Mexico contain elevated uranium and the disposal of concentrated uranium waste resulting from drinking-water treatment is a problematic issue. The WQCC adopted groundwater standards for uranium and radium in 1977, but has never adopted groundwater standards for alpha and beta activity, which can originate from multiple radionuclides, even though drinking water standards for alpha and beta emitters have long existed. Additionally, the definition of "water contaminant" in the New Mexico Water Quality Act also explicitly excludes source, special nuclear or by-product material as defined by the federal Atomic Energy Act of 1954. For these reasons, NMED does not propose to add the EPA National Primary Drinking-Water Standards for alpha particles, beta particles and photon emitters to the list of WQCC groundwater standards at this time.

Copper – Copper is a parameter for which EPA has established both Primary and Secondary drinking water standards. The EPA National Primary Drinking Water Standard for copper is set at 1.3 mg/L. The non-enforceable EPA secondary drinking-water standard, and the enforceable WQCC aesthetic groundwater standard, for copper are both set at 1.0 mg/L. Since the existing WQCC standard is equal to or more stringent than both EPA's Primary and Secondary drinking water standards, NMED is not proposing to amend the 20.6.2.3103.B NMAC groundwater standard for copper at this time. In 2004, the WQCC made a similar decision that the existing groundwater manganese standard in 20.6.2.3103.B NMAC was protective of both health and aesthetic issues, and declined to adopt the groundwater health standard that NMED had proposed for manganese.

Pesticides other than Atrazine – A review of New Mexico groundwater monitoring data for pesticides for which EPA has set a Drinking Water Standard (NMED Exhibit 8), reveals that atrazine has been detected in groundwater at multiple locations in New Mexico, with the maximum concentration detected nearly equal to the EPA standard of 0.003 mg/L. NMED proposes that a WQCC groundwater health standard for atrazine be set at the same concentration as the EPA MCL. NMED does not propose that groundwater standards be set for any of the other pesticides for which EPA has set an MCL since these other pesticides have not been confirmed to be groundwater contaminants at concentrations of potential human health concern.

Hydrophobic and Other Organic Compounds – EPA's National Primary Drinking-Water Standards apply to public water systems that utilize both groundwater and/or surface water sources. Consequently, some of the parameters regulated by EPA have been detected in surface water, but pose little or no threat to groundwater because of their hydrophobic ("water-fearing") chemical and physical properties. Hydrophobic organic contaminants, such as dioxin, typically have low water solubility, become strongly attached to soil, and have very low subsurface mobility. It is possible that hydrophobic organics could migrate in the subsurface as dissolved constituents of non-aqueous phase liquids (NAPLs). But this would be a rare condition, and the WQCC already has a narrative human health standard that provides that NAPL shall not be present floating atop or immersed within groundwater. Other organic contaminants for which EPA has set drinking water standards have not been confirmed to be groundwater contaminants at concentrations of human health concern in New Mexico. For these reasons, NMED does not propose to add EPA's National Primary Drinking-Water Standards for hydrophobic and other organic compounds to WQCC groundwater human-health standards at this time.

G. Proposed Adjustment of Existing WQCC Numerical Groundwater Human-Health Standards, 20.6.2.3103.A NMAC

Existing WQCC groundwater human-health standards numerically differ from EPA National Primary Drinking-Water Standards for 23 parameters: arsenic, barium, cadmium, chromium, fluoride, lead, radium, benzene, toluene, ethylbenzene, total xylenes, methylene chloride, carbon tetrachloride, ethylene dichloride, 1,1,1-trichloroethane, 1,1,2-trichloroethane, ethylene dibromide, vinyl chloride, 1,1,-dichloroethene, trichloroethene, tetrachloroethene, polychlorinated biphenyls, and benzo-a-pyrene. For these parameters, NMED proposes to adjust existing WQCC groundwater standards to be numerically equivalent to EPA standards, with the exception of chromium, fluoride, and total xylenes.

NMED's specific concerns with chromium, fluoride, and total xylenes, and reasons for not proposing to adjust existing WQCC groundwater standards to be numerically equivalent to EPA's drinking-water standards for these constituents, are explained as follows.

Chromium – EPA is currently evaluating new scientific data regarding chromium toxicity and may propose to amend its National Primary Drinking-Water Standard in the future. NMED, therefore, does not propose to amend the WQCC groundwater standard for chromium at this time.

Fluoride – In 1975, EPA set the drinking-water standard for fluoride at concentrations ranging from 1.4 to 2.4 mg/L depending on the annual average of the maximum daily air temperature for the community in which the water system was located. The temperature based standard was developed assuming that people in warmer climates would consume more water, and ingest more fluoride, than people in cooler climates. In 1977, the WQCC set New Mexico's groundwater fluoride standard at 1.6 mg/L. In 1986, the EPA adjusted the National Primary Drinking-Water Standard to 4 mg/L to protect against skeletal fluorosis, and established a national secondary (non-enforceable) fluoride standard of 2 mg/L to protect against dental fluorosis. All WQCC groundwater standards, however, are enforceable, and NMED does not believe it would be in the best public's interest to have two different numerical groundwater standards for fluoride; one for skeletal fluorosis in 20.6.2.3103.A NMAC, and another for dental fluorosis in 20.6.2.3103.B NMAC. Since the existing WQCC standard of 1.6 mg/L is approximately equal to EPA's dental fluorosis standard of 2 mg/L, and also is protective against skeletal fluorosis, NMED does not propose to amend the WQCC groundwater standard for fluoride at this time.

Total Xylenes – Xylenes, ethylbenzene and toluene are alkylbenzenes that have similar chemical and physical properties. These alkylbenzenes often occur together, and with benzene, in many petroleum products such as gasoline. The WQCC set the existing groundwater standard for total xylenes at 0.62 mg/L in 1985. Six years later, in 1991, EPA promulgated the National Primary Drinking-Water Standard for xylenes at 10 mg/L. The large difference between the WQCC and EPA standards that presently exists for xylenes is similar to a situation that existed regarding the WQCC toluene groundwater standard in the early 1980's. The WQCC originally adopted a groundwater health standard for toluene set at 15 mg/L in 1981. The WQCC lowered the toluene groundwater standard from 15 mg/L to 0.75 mg/L in 1985, based on expert medical/toxicological testimony from Victor Zalma, M.D. (NMED Exhibit 9) regarding:

- the potential for "contaminant hysteria" caused by the taste and odor that 15 mg/L of toluene would impart to groundwater, and illness, whether imagined or real, associated with the "extremely disagreeable" taste and odor;
- the fact that toluene is often detected in groundwater along with ethylbenzene, xylenes, and benzene; and
- concerns about how such a high level of toluene (15 mg/L) would take up an amount of metabolic function of the liver such that the capacity of the liver to detoxify other substances (ethylbenzene, xylenes, and benzene) might be decreased.

Dr. Zalma also testified that his concerns about toluene, ethylbenzene and xylenes were very similar, and he recommended against setting the groundwater standard at high levels for any of these compounds (NMED Exhibit 9). As a result of Dr. Zalma's testimony at the 1985 public hearing, the WQCC set groundwater health standards for toluene, ethylbenzene and total xylenes at the very similar concentrations of 0.75, 0.75 and 0.62 mg/L, respectively (Table 2). EPA subsequently set drinking water MCLs for these same compounds at 1, 0.7 and 10 mg/L, respectively (Table 2).

Table 2. Comparison of WQCC Groundwater Health Standards and EPA Drinking Water MCLs for Alkylbenzenes.

Alkylbenzene	WQCC Health Standard (mg/L)	EPA Primary MCL
Toluene	0.75	1
Ethylbenzene	0.75	0.7
Total Xylenes	0.62	10

NMED is comfortable in proposing to slightly adjust the WQCC groundwater standards to be numerically equivalent to the EPA MCLs for toluene and ethylbenzene. NMED would not be comfortable, however, with raising the total xylene standard from 0.62 to 10 mg/L as that would be contrary to what Dr. Zalma testified to when the WQCC standards were set. Based on Dr. Zalma's testimony regarding alkylbenzenes, and in light of the fact that NMED presently has not hired a medical/toxicological expert, NMED is not proposing to amend the WQCC groundwater standard for total xylenes at this time.

H. Proposed Adoption of Additional WQCC Numerical Groundwater Aesthetic Standard for MTBE, 20.6.2.3103.B NMAC

In 1990, the EIB adopted a groundwater standard for MTBE of 0.1 mg/L based on aesthetic concerns (Corrective Action for Storage Tank Systems Containing Petroleum Products, 20.5.12.42.A.2 NMAC). Because some of the facilities that have discharged MTBE into groundwater in New Mexico are under the authority of WQCC, rather than EIB regulations, NMED proposes to add the EIB standard to the list of WQCC aesthetic groundwater standards in 20.6.2.3103.B NMAC.

IV. Proposed Amendments to Exemptions From Discharge Permit Requirements, 20.6.2.3105.A, L, M, N and O NMAC

NMED proposes to clarify three existing exemptions and add two new exemptions to be consistent with the statutory delegation of authority and with existing administrative permitting procedures.

A. Proposed Amendment of Existing Exemption 20.6.2.3105.A NMAC

This exemption has existed since the original regulations became effective in 1977. WQCC regulations do not contain a definition of "effluent".

Wastewater treatment technology has advanced to the point where some facilities produce treated effluent that is virtually of drinking water quality. Wastewater treatment facilities can be subject to failure, however, from a variety of causes including but not limited to improper construction, maintenance or operation, and storm events. It is therefore important, for the purpose of protecting water quality and public health, that all wastewater treatment facilities be subject to regulatory permits to ensure that they are properly constructed, operated, maintained, and monitored, and to provide for enforcement if permit violations occur. There is indeed an expectation by many in the public that regulatory agencies will protect water quality and public health by permitting and overseeing wastewater treatment facilities.

While the existing exemption could be construed to allow some wastewater treatment facilities to operate without any kind of regulatory permit, NMED has long held the position that this exemption applies only to *untreated* effluent. NMED proposes the following language to ensure that wastewater treatment facilities under the authority of WQCC regulations continue to be subject to permitting requirements.

> **20.6.2.3105 EXEMPTIONS FROM DISCHARGE PERMIT REQUIREMENT:** Sections 20.6.2.3104 and 20.6.2.3106 NMAC do not apply to the following:
>
> A. Effluent or leachate which conforms to all the listed numerical standards of Section 20.6.2.3103 NMAC and has a total nitrogen concentration of 10 mg/l or less, and does not contain any toxic pollutant. <u>If treatment or blending is required to achieve these standards this exemption does not apply.</u> To determine conformance, samples may be taken by the agency before the effluent or leachate is discharged so that it may move directly or indirectly into ground water; provided that if the discharge is by seepage through non-natural or altered natural materials, the agency may take samples of the solution before or after seepage. If for any reason the agency does not have access to obtain the appropriate samples, this exemption shall not apply;

B. Proposed Amendment of Existing Exemption 20.6.2.3105.L NMAC

NMED proposes to amend the existing exemption for coal mining to clarify the statutory delegation of authority by the Surface Mining Act to the Coal Surface Mining Commission, and to the Mining and Minerals Division of the Energy, Minerals and Natural Resources Department.

C. Proposed Amendment of Existing Exemption 20.6.2.3105.M NMAC

NMED proposes to amend the existing exemption for oil and gas activities to clarify the existing statutory delegation of authority by the Oil and Gas Act and the Water Quality Act to the Oil Conservation Commission, and to the Oil Conservation Division of the Energy, Minerals and Natural Resources Department.

D. Proposed Exemption 20.6.2.3105.N

The Geothermal Resources Development Act, NMSA 1978, Section 71-9-5.D states:

> The division shall have exclusive authority to regulate injection into geothermal wells pursuant to the Geothermal Resources Development Act and shall have exclusive authority over matters related to the protection of natural resources, property, health and public welfare as they relate to geothermal injection wells.

NMED proposes a new exemption for geothermal activities to clarify this statutory delegation of exclusive authority to the Energy Conservation and Management Division of the Energy, Minerals and Natural Resources Department.

E. Proposed Exemption 20.6.2.3105.O NMAC

The Water Quality Act, NMSA 1978, Section 74-6-12.B states:

> The Water Quality Act does not apply to any activity or condition subject to the authority of the environmental improvement board pursuant to the Hazardous Waste Act [Chapter 74, Article 4 NMSA 1978], the Ground Water Protection Act [Chapter 74, Article 6B NMSA 1978] or the Solid Waste Act except to abate water pollution or to control the disposal or use of septage and sludge.

NMED proposes a new exemption, 20.6.2.3105.O NMAC, to clarify this statutory delegation of authority.

V. PROPOSED NEW ABATEMENT STANDARD FOR SUBSURFACE WATER CONTAMINANTS, 20.6.2.4103.B NMAC

NMED proposes a new 20.6.2.4103.B NMAC providing for the abatement of subsurface water contaminants. The purpose of this proposed narrative standard is to ensure that abatement actions include subsurface water, and protect against the types of injuries specified by the Legislature in the statutory definition of "water pollution".

The water cycle is the continuous circulation of water on, above, and below the surface of the Earth (Figure 2). Circulating water can occur in, and transfer between, the liquid, vapor and solid (ice) phases. In the definition of "water" in the Water Quality Act, the New Mexico Legislature did not differentiate between the liquid, vapor or solid phases of water that occur in the state, but defined the term very broadly: "'[w]ater' means all water, including water situated wholly or partly within or bordering upon the state, whether surface or subsurface, public or private, except private waters that do not combine with other surface or subsurface water;" NMSA 1978, § 74-6-2.H (2003).

It is important to note that the Legislature used the term “subsurface water” rather than “ground water”. The WQCC defined the term “subsurface water” in 20.6.2 NMAC to include, but not be limited to, groundwater: “’subsurface water’ means ground water and water in the vadose zone that may become ground water or surface water in the reasonably foreseeable future or may be utilized by vegetation”. 20.6.2.7.UU NMAC.

In some areas of New Mexico, particularly along the valleys of losing streams, subsurface water migrates down through the vadose zone in unsaturated flow conditions to eventually become groundwater. In other areas, such as in some arid inter-drainage locations, most or all shallow subsurface water is taken up by vegetation[10] and does not significantly migrate deeper than the root zone. Subsurface water in the vadose zone can be measured as soil-moisture content (directly in soil samples and indirectly through neutron geophysics), and as soil-vapor humidity.

Contaminants can exist in the vadose zone in the following four interactive physical phases (Figure 3), as well as in biomass:

- dissolved in water (aqueous phase)
- soil gas (vapor phase, includes organic vapor and contaminated water vapor)
- soil (adsorbed or precipitated phases, contaminants attached to soil and rock)
- non-aqueous phase liquid (“NAPL”, such as gasoline or chlorinated solvent)

Contaminants can transfer between these four physical phases based on properties such as water solubility, Henry’s Law constant, carbon adsorption capacity, and other partitioning coefficients. Contaminants in the aqueous, vapor and NAPL phases can migrate through the vadose zone. Chlorinated degreasing solvents discharged as NAPL, for example, can migrate

---

[10] Walvoord, M. A., M. A. Plummer, F. M. Phillips, and A. V. Wolfsberg, 2002, Deep arid system hydrodynamics, 1, Equilibrium states and response times in thick desert vadose zones, Water Resour. Res., 38(12), 1308.

downward through the vadose zone dissolving into soil moisture, vaporizing into soil gas, and adsorbing onto soil particles. Transport mechanisms involving water and vapor are particularly important for vadose zone contaminants[9, 11]. Contaminants in the vadose zone can be measured in samples of pore fluid, soil/sediment, and soil vapor. The detection of NAPL phases in the vadose zone can be difficult, and their presence is sometimes inferred from high concentrations of contaminants in soil vapor or in underlying groundwater.

Figure 2. The Water Cycle. http://water.usgs.gov/edu/watercycle.html

---

[11] Stephens, D.B., 1996, Vadose Zone Hydrology, CRC Press, ISBN 0873714326, 9780873714327.

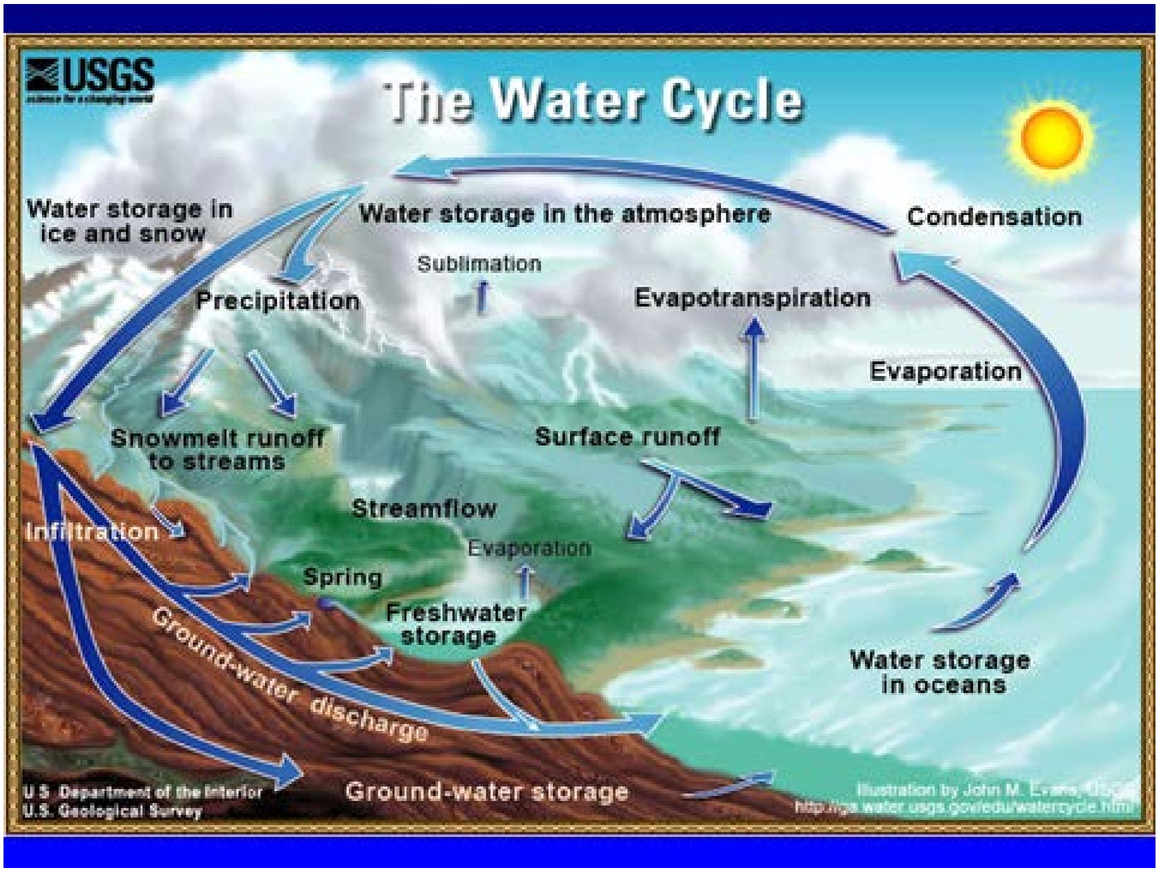
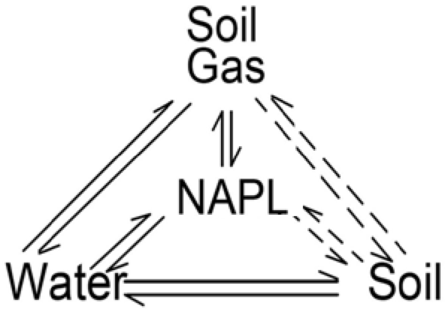


Figure 3. Four Possible Physical Phases of Vadose-Zone Contaminants.



The New Mexico Legislature defined the term "water pollution" very broadly in the Water Quality Act:

> ’water pollution’ means introducing or permitting the introduction into water, either directly or indirectly, of one or more water contaminants in such quantity and of such duration as may with reasonable probability injure human health, animal or plant life or property, or to unreasonably interfere with the public welfare or use of property;

NMSA 1978, § 74-6-2.C (2003).

The statutory definition of water pollution is not limited to injuries that may be caused by use of contaminated groundwater for potable drinking water, or for livestock watering, and irrigation. Volatile subsurface water contaminants, for example, can vaporize from groundwater or soil moisture and intrude into buildings, utility infrastructure and construction excavations. A conceptual diagram of vapor intrusion into a building is illustrated in Figure 4. Many instances of vapor intrusion into homes or businesses, often originating from shallow groundwater contaminated by gasoline or chlorinated solvents, have occurred in New Mexico. The intruding vapors can create risks to human health through inhalation and can on occasion accumulate at even higher concentrations creating explosive hazards. There have been at least two instances where workers in New Mexico have been burned by explosions of gasoline vapor in construction excavations, with the most recent event occurring in 2009. An environmental professional in New Mexico died from asphyxiation by soil-vapor contaminants in 2007 (Figure 5). Engineered systems to mitigate vapor intrusion have been installed at many sites in New Mexico.

Figure 4. Conceptual Diagram of Vapor Intrusion into a Building.

https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/jne_background_forward.html

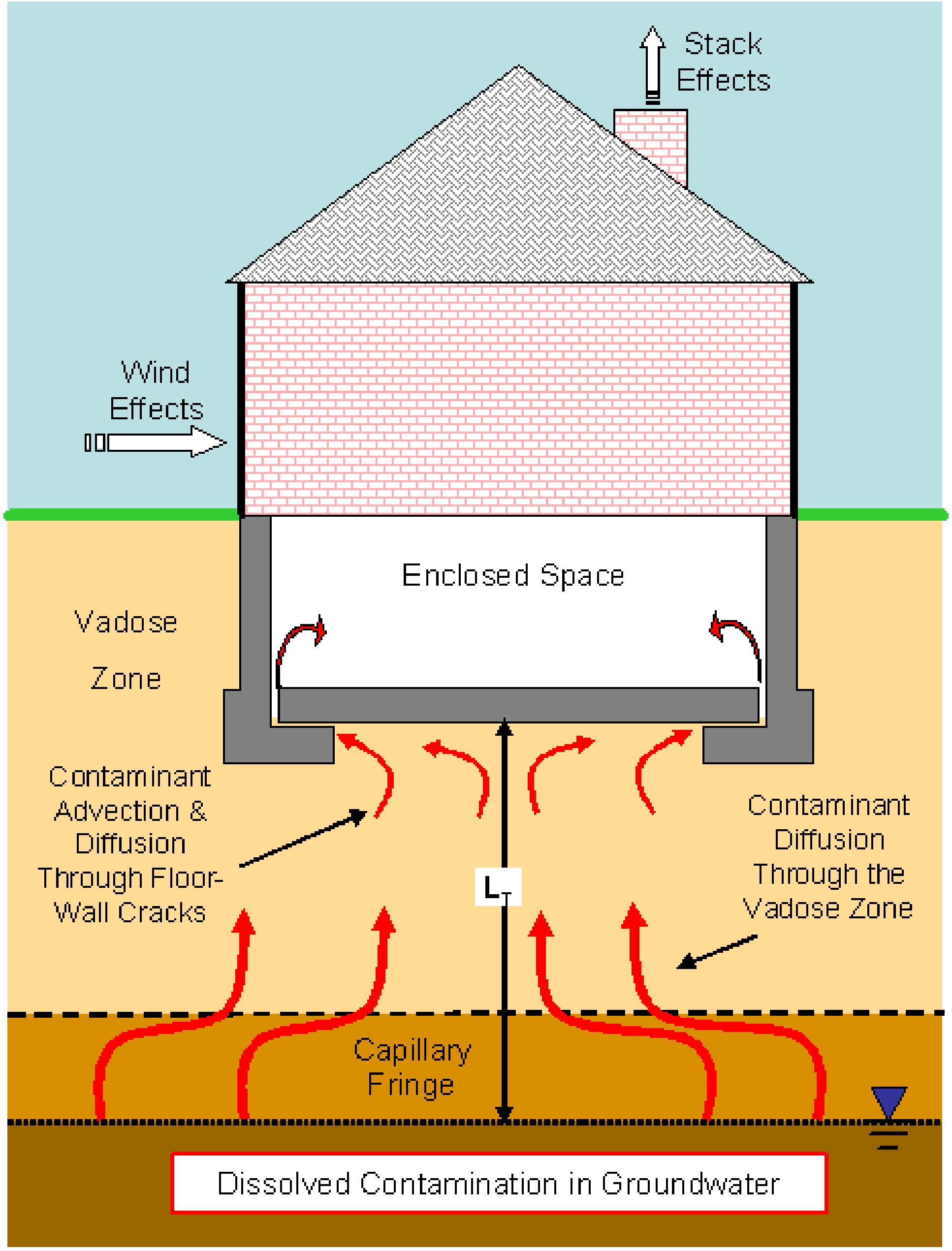


Figure 5. Workplace Soil-Vapor Asphyxiation Fatality of an Environmental Professional at a Soil and Groundwater Contamination Site in New Mexico.


[redacted]

Stricter regulations controlling the transportation and storage of flammable liquids have greatly reduced the number of vapor intrusion incidents from gasoline and other petroleum products over the last few decades. Tanker truck crashes and other events still occur, however, that release volatile contaminants onto and below the surface of the ground and have the potential to create vapor intrusion hazards. Some of these releases are not under the authority of EIB Petroleum Storage Tank Regulations and are abated pursuant to 20.6.2.4101 to 4115 NMAC instead. A number of chlorinated solvent soil and groundwater contamination sites were addressed by WQCC abatement or federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known also as Superfund) authority years ago. At that time, soil remediation at these sites focused on preventing additional groundwater contamination, and did not fully consider the potential for vapor intrusion. These chlorinated solvent sites are now being evaluated for potential vapor intrusion hazards. Additional corrective actions will be needed to abate public health hazards from intrusion of chlorinated solvent vapor at some of these sites. It should be noted that five-year reviews generally are required for CERCLA (Superfund) sites when hazardous substances remain above levels that permit unrestricted use and unlimited exposure, but no such review is required under WQCC abatement authority. In addition to relic abatement sites, several current Superfund site investigations (e.g. - Eagle Picher in Socorro, Grants Chlorinated Solvent Plume in Grants, McGaffey and Main Plume in Roswell) in New Mexico also have found vapor intrusion into homes that sit above either groundwater or vadose zone chlorinated solvent contamination. Migration of these volatile organic constituents into indoor air and utility corridors are a threat to human health. Structures with vapor intrusion impacts must be mitigated with vapor barriers, soil-vapor extraction systems, or radon-type venting systems to ensure people are protected from these subsurface environmental impacts.

A number of inorganic and organic contaminants, if discharged into subsurface water in the vadose zone, can create potential hazards to crops and other plant life. Subsurface water contaminants can damage crop health, agricultural productivity, and render once-productive cropland unfarmable[12]. Phytoextraction is a process where contaminants in soil and subsurface water can be extracted by plants and accumulated in plant tissue. The accumulation of contaminants in edible crop tissue is a potential concern for human and livestock health. Additionally, some contaminants can interfere with the ability of crops and other plants to

---

[12] Stephens, Daniel B.; Spalding, Charles P., 1984, Oil-field brine contamination--A case study, Lea County, New Mexico, *in:* Selected papers on water quality and pollution in New Mexico, Stone, W. J., *ed(s),* New Mexico Bureau Mines Mineral Resources, Hydrologic Report, v. 7, pp. 194-203.

manufacture chlorophyll, and can result in chlorosis[13]. The symptoms of chlorosis can range from paling of leaf tissue, stunted growth, failure to produce flowers and fruit, to death of the entire plant. Contaminants discharged by the Gold King Mine spill appear to have caused chlorosis of alfalfa grown in Cedar Hill, New Mexico, and investigations are underway to determine if crops grown in the Animas River and San Juan River watersheds have accumulated harmful concentrations of heavy metals. Phytoextraction also can be used as technology to clean up soil contamination, a process known as phytoremediation, where specific types of vegetation are planted for the purpose of extracting contaminants from soils. Phytoremediation also can include plants that transform or degrade subsurface contaminants.

The following narrative standard regarding abatement of subsurface water contaminants is proposed to ensure that abatement actions include subsurface water, and protect against the types of injuries specified by the Legislature in the definition of "water pollution".

> B. Subsurface water contaminants shall be abated to concentrations below those which may with reasonable probability injure human health, animal or plant life or property, or unreasonably interfere with the public welfare or the use of property through percolation, capillary suction, sequestration, phytoextraction, plant uptake, volatilization, advection or diffusion into crops, structures, utility infrastructure, or construction excavations.

---

[13] http://extension.illinois.edu/focus/index.cfm?problem=chlorosis

VI. Proposed Amendment to Abatement Plan Exemptions 20.6.2.4105.B NMAC

Abatement regulation 20.6.2.4105.B authorizes the NMED cabinet secretary to require an Abatement Plan for abatement activities that are otherwise exempted from Abatement Plan requirements if the exempted activity:

1. will not meet the WQCC vadose zone (20.6.2.4103.A NMAC), and groundwater (20.6.2.4103.B NMAC) standards; or
2. is not protective of health, welfare, environment or property.

NMED proposes to add the narrative subsurface water standard, proposed new 20.6.2.4103.B NMAC, to the list of standards for which lack of compliance could authorize the NMED cabinet secretary to require an Abatement Plan for an otherwise exempted abatement activity. This authority might be applied, for example, at a site where vadose zone contaminants pose an imminent threat migrating into groundwater, but where existing groundwater concentrations have not yet exceeded numerical standards. Another example might be a site where subsurface water contaminant vapor has intruded a home at potentially toxic concentrations, but where groundwater concentrations have not yet exceeded numerical standards.

This concludes my written direct testimony.

Protecting New Mexico's Buried Treasure
A Brief History of Groundwater Protection in New Mexico

Dennis McQuillan
Chief Scientist
New Mexico Environment Department

September 11, 2017

Thousands of years ago, changes in the Earth's orbit caused the climate in the Southern High Plains of North America to became warmer and more arid. As surface water resources dried up, the tenacious aboriginal populations of eastern New Mexico and western Texas adapted by digging water wells. Archaeologists have identified a number of prehistoric water wells in this region that were dug around the time of this climate change[1]. The "oldest prehistoric well in America" was hand-dug in Blackwater Draw near Clovis, New Mexico approximately 13,500 years ago[2].

Groundwater continues to be a vital resource for the residents of New Mexico. Approximately 95% of the state's 2.1 million people depend on groundwater for all or part of their domestic water supply, including more than 300,000 people who rely on private domestic wells[3]. Many farms, ranches and industries in the state also use wells to supply their water needs. The New Mexico Legislature and state government agencies have a 112-year history of pioneering efforts to protect groundwater resources, and to protect the health of citizens who drink groundwater.

The first well was drilled in the Roswell artesian basin in 1891. Geologically pressurized groundwater flowed at the surface without any pump or machinery. By 1904, after hundreds of wells had been drilled into the aquifer, decreases in the artesian pressure of the aquifer were first observed. These pressure decreases provided the first evidence of groundwater depletion in New Mexico. In 1905, the New Mexico Territorial Legislature passed a law to protect the Roswell artesian basin. The law created a county well supervisor whose job was to issue permits for new wells, keep records and logs of each well drilled, and to measure the flow and pressure of the wells.

In 1907, the Territorial Legislature passed New Mexico's Territorial Water Code. This visionary law assigned to courts the task of adjudicating New Mexico's water rights, and created the office

---

[1] Meltzer, D.J and M.B. Collins, 1987, Prehistoric Water Wells on the Southern High Plains: Clues to Altithermal Climate: Journal of Field Archaeology, Vol. 14, No. 1, pp. 9-28, https://www.jstor.org/stable/530204?seq=1#page_scan_tab_contents.

[2] Haynes Jr., C.V., Stanford, D.J., Jodry, M., Dickenson, J., Montgomery, J.L., Shelley, P.H., Rovner, I and G.A. Agogino, 1999, A Clovis well at the type site 11,500 B.C.: The oldest prehistoric well in America: Geoarchaeology, Vol. 14, Issue 5, pp. 455–470, https://www.researchgate.net/publication/230099596_A_Clovis_Well_at_the_Type_Site_11500_BC_The_Oldest_Prehistoric_Well_in_America.

[3] *See* EPA-Approved 2016-2018 CWA §§ 303(d)/ 305(b) Integrated Report, p. 73. Available at https://www.env.nm.gov/swqb/303d-305b/2016-2018/documents/EPA-APPROVED2016-2018IR092316.pdf.

of the Territorial Engineer to have general supervision over the measurement, appropriation and distribution of New Mexico's water. When New Mexico became a state in 1912, the new constitution adopted the water doctrine of prior appropriation that is embodied in the Code and, through N.M Const. art. XXII, § 4, made the Territorial Water Code the State Water Code.[4]

In 1931, a Groundwater Code was added to the State Water Code, and the State Engineer's authority to regulate groundwater was affirmed[4]. The Groundwater Code was passed, in part, in response to the effects that groundwater development was having on streamflow and on the rights of other groundwater users.

In 1932, C.V. Theis published a report[5] documenting a five to ten foot lowering of the water table in the vicinity of Portales that had occurred from roughly 1910 to 1931. Theis suggested that the safe yield of the aquifer may have been reached, and recommended that the Portales Valley area be formed into a groundwater district under the supervision of the State Engineer for the conservation and proper utilization of the groundwater. Theis' report was among the first in the state to map regional water-table declines caused by groundwater depletion. Since then, declining groundwater levels have been documented in many other areas of New Mexico.

In 1934, the infant death rate in New Mexico was 145 deaths per 1,000 live births, the highest in the nation and twice the national average[6]. Many deaths were caused by dysentery and diarrheal illness from unsafe water supplies and poor sanitation. At that time, more than 65% of homes in New Mexico, did not have complete indoor plumbing and a flush toilet[7]. Potentially unsanitary hand dug wells, large and small (Figures 1 and 2), and privies, were still used in many areas of the state.

In 1937 the New Mexico Board of Public Health issued pioneering regulations to prevent pollution of water resources, including wells[8]:

> "No person, firm or corporation, public utility, city, town, village or other public body or institution, shall discharge drain or deposit, or cause or suffer to be discharged, drained or deposited, any sewage, garbage, offal, filth, or any animal, mineral, or vegetable matter or substance, offensive, injurious or dangerous to health, into any springs, streams, rivers, lakes, tributaries thereof, acequias, ditches, wells or other waters used or intended to be used for human consumption or for domestic purposes;…"

---

[4] Brief History of the Office of the State Engineer, http://www.ose.state.nm.us/OSE/seHistory.php

[5] Theis, C.V., 1931, Groundwater in Curry and Roosevelt Counties, New Mexico: 10th Biennial Report of the State Engineer of New Mexico.

[6] Whorton, B., 2002, New Mexico Public Health Achievements During the 20th Century, https://nmhealth.org/data/view/vital/1884/

[7] Historical Census of Housing Table, Plumbing Facilities, https://www.census.gov/hhes/www/housing/census/historic/plumbing.html; Sewage Disposal, https://www.census.gov/hhes/www/housing/census/historic/sewage.html

[8] New Mexico Bureau of Public Health, Regulations Governing Water Supplies and Sewage Disposal, adopted June 28, 1937, https://www.env.nm.gov/fod/LiquidWaste/documents/1937DeptofPublicHealth.pdf;
New Mexico Bureau of Public Health, Regulations Prohibiting Insanitary Toilets in Certain Places, adopted June 28, 1937, https://www.env.nm.gov/fod/LiquidWaste/documents/1937BureauofPublicHealth.pdf.

The 1937 regulations specifically prohibited the disposal of human waste in a manner where the waste could be carried into a well "by surface drainage or seepage." Use of the term "seepage" indicates knowledge at that time of the ability of contaminants to migrate underground into a water supply well. The 1937 regulations also created a permitting process for the "deposit or discharge" of waste, that could be approved by the State Commissioner of Health upon a finding that the deposit or discharge would not "contaminate or pollute" water.

Figure 1. Ruins of a large hand-dug well that supplied water to the Village of Magdalena, NM circa 1930's to 1940's. (Photograph taken in 2013.)

In 1947, a year before the United States Congress passed the Water Pollution Control Act, the New Mexico State Legislature passed the Sanitary Projects Act (SPA) to address the high infant mortality rate in New Mexico resulting from unsafe water supplies. For the past 70 years, projects authorized and funded by the SPA have played a major role in preventing groundwater pollution and water-borne illness from substandard wastewater disposal infrastructure, and from polluted private domestic water-supply wells. Numerous communities in New Mexico are now served by public drinking water and wastewater infrastructure that are subject to the protection of state and federal requirements for construction, inspection, testing, permitting, and operator certification.

Figure 2. Hand-dug well at an abandoned homestead in northern New Mexico. (Photograph taken in 2010.)

In the 1950's and 60's, multiple instances of groundwater pollution were documented in New Mexico, and state agencies took additional actions to protect groundwater quality:

- In 1953, crude oil (also known as non-aqueous phase liquid or NAPL) was observed floating atop the Ogallala aquifer in Hobbs, New Mexico where oil production had been occurring since 1928. Up to six feet of crude oil was measured floating on the water level inside supply wells[9]. The New Mexico Oil Conservation Commission (OCC, created

---

[9] Hurt, K., 2001, Preliminary Assessment of the Windmill Oil Site, Unit J, Section 30, Township 18S, Range 38E, Lease County, New Mexico: Prepared for U.S. Department of the Interior, Bureau of Land Management.

by the Oil and Gas Act of 1935) issued an order in 1953 requiring oil companies to test their production wells for casing leaks. The OCC issued a second order in 1954 requiring additional casing tests to be observed by agency staff. The OCC also seated a Committee consisting of government and industry representatives to study the "Hobbs Fresh Water Sands" aquifer. Numerous casing leaks were identified and repaired, and evidence of oil well casing leakage and contaminated water wells was observed in 16 sections (one square mile tracts) in the Hobbs region. Records from this time period show that protecting the City of Hobbs municipal supply wells from crude oil contamination was a top priority of the organizations that participated in the Committee. Efforts to recover the crude oil floating on the water table led to the formation of businesses such as the Windmill Oil Company who were required to submit production reports to the state. More than 450,000 barrels (approximately 20 million gallons) of crude oil were recovered from the Ogallala aquifer over a period of decades.

- High nitrate (81 mg/L NO_3 as N) was detected in a 1956 sample collected by the United States Geological Survey (USGS) from a water supply well in Hells Canyon in Valencia County in 1956[10].

- Two public water-supply wells for a company village near Bluewater, New Mexico were taken out of service in 1956 after discovery of high nitrate (284 mg/L NO_3 as N) from uranium mill effluent. There is an anecdotal report of a case of methemoglobinemia (the Blue Baby Syndrome) in an infant residing in Bluewater at that time. The contaminated wells were restricted to supply water for non-potable uses only, and efforts began to design, construct and operate a deep injection well to dispose of the uranium mill waste. Decanted mill tailings raffinate was injected into the Permian Yeso Formation at depths from 950 to 1423 feet from 1960 to 1977. Some of the injected waste, however, leaked upwards into the Permian San Andres/Glorieta regional aquifer, causing increases in sodium, sulfate, chloride and nitrate. After 1977, mill waste was discharged into lined evaporation ponds that were excavated into the low permeability Triassic Chinle Formation. ([11] ,[12])

- High nitrate (39 mg/L NO_3 as N) was detected in a 1957 sample collected by the USGS from a supply well in Tijeras Arroyo near Albuquerque[13].

- In 1959, the State Board of Public Health issued a Policy for Individual Water Supplies and Sewage Disposal Systems[14] that set minimum lot size requirements for onsite

---

[10] Titus, F. B., 1963, Geology and Ground-Water Conditions in Eastern Valencia County, New Mexico: N.M. Bureau of Mines and Mineral Resources, Ground-Water Report 7. https://geoinfo.nmt.edu/publications/water/gw/7/GW7.pdf

[11] Gordon, Ellis D., 1961, Ground-water resources of the Grants-Bluewater area, Valencia County, New Mexico, New Mexico State Engineer, Technical Report, v. 20, pp. 1-109, http://www.ose.state.nm.us/Pub/TechnicalReports/TechReport-020.pdf.

[12] West, Sam W., 1972, Disposal of uranium-mill effluent by well injection near Grants, New Mexico, U.S. Geological Survey, Professional Paper, v. 00386-D, pp. 1-28., https://pubs.er.usgs.gov/publication/pp386D.

[13] Bjorklund, L.J. and B. W. Maxwell, 1961, Availability of ground water in the Albuquerque area, Bernalillo and Sandoval Counties, New Mexico, New Mexico State Engineer, Technical Report, v. 21, pp. 1-117. http://www.ose.state.nm.us/Pub/TechnicalReports/TechReport-021.pdf

wastewater systems based on whether the lot was served by a private well or by a public water system. The policy stated, "The development of fringe areas and subdivisions that do not have access to municipal water and sewage facilities is creating a continuously growing problem in the proper protection of public health in these areas. … Septic tanks and leaching systems were never intended for use in closely built-up housing areas." Subsequent NMED investigations demonstrated that lot size is a critical factor in potential groundwater quality impacts from septic systems[15].

- The state legislature amended the Oil and Gas Act in 1961 to authorize the OCC to make rules providing for fresh water protection from improper disposal of drilling or production waters.

- In 1961, a case of methemoglobinemia (the Blue Baby Syndrome) was documented in an infant living in a home supplied by a private domestic well producing water with 182 mg/L NO_3 as N in Carnuel, New Mexico[16]. Subsequent monitoring of well water in this area by Bernalillo County, USGS and the New Mexico Environment Department (NMED)[17] identified widespread nitrate contamination caused, at least in part, by onsite wastewater systems discharging into a fractured bedrock aquifer.

- "Gasoline on top of water" was reported inside two wells near a petroleum refinery in Prewitt, New Mexico in 1961[18].

- In 1963, the state legislature prohibited "polluting water" as a public nuisance and misdemeanor criminal offense. The public nuisance statute explicitly mentioned springs, wells and "known ground waters", and provided the state with authority to require abatement of public nuisances. Public nuisance statues were routinely cited by NMED in enforcement actions to require abatement of water pollution through 1995 when comprehensive abatement regulations were adopted (discussed below).

- In 1966, tritium was discovered in alluvial groundwater at Los Alamos, New Mexico[19].

---

[14] https://www.env.nm.gov/fod/LiquidWaste/documents/1959HealthandSocialServices.pdf

[15] McQuillan, D. 2004. Ground-Water Quality Impacts from Onsite Septic Systems. 2004. Proceedings, National Onsite Wastewater Recycling Association, 13th Annual Technical Education Conference, Albuquerque, New Mexico, November 7-10, 2004, http://www.nmenv.state.nm.us/fod/LiquidWaste/NOWRA.paper.pdf.

[16] West, S.W., 1961, Meeting with Health Department Personnel to discuss high nitrate in groundwater near Mountainview School, Bernalillo County, N. Mexico, USGS memorandum dated October 17, 1961.

[17] As used in this paper, the term "NMED" includes the New Mexico Environment Department and predecessor agencies including the Environmental Improvement Division of the New Mexico Health and Environment Department.

[18] Cooper, J.B. and E.C. John, 1968, Geology and Ground Water Occurrence in Southeastern McKinley County, New Mexico: NM State Engineer Technical Report 35, Table 1, http://www.ose.state.nm.us/Pub/TechnicalReports/TechReport-035.pdf.

[19] Purtymun, W.D., 1973, Regional Survey of Tritium in Surface and Ground Water in the Los Alamos Area, New Mexico, August 1966 through May 1969: Los Alamos Scientific Laboratory of the University of California, Informal Report LA-5234-MS, https://catalog.hathitrust.org/Record/012213871.

- In 1967, the state legislature passed the Water Quality Act (NMSA 1978, Sections 74-6-1 to -15), that specifically mentioned groundwater, while the closest equivalent federal statute at that time, the Water Pollution Control Act, did not. The Water Quality Act created the Water Quality Control Commission (WQCC), and authorized it to adopt regulations including water-quality standards.

- In 1967, after testing had discovered abnormally high concentrations of chloride and specific conductance in a number of water supply wells in Lea County, New Mexico, the OCC issued an order that prohibited the disposal of produced water (highly saline water that is co-produced with crude oil and natural gas in the region) into unlined pits in the southeastern oil fields of the state [20].

New Mexico's extensive efforts to protect groundwater quality from 1937 through 1967, as discussed above, occurred prior to 1970 when President Nixon created the U.S. Environmental Protection Agency (EPA), and prior to the subsequent enactment of numerous federal and state environmental laws and regulations that began in the early 1970's.

In 1971, the "Pollution Control" amendment was added to the New Mexico State Constitution:

> The protection of the state's beautiful and healthful environment is hereby declared to be of fundamental importance to the public interest, health, safety and the general welfare. The legislature shall provide for control of pollution and control of despoilment of the air, water and other natural resources of this state, consistent with the use and development of these resources for the maximum benefit of the people. (N.M. Const. art. XX, s§ 21).

In 1974, the WQCC adopted a preliminary set of regulations that included a notice of intent to discharge and spill reporting and corrective action requirements.

In 1977, the WQCC promulgated a comprehensive set of groundwater quality regulations, the first in the nation, that included a permitting program for discharges onto or below the surface of the ground, numerical groundwater standards for metals and inorganic compounds, and a narrative standard of "Toxic Pollutant". These regulations and standards were appealed, but not stayed by the court, and began to be implemented in 1977. New Mexico's pioneering groundwater regulations were largely upheld by the Court of Appeals in 1978 and by the Supreme Court in 1979[21]. The narrative "Toxic Pollutant" standard, however, was deemed by the court to be unconstitutionally vague, and was subsequently deleted by the WQCC.

Many additional instances of groundwater pollution were documented in New Mexico during the 1970s, and the first analyses using gas chromatography to identify toxic organic contaminants in groundwater were conducted. Since then, analytical chemistry has advanced such that many organic contaminants can be detected down to ng/L levels. One ng/L is equal to 0.000001 (1×10^{-6}) mg/L.

---

[20] New Mexico Oil Conservation Commission, Order R-3221, http://www.emnrd.state.nm.us/OCD/3221_000.html.

[21] Bokum Resources Corporation v. N.M. WQCC, 93 N.M. 546, 603 P.2d 285 (1979)

In 1980:

- Two municipal water supply wells in the South Valley of Albuquerque were shut down due to contamination with chlorinated solvents. Investigations began, and this site was eventually listed in the federal Superfund program.
- NMED compiled the first inventory of groundwater contamination in the State of New Mexico[22].

In 1981, the WQCC adopted a revised narrative standard of “Toxic Pollutant” that was more limited in scope that the original standard, and was upheld on appeal[23].

In 1982:

- The WQCC adopted Underground Injection Control (UIC) regulations (20.6.2 Part V NMAC) that, coupled with injection regulations previously adopted by the OCC, allowed the State of New Mexico to obtain complete primacy from EPA to administer the UIC program of the federal Safe Drinking Water Act.
- The WQCC adopted eight numerical standards for toxic organic contaminants. The numerical standards were not appealed.
- NMED conducted the first “Water Fair” in the state where free testing of private domestic wells was made available. Private domestic well users are not protected by the construction, inspecting and testing requirements of the federal Safe Drinking Water Act. NMED developed the Water Fair program to provide private domestic well users with field tests for important parameters including specific conductance, pH, fluoride, iron and nitrate (Figure 3). The Water Fair program also provides the benefit of putting private well users in contact with NMED water quality experts. Since 1982, NMED has tested approximately 20,000 private domestic wells in the state.

Figure 3. Shannon and Aiden McQuillan assist with a Water Fair in Pojoaque, NM in 2004.

In 1983, the WQCC and NMED sued an oil company over soil and groundwater contamination with gasoline, including the presence of potentially explosive gasoline vapor in the crawl space of a home (State of New Mexico, Bernalillo County District Court No. CV-83-01646). The WQCC, NMED, and the oil company entered into a Settlement Agreement that was filed in state District Court. The Settlement Agreement required the oil company to clean up the aquifer to

---

[22] Boyer, D.G., D. McQuillan and M.S. Goad. 1980. New Mexico Surface Impoundment Assessment. A Report to the U.S. Environmental Protection Agency of Work completed Under EPA Grant F-006213-01-1, 98 p.

[23] Kerr-McGee Nuclear Corporation v. N.M. WQCC, 98 N.M. 240, 647 P.2d 873 (1982)

WQCC numerical groundwater standards, reduce polynuclear aromatic hydrocarbons (listed in the WQCC Toxic Pollutant narrative standard) to below detectable concentrations in groundwater, and to mitigate all potentially explosive gasoline vapor in the subsurface (defined in the Settlement Agreement as being no greater than 30% of the Lower Explosive Level[24]. This Settlement Agreement became the prototype for many other Settlement Agreements and Administrative Orders on Consent until provisions of these cleanup documents were codified into the WQCC abatement regulations in 1994.

In 1984, NMED published detailed inventories and assessments of the widespread groundwater contamination in New Mexico from refined petroleum products[24] and other organic contaminants[25].

In 1986, the WQCC adopted 12 additional numerical groundwater standards for toxic organic compounds, and added constituents to the Toxic Pollutant narrative standard. The numerical standards were appealed and upheld[26].

In 1989, NMED's Wellhead Protection Program under the federal Safe Drinking Water Act (SDWA), designed to protect wells used by public water systems, was approved by EPA.

In 1990, the state legislature passed the Ground Water Protection Act (NMSA 1978, Sections 74-6B-1 to -14) that provided authority and funding for the abatement of soil and groundwater pollution from underground petroleum product storage tanks. Hundreds of contamination sites have been cleaned up pursuant to this law.

In 1994, the WQCC adopted detailed regulations addressing the abatement of water pollution, including narrative standards requiring abatement of water contaminants in the vadose zone, and prohibiting the presence of non-aqueous phase liquid (NAPL) floating atop of or immersed within groundwater. Most of the 1994 amendments were agreed upon by a working committee of government, industry and environmental organizations, and there was no appeal of the regulations that were adopted by the WQCC.

In 1996, Congress amended the SDWA to create the Source Water Protection Program that went beyond the Wellhead Protection Program, for example, to include surface waters that are used as water sources by public water systems.

In 2004, the WQCC amended the numerical groundwater standard for uranium, and added several constituents to the Toxic Pollutant narrative standard. The amended groundwater uranium standard was appealed and upheld[27].

---

[24] Jercinovic, D.E., 1984, Petroleum-Product Contamination of Soil and Water in New Mexico: NMED Open-File Report EID/GWH-84/4.

[25] McQuillan, D.M. 1984. Organic Water Contaminants in N.M.: An Assessment of Known and Potential Problems. NMED Open-File Report EID/GWH-84/3, 58 p.

[26] Tenneco Oil Company v. N.M. WQCC, 107 N.M. 469, 760 P2d 161 (1988)

[27] New Mexico Mining Association and New Mexico Oil and Gas Association v. N.M. WQCC, 150 P.3d 991 (2006)

At the present time, numerous New Mexico statutes, and regulatory programs authorized by these laws, serve to protect groundwater quality in the state (Table 1). The Water Quality Act and WQCC regulations, however, continue to be the primary state authority for protecting groundwater quality in New Mexico. Some NMED programs developed by other state statutes make reference to, and require compliance with, WQCC regulations and standards.

For additional information, former NMED employees Maxine Goad[28] and Bruce Garber[29] have written useful papers on the development of New Mexico's groundwater protection program.

Table 1. New Mexico State Laws that Protect Groundwater Quality.

