Mine Site Groundwater

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Presentation Outline

- Well installation and sampling
- Characteristics
- Mine site and reference chemistry
- Operational pumping
- Best Management Practices (BMPs)
- Alluvial aquifer loading
- Nature and extent
- Summary

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Questions Being Asked by RI/FS

- Groundwater Data Quality Objectives (DQOs)
  - Concentrations > RBSLs?
  - Concentrations > State Groundwater Standards and MCLs?
  - Adequately determined the nature and extent of concentrations > RBSLs?

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Well Installation During the RI

Well ID	Location	Completion Zone	Completion Lithology	Borehole Depth (ft, bgs)	Screened Interval (ft,bgs)
New RI/FS Monitoring Wells					
MMW-31B	Mine core storage area	Bedrock	qtz monzonite	205	180 to 200
MMW-42B	Goathill Gulch drainage	Bedrock	qtz monzonite	230	195 to 225
MMW-44A	Goathill Gulch drainage	Colluvium	sandy gravel	116	90 to 110
MMW-44B	Goathill Gulch drainage	Bedrock	diorite	340	308 to 338
MMW-45A	Capulin Gulch drianage	Alluvium	sandy gravel	30	8 to 28
MMW-45B	Capulin Gulch drainage	Bedrock	quartz monzonite	115	80 to 100
MMW-46B	West of Columbine Campground	Installation Attempted	--	205	--
MMW-47A	East of mine Admin. Bldg.	Alluvium	gravel	51	15 to 35
MMW-48A	300 ft southeast of Guard Post	Colluvium	sandy gravel	228	101 to 121
MMW-49A	Base South Sugar Shack Pile	Alluvium	sandy gravel	90	40 to 70

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Groundwater Sampling

- Quarterly events (all wells and springs):
  - Completed: Fall 2002; January, April, July, and October 2003; and January 2004
  - Planned: April 2004
- Monthly events (select wells and springs):
  - Completed: December 2002; February, March, May, June, August, September, November, and December 2003
  - No monthly sampling planned for 2004

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Mine Site Characteristics

Where Does Groundwater Occur?

- Alluvial aquifer: found along Red River
  - consists of sand, gravel, and cobbles
  - primary porosity between grains
- Colluvium/debris flow: found along drainages
  - debris or mud flow materials that are angular and distinctly different than alluvium
  - has minimal saturated thickness and extent – referred to as water-bearing unit instead of aquifer
- Bedrock aquifer: found at mine site and underlying mine site and alluvial aquifer
  - consists of consolidated bedrock
  - secondary porosity within fractures

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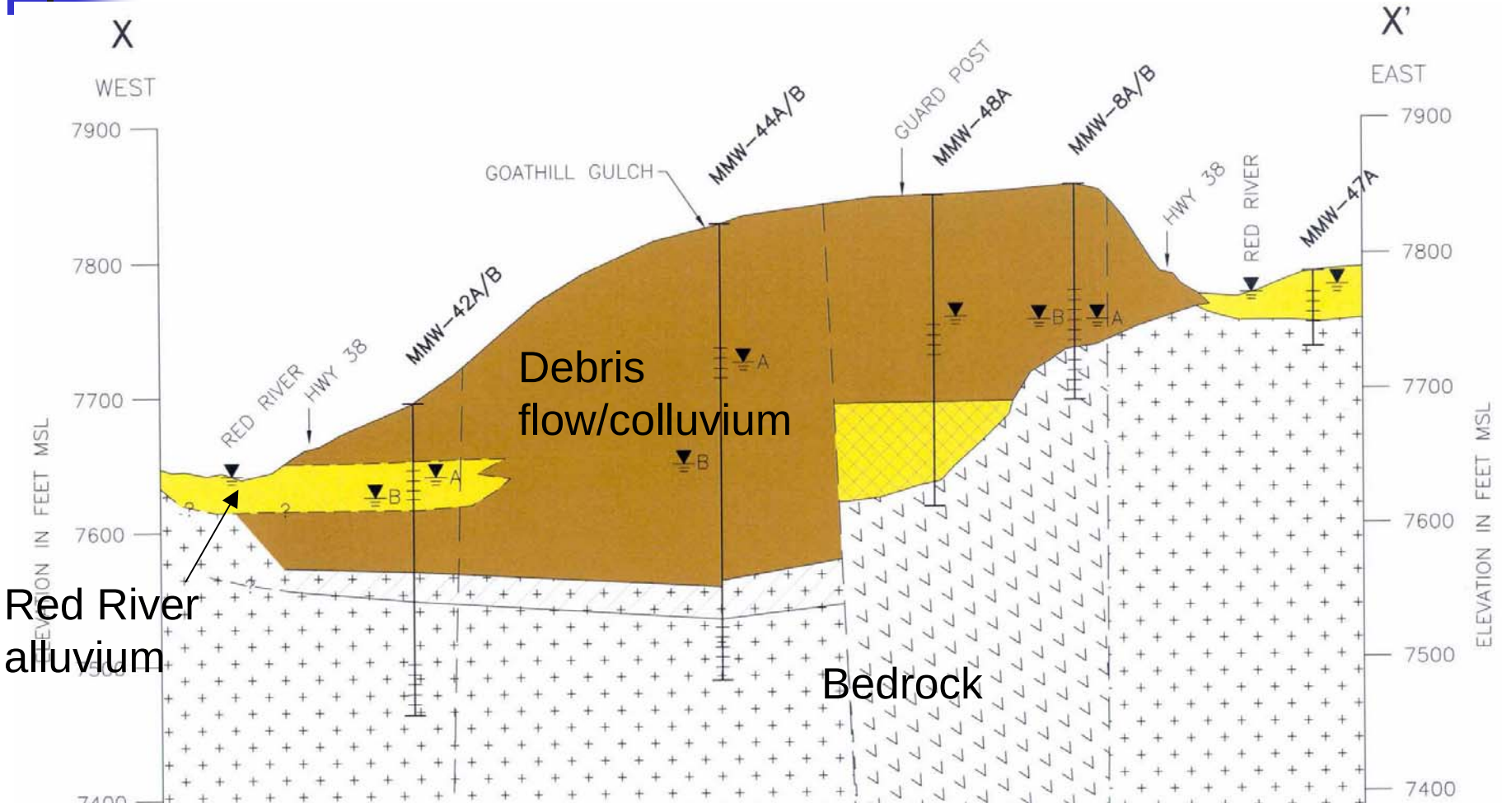
West to East Geologic Cross Section Through Goathill Debris Flow