Statute	**Year Enacted**	**Summary of Groundwater Protection Provisions**
Oil and Gas Act Amendments	1961	Authorized development of OCC rules providing for fresh water protection from improper disposal of drilling or production waters
Public Nuisance Statute	1963	Prohibited the pollution of springs, wells or "known ground waters" and authorized abatement
Water Quality Act	1967	Pioneering statute that provided the authority for New Mexico's comprehensive groundwater protection program, the first in the nation
Environmental Improvement Act	1971	Authorizing statute for NMED drinking water, hazardous waste, liquid waste, petroleum storage tank, radiation protection, and solid waste programs, all of which have requirements that prevent or abate groundwater pollution
Pollution Control Amendment to NM State Constitution	1971	Declaration that protection of New Mexico's environment is of fundamental importance, and that the legislature shall provide for control of water pollution
Radiation Protection Act	1971	Authorizing statute for NMED radiation protection bureau; broad mandate to protect the environment from use, management, storage and disposal of radioactive material
Pesticide Control Act	1973	Prohibited acts include disposal or storage of pesticides and pesticide containers that may pollute any water supply, and use of pesticides in such a manner as to endanger man and his environment (environment defined in statute to include water and every living thing in water)
Subdivision Act	1973	Authorizes counties to set subdivision requirements for protecting water supplies from contamination, and for proper disposal of liquid waste and solid waste; requires counties to

---

[28] Goad, Maxine S., 1988, Historical overview of New Mexico ground water quality protection programs, in: 32nd Annual New Mexico Water Conference: Ground water management, Niovember 5-6, 1887, Albuquerque, NM, Ortega Klett, Catherine T., ed(s), New Mexico State University, Water Resources Research Institute, Technical Report, v. 229, pp. 34-44, https://nmwrri.nmsu.edu/wp-content/uploads/2015/watcon/proc32/Goad.pdf.

[29] Garber, Bruce S., 1984, State legal mechanisms for the control of ground-water pollution in New Mexico, in: Selected papers on water quality and pollution in New Mexico, Stone, W. J., ed(s), New Mexico Bureau Mines Mineral Resources, Hydrologic Report, v. 7, pp. 281-289, http://geoinfo.nmt.edu/publications/water/hr/home.cfml?volume=7.

Statute	**Year Enacted**	**Summary of Groundwater Protection Provisions**
		request NMED opinion on such water/waste issues when preliminary subdivision plats are submitted for proposed development
Utility Operators Certification Act	1973	Requires certification and continuing education for operators of public drinking water systems (implementation of wellhead and source water protection programs) and waste water treatment facilities (compliance with discharge permits to prevent groundwater pollution)
Hazardous Waste Act	1977	Authorizing statute for NMED hazardous waste and petroleum storage tank programs, both of which have requirements to prevent or abate groundwater pollution
Surface Mining Act	1979	Requires that surface coal mining operations are conducted in a manner which will protect the environment
Mine Dewatering Act	1980	Avert or minimize threats to the public health, safety and welfare
Groundwater Protection Act	1990	Provides authority and funding for abatement of groundwater pollution from petroleum storage tanks
Solid Waste Act	1990	Authorizing statute for NMED solid waste program that has requirements to prevent or abate groundwater pollution
Department of Environment Act	1991	Established NMED as a cabinet-level executive agency; provided NMED with additional enforcement authority that has been used to protect groundwater quality
Mining Act	1993	Established a permitting program for mines, administered by the Energy and Minerals Dept. in coordination with NMED, that includes groundwater protection
Natural Resources Trustee Act	1993	Created the Office of the Natural Resource Trustee and provided authority to seek compensation for damages to groundwater quality and to restore or replace groundwater resources damaged by pollution
Voluntary Remediation Act	1997	Created the voluntary remediation program, a business-friendly option that can be used to abate groundwater pollution
Groundwater Storage and Recovery Act	1999	Legislative finding that groundwater storage and recovery project may improve water and environmental quality
Geothermal Resources Development Act	2016	Protects against contamination of fresh water, and protects human life and environment

Groundwater Depletion

Groundwater depletion is the long-term decline of water levels caused by sustained groundwater pumping, and is occurring in many places in the world. Groundwater depletion can result in water table declines, saline intrusion, water quality degradation, diminished production from water-supply wells and springs, and land-surface subsidence which can damage property and permanently reduce aquifer porosity and storage capacity[30][31] (Johnson, 2001).

In New Mexico, evidence of groundwater depletion became apparent in the early 20th century, as discussed above. Theis[4] mapped up to ten feet of water table decline in the Portales region from approximately 1910 to 1931 (Figure 4). Water table declines in Deming and the Mimbres Basin from 1910 to 1970 are shown in Figure 5[32]. Groundwater levels also have declined in the Estancia Basin[33], High Plains aquifer[34], and in other areas of New Mexico.

By 2002, the water table in Albuquerque had declined by more than 120 feet in some areas (Figure 6)[35]. In 2008, the San Juan-Chama Drinking Water Project provided surface-water resources to augment the groundwater supply used for drinking water supply by the Albuquerque Bernalillo County Water Utility Authority (ABCWUA). Water consumers served by the ABCWUA also did an exemplary job of water conservation. Use of surface water and successful water conservation allowed for a reduction in groundwater pumping in the Albuquerque Basin. By 2009-10, groundwater levels in the Basin began to recover[36]. As of the writing of this paper, water levels in some areas of the Basin continue to rise (see Figure 7 showing 30 feet of water-level rise since 2010).

Overdrafting of aquifers is a major cause of subsidence in the southwestern United States[37]. As groundwater is pumped out, the water table declines, and ground compaction occurs, leading to subsidence. In New Mexico subsidence caused by groundwater depletion and declining water

---

[30] Bartolino, J.R. and W.L. Cunningham. 2003. Ground-water depletion across the nation. U.S. Geological Survey Fact Sheet 103-03. https://pubs.usgs.gov/fs/fs-103-03/#pdf.

[31] Johnson, Peggy S., 2001, The challenge of sustainable ground-water development, in: Water, watersheds, and land use in New Mexico, Johnson, Peggy S., ed(s), New Mexico Bureau Mines Mineral Resources, Decision-makers Field Guide, v. 1, pp. 147-149. ISBN: 1-883905-08-7, http://geoinfo.nmt.edu/publications/guides/decisionmakers/2001/dmfg2001_day3.pdf.

[32] Hydrologic Framework and Preliminary Simulation of Groundwater Flow in the Mimbres Basin, Southwestern New Mexico, 1994, Hanson, Tr. J.S. MeLean and R.S. Miller, USGS Water-Resources Investigations Report 94-4011. https://pubs.usgs.gov/wri/1994/4011/report.pdf.

[33] White R.R., 1993, Hydrology of the Estancia Basin, central New Mexico: USGS Water-Resources Investigations Report 93-4163 https://pubs.er.usgs.gov/publication/wri934163

[34] McGuire, V.L. 2007. Changes in water level and storage in the High Plains aquifer, predevelopment to 2005: U.S. Geological Survey Fact Sheet 2007-3029, 2 p. http://pubs.usgs.gov/fs/2007/3029/.

[35] Laura M. Bexfield and Scott K. Anderholm, 2002, Estimated water-level declines in the Santa Fe Group aquifer system in the Albuquerque area, central New Mexico, predevelopment to 2002: USGS Water-Resources Investigations Report 2002-4233, https://pubs.er.usgs.gov/publication/wri024233.

[36] Driscoll, J.M. and J.T. Brandt, 2017, Land Subsidence and Recovery in the Albuquerque Basin: USGS Scientific Investigations Report 2017-5057, https://pubs.usgs.gov/sir/2017/5057/sir20175057.pdf.

[37] Leake, S.A. 2004. Land subsidence from ground-water pumping. U.S. Geological Survey. http://geochange.er.usgs.gov/sw/changes/anthropogenic/subside/.

tables has occurred near Deming creating large earth fissures[38], and near Santa Fe, creating a half-mile long fissure with nearly 20 cm of offset[39].

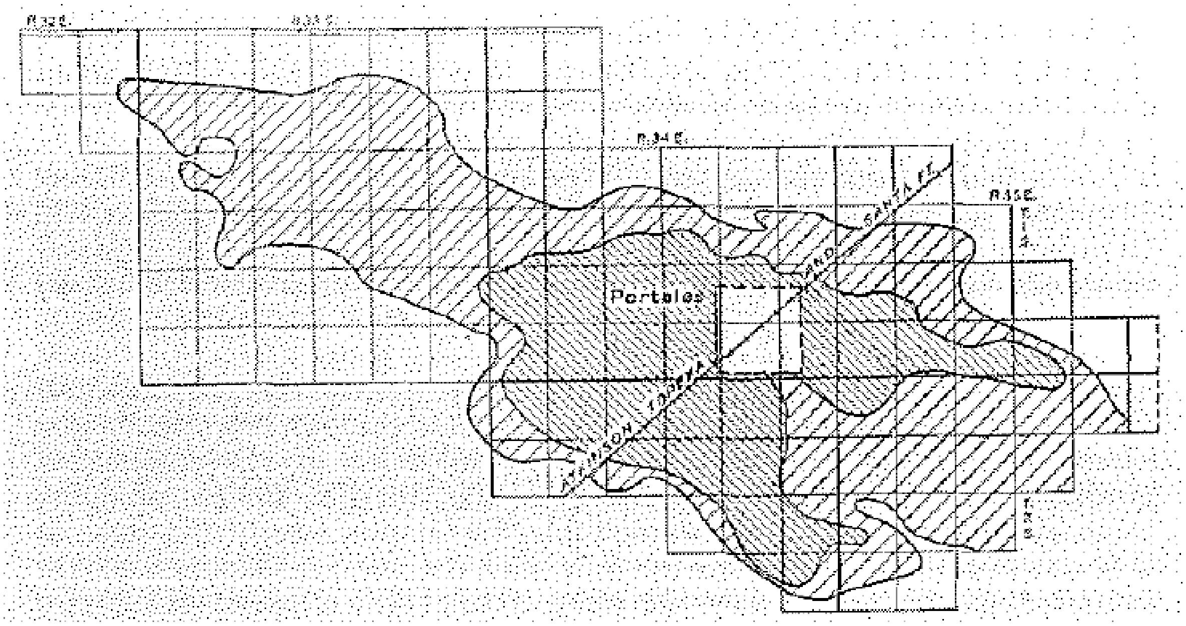


Figure 4. C.V. Theis (1931) Map Showing Lowering of the Water Table in a Portion of the Portales Valley from 1910 (?) to 1931. In the closely hachured area, including Portales, the water table has fallen between five and ten feet; in the less closely hachured area less than five feet.[4]

---

[38] Contaldo, Gregory J.; Mueller, Jerry E., 1991, Earth fissures of the Mimbres Basin, southwestern New Mexico, New Mexico Geology, v. 13, no. 4, pp. 69-74, http://geoinfo.nmt.edu/publications/periodicals/nmg/13/n4/nmg_v13_n4_p69.pdf.

[39] Thomsen, D.R. and Y. Fialko. 2005. InSAR observed ground subsidence near Buckman Well Field, New Mexico. In Geologic and Hydrogeologic Framework of the Espanola Basin – Proceedings of the 4th Annual Espanola Basin Workshop, Santa Fe, New Mexico, March 1-3, 2005. U.S. Geological Survey Open File Report 2005-1130, p 24. http://pubs.usgs.gov/of/2005/1130/.

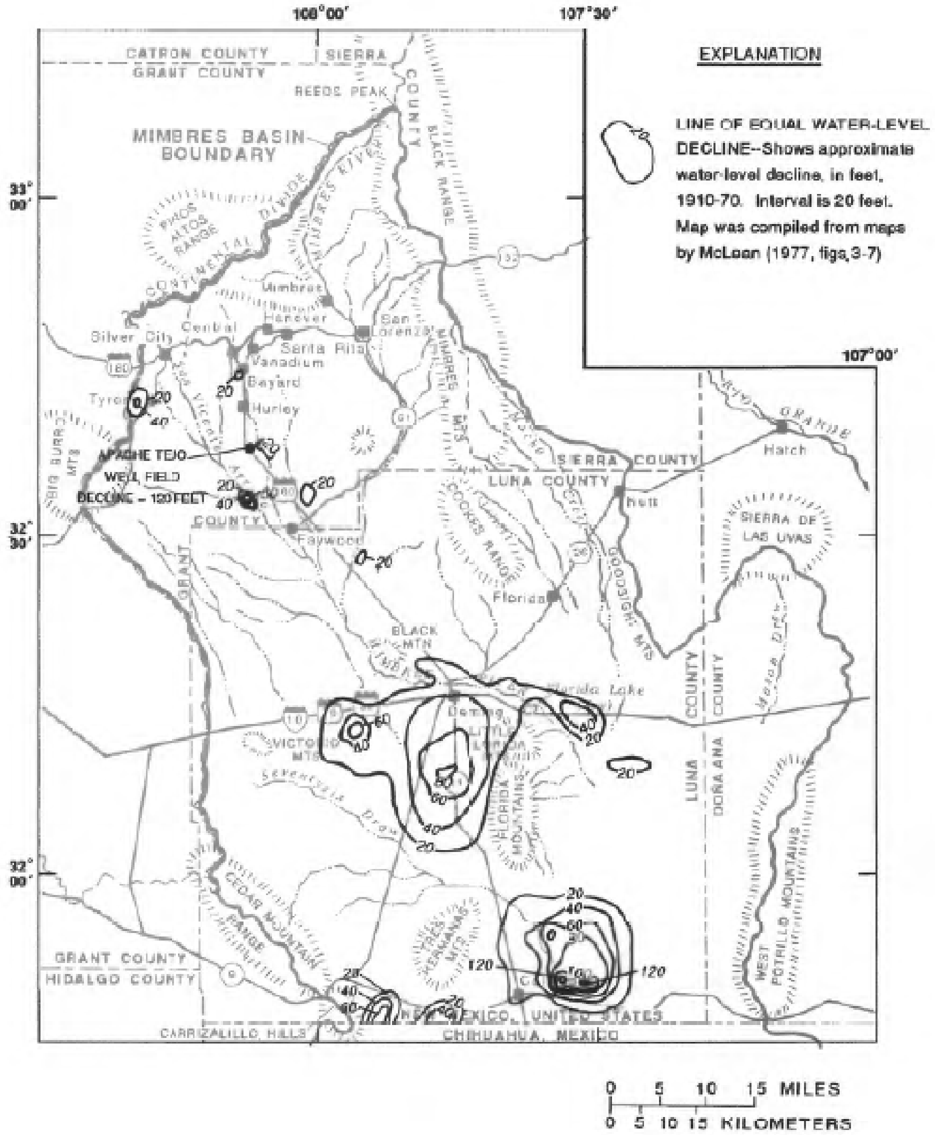


Figure 5. Approximate Water Level Decline in the Mimbres Basin, 1910-70[25].

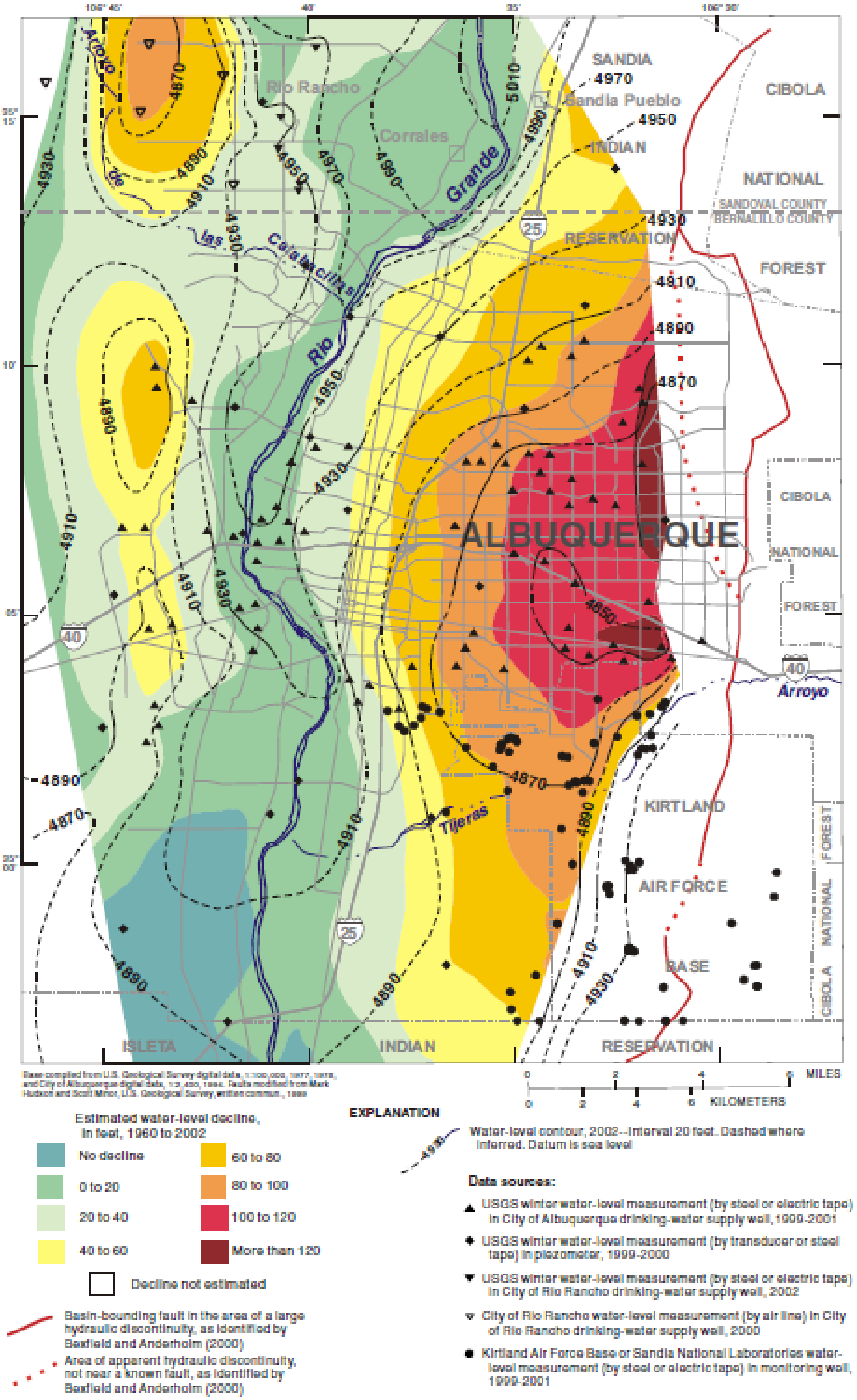


Figure 6. Estimated Water Level Decline in the Albuquerque Area in Feet, 1960 to 2002[25].

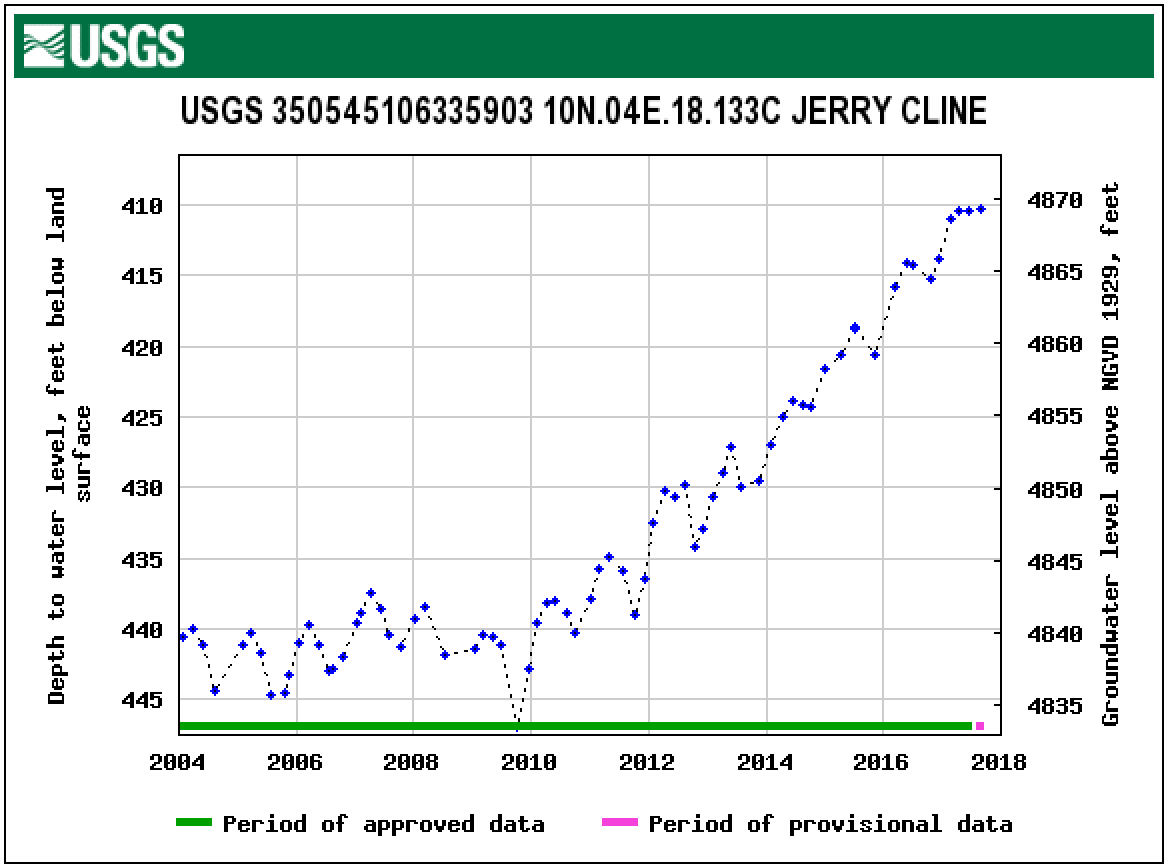


Figure 7. Water-Level Recovery in a Monitoring Well in the Albuquerque Basin.

https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=350545106335903

Comparison of Existing and Proposed N.M. WQCC Groundwater Standards
With Other State and Federal Groundwater and Drinking Water Standards, Advisories, Risk Levels and Criteria
For Chemical and Physical Parameters
September 5, 2017

Column descriptions:

Parameter – name of constituent(s) sometimes including a synonym.

CAS # – a unique number assigned by the Chemical Abstracts Service (CAS), a Division of the American Chemical Society, to a specific chemical substance or group of substances. The CAS registry contains information on more than 131 million inorganic and organic chemical substances, with about 15,000 new substances added each day. More than 348,000 CAS substances are identified as being regulated by international, national, or state agencies. https://www.cas.org/index

WQCC GW Std. – Numerical groundwater standard adopted by the N.M. Water Quality Control Commission (WQCC); human health standard, unless indicated as S (secondary (aesthetic) standard) or Irr (irrigation standard); New Mexico Administrative Code 20.6.2.3103. New standards, and amendments to existing standards proposed by the N.M. Environment Department are highlighted in yellow and designated with underscore and ~~strikeout~~.

WQCC TP – N.M. Water Quality Control Commission narrative groundwater standard for “Toxic Pollutant”. Constituents proposed by NMED for inclusion in the standard are highlighted in yellow.

NMED Tap Water SL – Non-enforceable Risk-Based Tap Water Screening Level established by the New Mexico Environment Department based on cancer (C), or noncancer (NC) potential health risk. https://www.env.nm.gov/wp-content/uploads/2016/11/NMED-SSG-VOL-I -March-2017.pdf

EPA Drinking Water MCL – Maximum Contaminant Level established by the U.S. Environmental Protection Agency (EPA) for public water supply systems. https://www.epa.gov/dwstandardsregulations

EPA Lifetime Health Advisory – Non-enforceable health advisory issued by EPA. https://www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf, https://www.epa.gov/ground-water-and-drinking-water/drinking-water-health-advisories-pfoa-and-pfos

New Jersey Groundwater Criteria/PQL – New Jersey Groundwater Quality Standards list both the Groundwater Quality Criteria, and the practical quantitation level (PQL) for each constituent. In cases where the PQL is at a higher concentration than the groundwater criterion, both concentrations are listed in the table below. http://www.state.nj.us/dep/wms/bears/gwqs.htm

Washington Groundwater Criteria – C: carcinogenic standard; P: primary (human health) standard; S: secondary (aesthetic) standard. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-200-040

Wisconsin Public Health Groundwater Standard – Groundwater quality enforcement standards http://docs.legis.wisconsin.gov/code/admin_code/nr/100/140.pdf

Additional abbreviations: ABS/LAS – foaming agents; fpl – fibers per liter; pCi/L – pico Curies per liter; tt – treatment technique

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
Inorganic Contaminants									
aluminum	7429-90-5	5 Irr		19.9 NC		0.05 to 0.2 S	0.2		0.2
antimony	7440-36-0	0.006		0.00726 NC	0.006	0.006	0.006		0.006
arsenic	7440-38-2	~~0.1~~ 0.01		0.000855 C 0.00355 NC	0.01		0.00002/ 0.003	0.05 C	0.01
asbestos					7 x 10^6 fpl		7 x 10^6 fpl		7 x 10^6 fpl
barium	7440-39-3	~~1.0~~ 2		3.28 NC	2		6	1 P	2
beryllium	7440-41-7	0.004		0.0124 NC	0.004		0.001		0.004
boron	7440-42-8	0.75 Irr		3.95 NC		5			1
bromate	15541-45-4				0.01				
cadmium	7440-43-9	~~0.01~~ 0.005		0.00624 NC	0.005	0.005	0.004	0.01 P	0.005
chloramine	10599-90-3				4	3			
chloride	16887-00-6	250 S			250 S		250	250 S	
chlorine	7782-50-5				4	4			
chlorine dioxide	10049-04-4				0.8	0.8			
chlorite	14998-27-7				1	0.8			
chromium III	16065-83-1			13.6 NC					
chromium VI	18540-29-9			0.000501 C 0.0267 NC					
chromium, total	7440-47-3	0.05		0.0057 C 11.7 NC	0.1		0.07	0.05 P	0.1
cobalt	7440-48-4	0.05 Irr		0.00598 NC					0.04
copper	7440-50-8	1.0 S		0.79 NC	1.3 tt 1.0 S		1.3	1 S	1.3
cyanide	57-12-5	0.2		0.00146 NC	0.2		0.1		0.2
cyanogen	12539-57-0			0.0199 NC					
cyanogen bromide	506-68-3			1.8 NC					
cyanogen chloride	506-77-4			0.999 NC					
fluoride	16984-48-8	1.6		1.18 NC	4.0/2 .0 S		2	4 P	4
hardness (as $CaCO_3$)							250		
hydrogen cyanide	74-90-8			0.00146 NC					
hydrogen sulfide	7783-06-4								0.03
iron	7439-89-6	1.0 S		13.8 NC	0.3 S		0.3	0.3 S	
lead	7439-92-1	~~0.05~~ 0.015			0.015 tt		0.005	0.05 P	0.015
lead (tetraethyl-)	78-00-2			1.24 x 10^{-6} NC					
manganese	7439-96-5	0.2 S		2.02 NC	0.05 S	0.3	0.05	0.05 S	0.3
mercury, total	7439-97-6	0.002					0.002	0.002 P	0.002
mercury, elemental				0.000626 NC					
mercury, inorganic					0.002	0.002			
mercury, methyl				0.00196 NC					
mercury, salts				0.00492 NC					

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
molybdenum	7439-98-7	1.0 Irr		0.0987 NC		0.04	0.04		0.04
nickel	7440-02-0	0.2 Irr		0.372 NC		0.1	0.1		0.1
perchlorate	14797-73-0		X	0.0138 NC		0.015			0.001
pH		6 to 9 S			6.5 to 8.5 S		6.5 to 8.5	6.5 to 8.5 S	
phosphorous, white	7723-14-0					0.0001			
selenium	7782-49-2	0.05		0.0987 NC	0.05	0.05	0.04	0.01 P	0.05
silver	7440-22-4	0.05		0.0812 NC	0.1 S	0.1	0.04	0.05 P	0.05
sodium							50		
strontium	7440-24-6			11.8 NC		4			
sulfate		600 S			250 S		250	250 S	
thallium	7440-28-0	0.002		0.000197 NC	0.002		0.0005/ 0.002		0.002
total dissolved solids (TDS)		1,000 S			500 S		500	500 S	
vanadium	7440-62-2			0.0631 NC					0.03
vanadium pentoxide	1314-62-1						0.06		
zinc	7440-66-6	10.0 S		5.96 NC	5 S	2	2	5 S	
Nitrogen Species									
ammonia-N	7664-41-7						3		0.0097
nitrate-N	14797-55-8	10.0		31.24	10		10	10 P	10
nitrite-N	14797-65-0	1.0		1.98	1		1		1
nitrate-N plus nitrite-N					10		10		10
Radionuclides									
alpha particles	12587-46-1				15 pCi/L			15 pCi/L	
beta particles	12587-47-2				4 mRem/yr			50 pCi/L	
radium-226								3 pCi/L	
radium, 226 + 228 combined	13982-63-3 15262-20-1	~~30~~ 5			5 pCi/L			5 pCi/L	
radon	10043-92-2				300/4000[1] pCi/L				
strontium-90	10098-97-2							8 pCi/L	
tritium	10028-17-8							20,000 pCi/L	
uranium	7440-61-1	0.03		0.0592 NC	0.03				

---

[1] Alternative MCL of 4,000 pCi/L for states with radon abatement programs.

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
Organic Contaminants									
Phase-Separated Organic Liquids									
non-aqueous phase liquid		not present							
oil & grease & petroleum hydrocarbons							none noticeable		
Benzene and Substituted Benzenes									
benzene	71-43-2	~~0.01~~ 0.005	X	0.00454 C 0.0332 NC	0.005	0.003	0.0002/ 0.001	0.001 C	0.005
Alkylbenzenes									
toluene (methylbenzene)	108-88-3	~~0.75~~ 1	X	1.09 NC	1		0.6		0.8
ethylbenzene	100-41-4	~~0.75~~ 0.7	X	0.0150 C 0.8 NC	0.7	0.7	0.7		0.7
xylenes, total (dimethylbenzenes)	1330-20-7	0.62	X	0.193 NC	10		1		2
o-xylene	95-47-6			0.193 NC					
m-xylene	108-38-3			0.193 NC					
p-xylene				0.193 NC					
styrene (ethenylbenzene)	100-42-5	0.1	X	1.21 NC	0.1	0.1	0.1		0.1
alpha methyl styrene ((1-methylethenyl)benzene)	98-83-9			0.765 NC					
methyl styrene (mixture)				0.0373 NC					
trimethylbenzenes (1,2,4 and 1,3,5 combined)	95-63-6 and 108-67-8								0.48
cumene (isopropylbenzene)	98-82-8			0.447 NC			0.7		
Halogenated Benzenes and Toluenes									
bromobenzene	108-86-1				0.06				
monochlorobenzene	108-90-7		X	0.0776 NC	0.1	0.1	0.05		0.1
o-dichlorobenzene (1,2-dichlorobenzene)	95-50-1	0.6	X	0.302 NC	0.6	0.6	0.6		0.6
m-dichlorobenzene (1,3-dichlorobenzene)	541-73-1					0.6	0.6		0.6
p-dichlorobenzene (1,4-dichlorobenzene)	106-46-7	0.075	X	0.00482 C 0.563 NC	0.075	0.075	0.075	0.004 C	0.075

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
1,2,4-trichlorobenzene	120-82-1	0.07	X	0.0115 C 0.00398 NC	0.07	0.07	0.009		0.07
1,3,5-trichlorobenzene	108-70-3					0.04			
1,2,4,5-tetrachlorobenzene	95-94-3		X	0.00166 NC					
pentachlorobenzene	608-93-5		X	0.00307 NC					
hexachlorobenzene	118-74-1		X	0.0000976 C 0.016 NC	0.001		0.00002	0.00005 C	0.001
o-chlorotoluene	95-49-8			0.233 NC		0.1			
p-chlorotoluene	106-43-4					0.1			
p,α,α,α-tetrachlorotoluene	5216-25-1							4×10^{-6} C	
Phenols									
phenol	108-95-2		X	5.76 NC		2	2		2
phenols		0.005 S							
2-chlorophenol	95-57-8			0.091 NC		0.04	0.04		
2,4-dichlorophenol	120-83-2		X	0.0453 NC		0.02	0.02		
2,4-dimethylphenol	105-67-9			0.354 NC			0.1		
2,4,5-trichlorophenol	95-95-4		X	1.17 NC			0.7		
2,4,6-trichlorophenol	88-06-2		X	0.0411 C 0.0119 NC			0.001/ 0.02	0.004	
2,3,4,6-tetrachlorophenol	58-90-2						0.2		
pentachlorophenol	87-86-5	0.001	X	0.000413 C 0.0221 NC	0.001	0.04	0.0003		0.001
Other Substituted Benzenes									
aniline (aminobenzene)	62-53-3						0.006	0.014 C	
4-chloroaniline	106-47-8						0.03		
4-chloro-2-methylaniline	95-69-2							0.0001 C	
4-chloro-2-methylaniline hydrochloride	3165-93-3							0.0002 C	
2-methoxy-5-nitroaniline	99-59-2							0.002 C	
4,4’-methylene bis(N,N’-dimethyl) aniline	101-61-1							0.002 C	
2-methylaniline (o-toluidine)	95-53-4							0.0002 C	
2-methylaniline hydrochloride	636-21-5							0.0005 C	
benzoic acid (carboxybenzene)	65-85-0						30		
benzotrichloride ((trichloromethyl)benzene)	98-07-7							7×10^{-6} C	
benzyl alcohol (hydroxymethyl benzene)	100-51-6						2		

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
benzyl chloride (chloromethyl benzene)	100-44-7							0.0005 C	
2,4-toluenediamine (2,4-diaminotoluene)	95-80-7							2×10^{-6} C	
Methanes									
bromomethane (methyl bromide)	74-83-9		X	0.00754 NC		0.01	0.01		0.01
methylene bromide (dibromomethane)	74-95-3			0.008 NC					
chloromethane (methyl chloride)	74-87-3		X	0.0203 C 0.188 NC					0.03
methylene chloride (dichloromethane)	75-09-2	~~0.1~~ 0.005	X	0.118 C 0.106 NC	0.005	0.2	0.003	0.005 C	0.005
bromochloromethane	74-97-5					0.09			
"Total Trihalomethanes"					0.08				
dibromochloromethane	124-48-1			0.00168 C 0.378 NC		0.06	0.0004/ 0.001	0.0005 C	0.06
bromodichloromethane	75-27-4		X	0.00134 C 0.377 NC			0.0006/ 0.001	0.0003 C	0.0006
bromoform (tribromomethane)	75-25-2		X	0.0329 C 0.376 NC			0.004	0.005 C	0.0044
chloroform (trichloromethane)	67-66-3	0.1	X	0.00229 C 0.0972 NC		0.07	0.07	0.007 C	0.006
carbon tetrachloride (tetrachloromethane)	56-23-5	~~0.01~~ 0.005	X	0.00455 C 0.0492 NC	0.005	0.03	0.0004/ 0.001	0.0003 C	0.005
chlorodifluoromethane (fluorocarbon 22)	75-45-6			104 NC					7
dichlorodifluoromethane (fluorocarbon 12)	75-71-8		X	0.197 NC		1	1		1
trichlorofluoromethane (fluorocarbon 11)	75-69-4		X	1.14 NC		2	2		3.49
methanol (hydroxymethane)	67-56-1						4		5
formaldehyde (oxomethane)	50-00-0					1	0.1		1
Ethanes									
chloroethane (ethyl chloride)	75-00-3			20.9 NC					0.4
1,1-dichloroethane	75-34-3	0.01	X	0.0275 C 3.74 NC			0.05	0.001 C	0.85
1,2-dichloroethane (ethylene dichloride, EDC)	107-06-2	~~0.01~~ 0.005	X	0.00171 C 0.013 NC	0.005		0.0003/ 0.002	0.0005 C	0.005

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
1,1,1-trichloroethane (TCA)	71-55-6	~~0.06~~ 0.2	X	8 NC	0.2		0.03	0.2 P	0.2
1,1,2-trichloroethane	79-00-5	~~0.01~~ 0.005	X	0.00275 C 0.000415 NC	0.005	0.003	0.003		0.005
1,1,1,2-tetrachloroethane	630-20-6			0.00574 C 0.477 NC		0.07	0.001		0.07
1,1,2,2-tetrachloroethane	79-34-5	0.01	X	0.000757 C 0.36 NC			0.001		0.0002
hexachloroethane	67-72-1		X	0.00328 C 0.00614 NC		0.001	0.002/ 0.007		
1,2-dibromoethane (ethylene dibromide, EDB)	106-93-4	~~0.0001~~ 0.00005	X	0.0000747 C 0.0169 NC	0.00005		4×10^{-7}/ 0.00003	1×10^{-6} C	0.00005
1-chloro-1,1-difluoroethane (fluorocarbon 142b)	75-68-3			104 NC					
1,1,2-trichloro-1,2,2-trifluoroethane (fluorocarbon 113)	76-13-1			55 NC					
Ethenes									
chloroethene (vinyl chloride)	75-01-4	~~0.001~~ 0.002	X	0.000324 C 0.0443 NC	0.002		0.00008/ 0.001	0.00002 C	0.0002
1,1-dichloroethene	75-35-4	~~0.005~~ 0.007	X	0.284 NC	0.007	0.4	0.001		0.007
cis-1,2-dichloroethene	156-59-2	0.07	X	0.0365 NC	0.07	0.01	0.07		0.07
trans-1,2-dichloroethene	156-60-5	0.1	X	0.0932 NC	0.1	0.1	0.1		0.1
trichloroethene (TCE)	79-01-6	~~0.1~~ 0.005	X	0.00259 C 0.00282 NC	0.005		0.001	0.003 C	0.005
tetrachloroethene (PCE)	127-18-4	~~0.02~~ 0.005	X	0.113 C 0.0403 NC	0.005	0.01	0.0004/ 0.001	0.0008 C	0.005
bromoethene (vinyl bromide)	593-60-2			0.00175 C 0.00626 NC					
Propanes/Propenes									
acetone (2-propanone)	67-64-1			14.1 NC			6		9,000
2-chloropropane	75-29-6			0.209 NC					
1,2-dibromo-3-chloropropane (DBCP)	96-12-8			3.34×10^{-6} C 0.000372 NC			0.00002		0.0002
1,2-dichloropropane (propylene dichloride, PDC)	78-87-5	0.005	X	0.00438 C 0.0083 NC	0.005		0.0005/ 0.001	0.0006 C	0.005
1,3-dichloropropene (cis/trans)	10061-01-5 542-75-6		X	0.00471 C 0.0388 NC			0.0004	0.0002 C	0.0004
1,1,2-trichloropropane	598-77-6			0.0881 NC					

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
1,2,3-trichloropropane	96-18-4			8.35 x 10^{-6} C 0.00062 NC			5 x 10^{-6}/ 0.00003		0.06
Butanes									
n-butanol (n-butyl alcohol)	71-36-3						0.7		
1-chlorobutane (butyl chloride)	109-69-3			0.631 NC					
methyl ethyl ketone (MEK, 2-butanone)	78-93-3			5.56 NC		4	0.3		4
Chloroalkyl Ethers									
bis (2-chloroethyl) ether	111-44-4		X	0.000137 C		0.3	0.00003/ 0.007	0.00007 C	
bis (2-chloroisopropyl) ether	39638-32-9		X	0.00981 C			0.3		
bis (chloromethyl) ether	542-88-1		X	7.2 x 10^{-7} C				4 x 10^{-7} C	
Halo Acetic Acids ("HAA5")					0.06				
bromoacetic acid	631-64-1								
chloroacetic acid	79-11-8					0.07			
dibromoacetic acid	631-64-1								
dichloroacetic acid	79-43-6					0.03			
trichloroacetic acid	76-03-9					0.02			
Nitroaromatics and High Explosives									
nitrobenzene	98-95-3		X	0.0014 C 0.0125 NC			0.004/ 0.006		
1,3-dinitrobenzene	99-65-0					0.001			
o-chloronitrobenzene (2-chloronitrobenzene)	88-73-3			0.00236 C 0.0549 NC				0.003 C	
p-chloronitrobenzene (4-chloronitrobenzene)	100-00-5			0.11 C 0.0179 NC				0.003 C	
2-nitrotoluene (o-nitrotoluene)	88-72-2			0.00313 C 0.0161 NC					
3-nitrotoluene (m-nitrotoluene)	99-08-1			0.00174 NC					
4-nitrotoluene (p-nitrotoluene)	99-99-0			0.0427 C 0.0707 NC					
2,4-dinitrotoluene (2,4-DNT)	121-14-2		X	0.00237 C 0.038 NC				0.0001 C	0.00005

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
2,6-dinitrotoluene (2,6-DNT)	606-20-2		X	0.000485 C 0.00564 NC				0.0001 C	0.00005
2,4-DNT plus 2,6-DNT				0.00106 C			0.00005/ 0.01		
dinitrotoluene, total residues[2]									0.00005
octrahydro-1,3,5,7-tetranitro-1,3,5,7 tetrazocine (HMX)	2691-41-0		X	1 NC		0.4			
hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4		X	0.00702 C 0.0597 NC		0.002			
2,4,6-trinitrotoluene (TNT)	118-96-7		X	0.0253 C 0.0098 NC		0.002			
2,4-dinitro-o-cresol (4,6-dinitro-o-cresol)	534-52-1		X	0.00152 NC					
p-nitrophenol	100-02-7					0.06			
dinitrophenols			X						
2,4-dinitrophenol	51-28-5			0.0387 NC			0.01/ 0.04		
Nitroglycerin (trinitroglycerol)	55-63-0			0.0447 C 0.00196 NC		0.005			
nitroguanidine	556-88-7					0.7			
tetryl (trinitrophenylmethylnitramine)	479-45-8			0.0394 NC					
Nitrosamines									
N-nitrosodibutylamine	924-16-3		X	0.0000273 C				0.00002 C	
N-nitrosodiethanolamine	1116-54-7							0.00003 C	
N-nitrosodiethylamine	55-18-5		X	1.67 x 10^{-6} C				5 x 10^{-7} C	
N-nitrosodimethylamine	62-75-9		X	4.91 x 10^{-6} C 0.00016 NC			7 x 10^{-7} 0.0008	2 x 10^{-6} C	
N-nitrosodiphenylamine	86-30-6		X	0.122 C			0.007 0.01	0.017 C	
N-nitrosodipropylamine	621-64-7						5 x 10^{-6} 0.01	0.00001 C	
N-nitrosoethylmethylamine	10595-95-6							4 x 10^{-6} C	
N-nitrosopyrrolidine	930-55-2		X	0.00037 C				0.00037 C	

---

[2] Includes dinitrotoluene (DNT) isomers 2,3-DNT, 2,4-DNT, 2,5-DNT, 2,6_DNT, 3,4-DNT and 3,5_DNT

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
Perfluorinated Chemicals (PFCs)				0.00007 NC					
perfluorohexane sulfonic acid (PFHxS)	355-46-4		X						
perfluorooctane sulfonate (PFOS)	45298-90-6		X	0.00007 NC		0.00007			
perfluorooctanoic acid (PFOA)	335-67-1		X	0.00007 NC					
PFOA and PFOS individually or combined									
Pesticides									
acetochlor	34256-82-1								0.007
acetochlor ethane sulfonic acid plus oxanilic acid									0.23
alachlor	15972-60-8			0.000137 C 0.186 NC	0.002		0.0004		0.002
alachlor ethane sulfonic acid									0.02
aldicarb	116-06-3				0.003	0.007			0.01
aldicarb sulfone	1646-88-4				0.002	0.007	0.007		
aldicarb sulfoxide	1646-87-3				0.004	0.007			
aldrin	309-00-2		X	1.98 X 10^{-6} C 3.31 X 10^{-5} NC			2 x 10^{-6}/ 0.00004	0.000005 C	
ametryn	834-12-8					0.06			
ammonium sulfamate	7773-06-0					2			
aramite	140-57-8							0.003 C	
atrazine	1912-24-9	0.003	X	0.00339 C 0.702 NC	0.003		0.003		0.003[3]
baygon	114-26-1					0.003			
bentazon	25057-89-0					0.2			0.3
bromacil	314-40-9					0.07			
butylate	2008-41-5					0.4			0.4
carbaryl	63-25-2								0.04
carbofuran	1563-66-2			0.0936 NC	0.04		0.04		0.04
carbon disulfide	75-15-0			0.81 NC			0.7		1
carboxin	5234-68-4					0.07			
chloramben	133-90-4					0.1			0.15
chlordane	12789-03-6		X	0.000448 C 0.00127 NC	0.002	0.004	0.00001/ 0.0005	0.00006 C	0.002
chlorothalonil	1897-45-6							0.03 C	

---

[3] Atrazine plus total chlorinated residues

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
chlorpyrifos	2921-88-2					0.002	0.02		0.002
cyanazine	21725-46-2					0.001			0.001
DDD	72-54-8			0.000317 C			0.0001		
DDE	72-55-9			0.000462 C			0.0001		
DDT	50-29-3		X	0.00229 C 0.01 NC			0.0001		
DDD, DDE Plus DDT								0.0003 C	
Dacthal (DCPA)	1861-32-1					0.07			0.07
dalapon	75-99-0				0.2	0.2	0.2		
demeton	8065-48-3						0.0003/ 0.001		
diallate	2303-16-4							0.001 C	
diazinon	333-41-5					0.001			
1,2-dibromo-3-chloropropane (DBCP)	96-12-8				0.0002				
dicamba	1918-00-9					4			0.3
(2,4-dichlorophenoxy)acetic acid (2,4-D)	94-75-7				0.07		0.07	0.1 P	0.07
dichlorvos	62-73-7							0.0003 C	
dieldrin	60-57-1		X	0.0000175 C 0.000372 NC			2 x 10^{-6}/ 0.00003	5 x 10^{-6} C	
dimethenamid/ dimethenamid-P	957-51-7								0.05
dimethoate	60-51-5								0.002
dimethrin	70-38-2					2			
dinoseb	88-85-7				0.007	0.007	0.007		0.007
diphenamid	957-51-7					0.2			
diquat	2764-72-9				0.02		0.02		
disulfoton	298-04-4					0.0007			
endosulfan, mixed isomers	115-29-7		X	0.0987 NC			0.04		
endosulfan, alpha	959-98-8						0.04		
endosulfan, beta	33213-65-9						0.04		
endosulfan sulfate	1031-07-8						0.04		
endothall	145-73-3				0.1	0.05	0.1		
endrin	72-20-8		X	0.00223 NC	0.002	0.002	0.002	0.002 P	0.002
ethion	563-12-2						0.004		
S-ethyl dipropylthiocarbamate (EPTC)	759-94-4								0.25
ethylene thiourea	96-45-7							0.002 C	
fenamiphos	22224-92-6					0.0007			
fluometuron	2164-17-2					0.09			

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
folpet	133-07-3							0.02 C	
fonofos	944-22-9					0.01			
furmecyclox	60568-05-0							0.003 C	
glyphosate	1071-83-6			2.01 NC	0.7		0.7		
heptachlor	76-44-8		X	0.0000221 C 0.00272 NC	0.0004		8 x 10^{-6}/ 0.00005	0.00002 C	0.0004
heptachlor epoxide	1024-57-3				0.0002		4 x 10^{-6}/ 0.0002	9 x 10^{-9} C	0.0002
hexazinone	51235-04-2					0.4			
hexachlorocyclohexane (HCH, lindane)	58-89-9		X	0.000415 C 0.0036 NC	0.0002		0.00003	0.00006 C	0.0002
alpha-HCH	319-84-6		X	6.93 X 10^{-5} C 0.0918 NC			6 x 10^{-6}/ 0.00002	1 x 10^{-6} C	
beta-HCH	319-85-7		X	0.000243 C			0.00002/ 0.00004		
gamma-HCH	58-89-9		X				0.00003		
technical HCH			X					0.00005 C	
hexachlorocyclopentadiene	77-47-4		X	0.000411 NC	0.05		0.04		
malathion	121-75-5					0.5	0.1		
methoxychlor	72-43-5				0.04	0.04	0.04	0.1 P	0.04
2-methyl-4-chlorophenoxyacetic acid (MCPA)	94-74-6					0.03			
methomyl	16752-77-5			0.498 NC		0.2			
metolachlor	51218-45-2					0.7			0.1
metolachlor ethane sulfonic acid plus oxanilic acid									1.3
metribuzin	21087-64-9					0.07			0.07
mirex	2385-85-5						0.0001	0.00005 C	
oxamyl (vydate)	23135-22-0				0.2		0.2		
paraquat	1910-42-5					0.03			
Parathion (ethyl)	56-38-2						0.004		
methyl parathion	298-00-0					0.001			
picloram	1918-02-1				0.5		0.5		0.5
prometon	1610-18-0		X			0.4			0.1
propazine	139-40-2					0.01			0.01
propham	122-42-9					0.1			
simazine	122-34-9			0.00607 C 0.094 NC	0.004		0.0003/ 0.0008		0.004
tebuthiuron	34014-18-1					0.5			
terbacil	5902-51-2					0.09			
terbufos	13071-79-9					0.0004			

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
toxaphene	8001-35-2		X	0.000158 C	0.003		0.00003/ 0.002	0.00002 C	0.003
2-(2,4,5-trichlorophenoxy) acetic acid (2,4,5-T)	93-76-5					0.07			
2-(2,4,5-trichlorophenoxy) propionic acid (2,4,5-TP; silvex)	93-72-1				0.05	0.05	0.06	0.01 P	0.05
trifluralin	1582-09-8					0.01			0.0075
Phthalates									
butylbenzyl phthalate	85-68-7						0.1		
dibutyl phthalate	84-74-2		X	0.885 NC			0.7		1
di-2-ethylhexyl phthalate (DEHP; bis(2-ethylhexyl)phthalate)	117-81-7		X	0.0556 C 0.401 NC	0.006		0.002/ 0.003	0.006 C	0.006
diethyl phthalate (DEP)	84-66-2		X	14.8 NC			6		
diisodecyl phthalate (DIDP)	26761-40-0						0.1		
dimethyl phthalate (DMP)	131-11-3		X	0.612 NC					
di-n-octyl phthalate	117-84-0						0.1		
Polycyclic Compounds									
azobenzene	103-33-3							0.007 C	
benzidine	92-87-5		X	1.09 x 10^{-6} C 0.0589 NC			2 x 10^{-7}/ 0.02	4 x 10^{-7} C	
dichlorobenzidine	1331-47-1		X						
3,3’-dichlorobenzidine	91-94-1			0.00125 C			0.00008/ 0.03	0.0002 C	
3,3’-dimethoxybenzidine	119-90-4							0.006 C	
3,3’-dimethylbenzidine	119-93-7							7 x 10^{-6} C	
direct black 38[4]	1937-37-7							9 x 10^{-6} C	
direct blue 6[5]	2602-46-2							9 x 10^{-6} C	
direct brown 95[6]	16071-86-6							9 x 10^{-6} C	
1,1’-biphenyl	92-52-4			0.0371 C 0.000834 NC			0.4		

---

[4] disodium;(6Z)-4-amino-3-[[4-[4[(2,4diaminophenyl)diazenyl]phenyl]phenyl]diazenyl]-5-oxo-6-(phenylhydrazinylidene)naphthalene-2,7-disulfonate