Geologic Cross Section at Sugar Shack South Rock Pile

- Two cross sections
  - North to south along pre-existing drainage – shows the relationship between mine rock, underlying colluvium, bedrock and groundwater table
  - West to east along the toe of the rock pile – shows the geometry of the pre-existing drainage and groundwater table

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Hydraulic Conductivity

- Red River alluvial aquifer:
  - 100's feet/day
- Colluvial/debris flow unit:
  - 0.01's to 1's feet/day
- Bedrock aquifer:
  - 0.001's to 1's feet /day

Alluvium >>> Colluvium >= Bedrock

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Saturate Thickness

- Alluvium:
  - 120 feet thick in Mill area
  - 30 feet thick near downstream mine boundary
- Colluvium/debris flow:
  - 290 feet thick at Goathill Gulch
  - 0 to <50 feet along drainages
- Bedrock:
  - 100’s feet thick

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Borehole Information for Front Rock Pile Areas

Rock Pile	Relative Location	Borehole ID	Total Borehole Depth (ft bgs)	Depth to Top of Bedrock (ft bgs)	Depth to Top of Colluvium (ft bgs)	Thickness of Saturated Mine Rock (ft)	Thickness of Saturated Colluvium (ft)
Sulphur Gulch	Within Rock Pile	WRD-11	295	NE	250	0	0
		MMW-39A (WRD-12)	417	416	335	0	10
		WRD-13	199	NE	NE	0	0
		SI-6	298	284	NR	0	0
		SI-7	108	93	NR	0	0
	Base of Rock Pile	MMW-14	75	NE	0	NE	<30 est.
		MMW-16	98	90	0	NE	<10
Middle	Within Rock Pile	MMW-38A (WRD-10)	295	293	288	7	12
		S-2	307	292	NE	0	0
		SI-4	284	273	NR	0	0
		SI-5	95	78	NR	0	0
	Base of Rock Pile	MMW-25A	74	73	0	NE	<1
		MMW-13	148	120	0	NE	0 to 5
Sugar Shack South	Within Rock Pile	MMW-37A	363	NE	296	0	<20 est.
		WRD-3	120	NE	NE	0	0
		WRD-4	75	NE	NE	0	0
		WRD-5	80	NE	NE	0	0
		S-1	260	231	NE	0	0
		SI-2	140	131	NE	0	0
	Base of Rock Pile	MMW-11/11A	106	145	0	NE	50
		MMW-26A	104	101	0	NE	<1
		MMW-18A/B	97	95	0	NE	<1
		MMW-27A	109	NE	0	NE	<30 est.
Sugar Shack West	Within Rock Pile	WRD-6	60	NE	NE	0	0
		WRD-7	80	NE	NE	0	0
		SI-1	208	197	NE	0	0
	Base of Rock Pile	MMW-36A	154	149	0	NE	0

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Horizontal Groundwater Gradients

- Alluvium:
  - 0.002 to 0.06, average = 0.02 (~ slope of river)
- Colluvium:
  - 0.2 to 0.3 (steep drainages)
- Bedrock:
  - 0.2 to to 0.3 (steep bedrock slopes)

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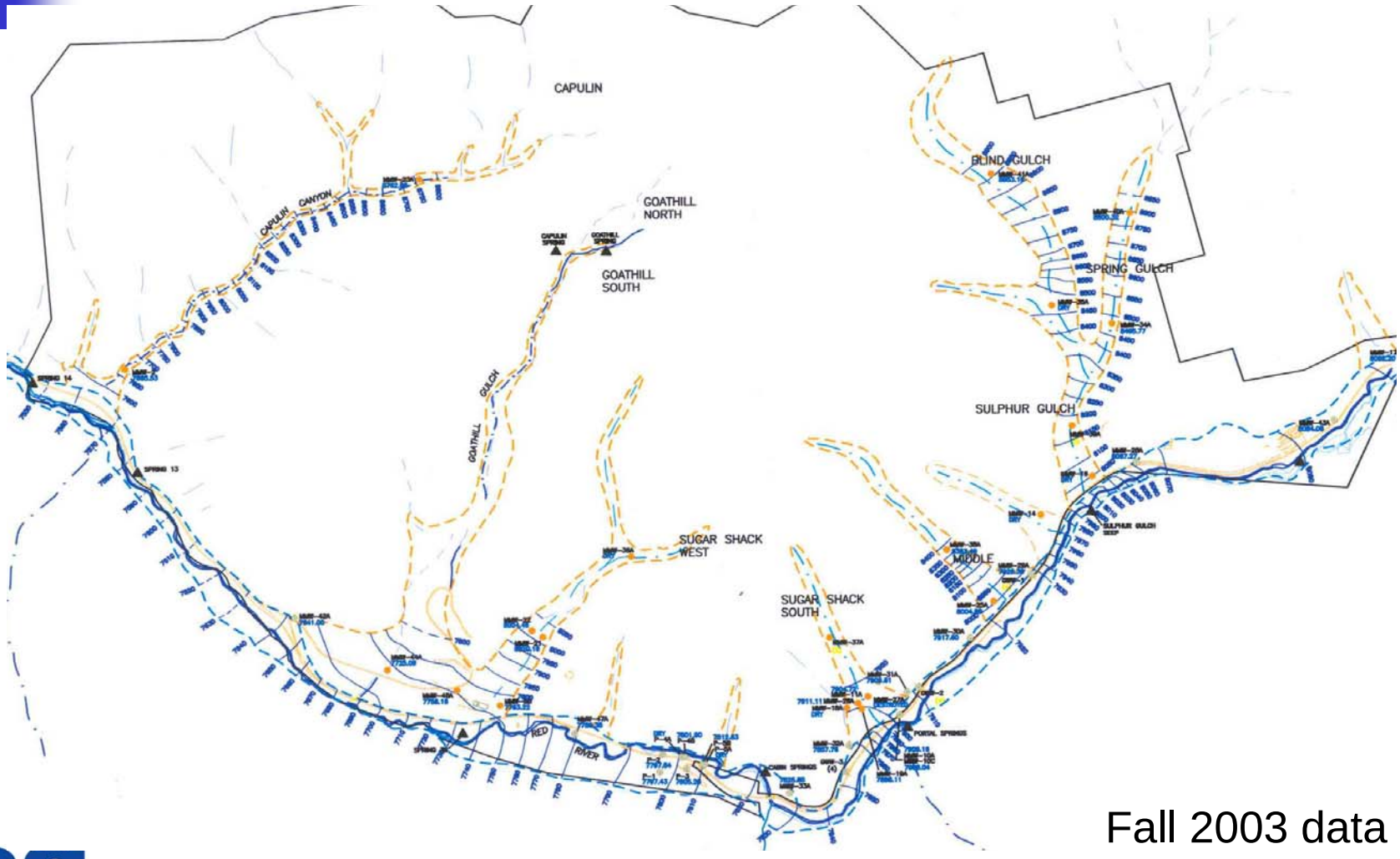
Water Table Elevation Contours for the Alluvial Aquifer and Colluvial Unit



Fall 2003 data

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Groundwater Level Fluctuations in Alluvial Aquifer

Upstream

Downstream

- Mill area = 30 ft
- Cabin Springs = 5 to 15 ft
- Below M&E area = 6 ft
- Mine boundary = 1 to 2 ft
- Water level fluctuations decrease downstream due Goathill debris fan and bedrock valley constrictions