[5] tetrasodium;(3E)-5-amino-3-[[4-[4-[(2Z)-2-(8-amino-1-oxo-3,6-disulfonatonaphthalen-2-ylidene)hydrazinyl]phenyl]phenyl]hydrazinylidene]-4-oxonaphthalene-2,7-disulfonate

[6] copper;disodium;2-oxido-5-[[4-[4-[(2E)-2-[(5E)-5-[(2-oxido-5-sulfonatophenyl)hydrazinylidene]-2,6-dioxocyclohex-3-en-1-ylidene]hydrazinyl]phenyl]phenyl]diazenyl]benzoate

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
carbazole	86-74-8							0.005 C	
diphenylamine (4-amino-o-xylene)	95-64-7						0.2		
Polybrominated biphenyls (PBBs)	67774-32-7						4 x 10^{-6}	0.00001 C	
Polychlorinated Biphenyls (PCBs)	1336-36-3	~~0.001~~ 0.0005	X		0.0005		0.00002/ 0.0005	0.00001 C	0.00003
aroclor 1016				0.00224 C 0.0014 NC					
aroclor 1221				0.0000561 C					
aroclor 1232				0.0000561 C					
aroclor 1242				0.0000768 C					
aroclor 1248				0.0000768 C					
aroclor 1254				0.0000768 C 0.000401 NC					
aroclor 1260				0.0000768 C					
1,1'-biphenyl, 2,2',3,3',4,4',5-heptachloro- (PCB 170)	35065-30-6			0.0000599 C 0.000401 NC					
1,1'-biphenyl, 2,2',3,4,4',5,5'-heptachloro- (PCB 180)	35065-29-3			0.000599 C 0.0014 NC					
1,1'-biphenyl, 2,3,3',4,4',5,5'-heptachloro- (PCB 189)	39635-31-9			0.0000395 C 0.00401 NC					
1,1'-biphenyl, 2,3',4,4',5,5'-hexachloro- (PCB 167)	52663-72-6			0.0000395 C 0.00401 NC					
1,1'-biphenyl, 2,3,3',4,4',5'-hexachloro- (PCB 157)	69782-90-7			0.0000395 C 0.00401 NC					
1,1'-biphenyl, 2,3,3',4,4',5-hexachloro- (PCB 156)	38380-08-4			0.0000395 C 0.00401 NC					
1,1'-biphenyl, 3,3',4,4',5,5'-hexachloro- (PCB 169)	32774-16-6			3.95 x 10^{-8} C 4.01 X 10^{-7} NC					
1,1'-biphenyl, 2,3',4,4',5'-pentachloro- (PCB 123)	65510-44-3			0.0000395 C 0.00401 NC					
1,1'-biphenyl, 2,3',4,4',5-pentachloro- (PCB 118)	31508-00-6			0.0000395 C 0.00401 NC					
1,1'-biphenyl, 2,3,3',4,4'-pentachloro- (PCB 105)	32598-14-4			0.0000395 C 0.00401 NC					
1,1'-biphenyl, 2,3,4,4',5-pentachloro- (PCB 114)	74472-37-0			0.0000395 C 0.00401 NC					
1,1'-biphenyl, 3,3',4,4',5-pentachloro- (PCB 126)	57465-28-8			1.19 x 10^{-8} C 1.2 X 10^{-7} NC					

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
1,1'-biphenyl, 3,3',4,4'-tetrachloro- (PCB 77)	32598-13-3			0.0000599 C 0.000401 NC					
1,1'-biphenyl, 3,4,4',5-tetrachloro- (PCB 81)	70362-50-4			3.95 X 10^{-6} C 4.01 X 10^{-5} NC					
Polynuclear Aromatic Hydrocarbons (PAHs)								0.00001 C	
acenaphthene	83-32-9			0.535 NC			0.4		
anthracene	120-12-7		X	1.72 NC			2		3
benzo(a)anthracene (tetraphene)	56-55-3			0.00012 C			0.00005/ 0.0001		
benzo(b)fluoranthene (3,4-benzofluoranthene)	205-99-2			0.000343 C			0.00005/ 0.0002		0.0002
benzo(k)fluoranthene	207-08-9		X	0.00343 C			0.0005		
benzo(a)phenanthrene (chrysene)	218-01-9			0.0343 C			0.005		0.0002
benzo(a)pyrene	50-32-8	~~0.0007~~ 0.0002	X	0.0000251 C 0.00602 NC	0.0002		5 x 10^{-6}/ 0.0001	8 x 10^{-6} C	0.0002
dibenz(a,h)anthracene	53-70-3			0.0000343 C			5 x 10^{-6}/ 0.0003		
fluoranthene	206-44-0		X	0.802 NC			0.3		0.4
fluorene	86-73-7		X	0.288 NC			0.3		0.4
indeno(1,2,3-c,d)pyrene	193-39-5			0.000343 C			0.00005/ 0.0002		
naphthalene	91-20-3	0.03	X	0.00165 C 0.00611 NC		0.1	0.3		0.1
1-methylnaphthalene	90-12-0		X	0.0114 C 0.611 NC					
2-methylnaphthalene	91-57-6		X	0.0351 NC					
naphthalene plus monomethylnaphthalenes									
b-chloronaphthalene (2-chloronaphthalene)	91-58-7			0.733 NC			0.6		
phenanthrene	85-01-8		X	0.17 NC					
pyrene	129-00-0		X	0.117 NC			0.2		0.25
Other Organics									
acetaldehyde	75-07-0			0.0255 C 0.0188 NC					
Acetophenone	98-86-2			1.92 NC			0.7		

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
acrolein	107-02-8		X	0.0000415 NC			0.004/ 0.005		
acrylamide	79-06-1				tt		8×10^{-6}/ 0.0002	0.00002 C	
acrylonitrile (vinyl cyanide)	107-13-1		X	0.000523 C 0.00415 NC			0.00006/ 0.002	0.00007 C	
methacrylonitrile	126-98-7			0.00191 NC					
1,3-butadiene	106-99-0			0.00018 C 0.00417 NC					
2-chloro-1,3-butadiene	126-99-8			0.000187 C 0.037 NC					
hexachloro-1,3-butadiene	87-68-3		X	0.00139 C 0.0063 NC			0.0004/ 0.001		
camphor	76-22-2						1		
crotonaldehyde	123-73-9			0.000404 C 0.0198 NC					
dicyclopentadiene	77-73-6			0.000625 NC					
1,4-dichloro-2-butene				0.0000134 C					
di(2-ethylhexyl) adipate	103-23-1				0.4	0.4	0.03		
diisopropyl ether (DIPE)	108-20-3						20		
1,4-dioxane (p-dioxane)	123-91-1		X	0.00459 C 0.0567 NC		0.2		0.007 C	0.003
dioxins and furans, chloro dibenzo-p-									
hexachlorodibenzo-p-dioxin, mix								1×10^{-8} C	
2,3,7,8-tetrachlorodibenzo-p-dioxin (dioxin; 2,3,7,8-TCDD)	1746-01-6			1.19×10^{-6} C 1.2×10^{-5} NC	3×10^{-8}		2×10^{-7} 0.00001	6×10^{-10} C	3×10^{-8}
2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF)	51207-31-9			1.84×10^{-6} C					
1,4-dithiane	505-29-3					0.08			
epichlorohydrin	106-89-8			0.0292 C 0.00205 NC	tt		0.004/ 0.005	0.008 C	
ethyl acetate	141-78-6			0.145 NC			6		
ethyl acrylate	140-88-5			0.0157 C				0.002 C	
ethylene glycol (ethane-1,2-diol)	107-21-1					14	0.3		14
ethylene glycol monomethyl ether	109-86-4						0.007/ 20		

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
ethylene oxide	75-21-8			0.0000186 C 0.0626 NC					
ethyl ether (ethoxyethane)	60-29-7			3.93 NC			1		1
ethyl methacrylate	97-63-2			0.455 NC					
foaming agents (ABS/LAS)						0.5	0.5	0.5 S	
furan	110-00-9			0.0192 NC					
furazolidone	67-45-8							0.00002 C	
furium	531-82-8							2×10^{-6} C	
n-hexane	110-54-3			0.319 NC			0.03		0.6
hydrazine (anhydrous & sulfate)	302-01-2			0.000011 C 0.000026 NC				0.00003 C	
hydrazine, 1,2-dimethyl	540-73-8							0.06 C	
hydrazine, 1,2-diphenyl	122-66-7		X	0.00078 C			0.00004/ 0.02	0.00009 C	
isobutanol (isobutyl alcohol)	78-83-1			5.91 NC					
isophorone	78-59-1		X	0.781 C 3.83 NC		0.1	0.04		
maleic hydrazide	123-33-1			10 NC		4			
methyl acetate	79-20-9			19.9 NC			7		
methyl acrylate	96-33-3			0.039 NC					
methyl cyclohexane	108-87-2			6.26 NC					
methyl isobutyl ketone (MIBK)	108-10-1			1.24 NC					0.5
methyl methacrylate	80-62-6			1.39 NC					
methylphosphonate, diisopropyl	1445-75-6					0.6			
methylphosphonate, dimethyl	756-79-6					0.1			
methylphosphonate, isopropyl	1832-54-8					0.7			
methyl salicylate	119-36-8						4		
methyl tert-butyl ether (MTBE)	1634-04-4	0.01 S	X	0.143 C 6.26 NC			0.07		0.06
nitrofurazone	59-87-0							0.00006 C	
o-phenylenediamine	95-54-5							5×10^{-6} C	
propylene oxide	75-56-9			0.00266 C 0.0626 NC				0.00001 C	
pyridine	110-86-1								0.01
salicylic acid	69-72-7						0.08		
sulfolane (thiolane 1,1-dioxide)	126-33-0		X	0.02 NC					
tertiary butyl alcohol (TBA)	75-65-0						0.1		0.012
tetrahydrofuran	109-99-9						0.01		0.05
triethylamine	121-44-8			0.0146 NC					

Parameter All units are milligrams per liter unless otherwise specified.	**CAS #**	**WQCC Groundwater Standard**	**WQCC Toxic Pollutant**	**NMED Tap Water Screening Level**	**EPA Drinking Water MCL**	**EPA Lifetime Health Advisory**	**New Jersey Groundwater Criteria/ PQL**	**Washington Groundwater Criteria**	**Wisconsin Public Health Groundwater Standard**
trimethyl phosphate	512-56-1							0.002 C	
vinyl acetate	108-05-4			0.409 NC			7		
Drinking Water Contaminants that Can Originate from Plumbing Materials									
asbestos					7 x 10^6 fpl		7 x 10^6 fpl		7 x 10^6 fpl
copper	7440-50-8	1.0 S		0.79 NC	1.3 tt 1.0 S		1.3	1 S	1.3
epichlorohydrin	106-89-8			0.0292 C 0.00205 NC	tt		0.004/ 0.005	0.008 C	
iron	7439-89-6	1.0 S		13.8 NC	0.3 S		0.3	0.3 S	
lead	7439-92-1	~~0.05~~ 0.015			0.015 tt		0.005	0.05 P	0.015
Drinking Water Contaminants that Can Originate from Disinfectants or Disinfectant By-Products									
bromate	15541-45-4				0.01				
chloramine	10599-90-3				4	3			
chlorine	7782-50-5				4	4			
chlorine dioxide	10049-04-4				0.8	0.8			
chlorite	14998-27-7				1	0.8			
"Total Trihalomethanes"					0.08				
dibromochloromethane	124-48-1			0.00168 C 0.378 NC		0.06	0.0004/ 0.001	0.0005 C	0.06
bromodichloromethane	75-27-4		X	0.00134 C 0.377 NC			0.0006/ 0.001	0.0003 C	0.0006
bromoform (tribromomethane)	75-25-2		X	0.0329 C 0.376 NC			0.004	0.005 C	0.0044
chloroform (trichloromethane)	67-66-3	0.1	X	0.00229 C 0.0972 NC		0.07	0.07	0.007 C	0.006
Halo Acetic Acids ("HAA5")					0.06				
bromoacetic acid	631-64-1								
chloroacetic acid	79-11-8					0.07			
dibromoacetic acid	631-64-1								
dichloroacetic acid	79-43-6					0.03			
trichloroacetic acid	76-03-9					0.02			

Pesticide Monitoring of Groundwater in New Mexico

Dennis McQuillan, New Mexico Environment Department
Joe Martinez, New Mexico Environment Department
Jacob Kruse, New Mexico Department of Agriculture

September 1, 2017

Abstract

The potential for agricultural and non-agricultural pesticides to contaminate groundwater has long been of concern in the United States and in New Mexico. Pesticides, and their degradation byproducts, have varying degrees of subsurface mobility, persistence, and potential concern for drinking water quality. Decades of monitoring by multiple organizations, including analyses for 195 pesticides and degradates, have detected 30 pesticide compounds (15%) in groundwater among 20 counties in New Mexico. Atrazine, 2,4-D, pentachlorophenol (PCP), and Prometon were the most frequently detected pesticides statewide. Most agricultural herbicide detections occurred in Curry and Doña Ana Counties, both of which have major agricultural productivity. Most non-agricultural herbicide detections occurred in Bernalillo and Doña Ana Counties where Albuquerque and Las Cruces, the two largest metropolitan areas of the state are located, respectively. Most insecticide detections occurred in Bernalillo, Curry and Doña Ana Counties. Many pesticides, however, were detected at concentrations less than 1 µg/L. Only four pesticides and degradates (grain fumigant carbon tetrachloride and degradates chloroform and methylene chloride, and non-agricultural insecticide PCP) were detected at concentrations exceeding human-health standards, advisories, or screening levels.

Introduction

The potential for agricultural and non-agricultural pesticides to contaminate groundwater has long been of concern in the United States and in New Mexico (Figure 1). Pesticides have varying degrees of subsurface mobility, persistence, and potential public health concern if detected in drinking water. Once released into the environment, pesticides are sometimes transformed over time by a variety of chemical, photochemical, and biologically mediated reactions into other compounds known as degradates. These reactions can include hydrolysis, biodegradation, photolysis, oxidation, hydroxylation, dealkylation, dechlorination, and epoxidation. Examples of pesticides that have been observed to degrade in natural environments are summarized in Table 1, along with known degradates. Specific atrazine transformation reactions, for example, are shown in Figure 2. Some pesticides and/or their degradates are still detectable in soil and groundwater even though use of the pesticide was discontinued decades ago.

Over the past few decades, multiple organizations have tested numerous well-water samples in New Mexico for pesticides. The purpose of this report is to compile and summarize reported pesticide detections in New Mexico groundwater, including detections of pesticide degradates.

Pesticide Monitoring

EPA conducted a National Survey of Pesticides in Drinking Water Wells during 1988-90 (EPA, 1990, 1992). EPA sampled 1300 community water system wells and rural domestic wells nationwide for 101 pesticides, 25 pesticide degradates, and nitrate. Twelve of the 126 pesticides and degradates (10%) were detected in the survey. DCPA acid metabolites and atrazine were detected most frequently. Other pesticides detected in well water included alachlor, bentazon, DBCP, dinoseb, EDB, ethylene thiourea (ETU), hexachlorobenzene, gamma-HCH (Lindane), prometon and simazine. Pesticide concentrations did not exceed EPA Maximum Contaminant Levels (MCLs) or Health Advisories (HAs) in any community water wells tested. Concentrations of alachlor, atrazine, DBCP, EDB, and gamma-HCH (Lindane), however, did exceed MCLs and HAs in some rural domestic wells.

USGS, during the first decade of its National Water Quality Assessment (NAWQA) program, tested for pesticides in groundwater samples collected from 5,047 wells in the nation (Gilliom and others, 2007). Most of these groundwater samples were analyzed for 75 pesticides and 8 pesticide degradates. USGS found that the most prevalent pesticides detected in both agricultural and urban groundwater were the herbicides atrazine (and degradate deethylatrazine), metolachlor, prometon, and simazine (Figure 3). USGS also has detected pesticides in New Mexico groundwater in regional NAWQA studies that include portions of New Mexico (Anderholm, 2002; Anderholm and others, 1995; Bexfield and Anderholm, 1997; Bexfield and others, 2011; Fahlquist, 2003; Gurdak and others, 2009; Levings and others, 1998; Paul and others, 2007; Thiros and others, 2014).

Pursuant to the federal Safe Drinking Water Act (SDWA), EPA has established Maximum Contaminant Levels, Health Advisories, and monitoring requirements for pesticides in public drinking water systems. EPA has granted the NM Environment Department (NMED) primacy to administer the requirements of the SDWA in New Mexico. The NMED Drinking Water Bureau oversees the testing requirements for approximately 1,095 public water supply systems in New Mexico, and maintains the *Drinking Water Watch* online data base (NMED, 2017) of test results. Some of the 79 pesticides that are periodically analyzed in drinking water samples have occasionally been detected in public water systems that are supplied by groundwater. Public water systems in New Mexico also have been tested for a number of pesticides pursuant to the Unregulated Contaminant Monitoring Rule established by EPA.

The pesticide compounds analyzed by EPA (1990), by NMED (2017), and by the various USGS investigations are compared in Appendix A. Pesticides also have been detected in New Mexico groundwater during investigations conducted by Bowman and Hendrickx (1998), Intera (1997), McQuillan and others (1998), and Stephens (1996). Between the monitoring programs of EPA, NMED Drinking Water Bureau, and the USGS (Appendix A), and site specific investigations, groundwater in New Mexico has been tested for 195 pesticides, and pesticide breakdown products (Table 2; Appendix A).

Table 1. Examples of Pesticide Degradates. (Anderholm, 2002; Bexfield and others 2011; EPA, 1990, 1992; Fernandez-Ramos and others, 2014; Gilliom and others, 2007; Gurdak and others, 2009; Levings and others, 1998; and others, 2007; Roberts, and others 1998, 1999; Scribner and others, 2004; Thiros and others, 2014)

Pesticide	**Degradate(s)**
Acetochlor	Acetochlor ethane sulfonic acid, Acetochlor oxanilic acid, Acetochlor sulfinyl acetic acid
Alachlor	Alachlor oxanilic acid, Alachlor sulfinyl acetic acid, Alachlor ethanesulfonic acid, 2,4-diethylaniline, 2,6-diethylaniline
Aldicarb	Aldicarb sulfoxide, Aldicarb sulfone
Aldrin	Dieldrin
Atrazine	deethylatrazine, deisopropyl atrazine, hydroxyatrazine
Carbaryl	1-naphthol
Carbofuran	3-hydroxycarbofuran
Carbon tetrachloride	chloroform, methylene chloride, methyl chloride
Chlordane	oxychlordane
Dacthal (DCPA)	monomethyl tetrachloroterephthalic acid (MTP), tetrachloroterephthalic acid (TPA)
DDT	DDD*, DDE
Dimethenamid	Dimethenamid ethanesulfonic acid, Dimethenamid oxanilic acid
Endrin	Endrin aldehyde, Endrin ketone
Heptachlor	Heptachlor expoxide
HCH, gamma (Lindane)	alpha HCH, delta HCH
Metolachlor	Metolachlor ethanesulfonic acid, Metolachlor oxanilic acid
Monuron	N-(4-chlorophenyl)-N'-methylurea
Pentachlorophenol	pentachloroanisole
Prometon	deisopropylprometon, hydroxyprometon

*DDD was an ingredient of DDT products, and is also a potential DDT degradate.

Figure 1. Conceptual model of major natural and human factors affecting the vulnerability of Southwestern basin-fill aquifers to contamination with pesticide compounds. From Bexfield and others (2011).

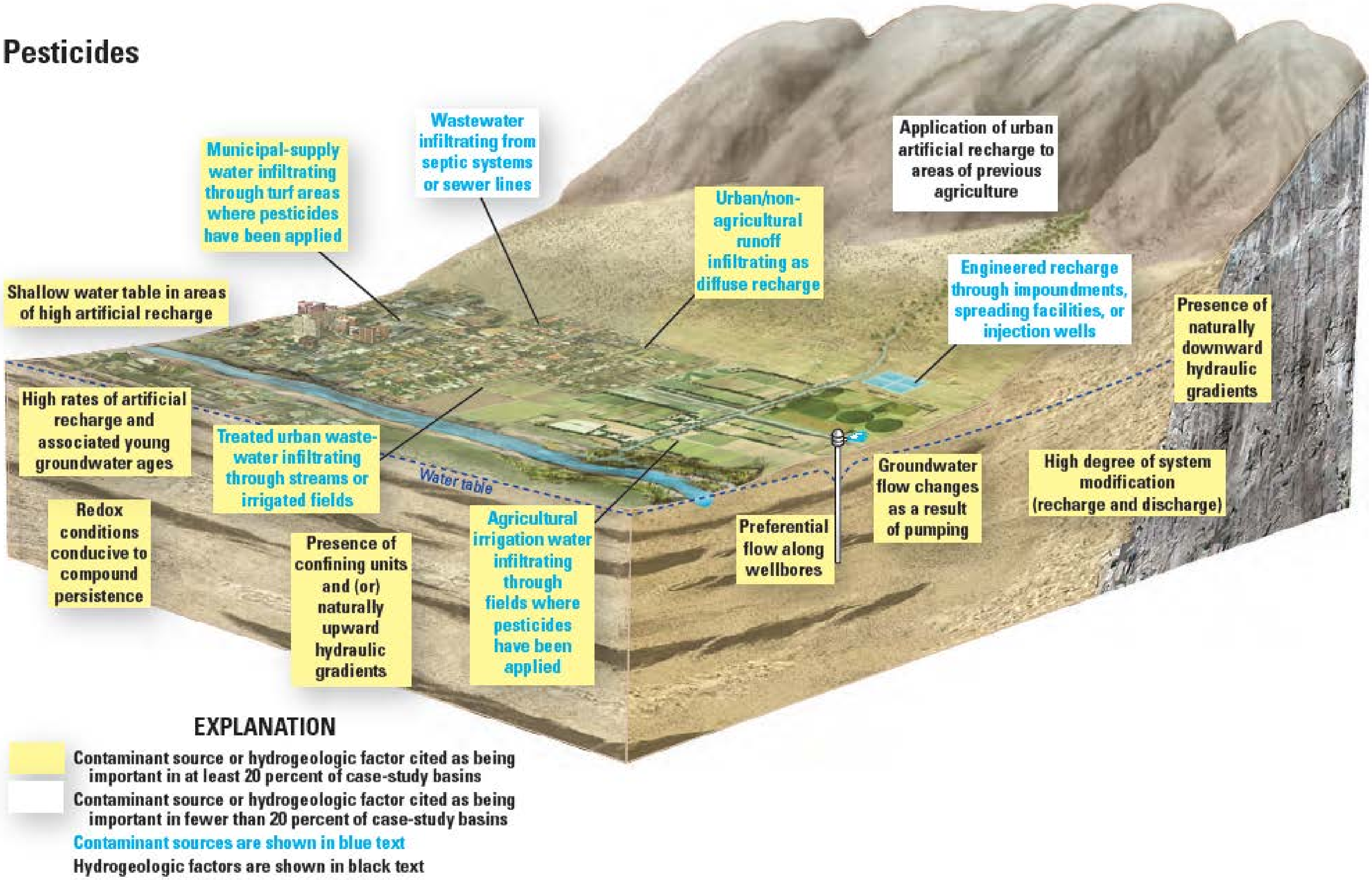


Figure 2. Atrazine transformation reactions observed in natural environments. (From Paul and others, 2007).

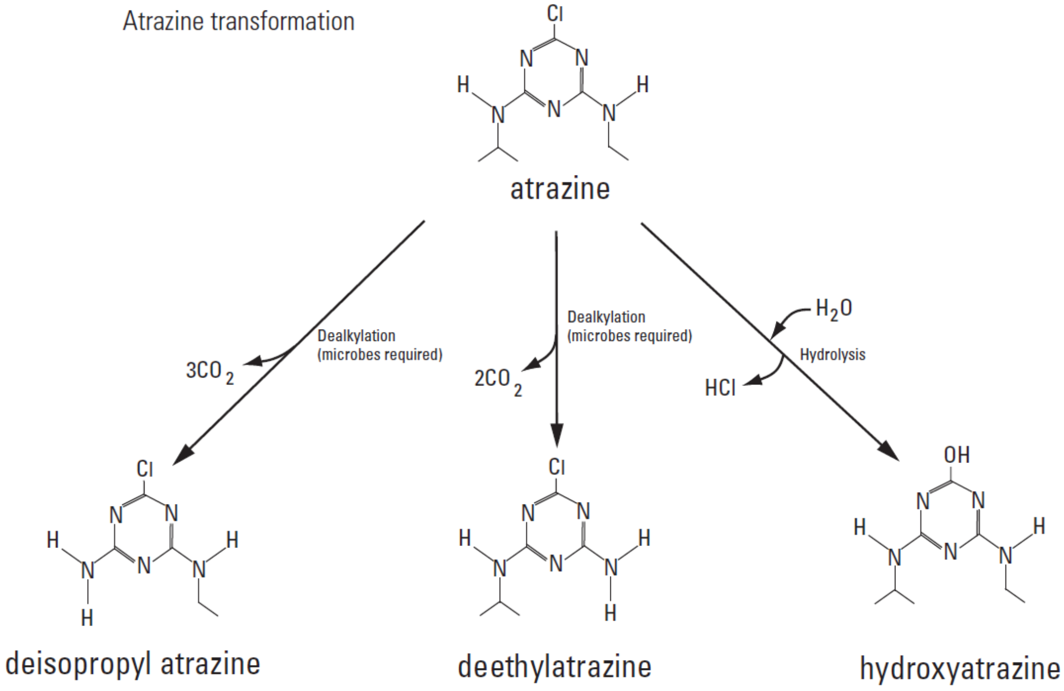


Figure 3. Pesticides most frequently detected in groundwater in the United States during the first decade of the USGS NAWQA Program. From Gilliom and others (2007).

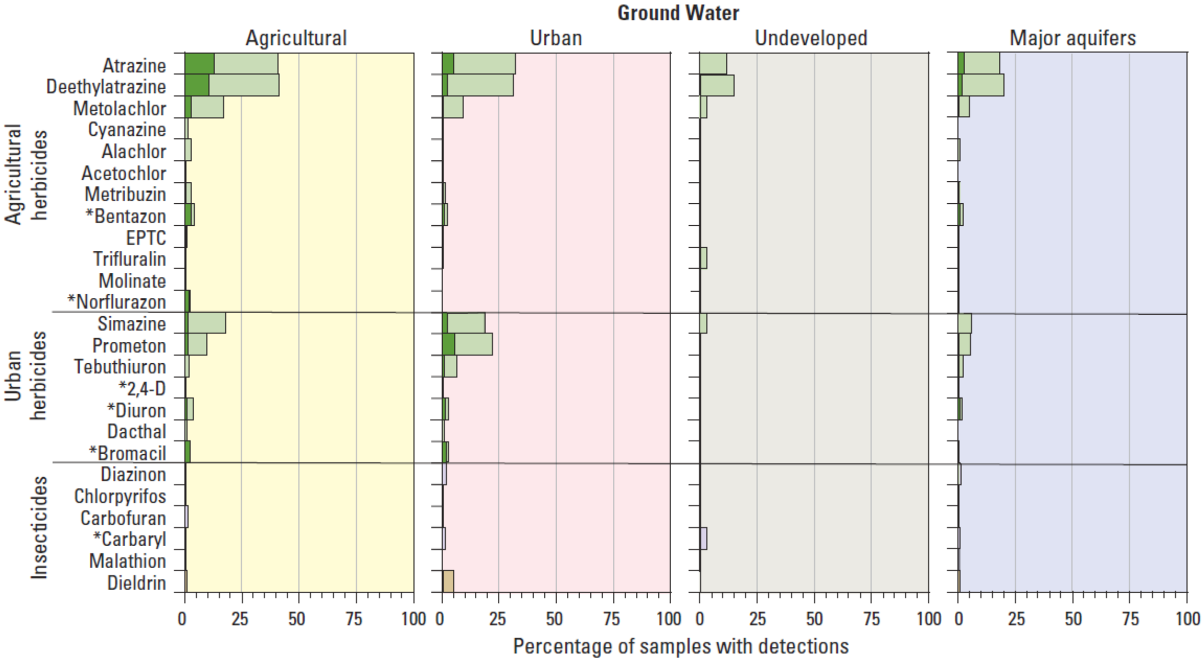


Table 2. Pesticides and Degradates Analyzed in New Mexico Groundwater

Not detected
Detected
Detected at a level greater than a human health criterion

- Acetochlor
  - Acetochlor ESA
  - Acetochlor OXA
- Acifluorfen
- Alachlor (Lasso)
  - Alachlor ESA
  - Alachlor OXA
  - 2,4-Diethylaniline
  - 2,6-Diethylaniline
- Aldicarb
- Aldicarb sulfone
- Aldicarb Sulfoxide
- Aldrin
- Ametryn
- Amiben
- Atratron
- **Atrazine**
  - **Atrazine, deethyl**
  - **Atrazine, 2-hydroxy**
  - Atrazine, deethyl, deisopropl
  - **Atrazine, deisopropyl**
- Azinphos, methyl (Guthion)
- Barban
- Baygon
- Bendiocarb
- Benfluralin
- Benomyl
- Bensulfuron, methyl
- Bentazon
- **Bromacil**
- Bromoxynil
- Butachlor
- Butylate
- **Carbaryl**
- **Carbofuran**
  - Carbofuran, 3-hydroxy
  - Carbofuran, 3-keto
- **Carbon tetrachloride**
  - **Chloroform**
  - **Methylene chloride**
- Carboxin
- Chloramben
- **Chlordane (trans-Nonachlor)**
- Chlorimuron, ethyl
- Chlorobenzilate
- 3(chlorophenyl)-1-methyl urea
- Chlorothalonil
- Chlorpropham
- **Chlorpyrifos**
- Chlorsulfuron
- Clopyralid
- Cyanazine
- Cycloate
- **2,4-D**
  - 2,4-D methyl ester
- **Dacthal (DCPA)**
  - DCPA mono/di-acid degradates
- **Dalapon**
- 2,4-DB
- DBCP
- DDT
  - **DDD**
  - **DDE**
- Demeton, methyl
- **Diazinon**
- Dicamba
  - Dicamba, 5-hydroxy
- Dichlobenil
- 1,2-Dichloropropane
- cis-1,3-Dichloropropene
- trans-1,3-Dichloropropene
- Dichlorprop
- Dichlorvos
- Dichrotophos
- **Dieldrin**
- Dimethenamid ESA
- Dimethenamid OXA
- Dimethoate
- 4,6-Dinitro-ortho-cresol (DNOC)
- **Dinoseb**
- Dioxin, 2,3,7,8-TCDD
- Diphanamid
- **Diquat**
- Disulfoton
  - Disulfoton sulfone
  - Disulfoton sulfoxide
- Diuron
- EDB
- Endosulfan I
- Endosulfan II
- Endosulfan sulfate
- Endothall
- Endrin
- Endrin aldehyde
- EPTC
- Esfenvalerate
- Ethalfluralin
- Ethoprop (Prophos)
- Ethylene thiourea (ETU)
- Etridiazole
- Fenamiphos
  - Fenamiphos sulfone
  - Fenamiphos sulfoxide
- Fenarimol
- Fenuron
- Flufenacet ESA
- Flufenacet OXA
- Flumetsulam
- Fluometuron
- Fluridone
- Fonofos
- Glyphosate
- **HCCPD**
- HCH, alpha
- HCH, beta
- HCH, delta
- HCH, gamma (Lindane)
- Heptachlor
- Heptachlor epoxide
- Hexachlorobenzene
- Hexazinone
- Imazaquin
- Imazethapyr
- Imidacloprid
- Linuron
- Malathion
- MCPA

- MCPB
- Merphos
- Metalaxyl
- Methiocarb
- Methomyl
- Methoxychlor
- Methyloxime
- **Metolachlor**
    - Metolachlor ESA
    - Metolachlor OXA
- Metribuzin
    - Metribuzin, DA
    - Metribuzin, DADK
    - Metribuzine, DK
- Metsulfuron, methyl
- Mevinphos
- MGK-264
- Molinate
- 1-Naphthol
- **Napropamide**
- Neburon
- Nicosulfuron
- Norflurazon
- Ocresol
- Oryzalin
- Oxamyl
- Oxamyl oxime
- Paraoxon, methyl
- Parathion
    - Parathion, ethyl
    - Parathion, methyl
- **Pentachlorophenol (PCP)**
- Pebulate
- Pendimethalin
- Permethrin
- Phorate (Thimet)
- **Picloram**
- **Prometon**
- Pronamide
    - Pronamide metabolite
- Propachlor
- Propanil
- Propargite
- **Propazine**
- Propham
- Propiconazole
- Propoxur
- Siduron
- **Simazine**
- Simetryn
- Sulfometuron, methyl
- Swep
- Tebuthiuron
- Terbacil
- Terbufos
- Terbutryn
- Tetrachlorvinphos (Stirofos)
- Thiobencarb
- Toxaphene
- 2,4,5-T
- **2,4,5-TP (Silvex)**
- Triademefon
- Triallate
- Tribenuron, methyl
- Triclopyr
- Tricyclazole
- Trifluralin
- Vernolate

Pesticide detections reported by organizations other than NMED are included herein as documented in the sources of information discussed above, and no attempt was made to validate or reproduce the analytical results. It is possible, therefore, that some of the detections included in this compilation may have resulted from mechanisms other than actual groundwater contamination, particularly for pesticide compounds that have low water solubility and low subsurface mobility.

Carbon tetrachloride, 1,2-dibromoethane (EDB), and 1,2-dichloropropane have been used as agricultural fumigants, but have also been used as industrial solvents or, in the case of EDB, as a gasoline additive. Most detections of these compounds in New Mexico groundwater have been attributable to these non-agricultural uses. While agricultural fumigants have not been heavily used in New Mexico, at least two cases of groundwater contamination resulting from fumigation with carbon tetrachloride have been documented, and these are included in this compilation.

Pesticide Detections

Of the 195 pesticides, and pesticide breakdown products that have been analyzed in New Mexico groundwater, (Table 2; Appendix A), 30 (15% of those tested) were reportedly detected in groundwater in one or more locations among 20 counties in New Mexico. Table 3 lists reported pesticide detections by county, and compares maximum detected concentrations with EPA drinking water health standards and health advisories, and with NMED tap water screening levels.

Atrazine, 2,4-D, pentachlorophenol (PCP) and Prometon were the most frequently detected pesticides in New Mexico groundwater (Figure 4). Most agricultural herbicide detections occurred in Curry and Doña Ana Counties (Figure 5), both of which have major agricultural productivity. Most non-agricultural herbicide detections occurred in Bernalillo and Doña Ana Counties (Figure 5) where Albuquerque and Las Cruces, the two largest metropolitan areas of the state are located, respectively. Most insecticide detections occurred in Bernalillo, Curry, and Doña Ana Counties (Figure 5).

Of the 30 pesticide and degradate compounds detected in New Mexico groundwater, only four (grain fumigant carbon tetrachloride and degradates chloroform and methylene chloride, and non-agricultural insecticide pentachlorophenol) were detected at concentrations exceeding human-health standards, advisories, or screening levels. Health-based reference levels, however, have not been developed for 5 of the 29 detected pesticide compounds.

Table 3. Pesticide Detections Reported in New Mexico Groundwater, December 2016. All concentrations are µg/L.

	Atrazine	Atrazine, deethyl	Atrazine, 2-hydroxy	Atrazine, deisopropyl	Bromacil	Carbaryl	Carbofuran
EPA MCL	3	--	--	--	--	--	40
EPA HA	--	--	--	--	70	--	--
NMED Tap Water SL	3.39	--	--	--	--	--	93.6
Max. Detected in NM	2.3	0.037	0.012	0.06	0.52	0.021	0.01
Pesticide Detections in Each County							
Bernalillo	1				1	1	1
Catron							
Curry	7		1				
Doña Ana					1		
Eddy	1						
Grant	2						
Hidalgo	1						
Lea		1		1			
Lincoln							
Luna							
McKinley							
Otero							
Roosevelt	3						
Sandoval							
Santa Fe	1						
Sierra							
Socorro							
Taos							
Torrance	2						
Valencia							
Total Detections	18	1	1	1	2	1	1

Table 3. Pesticide Detections Reported in New Mexico Groundwater, December 2016, Contd. All concentrations are µg/L.

	Carbon Tetrachloride	Chloroform	Methylene Chloride	Chlordane	Chlorpyrifos	2,4-D	Dacthal (DCPA)	Dalapon
EPA MCL	**5**	**80**	**5**	**2**	**--**	**70**	**--**	**200**
EPA HA	**30**	**70**	**200**	**4**	**2**	**--**	**70**	**200**
NMED Tap Water SL	**4.55**	**2.29**	**118**	**0.448**	**--**	**--**	**--**	**--**
Max. Detected in NM	**575**	**97**	**22**	**0.022**	**0.18**	**1.99**	**31**	**0.3**
Pesticide Detections in Each County								
Bernalillo						**1**		
Catron						**1**		
Curry	**2**	**2**	**2**			**3**		
Doña Ana						**7**	**1**	
Eddy								
Grant						**1**		
Hidalgo							**1**	
Lea							**1**	
Lincoln								
Luna							**1**	
McKinley				**1**				
Otero						**1**		
Roosevelt								
Sandoval								
Santa Fe								
Sierra						**1**		
Socorro					**1**			
Taos								**1**
Torrance								
Valencia								
Total Detections	**2**	**2**	**2**	**1**	**1**	**15**	**4**	**1**

Table 3. Pesticide Detections Reported in New Mexico Groundwater, December 2016, Contd. All concentrations are µg/L.

	DDD	DDE	Diazinon	Dieldrin	Dinoseb	Diquat	HCCPD	Metolachlor
EPA MCL	--	--	--	--	7	20	50	--
EPA HA	--	--	1	--	7	--	--	700
NMED Tap Water SL	0.317	0.462	--	0.0175	--	--	0.411	--
Max. Detected in NM	0.002	0.002	0.077	<1	1.559	2.9	0.061	5.4
Pesticide Detections in Each County								
Bernalillo								
Catron								
Curry					3			
Doña Ana	1	1	1		4			9
Eddy					1			
Grant					1			
Hidalgo								
Lea								
Lincoln						1		
Luna								
McKinley						1	1	
Otero								
Roosevelt								
Sandoval						1		
Santa Fe								
Sierra								
Socorro								
Taos								
Torrance								
Valencia						1		
Total Detections	1	1	1	1	9	4	1	9

Table 3. Pesticide Detections Reported in New Mexico Groundwater, December 2016, Contd. All concentrations are µg/L.

	Napropamide	PCP	Picloram	Prometon	Propazine	Simazine	2,4,5-TP (Silvex)	Total Detections
EPA MCL	--	1	500	--	--	4	50	
EPA HA	--	40	--	0.4	10	--	50	
NMED Tap Water SL	--	0.413	--	--	--	6.07	--	
Max. Detected in NM	0.014	1.031	6.05	0.38	0.2	0.13	4.95	
Pesticide Detections in Each County								
Bernalillo		1		5				11
Catron		1						2
Curry		7					1	24
Doña Ana	2	4	3	6				40
Eddy								2
Grant		1						5
Hidalgo		1			2			5
Lea		1	1				1	6
Lincoln								1
Luna					1			2
McKinley								3
Otero								1
Roosevelt								3
Sandoval								1
Santa Fe			1			1		3
Sierra								1
Socorro								1
Taos								1
Torrance								2
Valencia								1
Total Detections	2	16	5	11	3	1	2	115

Figure 4. Pesticides Detected in NM Groundwater.

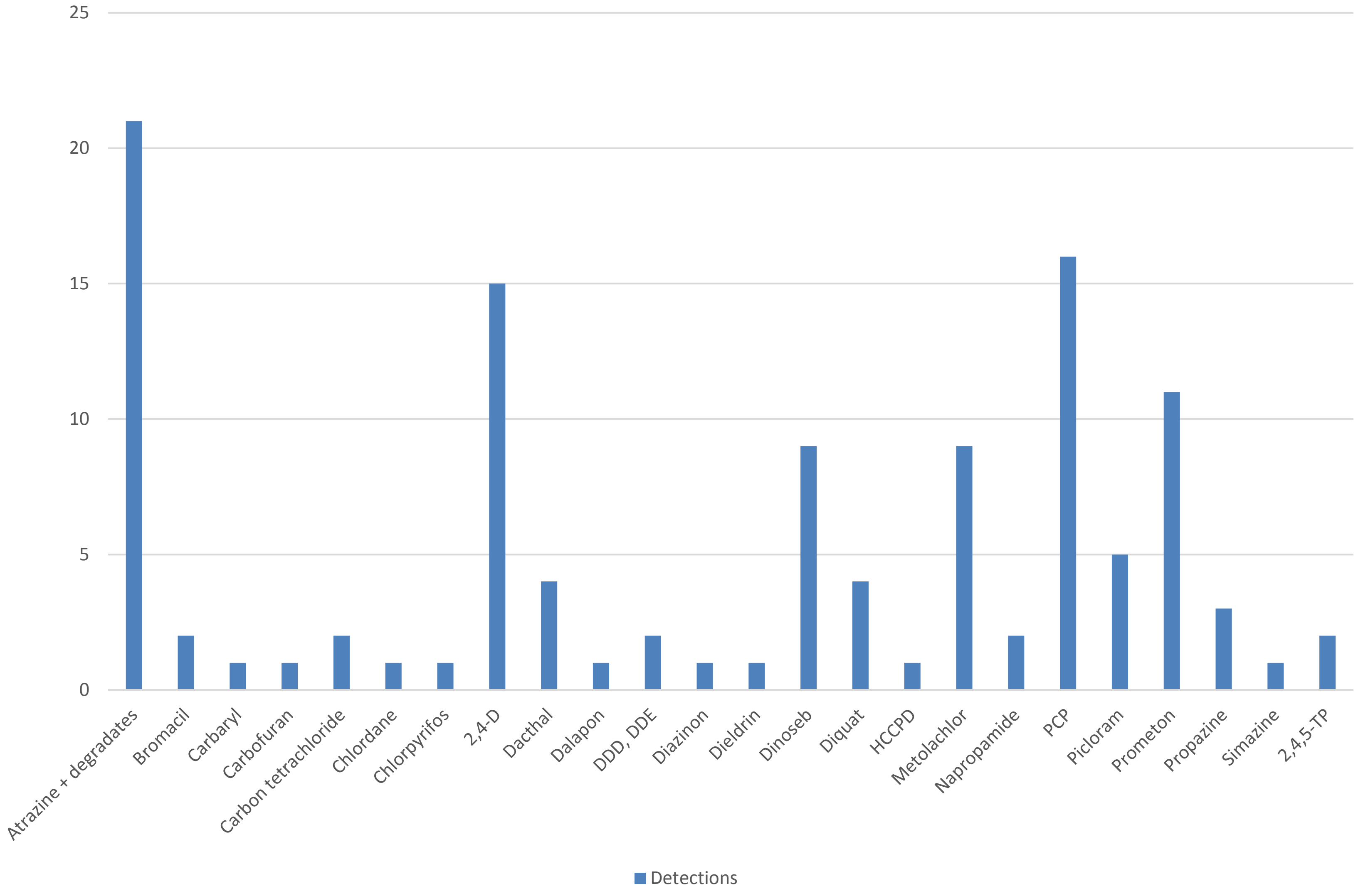
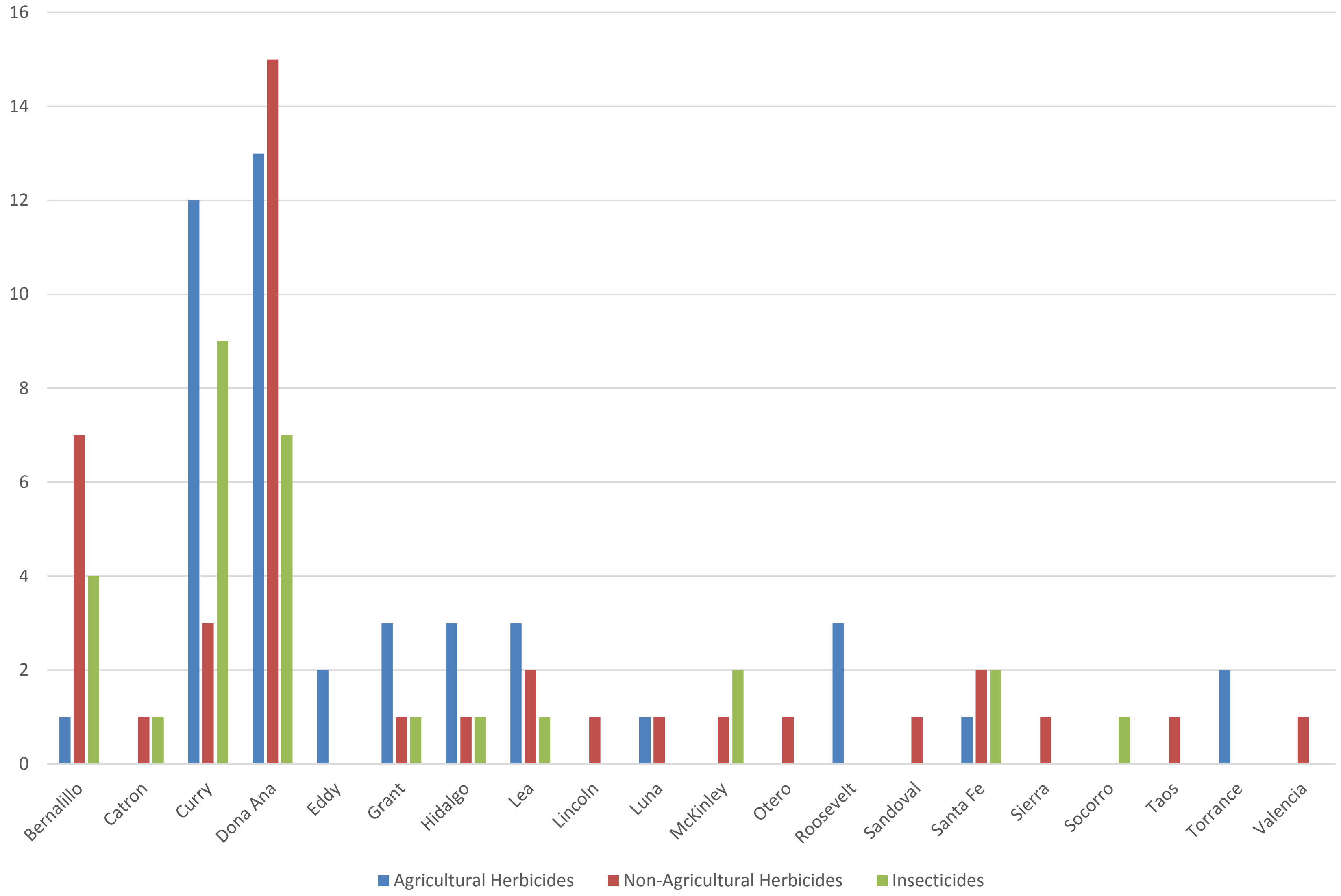


Figure 5. Pesticide Detections in NM Groundwater by County.



Discussion and Conclusions

A number of the pesticides listed in Table 3 were reportedly detected only once and at only one location in the state. As discussed above, it is possible that some detections included in this compilation may have resulted from mechanisms other than actual groundwater contamination.

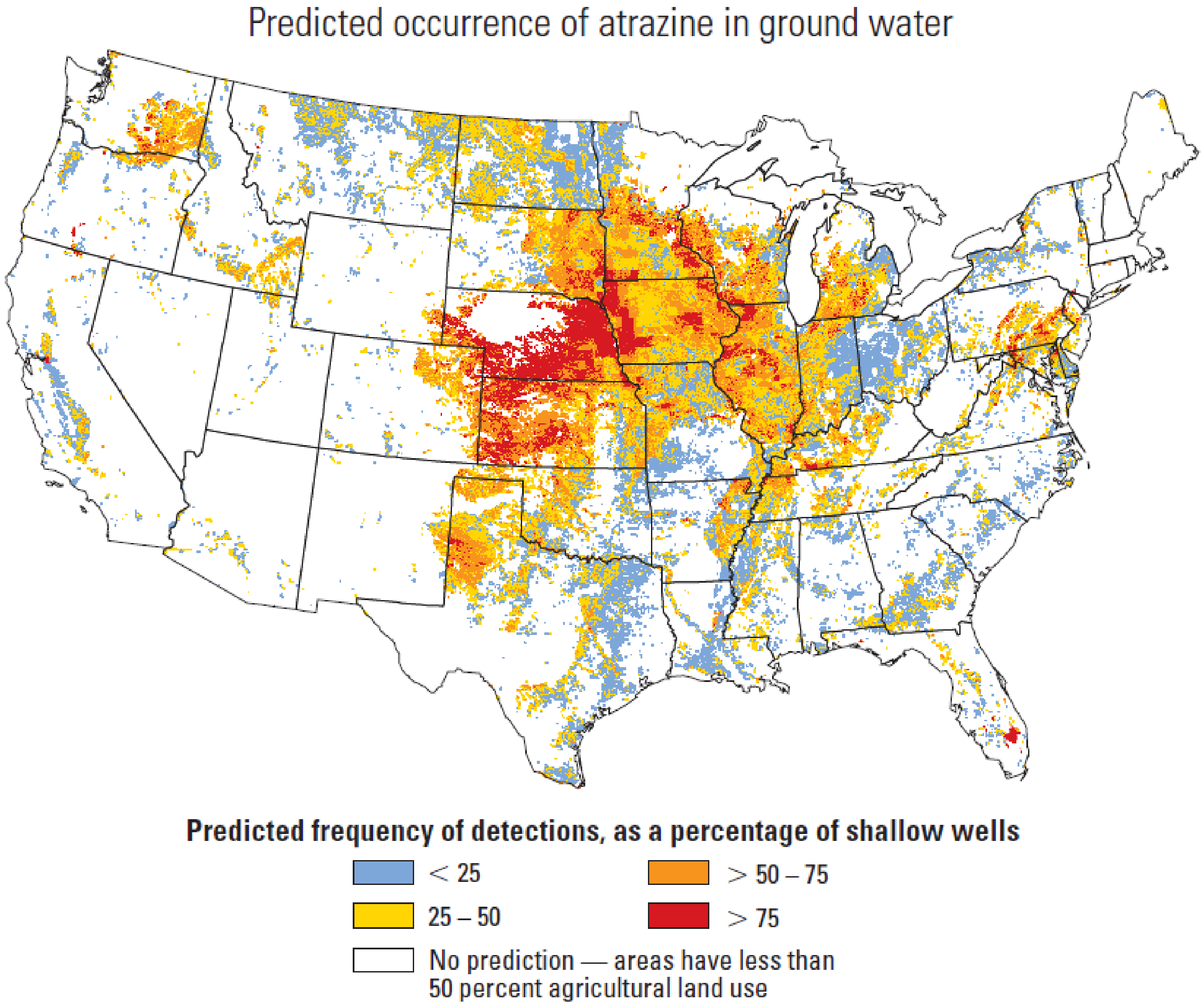
The findings of this data and literature review reveal that:

- Numerous samples of well water in New Mexico have been tested for pesticides by various agencies over the past three decades.
- Detections of agricultural and non-agricultural pesticides in New Mexico groundwater are infrequent.
- Pesticide detections occur more often in agricultural and urban areas where pesticide use is relatively greater than in non-agricultural and rural residential areas.
- Detection of pesticide concentrations exceeding drinking water standards, health advisories or screening levels is even less frequent.
- Only four pesticides and degradates (grain fumigant carbon tetrachloride and degradates chloroform and methylene chloride, and non-agricultural insecticide PCP) were detected at concentrations exceeding human-health standards, advisories, or screening levels.