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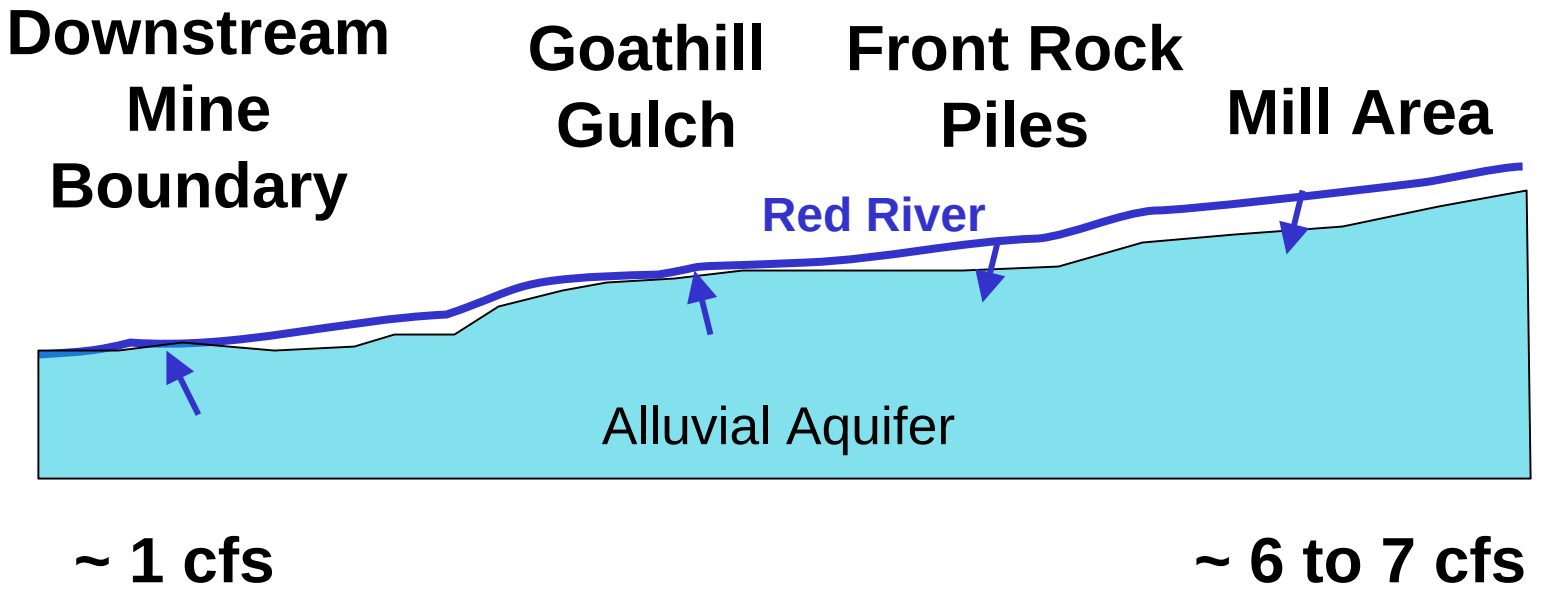
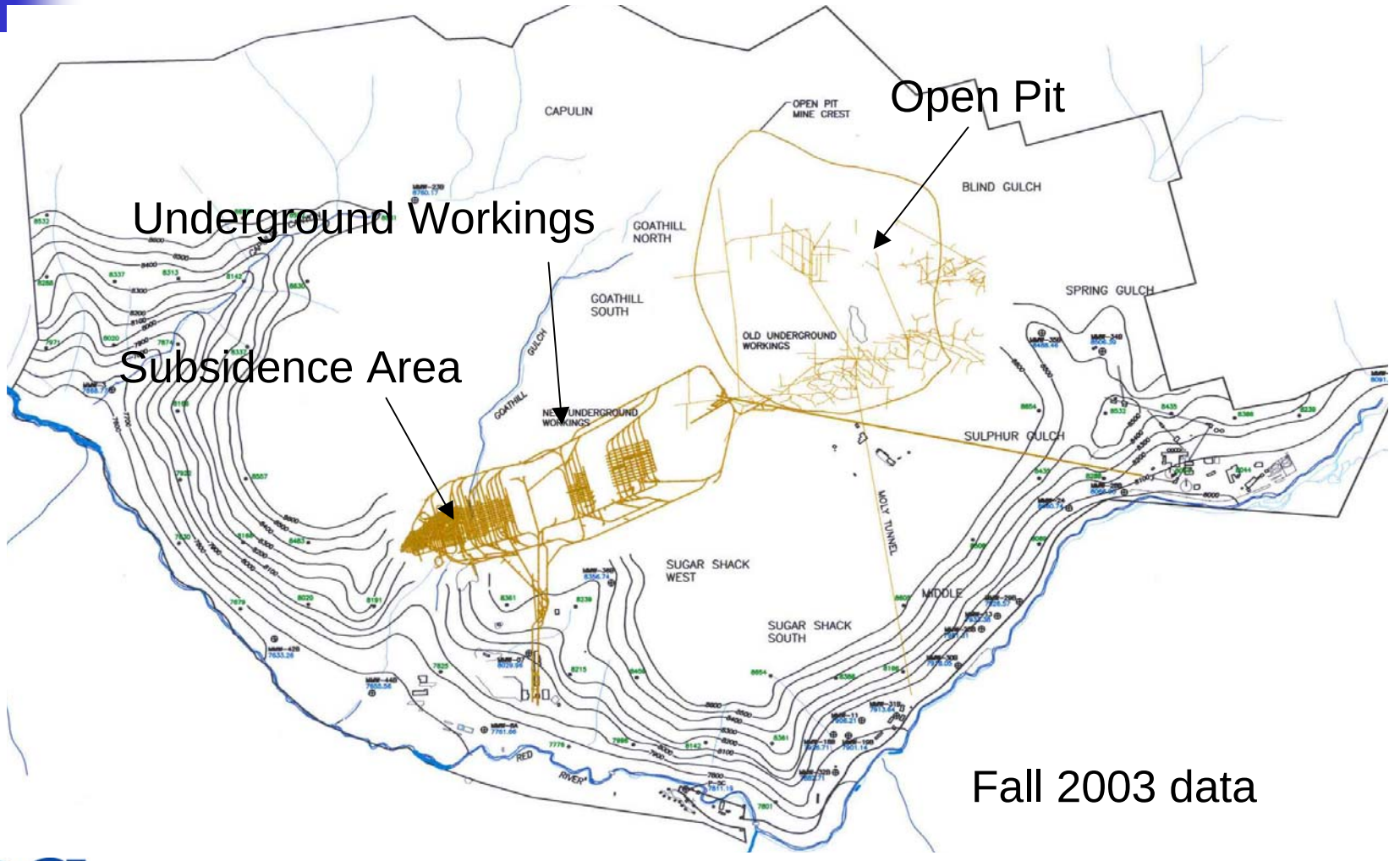
Approximate Flow Through the Alluvial Aquifer