The findings of this literature review are consistent with previous assessments that pesticide detections in New Mexico groundwater are infrequent and typically occur at very low concentrations (WQCC 2002), and that New Mexico does not have a serious problem with groundwater contamination by pesticides (Mathews, 1989).

The USGS modeled atrazine use rates, coupled with hydrogeologic settings that favor transport of pesticides to groundwater, to predict the occurrence of atrazine detections in groundwater in the U.S. (Figure 6). While the overall predicted level of groundwater atrazine detection in New Mexico was low relative to that in corn belt states to the northeast, the USGS model predicted elevated detections in the central eastern region of the state (Figure 6) where Curry and Roosevelt Counties are located. Ten of the 18 groundwater detections of Atrazine in New Mexico occur in Curry and Roosevelt Counties, (Table 3). These findings support the validity of the USGS Atrazine detection model as a predictive tool.

Figure 6. Predicted occurrence of atrazine in groundwater in the United States. From Gilliom and others (2007).



Acronyms and Abbreviations

2,4-D: 2,4-dichlorophenoxyacetic acid

DBCP: 1,2-dibromo-3-chloropropane

DCPA: dimethyl tetrachloroterephthalate, “Dacthal”

DDD: dichlorodiphenyldichloroethane

DDE: dichlorodiphenyldichloroethylene

DDT: dichlorodiphenyltrichloroethane

EDB: 1,2-dibromoethane; ethylene dibromide

EPTC: S-ethyl dipropylthiocarbamate

ESA: ethanesulfonic acid

HA: Drinking water Health Advisory established by the U.S. Environmental Protection Agency, https://www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf

HCCPD: hexachlorocyclopentadiene

HCH: hexachlorocyclohexane

MCL: Drinking water Maximum Contaminant Level promulgated by the U.S. Environmental Protection Agency, https://www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf

MCPA: 2-methyl-4-chlorophenoxyacetic acid

MCPB: 4-(4-chloro-2-methylphenoxy)butanoic acid

MGK-264: N-octyl bicycloheptene dicarboximide

OXA: oxanilicacid

PCP: pentachlorophenol

SL: Tap water Screening Level established by NMED, https://www.env.nm.gov/HWB/documents/SSLs_RA_Guidance_for_SI_and_Remediation_July_2015.pdf

Swep: methyl-N-(3,4-dichlorophenyl)-carbamate

2,4,5-T: 2,4,5-trichlorophenoxyacetic acid

2,4,5-TP: 2-(2,4,5-trichlorophenoxy)propionic acid; Silvex

References

Anderholm, S.K., 1997, *Water-quality assessment of the Rio Grande Valley, Colorado, New Mexico, and Texas : shallow ground-water quality and land use in the Albuquerque area, central New Mexico, 1993*: U.S. Geological Survey Water-Resources Investigations Report 97-4067, 73 p., https://pubs.er.usgs.gov/publication/wri974067.

Anderholm, S.K., 2002, *Water-quality assessment of the Rio Grande Valley, Colorado, New Mexico, and Texas--Surface-water quality, shallow ground-water quality, and factors affecting water quality in the Rincon Valley, south-central New Mexico, 1994-95*: U.S. Geological Survey Water-Resources Investigations Report 02–4188, https://pubs.usgs.gov/wri/wri02-4188/.

Anderholm, S.K. Radell, M.J., and S.F. Richey, 1995, *Water-quality assessment of the Rio Grande Valley study unit, Colorado, New Mexico, and Texas; analysis of selected nutrient, suspended-sediment, and pesticide data*: U.S. Geological Survey Water-Resources Investigations Report 94-4061, https://pubs.er.usgs.gov/publication/wri944061.

Bexfield, L.M. and S.K. Anderholm, 1997, *Water Quality Assessment of the Rio Grande Valley, Colorado, New Mexico, and Texas – Ground-Water Quality in the Rio Grande Floodplain, Cochiti Lake, New Mexico, to El Paso, Texas, 1995*: U.S. Geological Survey Water-Resources Investigations Report 96-4249, 93 p., https://pubs.er.usgs.gov/publication/wri964249.

Bexfield, L.M., Thiros, S.A., Anning, D.W., Huntington, J.M., and McKinney, T.S., 2011, *Effects of natural and human factors on groundwater quality of basin-fill aquifers in the southwestern United States—conceptual models for selected contaminants*: U.S. Geological Survey Scientific Investigations Report 2011-5020, 90 p., https://pubs.usgs.gov/sir/2011/5020/.

Bowman, R.S. and M.H. Hendrickx, 1998, *Determination of Agricultural Chemical Impacts on Shallow Groundwater Quality in the Rio Grande Valley, Las Nutrias Groundwater Project*: Technical Completion Report for the N.M. Water Resources Research Institute, 45 p., http://www.wrri.nmsu.edu/publish/techrpt/tr308/tr308.pdf.

Fahlquist, L., 2003, *Groundwater quality of the southern High Plains aquifer, Texas and New Mexico, 2001*: U.S. Geological Survey Open-file Report 03-345, 59 p., http://co.water.usgs.gov/nawqa/hpgw/reports/ofr03_345.pdf.

Fernandez-Ramos, C., Ferrer, I., Mauch, K., Satinsky, D., and E.M. Thurman, 2014, *Identification of Prometon, Deisopropylprometon, and Hydroxyprometon in Groundwater by High Resolution Liquid Chromatography/Mass Spectrometry*: Science of The Total Environment 497-498C:459-466, http://www.sciencedirect.com/science/article/pii/S0048969714011607

Gilliom, R.J., Barbash, J.E., Crawford, C.G., Hamilton, P.A., Martin, J.D., Nakagaki, N., Nowell. L.H., Scott, J.C., Stackelberg, P.E., Thelin, G.P. and D.M. Wolock, 2007, *Pesticides in* *the Nation's Streams and Groundwater, 1992-2001*: U.S. Geological Survey Circular 1291, 173 p., https://pubs.usgs.gov/circ/2005/1291/.

Gurdak, J.J., McMahon, P.B., Dennehy, K.F., and Qi, S.L., 2009, *Water quality in the High Plains aquifer, Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming, 1999–2004*: U.S. Geological Survey Circular 1337, 63 p., https://pubs.usgs.gov/circ/1337/

Intera, 1997, *Well-Water Quality Assessment for Southern New Mexico*: Report prepared for New Mexico Department of Health, Border Health Office.

Levings, G.W., Healy, D.F., Richey, S.F. and L.F. Carter, 1998, *Water Quality in the Rio Grande Valley, Colorado, New Mexico and Texas, 1992-95*: U.S. Geological Survey Circular 1162, 39 p., https://pubs.usgs.gov/circ/circ1162/.

Mathews, L., 1989, *New Mexico Department of Agriculture's Program for the EPA's Pesticide/Ground Water Directive*: Proceedings, 34th Annual New Mexico Water Conference, Roswell, NM, October 26-27, 1989, pp. 53-55, http://www.wrri.nmsu.edu/publish/watcon/proc34/Mathews.pdf.

McQuillan, D.M., Faris, B.H., and B.H. Swanson, 1998, *Intrinsic Cometabolism of Carbon Tetrachloride with Gasoline: Regulatory Site-Closure*: In Natural Attenuation – Chlorinated and Recalcitrant Compounds, Battelle Press, pp. 263-268.

New Mexico Environment Department, 2017, *Drinking Water Watch* (online database): https://dww.water.net.env.nm.gov/NMDWW/.

New Mexico Water Quality Control Commission (WQCC), 2002, *Water Quality and Water Pollution Control in New Mexico, 2002*: A Report Prepared for Submission to the Congress of the United States by the State of New Mexico Pursuant to Section 305(b) of the Federal Clean Water Act, p. 90, https://www.env.nm.gov/swqb/305b/2002/2002_305b_Report-Chapter5.pdf.

Paul, A.P., Seiler, R.L., Rowe, T.G., and M.R. Rosen, 2007, *Effects of Agriculture and Urbanization on Quality of Shallow Ground Water in the Arid to Semiarid Western United States, 1993–2004*: U.S. Geological Survey Scientific Investigations Report 2007–5179, https://pubs.usgs.gov/sir/2007/5179/.

Roberts, T.R., Hutson, D.H., Lee, P.W., Nicholls, P.H., and J.R. Plimmer, 1998, *Metabolic Pathways of Agrochemicals, Part 1, Herbicides and Plant Growth Regulators*: The Royal Society of Chemistry, Cambridge, UK.

Roberts, T.R., Hutson, D.H., Jewess, P.J., Lee, P.W., Nicholls, P.H., and J.R. Plimmer, 1999, *Metabolic Pathways of Agrochemicals, Part 2, Insecticides and Fungicides*: The Royal Society of Chemistry, Cambridge, UK.

Scribner, E.A., Dietze, J.E., and E.M. Thurman, 2004, *Acetamide herbicides and their degradation products in ground water and surface water of the United States, 1993–2003*: U.S. Geological Survey Data Series 88, 252 p., https://pubs.usgs.gov/ds/ds88/pdf/DS88.pdf.

Stephens, Daniel B., and Associates, 1996, *Water Quality of Domestic Wells in Dona Ana County*: Report prepared for New Mexico Department of Health, Border Health Office.

Thiros, S.A., Paul, A.P., Bexfield, L.M., and Anning, D.W., 2014, *The quality of our Nation's waters—Water quality in basin-fill aquifers of the southwestern United States: Arizona, California, Colorado, Nevada, New Mexico, and Utah, 1993–2009*: U.S. Geological Survey Circular 1358, 113 p., https://dx.doi.org/10.3133/cir1358.

U.S. Environmental Protection Agency (EPA), 1990, *National Survey of Pesticides in Drinking Water Wells, Phase 1 Report*: EPA 570/9 -90-019.

U.S. Environmental Protection Agency (EPA), 1992, Another Look: *National Survey of Pesticides in Drinking Water Wells, Phase 2 Report*: EPA 570/9 -91-020, 166p.

Appendix A

Pesticide Compounds Included in Systematic Monitoring Programs of New Mexico Groundwater

Not detected
Detected
Detected at a level greater than a human health criterion

Pesticide	**NMED SDWA Monitoring[1]**	**EPA National Survey[2]**	**USGS National and Regional Surveys[3]**
Acetochlor			X
Acetochlor ESA			X
Acetochlor OXA			X
Acifluorfen		X	X
Alachlor (Lasso)		X	X
Alachlor ESA			X
Alachlor OXA			X
2,4-Diethylaniline			
2,6-Diethylaniline			X
Aldicarb	X	X	X
Aldicarb sulfone	X	X	X
Aldicarb Sulfoxide	X	X	X
Aldrin	X	X	
Ametryn		X	
Amiben			X
Atratron		X	
Atrazine	X	X	X
Atrazine, deethyl		X	X
Atrazine, 2-hydroxy			X
Atrazine, deethyl, deisopropl			X
Atrazine, deisopropyl			X
Azinphos, methyl (Guthion)	X		X
Barban		X	
Baygon	X	X	
Bendiocarb			X
Benfluralin	X		X
Benomyl			X
Bensulfuron, methyl			X
Bentazon	X	X	X
Bromacil	X	X	X

Pesticide	**NMED SDWA Monitoring**[1]	**EPA National Survey**[2]	**USGS National and Regional Surveys**[3]
Bromoxynil	X		X
Butachlor	X	X	
Butylate		X	X
Carbaryl	X	X	X
Carbofuran	X	X	X
Carbofuran, 3-hydroxy	X	X	X
Carbofuran, 3-keto		X	X
Carbon tetrachloride	X	X	X
Chloroform	X	X	X
Methylene chloride	X	X	X
Carboxin		X	
Chloramben	X	X	X
Chlordane (trans-Nonachlor)	X	X	
Chlorimuron, ethyl			X
Chlorobenzilate		X	
3(chlorophenyl)-1-methyl urea			X
Chlorothalonil	X	X	X
Chlorpropham		X	
Chlorpyrifos	X		X
Chlorsulfuron	X		
Clopyralid			X
Cyanazine	X	X	X
Cycloate		X	X
2,4-D	X	X	X
2,4-D methyl ester			X
Dacthal (DCPA)	X	X	X
DCPA mono/di-acid degradates	X	X	X
Dalapon	X	X	
2,4-DB	X	X	X
DBCP	X	X	X
DDT	X	X	
DDD	X	X	X
DDE	X	X	X
Demeton, methyl	X		
Diazinon		X	X
Dicamba	X	X	X
Dicamba, 5-hydroxy		X	
Dichlobenil			X

Pesticide	**NMED SDWA Monitoring**[1]	**EPA National Survey**[2]	**USGS National and Regional Surveys**[3]
1,2-Dichloropropane	X	X	X
cis-1,3-Dichloropropene trans-1,3-Dichloropropene		X X	
Dichlorprop	X	X	X
Dichlorvos		X	
Dichrotophos	X		
Dieldrin	X	X	X
Dimethenamid ESA Dimethenamid OXA			X X
Dimethoate	X		
4,6-Dinitro-ortho-cresol (DNOC)			X
Dinoseb	X	X	X
Dioxin, 2,3,7,8-TCDD	X		
Diphanamid		X	X
Diquat	X		
Disulfoton Disulfoton sulfone Disulfoton sulfoxide		X X X	X
Diuron		X	X
EDB	X	X	X
Endosulfan I Endosulfan II Endosulfan sulfate	X X X	X X X	
Endothall	X		
Endrin Endrin aldehyde	X X	X X	
EPTC	X	X	X
Esfenvalerate			X
Ethalfluralin	X		X
Ethoprop (Prophos)	X	X	X
Ethylene thiourea (ETU)		X	
Etridiazole		X	
Fenamiphos Fenamiphos sulfone Fenamiphos sulfoxide		X X X	
Fenarimol		X	
Fenuron			X
Flufenacet ESA Flufenacet OXA			X X

Pesticide	**NMED SDWA Monitoring[1]**	**EPA National Survey[2]**	**USGS National and Regional Surveys[3]**
Flumetsulam			X
Fluometuron		X	X
Fluridone		X	
Fonofos			X
Glyphosate	X		
HCCPD	X		
HCH, alpha	X	X	X
HCH, beta	X	X	
HCH, delta		X	
HCH, gamma (Lindane)		X	X
Heptachlor	X	X	
Heptachlor epoxide	X	X	
Hexachlorobenzene	X	X	
Hexazinone		X	
Imazaquin			X
Imazethapyr			X
Imidacloprid			X
Linuron		X	X
Malathion	X		X
MCPA			X
MCPB			X
Merphos		X	
Metalaxyl			X
Methiocarb	X	X	X
Methomyl	X	X	X
Methoxychlor	X	X	X
Methyloxime			
Metolachlor	X	X	X
Metolachlor ESA			X
Metolachlor OXA			X
Metribuzin	X	X	X
Metribuzin, DA		X	
Metribuzin, DADK		X	
Metribuzine, DK		X	
Metsulfuron, methyl			X
Mevinphos		X	
MGK-264		X	
Molinate		X	X
1-Naphthol			X

Pesticide	**NMED SDWA Monitoring[1]**	**EPA National Survey[2]**	**USGS National and Regional Surveys[3]**
Napropamide		X	X
Neburon		X	X
Nicosulfuron			X
Norflurazon		X	X
Ocresol			X
Oryzalin			X
Oxamyl	X	X	X
Oxamyl oxime			X
Paraoxon, methyl		X	
Parathion	X		X
Parathion, ethyl	X		X
Parathion, methyl			X
Pentachlorophenol (PCP)	X	X	
Pebulate		X	X
Pendimethalin	X		X
Permethrin	X	X	X
Phorate (Thimet)	X		X
Picloram	X	X	X
Prometon		X	X
Pronamide		X	X
Pronamide metabolite		X	
Propachlor	X	X	X
Propanil		X	X
Propargite			X
Propazine	X	X	
Propham		X	X
Propiconazole			X
Propoxur			X
Siduron			X
Simazine	X	X	X
Simetryn		X	
Sulfometuron, methyl			X
Swep		X	
Tebuthiuron	X	X	X
Terbacil	X	X	X
Terbufos		X	X
Terbutryn		X	
Tetrachlorvinphos (Stirofos)		X	
Thiobencarb			X

Pesticide	**NMED SDWA Monitoring**[1]	**EPA National Survey**[2]	**USGS National and Regional Surveys**[3]
Toxaphene	X		
2,4,5-T	X	X	X
2,4,5-TP (Silvex)	X	X	X
Triademefon		X	
Triallate			X
Tribenuron, methyl			X
Triclopyr			X
Tricyclazole		X	
Trifluralin	X	X	X
Vernolate		X	

[1] NMED (2017)

[2] EPA (1990)

[3] Anderholm (2002); Fahlquist (2003); Gilliom and others (2007); Scribner and others (2004)

LW

BEFORE THE
WATER QUALITY CONTROL COMMISSION
STATE OF NEW MEXICO

IN THE MATTER OF:)
)
PROPOSED AMENDMENTS TO WATER)
QUALITY CONTROL COMMISSION)
REGULATIONS.)

TRANSCRIPT OF PROCEEDINGS

BE IT REMEMBERED that on to-wit, the fifth day of September, 1985, this matter came on for continuation of hearing before the New Mexico Water Quality Control Commission at Apodaca Hall, Second Floor Auditorium, PERA Building, Santa Fe, New Mexico, at the hour of ten o'clock in the forenoon.

VOLUME II

NMED EXHIBIT 9

DOCTOR ZALMA: As I mentioned in my general testimony, there are two mechanisms of carcinogenicity, genetic and epigenetic. And as Doctor Puck pointed out, we feel that chloroform is an epigenetic carcinogen. The calculation of its carcinogenic risk is probably significantly overstated by the linear multi-stage model that's used in calculations by the Carcinogen Advisory Group.

Q Could you address the public health concerns associated with the next compound on the list for which a standard is being proposed, that being toluene? In this case, the proposed standard is point two five, whereas the existing standard is fifteen. I wonder if you could discuss the public health concerns associated with this compound and why you feel the toluene standard should be lowered?

DOCTOR ZALMA: The previous state standard comes from strictly toxicological work on no adverse effect level for toxicity of toluene, probably central nervous system toxicity.

This is a very large number. Fifteen milligrams of toluene in a liter of water not only can be seen in some cases floating on the surface, but it can be smelled and tasted. Now, I realize that these are health criteria and not organoleptic criteria. However, I must mention that once a population is exposed to toluene at fifteen milligrams per liter, I can assure you and everyone else that there will be another round of contaminant hysteria, because it is extremely disagreeable, and there will be illness associated with that level, whether real or imagined. That's one point.

Now, this high level, if ingested on a chronic basis, presents a fair amount of toluene to the body every day. What it does is it takes up some of the metabolic space that can be used for metabolizing other organic compounds in the liver. The EPA has accordingly set the one- to two-year health advisory for toluene in drinking water at point three four, which I think is a reasonable estimate of its total overall toxicity and objectionableness, as far as public health is concerned.

Realizing that toluene is rarely alone in contamination incidents and that it is often associated with ethyl benzenes, xylenes liens and occasionally benzene, I further propose that the standard be even below the health advisory proposed by the EPA, since it's almost inevitable that where there is toluene contamination, there is other organic contamination, as well.

Therefore, for instance, if we have two or three contaminants, toluene, ethyl benzene and xylene at near their maximum-allowable standard of point two five, we're getting up to pretty close to three-quarters of a milligram of these substances. That's getting pretty close to the EPA health advisory for, for instance, xylene alone. And I just think it's not appropriate for the state to continue using the existing standard for these reasons.

Q You mentioned that toluene takes up space in --

DOCTOR ZALMA: I don't mean in the sense of physical space, that it's accumulating in your liver. But I mean, for instance, if there is a machine that can only handle five hundred units per hour, if you put in two hundred units of something, then you only have a space for three hundred other units. And toluene is metabolized in the liver, and if you present fairly large amounts of toluene to the liver every day, even though it's not going to cause, as far as we know, cancer, it does take up some of the metabolic function of the liver unnecessarily, and the liver can be -- maybe not saturated with activity, but at least its ability to detoxify other substances is accordingly decreased -- other substances similar to toluene, other organic substances.

Q Doctor Puck, do you have anything to add on toluene?

DOCTOR PUCK: No.

Q Going on to the next compound, ethyl benzene. Would you please address the public health concerns there?

DOCTOR ZALMA: Ethyl benzene is a compound very similar to toluene. It's metabolized almost the same way. The only difference between toluene and ethyl benzene is an extra carbon. Instead of an ethyl group coming out of the benzene group, there is a methyl group. The body does not distinguish these two different models very differently, and the metabolic products of toluene and ethyl benzene are almost identical. They just differ by one carbon, and they are harmless organic acids.

Therefore, I propose a very similar standard for toluene as I do for ethyl benzene. EPA has a standard based on toxicity of one point four. I can't remember if that's a health advisory or not. Occupational standards are quite high in their tolerance to ethyl benzene of four hundred and thirty-five milligrams per cubic meter, and that compares with tetrachloroethylene, which is rated by us -- has been rated by New Mexico as a point zero two standard. So that we're being ten times more liberal with ethyl benzene, and I think that's liberal enough.

Now, I have to mention here again that a revision of the proposed standard for toluene or ethyl benzene upward by one -- by one point five, two or three times that amount is not going to adversely affect public health. It may not even adversely affect the risk of organic overload. My main thrust is the fact that high levels of these compounds are really, as far as public health and public acceptability and overall public health, including mental health, not acceptable.

The same argument goes for xylene, where there is also a point two five standard proposed. The EPA health advisory is point six two, and I really don't have too much information on the genetics of these compounds, but I believe Doctor Puck has one bit of information on ethyl benzene.

DOCTOR PUCK: Yes. That's the only one where any information was available, and that's summarized in the EPA 1980 document showing that one or more of the metabolites of ethyl benzene is mutagenic.

Q Am I correct in assuming that the general reasons for the toluene, ethyl benzene and xylene standards being at two point five are similar?

DOCTOR ZALMA: Yes.

Q The next compound that there is a proposed standard proposed is naphthalene and monomethylnaphthalenes, the total quantity of those compounds. Is that correct? It says "total" underneath this.

DOCTOR ZALMA: I made an error in my research on this, and I would like to correct it at this time. It should be naphthalene and monomethyl and monoethylnaphthalenes.

By not doing that, I would have unfairly committed ethylnaphthalene to the other category of naphthalenes which are cocarcinogenic. Ethylnaphthalene is not cocarcinogenic. 1-ethylnaphthalene and 2-ethylnaphthalene are not carcinogenic or cocarcinogenic.

Naphthalene is used for the manufacture of dyes,

BLAYNE HARTMAN, Ph.D.

Solana Beach, CA 92075

EDUCATION

Ph.D., Geological Sciences - 1983; University of Southern California, Los Angeles, CA

M.S., Geological Sciences - 1978; University of Southern California, Los Angeles, CA

B.S., Chemical Engineering- 1975; Clarkson University, Potsdam, New York

EMPLOYMENT HISTORY

Present:	Hartman Environmental Geoscience, Vapor Intrusion Assessments of methane and volatile organic compounds (VOCs) & Soil Gas Support
1998 to 2008:	*H&P Mobile Geochemistry,* Carlsbad, CA, 92010 Founder, partner, principal geochemist.
1988 to 1998:	*Transglobal Exploration and Geoscience (TEG), Inc.*, Solana Beach, CA President , founder, principal geochemist.
1986 to 1988:	*InterOcean Systems, Inc.*, San Diego, California, Chief Geochemist
1982 to 1986:	*Unocal Science and Technology Division,* Brea, California Research Geochemist

SUMMARY OF PROFESSIONAL EXPERIENCE

Dr. Hartman is an internationally recognized expert on soil vapor sampling, soil vapor analysis, and vapor intrusion of volatile compounds and methane. He has provided training on soil gas methods and vapor intrusion to County and State regulatory agencies in over 30 states, many of the EPA regions, the DOD, and numerous stakeholder groups and consultants. He has written numerous articles on the collection, analysis, and interpretation of soil vapor data, including chapters in four textbooks. He has participated in technical workgroups on soil vapor methods for EPA, CA-EPA, ITRC, ASTM, CA Regional Water Boards, County of San Diego, has reviewed/edited instructional manuals for the EPA OUST and Superfund groups, and lectured on soil gas methods in the EPA-OSWER vapor intrusion seminars. He has performed research with EPA-ORD on soil gas methods and soil gas variations in 2007, 2008, 2009, 2010, 2012 & 2013.

At H&P Geochemistry, Dr. Hartman was primarily responsible for geochemical data interpretation, corporate and business development, and method development. As

Founder and President of TEG, Dr. Hartman was personally responsible for geochemical technical development, equipment design and maintenance, laboratory director, applications development, and implementation of exploration programs, analyses, and reporting. Prior to co-founding TEG, Dr. Hartman was chief marine geochemist with InterOcean Systems, where his responsibilities included direction of marine sediment and bottom-water geochemical exploration programs. As a research chemist with Unocal Research, Dr. Hartman was responsible for development of geochemical prospecting techniques in onshore and offshore applications including fingerprinting of methane and light hydrocarbons using isotopes.

RECENT PUBLICATIONS ON SOIL GAS METHODS & VAPOR INTRUSION

Hartman, B. (2010). *Vapor Intrusion Pathway: Regulatory Updates and Issues Specifically for Petroleum Hydrocarbons*, LustLine, November 2010.

McHugh, Thomas E., Hammond, Douglas E., Nickels, Tim & Hartman, Blayne (2008) '*Use of Radon Measurements for Evaluation of Volatile Organic Compound (VOC) Vapor Intrusion*', Environmental Forensics, 9:1, 107 - 114

Hartman, B. et. al., (2007). *Results from EPA Funded Research Programs on the Importance of Purge Volume, Sample Volume, Sample Flow Rate and Temporal Variations On Soil Gas Concentrations.* Proceedings AWMA Vapor Intrusion Conference, Providence, RI, September 2007

Hartman, B. (2006). *How to Collect Reliable Soil Gas Data for Risk Based Applications, Part 4: Updates on Soil Gas Collection & Analytical Procedures*, LustLine #53, September 2006.

Hartman, B. (2004). *How to Collect Reliable Soil Gas Data for Risk Based Applications, Part 3: Answers to Frequently Asked Questions*, LustLine, November 2004.

Hartman, B. (2003). *How to Collect Reliable Soil Gas Data for Risk Based Applications, Part 2: Surface Flux Chamber Method,* LustLine #44, NEIWPIC, August 2003.

Hartman, B. (2002). *How to Collect Reliable Soil Gas Data for Risk Based Applications, Part 1: Active Soil Gas Method,* LustLine #42, NEIWPIC, October 2002.

Hartman, B. (2002). *Reevaluating the Upward Vapor Migration Rick Pathway, LustLine #41*, NEIWPIC, June 2002.

Hartman, B. and J. Jacobs (2000a). *Soil vapor principles,* in Standard Handbook of Environmental Science, Health, and Technology, Lehr, J. and J. Lehr, eds., Mc Graw Hill, ISBN#0-07-038309-X.

Hartman, B. and J. Jacobs (2000b). *Applications and interpretation of soil vapor data to volatile organic compound contamination,* in Standard Handbook of Environmental

Science, Health, and Technology, Lehr, J. and J. Lehr, eds., Mc Graw Hill, ISBN#0-07-038309-X.

Hartman, B. (1999). *Applications and Interpretation of Soil Vapor Data*, in Chlorinated Solvent Contamination: Legal and Technical Issues, Morrison et.al., eds., Argent Communications Group, Foresthill, CA.

Hartman, B. (1998a). *Applications and Interpretation of Soil Vapor Data, in Petroleum Hydrocarbon Contamination*: Legal and Technical Issues, Morrison et.al., eds., Argent Communications Group, Foresthill, CA.

Frez, W.A., Tolbert, J.N., Hartman, Blayne, and T.R. Kline (1998), *Determining Risk Based Remediation Requirements Using Rapid Flux Chamber Technology*, in proceedings, Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, Battelle Press

Hartman, B. (1998). *The Downward Migration of Vapors*, LUSTLine Bulletin 28, NEIWPCC, Wilmington, MA, December 1998.

Hartman, B. (1997). *The Upward Migration of Vapors*, LUSTLine Bulletin 27, NEIWPCC, Wilmington, MA, December 1997.

PRESENTATIONS & TRAINING ON SOIL GAS METHODS & VAPOR INTRUSION

Too numerous to list. Partial list available at www.hartmaneg.com.

REGULATORY GUIDANCE DOCUMENTS CONTRIBUTED TO

- ITRC Petroleum Vapor Intrusion Tech Reg, October/2014
- Australia Petroleum Vapor Intrusion guidance, Summer 2013
- Louisiana RECAP, Summer 2012
- CA Leaking Underground Fuel Tanks (LUFT) Manual, August 2010
- CA-EPA (DTSC) Soil Gas Collection Guidance, March 2010
- ASTM Vapor Intrusion Standard, March 2008
- ITRC Vapor Intrusion Guidance, February 2007
- States of CA, MO, MI, TN, AZ, NY, NJ, KS, IN, WA, NH, TN, WI, AK, OH
- CA-EPA (DTSC) Soil Gas Collection Guidance, 2003
- San Diego County Dept. Env. Health Soil Gas Collection Guidance, 2002
- San Diego County Dept. Env. Health Soil Gas Analytical Guidance, August 2001
- San Diego County Building Dept. Methane Testing Ordinance, 2001
- EPA OUST Site Assessment Manual, 1997
- LA-RWQCB Soil Gas Analytical Guidance, 1997-1992

STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

In the Matter of:

PROPOSED AMENDMENTS TO **No. WQCC 17-03 (R)**
GROUND AND SURFACE WATER
***PROTECTION* REGULATIONS,**
20.6.2 NMAC

DIRECT TESTIMONY OF BLAYNE HARTMAN, Ph.D.

My name is Blayne Hartman and I am the founder of Hartman Environmental Geoscience. I have a Ph.D. in geochemistry and have specialized in the vapor intrusion risk pathway for over 20 years. I am considered a national and international expert on this subject. I have been asked to provide testimony on behalf of the New Mexico Environment Department ("NMED") in this proceeding on revisions to the Ground and Surface Water Protection Regulations, 20.6.2 NMAC.

I. QUALIFICATIONS

I have a Bachelor's of Science degree in Chemical Engineering, a Master's of Science in Geological Science, and a Ph.D in Geological Science from Southern California University. I have worked in the Environmental Field as a Geochemist for 35 years in various capacities, including that of a principal geochemist at two environmental laboratories. One of these analytical laboratories functioned as a mobile laboratory used in the field for large soil vapor and indoor air projects. I have studied, collected, analyzed, and synthesized soil gas and indoor air data for over 20 years. A copy of my resume is marked as NMED Exhibit 10. It is current and accurate.

II. INTRODUCTION TO VAPOR INTRUSION

The vapor intrusion risk pathway has been one of the hottest environmental topics since the early 2000s, concern has reached an all-time high over the past several years. The U.S. Environmental Protection Agency's ("EPA's") Office of Solid Waste and Emergency Response

("OSWER") and Office of Underground Storage Tanks ("OUST") each released new guidance documents on this pathway in the summer of 2015. In December 2016, EPA added vapor intrusion into the Superfund Hazard Ranking System. As of January 2016, at least 39 states have their own written guidance/policy documents regarding the vapor intrusion pathway. Further increasing the attention to his pathway, there is currently huge concern over possible malformation of the hearts of fetuses caused by short-term exposures of pregnant mothers to trichloroethylene ("TCE") vapors.

III. BACKGROUND AND HISTORY OF THE VAPOR INTRUSION PATHWAY

Vapor intrusion refers to the migration of compounds in the vapor phase from the subsurface up into overlying structures. The vapor intrusion risk pathway refers to the potential threat (risk) to human health and safety by the compounds once humans are exposed to them through inhalation. Vapor intrusion by radon and methane has long been known to be a potential risk, many Federal and individual State policies had policies/guidance to deal with this risk. However, risk to human health due to other volatile organic compounds ("VOCs") was ignored until early 2000, when two sites in Colorado showed evidence of chlorinated VOCs in residences due to vapor intrusion.

In 2002, EPA OSWER issued a guidance document regarding the vapor intrusion risk pathway of VOCs (EPA, 2002). This document resulted in increased attention to this pathway by the individual states. States began to issue their own vapor intrusion guidance documents shortly thereafter. Other groups began to issue guidance documents including the Interstate Technology Research Council ("ITRC"), the U.S. Department of Defense ("DOD"), the American Petroleum Institute ("API"), and finally, in 2008, the American Society of Testing Materials ("ASTM"). As of January 2016, at least 39 states have their own written guidance/policy documents regarding the vapor intrusion pathway.

IV. CURRENT STATE OF THE SCIENCE ON VAPOR INTRUSION

EPA OSWER and OUST each released new guidance documents on this pathway in the summer of 2015. The 2015 guidance documents are much more restrictive than the guidance document released in 2002, and have lowered the allowable sub-surface contaminant levels by more than 15 times.

In December 2016, EPA was so concerned about the risk by vapor intrusion that it added vapor intrusion as a component to the Superfund Hazard Ranking System.

In 2013, EPA Regions 9 and 10 issued new written policies on TCE due to potential malformation of developing hearts in fetuses if the pregnant mother was exposed to TCE vapors for short periods of time (EPA, 2013). Since then, numerous states have issued similar policies (e.g., California, Massachusetts, Ohio, New York, Washington, Connecticut). In November 2016, EPA Region 7 issued a document stating that the exposure period of concern can be as short as hours (EPA Region 7, 2016).

V. CONCLUSION

The vapor intrusion risk pathway has never been at a higher level of concern. At last count, at least 29 states have policies regarding this pathway. Short-term exposures of pregnant mothers to TCE are of utmost concern. Regulatory agencies with the authority to require environmental cleanup should have the regulatory authority to require cleanup of this environmental pathway that impacts human health so readily.

Kurt M. Vollbrecht
E-mail: kurt.vollbrecht@state.nm.us

Education

M.S. in Geology, August, 1997, **New Mexico Institute of Mining and Technology**, Socorro, NM

B.S. in Geology, June, 1994, **California State University, Hayward (CSUH)**

Professional Experience

Program Manager, NMED Mining Environmental Compliance Section, NMED GWQB, 3/12-12/12 and 7/13-present: Manager of the Mining Environmental Compliance Section, including developing regulations, policies, and guidelines for mine related discharges; review and approval of discharge permits; assigning, directing, and tracking the work of current MECS technical staff and Team Leaders on permit development and enforcement actions; coordination with the United States Environmental Protection Agency regarding National Priorities List sites; conducting meetings with permittees, public members, and senior management.

NMED Mining Environmental Compliance Section Operational and Closure Team Leader, NMED GWQB 12/12-3/14: Responsible for evaluating, drafting and ensuring consistency and compliance with Ground Water Discharge Permits, specific to hard rock mine sites in New Mexico for protection of groundwater pursuant to the NM Water Quality Act and WQCC Regulations. Supervision of several NMED technical staff including Tyrone Mine, Chino Mine and Continental Mine permit leads, AOC, and uranium mine permit lead.

Mining Act Team Leader, NMED GWQB, 9/05-3/12: Responsible for coordination with the Mining and Minerals Division (MMD) in implementation of the NM Mining Act and providing comments and environmental determinations to MMD pursuant to the NM Mining Act. Evaluate and ensure compliance with Ground Water Discharge Permits specific to hard rock mine sites in New Mexico for protection of ground water pursuant to the NM Water Quality Act and WQCC Regulations. Evaluate reclamation practices and water quality issues at hard rock mine sites pursuant to the NM Mining Act. Supervise 3 technical staff.

Industrial Waste Team Leader, NMED GWQB, 7/04-9/05: Lead facility-type team by identifying, prioritizing, and implementing ways to improve program effectiveness in regulating facilities including development of policies, guidelines, templates and regulations. Provide technical and regulatory guidance to staff to ensure compliance with domestic, agricultural, and industrial Ground Water Discharge Permits for protection of groundwater pursuant to the NM Water Quality Act and WQCC Regulations. Supervise 3 technical staff.

Geoscientist A, NMED GWQB, 7/00-7/04: Evaluate and ensure compliance with domestic, agricultural, and industrial Ground Water Discharge Permits for protection of groundwater pursuant to the NM Water Quality Act and WQCC Regulations. Supervise 3 technical staff as above. Assistant to Domestic Waste Team Leader for oversight of 600+ domestic waste discharge permits.

Water Resource Specialist, NMED GWQB, 10/98 – 7/00*:* Technical staff member responsible for review of a large, diverse caseload including domestic, agricultural, mining, and industrial Ground Water Discharge Permits. Duties include technical review of existing Ground Water Discharge Permits, review of new, renewal, and modification applications for Ground Water Discharge Permits, and evaluation of technical submittals to ensure compliance with NM Water Quality Act and WQCC Regulations.

Exploration Field Geologist**:** Havilah Mining, Houston, Texas. 9/97 - 6/98, Mapping of potential ore body in southwest Texas, on-sight supervision of drilling program, core logging, splitting, and sample preparation for assay. On-site supervision of an exploratory placer operation in Sonora, Mexico. Duties included field mapping of veins and placer deposits, selection of sample locations to properly characterize potential deposit, overseeing operation of sluice and mineral separation equipment. *Supervisor:* Al Wadsworth, Consulting Geologist.

Masters Research**:** New Mexico Tech, Socorro, NM. 9/94 - 9/97, In-depth study of Precambrian rocks including: detailed field mapping, structural analysis, petrographic study, microprobe analysis, and ^{40}Ar/^{39}Ar and U/Pb dating of igneous and metamorphic rocks. *Supervisor:* Dr. Laurel Goodwin.

Assistant Manager**:** 6/85 – 6/93, Buss Automotive Parts, Oakland, CA.

Teaching Experience

Teaching Assistant, Geologic Field Courses:

New Mexico Tech, assisted students in detailed mapping of structurally complex Precambrian rocks in northern New Mexico. *Supervisors:* Drs. Steve Ralser and Maureen Wilks. Summer, 1996 and 1997.

CSUH advanced field course with emphasis on field mapping and study of Cascade Range volcanoes and associated deposits. *Supervisor:* Dr. Elwood R. Brooks. Summer, 1995.

CSUH summer field course including mapping of Devonian-Pennsylvanian miogeoclinal rocks in eastern Nevada, Mesozoic sedimentary rocks of the northern Colorado Plateau, and folded Mesozoic strata in the Gros Ventre River Valley, Wyoming, structural analysis of mesoscopic features, Grand Teton Range, Wyoming, and tape and compass mapping of a Paleozoic dike complex, northern Sierra Nevada. *Supervisor:* Dr. Elwood R. Brooks. Summer, 1994.

Lab Instructor, Igneous and Metamorphic Petrology, Structural Geology, New Mexico Tech. *Supervisor:* Dr. Laurel Goodwin. 9/94 - 5/97.

Instructor, Beginning Rock Climbing, New Mexico Tech. Responsible for safety and instruction of a large group (20-25 students). 9/96 - 5/97.

Teaching Assistant, Igneous and Metamorphic Petrology, CSUH. *Supervisor:* Dr. Nancy Fegan. 1/94 - 3/94.

Awards and Scholarships

New Mexico Bureau of Mines and Mineral Resources Research Grant, 1997; Leon Redbone Scholarship, 1996; Geological Society of America Penrose Grant, 1995; New Mexico Tech Graduate Research Grant, 1995; Livermore Lithophiles Brunton Compass Award (outstanding field student), 1993; CSUH Dept. Scholarship, 1993.

STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

In the Matter of:

PROPOSED AMENDMENTS TO
GROUND AND SURFACE WATER
***PROTECTION* REGULATIONS,**
20.6.2 NMAC

No. WQCC 17-03 (R)

WRITTEN DIRECT TESTIMONY OF KURT VOLLBRECHT

My name is Kurt Vollbrecht, and I am the Program Manager of the Mining Environmental Compliance Section ("MECS") of the Ground Water Quality Bureau ("Bureau") within the Water Protection Division of the New Mexico Environment Department ("Department" or "NMED"). I am presenting this written testimony on behalf of the Department in this proceeding on proposed revisions to the Water Quality Control Commission's Ground and Surface Water Protection Regulations at 20.6.2 NMAC ("Regulations" or "Part 20.6.2"). My testimony is focused on three primary areas of the Department's proposed revisions to Part 20.6.2: discharge permit amendments, variance requests, and alternative abatement standards.

I. QUALIFICATIONS

I have worked for the Bureau for over 19 years in a variety of technical and supervisory positions, including the last 12 years with MECS. The Bureau is responsible for permitting, spill response, abatement, and public participation activities associated with mining, domestic wastewater, and industrial facilities in New Mexico under the New Mexico Water Quality Act, NMSA 1978, §§ 74-6-1 to -17 ("WQA"), and the Ground and Surface Water Protection Regulations, 20.6.2 NMAC, 20.6.6 NMAC, and 20.6.7 NMAC. I have held the position of Program Manager of MECS for over four years, and I oversee 12 supervisory and technical staff. Prior to my technical and supervisory positions with MECS, I was a technical staff person and supervisor in the Pollution Prevention Section, responsible for permitting and abatement oversight of a variety of domestic and industrial waste type facilities. During my tenure with the Bureau, I have become intimately familiar with the Water Quality Control Commission regulations, both as a technical staff person and as a supervisor and manager. As a result, I have significant experience in the nuances of effective regulatory oversight. I hold a Bachelor of Science degree in Geology from California State University, Hayward and a Master of Science degree in Geology from the New Mexico Institute of Mining and Technology.

A copy of my resume is marked as NMED Exhibit 12. It is accurate and current.

II. DEFINITION OF DISCHARGE PERMIT AMENDMENT

The Department is proposing to add a definition for "discharge permit amendment" in the definitions section of the Regulations at 20.6.2.7.D(4) NMAC. This new definition would codify the Department's longstanding practice of issuing discharge permit amendments, which I discuss below. Defining "discharge permit amendment" and dictating a regulatory process for such amendments will help ensure consistency with respect to when and how discharge permit amendments are issued. The proposed revisions include a process for discharge permit amendments, which will provide a standardized regulatory mechanism to make minor changes to a discharge permit in a manner that is not overly-burdensome for the Department and regulated entities, and will allow for notification to those members of the public who would most likely be interested in such minor changes, including clarification of the process for appeal. In addition to the new definition of discharge permit amendment, associated rule revisions include: submittal of an amendment request (20.6.2.3106.H NMAC); Department review and approval of discharge permit amendments (20.6.2.3109.B(2) and 20.6.2.3109.D NMAC); notification to interested parties (20.6.2.3109.B(2) NMAC); and notification of the process for appeal of the Secretary's decision regarding amendments (20.6.2.3112.A NMAC).

A. History of Discharge Permit Amendments

The Water Quality Control Commission Regulations have always allowed for minor changes to a discharge plan or discharge permit without requiring the process associated with a discharge permit modification, provided that those changes do not substantially change the quantity or quality of the discharge. This is evident in the existing language of 20.6.2.1202.A NMAC,[1] which implies that there can be minor changes to the character of a discharge that do not rise to the level of a discharge permit modification. This language has been in the regulations essentially unchanged since the Commission adopted the first regulations under the WQA in 1967 ("1967 Regulations"). A copy of the 1967 Regulations is attached as NMED Exhibit 14. Prior to the 1977 promulgation of the permitting regulations, a discharger would notify the Department of proposed changes by submitting plans and specifications for modifications that would "change substantially the quantity or quality" of a discharge at the time that change was engineered.[2] Plans

---

[1] 20.6.2.1202.A NMAC provides as follows:

> Any person proposing to construct a sewerage system or proposing to modify any sewerage system in a manner that will change substantially the quantity or quality of the discharge from the system shall file plans and specifications of the construction or modification with ground water quality bureau of the department for discharges that may affect ground water, and/or the surface water quality bureau of the department for discharges that may affect surface water. Modifications having a minor effect on the character of the discharge from sewerage systems shall be reported as of January 1 and June 30 of each year to the ground water quality bureau of the department for discharges that may affect ground water, or the surface water quality bureau of the department for discharges that may affect surface water.

[2] Regulation No. 2 of the 1967 Regulations provides as follows:

> Any person proposing to construct a sewerage system or proposing to modify any sewerage system in a manner that will change substantially the quantity or quality of the discharge from the system, shall file with the Water and Liquid Waste Division of the New Mexico Environment Department of Health and Welfare plans and specifications for such works. Modifications having a minor effect on the character of the discharge from sewerage systems shall be reported as of January 1st and June 30th of each year to the Water and Liquid Waste Division.

and specifications for modifications having a minor effect on the character of a discharge were required to be submitted on January 1 and June 30 of each year following their implementation.

In 1977, the Commission promulgated regulations ("1977 Regulations") setting forth the procedures for submittal and Department approval of discharge plans. A copy of the 1977 regulations is attached as NMED Exhibit 15. Also included in the 1977 Regulations were the first public notice requirements. Throughout the 1980's, the Department (or its predecessor agencies) issued letters, typically no longer than one or two pages, that approved the discharge plan as contained within the administrative record, following technical review and submittal of supplemental information as necessary. During this time the requirements of what is now designated as 20.6.2.1202 NMAC provided the only regulatory guidance on making changes to an approved discharge plan. Proposed changes that would result in a significant change to the quantity or quality of the discharge would be submitted to the Department in the form a discharge plan modification and would be subject to the public notification requirements. Those changes to a discharge plan that did not significantly change the quantity or quality of the discharge were not subject to notification requirements. Not only was the phrase "significant change" undefined in the regulations, but the term "discharge permit modification" was undefined as well. Thus, it was left to the Department's discretion to determine what constituted a "significant change" to a discharge plan. However, until the Commission adopted a definition of "discharge permit modification," a significant change requiring notification was limited to changes to the quantity and quality of the discharge pursuant to the language currently codified at 20.6.2.1202 NMAC.

Beginning in the early 1990's, the Department began issuing discharge permits that included substantial details about the permitted activity, in contrast to the simple approval letters that were being issued previously. The permits issued by the Department included specific conditions of approval with prescriptive requirements for operational plans, monitoring plans, contingency plans, and closure plans. In order for the Department to effectively and efficiently make changes to these detailed permit conditions that did not rise to the level of a significant modification as set forth in 20.6.2.1202 NMAC, a process for minor modification of a permit was necessary. As a result, dating back to the early 1990's the Department has issued what are known as "discharge permit amendments" for minor changes to the requirements of a discharge permit that would not result in a significant change to the quantity or quality of a discharge.

A review of the available scanned reading file of letters issued by NMED reveals that the Department has issued over 330 discharge permit amendments since 2000. As early as 1993 the Department was issuing "minor modifications" to discharge permits that did not result in a significant change to the quantity or quality, or the location of the discharge. In general, the permit amendments fall into two broad categories. The first category includes changes to monitoring requirements, which include but are not limited to the following: installation of new wells, abandonment of existing wells, and installation of replacement wells; changes to analytical requirements including analyte sampling lists and sampling locations; and changes to the frequency of required sampling, inspection schedules, and submittal dates. The second major category of amendment types includes what are best described as process changes that do not result in significant changes to the quantity, quality, or location of a permitted discharge. These are quite variable, and each is unique based on the characteristics of the nearly 2,000 discharge permits that have been issued since promulgation of the permitting rules in 1977. I discuss some examples of these types of amendments below.

The Commission first defined "discharge permit modification" in 1991 as part of a rule change that adopted a discharge permit fee structure. That language, in what was then designated as Section 3-3114.A, indicated that the definition was intended for use within that section as it pertained to discharge permit fees. A copy of the pertinent section of the 1991 rule change is attached as NMED Exhibit 16. Testimony from the 1991 rulemaking hearing on fee regulations, a copy of the pertinent portion of which is attached as NMED Exhibit 17, indicates that a permittee should not be required to pay fees associated with a discharge permit modification for changes to a discharge permit that did not result from significant changes to the quantity or quality, or to the location of a discharge. The rationale for this approach was based on both the significance of the permit change as it related to the potential for impacts to water quality, as well as the time and effort required by the Department to review a request and make minor changes to a discharge permit.

In 2001 the Commission moved the definition of "discharge permit modification" from the "Fees" section of the regulations to the "Definitions" section at 20.6.2.7.N NMAC, without making any changes to the definition established in 1991, thus giving that definition broader application. A copy of the definitions section in the 2001 rules is attached as NMED Exhibit 18. At that time, the definition read as follows:

> **"discharge permit modification"** means a change in requirements of a discharge permit as requested by a discharger as a result of past, present or anticipated changes in the quality or quantity of effluent or the location of the discharge; or as required by the secretary;

In 2005, the Legislature amended Section 74-6-5 of the WQA to provide that an appeal of an agency permitting action will be conducted as a record review by the Commission, rather than as a *de novo* evidentiary hearing, and added additional prescriptive public notice requirements for discharge permit approvals and modifications. Copies of the pre-2005 version of NMSA 1978, Section 74-6-5 and the 2005 changes to that section are attached as NMED Exhibits 19 and 20, respectively. To implement those statutory changes, the Commission amended 20.6.2 NMAC in

2006. In addition to the more burdensome public notice requirements associated with discharge permit modifications, the Commission changed the definition of "discharge permit modification" to provide that changes to a discharge permit that did not result in a ***significant*** change to the quantity or quality of the discharge would not qualify as a discharge permit modification. It should also be noted that under this definition, only significant changes to quantity or quality, and changes to the location of a discharge are subject to public notice; all other changes would not be considered modifications subject to public notice. These changes to the WQA and Commission regulations in 2005 and 2006 respectively were based on negotiations between a multi-stakeholder group including Concerned Citizens for Nuclear Safety, the New Mexico Environmental Law Center, Citizens for Clean Water, New Mexico Dairy Producers, the Association of Commerce and Industry, the Oil Conservation Division of the Energy, Minerals and Natural Resources Department, and the Department.

The current definition of discharge permit modification that has been in place since the 2006 rule revision is as follows:

> **"discharge permit modification"** means a change to the requirements of a discharge permit that result from a change in the location of the discharge, a significant increase in the quantity of the discharge, a significant change in the quality of the discharge; or as required by the secretary;

Thus, the current version of the Commission's rules, as well as all previous versions, have language that clearly implies that changes to a discharge permit and corresponding discharge plan that do not result in significant changes to the quantity or quality, or to the location of a discharge are not considered a modification requiring public notice.

In 2012, the Department began the process of drafting regulations specific to copper mines that included a proposed definition of discharge permit amendment mirroring the current definition of discharge permit modification. The drafters of this definition were the Department's contractor for development of the copper mine rule and myself. The Commission promulgated the copper mine rule at 20.6.7.7B(17) NMAC, including the following definition of discharge permit amendment:

> **"Discharge permit amendment"** means a minor modification of a discharge permit that does not result in a significant change in the location of a discharge, an increase in daily discharge volume of greater than ten percent of the original daily discharge volume approved in an existing discharge permit for an individual discharge location, a significant increase in the concentration of water contaminants discharged, or introduction of a new water contaminant discharged.

None of the parties to the rulemaking proceeding on the copper mine rule, which included Amigos Bravos and GRIP, raised any objections to the concept of discharge permit amendments, either during rule development, the hearing, or on appeal of the final rule.

B. Discharge Permit Amendments Facilitate Protection of Human Health and the Environment

Providing a structured framework for issuance of discharge permit amendments for changes to a discharge permit that are not the result of significant changes to quantity or changes to the quality or location of a discharge leads to greater protection of human health and the environment. In many instances, activities at permitted sites result in circumstances that must be addressed quickly, thus necessitating prompt changes to a discharge permit. In such cases, the ability of the Department to expeditiously approve such changes is beneficial to protection of human health and the environment. For example, at permitted mining sites, operational or closure activities often uncover deleterious material that must be removed and relocated. An example of a discharge permit amendment that authorized placement of demolition debris and historic tailing material encountered during demolition activities at the Questa Mine Mill Site in the Questa Mine Open Pit, a previously authorized discharge location, is included at NMED Exhibit 21. Another example of a discharge permit amendment that does not significantly change the quantity, quality or location of discharge, while allowing for greater protection of human health and the environment is provided for the Chino Mine, where construction of lined stormwater holding ponds and conveyance systems were incorporated into an existing discharge permit by amendment. The construction of the lined ponds and conveyance systems were necessary to reduce hydraulic loading from stormwater to an area of the open pit wall that was in danger of slope failure and posed a direct threat to mining operations and mine employees. A copy of this discharge permit amendment is provided as NMED Exhibit 22. Department authorization under a discharge permit amendment can be completed in a very short time frame – provided, of course, that the proposed actions do not result in a significant change to the quantity or quality, or to the location of a permitted discharge – thereby addressing immediate threats to water quality.

Other types of amendments result in the inclusion of activities that were not previously a component of a discharge permit, providing more complete regulatory coverage. The same holds true for minor changes resulting from construction of new facilities that do not significantly change the quantity, quality, or location of a discharge. Both of these situations are illustrated in a discharge permit amendment issued for the Ghost Ranch Conference Center that incorporated four existing septic tank/leachfield systems and a proposed new septic tank/leachfield system into the existing permit, resulting in an increase in discharge volume that was less than ten percent of the previously permitted discharge volume. A copy of this discharge permit amendment is included as NMED Exhibit 23.

Another example where amendments can enhance the effectiveness and efficiency of regulation is with respect to monitoring requirements. Department decisions regarding whether to reduce or increase monitoring requirements are based on scientific evaluation. Monitoring wells may become dry over time and need to be replaced, or analytical results may indicate that a reduction or expansion in monitoring requirements is appropriate. An example of this is associated with monitoring wells at the Rio Algom uranium mill site in Ambrosia Lake where numerous monitoring wells had gone dry following closure of the mill water evaporation ponds, and the only remaining well that contained water was not previously included in the discharge permit. A copy of the Rio Algom amendment is attached as NMED Exhibit 24. Another example is a discharge permit amendment for the Delta-Person Generating Station that was issued in 2000, adding three constituents to the analytical requirements for ground water monitoring. A copy of the Delta-Peterson amendment is included as NMED Exhibit 25. Incorporating these types of changes into a discharge permit allows for greater enforcement capabilities because it provides the Department with a clearer understanding of site conditions. Delaying the inclusion of these types of changes in a discharge permit could result in adverse impacts to human health and the environment.

If a discharge permit modification is required to permit activities that do not result in a significant change to the quantity of a discharge, or a change to the quality or location of a discharge, the Department's resources will be compromised in a manner that will undermine its ability to effectively regulate. Processing a discharge permit modification application typically takes six months at a minimum, and involves significant staff resources. Following that process for minor changes that do not result in a significant change to the quantity of a discharge or quality of a discharge, or a change to the location of a discharge would strain the Department's resources, requiring review of discharge permit modification requests, issuance of public notification documents, and drafting of discharge permit modification documents for minor changes. This would leave fewer staff resources available to address more significant permitting activities, including issuance of new discharge permits, discharge permit renewals, and changes that result in a significant change to the quantity or quality of a discharge, or a change to the location of a discharge (i.e. that fall under the definition of discharge permit modification), as well as for enforcement and inspections.

In sum, eliminating the Department's ability to issue discharge permit amendments for minor changes to a discharge permit that do not result in changes to the quantity, quality, or location of a discharge would limit flexibility, strain resources, and ultimately result in less effective protection of water quality.

B. Proposed Definition of "Discharge Permit Amendment" and Process for Secretary Approval

The language the Department initially proposed for the definition of "discharge permit amendment" simply mirrored the existing definition of "discharge permit modification," stating that amendments were anything that did not qualify as a discharge permit modification. Following meetings with various stakeholders, however, it became apparent that more specificity was necessary to define what would qualify as an amendment. In particular, the Department met and corresponded with stakeholder representatives to refine the definition, adding more specific limitations on what types of changes can be considered discharge permit amendments as opposed to modifications. Several stakeholder groups, including Amigos Bravos, the New Mexico Environmental Law Center ("NMELC"), and William C. Olson expressed concern about language the Department initially proposed that would have allowed discharge of new water contaminants below Commission's standards under a discharge permit amendment. The Department subsequently removed this language. Another concern raised by these same groups was the possibility that a permittee could request permit amendments for multiple ten percent increases in discharge volume within a permit term. In response to this concern, the Department included language in the definition of discharge permit amendment that would prohibit this from occurring. Both Amigos Bravos and William C. Olson suggested that an overall limit of 50,000 gallons per day should be included in the definition of discharge permit amendment and the Department added this limitation to the proposed language. NMELC raised a question as to whether or not a discharge permit amendment could be appealed to the Commission, and the Department added language to the section on appeals to clarify that the Secretary's decision regarding a discharge permit amendment could be appealed to the Commission.

The current proposed definition includes the following limitations on what types of changes can be considered discharge permit amendments:

- increases in the discharge volume of no greater than ten percent of the permitted discharge volume over the five-year term of a discharge permit, as well as an overall maximum limitation on increases in discharge volume of 50,000 gallons per day under a discharge permit amendment;
- no change in the location of a discharge that would affect groundwater not already affected by the existing discharge;
- no introduction of a new water contaminant; and no increase in an existing permitted effluent limitation.

Any proposed change to a discharge permit that is in excess of these limitations would be considered a discharge permit modification subject to the attendant public notice and procedural requirements. As a result of the greater specificity added to the proposed definition of discharge permit amendment, the Department has proposed corresponding changes to the definition of "discharge permit modification" so that the two definitions will align.

The process for Secretary approval of a discharge permit amendment, as proposed in 20.6.2.3109.B NMAC, includes establishment of a time frame for the Department to act upon an application for amendment, as well as a requirement that the Department notify persons on the facility-specific list maintained by the Department of a final decision regarding permit amendments. Any final action of the Secretary can be appealed to the Commission as set forth in 20.6.2.3112.A NMAC, providing a process by which a discharge permit amendment can be challenged. In addition, upon renewal or modification of a discharge permit, any amendments made during the previous permit term must be incorporated in the renewed or modified permit for the amendment to remain in effect. A discharge permit renewal or modification is subject to the public notification requirements of 20.6.2.3108 NMAC, including the opportunity for a public hearing.

The Department's proposed changes create a structured framework for issuance of discharge permit amendments to codify the longstanding practice of issuance of discharge permit amendments. This practice has been in alignment with the language and intent of the Commission's regulations since they were first promulgated in 1967. The process as proposed, and the ensuing burden placed on the Department to process amendments, is commensurate with the scope of the potential for impact to the public and the environment. The changes that would be allowed under a discharge permit amendment as defined do not include changes to the quality or location of a discharge, and they will not result in significant changes to the quantity of a discharge. The potential for the public to be impacted by such changes is minimal, and those parties who have an interest in a specific facility will be notified of the Department's final decisions on amendments and may appeal those decisions to the Commission if they so choose.

III. VARIANCES

The Department's proposed changes to 20.6.2.1210 NMAC would remove the five-year limit on Commission approval of a variance, and replace it with a requirement that a variance be reviewed at five year intervals to ensure that the conditions upon which the variance was granted are still being met. To achieve this, the petitioner who has been granted a variance would be required to submit to the Department for review a variance compliance report at five year intervals. The Department is also proposing a process for public notification of the five-year variance compliance report, and, in the event the public or the Department determine the conditions of the variance are not being met due to changed circumstances or newly discovered facts, any person, including the Department, may request a hearing before the Commission to revoke, modify, or otherwise reconsider the variance as issued. It should also be noted that, in the event a variance granted by the Commission is associated with a groundwater discharge permit issued by the Department, there would be additional review through the discharge permitting process, as well as public notification of the related permitting action and opportunity for public hearing. Implementation of this proposed revision would allow for a variance to be issued in alignment with the length of time a petitioner intended to operate the facility for which the variance is sought.

A. History of Variances

In 1967 the Commission adopted five regulations. One of these five regulations pertained to variances. *See* 1967 Regulations, NMED Exhibit 14. The other four regulations at that time addressed Notices of Intent to Discharge, Filing of Plans and Specifications, Disposal of Refuse in a Watercourse, and Effluent Quality. Under the 1967 Regulations, a variance from one of the four other regulations could only be granted for a period of one year. These regulations would become the cornerstones of the Commission's regulations over time, and if a variance was granted from one of the four substantive regulations, annual review and reissuance of that variance was practical. In 1977, with the Commission's promulgation of more detailed permitting regulations, the time period for granting a variance was increased to five years. This time frame coincides with the term for a discharge permit issuance.

B. Rationale for Proposed Changes Regarding Variances

Pursuant to amendments to the WQA in 2009, the Commission has now developed prescriptive rules for the dairy and copper mining industries. With these prescriptive rules comes a greater potential for regulated entities to need variances from a much wider array of highly specific regulations. Given the detail and specificity present in the Commission's rules at this time, it is prudent to remove the five-year limit on variances and instead allow a variance to be issued for a time frame determined by the Commission based on the particular circumstances and the regulatory provision from which a variance is sought.

From a practical perspective, it does not make sense to construct a facility and operate it on the basis of a variance that is subject to a new, full-fledged hearing before the Commission every five years. Holding a variance hearing before the Commission on the same exact basis on which Commission previously issued that variance could result in a different outcome, causing great uncertainty for an operator. With respect to variances that may be granted from one of the highly prescriptive rules now in place, including the copper mine rule and the dairy rule, being subject to a hearing before the Commission every five years on a variance from regulations such as those requiring a well at a specific location or a meter location would place a burden on the regulated entity, the Department, and the Commission that is inconsistent with the scope of the variance. Provided there are no changes to a facility and it is operating in accordance with a variance as approved by the Commission, whether it be a variance from the Part 20.6.2 rules or one of the more prescriptive rules related to dairies and copper mines, there would be no justifiable basis for holding another hearing before the Commission on that variance.

III. ALTERNATIVE ABATEMENT STANDARDS

The Department's proposed changes to the regulations at 20.6.2.4103 NMAC regarding technical infeasibility and associated alternative abatement standards petitions seek to accomplish two primary goals that would bring the regulations in line with Section 74-6-4(G) of the WQA. First, the proposed changes would no longer allow for Secretary approval of alternative abatement standards based on technical infeasibility where the proposed alternative standard is less than 200% above the existing standard; instead, all petitions for alternative abatement standards, which the Department regards as a unique type of variance, would be decided by the Commission, as is required for variances under Section 74-6-4(G) of the WQA. Second, the proposed changes would ensure that there is public notification and a public hearing on all petitions for alternative abatement standards.

Under the current regulations, the Secretary is authorized to approve alternative abatement standards based on technical infeasibility demonstrations for contaminant concentrations up to 200% of the existing standard, provided certain criteria are met, while approval of alternative abatement standard petitions based on technical infeasibility for concentrations above 200% are subject to Commission approval. Secretary approval of alternative abatement standards is not consistent with Section 74-6-4(G) of the WQA, which indicates that the Commission has sole authority to grant a variance from any regulation of the Commission. In addition, there is currently no public notice process associated with Secretary approval of a technical infeasibility proposal. The proposed regulations in 20.6.2.4103.F NMAC would address this issue by requiring all alternative abatement standard petitions for technical infeasibility be filed with the Commission, regardless of the concentrations proposed relative to the abatement standards. Any hearing before the Commission on a petition for alternative abatement standards will be subject the public notification requirements of 20.1.3 NMAC.

Other proposed changes to 20.6.2.4103.F NMAC of the regulations include restructuring of the subsection to provide better clarity regarding the acceptable criteria that must be demonstrated for granting of an alternative abatement standard, and the information that must be contained in a petition for alternative abatement standards. Regarding criteria for granting alternative abatement standards, technical capability and financial capability have been split into two separate criteria for clarity. Under the existing regulations these are essentially already two criteria, although the regulation is written as one single criteria. It is possible to have a case where abatement to groundwater standards is technically infeasible regardless of the financial capability of the petitioner, or vice versa, where meeting the standard is not within the financial capability of the petitioner regardless of technical feasibility.

The Department proposes to restructure the existing provision such that there are four criteria, listed in 20.6.2.4103.F(1) NMAC, that can be used as justification for alternate abatement standards. These criteria can be described in general terms as follows: 1) there is no available technology that can be implemented to achieve standards; 2) the person required to abate is not financially capable of abating groundwater to achieve standards; 3) the relationship between the social and economic costs outweigh the benefits of abating groundwater to achieve standards; and 4) attempts to abate groundwater through the use of commercially available technology have resulted in some level of clean up, but the concentration of contaminants over time will not achieve standards based on statistical analysis of the data, subject to the criteria described in 20.6.2.4103.F(1)(d) NMAC. Only one of these criteria would need to be demonstrated, however more than one may be met in a given situation. All four of these criteria are already contained in the existing regulations, the only difference being that under the proposed changes, Commission approval would be required for all alternative abatement standards petitions, as described above. In order to justify use of one of the first three criteria in a petition for alternative abatement standards, a petitioner would have to comply with 20.6.2.4106.E(2) NMAC, which requires completion of a feasibility study to develop and assess potential abatement options.

The existing regulations require that a petition for alternative abatement standards must demonstrate that the proposed standards are technically achievable and cost benefit justifiable, and that compliance with the standards will not create a present or future hazard to public health or undue damage to property. 20.6.2.4103.F(1)(a) and (b) NMAC. These requirements are retained in the proposed rules at 20.6.2.4103.F(3)(b) and 20.6.2.4103.F(3)(c) NMAC.

The Department is also proposing a change to 20.6.2.4103.F(1)(d) NMAC that would allow greater flexibility to the requirements for eight consecutive sampling events for demonstration of technical infeasibility following implementation of an abatement option. This proposal would allow for sampling at a less then quarterly frequency, but would limit the time frame over which such sampling could occur to four years. This proposed change would allow for petitions for alternative abatement standards at sites where sampling frequency has been reduced over time due to stabilization of data trends.

IV. ADDITIONAL CHANGES TO THE ABATEMENT REGULATIONS

The Department is proposing revisions to 20.6.2.4106.D NMAC to allow the Secretary to grant an extension of time to submit a Stage 2 abatement plan beyond 60 days after approval of the final site investigation report prepared pursuant to Stage 1 of the abatement plan for good cause shown. In the current rules, the maximum time allowed for submittal of a Stage 2 abatement plan after approval of the final site investigation report prepared pursuant to Stage 1 of the abatement plan is 120 days. In the event an extension of time is necessary, the time extension granted should be based on the reasons for which that extension is sought. As stated above, the Stage 2 abatement plan must include a feasibility study to develop and assess abatement options. Section 20.6.2.4106.E NMAC states that "the purpose of the Stage 2 abatement plan shall be to select and design, if necessary, an abatement option." For a large, complex site, this may require an extension of time beyond 120 days. One recent example is the abatement process for the St. Anthony Mine, where development and assessment of preferred abatement options involved a multi-stakeholder process that took over a year to complete and resulted in a need to collect additional data. Other examples include the Chino and Tyrone Mines in southwestern New Mexico where development and assessment of abatement options was not possible within a 120-day time frame. A more appropriate alternative for such large, complex sites under abatement is for the responsible person to submit a proposed schedule to achieve various milestones associated with a Stage 2 abatement plan. This would be possible under the Department's proposed change.

The Department has also proposed several changes to Section 20.6.2.4108.B, C, and D NMAC to clarify the public notification process associated with submittal of a Stage 2 abatement plan. Under the current rules, the process and timelines for submittal of a proposed public notice to the Department for approval is unclear. The proposed revisions to 20.6.2.4108 NMAC, in conjunction with the timeline for Secretary approval or notification of deficiencies in a Stage 2 abatement plan, provide clarity regarding when the public notice proposal must be submitted, and sets out a time frame for Secretary approval of a public notice proposal prior to final agency determination on the Stage 2 abatement plan itself.

Finally, the Department's proposed revisions to 20.6.2.4103.F NMAC include an error that requires correction. This subsection addresses the filing of a petition for alternative abatement standards based on inability to meet the abatement standards under Section 20.6.2.4103 NMAC. In five places the proposed revisions to 20.6.2.4103.F NMAC use the phrase "…standard set forth in Subsections A, B, C, ***and D*** of this section…." (emphasis added). The references to Subsection D of 20.6.2.4103 NMAC should be removed from 20.6.2.4103.F NMAC because Subsection D refers to surface water standards, to which the alternative abatement standard process set forth in 20.6.2.4103.F NMAC does not apply. Variances from surface water standards requires an entirely different process that is not addressed in Section 20.6.2.4103 NMAC. Thus, the phrase should instead read "…standard set forth in Subsections A, B, and C of this section…."

V. CHANGES TO 20.6.2.3106.C NMAC

The Department is proposing to add language to 20.6.2.3106.C that will clarify the information required for submittal of a discharge plan modification application. The existing rules do not state what information must be submitted as part of an application for discharge permit modification, nor do they state that the Secretary shall review a discharge permit modification application pursuant to 20.6.2.3108 and 20.6.2.3109 NMAC. The proposed revision clarifies that the process for submittal and review of a discharge permit modification application shall be the same as that for a new discharge permit or a discharge permit renewal. The Department has previously addressed this through the use of a standardized discharge permit application form that included an option for checking a box to identify if the application was for discharge permit modification.

This concludes my written direct testimony.

WQC 67-2

S#2.0

NEW MEXICO
STATE RECORDS CENTER
1967 DEC -5 AM 9:22

NEW MEXICO
SUPREME COURT LAW LIBRARY
'67 DEC 5 PM 3 34

REGULATIONS GOVERNING
WATER POLLUTION CONTROL
IN
NEW MEXICO

1912

WATER QUALITY CONTROL COMMISSION
SANTA FE, NEW MEXICO

NMED EXHIBIT 14

New Mexico
Water Quality Control Commission
Regulations

The following regulations have been adopted by the Water Quality Control Commission in accordance with Section 4 of the Water Quality Act, Chapter #190, Laws of 1967, Chapter 75, Article 39, Section 1 through 12, New Mexico Statutes Annotated, 1953 Compilation.

Definitions from the Act

> "wastes" means sewage, industrial wastes or any other liquid, gaseous or solid substance which will pollute any waters of the state.
>
> "person" means the state or any agency, institution or political subdivision thereof, any public or private corporation, individual, partnership, association or other entity, and includes any officer, or governing or managing body of any political subdivision or public or private corporation.
>
> "treatment works" means any plant or other works used for the purpose of treating, stabilizing of holding wastes.
>
> "sewer system" means pipelines, conduits, pumping stations, force mains or any other structures, devices, appurtenances or facilities used for collecting or conducting wastes to an ultimate point for treatment or disposal.
>
> "sewerage system" means a system for disposing of wastes, either by surface or underground methods, and includes sewer systems, treatment works, disposal wells and other systems.

Superseded

Regulation No. 1 - Notice of Intent to Discharge

Any person intending to make a new waste discharge or to alter the character or location of an existing waste discharge, unless the discharge is being made or will be made into a community sewer system, shall file with the Water and Liquid Waste Division of the New Mexico Department of Health and Welfare a Notice of such proposed discharge; provided that such notice of new discharges or alterations in discharges from facilities for the production, refinement and pipeline transmission of oil and gas, or products thereof, shall be filed with the Oil Conservation Commission in lieu of the Department of Health and Welfare.

The Notice of such proposed waste discharge shall contain at least the following information:

Name of person making discharge
Address of person making discharge
Location of discharge
General quality of discharge
Quantity of discharge

The reporting of a discharge of sewage from single family dwelling into individual sewage disposal facilities is not required.

Adopted by the New Mexico
Water Quality Control Commission
This 16th Day of November
1967 Anno Domini at Santa Fe,
New Mexico

Regulation No. 2 - Filing of Plans and Specifications - Sewerage System

Any person proposing to construct a sewerage system or proposing to modify any sewerage system in a manner that will change substantially the quantity or quality of the discharge from the system, shall file with the Water and Liquid Waste Division of the New Mexico Department of Health and Welfare plans and specifications of such works. Modifications having a minor effect on the character of the discharge from sewerage systems shall be reported as of January 1st and June 30th of each year to the Water and Liquid Waste Division.

Plans, specifications and reports required hereby, if related to facilities for the production, refinement and pipeline transmission of oil and gas, or products thereof, shall be filed with the Oil Conservation Commission in lieu of the Department of Health and Welfare.

Adopted by the New Mexico
Water Quality Control Commission
This 16th Day of November
1967 Anno Domini at Santa Fe,
New Mexico

WQC 67-2
Amendment No. 2

S #2.2

Regulation No. 3 - Disposal of Refuse

No person shall dispose of any refuse in a natural watercourse or in a location and manner where there is a reasonable probability that the refuse will be moved into a natural watercourse by leaching or otherwise, provided that solids diverted from the stream and returned thereto are not subject to abatement under this regulation.

Adopted by the New Mexico
Water Quality Control Commission
This 4th Day of March
1968 Anno Domini at Santa Fe,
New Mexico

WQC 67-2
Amendment No. 3

Superseded

S# 2,3

Regulation No. 4 - Effluent Quality

No person shall cause or allow effluent to discharge to a watercourse if the effluent contains concentrations of the constituents listed below (as indicated by daily composite samples examined in accordance with the latest edition of Standard Methods for the Analyses of Water and Waste Water published by the American Public Health Association) in excess of the indicated value in:

(a) any two consecutive daily composite samples or

(b) more than one sample per month (when less than 10 daily composite samples are examined per month) or

(c) more than 10% of the daily composite samples per month (when 10 or more daily composite samples are examined per month):

Constituent	Concentration in a daily sample
Bio-Chemical Oxygen Demand (BOD)	30 mg/l
Chemical Oxygen Demand (COD)	50 mg/l
Settleable Solids	0.5 ml/l

provided that this regulation does not apply to constituents diverted from the stream and returned thereto.

Adopted by the New Mexico
Water Quality Control Commission
This 4th Day of March
1968 Anno Domini at Santa Fe,
New Mexico

~~Health & Social Services Dept~~
~~Environmental Services~~
~~P.O. Box 2348, Santa Fe, N. Mex.~~

S#2.4

WQC 67-2
Amendment No. 4

Regulation No. 5 - Procedure for Requesting a Variance

I. APPLICATION. Applications for variances pursuant to Section 75-39-4 G, N.M.S.A. 1953 Comp., shall be addressed in writing to the Chairman of the Commission and shall contain the following information:

Regulation from which a variance is sought;

Name of applicant;

Date of application;

Type discharge;

Whether for established or proposed facility;

Quantity and quality of existing or proposed discharge;

Description of existing treatment facilities and proposed facilities [including capital costs and annual operation and maintenance costs for such treatment];

Reasons or justifications for the variance;

Period of time for which variance is desired.

II. COMMISSION ACTION. The Commission shall act upon the variance application within 30 days after receipt, and shall inform the applicant of its decision in writing, the decision to be served personally or by registered mail. If the application is denied, in whole or in part, the denial shall include a statement explaining the grounds for the action, together with a copy of this regulation.

III. PROCEDURE FOR REVIEW. An applicant dissatisfied with Commission action upon an application for variance may secure administrative review thereof by filing a request for review with the Commission in writing within 30 days after the entry of the Commission's decision.

superseded

After written request for hearing has been filed, the Commission shall notify the applicant by certified mail return receipt requested or by personal service of the hearing. The notice shall include the time, place, date of the hearing, which time shall be not less than 10 nor more than 30 days from the date of filing of the request for hearing, provided that the Commission may for good cause or upon request of the applicant set the hearing for a later date.

Hearings shall be conducted in Santa Fe, provided, however, that upon stipulation of the Commission and the applicant the hearing may be conducted elsewhere.

IV. CONDUCT OF THE HEARING. Hearings for administrative review of Commission action on applications for variance shall be conducted by at least a quorum of the Commission members or by a Hearing Officer designated by the Commission. A complete record of the proceedings shall be kept, but the Commission need not arrange to transcribe shorthand notes or sound recordings unless the hearing is conducted by a Hearing Officer or the transcript is requested by a party. In the latter case the cost of any transcript shall be borne by the applicant.

V. PROCEDURES -- EVIDENCE. In the conduct of review proceedings:

A. irrelevant, incompetent, immaterial, or unduly repetitious evidence shall be excluded. The rules of evidence as applied in non-jury civil cases in the District Courts of New Mexico shall be followed. When necessary to ascertain facts not reasonably susceptible of proof under those rules, evidence not admissible thereunder may be admitted, except where precluded by statute, if it is of a type commonly relied upon by reasonably prudent men in the conduct of their affairs.

The Commission shall give effect to the rules of privilege recognized by law. Objections to evidentiary offers may be made, and should be noted in the record. No greater exclusionary effect shall be given any rule or privilege than would obtain in an action in court. Subject to these requirements, when a hearing will be expedited and the interests of the parties will not be prejudiced substantially, any part of the evidence may be received in written form;

B. all evidence, including any records, investigation reports and documents in the possession of the Commission, of which it desires to avail itself as evidence in making a decision, shall be offered and made a part of the record in the proceeding, and no other factual information or evidence shall be considered, except as provided in Paragraphs C and D of this section. Documentary evidence may be received in evidence in the form of copies of excerpts, or by specific citation to page numbers in published documents;

C. the parties and the Commission shall have the right to call and examine witnesses, to introduce exhibits, to cross-examine witnesses who testify, and to submit rebuttal evidence;

D. official notice may be taken of all facts of which judicial notice may be taken and of other facts within the specilized knowledge of the Commission, but whenever the Commission take official notice of a fact, the noticed fact and its source shall be stated at the earliest practicable time, but before the final report or decision, and any party shall on timely request be afforded an opportunity to show the contrary;

E. the experience, technical competence, and specialized knowledge of the commission and its staff may be utilized in the evaluation of the evidence;

Superseded

F. any party shall at all times have the right to be represented by counsel, provided that such counsel is duly licensed to practice law in the State of New Mexico and is in good standing; and

G. if a person who has requested a hearing does not appear and no continuance has been granted, the Commission may hear the evidence of such witnesses as may have appeared, and the Commission may proceed to consider the matter and dispose of it on the basis of the evidence before it.

VI. DECISION OF THE COMMISSION. The final decision of the Commission, after administrative review, shall be in writing and shall be entered within 60 days after the hearing. Parties shall be notified either personally or by mail of any decisions or Order. A copy of the decision or Order shall be delivered or mailed forthwith to each party or to his attorney of record.

Adopted by the New Mexico
Water Quality Control Commission
This 11th Day of June
1968 Anno Domini at Santa Fe,
New Mexico

January 11, 1977
As amended June 14, 1977
Nov. 8, 1977

WATER QUALITY CONTROL COMMISSION
Post Office Box 968
Santa Fe, New Mexico 87503
Phone: (505) 827-5271, Ext. 318

RECEIVED
'77 JAN 13 PM 3 10
STATE RECORDS CENTER
PUBLIC RECORDS & ARCHIVES

AMENDED
WATER QUALITY CONTROL COMMISSION REGULATIONS

PART 1

General Provisions and Procedures

1-100. GENERAL PROVISIONS.

1-101. DEFINITIONS.--As used in the Water Quality Control Commission Regulations:

A. "agency" means the New Mexico environmental improvement agency;

B. "board" means the Utility Operators Certification Advisory Board;

C. "certification act" means the Utility Operators Certification Act, Chapter 394, Laws of 1973;

D. "certified operator" means a person who is certified by the commission as being qualified to supervise or operate one of the classifications of water supply systems or wastewater facilities;

E. "collection system" means pipelines or conduits, pumping stations, force mains, and all other devices, appurtenances and facilities used for collecting and conducting waste to a point of treatment and disposal;

F. "commission" means the New Mexico water quality control commission;

G. "daily composite sample" means a sample collected over any twenty-four-hour period at intervals not to exceed one hour and obtained by combining equal volumes of the effluent collected, or means a sample collected in accordance with federal permit conditions where a permit has been issued under the National Pollutant Discharge Elimination System or for those facilities which include a waste stabilization pond in the treatment process where the retention time is greater than twenty (20) days, means a sample obtained by compositing equal volumes of at least two grab samples collected within a period of not more than twenty-four (24) hours;

H. "director" means the director of the New Mexico environmental improvement agency;

ah/1/77

NMED EXHIBIT 15

I. "discharge plan" means a description of methods and conditions, including any monitoring and sampling requirements, for the discharge of effluent or leachate which may move directly or indirectly into ground water;

J. "distribution system" means pipelines, appurtenances, devices and facilities which carry potable water under pressure to each consumer;

K. "education" means academic credit received attending any public or private primary, secondary or high school, approved vocational training courses in the water supply and wastewater field, college or university;

L. "experience" means actual work experience, full or part-time, in the fields of potable water supply or wastewater treatment. Applicable experience may be in the categories of design, construction, administration, control, surveillance, operation or maintenance. Work experience in a related field may be accepted at the discretion of the commission;

M. "ground water" means interstitial water which occurs in saturated earth material and which is capable of entering a well in sufficient amounts to be utilized as a water supply;

N. "hazard to public health" exists when water which is used or is reasonably expected to be used in the future as a human drinking water supply exceeds at the time and place of such use, one or more of the numerical standards of Subsection 3-103A. or the naturally-occurring concentrations, whichever is higher, or if a toxic pollutant affecting human health is present in the water. In determining whether a discharge would cause a hazard to public health to exist, the director shall investigate and consider the purification and dilution reasonably expected to occur from the time and place of discharge to the time and place of withdrawal for use as human drinking water;

O. "operator" means any person employed by the owner as the person responsible for the operation of all or any portion of a water supply system or wastewater facility. Not included in this definition are such persons as directors of public works, city engineers, city managers, or other officials or persons whose duties do not include actual operation or direct supervision of water supply systems or wastewater facilities;

P. "owner" means the person or persons having the responsibility of managing or maintaining a water supply system or a wastewater facility;

Q. "person" means the state or any agency, institution, commission, municipality, or other political subdivision thereof, federal agency, public or private corporation, individual, partnership, association or other entity, and includes any officer or governing or managing body of any institution, political subdivision, agency or public or private corporation;

R. "petitioner" means a person seeking a variance from a regulation of the commission pursuant to Section 75-39-4(G), N.M.S.A., 1953 Comp.;

S. "population served" means actual or estimated maximum number of persons served by the water supply system or wastewater facility;

T. "refuse" includes food, swill, carrion, slops and all substances from the preparation, cooking and consumption of food and from the handling, storage and sale of food products, the carcasses of animals, junked parts of automobiles and other machinery, paper, paper cartons, tree branches, yard trimmings, discarded furniture, cans, oil, ashes, bottles and all unwholesome material;

U. "sewer system" means pipelines, conduits, pumping stations, force mains or other structures, devices, appurtenances or facilities used for collecting or conducting wastes to an ultimate point for treatment or disposal;

V. "sewerage system" means a system for disposing of wastes, either by surface or underground methods, and includes sewer systems, treatment works, disposal wells and other systems;

W. "TDS" means total dissolved solids as determined by the "calculation method" (sum of constituents), by the "residue on evaporation method at 180°" of the "U.S. Geological Survey Techniques of Water Resource Investigations," or by conductivity, as the director may determine;

X. "toxic pollutants" means those water contaminants, or combinations of water contaminants present in concentrations which, upon exposure, ingestion, inhalation or assimilation into humans or other organisms of direct or indirect commercial, recreational or esthetic value, either directly from the environment or indirectly by ingestion through food chains, will, on the basis of information available to the director or the commission, cause death, disease, behavioral abnormalities, genetic mutation, physiological malfunctions or physical deformations in such organisms or their offspring;

Y. "training" means the non-academic training in the field of water supply or wastewater;

Z. "training credit" means the amount of credit earned by a participant in a training program;

AA. "treatment works" means any plant or other works used for the purpose of treating, stabilizing or holding wastes;

BB. "wastes" means sewage, industrial wastes or any other liquid, gaseous or solid substance which will pollute any waters of the state;

CC. "wastewater facility" means a system of structures, equipment and processes designed to collect and treat domestic and industrial wastes and dispose of the effluents from a public system;

DD. "water" means all water including water situated wholly or partly within or bordering upon the state, whether surface or subsurface, public or private, except private waters that do not combine with other surface or subsurface water;

EE. "water contaminant" means any substance which alters the physical, chemical or biological qualities of water;

FF. "water supply system" means a system of pipes, structures and facilities through which potable water is obtained, treated and distributed to the public; and

GG. "watercourse" means any river, creek, arroyo, canyon, draw, or wash, or any other channel having definite banks and beds with visible evidence of the occasional flow of water.

1-200. PROCEDURES.

1-201. NOTICE OF INTENT TO DISCHARGE.--

A. Any person intending to make a new water contaminant discharge or to alter the character or location of an existing water contaminant discharge, unless the discharge is being made or will be made into a community sewer system, shall file a notice with the water quality division of the environmental improvement agency. However, notice regarding discharges from facilities for the production, refinement and pipeline transmission of oil and gas, or products thereof, shall be filed instead with the Oil Conservation Commission.

B. Notices shall state:

1. the name of the person making the discharge;
2. the address of the person making the discharge;

3. the location of the discharge;
4. an estimate of the concentration of water contaminants in the discharge; and
5. the quantity of the discharge.

C. The filing of a notice of intent to discharge sewage from any sewerage system which receives 2,000 gallons or less of liquid waste per day is not required.

1-202. FILING OF PLANS AND SPECIFICATIONS--SEWERAGE SYSTEMS.--

A. Any person proposing to construct a sewerage system or proposing to modify any sewerage system in a manner that will change substantially the quantity or quality of the discharge from the system shall file plans and specifications of the construction or modification with the water quality section of the environmental improvement agency. Modifications having a minor effect on the character of the discharge from sewerage systems shall be reported as of January 1st and June 30th of each year to the Water Quality Section.

B. Plans, specifications and reports required by this section, if related to facilities for the production, refinement and pipeline transmission of oil and gas, or products thereof, shall be filed instead with the Oil Conservation Commission.

C. Plans and specifications required to be filed under this section must be filed prior to the commencement of construction.

1-203. NOTIFICATION OF DISCHARGE--REMOVAL.--

A. Any person in charge of a facility, as soon as he has notice or knowledge of a discharge from the facility, of oil or other water contaminant, in such quantity as may with reasonable probability injure or be detrimental to human health, animal or plant life, or property, or unreasonably interfere with the public welfare or the use of property, shall immediately:

1. notify the chief, water quality division, environmental improvement agency, of the nature, amount and location of the discharge; provided, however, that such notification shall not be required if notification

is required under rules, regulations or orders promulgated by the oil conservation commission; and

2. take appropriate and necessary steps to contain and remove or mitigate the damage caused by the discharge.

B. Exempt from the requirements of this section are continuous or periodic discharges which are made:

1. in conformance with water quality control commission regulations and rules, regulations or orders of other state or federal agencies; or

2. in violation of water quality control commission regulations but pursuant to an assurance of discontinuance or schedule of compliance approved by the commission or one of its duly authorized constituent agencies.

C. As used in this section:

1. "discharge" means spilling, leaking, pumping, pouring, emitting, emptying, or dumping into water or in a location and manner where there is a reasonable probability that the discharged substance will reach surface or subsurface water;

2. "facility" means any structure, installation, operation, storage tank, transmission line, motor vehicle, rolling stock, or activity of any kind, whether stationary or mobile; and

3. "oil" means oil of any kind or in any form including petroleum, fuel oil, sludge, oil refuse and oil mixed with wastes.

D. Notification of discharge received pursuant to this regulation or information obtained by the exploitation of such notification shall not be used against any such person in any criminal case, except for perjury or for giving a false statement.

1-210. VARIANCE PETITIONS.--

A. Any person seeking a variance from a regulation of the commission pursuant to Section 75-39-4(G), N.M.S.A., 1953 Comp., shall do so by filing a written petition with the commission. The petitioner may submit with his petition any relevant documents or material which the petitioner believes would support his petition. Petitions shall:

1. state the petitioner's name and address;

2. state the date of the petition;

3. describe the facility or activity for which the variance is sought;

4. state the address or description of the property upon which the facility is located;

5. describe the water body or watercourse affected by the discharge;

6. identify the regulation of the commission from which the variance is sought;

7. state in detail the extent to which the petitioner wishes to vary from the regulation;

8. state why the petitioner believes that compliance with the regulation will impose an unreasonable burden upon his activity; and

9. state the period of time for which the variance is desired.

B. Within fifteen days after the receipt of the petition by the commission, the commission shall notify the petitioner by certified mail of the date, time and place of the public hearing.

C. At least fifteen days prior to each hearing date, the commission shall publish notice of the date, time, place and subject of the variance hearing in a newspaper of general circulation in the county in which the facility is located and in a newspaper of general circulation in the state. The notice shall also state the watercourse or water body affected. The commission shall maintain a file of persons interested in variance hearings and shall make a reasonable effort to notify them by mail of the date, time, place and subject of scheduled public hearings.

D. 1. Public hearings shall be held not less than twenty days nor more than sixty days from the date the commission mails the notice of the hearing to the petitioner.

2. Public hearings shall be held in Santa Fe unless the commission and the petitioner agree

upon another site in the state.

3. The commission may designate a hearing officer to take evidence at the hearing.

4. A record shall be made at each hearing, the cost of which shall be borne by the environmental improvement agency. Transcript costs shall be paid by those persons requesting transcripts. If the hearing is conducted by a hearing officer designated by the commission, a transcript shall be prepared and the cost of providing transcript to the commission members shall be borne by the Environmental Improvement Agency.

5. In variance hearings, the technical rules of evidence and the rules of civil procedure shall not apply, but the hearings shall be conducted so that all relevant views are amply and fairly presented without undue repetition. The commission may require reasonable substantiation of statements or records tendered and may require any view to be stated in writing when the circumstances justify.

6. The commission shall allow all persons a reasonable opportunity at a hearing to submit written and oral evidence and arguments and to introduce exhibits.

7. The commission shall allow reasonable cross-examination of persons who testify at a hearing by persons who have submitted a written request to do so. Requests must be submitted to the chairman of the commission by 4:00 p.m. on the day before each hearing.

8. The petitioner and the commission shall have the right to call and examine witnesses, introduce exhibits and cross-examine anyone who testifies.

9. A petitioner may represent himself at the hearing or be represented by any other individual.

10. The commission may grant the requested variance, in whole or in part, or may deny the variance. Any action taken by the commission shall be by written order entered within sixty days after the hearing. A copy of the order shall be mailed to the petitioner. All persons appearing or represented at the hearing shall be mailed notice of the commission's action.

11. The commission shall not grant a variance for a period of time in excess of one year.

12. Orders of the commission shall:

(a) state the petitioner's name and address;

(b) state the date the order is made;

(c) describe the facility for which the variance is sought;

(d) identify the regulation of the commission from which the variance was sought;

(e) state the decision of the commission;

(f) if a variance is granted, state the period of time for which it is granted; and

(g) state the reasons for the commission's decision.

13. The commission shall maintain a file of all orders made by the commission. The file shall be open for public inspection.

E. An order of the commission is final and bars the petitioner for petitioning for the same variance without special permission from the commission. The commission may consider, among other things, the development of new information and techniques to be sufficient justification for a second petition. If the petitioner, or his authorized representative, fails to appear at the public hearing on the variance petition, the commission shall proceed with the hearing on the basis of the petition. A variance may not be extended or renewed unless a new petition is filed and processed in accordance with the procedures established by this section.

F. When the last day for performing an act falls on Saturday, Sunday or a legal, state or national holiday, the performance of the act is timely if performed on the next succeeding day which is not a Saturday, Sunday, or a legal, state or national holiday. Except as provided in Subsection D.7., all matters required to be filed or mailed under this section are timely if deposited in the United States mail on or before the required date.

PART 2

Water Quality Control

2-100. APPLICABILITY OF REGULATIONS.--The requirements of Part 2 of these regulations shall not apply to any discharge which is subject to a permit under the National Pollutant Discharge Elimination System of P.L. 92-500; provided that any discharger who is given written notice of National Pollutant Discharge Elimination System permit violation from the administrator of the Environmental Protection Agency and who has not corrected the violation within thirty days of receipt of said notice shall be subject to Part 2 of these regulations until in compliance with the National Pollutant Discharge Elimination System permit conditions; provided further that nothing in these regulations shall be construed as a deterrent to action under Section 75-39-10 N.M.S.A., 1953 Comp.

2-101. GENERAL REQUIREMENTS.--

A. Except as otherwise provided in Part 2 of these regulations, no person shall cause or allow effluent to discharge to a watercourse if the effluent as indicated by:

1. any two consecutive daily composite samples;
2. more than one daily composite sample in any thirty-day period (in which less than ten [10] daily composite samples are examined); or
3. more than ten percent (10%) of the daily composite samples in any thirty-day period (in which ten [ten] or more daily composite samples are examined);

does not conform to the following:

Bio-chemical Oxygen Demand (BOD)	Less than 30 mg/l
Chemical Oxygen Demand (COD)	Less than 125 mg/l
Settleable Solids	Less than 0.5 mg/l
Fecal Coliform Bacteria	Less than 500 organisms/100 ml
pH	Between 6.6 and 8.6

B. Upon application, the director of the environmental improvement agency may eliminate the pH requirement for any effluent source that the director determines does not unreasonably degrade the water into which the effluent is discharged.

C. Subsection A of this section does not apply to the weight of constituents in the water diverted.

D. Samples shall be examined in accordance with the most current edition of Standard Methods for the Examination of Water and Wastewater published by the American Public Health Association or the most current edition of Methods for Chemical Analysis of Water and Wastes published by the Environmental Protection Agency, where applicable.

2-102. RIO GRANDE BASIN--COMMUNITY SEWERAGE SYSTEMS.--

A. No person shall cause or allow effluent from a community sewerage system to discharge to a watercourse in the Rio Grande Basin between the headwaters of Elephant Butte Reservoir and Angostura Diversion Dam as described in Subsection E of this section if the effluent, as indicated by:

1. any two consecutive daily composite samples;

2. more than one daily composite sample in any thirty-day period (in which less than ten daily composite samples are examined); or

3. more than ten percent (10%) of the daily composite samples in any thirty-day period (in which ten or more daily composite samples are examined);

does not conform to the following:

Bio-chemical Oxygen Demand (BOD)	Less than 30 mg/l
Chemical Oxygen Demand (COD)	Less than 80 mg/l
Settleable Solids	Less than 0.1 mg/l
Fecal Coliform Bacteria	Less than 500 organisms/ 100 ml
pH	Between 6.6 and 8.6

B. Upon application, the director of the environmental improvement agency may eliminate the pH requirement for any effluent source that the director determines does not unreasonably degrade the water into which the effluent is discharged.

C. Subsection A of this section does not apply to the weight of constituents in the water diverted.

D. Samples shall be examined in accordance with the most current edition of Standard Methods for the Analysis of Water and Wastewater published by the American Public Health Association or the most current edition of Methods for Chemical Analysis of Water and Wastes published by the Environmental Protection Agency, where applicable.

E. The following is a description of the Rio Grande Basin from the headwaters of Elephant Butte Reservoir to Angostura Diversion Dam as used in this section:

> Begin at San Marcial USGS gauging station, which is the headwaters of Elephant Butte Reservoir Irrigation Project, thence northwest to U.S. Highway 60, nine miles ± west of Magdalena; thence west along the northeast edge of the San Agustin Plains closed basin; thence north along the east side of the north plains closed basin to the Continental Divide; thence northerly along the Continental Divide to the community of Regina on State Highway 96; thence southeasterly along the crest of the San Pedro Mountains to Cerro Toledo Peak; thence southwesterly along the Sierra de Los Valles ridge and the Borrego Mesa to Bodega Butte; thence southerly to Angostura Diversion Dam which is the upper reach of the Rio Grande in this basin; thence southeast to the crest of the Sandia Mountains; thence south along the crest and the crest of the Manzano Mountains and the Los Pinos Mountains; thence southerly along the divide that contributes to the Rio Grande to San Marcial gauging station to the point and place of beginning; excluding all waters upstream of Jemez Pueblo which flow into the Jemez River drainage and the Bluewater Lake. Counties included in the basin are:

1. north portion of Socorro County;
2. northeast corner of Catron County;
3. east portion of Valencia County;
4. west portion of Bernalillo County;
5. east portion of McKinley County; and
6. most of Sandoval County.

2-200. WATERCOURSE PROTECTION.--

2-201. DISPOSAL OF REFUSE.--No person shall dispose of any refuse in a natural watercourse or in a location and manner where there is a reasonable probability that the refuse will be moved into a natural watercourse by leaching or otherwise. Solids diverted from the stream and returned thereto are not subject to abatement under this section.

PART 3

Water Quality Control

3-100. REGULATIONS FOR DISCHARGES ONTO OR BELOW THE SURFACE OF THE GROUND.

3-101. PURPOSE.--

A. The purpose of these regulations controlling discharges onto or below the surface of the ground is to protect all ground water of the state of New Mexico which has an existing concentration of 10,000 mg/l or less TDS, for present and potential future use as domestic and agricultural water supply, and to protect those segments of surface waters which are gaining because of ground water inflow, for uses designated in the New Mexico Water Quality Standards. The regulations are written so that in general:

1. if the existing concentration of any water contaminant in ground water is in conformance with the standard of Section 3-103 of these regulations, degradation of the ground water up to the limit of the standard will be allowed; and

2. if the existing concentration of any water contaminant in ground water exceeds the standard of Section 3-103, no degradation of the ground water beyond the existing concentration will be allowed.

B. Ground water standards are numbers that represent the pH range and maximum concentrations of water contaminants in the ground water which still allow for the present and future use of ground water resources.

C. The standards are not intended as maximum ranges and concentrations for use, and nothing herein contained shall be construed as limiting the use of waters containing higher ranges and concentrations.

3-102. AUTHORITY.--Standards are adopted by the commission under the authority of Section 75-39-4, N.M.S.A., 1953 Comp. (the New Mexico Water Quality Act, Chapter 326, Laws of 1973, as amended). Regulations are adopted by the commission under the authority of Section 75-39-4 and 75-39-4.1 of the New Mexico Water Quality Act.

3-103. STANDARDS FOR GROUND WATER OF 10,000 mg/l TDS CONCENTRATION OR LESS.--The following standards are the allowable pH range and the maximum allowable concentration in ground water for the contaminants specified unless the existing condition exceeds the standard or unless otherwise provided in Subsection 3-109D. or Section 3-110. When an existing pH or concentration of any water contaminant exceeds the standard specified in Subsection A, B or C, the existing pH or concentration shall be the allowable limit, provided that the discharge at such concentrations will not result in concentrations at any place of withdrawal for present or reasonably forseeable future use in excess of the standards in this section.

These standards shall apply to the dissolved portion of the contaminants specified with a definition of dissolved being that given in the publication "Methods for Chemical Analysis of Water and Waste of the U.S. Environmental Protection Agency," with the exception of mercury which shall be total.

A. Human Health Standards - Ground water shall meet the standards of Section A and B unless otherwise provided.

Arsenic (As)	0.1 mg/l
Barium (Ba)	1.0 mg/l
Cadmium (Cd)	0.01 mg/l
Chromium (Cr)	0.05 mg/l
Cyanide (CN)	0.2 mg/l
Fluoride (F)	1.6 mg/l
Lead (Pb)	0.05 mg/l
Total Mercury (Hg)	0.002 mg/l
Nitrate (NO_3 as N)	10.0 mg/l
Selenium (Se)	0.05 mg/l
Silver (Ag)	0.05 mg/l
Uranium (U)	5.0 mg/l
Radioactivity: Combined Radium-226 and Radium-228	30.0 pCi/l

B. Other Standards for Domestic Water Supply

Chloride (Cl)	250. mg/l
Copper (Cu)	1.0 mg/l
Iron (Fe)	1.0 mg/l
Manganese (Mn)	0.2 mg/l
Phenols	0.005 mg/l
Sulfate (SO_4)	600. mg/l
Total Dissolved Solids (TDS)	1000. mg/l
Zinc (Zn)	10.0 mg/l
pH	between 6 and 9

C. Standards for Irrigation Use - Ground water shall meet the standards of subsections A, B and C unle otherwise provided.

Aluminum (Al)	5.0 mg/l
Boron (B)	0.75 mg/l
Cobalt (Co)	0.05 mg/l
Molybdenum (Mo)	1.0 mg/l
Nickel (Ni)	0.2 mg/l

3-104. DISCHARGE PLAN REQUIRED.--Unless otherwise provided by these regulations, no person shall cause or allow effluent or leachate to discharge so that it may move directly or indirectly into ground water unless he is discharging pursuant to a discharge plan approved by the director. When a plan has been approved, discharges must be consistent with the terms and conditions of the plan.

3-105. EXEMPTIONS FROM DISCHARGE PLAN REQUIREMENT.--Sections 3-104 and 3-106 of these regulations do not apply to the following:

A. effluent or leachate which conforms to all the listed numerical standards of Section 3-103, has a total nitrogen concentration of 10 mg/l or less, and does not contain toxic pollutants. To determine conformance, samples may be taken by the agency before the effluent or leachate is discharged so that it may move directly or indirectly into ground water; provided that if the discharge is by seepage through non-natural or altered natural materials, the agency may take samples of the solution before or after seepage. If for any reason the agency does not have access to obtain the appropriate samples, this exemption shall not apply;

B. effluent which is discharged from a sewerage system used only for disposal of household and other domestic waste which receives 2,000 gallons or less of liquid waste per day;

C. water used for irrigated agriculture, for watering of lawns, trees, gardens or shrubs, or for irrigation for a period not to exceed five years for the revegetation of any disturbed land area, unless that water is received directly from any sewerage system;

D. discharges resulting from the transport or storage of water diverted, provided that the water diverted has not had added to it after the point of diversion any effluent received from a sewerage system, that the source of the water diverted was not mine workings, and that the director has not determined that a hazard to public health may result;

E. effluent which is discharged to a watercourse which is naturally perennial; discharges to dry arroyos and ephemeral streams are not exempt from the discharge plan requirement, except as otherwise provided in this section;

F. those constituents which are subject to effective and enforceable effluent limitations in a National Pollutant Discharge Elimination System (NPDES) permit, where discharge onto or below the surface of the ground so that water contaminants may move directly or indirectly into ground water occurs downstream from the outfall where NPDES effluent limitations are imposed, unless the director determines that a hazard to public health may result. For purposes of this subsection, monitoring requirements alone do not constitute effluent limitations;

G. discharges resulting from flood control systems;

H. leachate which results from the direct natural infiltration of precipitation through disturbed or undisturbed materials, unless the director determines that a hazard to public health may result;

I. leachate from solids disposed of in accordance with the Solid Waste Management Regulations adopted by the New Mexico environmental improvement board on April 19, 1974;

J. natural ground water seeping or flowing into conventional mine workings which re-enters the ground by natural gravity flow prior to pumping or transporting out of the mine and without being used in any mining process; this exemption does not apply to solution mining;

K. effluent or leachate discharges resulting from activities regulated by a mining plan approved and permit issued by the New Mexico coal surface mining commission, provided that this exemption shall not be construed as limiting the application of appropriate ground water protection requirements by the New Mexico coal surface mining commission;

L. effluent or leachate discharges which are regulated by the oil conservation commission and the regulation of which by the water quality control commission would interfere with the exclusive authority granted under Section 65-3-11, N.M.S.A., 1953 Comp. or under other laws, to the oil conservation commission.