Groundwater Elevation Contours for the Bedrock Aquifer



Fall 2003 data

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Underground Workings

- Lowermost level is 7,120 feet; 500 to 700 feet below the elevation of Red River
- Inflows average 250 gpm
- Approximately 20 gpm is from infiltration of surface water along Goathill Gulch
- Workings are dewatered (pumped to Mill) and this dewatering influences the bedrock aquifer

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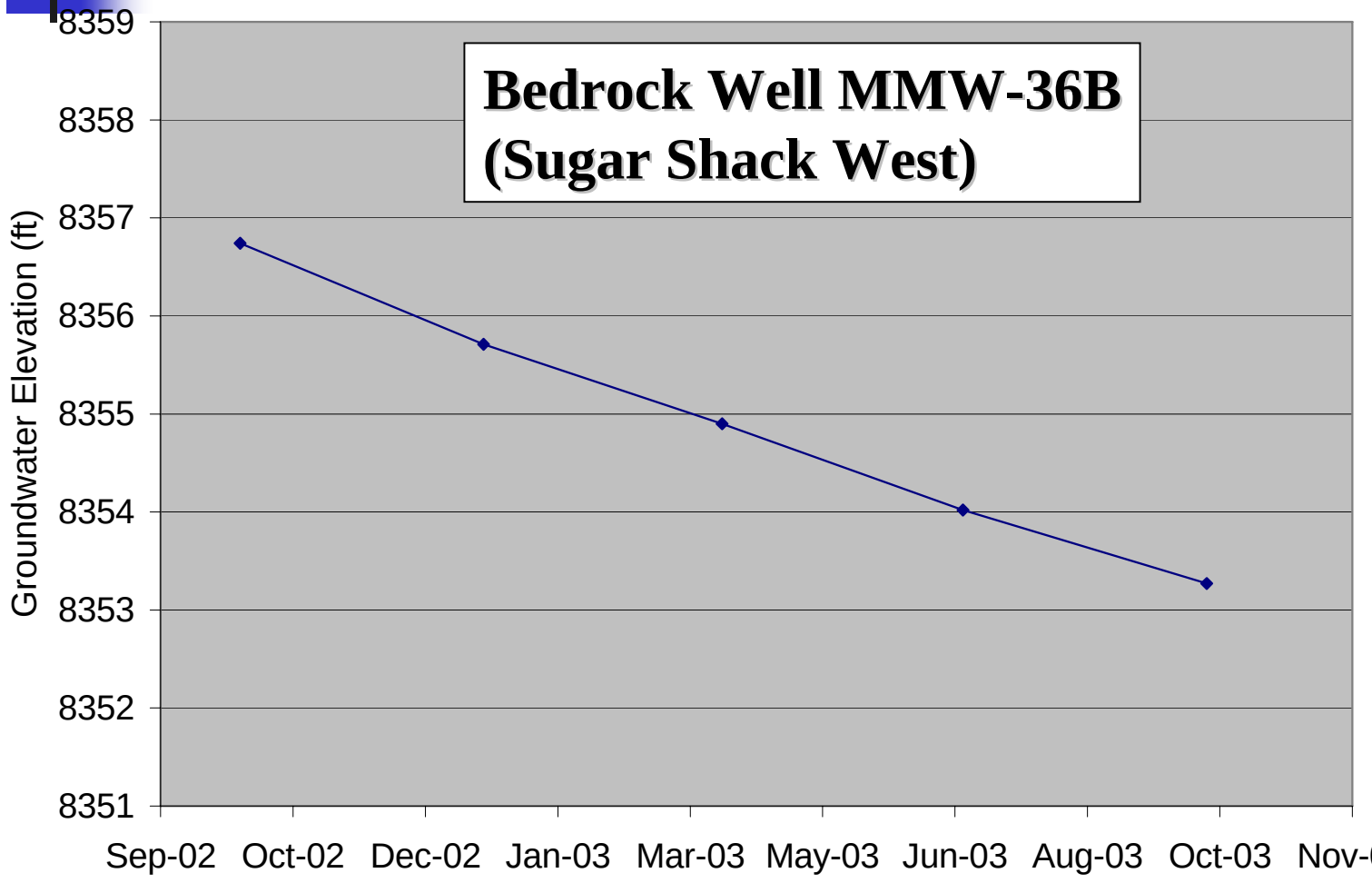
Example of Dewatering Influences