3-106. APPLICATION FOR DISCHARGE PLAN APPROVAL.--

A. Any person who, before or within 120 days after the effective date of these regulations, is discharging any of the water contaminants listed in Section 3-103 or toxic pollutants so that they may move directly or indirectly into ground water shall, within 120 days of receipt of written notice from the director that a discharge plan is required, or such longer time as the director shall for good cause allow, submit a discharge plan to the director for approval; such person may discharge without an approved discharge plan until 240 days after written notification by the director that a discharge plan is required or such longer time as the director shall for good cause allow.

B. Any person who intends to begin, more than 120 days after the effective date of these regulations, discharging any of the water contaminants listed in Section 3-103 or toxic pollutants so that they may move directly or indirectly into ground water shall notify the director giving the information enumerated in Subsection 1-201B.; the director shall, within 60 days, notify such person if a discharge plan is required; upon submission the director shall review the discharge plan pursuant to Sections 3-108 and 3-109; for good cause shown the director may allow such person to discharge without an approved plan for a period not to extend beyond one year after the effective date of these regulations; after one year after the effective date of these regulations, for good cause shown the director may allow such person to discharge without an approved discharge plan for a period not to exceed 120 days.

C. A proposed discharge plan shall set forth in detail the methods or techniques the discharger proposes to use or processes expected to naturally occur which will ensure compliance with these regulations. At least the following information shall be included in the plan:

1. quantity, quality and flow characteristics of the discharge;

2. location of the discharge and of any bodies of water, watercourses and ground water discharge sites within one mile of the outside perimeter of the discharge site, and existing or proposed wells to be used for monitoring;

3. depth to and TDS concentration of the ground water most likely to be affected by the discharge;

4. flooding potential of the site;

5. location and design of site(s) and method(s) to be available for sampling, and for measurement or calculation of flow;

6. depth to and lithological description of rock at base of alluvium below the discharge site if such information is available; and

7. any additional information that may be necessary to demonstrate that approval of the discharge plan will not result in either concentrations in excess of the standards of Section 3-103 or the presence of toxic pollutants at any place of withdrawal of water for present or reasonably forseeable future use. Detailed information on site geologic and hydrologic conditions may be required for a technical evaluation of the applicant's proposed discharge plan.

3-107. MONITORING, REPORTING, AND OTHER REQUIREMENTS.--

A. Each discharge plan shall provide for the following as the director may require:

1. the installation, use, and maintenance of effluent monitoring devices;

2. the installation, use, and maintenance of monitoring devices for the ground water most likely to be affected by the discharge;

3. monitoring in the vadose zone;

4. continuation of monitoring after cessation of operations;

5. periodic submission to the director of results obtained pursuant to any monitoring requirements in the discharge plan and the methods used to obtain these results;

6. periodic reporting to the director of any other information that may be required as set forth in the discharge plan;

7. the discharger to retain for a period of at least five years any monitoring data required in the discharge plan;

8. a system of monitoring and reporting to verify that the plan is achieving the expected results;

9. procedures for detecting failure of the discharge system;

10. contingency plans to cope with failure of the discharge plan or system;

11. measures to prevent ground water contamination after the cessation of operation, including post-operational monitoring.

B. Sampling and analytical techniques shall conform with the following references unless otherwise specified by the director;

1. Standard Methods for the Examination of Water and Wastewater, latest edition, American Public Health Association; or

2. Methods for Chemical Analysis of Water and Waste and other publications of the Analytical Quality Laboratory, EPA; or

3. Techniques of Water Resource Investigations of the U.S. Geological Survey.

C. The discharger shall notify the director of any facility expansion, production increase or process modifications that would result in any significant modification in the discharge of water contaminants.

D. Any discharger of effluent or leachate shall allow any authorized representative of the director to:

1. inspect and copy records required by a discharge plan;

2. inspect any treatment works, monitoring and analytical equipment;

3. sample any effluent before and after discharge;

4. use monitoring systems and wells installed pursuant to a discharge plan requirement in order to collect samples from ground water or the vadose zone.

3-108. PUBLIC NOTICE AND PARTICIPATION.--

A. Within thirty (30) days of filing of a proposed discharge plan, the director shall notify the following persons:

1. the public, who shall be notified through publication of a notice in a newspaper of general circulation in this state;

2. those persons who have requested notification, who shall be notified by mail;

3. any local, state or federal governmental agency affected which shall be notified by certified mail.

B. The public notice shall include:

1. name and address of the proposed discharger;

2. location of the discharge;

3. brief description of the activities which produce the discharge described in the proposed discharge plan;

4. quantity, quality and flow characteristics of the discharge;

5. depth to and TDS concentration of the ground water most likely to be affected by the discharge;

6. brief description of the procedures followed by the director in making a final determination;

7. statement on the comment period; and

8. address and telephone number at which interested persons may obtain further information.

C. Following the public notice and prior to ruling on any proposed discharge plan or its modification, the director shall allow a period of at least thirty (30) days during which comments may be submitted to the director and a public hearing may be requested by any interested person. Requests for a public hearing shall set forth the reasons why a hearing should be held. A public hearing shall be held if the director determines there is significan public interest. The time and place of the hearing shall be determined by the director and notice shall be given at least thirty (30) days prior to the hearing pursuant to Subsections A and B above. The director may appoint a hearing officer. A transcript of the hearing shall be made at the request of either the director or the discharger and at the expense of the person requesting the transcrip At the hearing, all interested persons shall be given a reasonable chance to submit data, views or arguments orally or in writing and to examine witnesses testifying at the hearing.

3-109. DIRECTOR APPROVAL, DISAPPROVAL, MODIFICATION OR TERMINATION OF PROPOSED DISCHARGE PLANS.--

A. If no public hearing is held pursuant to Subsection 3-108.C., then the director shall, within sixty (60) days after required information is available to him, approve or disapprove the proposed plan based on the information available to him.

B. If a public hearing is held pursuant to Subsection 3-108.C., then the director shall, within sixty (60) days after the public hearing or after all required information is available to him, whichever is later, approve or disapprove the proposed plan based on information contained in the proposed plan and information submitted at the hearing.

C. Provided that the other requirements of these regulations are met and provided further that the discharge plan demonstrates that neither a hazard to public health nor undue risk to property will result, the director shall approve a proposed discharge plan if the following requirements are met:

1. the discharge plan demonstrates that the standards of Section 3-103 will be met except for contaminants in the water diverted as provided in Subsection 3-109.D., or

2. ground water that has a TDS concentration of 10,000 mg/l or less will not be affected by the discharge, or

3. the person proposing to discharge demonstrates that approval of the discharge plan will not result in either concentrations in excess of the standards of Section 3-103 or the presence of toxic pollutants at any place of withdrawal of water for present or reasonably foreseeable future use, or

4. the plan conforms to either Subsection a or b below and Subsection c below.

a. Municipal, Other Domestic Discharges, and Discharges from Sewerage Systems Handling Only Animal Wastes.

The effluent is entirely domestic, is from a sewerage system handling only animal wastes or is from a municipality and conforms to the following:

(1) the discharge is from an impoundment or a leach field existing on the effective date of these regulations which receives less than 10,000 gallons per day and the director has not found that the discharge may cause a hazard to public health; or

(2) the discharger has demonstrated that the total nitrogen in effluent that enters the subsurface from a leach field or surface impoundment will not exceed 200 pounds per acre per year and that the effluent will meet the standards of Section 3-103 except for nitrates and except for contaminants in the water diverted as provided in Subsection 3-109.D.; or

(3) the total nitrogen in effluent that is applied to a crop which is harvested shall not exceed by more than 25% the maximum amount of nitrogen reasonably expected to be taken up by the crop and the effluent shall meet the standards of Section 3-103 except for nitrates and except for contaminants in the water diverted as provided in Subsection 3-109.D.

b. Discharges from Industrial, Mining or Manufacturing Operations

(1) the discharger has demonstrated that the amount of effluent that enters the subsurface from

a surface impoundment will not exceed 0.5 acre-feet per acre per year; or

(2) the discharger has demonstrated that the total nitrogen in effluent that enters the subsurface from a leach field or surface impoundment shall not exceed 200 pounds per acre per year and the effluent shall meet the standards of Subsection 3-103 except for nitrate and contaminants in the water diverted as provided in Subsection 3-109D.; or

(3) the total nitrogen in effluent that is applied to a crop that is harvested shall not exceed by more than 25% the maximum amount of nitrogen reasonably expected to be taken up by the crop and the effluent shall meet the standards of Section 3-103 except for nitrate and contaminants in the water diverted as provided in Subsection 3-109D.

c. All Discharges

(1) the monitoring system proposed in the plan includes adequate provision for sampling of effluent and adequate flow monitoring so that the amount being discharged onto or below the surface of the ground can be determined.

(2) the monitoring data is reported to the director at a frequency determined by the director.

D. The director shall allow the following unless he determines that a hazard to public health may result:

1. the weight of water contaminants in water diverted from any source may be discharged provided that the discharge is to the aquifer from which the water was diverted or to an aquifer containing a greater concentration of the contaminants than contained in the water diverted; and provided further that contaminants added as a result of the means of diversion shall not be considered to be part of the weight of water contaminants in the water diverted;

2. the water contaminants leached from undisturbed natural materials may be discharged provided that:

a. the contaminants were not leached as a product or incidentally pursuant to a solution mining operation; and

b. the contaminants were not leached as a result of direct discharge into the vadose zone from municipal or industrial facilities used for the storage, disposal, or treatment of effluent;

3. the water contaminants leached from undisturbed natural materials as a result of discharge into ground water from lakes used as a source of cooling water.

E. If data submitted pursuant to any monitoring requirements specified in the approved plan or other information available to the director indicates that these regulations are being or may be violated or that the standards of 3-103 are being or will be exceeded in ground water at any place of withdrawal for present or reasonably forseeable future use due to the discharge, except as provided in Subsections 3-109D. and Section 3-110 of these regulations;

1. the director may require a discharger to modify a discharge plan within the shortest reasonable time so as to achieve compliance with these regulations and to provide that any exceeding of standards in ground water at any place of withdrawal for present or reasonably foreseeable future use due to the discharge except as provided in Subsections 3-109D. and Section 3-110 will be abated or prevented.

2. the director may terminate an approved discharge plan when a discharger fails to modify the plan in accordance with Subsection E.1. of this subsection.

F. At the request of the discharger, an approved discharge plan may be modified in accordance with these regulations.

G. The director shall not approve a discharge plan for:

1. any discharge for which the discharger has not provided a site and method for flow measurement and sampling;

2. any discharge that will cause any stream standard to be violated;

3. the discharge of any water contaminant which may result in toxic pollutants being present in the ground water at any place of withdrawal for present or reasonably foreseeable future use; or

4. a period longer than five years.

3-110. APPROVAL OR DISAPPROVAL OF PROPOSED DISCHARGE PLANS THAT DO NOT MEET THE STANDARDS OF SECTION 3-103.

A. The discharger may file a written petition with the director seeking commission consideration of a discharge plan that would not meet the standards of Section 3-103 if he believes that the discharge plan demonstrates the maximum use of technology within the economic capability of the discharger or that there is no reasonable relationship between the economic and social costs and benefits (including attainment of the standards of Section 3-103) to be obtained and that discharge under the plan would not create a hazard to public health or undue risk to property.

B. The petition shall state the extent to which the plan would violate the standards of Section 3-103 and why the plan should be approved. The director may transmit the petition to the commission recommending that it be approved or refuse to transmit the petition.

C. If the director transmits the petition to the commission, the commission shall review the petition and determine to either grant or deny a public hearing on the applicability of the criteria of Subsection A above to the proposed discharge plan.

D. If the director refuses to transmit the proposed discharge plan to the commission, or if the commission refuses to grant a hearing on the applicability of the criteria of Subsection A above to the proposed discharge plan, the director shall act on the proposed discharge plan without consideration of the criteria of Subsection A.

E. If the director denies the proposed discharge plan pursuant to Subsection D, then the discharger may address the issue of whether the proposed discharge plan meets the criteria of Subsection A above upon appeal of the director's disapproval of his proposed discharge plan to the commission in accordance with the provisions of Subsection 75-39-4.1(L), N.M.S.A., 1953 Comp.

F. If the commission grants a public hearing, the hearing shall be held in accordance with the provisions of Subsection 75-39-4.1(L), (M) and (N), N.M.S.A., 1953 Comp.

G. If the commission, after hearing held pursuant to Subsection F, denies the proposed discharge plan, the discharger may appeal pursuant to Section 75-39-4.1 (O), N.M.S.A., 1953 Comp. and on appeal may address the issue of whether the proposed discharge plan meets the criteria of Subsection A.

H. After public hearing and consideration of all facts and circumstances included in Section 75-39-4(D), N.M.S.A., 1953 Comp., the commission may authorize the director to approve a proposed discharge plan if the commission determines that the plan meets the criteria of Subsection A above.

3-111. TRANSFER OF DISCHARGE PLAN.--

A discharger shall notify by letter the succeeding owner of a facility which is operating pursuant to an approved discharge plan of the existence of the discharge plan. The notice shall be given on or before transfer of possession of the facility. A copy of the letter shall be forwarded to the director. The succeeding owner shall be responsible for compliance with the approved discharge plan upon taking possession of the facility and receiving notice of the discharge plan.

3-112. APPEALS FROM DIRECTOR'S DECISIONS.--

If the director disapproves a proposed discharge plan, approves a proposed discharge plan subject to condition, or modifies or terminates an approved plan, appeal therefrom and any action of the commission thereon shall be in accordance with the provisions of Subsection 75-39-4.1(L), (M) and (N), N.M.S.A., 1953 Comp.

3-113. APPEALS FROM COMMISSION DECISIONS.-- A discharger may appeal the decision of the commission in accordance with the provisions of Section 75-39-4.1(O), N.M.S.A., 1953 Comp.

3-114. SEVERABILITY.--If any section, subsection, individual standard or application of these standards or regulations is held invalid, the remainder shall not be affected.

PART 4

Utility Operators Certification

4-100. CLASSIFICATION OF WATER SUPPLY SYSTEMS AND WASTEWATER FACILITIES.--

4-101. GENERAL PROVISIONS.--

Water supply systems and wastewater facilities shall be classified by the commission in accordance with Section 4(A) of the Certification Act.

4-102. WATER SUPPLY SYSTEMS.--

Population Served	2,500 5,000	5,001 10,000	10,001 20,000	20,000+
Treatment Process		Classification		
Filtration (sand, gravity)	III	III	III	IV
Coagulation, Sedimentation, Filtration	III	III	IV	IV
Chemical Precipitation (Mn, Fe, Softening)	III	III	IV	IV
Aeration	II	III	III	IV
Odor and Taste Control (activated carbon)	II	III	III	IV
Chemical Addition (stabilization)	II	II	III	IV
Pressure Filtration	II	II	III	IV
Ion Exchange (softening, defluoridation)	II	III	III	IV
Chlorination	II	II	III	IV
Fluoridation	II	II	III	IV
Special, such as desalinization	IV	IV	IV	IV
Production, ground water only	I	II	III	IV
Distribution Systems		Classification		
Distribution of Treated Surface Water	II	II	II	III
Distribution of Chlorinated Ground Water	II	II	II	III
Distribution of Unchlorinated Ground Water	I	II	II	III

4-103. WASTEWATER FACILITIES.--

Population Served	2,500 5,000	5,001 10,000	10,001 20,000	20,000+
Treatment Process	Classification			
Raw Sewage Lagoons	I	I	I	I
Aerated Lagoons	II	II	II	II
Primary Treatment	II	II	II	II
Primary Treatment and Oxidation Ponds	II	II	II	II
Secondary Treatment, Trickling Filter	II	III	III	IV
Secondary Treatment, Aeration	III	III	IV	IV
Physical-Chemical Treatment Processes	III	III	IV	IV
Advanced Waste Treatment Process	III	IV	IV	IV

Collection System

Ordinarily, collection systems are considered as a part of the treatment works; however, where the jurisdiction or responsibility for the collection system is not the same as the jurisdiction or responsibility for the treatment works, the collection system shall be classified as Grade I, if the population served is less than 15,000 persons and as Grade II, if the population served is greater than 15,000 persons.

4-200. OPERATOR CERTIFICATION.--

4-201. GENERAL PROVISIONS.--

A. After July 1, 1976, each owner of a water supply system or wastewater facility, for public or commercial use, serving 2,500 persons or more shall employ a certified operator(s).

B. Class IV is the highest classification level and Class I is the lowest. The classes of certification are ranked so that a person holding certification in a particular class may operate any facility in that particular class and any lower class.

C. The name(s) of the certified operator(s) must be on file at all times with the agency. A certified operator may be replaced with another certified operator of the required particular class at any time. The owner shall notify the agency in writing within ten days after the replacement.

4-202. REQUIREMENTS FOR CERTIFICATION.--Each applican for certification as a water system operator or wastewater facility operator shall:

A. Make application on forms furnished by the agency. Applications shall be submitted to the agency not later than thirty (30) days prior to the date of the examination.

B. Submit evidence that the applicant has reached the age of majority.

C. Pay a fee, in advance, to the agency through the commission. The fee shall be $2.00 for each agency action such as examination for certification, re-examination for certification, issuance of a certificate, issuance of a temporary certificate, or annual renewal.

D. Successfully meet the educational, experience and training requirements stipulated in Section 4-203 of this regulation. All training programs must be approved by the commission and the commission shall assign the number of training credits for each approved training program.

E. Successfully pass the examination for the class and type of certification being applied for:

1. Examinations for certification shall be scheduled at such times and locations as the commission deems necessary.

2. Examinations shall be used in determining skill, knowledge, ability and judgment of the applicant.

3. All examinations will be graded and the applicants notified of the results. Examination papers will not be returned to the applicant, but may be reviewed by the applicant at the agency office.

4-203. REQUIREMENTS FOR THE CLASSES.--

A. Basic requirements are:

1. Class I requires one year of experience plus ten training credits;

2. Class II requires three years of experience plus thirty training credits;

3. Class III requires five years of experience plus 50 training credits; and

4. Class IV requires high school graduation, or G.E.D. equivalent, plus one year's experience as a Class III certificate holder plus 80 training credits.

B. Substitutions:

In no case shall the actual experience be less than one year for any class.

Education may be substituted for experience as follows:

1. High school graduation of G.E.D. equivalent may be substituted for one year's experience.

2. One year (30 semester hours) of successfully completed college education may be substituted for six months of the required experience.

3. One year of an approved vocational school in the water and wastewater field may be substituted for one year of the required experience.

4-204. TEMPORARY CERTIFICATION.--If, after reasonable time and effort by an owner, a qualified operator cannot be employed, temporary certification may be issued for the operator of a system or facility. Such a certificate is issued to an individual for a period not to exceed six months. A temporary certificate may be extended to a maximum of 18 months if the operator is involved in a training program that will qualify him for the required level in that period.

4-205. PRIOR CERTIFICATION.--Certificates in appropriate classification shall be issued without examination to persons who hold valid certificates of competency issued under the voluntary program co-sponsored by the New Mexico Environmental Improvement Agency, provided application is made on or before July 1, 1976.

4-206. CERTIFICATION WITHOUT EXAMINATION.--

A. Certificates shall be issued without an examination to persons who, on July 1, 1973, were operators of a system or facility. Applications for certification under this section must have been made on or before January 1, 1974.

Certificates issued under this section will be restricted to the particular system or facility for which the applicant is employed as it existed on July 1, 1973. Major modification of the type of treatment employed which would significantly affect the operation of the system or facility shall cause any certificate issued under this section to become invalid. The limitations of the certificate will be printed thereon.

An operator certified under this section may request to have his certificate transferred to another facility of the same general class and type or to another facility of lower class. Such a request will be granted if, in the opinion of the commission, such a transfer would not adversely affect the health and safety of the public or the environment.

B. The commission may issue certificates, in equivalent classification, without examination to applicants who hold valid certificates or licenses issued by any state, territory, or foreign jurisdiction, provided that the requirements for issuance of such certificates or licenses are, in the opinion of the commission, equal to or higher than those set forth in this regulation.

4-207. RENEWAL OF CERTIFICATES.--

A. Application for certificate renewal shall be made annually prior to the last working day of the holder's birth month in accordance with Section 3-202(C).

B. The agency shall mail each holder of a certificate a renewal notice at least thirty days prior to the expiration date, mailed to his last address of record. Failure to receive such notice shall not relieve the holder of his responsibility to apply for renewal prior to the expiration date.

C. Annual renewal of certificates issued under Section 4-206 shall be required.

4-208. LAPSED CERTIFICATES.--

A. Certificates which have not been renewed in accordance with Section 4-207 will be considered lapsed and invalid.

B. Lapsed certificates may be reinstated without penalty upon application within thirty days of the date of expiration. A lapsed certificate which has not been renewed within the thirty-day period may be reinstated upon reapplication and payment of a $2.00 per month penalty fee for each month or portion thereof beyond the expiration date.

If a lapsed certificate has not been reinstated within one year of its expiration date, the commission shall give notice and may hold a hearing, if the applicant so requests, as required by the Uniform Licensing Act to determine whether re-examination is required for reinstatement.

4-209. SUSPENSION AND REVOCATION.--

A. In the event of suspension or revocation of a certificate, the commission shall notify the applicant by registered mail of the reason for such action. Within 20 days after receipt of the notice, the applicant may request in writing that a hearing be held by the commission.

B. Re-issuance of a revoked certificate shall be accomplished by reapplication as provided for an original certificate. Any person whose certificate is revoked shall be ineligible for admission to any examination for certification for a period of not less than 6 months.

C. The commission may suspend a certificate for a specified period of time not to exceed 6 months.

4-210. ELIGIBILITY FOR OPERATOR TRAINING GRANT FUNDS.-- Each applicant for operator training grant funds administered by the agency shall:

A. submit evidence satisfactory to the agency that the recipient of the training;

1. is a person who is or is a candidate for employment as a "certified operator" as defined under Section 1-101 of these regulations; or

2. is a person in a supervisory role responsible for the management of a Water Supply System or Wastewater Treatment facility; or

3. is a person who is or will be involved in the instruction of operators.

B. submit evidence satisfactory to the agency that not less than ten percent (10%) of the training cost is provided by the employer of the utility operator; the cost of per diem and mileage may not be paid from grant funds but may be accounted in determining the training cost provided by the employer; and

C. supply any other pertinent information deemed necessary by the agency.

Adopted 11/16/67
Amended 3/4/68
6/11/68
7/25/69
9/29/70
2/3/71
8/27/71
7/25/72
8/4/72
1/14/74
3/12/74
6/14/76
10/12/76
1/11/77

Above are the complete New Mexico Water Quality Control Commission Regulations as amended on January 11, 1977. The January 11, 1977 amendments unanimously adopted by the Commission include Part 3, and Subsections 1-101A., F., H., I., M., N., Q., R., W., X. above and several changes in numbering and letter designations.

Cubia L. Clayton
CUBIA L. CLAYTON, Chairman
Water Quality Control Commission

RECEIVED
'77 JUN 17 PM 4:1
STATE COMMISSION OF
PUBLIC RECORDS & ARCHIVES

AMENDMENTS TO
WATER QUALITY CONTROL COMMISSION REGULATIONS

[3-109.G.] 3. the discharge of any water contaminant which may result in toxic pollutants being present in the ground water at any place of withdrawal for present or reasonably foreseeable future use; or

[3-110] A. The discharger may file a written petition with the director seeking commission consideration of a discharge plan that would not meet the standards of Section 3-103 if he believes that the discharge plan demonstrates the maximum use of technology within the economic capability of the discharger or that there is no reasonable relationship between the economic and social costs and benefits (including attainment of the standards of Section 3-103) to be obtained and that discharge under the plan would not create a hazard to public health or undue risk to property.

The above are Sections 3-109.G.3 and 3-110.A. of the New Mexico Water Quality Control Commission Regulations as amended by unanimous vote of the New Mexico Water Quality Control Commission on June 14, 1977.

CUBIA L. CLAYTON, Chairman
New Mexico Water Quality Control Commission

Deliberations
re-opened
6/14/77

RECEIVED
'77 NOV -8 PM 4:46
[illegible]

AMENDMENTS TO
WATER QUALITY CONTROL COMMISSION REGULATIONS

[3-109] C. Provided that the other requirements of these regulations are met and provided further that the discharge plan demonstrates that neither a hazard to public health nor undue risk to property will result, the director shall approve a proposed discharge plan if the following requirements are met:

1. the discharge plan demonstrates that the standards of Section 3-103 will be met except for contaminants in the water diverted as provided in Subsection 3-109.D. or

2. ground water that has a TDS concentration of 10,000 mg/l or less will not be affected by the discharge, or

The above sections are Subsections 3-109.C.1. and 2. of the New Mexico Water Quality Control Commission Regulations as amended by unanimous vote of the New Mexico Water Quality Control Commission on November 8, 1977. The language following the letter C. until the numeral 1. also applies to Subsection 3-109.C.3. and 4.

CUBIA L. CLAYTON
New Mexico Water Quality Control Commission

B. If the director determines that a discharger is not exempt from filing a discharge plan, or that the material to be discharged contains any toxic pollutant as defined in Section 1-101.UU., which is not included in the numerical standards of Section 3-103, then the discharger may appeal such determination by filing with the commission's secretary a notice of appeal to the commission within thirty days after receiving the director's written determination, and the appeal therefrom and any action of the commission thereon shall be in accordance with the provisions of Subsections 74-6-5 (K), (L), (M)and (N) NMSA 1978.

3-113. APPEALS FROM COMMISSION DECISIONS--A discharger may appeal the decision of the commission in accordance with the provisions of Section 74-6-5 (N), NMSA 1978.

3-114. FEES.

A. DEFINITIONS. - As used in this section:

1. "average discharge" means the average daily flow rate of effluent discharge as measured or estimated over the period of one year;

2. "billable facility" means any facility or portion of a facility required to have a discharge plan.

3. "discharge plan modification" means a change in requirements of a discharge plan as requested by the discharger as a result of past, present or anticipated changes in the quality or quantity of effluent or the location of the discharge; or as required by the director.

B. FEE AMOUNT AND SCHEDULE OF PAYMENT - Every billable facility submitting a discharge plan for approval, modification or renewal shall pay the fees specified in this subsection to the Water Quality Management Fund.

1. The amount of the fee payment for a new discharge plan shall be calculated using the following formula:

TOTAL FEE = FILING FEE + FLAT FEE or DISCHARGE FEE

(a) The filing fee is fifty (50) dollars for each new discharge plan application.

(b) Billable facilities in the following categories applying for a new discharge plan will pay a flat fee as indicated:

FLAT FEE

Facility Category	Flat Fee
Fuel Terminals	$ 2300
Gas Compressor Stations	
0 to 1000 Horsepower	0
1001 to 3000 Horsepower	690
Greater than 3000 Horsepower	1380
Gas Processing Plants	3335
Injection Wells: Classes I & III and Geothermal	1380
In Situ Leach - except salt	3335
Leach Heaps - copper	3335
Leach Heaps - precious metals	3510
Mine Dewatering	1065
Oil & Gas Service Companies	1380
Refineries	7820
Remediations - discharge plan only	1380
Tailings - copper, uranium & molybdenum	4860
Uranium - ion exchange & evaporation pond	1210

(c) All billable facilities applying for a new discharge plan but which are not subject to a flat fee will pay the following fees according to their rate of effluent discharge:

DISCHARGE FEE

Average Discharge Gallons per Day			Fee
0	to	9,999	$ 575
10,000	to	49,999	1150
50,000	to	99,999	1725
100,000	to	499,999	2300
500,000	to	999,999	2875
1,000,000	to	4,999,999	3450
5,000,000	to	9,999,999	4025
10,000,000	and greater		4600

2. Billable facilities applying for discharge plans which are subsequently withdrawn or denied shall pay one-half of the flat fee or discharge fee at the time of denial or withdrawal.

3. Every billable facility submitting a discharge plan modification or renewal will be assessed a fee equal to the filing fee plus one-half of the flat fee or the discharge fee, whichever is applicable. Applications for both renewal and a modification will pay a fee equal to that assessed a new discharge plan application.

4. If the director requires a discharge plan modification as a component of an enforcement action, the facility shall pay the applicable discharge plan modification fee. If the director requires a discharge plan modification outside the context of an enforcement action, the facility shall not be assessed a fee.

5. The director may waive flat fees or discharge fees for discharge plan modifications which require little or no cost for investigation or issuance.

6. Billable facilities shall pay the filing fee at the time of discharge plan application. The filing fee is nonrefundable. The required flat fees or discharge fees may be paid in a single payment or in equal installments over the expected duration of the discharge plan. Installment payments shall be remitted yearly, with the first installment due on the date of discharge plan approval. The discharge plan or discharge plan application review of any facility shall be suspended or terminated if the facility fails to submit an installment payment by its due date.

3-115. SEVERABILITY.--If any section, subsection, individual standard or application of these standards or regulations is held invalid, the remainder shall not be affected.

ORIGINAL

BEFORE THE
HEALTH AND ENVIRONMENTAL DEPARTMENT
STATE OF NEW MEXICO

IN THE MATTER OF:)
PROPOSED AMENDMENTS TO NEW MEXICO)
WATER QUALITY CONTROL COMMISSION)
REGULATIONS)

TRANSCRIPT OF PROCEEDINGS

BE IT REMEMBERED that on to-wit, the eighth day of April, 1991, the above-entitled matter came on for public hearing before the New Mexico Water Quality Control Commission, the same being taken at Morgan Hall, State Land Office Building, 310 Old Santa Fe Trail, Santa Fe, New Mexico, at the hour of one fifty-five o'clock in the afternoon.

NMED EXHIBIT 17

APPEARANCES

FOR THE COMMISSION:

MR. JON THOMPSON
Deputy Director
Environmental Department
Harold Runnels Building
1190 St. Francis Drive
Santa Fe, New Mexico 87503

FOR THE DEPARTMENT:

MR. WELDON MERRITT
Office of General Counsel
Environment Department
Harold Runnels Building
1190 St. Francis Drive
Santa Fe, New Mexico 87503

* * * * *

MR. THOMPSON: Good afternoon. I will hereby call this public hearing to order.

The time is approximately one fifty-five and the date is April 8th, 1991.

This public hearing is being conducted in Santa Fe here at Morgan Hall in the State Land Office Building. My name is Jon Thompson and I have been delegated the responsibility for conducting this public hearing this afternoon.

This public hearing is relative to proposed amendments to the New Mexico Water Quality Control Commission regulations creating a system of user fees for groundwater discharge permits.

MR. MERRITT: Mr. Hearing Officer, the Environmental Department calls Mr. Ernest Rebuck.

ERNEST REBUCK

was called as a witness, and having been first duly sworn, testified upon his oath as follows, to-wit:

DIRECT EXAMINATION

BY MR. MERRITT:

Q Mr. Rebuck, for the record please state your name.

A Ernest Rebuck.

Q And by whom are you employed?

A By the Environmental Department, State of New Mexico.

Q Okay, what Bureau?

A I work for the Groundwater Bureau.

Q Okay. Now, what are your educational and professional qualifications for the -- first of all, what is your specific position in the Groundwater Bureau?

A I manage the groundwater section, that is, program manager of the groundwater section. I supervise the staff of about twelve professional and about two secretarial.

Q Okay. And what are your professional and educational qualifications for that position?

A Okay, my education -- my Bachelor's degree was in agricultural engineering from Penn State University in 1966. I also have a Master's degree from the same institution, also in agriculture engineering. And I hold a PhD in hydrology from the University of Arizona, which was awarded in 1972.

Following my PhD I was on staff at the University of Maryland as an assistant professor in engineering. I also was employed following that by the State of Maryland Department of Natural Resources, in which capacity I supervised discharge permits, well drilling permits, water appropriation, MTS permits; hazardous waste facility permits, also.

I also was employed following that by Greenhorne & O'Mara, which was a private consulting firm with headquarters in Maryland and with service offices throughout the country, including Colorado and some other states.

I also was working -- I served, again, at the University of Maryland as assistant professor and then I was fortunate enough to be employed by the Environmental Department here in New Mexico.

Q And what has been your involvement in developing the proposed amendments that are before the Commission today?

A Well, I had an active role in conjunction with other senior staff of the Groundwater Bureau, so I was one of the drafters of those regulations.

Q Can you tell the Commission and the audience some of the background leading up to these proposed amendments?

A Yes. The New Mexico Water Quality Act was amended in the 1989 session of the New Mexico General Assembly. Specifically, it was House Bill 191, which was introduced by Representative Gary King, Don Silva, Nick Salazar, and Robert Hawk.

House Bill 191 created a Water Quality Management Fund. It is stipulated that fees collected for the cost of investigations and issuance of groundwater discharge permits would go into that fund.

Now, in 1989, later that year, November to be exact, an in-house committee was appointed within the Environmental Department to put into place those fees. The committee met several times in November and December of 1989 as well as January of 1990. All those -- primarily the Environmental Department committee, we did have active input from David Boyer of the Division and he attended some of these meetings.

The effort of the committee and the accomplishments throughout were as follows:

The committee contacted about forty-two states for information on their fee systems, and in most cases we were fortunate enough to get copies of their regulations covering their fees.

We also prepared staff estimates of the time required to do the administrative work, the issuance and processing and investigation work for discharge plans. We did draft a fee schedule. It was the third task that we accomplished. And the fourth item here was to set up a task force of outside people, those specifically having discharge plans -- dischargers, if you would.

Now, the task force members that were selected include the following --

Q Hang on. Let me -- I will go ahead and let you mention that, but before you do, is this a copy of the list of task force members? This is, by the way, NMED Exhibit One that I have handed you?

A It is.

Q I would ask that NMED Exhibit One be admitted in the record?

MR. THOMPSON: This is the members of the task force?

MR. MERRITT: Yes, copy of the members of the task force.

MR. THOMPSON: Any objections to submittal of this exhibit? Seeing none, it is so.

(THEREUPON, NMED Exhibit One was marked for identification and admitted into evidence.)

Q Mr. Rebuck, please proceed.

A Could I read the names for the record?

Q Yes.

A Paul Austing and Mr. Arturo Jaramillo represented the watchers or watching facilities and restaurants. Both these individuals own restaurants and have discharge plans.

Betty Behrend and Arky Wheeler representing municipalities. Stan Smith and Robert Cantrell representing industry.

Matt Clifton representing refineries. John Draper and Mike Koranda representing mining.

Ken Miller represented dairies, Ron Morgan and Tim Vaughn, gas plants.

Ron Jenson represented electric generating stations. Wayne Price represented brine production. Sue Umshler represented federal facilities. And Tim Vaughn represented food processing.

This task force met two times in March of 1990. On March 9th, 1990, it was decided that the following: Basically five provisions that came out of that task force meeting, one of those was to initiate the payment of fees at the time of renewal or modification. That means instead of having the regulated industry pay the full fee at the start when the fee program was initiated, there will be a phase-in and that phase-in would be generally over the period of five years as renewals of discharge plans occurred.

Two, the task force decided that the cost of processing renewals and modifications would be one-half the cost of processing a new application. Arbitrary rule, but it was one that was agreed to by the task force. And on that premise, too, processing both renewal and any modification together would equal the total cost of a new application.

The third provision was that if the Environmental Department required modification of discharge plan, the discharger should not have to pay a fee unless that modification is part of a law enforcement act.

Fourth, the discharger should be given the choice of paying the fee in one lump sum or spread over the period of the discharge plan approval.

Fifth, and final, EID was the -- well, new fee schedule that was much simplified. First one was considered a little bit too cumbersome and complex to be useful.

Now, at the second, and last meeting to date, of that task force, on March 30th the task force agreed to accept flat fees for all OCD regulated facilities. Those flat fees are, in fact, in the revised regulation changes.

The EID -- the Environmental Department was to meet with the environmental committee of the New Mexico Mining Association and develop flat fees for the mining facilities. Now, all other facilities under discharge plans agreed to pay a fee based on the average discharge only.

Now, the flat fees for mining took some time to develop because the user required, as was done with the OCD regulated facilities, the agency went back and tried to come up with an honest estimate of the amount of hours required for the issuance, investigation leading to a discharge plan approval. And this effort was then initiated for the mining facilities. And it took some time to follow through that process. So it wasn't until August of 1990, some months later, that there was a schedule of flat fees available for the mining facilities.

Now, those were combined with the other fees and a total package of fees. No language of the regulations mentions it, but strictly a fee schedule, if you would, was mailed out to all the task force members and they were given an option to agree with it or to request another meeting, and I am happy to report there was a consensus in favor of that fee schedule among all the task force members.

The regs then were drafted in November of 1990, and they were submitted to the office of general counsel and received legal review, which was completed in December of 1990.

Additional changes were made late in December of 1990 and the final package, if you would, as revised, was then submitted to the task force members about February of 1991.

In that version that was submitted to the task force members, it's the same one that was distributed to those requesting copies from our mailing list or those who saw the notice in the paper or the New Mexico Register.

Now, subsequent there were some additional changes made just this morning, April 8th, in response to certain questions and comments that were received. So we have some amendments, if you would, of the amended regulations and those copies were available on the back table.

Q I believe they are up here on the front table now.

A Excuse me, I stand corrected; here now on the front table. So if you don't have an April 8th version you may not have the latest version.

Q Okay. That's all concerning the development then?

A Yes.

Q Okay. Let me hand you what I have marked as NMED Exhibit Two and ask you if -- is that the proposal that's -- that was developed just this morning, finished just this morning?

A Yes.

Q Okay. Now, first of all let me ask that NMED Exhibit Two be admitted in evidence. You have a copy of it already, Mr. Hearing Officer, but I will show you the one that I marked. That's the April 8th version and I will have -- Mr. Rebuck will explain the differences and I will also have him explain how you can readily identify the differences.

MR. THOMPSON: Okay. Is this the copy that is available for --

MR. MERRITT: Yes, it is on the front table entitled --

MR. THOMPSON: I encourage anyone here that do not have a copy to pick up a copy at the front table. This is -- will be going in the official record as NMED Exhibit Two, and if there are no objections, so entered in the record.

(THEREUPON, NMED Exhibit Two was marked for identification and admitted into evidence.)

MR. MERRITT: Mr. Hearing Officer, I will note it will be -- look a little different, too, because what originally was sent out was basically started in the middle of the first section because it was copied from an existing page of the regulations.

What we have done with this one is go back to the beginning of that section, which had no changes on it, but we figured it would be better to include the full section as part of the text.

MR. THOMPSON: Is the copy that I have, is this the copy that I should be looking at?

MR. MERRITT: That is the one you should be looking at, yes.

Q Mr. Rebuck --

MR. THOMPSON: Before you start, why don't you wait until everyone gets a copy and gets settled again. All right, counsel.

Q Okay, Mr. Rebuck, before you talk about the specific amendments would you first tell everybody how they can distinguish between the amendments that were previously proposed and the ones that were added today?

A Okay. Actually, there's a note at the very back, the last part of this, that lays it out, but let me read into the record and discuss it a bit.

The first proposal that is the one that was mailed out in response to mailing list inquiries off the notice and to the task force. Those changes start from the existing regulations today, our New Mexico Water Quality

Control Commission regulations, and in those cases where something was deleted we put brackets around it and drew a line through it. And there isn't a lot deleted, but an example of that is when you page over to Section 3-114 that's deleted and a new number is 3-115.

So there isn't a lot of material that has been deleted, but that is the way that material is distinguished. Brackets and strike out.

Any additions, and this is to the regulations, themselves, as they exist today, are simply underlined. And you can see the example right above the section referring to where 3-115, that is added material and it is underlined.

The April 8th changes, if you would, we did the following: We needed something a little different. There for the deletion we put in what is called a brace, and we put the braces in in bold. Example of that -- well, there's several on the -- starting in the 3-114 you can look and there's several braces. This material in there is to be deleted and then we have material to be added, simply typed that in bold.

Q Okay. There is one other thing, Mr. Rebuck, that we -- I guess when we were preparing the note we overlooked and that is the fact that the new Section 3-114, because it was an entirely new section rather than being underlined, had the words "new material" in brackets following the section number, so that would -- is that correct?

A Yes, rather than underlining essentially all of 3-114 that is a little cumbersome to read, so we did it as indicated by Mr. Merritt, that we put a bracket and "new material" so essentially everything in 3-114 could be underlined if you rigorously followed that scheme that I just described.

Q I hope that is sufficiently clear, but perhaps if it is not it will come out during questions. Would you now proceed and explain the proposed amendments and also the reason for making the changes that we added today?

A Yes. On Section 3-106, the only addition to that is provision under (D) that fees shall be paid. And that is flagged under 3-106. That talks about applications for discharge plan approval and that is to make it clear for someone preparing a discharge plan application that there is a fee section here and that fees are required.

Now, 3-114 contains the part of the fee regulation. It has two sections. One -- the first one is entitled definitions. We found in going through the existing Water Quality Control Commission regulations that several terms were not defined at all. For example, billable facility and discharge plan modification and those two terms we needed definition in terms of billing.

Now, the first definition, however, is an average discharge, and we chose here to use an average annual discharge.

The second definition is billable facility. Now, this is to try to get a consistency. As you look at different facilities and particularly complex facilities that may have many circuits within it, this makes up many points of discharge, several sources, all within the same property line, and what is the correct number, if you would, of discharge plans are, you know, for some of these more complex facilities. This frequently comes up with some of the mining activities.

Now, basic part of the definition of billable facility is a facility or any portion thereof which discharges to a single effluent receiving or disposal site. There are a couple or few other provisions in here. Along with the disposal site is that the effluent flow combined at some point between the source and that disposal site. Based on the newest change we would delete part (B) which states that no more than one effluent flow to which materials are added or from which materials are removed subsequent to its generation; that is being deleted because it is a complex concept for one and, secondly, we feel that, A, people, they will cover the same provisions that B would not and it simplifies the definitions and makes it more clear.

The next provision is that all the effluents shall be owned by one person. We could have cases where a facility -- and it comes up more in municipal wastewater treatment plans than other types of facilities where they have buyers for -- people interested in receiving their effluent. So we want to be clear here of -- the effluent here would be owned by one person and this would impose, then, that there will be two billable facilities here. If you have wastewater treatment plant selling the effluent to a rancher or someone in agriculture activity, there would be two billable facilities by this definition and the last one is that there be reasonably uniform topographic and hydrogeologic characteristics. There's a provision that goes to the heart of the type of review that we do in discharge plan and that is we look at the hydrology of the site and try to come up with site specific environmental safeguards that fit.

So, this takes care of the definition of a billable facility and would parallel to the large extent what type of facility or what portions of the facilities best appropriate would get a discharge plan.

Discharge plan modification is a third definition and we want to indicate here that it can be presented by a discharger because of changes in quantity, quality, or the location.

Also modification could be required by -- we have the word director in there, but essentially by the Environmental Department and head of that department.

For the second part of Section 3-114, we address the fee amount and it really covers more than the amount of fee. It covers when nonpayments will be made and we attempted to reflect that by changing this morning from fee amount to fee amounts and schedule of payment.

Every billable facility submitting a discharge plan for approval, modification or renewal shall pay a fee specified in this subsection to the Water Quality Management Fund. There's some possible confusion earlier in this, the way it was first written that someone may read this and say, the fee would have to be paid at the time of application. That really wasn't the intent. We wanted the fee paid at the time of approval and this new language makes that much clearer.

Now, under one, we cover the -- we start at the amount of fee and there's a total fee here; one part is filing fee. That would come in at the time of application and that is a mere -- only fifty dollars, and then there would be another fee, and this is why it is spelled out here, total fee really has these two parts to it, the

2 Parts to fee
① filing
② flat fee
disc f

filing fee of fifty dollars and either a flat fee or discharge fee. The flat fees are laid out under (1) (B) and these are for those facilities where OCD has come up with estimates of the actual staff time required to do the work and Environmental Department has done likewise, primarily, then we are dealing with the oil and gas type industries as well as mining type facilities.

Now all those facilities under C -- (1)(c), that do not have a flat fee worked out that, flat fee again would apply, except there's one for special gas compressor stations. But for the most part it wouldn't matter on the size of the facility, they would all pay that same fee. The target was pretty much an average cost and, again, as the plan indicates, it would be paid by all the industries that meet that category.

The billable facilities that are not covered by flat fees will pay a fee based on the amount of their discharge and that is specifically the annual average discharge, although it is expressed as average discharge per day and this would reflect the size facility. A large facility, for the most part, will have a larger discharge and require a greater review time on the part of the OCD or the Environmental Department staff.

Under (2), billable facilities which apply for discharge plans which are subsequently withdrawn or denied shall pay one-half of the flat fee or discharge fee at the time of the denial or withdrawal. The provision here is that quite often the staff time will already have expended, that work will have already been done.

In other words it takes as much time, if you follow through an application, and decide to deny it as opposed to approve it. However, the denials are actually very infrequent. Generally, it's a negotiated process and conditions can be worked out that can allow for approval of a discharge plan.

The other category, withdrawal, does occur, of course, where discharge plans are often pursued early and at least in a couple of types industries they pursue the discharge plan simultaneously, almost with pursuing funding or mortgages or other, you know, financing.

And so we do find that after we have gone through the work and ready to approve or have approved the discharge plan that the person had difficulty getting funding and actually says, "No, I am not interested. I don't want the discharge plan."

So we wanted to cover some of our costs for expending the work.

Under (3), every facility which submits a discharge plan for modification or renewal shall be assessed at fees equal to the filing fee plus one-half of the flat fee or discharge fee, and that is worked out by the task force. This is a reasonable provision for discharges.

Under (4), if the director requires modification of discharge plan as a component of an enforcement action, the fee would have to be paid. However, if requirement for modification is outside of that context, then the fee would not be assessed. There's some specific language here that the director or the Environmental Department would be able to waive fees for minor changes, minor modifications of discharge plans, getting away from, you know, the quantity, quality and location whether it's a name change or whatever, of minor ones, even very minors changes perhaps in the quality or quantity that would have an effect on the environment that the agency would have the ability to waive that fee.

Under (5), billable facilities shall pay the filing fee at the time of the discharge plan application and that is nonrefundable and that's the fifty-dollar amount. Required flat fees or discharge fees may be paid in a single payment or in equal installments over the respective duration of that discharge plan.

The payments of -- if they take it on an installment basis, the payments would be made yearly. And the first installment would be due at the time of the discharge plan approval. As a matter of fact, it would work such that the review work would be done by either OCD or the Environmental Department and a letter would be sent to the applicant saying, "Okay, we are ready to approve this discharge plan, and upon receipt of payment of either the first installment or total fee, flat fee or discharge fee, we will mail you the approval."

The language change here is, again, to make it real clear that it Payment would be done at the time of approval, the discharge plan approval. I am reading -- let me read those last couple of sentences the way they should read: "Installment payments shall be remitted yearly, with the first installment due on the date of discharge plan approval. The discharge plan or discharge plan application review of any facility shall be suspended or terminated if the facility fails to submit an installment payment by its due date."

And then the last change is really simply renumbering, the severability. What was previously Section 3-114 is now 3-115.

Q Okay, does that complete your testimony on the proposed changes?

A Yes.

Q Okay.

MR. MERRITT: Mr. Hearing Officer, I have no further questions of this witness. Be glad to pass him for cross examination.

MR. THOMPSON: All right. I will open this up to cross examination. Yes, sir.

MR. ROYBAL: Thank you, Mr. Hearing Officer. My name is Charles Roybal, director of New Mexico Mining Association.

CROSS EXAMINATION

BY MR. ROYBAL:

Q We would like to thank the Department for this opportunity to appear at the hearing and also for the work of the task force.

Our concerns start with the definition of billable facility. As we understand it, there are current plans that have been evaluated and permits which are in place. Is this -- are we correct that those plans, those current plans, have been evaluated as to their appropriate size and that they do, in fact, comprise what should come under appropriate?

A Generally that is true.

Q And I guess our concern is whether these regulations will provide a vehicle for re-evaluating those permits or if current permits will, in fact, be allowed to remain their current size?

A Okay, again, I am qualifying a little bit. Generally, what is laid out here would not change the existing discharge permits that have been approved. It would certainly be a guideline that we would use from this point forward on new discharge plans.

Q Okay. As we understand it, the plans are evaluated and these types of concerns have, in fact, been the basis for the appropriateness or judging the appropriateness of those currently existing plans and that's what we would like to establish on the record, that we are not actually passing something or having a hearing on a redefinition, if you would, of what goes into a permit and what the appropriate size for permits would be.

A Essentially I agree with that, that basically this puts into writing the kinds of criteria and guidelines that we have been following within the Environmental Department in saying, "Yes, this is a discharge plan," or, "No, it's not. It would or it should be combined with an existing discharge plan."

Again, I want to qualify there may be some exceptions, but for the majority of the discharge plans that's a true statement and we are trying to make that guideline an in-house administrative practice, if you would, and put it into a regulation format here.

Q Thank you.

The next category of questions really has to do with five-year plan approvals.

Under current practice, there has been some permits that have been issued for less than five years, is that correct?

A Yes, that's true.

Q Do you see this -- under this regulation the fees and such, with the normal being somewhat established because of the fees, four- and five-year approvals solidified in a sense, that five-year normal?

A Well, let me respond to that. Certainly this works better if you have a five-year approval period, and my best reading -- I am not saying this is desirable enough, but my understanding as the way it was read, if there were, for example, a three-year approval it would be the same fee as for a five-year approval.

Now, we do have cases, however, where the applicant is only interested in the short-term approval. They are going to empty a lagoon out of sludge it's going to take six months effort. We may approve a permit for eight or nine months to allow that one time activity, so to speak.

So there are some cases where it's -- everybody agrees, and it's in everybody's interest to have a much shorter than five-year approval.

Q But those cases would usually be at the initiation of the applicant and at a minimum would have their approval as in the normal case?

A Correct, exactly. What -- my example, there the applicant was only interested in a few month's approval.

There's the other thing I would like to point out is that we don't have a provision in our present regulations for time of renewal and this is another case where the renewal comes in and may be timely by the applicant and may not, but for various reasons, workload or whatever, additional time is needed to do a correct review.

We have in some cases -- not frequently, but some cases given the six month's approval, which is for the actually because of the agency's action. The agency wasn't able to do the work it needed to in the time frame because there was a whole lot of recommendations coming in at one time or whatever, and that is, you know, an administrative decision and it would be my opinion that we may want to not have -- not charge a full fee for that, because it's kind of double-dipping in a way because we are working toward a full five-year approval.

Q Those temporary approvals, if you would, I don't know if that's -- I guess that's the best way to characterize it, so what you are saying, they would not be charged a fee, or at least that is your initial reading?

temporary approval:

A I would say that the temporary approval done by -- in terms of the agency needing to do it, because it needed time to do its administrative processing should not exert extra costs on the part of the applicant, absolutely not. At the same time, there are some short-term approvals, even less than a year, that are requested as such and approved as such. I think the fee should be paid.

So it's our initiative for a short-term one, for administrative reasons, and definitely we do call it temporary permission, you know, as it's referred to in our regulations. We should not be charging a fee for that.