Jan 12, 2004

Reference Monitoring Wells and Groundwater Chemistry

Reference/Background Monitoring Wells

- Near upstream mine boundary: MMW-17A/B
- Upper Capulin Canyon: CC-1A/B and C2-A/B; installed by USGS
- Straight Creek: SC-1A/B, SC-2B, SC-3A/B, SC-4A, SC-5A/B, SC-6A, SC-7A, SC-8A; installed by USGS
- Others wells have been installed in Hottentot and Hansen Creek drainages and at LaBobita Campground by USGS

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Straight Creek Alluvial Wells (October 2003)

Parameter mg/L	Alluvium		HH SLC at HQ=1
	SC-7A 195 ft	SC-8A 98 ft	
Aluminum	33.3	<0.22	37
Cadmium	<0.13	<0.0013	0.018
Copper	<0.23	<0.0023	1.4
Iron	29.2	<0.46	11
Manganese	5.36	<0.016	1.7
Nickel	<0.45	0.0056	0.73
Zinc	1.94	<0.04	11
Sulfate	919	115	No SLC
Fluoride	3.8	0.28	2.2
Total Alkalinity	<1	57.3	No SLC
pH (s.u.)	3.79	6.52	No SLC
SC (uS/cm)	1619	385	No SLC

SC-7A screen: 110 to 140 ft debris flow
140 to 195 ft alluvium

Sampled in October 2003; dissolved metals

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Straight Creek Debris Flow/Colluvial Wells (October 2003)

Parameter mg/L	Debris Flow/Colluvium					HH SLC at HQ=1
	SC-1A 75 ft	SC-3A 113 ft	SC-4A 115 ft	SC-5A 197 ft	SC-6A 150 ft	
Aluminum	98.7	80.5	58.8	42.1	93.6	37
Cadmium*	<0.13	<0.13	<0.13	<0.13	<0.13	0.018
Copper	1.03	0.88	<0.23	<0.23	0.76	1.4
Iron	31.6	<4.55	44.9	<4.55	11.9	11
Manganese	19.8	14.3	18	4.9	19.7	1.7
Nickel	1.16	0.56	0.55	<0.45	0.74	0.73
Zinc	11.6	5.16	5.19	1.96	6.83	11
Sulfate	1930	1640	1800	855	1970	No SLC
Fluoride	11.7	8.9	9.7	3.8	11.1	2.2
Total Alkalinity	<1	<1	<1	<1	<1	No SLC
pH (s.u.)	3.55	2.77	3.70	2.50	3.32	No SLC
SC (uS/cm)	2494	2520	2330	1669	2495	No SLC

*Cadmium exeeded SLC in all w ells except SC-5A in June 2003

Sampled in October 2003; dissolved metals

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Straight Creek Bedrock Wells (October 2003)

Parameter mg/L	Bedrock				HH SLC at HQ=1
	SC-1B 146 ft	SC-2B 86 ft	SC-3B 200 ft	SC-5B 358 ft	
Aluminum	<0.22	2.2	6.9	<0.22	37
Cadmium	<0.0005	<0.00013	<0.13	<0.00013	0.018
Copper	<0.002	0.3	<0.23	<0.002	1.4
Iron	1.37	32.8	64.6	<0.45	11
Manganese	6.04	18.2	27.2	2.34	1.7
Nickel	<0.0024	0.53	0.63	<0.0045	0.73
Zinc	<0.023	2.06	4.08	<0.019	11
Sulfate	1550	1420	1940	1420	No SLC
Fluoride	1.1	7.3	7.3	1.1	2.2
Total Alkalinity	458	97.8	45.1	202	No SLC
pH (s.u.)	6.56	5.92	5.90	6.80	No SLC
SC (uS/cm)	2867	2485	2280	2625	No SLC

SC-2B and SC-3B may be a mix of debris flow and bedrock groundwater

Sampled in October 2003; dissolved metals

Hottentot, Hansen, and LaBobita Wells (October 2003)

Parameter mg/L	Debris Flow/Colluvium		Bedrock	HH SLC at HQ=1
	Hottentot Creek Well HTT-A 115 ft	Hansen Creek Well HAN-A 109 ft	LaBobita Well* LB-A 63 ft	
Aluminum	59.9	80.1	16.1	37
Cadmium	<0.13	<0.13	<0.07	0.018
Copper	<0.23	<0.23	<0.2	1.4
Iron	87.4	<4.55	3.1	11
Manganese	6.59	10.4	2.45	1.7
Nickel	<0.45	<0.45	0.28	0.73
Zinc	3.27	2.6	1.7	11
Sulfate	920	2100	556	No SLC
Fluoride	5	<6	2.7	2.2
pH (s.u.)	2.9	3.8	4.3	No SLC
SC (uS/cm)	1769	2720	773	No SLC

Sampled in October 2003; dissolved metals

* Screened across alluvium and bedrock

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Summary of Metals Concentrations for Background Wells

- Based on June and October 2003 results:
  - Alluvium: Concentrations of Aluminum, Fluoride, Iron, and Manganese may be elevated in areas where alluvial groundwater mixes with debris flow/colluvial groundwater near the mouth of the drainages
  - Debris Flow/Colluvium: Concentrations of Aluminum, Cadmium, Fluoride, Manganese, Iron, Nickel and Zinc are elevated
  - Bedrock: Concentrations of Manganese, Iron, and Fluoride are elevated

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Mine Site Groundwater Chemistry