Q I guess the final question on this line, as drafted, the proposed rules state that if you have a change in a permit which is caused by -- or modification resulting from a enforcement action, then the fee would be charged, is that correct?

A Yes, that is in the proposed regulations.

Q But if a modification is not caused by an enforcement action, then the rules don't provide for a fee?

A Actually, the reading of it is if it is requested by the discharger.

Q That's it?

A That would pay -- okay, in other words, they are going to double the size of the facility and do a lot more processing, that should be a fee.

Q But if it is initiated by the department, not under an enforcement order, then that modification is not chargeable?

A Yes, that's correct.

Q Thank you, Mr. Hearing Officer.

MR. THOMPSON: Thank you, Mr. Roybal.

Others to cross examination this witness? All right, my chance to get him. I have a few questions.

EXAMINATION BY MR. THOMPSON:

Q For my education, no one else, would you explain the difference in simple terms between a flat fee and a discharge fee? Who pays the flat fee as opposed to who pays the discharge fee?

A Okay. Those going for flat fee are actually listed under Section 3-114 (B)(1)(b).

They include fuel terminals, gas compressor stations, gas processing plants, injection wells -- actually only classes one and three and geothermal. And those are primarily what I referred to as oil and gas OCC regulated facilities.

Leach heaps, both copper and precious metals, mine dewatering, those are mining, and then you have oil and gas service companies coming in here and refineries, oil and gas, regulated or OCC regulated facilities, remediations -- this would be an underground storage tank remediation and other types of underground remediation, tailings -- copper, uranium, molybdenum, and also uranium two types of facilities. There are ion exchange or evaporation ponds.

Those and only those would pay a flat fee and this primarily resulted from the task force with where various reasons the task force members did not feel that billing these facilities using the amount of their discharge would be equitable.

There's some specific reasons on that. There's some of these facilities, for example, that don't routinely discharge contaminated water. They circulate. They are processing oil. Refineries, for example, may have a very small water discharge because they are basically processing, and the time they come in or when there's a regulatory concern is if there is some type of spill.

So if you go through the volume of water for a refinery and come up with, you know, a very small amount based on the amount of their discharge.

MR. MERRITT: Mr. Hearing Officer, I think if I could interrupt for a minute. If I was listening correctly, I think the witness inadvertently omitted in situ leach. He started with leach heaps, but that would be one more.

A My apoligies.

Q Thank you. Dr. Rebuck, the regulated community, they were members of the task force?

A Correct.

Q Mining, oil and gas, et cetera?

A Yes.

Q They would have come under this. Did they all agree to these facility categories and to the amounts under the flat fee?

A That is correct. There was a consensus of those people on the task force, which we tried to have represented at the entire regulated community as best we could.

Q Now, how did you come up with the number like forty-two twenty-five for tailings, copper, uranium and moly? How did you come up -- how did you get a number like that, for instance?

A Excuse me, I am going to have to get a folder in my notebook.

Q Go ahead.

A Let me apologize, Mr. Hearing Officer. I don't have a copy for you, but I can make one for you and submit it for the record, if you would. But we had gone through with estimates of time required to process specifically that type of facility and at the time we started, which was in 1990, we went through our budget very carefully and came up with a computation that -- still trying to find --

Q Take your time.

A Okay, basically this is on the FY '78 operating budget available to the groundwater section and the Groundwater Bureau. For that fiscal year we had state general funds of four hundred twenty-four thousand dollars, four thousand -- four hundred and twenty-four thousand, four hundred and sixty-one dollars. *

We also had available to the Bureau monies available also to the section, an additional twenty-four thousand six hundred forty-five dollars. We received through our EPA underground injection control grant a hundred and eight thousand seven hundred eighty-eight dollars, for a total of five hundred fifty-seven thousand eight hundred and ninety-four dollars. ← to figure

FY '78 -- that's supportive and I took and measured -- I took my position that's supported eleven technical positions, two hundred and forty work days per year, eight hours per day and came up with an hourly rate of twenty-six dollars and forty-two cents as a term or base number. *

So you take that twenty-six forty-two. Now, we don't pay the same overhead a business would and the reason it looks a little lower, we don't have rent and so forth. I took the budget as it pertains to the groundwater section and part of the Groundwater Bureau budget and said, "For this many work days, this many people, this many hours, twenty-six dollars forty-two cents."

So now in looking through tailings the four thousand two hundred twenty-five dollars there was the number of hours we came up with times twenty-six dollars and forty-two cents rounded to the nearest five dollars is the way these numbers were put together.

Q That was the number of hours for this facility's category of tailings, or is that the man-hours on all your groundwater water discharge review whether it's leach heaps or mine dewatering or tailings or fuel terminals? Was that everything or did you break the man-hours down into facility categories, also?

A We broke the man-hours, if you would, you know, work hours.

Q Work hours?

A By category. As a matter of fact, I have those numbers in here. I am a little slow in pulling them together, but --

Q And the twenty-six dollars an hour is the same for all --

A That's correct.

Q -- all categories?

A Right. That number is uniform. Basically estimated -- I asked my staff to do this. We don't want to have any biased by geography, so you figure you are going to spend the same amount of time and we used a normal four hours driving to site, you do your technical work at the site, go and confirm the application and the materials that were submitted as supplements to that application, you drive back for four hours and that's the time I want. Essentially, that was the criteria here in putting these hours together.

I am looking through the hours that we estimated here roughly and I do have this. This is a memo that I can put in from -- mine dewatering was thirty-five hours, and I don't have a calculator, but thirty-five hours times twenty-six point forty-two, you get very close to the nine hundred twenty-five dollars there.

For tailings we came up with -- average we used a hundred and sixty hours. We targeted for average. We averaged -- well, we went from a low of a hundred and twenty hours to two hundred max, average about a hundred and sixty for a tailings impound. It's a hundred and sixty times twenty-four -- twenty-six forty-two, if my math is correct, should give us real close to the forty-two twenty-five.

Q Thank you. Now, they can pay -- each facility can pay the fee over the life of the discharge plan, which is five years?

installment plan due date

A Generally five years.

Q And can they pay -- they have to pay July 1 each year for five years if they want to? Is there a billing time or date that they need to pay?

A Some of the administrative parts have not been put in place. The way I read the regulations, the best of my understanding would be if the discharge plan were approved, particularly another one, May 1, they would have to submit the check in May, and then we would like for a like amount on the installment plan May of the following year, and May and so forth subsequently for the five years.

Q You didn't feel it necessary to list the time for payment on these regulations?

A Part five is where we address that and this is next to the last page. The payment shall be remitted yearly with the first installment due on the date of discharge plan approval, so if it was approved in May they get the first installment in May. And then if they fail to submit it by its due date, and I guess the implication here -- and as I understand it, if you are doing it yearly that would be precisely twelve months later, or May of the next year. That would be my reading of the regs, as proposed.

Q I would submit that I think there would be confusion on that. I would submit you may want to put a specific payment -- to me it's confusing. I pay -- I pay on the initial first installment due on the date of discharge plan and then -- then if I am going to pay over the next four years, then, on the life of the plan, I really don't know what date it is due. If it doesn't specify -- I am just wondering if you need to specify a time or make this -- clarify this and make it clearer.

A If you would explore some wording with me under the statement here --

Q I don't think you need to do that now. I am going to keep the record open for a period of time, and you can think about that.

A All right.

Q Now, the discharge fee facility, let's look at them a minute, Dr. Rebuck.

On the third -- I guess it's the third page -- second to the last page --

A Yes, sir.

Q What kind of facilities are these, now? I pretty well know what the facility group is. What would make up the discharge fee group?

A The facility types -- and there's -- the way we have them categorized really on your data base, first is campgrounds/RV parks; second, dairies, electric generating stations, ethanol plants, food processing facilities, and skipping fuel terminal because that has a flat fee on it, also the hydrocarbon cleanup. Another category that we have that is covered on a flat fee remediation for twelve hundred dollars.

The next category is industrial, institutional, ranching, manufacturing facilities, mining, and those really don't apply because we have addressed, I believe, all the mining activities under the flat fees, restaurant/bars, septic disposal, slaughter houses, sludge disposal sites, subdivision/villages, trailer parks, and wastewater treatment plants.

All those would come under -- unless otherwise noted, they would come under this discharge fee table and their amount of fee would be prorated based on the average daily discharge or based on the year.

Q Would that -- with the average daily discharge, is that a figure that the state provides or is that one the discharger provides?

A It is the -- there is a blank on the application form for the discharge quantity, so generally the discharger would put forth a number so that number would normally be looked at and confirmed by staff during the renewal process, revised if need be.

Q Okay. How much revenue -- once you get running, how much revenue will the state average yearly on these fees, both flat and discharge fee? Do you have an estimate

Revenue

FY78 budget
557,000
200,000 =
36% to start

on the amount of revenue on these?

A Yes, we do. I would like to put that in the record. We did start out with a target of about two hundred thousand a year, which, based on our circumstances, would be as much as four FDE's. I did a calculation -- and this is a little over a year ago -- and came up with about a hundred and eighty-six, hundred and eighty-seven thousand dollars. But I need to point out that that is the full pay out.

We looked -- there would be fees in here with the installments and picking up the discharge plans at the time of renewal. So maybe the first year you would have a fifth of that two hundred thousand, or something like forty thousand, eighty, hundred and twenty, and so forth.

Now, those are the initial estimates and as we bring more discharge permits into the program, there's many facilities out there, upwards of three hundred, three hundred seventy-seven facilities, that do not have a permit. As we bring those in the program, we would up our numbers and up the revenue to some extent.

There's also new categories that EPA is requiring that we regulate through the UST programs, so there's other categories that the program may have to move into for various reasons. And those, of course, bring in fees.

Another area that probably was there all along but we hadn't done as much work in and that is as we find the Environmental Department solid waste program coming into full time, they are, you know, picking out dischargers that use the discharge plant and having them come over and get discharge permits, particularly septic haulers, but which use landfill but no longer can under the new wastewater act and amendments.

So there is another category, Underground Storage Tank.

The groundwater remediation there's a full group there, discharge plans, so as the numbers go up, I think those revenues also can up go up.

Q Are the fees that you would obtain, are these -- do they go in an operating fund just for groundwater discharge reviews?

A There was part of the House Bill 181 set up a special fund, Water Quality Management Fund. However, there was a time limit placed on it. There's a sunset provision that that fund would only be there for three years. So we essentially have, you know, another year here to put money into that fund. And those monies in that fund are earmarked for this purpose, processing discharge plans by OCD or the Environmental Department.

Q Can you hire FDE's, buy equipment, vehicles, is that how --

A I appreciate the question. Let me comment on this, and I would like to get into the record that in looking at this program, there are some limitations in what the money can be used for. It doesn't distinguish between FDE's and hiring services on contract and we like that provision and we could actually hire, you know, through a proper bid process, a consultant to do some of our review work. But we want to keep that option. But it is specific to the issuance administration of the discharge permits and the philosophical point is simply that that -- in running a program like this, I believe it's appropriate to have at least two types of sources of revenue, one is a general fund provision, and that should cover -- and it is preserved in these regulations that the general fund monies would be used for public hearings, public meetings for compliance of inspection facilities and any enforcement efforts.

In other words, those type of things, public meetings, compliance inspections and enforcement are for the public good and rightfully should be paid by general tax monies.

The other part that we are looking at here is trying to have some income from the regulated industry. If industry didn't come to our door for an application for discharge plan, we wouldn't have to do that work. So the fundamental review and field inspection processing of the discharge plan application we feel is correct that part of that fee be borne, or much of it be borne by the industry, the regulated community.

Q Thank you, Dr. Rebuck. Is there any grandfather provision here? That is, those that have discharge plans now in effect, are they grandfathered from these fees?

A No. They would not have to pay a fee, however, until time of their renewal. And the other --

Q If a facility received approval today, and the Commission approved these fee schedules in three months, then this discharger that got approval today to go forwrd, could go four-and-a-half more years without paying a fee, is that it?

A That's correct.

Q So it would be well for anyone that wants a discharge plan to do it in the next couple months?

A Well, we are piling them up, those that come in.

MR. THOMPSON: How many more witnesses do you have, counsel?

MR. MERRITT: I have no more witnesses.

MR. THOMPSON: All right. I don't know if I am through with this witness. I think I will pass him on to anybody else for a while. Anybody else care to cross examination this witness?

MR. PRICE: I have something.

MR. THOMPSON: Please state your name and who you represent.

MR. PRICE: I am Wayne Price and I am with Unichem International out of Hobbs, New Mexico.

CROSS EXAMINATION

BY MR. PRICE:

Q I have a basic question to Mr. Rebuck concerning flat fees that are listed under Section 3-114, item (B)(1)(b). The question that I have is looking at the flat fee structure, nowhere can I see in this submittal here that we have -- that these flat fees are for what time limit. And I know, serving on the task force, that we had talked about this for a period of five years, is that correct?

A That is correct.

Q Okay. That was my basic question. It is nowhere in here that I see where it's -- the fees are for five years and may possibly -- if it is not listed, someone could possibly -- could possibly think it would be an annual fee.

A Okay, the similar concern that we discussed with Mr. Roybal on the flat fees for mining. The same comments there would apply here. I admit, I don't see the provision where it says five years here. That is the normal term of discharge plan approval and I know that is the intent of these, that the fee would be for the full term of the discharge plan approval.

Q I guess my next question is, I would like to make it part of the record here that we amend this to somewhere identify the fees, flat fees, and also the discharge fees, are for a period of five years.

MR. PRICE: That'S all I have.

MR. THOMPSON: Thank you. Anyone else for cross examining of this witness? Counsel, do you want to redirect?

MR. MERRITT: I think just one or two.

REDIRECT EXAMINATION

BY MR. MERRITT:

Q Mr. Rebuck, if you need to confer with other staff before you answer that, we can maybe do it on the break and come back because I will ask you --

A I would like to do that, yes.

Q But the question I was going to have, the Commission regulations elsewhere specify for a maximum discharge plan approval period of five years, do they not?

A Yes, and so does the statute.

Q Yes. Now if someone came in and, for whatever reason, said, "I only want a three-year discharge plan," we would not prorate the fee, would we?

A No. The basic review work, the cost of processing the three year versus five, is identical. Same amount of work.

Q So, basically, the fees would be for the discharge plan, and for whatever period up to five years the discharger requested?

A Generally that is true, yes.

MR. MERRITT: Okay. I have no further questions.

MR. THOMPSON: Fine.

Before we -- I would like, Dr. Rebuck, for you to be available for further questions later, but you are excused at this time. I would like -- I would like to call a fifteen-minute break here, and then we will have the next witness.

(THEREUPON, the witness was excused and the proceedings stood in a Brief recess.)

MR. THOMPSON: We are back on the record.

Before we go on to -- I meant to do this earlier and I forgot. Some people came up to me before the hearing and asked if they could introduce some written statements. I said, "Yes, we will do it when I open the hearing," and I forgot and I apologize to you. So at this time I will accept, through the court reporter, any written statements that you would like to submit that you do not want to to cross examine you, and is there anybody else out there that would like to cross examine Dr. Rebuck, the last witness? That lady in the white, are you going to be staying for the rest of the hearing, ma'am? Do you mind if we proceed with our witness and we can call Dr. Rebuck back and you can cross examine him, or do you need to leave?

MS. GUILBAULT: No, that's all right.

MR. THOMPSON: Fine.

MR. MERRITT: Mr. Hearing Officer, I don't have any great preference, but it seems like if it was cross examination it would make more sense if it's done in close proximity to where the rest of his testimony is. I don't have a real objection to doing it otherwise, but it seems like it would flow better for the Commission that way.

MR. THOMPSON: Fine. Fine. Why don't we do that, then. Ma'am, would you like to approach the mike and ask your questions.

If you would state your name and who you represent into the record.

MS. GUILBAULT: Jacqueline Guilbault, and I am with Valley Improvement Association and we are the owners of Rio Grande Utility Corporation and I had come here today, mostly out of curiosity.

ERNEST REBUck

was recalled as a witness, and having been previously sworn, testified further upon his oath as follows, to-wit:

CROSS EXAMINATION

BY MS. GUILBAULT:

Q I was wondering, on your discharge fees, the difference of fees from the amount of discharge, does it cost more to process -- what are your fees based on for discharge?

A Okay. You are making reference here to discharge fees, which would apply to wastewater treatment plants and similar type facilities.

The rationale on that was to come up with a system where you would have a bigger fee for bigger facilities and not because of deep pockets, but that was the best estimate of staff. It took a little more time with the bigger facility and many of our permits, the groundwater discharge permits, will just say -- land applications, say you are irrigating so if you have a bigger volume you are irrigating bigger area and so, therefore, more time for our review.

So it may not be an exact comparison, but that generally is the way it works. Smaller facilities a little bit less time and that seems to paralell the volume of discharge.

We also found, in looking through the other roughly forty states that have fees in place, that volume was a big factor in the way they proportioned out their fees. I am not sure they came from the same standpoint, the amount of work, more work more fee, but -- okay?

Q Is it based on the volume in the permit or the actual end result discharged?

A The intent here was actual volume. And the definition on that was -- means average daily flow, rate of effluent discharge as measured or estimated over the period of one year. The reason we say estimate, some people don't actually have flow meters on the wastewater discharge and well workup, but it's a good faith effort to come up with the actual quantities.

Q Okay. The reason I was asking, we had one plant that we know would be less capacity so we would be paying on that?

A You are absolutely right. This is intended to be actual.

MS. GUILBAULT: Thank you.

MR. THOMPSON: Thank you. While you are there, Ernie -- Dr. Rebuck.

EXAMINATION BY MR. THOMPSON:

Q On the task force, I guess that's an exhibit -- I haven't had a chance to look at it yet, the wastewater discharge facilities would pay a discharge fee, is that correct?

A Those that have discharge plans, there are several wastewater treatment plants that have permits and those we do not regulate.

Q But those that have discharge plans?

A Just those that have discharge plans, yes.

Q Were they represented on the task force, the municipalities, Municipal League?

A Not the Municipal League, per se. We really sought out to have actual dischargers.

Now, the two people that come to my mind here are Betty Behrend with Belen, and Arky Wheeler with Hobbs, both of which were on the task force. And I know Arky, in particular, did keep the municipals informed.

We did send out invitations or made it open to associations. We would have Mr. Roybal come in as the New Mexico Mining Association and attend the meeting. He did not have a vote when we were looking for a consensus on the fee schedule, but our meetings were open and we did specifically invite certain associations.

Q So the local governments are aware of the proposal then through the communication of your task force members to the Municipal League and do they have a copy of the proposal, the local governments and the Municipal League?

A I didn't send them a copy per se. I do know that Arky Wheeler has informed the Municipal League of it and actually had the letters for the Municipal League drafted.

Q So the Municipal League will not be shocked or surprised by this new fee schedule?

A That is correct.

Q The proposed?

A That is correct.

Q Okay, because I think it looks like the department put together a good task force that would be affected by this and I just wanted to know for sure that no one would be surprised once the Commission starts deliberating on these regulations and proposals. The application fee is fifty dollars, is that correct?

A Yes, sir.

Q Is that for everybody?

A Yes.

Q That's everybody, flat fee group as well as discharge fee group?

A That is correct.

Q And if they withdraw their application they don't get their money back?

A They do not. If they withdraw it, the fifty dollars is nonrefundable and there's some specific language stating that. They could only try to recoup half of the other part of the fee, either flat fee or discharge fee.

Q But the fifty-dollar fee is -- once it's paid, it's in the bank? They don't get anything back?

A That's right. In (5) -- under 3-114 (B)(5), the second line, says, "The filing fee is nonrefundable."

Very, very specific.

Q Okay.

I thank you. Anyone else care to cross examine this witness while he is still on the stand? If not, you are excused again.

(THEREUPON, the witness was excused.)

MR. THOMPSON: We will take the next witnesses.

DAVID G. BOYER

was called as a witness, and having been first duly sworn, testified upon his oath as follows, to-wit:

STATEMENT BY MR. BOYER:

Mr. Hearing Officer and other members of the public, my name is David Boyer, B-o-y-e-r, and I am the Environmental Bureau chief of the New Mexico Oil Conservation Division, and in that capacity I am in charge of administering the Water Quality Control Commission regulations for facilities under OCD jurisdiction and I will talk about that in just a minute.

I will give you an idea what my background is for the purposes of the record.

I would like to recall Dr. Rebuck to the stand.

MR. MERRITT: Mr. Hearing Officer before you do that, Mr. Boyer just handed me a copy of the earlier proposal that he had been referring to with page numbers and so that the Commission can follow his page numbers we would like to introduce that as OCD exhibit three.

MR. THOMPSON: All right, this was during Mr. Boyer's testimony when he was referring to --

MR. MERRITT: He was referring to page numbers which do not appear on the copy that we submitted.

MR. THOMPSON: And this was the earlier draft.

MR. MERRITT: This was the earlier draft that had gone out and I didn't introduce it because, you know, we had our draft.

MR. THOMPSON: I understand. This is going to get what label?

MR. MERRITT: OCD Exhibit Three.

MR. THOMPSON: OCD Exhibit Three. Thank you. There is no objection, submit it into the record.

(THEREUPON, OCD Exhibit Three was duly admitted into evidence.)

ERNEST REBUCK

was recalled as a witness, and having been previously sworn, testified further upon his oath as follows, to-wit:

EXAMINATION BY MR. THOMPSON:

Q Dr. Rebuck, do you recall the question that I asked Mr. Boyer that he deferred to you?

A Yes, sir.

Q Good, I don't have to repeat it. For the record, I will just -- anybody that reads the transcript will understand that.

The question that I earlier asked Mr. Boyer that he referred to you, on the discharge fee schedule there on the proposed amendments to the regulations, the second to the last page, discharge fees go from zero to nine thousand -- nine thousand nine hundred ninety-nine down to ten million, and the graduated fee from five hundred dollars to four thousand.

A Yes, sir.

Q Okay. My question, for the record again was, I noticed a graduated fee is five hundred dollars each time. But the average discharge gallons per day is significantly graduated, significantly more as you go from nine thousand to ten million.

For instance, there's a graduated increased fee of five hundred dollars when you go from ten thousand to forty-nine thousand gallons discharge per day as opposed to any of the others. As you go down the line from a hundred thousand to four hundred and ninety-nine thousand that's four hundred thousand dollars -- four hundred thousand gallons per day and yet each one of the graduated fees is only five hundred dollars for each one.

Can you help me understand the -- how you did this or how the task force put this together in terms of the fee, with the gallons per day? I don't think -- I don't believe I understand the graduated fee system.

It seems to me if that fee -- if the gallonage increases per day, you increase the fee because it is going to cause more work for some reason. But yet I -- forty thousand gallons per day discharge is going to cost as much as a four hundred thousand gallons per day discharge in terms of the graduated fee?

A I'm sorry. As I read the scale, Mr. Hearing Officer, forty thousand gallons per day would be a thousand dollars; four hundred thousand gallons would be two thousand.

Q But the graduation is as you go up, as you look at the gallons per day discharge you see you go from nine to forty-nine on the right-hand column and forty-nine to ninety-nine, and then ninety-nine to four ninety-nine, and -- okay? From ninety-nine to four ninety-nine you go from --

A Five hundred dollars.

Q You have five hundred dollars, and what is the difference in discharge there, gallons per day? Is that about --

A Five times.

Q Five times. But yet you go from nine to forty-nine in terms of a gallonage. It's much less but yet the same fee.

A I see what you are saying; the difference forty thousand versus four hundred is still in five-hundred-dollar increments?

Q Yes.

A I will take the credit for putting this together wrongly or rightly, but, anyhow, the background was this: This was put together by the in-house Environmental Department. The committee got together on a fee proposal and that was based on about five factors. One was the discharge factor, one was a volume of discharge, gallons per day, the third one was groundwater depth factor, and the fourth factor was the disposal method factor whether it is slightly done on the application or some other.

So there were four methods. So those factors, the in-house committee went through and put numbers on, oh, about fifty discharge plans and came up with a projected fee and it was exactly that document that was taken to the first task force meeting on March 9th, 1990.

The task force members felt that was too complex sorting out the physical items as well as the grow and so forth, so, very candidly, I took the numbers that came out of that and plotted versus volume and it turned out it was a pretty good fit on a semilog relationship.

That's what this table resulted from was frankly nothing more than simple semilog relationship. I did put before the task force that you have the table and the feeling was that it was better to have these brackets meaning what is the difference between twenty thousand and twenty-one thousand, probably nothing. Whereas with the formula you have a little bit different fee. Perhaps formally you are putting too much emphasis on the exact gallonage of discharge.

So breaking it off in these categories, zero to nine hundred ninety-nine or ten thousand to four hundred ninety-nine thousand, nine hundred ninety-nine, okay, that seemed -- you know, we wouldn't get too hung up on just the exact -- defining that discharge. But it seemed workable to the task force and I really came back from that first submittal, which, by circumstances, seemed to fit a semilog relationship.

Q I appreciate your answer and I understand better what you were doing.

Did -- you said that you had some municipal representation. Arky Wheeler from Hobbs was on this group?

A That's correct.

Q Did -- and he's public works director in Hobbs?

A That is correct.

Q Representing the Municipal League, essentially. I mean, kind of an eyes and ears for them on the task force?

A He was invited to -- selected for the task force on the basis that he was a discharger, he is our contact person for the City of Hobbs which had a discharge plan, but he did take upon himself to keep the Municipal League informed at every step and provide that information on.

Q So I assumed he saw this logarithm scale?

A I will preface that, after some discussion.

Q After some discussion?

A He supported this scale.

Q All right. And are you -- so you convinced Dr. Wheeler of this?

A Yes, we did.

Q Now, is there any facility in the state that discharges ten million gallons per day, or greater?

A Probably not. That will come under the discharge fee. We have several with the -- several of the mining activities, heap leach, copper.

Q I was thinking municipal dischargers.

A No, not that.

Q No municipal dischargers. What would be the -- what would be, on the scale, the highest in terms of municipal discharge? That is, where would Albuquerque fit into this?

A I don't know that simply because they -- Albuquerque has the MPS permit and I don't regulate Albuquerque. I know Hobbs is somewhere in the two to three million category, so their fee would be three thousand dollars.

Q Hobbs is where?

A It would be two to three million.

Q I see. So they would be between -- I see, okay. That gives me some idea where Albuquerque is.

MR. THOMPSON: All right, thank you, Dr. Rebuck. I have no further questions. Mr. Merritt, did you have any questions further?

MR. MERRITT: That's what we are trying to decide.

MR. THOMPSON: Do you want some time? Do you want a couple of minutes?

MR. MERRITT: I do have a few. Let me go ahead, if I could.

CROSS EXAMINATION

BY MR. MERRITT:

Q Dr. Rebuck, now let me ask you just a few follow up questions that I think will clarify some questions that have come up.

The proposed regulations that we have before the

Commission now allow the director to waive fees for plan modification that have little or no effect on the discharge quality or quantity, distribution or disposal or on the environment, correct?

A   Yes.

Q   And now is it possible that small changes in those factors could make a significant difference in the potential for a fixed numerical groundwater standard to be exceeded? Do you understand the question?

A   Okay. In other words, if there's a small change in the quantity of discharge, maybe ten percent increase, could that cause the groundwater to be exceeded that would not otherwise?

Q   Yes.

A   Yes.

Q   And then is the soil medium an environmental factor in determining potential effects on groundwater?

A   Yes, it is.

MR. MERRITT: That's all I have, Mr. Hearing Officer.

MR. THOMPSON: Thank you, Mr. Merritt. I believe you are excused again.

(THEREUPON, the witness was excused.)

MR. THOMPSON: Any rebuttal testimony, Mr. Merritt?

MR. MERRITT: Just a second. No, Mr. Hearing Officer.

MR. THOMPSON: Any rebuttal testimony that anyone here

TITLE 20 ENVIRONMENTAL PROTECTION
CHAPTER 6 WATER QUALITY
PART 2 GROUND AND SURFACE WATER PROTECTION

20.6.2.1 **ISSUING AGENCY:** Water Quality Control Commission
[12-1-95; 20.6.2.1 NMAC – Rn, 20 NMAC 6.2.I.1000, 1-15-01]

20.6.2.2 **SCOPE:** All persons subject to the Water Quality Act, NMSA 1978, Sections 74-6-1 et seq.
[12-1-95; 20.6.2.2 NMAC – Rn, 20 NMAC 6.2.I.1001, 1-15-01]

20.6.2.3 **STATUTORY AUTHORITY:** Standards and Regulations are adopted by the commission under the authority of the Water Quality Act, NMSA 1978, Sections 74-6-1 through 74-6-17.
[2-18-77, 9-20-82, 12-1-95; 20.6.2.3 NMAC – Rn, 20 NMAC 6.2.I.1002, 1-15-01]

20.6.2.4 **DURATION:** Permanent.
[12-1-95; 20.6.2.4 NMAC – Rn, 20 NMAC 6.2.I.1003, 1-15-01]

20.6.2.5 **EFFECTIVE DATE:** December 1, 1995 unless a later date is cited at the end of a section.
[12-1-95, 11-15-96; 20.6.2.5 NMAC – Rn, 20 NMAC 6.2.I.1004, 1-15-01; A, 1-15-01]

20.6.2.6 **OBJECTIVE:** The objective of this Part is to implement the Water Quality Act, NMSA 1978, Sections 74-6-1 et seq.
[12-1-95; 20.6.2.6 NMAC – Rn, 20 NMAC 6.2.I.1005, 1-15-01]

20.6.2.7 **DEFINITIONS:** Terms defined in the Water Quality Act, but not defined in this Part, will have the meaning given in the Act. As used in this Part:

A. **"abandoned well"** means a well whose use has been permanently discontinued or which is in a state of disrepair such that it cannot be rehabilitated for its intended purpose or other purposes including monitoring and observation;

B. **"abate" or "abatement"** means the investigation, containment, removal or other mitigation of water pollution;

C. **"abatement plan"** means a description of any operational, monitoring, contingency and closure requirements and conditions for the prevention, investigation and abatement of water pollution, and includes Stage 1, Stage 2, or Stage 1 and 2 of the abatement plan, as approved by the secretary;

D. **"background"** means, for purposes of ground-water abatement plans only and for no other purposes in this Part or any other regulations including but not limited to surface-water standards, the amount of ground-water contaminants naturally occurring from undisturbed geologic sources or water contaminants which the responsible person establishes are occurring from a source other than the responsible person's facility. This definition shall not prevent the secretary from requiring abatement of commingled plumes of pollution, shall not prevent responsible persons from seeking contribution or other legal or equitable relief from other persons, and shall not preclude the secretary from exercising enforcement authority under any applicable statute, regulation or common law;

E. **"casing"** means pipe or tubing of appropriate material, diameter and weight used to support the sides of a well hole and thus prevent the walls from caving, to prevent loss of drilling mud into porous ground, or to prevent fluid from entering or leaving the well other than to or from the injection zone;

F. **"cementing"** means the operation whereby a cementing slurry is pumped into a drilled hole and/or forced behind the casing;

G. **"cesspool"** means a "drywell" that receives untreated domestic liquid waste containing human excreta, and which sometimes has an open bottom and/or perforated sides. A large capacity cesspool means a cesspool that receives greater than 2,000 gallons per day of untreated domestic liquid waste;

H. **"collapse"** means the structural failure of overlying materials caused by removal of underlying materials;

I. **"commission"** means:

(1) the New Mexico Water Quality Control Commission or

(2) the Department, when used in connection with any administrative and enforcement activity;

J. **"confining zone"** means a geological formation, group of formations, or part of a formation that is capable of limiting fluid movement from an injection zone;

K. **"conventional mining"** means the production of minerals from an open pit or underground excavation. Underground excavations include mine shafts, workings and air vents, but does not include excavations primarily caused by in situ extraction activities;

L. **"daily composite sample"** means a sample collected over any twenty-four hour period at intervals not to exceed one hour and obtained by combining equal volumes of the effluent collected, or means a sample collected in accordance with federal permit conditions where a permit has been issued under the National Pollutant Discharge Elimination System or for those facilities which include a waste stabilization pond in the treatment process where the retention time is greater than twenty (20) days, means a sample obtained by compositing equal volumes of at least two grab samples collected within a period of not more than twenty-four (24) hours;

M. **"department", "agency", or "division"** means the New Mexico Environment Department or a constituent agency designated by the commission;

N. **"discharge permit modification"** means a change in requirements of a discharge permit as requested by the discharger as a result of past, present or anticipated changes in the quality or quantity of effluent or the location of the discharge; or as required by the secretary;

O. **"discharge plan"** means a description of any operational, monitoring , contingency, and closure requirements and conditions for any discharge of effluent or leachate which may move directly or indirectly into ground water;

P. **"discharge permit"** means a discharge plan approved by the department;

Q. **"disposal"** means to abandon, deposit, inter or otherwise discard a fluid as a final action after its use has been achieved;

R. **"domestic liquid waste"** means human excreta and water-carried waste from typical residential plumbing fixtures and activities, including but not limited to waste from toilets, sinks, bath fixtures, clothes or dishwashing machines and floor drains;

S. **"domestic liquid waste treatment unit"** means a watertight unit designed, constructed and installed to stabilize only domestic liquid waste and to retain solids contained in such domestic liquid waste, including but not limited to aerobic treatment units and septic tanks;

T. **"drywell"** means a well, other than an improved sinkhole or subsurface fluid distribution system, completed above the water table so that its bottom and sides are typically dry except when receiving fluids;

U. **"experimental technology"** means a technology which has not been proven feasible under the conditions in which it is being tested;

V. **"fluid"** means material or substance which flows or moves whether in a semisolid, liquid, sludge, gas, or any other form or state;

W. **"ground water"** means interstitial water which occurs in saturated earth material and which is capable of entering a well in sufficient amounts to be utilized as a water supply;

X. **"hazard to public health"** exists when water which is used or is reasonably expected to be used in the future as a human drinking water supply exceeds at the time and place of such use, one or more of the numerical standards of Subsection A of 20.6.2.3103 NMAC, or the naturally occurring concentrations, whichever is higher, or if any toxic pollutant affecting human health is present in the water. In determining whether a discharge would cause a hazard to public health to exist, the secretary shall investigate and consider the purification and dilution reasonably expected to occur from the time and place of discharge to the time and place of withdrawal for use as human drinking water;

Y. **"improved sinkhole"** means a naturally occurring karst depression or other natural crevice found in volcanic terrain and other geologic settings which have been modified by man for the purpose of directing and emplacing fluids into the subsurface;

Z. **"injection"** means the subsurface emplacement of fluids through a well;

AA. **"injection zone"** means a geological formation, group of formations, or part of a formation receiving fluids through a well;

BB. **"motor vehicle waste disposal well"** means a well which receives or has received fluids from vehicular repair or maintenance activities;

CC. **"non-aqueous phase liquid"** means an interstitial body of liquid oil, petroleum product, petrochemical, or organic solvent, including an emulsion containing such material;

DD. **"operational area"** means a geographic area defined in a project discharge permit where a group of wells or well fields in close proximity comprise a single Class III well operation;

EE. **"packer"** means a device lowered into a well to produce a fluid-tight seal within the casing;

FF. **"person"** means an individual or any other entity including partnerships, corporation, associations, responsible business or association agents or officers, the state or a political subdivision of the state or any agency, department or instrumentality of the United States and any of its officers, agents or employees;

GG. **"petitioner"** means a person seeking a variance from a regulation of the commission pursuant to Section 74-6-4(G) NMSA 1978;

HH. **"plugging"** means the act or process of stopping the flow of water, oil or gas into or out of a geological formation, group of formations or part of a formation through a borehole or well penetrating these geologic units;

II. **"project discharge permit"** means a discharge permit which describes the operation of similar Class III wells or well fields within one or more individual operational areas;

JJ. **"refuse"** includes food, swill, carrion, slops and all substances from the preparation, cooking and consumption of food and from the handling, storage and sale of food products, the carcasses of animals, junked parts of automobiles and other machinery, paper, paper cartons, tree branches, yard trimmings, discarded furniture, cans, oil, ashes, bottles, and all unwholesome material;

KK. **"responsible person"** means a person who is required to submit an abatement plan or who submits an abatement plan pursuant to this Part;

LL. **"secretary"** or "director" means the secretary of the New Mexico Department of Environment or the director of a constituent agency designated by the commission;

MM. **"sewer system"** means pipelines, conduits, pumping stations, force mains, or other structures, devices, appurtenances or facilities used for collecting or conducting wastes to an ultimate point for treatment or disposal;

NN. **"sewerage system"** means a system for disposing of wastes, either by surface or underground methods, and includes sewer systems, treatment works, disposal wells and other systems;

OO. **"significant modification of Stage 2 of the abatement plan"** means a change in the abatement technology used excluding design and operational parameters, or re-location of 25 percent or more of the compliance sampling stations, for any single medium, as designated pursuant to Paragraph (4) of Subsection E of 20.6.2.4106 NMAC;

PP. **"subsurface fluid distribution system"** means an assemblage of perforated pipes, drain tiles, or other mechanisms intended to distribute fluids below the surface of the ground;

QQ. **"subsurface water"** means ground water and water in the vadose zone that may become ground water or surface water in the reasonably foreseeable future or may be utilized by vegetation;

RR. **"TDS"** means total dissolved solids as determined by the "calculation method" (sum of constituents), by the "residue on evaporation method at 180 degrees" of the "U.S. Geological Survey Techniques of Water Resource Investigations," or by conductivity, as the secretary may determine;

SS. **"toxic pollutant"** means a water contaminant or combination of water contaminants in concentration(s) which, upon exposure, ingestion, or assimilation either directly from the environment or indirectly by ingestion through food chains, will unreasonably threaten to injure human health, or the health of animals or plants which are commonly hatched, bred, cultivated or protected for use by man for food or economic benefit. As used in this definition injuries to health include death, histopathologic change, clinical symptoms of disease, behavioral abnormalities, genetic mutation, physiological malfunctions or physical deformations in such organisms or their offspring. In order to be considered a toxic pollutant a contaminant must be one or a combination of the potential toxic pollutants listed below and be at a concentration shown by scientific information currently available to the public to have potential for causing one or more of the effects listed above. Any water contaminant or combination of the water contaminants in the list below creating a lifetime risk of more than one cancer per 100,000 exposed persons is a toxic pollutant.

acrolein

- acrylonitrile
- aldrin
- benzene
- benzidine
- carbon tetrachloride
- chlordane
- chlorinated benzenes
    - monochlorobenzene
    - hexachlorobenzene
    - pentachlorobenzene
- 1,2,4,5-tetrachlorobenzene
- chlorinated ethanes
    - 1,2-dichloroethane
    - hexachloroethane
    - 1,1,2,2-tetrachloroethane
    - 1,1,1-trichloroethane
    - 1,1,2-trichloroethane
- chlorinated phenols
    - 2,4-dichlorophenol
    - 2,4,5-trichlorophenol
    - 2,4,6-trichlorophenol
- chloroalkyl ethers
    - bis (2-chloroethyl) ether
    - bis (2-chloroisopropyl) ether
    - bis (chloromethyl) ether
- chloroform
- DDT
- dichlorobenzene
- dichlorobenzidine
- 1,1-dichloroethylene
- dichloropropenes
- dieldrin
- 2,4-dinitrotoluene
- diphenylhydrazine
- endosulfan
- endrin
- ethylbenzene
- halomethanes
    - bromodichloromethane
    - bromomethane
    - chloromethane
    - dichlorodifluoromethane
    - dichloromethane
    - tribromomethane
    - trichlorofluoromethane
- heptachlor
- hexachlorobutadiene
- hexachlorocyclohexane (HCH)
    - alpha-HCH
    - beta-HCH
    - gamma-HCH
    - technical HCH
- hexachlorocyclopentadiene
- isophorone
- nitrobenzene
- nitrophenols

- 2,4-dinitro-o-cresol
    - dinitrophenols
- nitrosamines
    - N-nitrosodiethylamine
    - N-nitrosodimethylamine
    - N-nitrosodibutylamine
    - N-nitrosodiphenylamine
    - N-nitrosopyrrolidine
- pentachlorophenol
- phenol
- phthalate esters
    - dibutyl phthalate
    - di-2-ethylhexyl phthalate
    - diethyl phthalate
    - dimethyl phthalate
- polychlorinated biphenyls (PCB's)
- polynuclear aromatic hydrocarbons (PAH)
    - anthracene
    - 3,4-benzofluoranthene
    - benzo (k) fluoranthene
    - fluoranthene
    - fluorene
    - phenanthrene
    - pyrene
- tetrachloroethylene
- toluene
- toxaphene
- trichloroethylene
- vinyl chloride
- xylenes
    - o-xylene
    - m-xylene
    - p-xylene
- 1,1-dichloroethane
- ethylene dibromide (EDB)
- cis-1,2-dichloroethylene
- trans-1,2-dichloroethylene
- naphthalene
- 1-methylnaphthalene
- 2-methylnaphthalene
- benzo-a-pyrene

TT. **"vadose zone"** means earth material below the land surface and above ground water, or in between bodies of ground water;

UU. **"wastes"** means sewage, industrial wastes, or any other liquid, gaseous or solid substance which will pollute any waters of the state;

VV. **"water"** means all water including water situated wholly or partly within or bordering upon the state, whether surface or subsurface, public or private, except private waters that do not combine with other surface or subsurface water;

WW. **"water contaminant"** means any substance that could alter if discharged or spilled the physical, chemical, biological or radiological qualities of water. "Water contaminant" does not mean source, special nuclear or by-product material as defined by the Atomic Energy Act of 1954;

XX. **"watercourse"** means any river, creek, arroyo, canyon, draw, or wash, or any other channel having definite banks and beds with visible evidence of the occasional flow of water;

YY. **"water pollution"** means introducing or permitting the introduction into water, either directly or indirectly, of one or more water contaminants in such quantity and of such duration as may with reasonable probability injure human health, animal or plant life or property, or to unreasonably interfere with the public welfare or the use of property;

ZZ. **"well"** means: (1) A bored, drilled, or driven shaft; (2) A dug hole whose depth is greater than the largest surface dimension; (3) An improved sinkhole; or (4) A subsurface fluid distribution system;

AAA. **"well stimulation"** means a process used to clean the well, enlarge channels, and increase pore space in the interval to be injected, thus making it possible for fluids to move more readily into the injection zone. Well stimulation includes, but is not limited to, (1) surging, (2) jetting, (3) blasting, (4) acidizing, (5) hydraulic fracturing.

[1-4-68, 4-20-68, 11-27-70, 9-3-72, 4-11-74, 8-13-76, 2-18-77, 6-26-80, 7-2-81, 1-29-82, 9-20-82, 11-17-84, 3-3-86, 8-17-91, 8-19-93, 12-1-95; 20.6.2.7 NMAC – Rn, 20 NMAC 6.2.I.1101, 1-15-01; A, 1-15-01; A, 12-1-01]

20.6.2.8 **SEVERABILITY:** If any Section, Subsection, individual standard or application of these standards or regulations is held invalid, the remainder shall not be affected.

[2-18-77, 12-1-95; 20.6.2.8 NMAC – Rn, 20 NMAC 6.2.I.1007, 1-15-01]

20.6.2.9 **DOCUMENTS:** Documents referenced in the Part may be viewed at the New Mexico Environment Department, Ground Water Quality Bureau, Harold Runnels Building, 1190 St. Francis Drive, Santa Fe, New Mexico 87503.

[12-1-95; 20.6.2.9 NMAC – Rn, 20 NMAC 6.2.I.1006, 1-15-01; A, 12-1-01]

20.6.2.10 – 20.6.2.1199: [RESERVED]

[12-1-95; 20.6.2.10 – 20.6.2.1199 NMAC – Rn, 20 NMAC 6.2.I.1008-1100, 1102-1199, 1-15-01]

20.6.2.1200 **PROCEDURES:**

[12-1-95; 20.6.2.1200 NMAC – Rn, 20 NMAC 6.2.I.1200, 1-15-01]

20.6.2.1201 **NOTICE OF INTENT TO DISCHARGE:**

A. Any person intending to make a new water contaminant discharge or to alter the character or location of an existing water contaminant discharge, unless the discharge is being made or will be made into a community sewer system or subject to the Liquid Waste Disposal Regulations adopted by the New Mexico Environmental Improvement Board, shall file a notice with the Ground Water Quality Bureau of the department for discharges that may affect ground water, and/ or the Surface Water Quality Bureau of the department for discharges that may affect surface water. However, notice regarding discharges from facilities for the production, refinement, pipeline transmission of oil and gas or products thereof, the oil field service industry, oil field brine production wells, geothermal installations and carbon dioxide facilities shall be filed instead with the Oil Conservation Division.

B. Any person intending to inject fluids into a well, including a subsurface distribution system, unless the injection is being made subject to the Liquid Waste Disposal Regulations adopted by the New Mexico Environmental Improvement Board, shall file a notice with the Ground Water Quality Bureau of the department. However notice regarding injection to wells associated with oil and gas facilities as described in Subsection A of Section 20.6.2.1201 NMAC shall be filed instead with the Oil Conservation Division.

C. Notices shall state:

(1) the name of the person making the discharge;
(2) the address of the person making the discharge;
(3) the location of the discharge;
(4) an estimate of the concentration of water contaminants in the discharge; and
(5) the quantity of the discharge.

D. Based on information provided in the notice of intent, the department will notify the person proposing the discharge as to which of the following apply:

(1) a discharge permit is required;
(2) a discharge permit is not required;
(3) the proposed injection well will be added to the department's underground injection well inventory;

N. M. S. A. 1978, § 74-6-5

West's New Mexico Statutes Annotated Currentness
Chapter 74. Environmental Improvement
Article 6. Water Quality Act (Refs & Annos)

§ 74-6-5. Permits; certification; appeals to commission

A. By regulation the commission may require persons to obtain from a constituent agency designated by the commission a permit for the discharge of any water contaminant or for the disposal or re-use of septage or sludge.

B. The commission shall adopt regulations establishing procedures for certifying federal water quality permits.

C. Prior to the issuance of a permit, the constituent agency may require the submission of plans, specifications and other relevant information that it deems necessary.

D. The commission shall by regulation set the dates upon which applications for permits shall be filed and designate the time periods within which the constituent agency shall, after the filing of an administratively complete application for a permit, either grant the permit, grant the permit subject to conditions or deny the permit.

E. The constituent agency shall deny any application for a permit or deny the certification of a federal water quality permit if:

(1) the effluent would not meet applicable state or federal effluent regulations, standards of performance or limitations;
(2) any provision of the Water Quality Act would be violated;
(3) the discharge would cause or contribute to water contaminant levels in excess of any state or federal standard. Determination of the discharges' effect on ground water shall be measured at any place of withdrawal of water for present or reasonably foreseeable future use. Determination of the discharges' effect on surface waters shall be measured at the point of discharge; or
(4) the applicant has, within the ten years immediately preceding the date of submission of the permit application:
  (a) knowingly misrepresented a material fact in an application for a permit;
  (b) refused or failed to disclose any information required under the Water Quality Act;
  (c) been convicted of a felony or other crime involving moral turpitude;
  (d) been convicted of a felony in any court for any crime defined by state or federal law as being a restraint of trade, price-fixing, bribery or fraud;
  (e) exhibited a history of willful disregard for environmental laws of any state or the United States; or
  (f) had an environmental permit revoked or permanently suspended for cause under any environmental laws of any state or the United States.

F. The commission shall by regulation develop procedures that ensure that the public, affected governmental agencies and any other state whose water may be affected shall receive notice of each application for issuance or modification of a permit. No ruling shall be made on any application for a permit without opportunity for a public hearing at which all interested persons shall be given a reasonable chance to submit data, views or arguments orally or in writing and to examine witnesses testifying at the hearing.

G. The commission may adopt regulations for the operation and maintenance of the permitted facility, including requirements, as may be necessary or desirable, that relate to continuity of operation, personnel training and financial responsibility, including financial responsibility for corrective action.

H. Permits shall be issued for fixed terms not to exceed five years, except that for new discharges, the term of the permit shall commence on the date the discharge begins, but in no event shall the term of the permit exceed seven years from the date the permit was issued.

I. By regulation, the commission may impose reasonable conditions upon permits requiring permittees to:

(1) install, use and maintain effluent monitoring devices;
(2) sample effluents and receiving waters for any known or suspected water contaminants in accordance with methods and at locations and intervals as may be prescribed by the commission;
(3) establish and maintain records of the nature and amounts of effluents and the performance of effluent control devices;
(4) provide any other information relating to the discharge or direct or indirect release of water contaminants; and
(5) notify a constituent agency of the introduction of new water contaminants from a new source and of a substantial change in volume or character of water contaminants being introduced from sources in existence at the time of the issuance of the permit.

J. The commission shall provide by regulation a schedule of fees for permits, not exceeding the estimated cost of investigation and issuance, modification and renewal of permits. Fees collected pursuant to this section shall be deposited in the water quality management fund.

K. The issuance of a permit does not relieve any person from the responsibility of complying with the provisions of the Water Quality Act, any applicable regulations or water quality standards of the commission or any applicable federal laws, regulations or standards.

L. A permit may be terminated or modified by the constituent agency that issued the permit prior to its date of expiration for any of the following causes:

(1) violation of any condition of the permit;
(2) obtaining the permit by misrepresentation or failure to disclose fully all relevant facts;
(3) violation of any provisions of the Water Quality Act or any applicable regulations, standard of performance or water quality standards;
(4) violation of any applicable state or federal effluent regulations or limitations; or
(5) change in any condition that requires either a temporary or permanent reduction or elimination of the permitted discharge.

M. If the constituent agency denies, terminates or modifies a permit or grants a permit subject to condition, the constituent agency shall notify the applicant or permittee by certified mail of the action taken and the reasons.

N. A person who participated in a permitting action before a constituent agency or a person affected by a certification of a federal permit and who is adversely affected by such permitting action or certification may file a petition for review before the commission. The petition shall be made in writing to the commission within thirty days from the date notice is given of the constituent agency's action. Unless a timely petition for review is made, the decision of the constituent agency shall be final.

O. If a timely petition for review is made, the commission shall hold a hearing within ninety days after receipt of the petition. The commission shall notify the petitioner and the applicant or permittee if other than the petitioner by certified mail of the date, time and place of the hearing. If the commission deems the action that is the subject of the petition to be affected with substantial public interest, it shall ensure that the public receives notice of the date, time and place of the hearing and is given a reasonable chance to submit data, views or arguments orally or in writing and to examine witnesses testifying at the hearing. A person submitting data, views or arguments orally or in writing shall be subject to examination at the hearing. In the hearing, the burden of proof shall be upon the petitioner. The commission may designate a hearing officer to take evidence in the hearing. Based upon the evidence presented at the hearing, the commission shall sustain, modify or reverse the action of the constituent agency.

P. If the petitioner requests, the hearing shall be recorded at the cost of the petitioner. Unless the petitioner requests that the hearing be recorded, the decision of the commission shall be final.

L. 1973, Ch. 326, § 4; L. 1985, Ch. 157, § 1; L. 1989, Ch. 248, § 1; L. 1993, Ch. 100, § 3; L. 1993, Ch. 291, § 5; L. 1999, Ch. 21, § 1.

Formerly 1953 Comp., § 75-39-4.1.

LIBRARY REFERENCES

Environmental Law 🔑194, 215.
Westlaw Key Number Searches: 149Ek194; 149Ek215.

RESEARCH REFERENCES

Treatises and Practice Aids

Law of Water Rights and Resources § 4:34.

State Environmental Law §§ 8:17, 8:19.

UNITED STATES SUPREME COURT

Pollution discharge permits,
In general,

Clean Water Act, discharge of pollutants, point source, discharge permit, see South Florida Water Manag. Dist. v. Miccosukee Tribe, 2004, 124 S.Ct. 1537.

Environmental protection, NPDES permits, interstate waters, water quality standards of affected states, see Arkansas v. Oklahoma, U.S.1992, 112 S.Ct. 1046, 503 U.S. 91, 117 L.Ed.2d 239, on remand 962 F.2d 996.

Standing,

Citizen group standing, civil penalties and injunctive relief, violations of pollution discharge permit, subsequent compliance with permit or shut down of facility, mootness doctrine, Clean Water Act, see Friends of Earth v. Laidlaw Environmental Services (TOC), Inc., U.S.S.C.2000, 120 S.Ct. 693, 528 U.S. 167.

NOTES OF DECISIONS

Abstention doctrine 2
Construction and application 1/2
Permit requirements 3
Validity of regulations and requirements 1

1/2. Construction and application

Defendant environmental consultant could not commit crimes, in violation of the Water Quality Act (WQA), of discharging in violation of a permit and of causing or allowing another to violate a permit, where permit upon which violations were based had expired, even though all the parties considered that permit was an active permit and acted accordingly; modification approval letter that Environmental Department sent to permit holder mistakenly stated that approval would expire at a later date, but permit modification did not extend the permit, and subsequent letter from Department to permit holder admitted mistake. State v. Villa, 2003, 134 N.M. 679, 82 P.3d 46, certiorari granted 135 N.M. 52, 84 P.3d 669, affirmed in part, reversed in part 136 N.M. 367, 98 P.3d 1017. Environmental Law 🔑 743

1. Validity of regulations and requirements

Water Quality Control Commission's regulations which required persons who discharge toxic pollutants to submit a discharge plan to the Director of the Environmental Improvement Division for approval, and which defined "toxic pollutants" as contaminants that will, "on the basis of information available to the Director or the Commission, cause death," or other dire results were unconstitutionally vague, since the discharger's acts were to be judged, not by what he could read in print about the standards, but by "information available to the Director or the Commission." Bokum Resources Corp. v. New Mexico Water Quality Control Commission, 1979, 93 N.M. 546, 603 P.2d 285. Environmental Law 🔑 196

It was not "clearly incorrect" for the Water Quality Control Commission to require the discharger of toxic pollutants to provide a site and method for flow measurement and to provide any pertinent information relating to the discharge of water contaminants in order to demonstrate to the Commission that the plans of the discharger would not result in a violation of the standards and regulations; such requirements were well within the statutory mandate. NMSA 1978, § **74**-**6**-**5**, subd. G. Bokum Resources Corp. v. New Mexico Water Quality Control Commission, 1979, 93 N.M. 546, 603 P.2d 285. Environmental Law 🔑 207

2. Abstention doctrine

Burford abstention was appropriate as to claim that acid mine drainage (AMD) at gold mine site constituted imminent and substantial endangerment to health or environmental under Resource Conservation and Recovery Act (RCRA), particularly as determination that AMD posed such endangerment would be irreconcilable with New Mexico Department of Environment's (NMED) determination to allow mine operators to proceed under discharge permit; New Mexico had taken great care to provide for specialized adjudication of its complicated environmental law scheme, plaintiffs extensively participated in permit proceedings and could have appealed NMED's decision, and their claim was little more than indirect collateral attack on NMED's adjudication and its present regulatory course. Solid Waste Disposal Act, § 7002(a)(1)(B), as amended, 42 U.S.C.A. § 6972(a)(1)(B); NMSA 1978, §§ **74**-**6**-**5**, 74-6-6, 74-6-7. Friends of Santa Fe County v. LAC Minerals, Inc., 1995, 892 F.Supp. 1333. Federal Courts 🔑 47.1

3. Permit requirements

Under the Water Quality Act (WQA), an applicant for a permit does not determine whether any limitations or exemptions apply; the Environmental Department makes such determination, and though an applicant may appeal the conditions of a permit, once a permit is issued the applicant is bound by its requirements. State v. Villa, 2003, 134 N.M. 679, 82 P.3d 46, certiorari granted 135 N.M. 52, 84 P.3d 669, affirmed in part, reversed in part 136 N.M. 367, 98 P.3d 1017. Environmental Law 🔑 197

Current through the Second Session of the 46th Legislature (2004)

End of Document

N. M. S. A. 1978, § 74-6-5

West's New Mexico Statutes Annotated Currentness

Chapter 74. Environmental Improvement

Article 6. Water Quality Act (Refs & Annos)

§ 74-6-5. Permits; certification; appeals to commission

A. By regulation, the commission may require persons to obtain from a constituent agency designated by the commission a permit for the discharge of any water contaminant or for the disposal or reuse of septage or sludge.

B. The commission shall adopt regulations establishing procedures for certifying federal water quality permits.

C. Prior to the issuance of a permit, the constituent agency may require the submission of plans, specifications and other relevant information that it deems necessary.

D. The commission shall by regulation set the dates upon which applications for permits shall be filed and designate the time periods within which the constituent agency shall, after the filing of an administratively complete application for a permit, either grant the permit, grant the permit subject to conditions or deny the permit.

E. The constituent agency shall deny any application for a permit or deny the certification of a federal water quality permit if:

(1) the effluent would not meet applicable state or federal effluent regulations, standards of performance or limitations;
(2) any provision of the Water Quality Act would be violated;
(3) the discharge would cause or contribute to water contaminant levels in excess of any state or federal standard. Determination of the discharges' effect on ground water shall be measured at any place of withdrawal of water for present or reasonably foreseeable future use. Determination of the discharges' effect on surface waters shall be measured at the point of discharge; or
(4) the applicant has, within the ten years immediately preceding the date of submission of the permit application:
  (a) knowingly misrepresented a material fact in an application for a permit;
  (b) refused or failed to disclose any information required under the Water Quality Act;
  (c) been convicted of a felony or other crime involving moral turpitude;
  (d) been convicted of a felony in any court for any crime defined by state or federal law as being a restraint of trade, price-fixing, bribery or fraud;
  (e) exhibited a history of willful disregard for environmental laws of any state or the United States; or
  (f) had an environmental permit revoked or permanently suspended for cause under any environmental laws of any state or the United States.

F. The commission shall by regulation develop procedures that ensure that the public, affected governmental agencies and any other state whose water may be affected shall receive notice of each application for issuance, renewal or modification of a permit. Public notice shall include:

(1) for issuance or modification of a permit:
  (a) notice by mail to adjacent and nearby landowners; local, state and federal governments; land grant organizations; ditch associations; and Indian nations, tribes or pueblos;
  (b) posting at a place conspicuous to the public and near the discharge or proposed discharge site; and
  (c) a display advertisement in English and Spanish in a newspaper of general circulation in the location of the discharge or proposed discharge; provided, however, that the advertisement shall not be displayed in the classified or legal advertisement sections; and

(2) for issuance of renewals of permits:
  (a) notice by mail to the interested public, municipalities, counties, land grant organizations, ditch associations and Indian nations, tribes or pueblos; and
  (b) a display advertisement in English and Spanish in a newspaper of general circulation in the location of the discharge; provided, however, that the advertisement shall not be displayed in the classified or legal advertisement sections.

G. No ruling shall be made on any application for a permit without opportunity for a public hearing at which all interested persons shall be given a reasonable chance to submit evidence, data, views or arguments orally or in writing and to examine witnesses testifying at the hearing. The hearing shall be recorded. Any person submitting evidence, data, views or arguments shall be subject to examination at the hearing.

H. The commission may adopt regulations for the operation and maintenance of the permitted facility, including requirements, as may be necessary or desirable, that relate to continuity of operation, personnel training and financial responsibility, including financial responsibility for corrective action.

I. Permits shall be issued for fixed terms not to exceed five years, except that for new discharges, the term of the permit shall commence on the date the discharge begins, but in no event shall the term of the permit exceed seven years from the date the permit was issued.

J. By regulation, the commission may impose reasonable conditions upon permits requiring permittees to:

(1) install, use and maintain effluent monitoring devices;
(2) sample effluents and receiving waters for any known or suspected water contaminants in accordance with methods and at locations and intervals as may be prescribed by the commission;
(3) establish and maintain records of the nature and amounts of effluents and the performance of effluent control devices;
(4) provide any other information relating to the discharge or direct or indirect release of water contaminants; and
(5) notify a constituent agency of the introduction of new water contaminants from a new source and of a substantial change in volume or character of water contaminants being introduced from sources in existence at the time of the issuance of the permit.

K. The commission shall provide by regulation a schedule of fees for permits, not exceeding the estimated cost of investigation and issuance, modification and renewal of permits. Fees collected pursuant to this section shall be deposited in the water quality management fund.

L. The issuance of a permit does not relieve any person from the responsibility of complying with the provisions of the Water Quality Act, any applicable regulations or water quality standards of the commission or any applicable federal laws, regulations or standards.

M. A permit may be terminated or modified by the constituent agency that issued the permit prior to its date of expiration for any of the following causes:

(1) violation of any condition of the permit;
(2) obtaining the permit by misrepresentation or failure to disclose fully all relevant facts;
(3) violation of any provisions of the Water Quality Act or any applicable regulations, standard of performance or water quality standards;
(4) violation of any applicable state or federal effluent regulations or limitations; or
(5) change in any condition that requires either a temporary or permanent reduction or elimination of the permitted discharge.

N. If the constituent agency denies, terminates or modifies a permit or grants a permit subject to condition, the constituent agency shall notify the applicant or permittee by certified mail of the action taken and the reasons. Notice shall also be given by mail to persons who participated in the permitting action.

O. A person who participated in a permitting action before a constituent agency or a person affected by a certification of a federal permit and who is adversely affected by such permitting action or certification may file a petition for review before the commission. Unless a timely petition for review is made, the decision of the constituent agency shall be final and not subject to judicial review. The petition shall:

(1) be made in writing to the commission within thirty days from the date notice is given of the constituent agency's action;
(2) include a statement of the issues to be raised and the relief sought; and
(3) be provided to all other persons submitting evidence, data, views or arguments in the proceeding before the constituent agency.

P. If a timely petition for review is made, the commission shall consider the petition within ninety days after receipt of the petition. The commission shall notify the petitioner and the applicant or permittee, if other than the petitioner, by certified mail of the date, time and place of the review. If the petitioner is not the applicant or permittee, the applicant or permittee shall be a party to the proceeding. The commission shall ensure that the public receives notice of the date, time and place of the review.

Q. The commission shall review the record compiled before the constituent agency, including the transcript of any public hearing held on the application or draft permit, and shall allow any party to submit arguments. The commission may designate a hearing officer to review the record and the arguments of the parties and recommend a decision to the commission. The commission shall consider and weigh only the evidence contained in the record before the constituent agency and the recommended decision of the hearing officer, if any, and shall not be bound by the factual findings or legal conclusions of the constituent agency. Based on the review of the evidence, the arguments of the parties and recommendations of the hearing officer, the commission shall sustain, modify or reverse the action of the constituent agency. The commission shall enter ultimate findings of fact and conclusions of law and keep a record of the review.

R. Prior to the date set for review, if a party shows to the satisfaction of the commission that there was no reasonable opportunity to submit comment or evidence on an issue being challenged, the commission shall order that additional comment or evidence be taken by the constituent agency. Based on the additional evidence, the constituent agency may revise the decision and shall promptly file with the commission the additional evidence received and action taken. The commission shall consider the additional evidence within ninety days after receipt of the additional evidence and shall notify the petitioner and the applicant or permittee, if other than the petitioner, of the date, time and place of the review.

S. The commission shall notify the petitioner and all other participants in the review proceeding of the action taken by the commission and the reasons for that action.

L. 1973, Ch. 326, § 4; L. 1985, Ch. 157, § 1; L. 1989, Ch. 248, § 1; L. 1993, Ch. 100, § 3; L. 1993, Ch. 291, § 5; L. 1999, Ch. 21, § 1; L. 2005, Ch. 195, § 1, eff. June 17, 2005.

Formerly 1953 Comp., § 75-39-4.1.

LIBRARY REFERENCES

Environmental Law 🔑194, 215.
Westlaw Key Number Searches: 149Ek194; 149Ek215.

RESEARCH REFERENCES

Treatises and Practice Aids

Law of Water Rights and Resources § 4:34.

State Environmental Law §§ 8:17, 8:19.

UNITED STATES SUPREME COURT

Pollution discharge permits,

In general,

Clean Water Act, discharge of pollutants, point source, discharge permit, see South Florida Water Manag. Dist. v. Miccosukee Tribe, 2004, 124 S.Ct. 1537.

Environmental protection, NPDES permits, interstate waters, water quality standards of affected states, see Arkansas v. Oklahoma, U.S.1992, 112 S.Ct. 1046, 503 U.S. 91, 117 L.Ed.2d 239, on remand 962 F.2d 996.

Standing,

Citizen group standing, civil penalties and injunctive relief, violations of pollution discharge permit, subsequent compliance with permit or shut down of facility, mootness doctrine, Clean Water Act, see Friends of Earth v. Laidlaw Environmental Services (TOC), Inc., U.S.S.C.2000, 120 S.Ct. 693, 528 U.S. 167.

NOTES OF DECISIONS

Abstention doctrine 2
Construction and application 1/2
Permit requirements 3
Validity of regulations and requirements 1

1/2. Construction and application

Defendant environmental consultant could not commit crimes, in violation of the Water Quality Act (WQA), of discharging in violation of a permit and of causing or allowing another to violate a permit, where permit upon which violations were based had expired, even though all the parties considered that permit was an active permit and acted accordingly; modification approval letter that Environmental Department sent to permit holder mistakenly stated that approval would expire at a later date, but permit modification did not extend the permit, and subsequent letter from Department to permit holder admitted mistake. State v. Villa, 2003, 134 N.M. 679, 82 P.3d 46, certiorari granted 135 N.M. 52, 84 P.3d 669, affirmed in part, reversed in part 136 N.M. 367, 98 P.3d 1017. Environmental Law 🔑 743

1. Validity of regulations and requirements

Water Quality Control Commission's regulations which required persons who discharge toxic pollutants to submit a discharge plan to the Director of the Environmental Improvement Division for approval, and which defined “toxic pollutants” as contaminants that will, “on the basis of information available to the Director or the Commission, cause death,” or other dire results were unconstitutionally vague, since the discharger's acts were to be judged, not by what he could read in print about the standards, but by “information available to the Director or the Commission.” Bokum Resources Corp. v. New Mexico Water Quality Control Commission, 1979, 93 N.M. 546, 603 P.2d 285. Environmental Law 🔑 196

It was not “clearly incorrect” for the Water Quality Control Commission to require the discharger of toxic pollutants to provide a site and method for flow measurement and to provide any pertinent information relating to the discharge of water contaminants in order to demonstrate to the Commission that the plans of the discharger would not result in a violation of the standards and regulations; such requirements were well within the statutory mandate. NMSA 1978, § **74**-**6**-**5**, subd. G. Bokum Resources Corp. v. New Mexico Water Quality Control Commission, 1979, 93 N.M. 546, 603 P.2d 285. Environmental Law 207

2. Abstention doctrine

Burford abstention was appropriate as to claim that acid mine drainage (AMD) at gold mine site constituted imminent and substantial endangerment to health or environmental under Resource Conservation and Recovery Act (RCRA), particularly as determination that AMD posed such endangerment would be irreconcilable with New Mexico Department of Environment's (NMED) determination to allow mine operators to proceed under discharge permit; New Mexico had taken great care to provide for specialized adjudication of its complicated environmental law scheme, plaintiffs extensively participated in permit proceedings and could have appealed NMED's decision, and their claim was little more than indirect collateral attack on NMED's adjudication and its present regulatory course. Solid Waste Disposal Act, § 7002(a)(1)(B), as amended, 42 U.S.C.A. § 6972(a)(1)(B); NMSA 1978, §§ **74**-**6**-**5**, 74-6-6, 74-6-7. Friends of Santa Fe County v. LAC Minerals, Inc., 1995, 892 F.Supp. 1333. Federal Courts 47.1

3. Permit requirements

Under the Water Quality Act (WQA), an applicant for a permit does not determine whether any limitations or exemptions apply; the Environmental Department makes such determination, and though an applicant may appeal the conditions of a permit, once a permit is issued the applicant is bound by its requirements. State v. Villa, 2003, 134 N.M. 679, 82 P.3d 46, certiorari granted 135 N.M. 52, 84 P.3d 669, affirmed in part, reversed in part 136 N.M. 367, 98 P.3d 1017. Environmental Law 197

Current through Chapter 351 (End) of the First Regular Session of the 47th Legislature (2005) (including Constitutional Amendments 1 and 2)

End of Document

NEW MEXICO
ENVIRONMENT DEPARTMENT

SUSANA MARTINEZ
Governor

JOHN SANCHEZ
Lieutenant Governor

P.O. Box 5469
1190 St. Francis Drive
Santa Fe, New Mexico 87502-5469
Phone (505) 827-2918 Fax (505) 827-2965
www.nmenv.state.nm.us

RYAN FLYNN
Secretary

BUTCH TONGATE
Deputy Secretary

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

February 23, 2015

Armando Martinez
Environmental Manager
Chevron Mining, Inc. (CMI)
PO Box 469
Questa, NM 87556

RE: Discharge Permit Amendment, DP-1055, Placement of Demolition Debris and Historic Tailing in the Open Pit at the Chevron Mine Site

Dear Mr. Martinez:

The Ground Water Quality Bureau of the New Mexico Environment Department (NMED) has reviewed the letter from Chevron Mining, Inc. (permittee) titled, *Discharge Permit DP-1055 Amendment Request, Placement of Tailing and Demolition Debris in the Open Pit, Questa Mine* (Letter), received via email by NMED on January 6, 2015. In the Letter, the permittee requests to place tailing removed from the Mill area and select demolition debris associated with demolition activities at the Mine Site in the open pit. On January 21, 2015, NMED sent the permittee a request for additional information in a letter titled *Request for Additional Information, Discharge Permit DP-1055 Amendment Request, Placement of Tailing and Demolition Debris in the Open Pit, Chevron Mining, Inc., Questa Mine Facility.* The permittee responded to NMED's request for additional information in a letter submitted via email on February 20, 2015 titled *Discharge Permit DP-1055 Amendment Request Placement of Tailing and Demolition Debris in the Open Pit, Questa Mine – Response to Agency Comments* (Response). NMED has reviewed the response and hereby conditionally approves the DP-1055 Amendment Request.

The facilities covered under DP-1055 are located approximately five miles east of the Village of Questa in Sections 1, 2, 3, 4, 11, 12 (projected) T28N, R13E, Sections 25, 26, 33, 34, 35 (projected) T29N, R13E, Section 6 (projected) T28N, R14E, and Section 31, T29N, R14E, Taos County.

NMED EXHIBIT 21

NMED issues this Discharge Permit Amendment pursuant to the New Mexico Water Quality Act (WQA), NMSA 1978 §§74-6-1 through 74-6-17, and the New Mexico Water Quality Control Commission (WQCC) Regulations, 20.6.2 NMAC. This Discharge Permit Amendment does not result in significant changes in the quantity or quality of effluent or the location of the discharge. This Discharge Permit Amendment changes specific terms and/or conditions contained in Discharge Permit, DP-1055, issued to the permittee on November 15, 2000. In issuing this Discharge Permit Amendment, NMED has determined that the requirements of Subsection C of 20.6.2.3109 NMAC have been met.

Amendment Description

The purpose of this Discharge Permit Amendment is to authorize the placement of tailing and select demolition debris from building demolition and tailing removal activities at the Mill Site in the open pit. The permittee is in the process of decommissioning and demolishing buildings at the Mill Site in accordance with plans approved by NMED and the New Mexico Energy, Minerals and Natural Resources Department, Mining and Minerals Division (MMD) and preparing for the construction of the following facilities and water conveyance systems:

- Water Treatment Plant (construction in progress)
- 005 Catchment
- Utility Corridor
- Sludge Repository

Prior to the mid-1960's, tailing material was deposited in the Mill Area. This tailing material is referred to as the historic mine tailing area. The permittee was required to determine the nature and extent of the historic mine tailing area pursuant to approval of the permittee's *Building Demolition and Cleanup Plan; Phase 1 Activities* issued on August 29, 2014. Additional tailing was discovered while demolishing the 175 Thickener, the Decline Maintenance Shop, and the Moly Storage Building. Currently, this tailing material is being stockpiled at the Mill site. The permittee is also stockpiling concrete from the demolition of building foundations and structures at the Mill site. The permittee has committed to removing the full extent of the historic mine tailing and has requested to place this material, additional tailing found during building demolition, and demolition debris in the open pit.

Permit Conditions

This Discharge Permit Amendment applies to the Questa Mine, DP-1055, which is still in effect pursuant to 20.6.3106.F NMAC. The following conditions will be added to the effective DP-1055 and continued upon renewal. The permittee shall comply with these conditions, which are enforceable by NMED.

1. At least one week prior to initiation of placement of tailing material and/or demolition debris in the open pit that are associated with Mine site demolition and/or tailing removal activities, CMI shall provide to NMED written notification of disposal activities.

2. The permittee shall place the material in the locations designated in the *Discharge Permit DP-1055 Amendment Request, Placement of Tailing and Demolition Debris in the Open Pit, Questa Mine,* dated January 6, 2015.
3. The permittee shall cover and revegetate the tailing and construction debris in accordance with MMD closeout requirements in Permit Revision 96-2 to TA001RD, the Open Pit Waiver, and closure requirements submitted in the revised closure plan pursuant to Condition 31 in DP-1055 in the event the open pit is not used as a waste rock repository for reclamation of the waste rock piles. [Section 20.6.2.3109 NMAC]
4. The permittee shall provide the results used to delineate the extent of the historic mine tailing material (*Phase 1 Soil Sampling and Analysis Plan,* dated October 2014) no later than 30 days following issuance of this permit amendment. Please include a map showing all of the sampling locations, a description of the samples taken (i.e. surface vs. subsurface), and the analytical results.

Other Requirements

Based on NMED's review of the Response, NMED requests that the permittee provide the following information in the forthcoming revised application for renewal of DP-1539.

1. In Figure 2 of the Response, the utility corridor appears to terminate where the former Gas Shop was located. NMED understands that the utility corridor extends from this location to the water treatment plant. Please clarify and modify the figure accordingly. In addition, there appears to be a haul road or another utility corridor that connects to the southern utility corridor west of the 005 Catchment and runs north of the 005 Catchment. Please clarify what this feature is. Finally, there is an unidentified corridor that runs from the eastern end of the 005 Catchment, intersects with the designated utility corridor, and then continues to run east to the Sludge Repository. Please clarify what this feature is.

2. Please provide a description with drawings of how stormwater is currently routed to and from the Mill site during demolition activities, and a description and drawings showing how stormwater will be collected and conveyed to the 005 catchment following completion of construction activities.. The description and map should include all existing and proposed stormwater conveyance structures (i.e. ditches, down drains, etc.).

The permittee shall comply with the terms and conditions contained herein and those in DP-1055 that remain unchanged which are enforceable by NMED pursuant to Section 20.6.2.3104 NMAC and NMSA 1978 §74-6-5 and §75-6-10. Please be advised that this Discharge Permit Amendment does not relieve the permittee of liability should its operation result in actual pollution of surface or ground water which may be actionable under other laws and/or regulations.

Period of Approval

Pursuant to 20.6.2.3109.H.4 NMAC, the term of this Discharge Permit Amendment for the DP-1055 shall be the same as the term of DP-1055. The timely submission of the Discharge Permit renewal application on August 2, 2010 keeps the existing permit and associated amendment(s) effective until the renewal process is complete. [Subsection F of 20.6.2.3106 NMAC]

Issuance of this Discharge Permit Amendment does not relieve the permittee of the responsibility to comply with the WQA, WQCC Regulations, and any other applicable federal, state and/or local laws and regulations, such as zoning requirements and nuisance ordinances.

If at any time in the future the permittee intends to change the disposition of any discharge relating to this amendment, the permittee is required to notify NMED prior to changing the discharge.

Please contact Anne Maurer of the Mining Environmental Compliance Section at 505-827-2906 with any questions.

Sincerely,

for:

Jerry Schoeppner, Chief
Ground Water Quality Bureau

JS:AM

cc: Brian Shields, Executive Director, Amigos Bravos (signed PDF copy sent via electronic mail to: bshields@amigosbravos.org)
Joe Vinson, EMNRD-MMD, (signed PDF copy sent via electronic mail to: joseph.vinson@state.nm.us)
Kurt Vollbrecht, Program Manager, GWQB-MECS (signed PDF copy sent via electronic mail to: kurt.vollbrecht@state.nm.us)
Joe Fox, AOC Team Leader, GWQB-MECS (signed PDF copy sent via electronic mail to: joseph.fox@state.nm.us)
Stephen Archuleta, Taos County Manager (signed PDF copy sent via electronic mail to: Stephen.archuleta@taoscounty.org)

NEW MEXICO
ENVIRONMENT DEPARTMENT

Harold Runnels Building
1190 South St. Francis Drive (87505)
P.O. Box 5469, Santa Fe, New Mexico 87502-5469
Phone (505) 827-2900 Fax (505) 827-2965
www.env.nm.gov

SUSANA MARTINEZ
Governor

JOHN A. SANCHEZ
Lieutenant Governor

RYAN FLYNN
Cabinet Secretary

BUTCH TONGATE
Deputy Secretary

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

June 8, 2016

Sherry Burt-Kested, Environmental Manager
Freeport-McMoRan Chino Mines Company
PO Box 10
Bayard, NM 88023

RE: Discharge Permit Amendment 06-12, DP-526, Update to Stormwater Management Plan, Lee Hill Area

Dear Ms. Burt-Kested:

The Mining Environmental Compliance Section (MECS) of the New Mexico Environment Department (NMED) has reviewed the letter from Freeport-McMoRan Chino Mines Company (permittee) titled, *Freeport-McMoRan Chino Mines Company – Discharge Permit 526 (DP-526) Amendment Request for Inclusion of the Interim Lee Hill Stormwater Management Plan,* ("Amendment Request"), dated May 19, 2016, and received by NMED on May 23, 2016. In the Amendment Request, the permittee requests to amend DP-526, Whitewater Leach System, for the construction of positive drainage features and stormwater conveyance structures to divert storm water away from the Lee Hill Open Pit and Lee Hill area in order to improve stability of the open pit high walls. The facilities covered under DP-526 include the West, South, and Upper South Stockpiles and the reach of Whitewater Creek from Hanover Creek to the northern boundary of the former Lake One, stretching from approximately 2 miles northeast of Bayard to the Town of Hurley in Sections 28, 29, 32, 33 and 34, T17S, R12W; Sections 3, 4, 5, 6, 7, 18, 19, 30 and 31, T18S, R12W; and Sections 12 and 13, T18S, R13W in Grant County.

NMED issues this Discharge Permit Amendment pursuant to the New Mexico Water Quality Act (WQA), NMSA 1978 §§74-6-1 through 74-6-17, and the New Mexico Water Quality Control Commission (WQCC) Regulations, 20.6.2 NMAC and 20.6.7 NMAC. As defined in Section 20.6.7.7 NMAC, this Amendment does not result in significant changes to the quantity or quality

NMED EXHIBIT 22

of effluent or the location of the discharge. This Discharge Permit Amendment changes specific terms and/or conditions contained in the Discharge Permit Renewal and Modification, DP-526, issued to the permittee on October 3, 2006. In issuing this Discharge Permit Amendment, NMED has determined that the requirements of Section 20.6.7.14 NMAC and Subsection C of 20.6.2.3109 NMAC have been met.

Background

NMED previously authorized placement of waste rock in the area above Lee Hill to create positive drainage in order to fulfill corrective action requirements pursuant to Condition #6 of the DP-526 amendment letter titled, "Discharge Permit Amendment 06-07, DP-526, Whitewater Leach System, Pipelines and Power Line Relocation – REISSUED," dated October 17, 2013. The purpose of this Discharge Permit Amendment is to authorize construction of four stormwater impoundments and associated pipelines to better route stormwater away from the Lee Hill Pit high wall to improve open pit stability. The area being addressed, located between the relocated pipeline corridor and the northwest portion of the Lee Hill pit rim haul road, generates approximately 11.5 acre-feet of stormwater runoff during a 100-year, 24-hour precipitation event.

The addition of the four new stormwater impoundments and associated pipelines will be integrated as a new component to the stormwater management plan for the Chino North Mine Area as referenced by Appendix D of the NMA Master Document dated October 8, 2015. The updates to the stormwater management plan authorized by this amendment are within the Open Pit Surface Drainage Area.

Amendment Description

The stormwater management plan includes placing waste rock fill material in a 4.3 acre area as previously authorized, and installation of three synthetically lined stormwater impoundments with a combined capacity of 10 acre-feet (Impoundments 526-1, Impoundment 526-2, and Impoundment 526-3). It also includes installation of a Secondary Containment Sump at the base of the placed fill material area (i.e., lowest elevation in the area) to capture stormwater and process water releases from pipelines that lie immediately north of this area. Stormwater from the impoundments will drain to Reservoir 4A during normal conditions, and to Estrella Pit as needed during upset conditions.

Conditions of Approval

This Discharge Permit Amendment applies to the existing Whitewater Leach System Discharge Permit, DP-526, which is still in effect pursuant to Subsection F of 20.6.3106 NMAC. The following conditions will be added to the effective DP-526 and continued upon renewal. The permittee shall comply with these conditions, which are enforceable by NMED.

1. Design, construction and location of the stormwater impoundments and associated pipelines shall be as outlined above and described in the Amendment Request and in accordance with applicable requirements of Section 20.6.7.D(2)(e), 20.6.7.17.D(3) NMAC as applicable, and 20.6.7.17.D(4) NMAC.

2. The permittee shall comply with all applicable contingency requirements described in Section 20.6.7.30 NMAC of the Copper Mine Rule.

3. Any leaks or spills from any of the impoundments and associated pipelines shall be shall be recorded, reported and corrected pursuant to Sections 20.6.2.1203 NMAC and Paragraphs (2) and (3) of Subsection B of 20.6.7.29 NMAC.

4. If the design changes from the Amendment Request, the Permittee shall submit updated plans and specifications for NMED approval prior to construction.

Other Requirements

The permittee shall comply with the terms and conditions contained herein and those in DP-526 that remain unchanged which are enforceable by NMED pursuant to Section 20.6.2.3104 NMAC and NMSA 1978 §74-6-5 and §75-6-10. Please be advised that this Discharge Permit Amendment does not relieve the permittee of liability should its operation result in actual pollution of surface or ground water which may be actionable under other laws and/or regulations.

Period of Approval

Pursuant to Paragraph (4) of Subsection H of 20.6.2.3109 NMAC, the term of this Discharge Permit Amendment shall be the same as the term of DP-526. The timely submission of the Discharge Permit renewal application on June 6, 2011 keeps the existing permit and associated amendment(s) effective until the renewal process is complete. [Subsection F of 20.6.2.3106 NMAC]

Issuance of this Discharge Permit Amendment does not relieve the permittee of the responsibility to comply with the WQA, WQCC Regulations, and any other applicable federal, state and/or local laws and regulations, such as zoning requirements and nuisance ordinances.

If at any time in the future the permittee intends to change the disposition of any discharge relating to this amendment, the permittee is required to notify NMED prior to changing the discharge.

If you have any questions, please contact Brad Reid at (505) 827-2963 or Kurt Vollbrecht, MECS Program Manager, at (505) 827-0195.

Sincerely,

Trais Kliphuis, Division Director
Water Protection Division

TK:BR

cc: Sherry Burt-Kested, Environmental Manager, Chino Mines Company (signed copy: Sherry_Burt-Kested@FMI.com)
Christian Krueger, Chino Mines Company (signed copy: christian_krueger@fmi.com)
Kariann Sokulsky, Chino Mines Company (signed copy: kariann_sokulsky@fmi.com)
Kurt Vollbrecht, Program Manager, MECS (signed copy: kurt.vollbrecht@state.nm.us)
Gila Resources Information Project (signed copy: grip@gilaresources.info)
David Ennis, MMD (signed copy: david.ennis@state.nm.us)

Summary of DP-526 Permit and Amendment Chronology:

Document Name	**Effective/Issuance Date**
Discharge Permit Renewal and Modification, Whitewater Leach System, DP-526	October 3, 2006
Discharge Permit Amendments 06-01, DP-526, DP-213 & DP-214, Placement of Hidalgo Copper Bearing Material on the Chino South Stockpile and Chino Mill Intermediate Ore Stockpile; and Staging of Hidalgo Material on the Chino Older Tailings Impoundments; Freeport – McMoRan Chino Mine	May 9, 2008
Discharge Permit Amendment 06-02, DP-526; Placement of Reservoir 7 Sediments on the South Stockpile	January 26, 2010
Discharge Permit Amendment 06-03, DP-526; Placement of Reservoir 7 Sediments on the South Stockpile	November 24, 2010
Discharge Permit Amendment 06-04, DP-526; Application of Process Solutions from the PLS Tank to the West Stockpile	November 24, 2010
Discharge Permit Amendment 06-05, Water Sources for Dust Suppression on Haul Roads at the Chino Mine, DP-1568, DP-459, DP-526, and DP-376, Freeport-McMoRan Chino Mines Company	June 22, 2012
Discharge Permit Amendment 06-06, DP-526,Whitewater Leach System, Pipelines and Power Line Relocation	August 6, 2013
Discharge Permit Amendment 06-07, DP-526, Whitewater Leach System, Pipelines and Power Line Relocation - REISSUED	October 17, 2013
Discharge Permit Amendment 06-08, DP-526, Haul Truck Wash Relocation	November 22, 2013
Discharge Permit Amendment 06-09, DP-526, Frog Pond Relocation	March 27, 2014
Discharge Permit Amendment 06-10, DP-526, South Stockpile Fill-in	May 5, 2015
Discharge Permit Amendment 06-11, DP-526, Conveyance Channel and Piping along West Stockpile at Dam 13 and Dam 14	November 23, 2015
Discharge Permit Amendment 06-12, DP-526, Update to Stormwater Management Plan, Lee Hill Area	June 8, 2016

F

NEW MEXICO
ENVIRONMENT DEPARTMENT

Ground Water Quality Bureau

Harold Runnels Building
1190 St. Francis Drive
PO Box 5469, Santa Fe, NM 87502
Phone (505) 827-2900 Fax (505) 827-2965
www.nmenv.state.nm.us

BILL RICHARDSON
Governor
DIANE DENISH
Lieutenant Governor

RON CURRY
Secretary
JON GOLDSTEIN
Deputy Secretary

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

December 30, 2009

Willie Picaro, Operator
Ghost Ranch Conference Center
HC 77, Box 11
Abiquiu, NM 87510

RE: Discharge Permit Amendment, Ghost Ranch Conference Center, DP-869

Dear Mr. Picaro:

The New Mexico Environment Department (NMED) issues the enclosed Discharge Permit Amendment for the above referenced facility to the Ghost Ranch Conference Center pursuant to the New Mexico Water Quality Act (WQA), NMSA 1978 §§74-6-1 through 74-6-17, and the New Mexico Water Quality Control Commission (WQCC) Regulations, 20.6.2 NMAC. This Discharge Permit Amendment is not a result of significant changes in the quantity or quality of effluent or the location of the discharge.

The Discharge Permit Amendment changes specific terms and/or conditions contained in the Discharge Permit, DP-869, issued to the Ghost Ranch Conference Center on September 19, 2005. The terms and conditions contained herein and those in the Discharge Permit that remain unchanged shall be complied with by the Ghost Ranch Conference Center and are enforceable by NMED pursuant to Section 20.6.2.3104 NMAC and NMSA 1978 §74-6-5 and §74-6-10. Issuance of this Discharge Permit Amendment does not relieve the permittee of the responsibility to comply with the WQA, WQCC Regulations, and any other applicable federal, state and/or local laws and regulations, such as zoning requirements and nuisance ordinances.

Pursuant to Paragraph (4) of Subsection H of 20.6.2.3109 NMAC, the term of this Discharge Permit Amendment shall be the same as the remaining term of the Discharge Permit, which will expire on September 19, 2010.

NMED EXHIBIT 23

If you have any questions, please contact Brad Reid at (505) 827-2963.

Sincerely,

George Schuman for W. Olson

William C. Olson, Chief
Ground Water Quality Bureau

WO: BR

enc: Discharge Permit Amendment, DP-869
Discharge Permit Renewal, DP-869, dated September 19, 2005

cc: Robert Italiano, District Manager, NMED District II (amendment)
NMED Española Field Office (amendment)
Jim Sizemore, Office of the State Engineer (amendment)

GROUND WATER DISCHARGE PERMIT AMENDMENT
Ghost Ranch Conference Center, DP-869

I. INTRODUCTION

The New Mexico Environment Department (NMED) issues this Discharge Permit Amendment pursuant to the New Mexico Water Quality Act (WQA), NMSA 1978 §§74-6-1 through 74-6-17, and the New Mexico Water Quality Control Commission (WQCC) Regulations, 20.6.2 NMAC. This Discharge Permit Amendment is not a result of significant changes in the quantity or quality of effluent or the location of the discharge. This Discharge Permit Amendment changes specific terms and/or conditions contained in the Discharge Permit Renewal, DP-869, issued to the Ghost Ranch Conference Center (permittee) on September 19, 2005. In issuing this Discharge Permit Amendment, NMED has determined that the requirements of 20.6.2.3109.C NMAC have been met.

The activities which produce the discharge, the location of the discharge, and the quantity, quality and flow characteristics of the discharge, as amended (changes indicated in italics), are briefly described as follows:

Up to 33,750 gallons per day of domestic wastewater from the Ghost Ranch Conference Center is discharged into two 15,000-gallon septic tanks, then to two concrete-lined facultative lagoons, followed by a free-surface constructed wetlands. *In addition, up to 2325 gallons per day of domestic wastewater from four individual residences (Pack Trailer, Casa Allegre, Director's House, and Farmhouse) and a lodge (Casa del Sol) located at various locations on Ghost Ranch property will be discharged to five individual septic tank/leachfield systems.* The discharge contains water contaminants or toxic pollutants that may be elevated above the standards of 20.6.2.3103 NMAC. The facility is located on the east side of Highway 84, approximately 12 miles north of Abiquiu, in Section 12, T24N, R4E, Rio Arriba County. *Ground water most likely to be affected by the discharges authorized by this permit range in depth from approximately 32 to 197 feet and has a total dissolved solids concentration of approximately 3,310 milligrams per liter.*

The permittee's Discharge Permit Amendment consists of the materials referenced in the amendment requests dated January 22, 2009 and October 30, 2009. The discharge shall be managed in accordance with all conditions and requirements of Discharge Permit Renewal, DP-869, dated September 19, 2005 and this Discharge Permit Amendment.

II. CONDITIONS

The condition listed below replaces the condition with the same number in the Discharge Permit Renewal, DP-869. This condition, and all other conditions in the Discharge Permit, must be complied with by the permittee and are enforceable by NMED.

OPERATIONAL PLAN

#	**Terms and Conditions**
3.	The permittee is authorized to discharge up to 33,750 gallons per day of domestic wastewater to two 15,000-gallon septic tanks, then to two concrete-lined facultative lagoons, followed by a free-surface constructed wetlands. *In addition, up to 2325 gallons per day of domestic wastewater from four individual residences (Pack Trailer, Casa Allegre, Director's House, and Farmhouse) and a lodge (Casa del Sol) located at various locations on Ghost Ranch property will be discharged to five individual septic tank/leachfield systems.* [20.6.2.3106 NMAC, 20.6.2.3109 NMAC]
3a.	Record drawings and construction details of the Casa del Sol septic tank/leachfield system shall be submitted to NMED within 30 days of completion. [20.6.2.3109 NMAC]

ISSUED: December 30, 2009
EXPIRES: September 19, 2010

George Schuman for W. Olson

WILLIAM C. OLSON
Chief, Ground Water Quality Bureau
New Mexico Environment Department

NEW MEXICO
ENVIRONMENT DEPARTMENT

Ground Water Quality Bureau

SUSANA MARTINEZ
Governor

JOHN SANCHEZ
Lieutenant Governor

P.O. Box 5469
1190 St. Francis Drive
Santa Fe, New Mexico 87502-5469
Phone (505) 827-2918 Fax (505) 827-2965
www.nmenv.state.nm.us

RYAN FLYNN
Cabinet Secretary-Designate

BUTCH TONGATE
Deputy Secretary

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

December 12, 2013

Mr. William Ray, Manager
Ambrosia Lake Site Manager
Rio Algom Mining LLC
POB 218
Grants, NM 87020

RE: Rio Algom Mining LLC Discharge Permit DP-71 Amendment

Dear Mr. Ray:

The New Mexico Environment Department ("NMED") issues the enclosed Discharge Permit Amendment to the above-referenced Discharge Permit to Rio Algom Mining LLC ("RAML" and "Permittee") pursuant to the New Mexico Water Quality Act ("WQA"), NMSA 1978 §§74-6-1 through 74-6-17, and the New Mexico Water Quality Control Commission ("WQCC") Regulations, 20.6.2 NMAC. This Discharge Permit Amendment does not result from significant changes in the quantity or quality of effluent or in the location of the discharge.

The Discharge Permit Amendment changes specific terms and/or conditions contained in the Discharge Permit, DP-71, which was issued to RAML on December 1, 2003. The terms and conditions contained herein and those in the Discharge Permit that remain unchanged shall be complied with by RAML and are enforceable by NMED pursuant to Section 20.6.2.3104 NMAC and NMSA 1978 §74-6-5 and §74-6-10. Issuance of this Discharge Permit Amendment does not relieve the Permittee of the responsibility to comply with the WQA, WQCC Regulations, and any other applicable federal, state, and/or local laws and regulations, such as zoning requirements and nuisance ordinances.

Pursuant to Paragraph (4) of Subsection H of 20.6.2.3109 NMAC, the term of this Discharge Permit Amendment shall be the same as the term of the Discharge Permit.

If you have any questions, please contact David L. Mayerson at (505) 476-3777 or david.mayerson@state.nm.us.

Sincerely,

Jerry Schoeppner, Chief
Ground Water Quality Bureau
New Mexico Environment Department

Enclosure: Discharge Permit Amendment DP-71

Copies:
David L. Mayerson, MECS
Tom McLaughlin, NRC
Kurt Vollbrecht, MECS

GROUND WATER DISCHARGE PERMIT AMENDMENT

DP-71—Rio Algom Mining LLC Section 4 Evaporation Ponds
December 12, 2013

I. INTRODUCTION

The New Mexico Environment Department ("NMED") issues this Discharge Permit Amendment pursuant to the New Mexico Water Quality Act ("WQA"), NMSA 1978 §§74-6-1 through 74-6-17, and the New Mexico Water Quality Control Commission ("WQCC") Regulations, 20.6.2 NMAC. This Discharge Permit Amendment addresses monitoring requirements only and is not a result of significant changes in the quantity or quality of effluent or in the location of discharge. This Discharge Permit Amendment changes specific terms and/or conditions contained in Discharge Permit DP-71, which was issued to Rio Algom Mining LLC ("RAML" or "Permittee") on December 1, 2003. In issuing this Discharge Permit Amendment, NMED has determined that requirements of 20.6.2.3109.C NMAC have been met.

DP-71, which was last renewed on December 1, 2003, permitted RAML to discharge up to 2,390,000 gallons per day of effluent from the Permittee's uranium mill facility, which is administered under Discharge Permit DP-169, to 11 synthetically-lined ponds ("Section 4 Evaporation Ponds"), and included requirements for ground water abatement activities relating to potential ground water impacts resulting from seepage from these ponds. At the time that DP-71 was renewed, discharge to the ponds had ceased, and reclamation began soon thereafter. RAML installed monitoring wells in compliance with Condition 6 of DP-71; monitoring of these wells in compliance with Conditions 10 and 13 of DP-71 has documented the progressive desiccation of the alluvial aquifer underlying these ponds, such that ground water now occurs in sufficient quantity for sample recovery in only one monitoring well (*e.g.*, MW-32).

This amendment to DP-71 includes the following:

- Incorporates existing monitoring wells MW-32 and MW-33, which were installed pursuant to Condition 6, into the alluvial aquifer monitoring program specified in Condition 10;
- Reduces the monitoring requirements for the alluvial aquifer monitoring program specified in Condition 10 from a quarterly to an annual schedule, due to the fact that only one monitoring well (*e.g.*, MW-32) has had measurable saturation for several years;
- Reduces the reporting requirement for such monitoring from a quarterly to an annual schedule.

The Section 4 Evaporation ponds are located approximately 15 miles north of the City of Milan in Section 4, Township 15 North, Range 9 West in McKinley County. Data acquired from monitoring of MW-32 indicate persistent exceedances of numerical ground water standards promulgated in 20.2.3103 NMAC for nitrate, sulfate, total dissolved solids, selenium, and uranium. Background concentrations of these constituents in ground water are unknown.

The Permittee's Discharge Permit Amendment consists of information provided to NMED during a meeting on October 23, 2013.

II. CONDITIONS

The conditions below replace the conditions of the same number in DP-71. These conditions, and all other conditions in the Discharge Permit, must be complied with by the Permittee and are enforceable by NMED.

Sampling and Field Measurements:

CONDITION NUMBER	AMENDED CONDITION
10	Ground Water Monitoring Wells—The Permittee shall monitor ground water quality as follows: A. Monitoring Wells 1 through 33 shall be sampled as follows: 1) The Permittee shall record the depth to the water table to the nearest hundredth of a foot (0.01 ft), annually. 2) If sufficient water is available in the well, the Permittee shall collect samples from each well annually and analyze for the water parameters listed in Conditions 13.B and 13.C. 3) The Permittee shall record the total depth of the well to the nearest hundredth of a foot (0.01 ft) annually. 4) Analytical results and depth to ground water shall be reported as required in Condition 15. [20.6.2.3107.A NMAC]

Reporting:

CONDITION NUMBER	AMENDED CONDITION
15	The Permittee shall submit to NMED an annual report by the last day of January of each year, which shall include, but not be limited to, the following: A. A summary of all activities and data relating to closure of the Section 4 evaporation ponds and abatement of ground water during the preceding year. These activities and data shall include, but are not limited to, contaminated sediment removal, cap construction, well drilling and abandonment, water quality trends, precipitation, water level trends, and potentiometric maps. B. Ground water data, presented in a single table in a paper and electronic format (*i.e.*, Microsoft Excel® spreadsheet), with only those constituents analyzed and water levels measured during a single event shown in columns. Tabulated electrical conductivity will include the measured field values and corrected values to 25 degrees Celsius. Monitoring sites will be shown in rows. Each

	new sampling event shall be added as an additional row to the existing spreadsheet with the date noted in the far left column. Values exceeding the numerical standards promulgated in 20.6.2.3103 NMAC will be **bolded**. Any constituent not analyzed for a particular monitoring well will be shown as "NA"; any well not sampled will be shown as "NS" with an associated reason; and any well not measured water levels will be shown as "NM" with an associated reason. C. Copies of the signed laboratory analyses sheets shall be provided annually. D. Annual reports with water quality trends, laboratory QA/QC and water level trends. At a minimum, graphs with the previous 5 years of indicator parameter data will be presented for total dissolved solids, sulfate, and hydrographs. E. Annual potentiometric map for the shallow alluvial aquifer in the vicinity of the Section 4 evaporation ponds. The map shall include all alluvial aquifer monitoring well data collected under all Discharge Permits that have been issued to RAML for facilities in the vicinity of the Section 4 evaporation ponds. [20.6.2.3107.A NMAC]

ISSUED: December 12, 2013

JERRY SCHOEPPNER
Chief, Ground Water Quality Bureau
New Mexico Environment Department

State of New Mexico
ENVIRONMENT DEPARTMENT
Ground Water Quality Bureau
Harold Runnels Building
1190 St. Francis Drive, P.O. Box 26110
Santa Fe, New Mexico 87502
(505) 827-2918 phone
(505) 827-2965 fax

GARY E. JOHNSON
GOVERNOR

PETER MAGGIORE
Secretary
PAUL R. RITZMA
Deputy Secretary

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

August 1, 2000

Mr. Richard Vicens, Vice President
Delta Person GP, LLC
89 Headquarters Plaza, North Tower, 14th Floor
Morristown, NJ 07960

RE: Discharge Plan Amendment Approval, DP-1260, Delta-Person Generating Station (formerly Cobisa-Person Generating Station)

Dear Mr. Vicens:

Pursuant to Water Quality Control Commission (WQCC) Reg. 3109, the application for amendment for DP-1260, submitted by Delta Person GP, LLC for a change in monitoring requirements for the approved disposal system of Delta-Person Generating Station is hereby approved, subject to the specific requirement listed below. The discharge plan was approved on March 6, 2000. The facility is located approximately 4 miles south of Albuquerque near the intersection of Rio Bravo and Broadway in Section 8, T9N, R, Bernalillo County. In approving this discharge plan amendment, the New Mexico Environment Department (NMED) has determined that the requirements of WQCC Reg. 3109.C have been met.

The approved amendment to the disposal system of Delta-Person Generating Station is briefly described as follows:

> Delta-Person Generating Station (DPGS) will sample the ground water from the DPGS water production well for 1,1,2,2-tetrachloroethylene (PCE), 1,1-dichloroethylene (1,1-DCE), and 1,1,1-trichloroethane (1,1,1-TCA) quarterly. Ground water is at a depth of approximately 110 feet and has a total dissolved solids concentration of approximately 610 milligrams per liter.

However, approval of this amendment to your discharge plan does not relieve you of your responsibility to comply with any other conditions or requirements of the approved discharge plan, DP-1260, or any other applicable federal, state, and/or local laws and regulations, such as zoning requirements and nuisance ordinances.

NMED EXHIBIT 25

SPECIFIC REQUIREMENT FOR APPROVAL

A new requirement will be added to the March 6, 2000, discharge plan approval letter as follows:

8. DPGS will sample ground water quarterly from the DPGS cooling water production well from the sampling port located on the influent line to the plant. Samples will be analyzed for 1,1,2,2-tetrachloroethylene (PCE), 1,1-dichloroethylene (1,1-DCE), and 1,1,1-trichloroethane (1,1,1-TCA) using EPA Method 8021 or an equivalent. Analytical results will be submitted to the Ground Water Quality Bureau and the Hazardous Waste Bureau on or before February 28, May 31, August 31 and November 30 of each year. Monitoring requirements are summarized on the attached Discharge Plan Summary.

OTHER REQUIREMENTS

Please be advised that approval of this discharge plan amendment does not relieve Richard Vicens of liability should your operation result in actual pollution of surface or ground water which may be actionable under other laws and/or regulations.

PERIOD OF APPROVAL

This amendment approval expires on March 6, 2005, the same date as the original plan, and you should submit an application for renewal at least 120 days before that date.

If you have any questions, please contact Susan von Gonten of the Ground Water Pollution Prevention Section staff at 827-0018.

Sincerely,

[illegible] for M-Leavitt

Marcy Leavitt, Chief
Ground Water Quality Bureau

ML:SvG/sg

cc: L. William Bartels, Dist. Manager, NMED Dist. 1
NMED Albuquerque Field Office
Paul Saavedra, Office of the State Engineer
Carl Will, NMED-HRMB
Clara Cates, Bernalillo Co. Environmental Health Department
Michael Gallagher, Plant Manager, Delta Person Generating Station
725 Electric Ave. SE, Albuquerque, NM 87501