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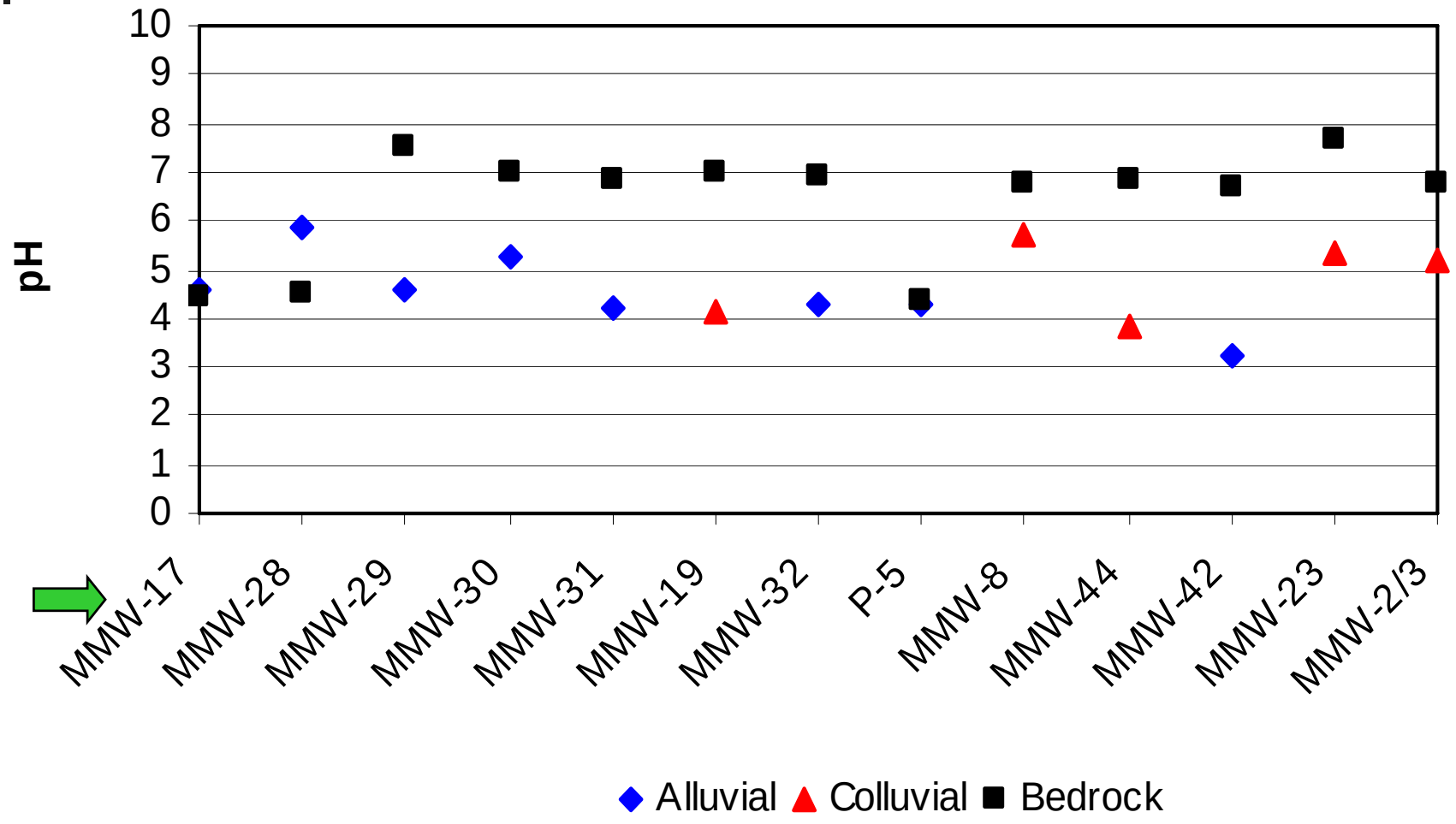
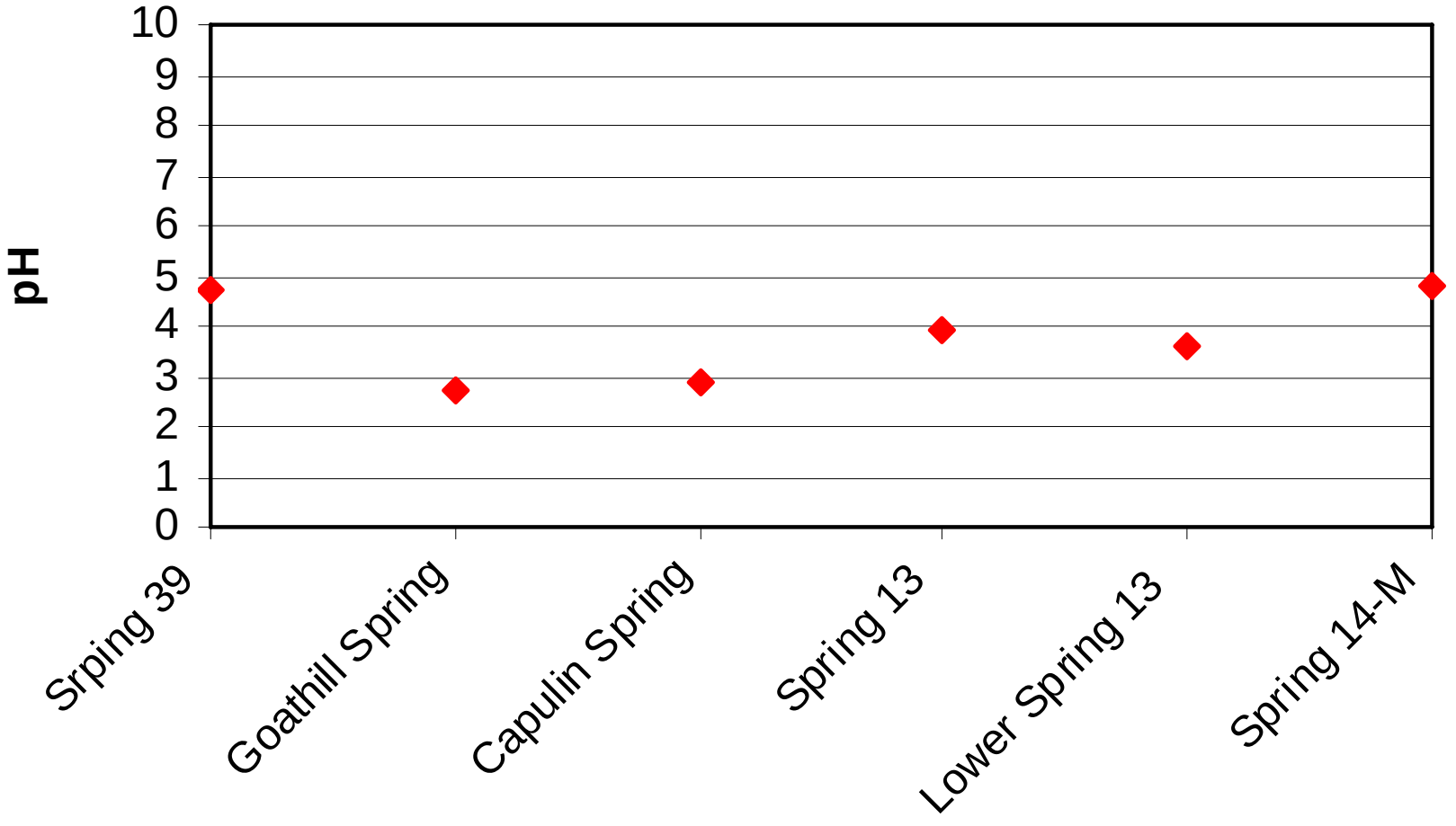
pH in Paired Monitoring Wells



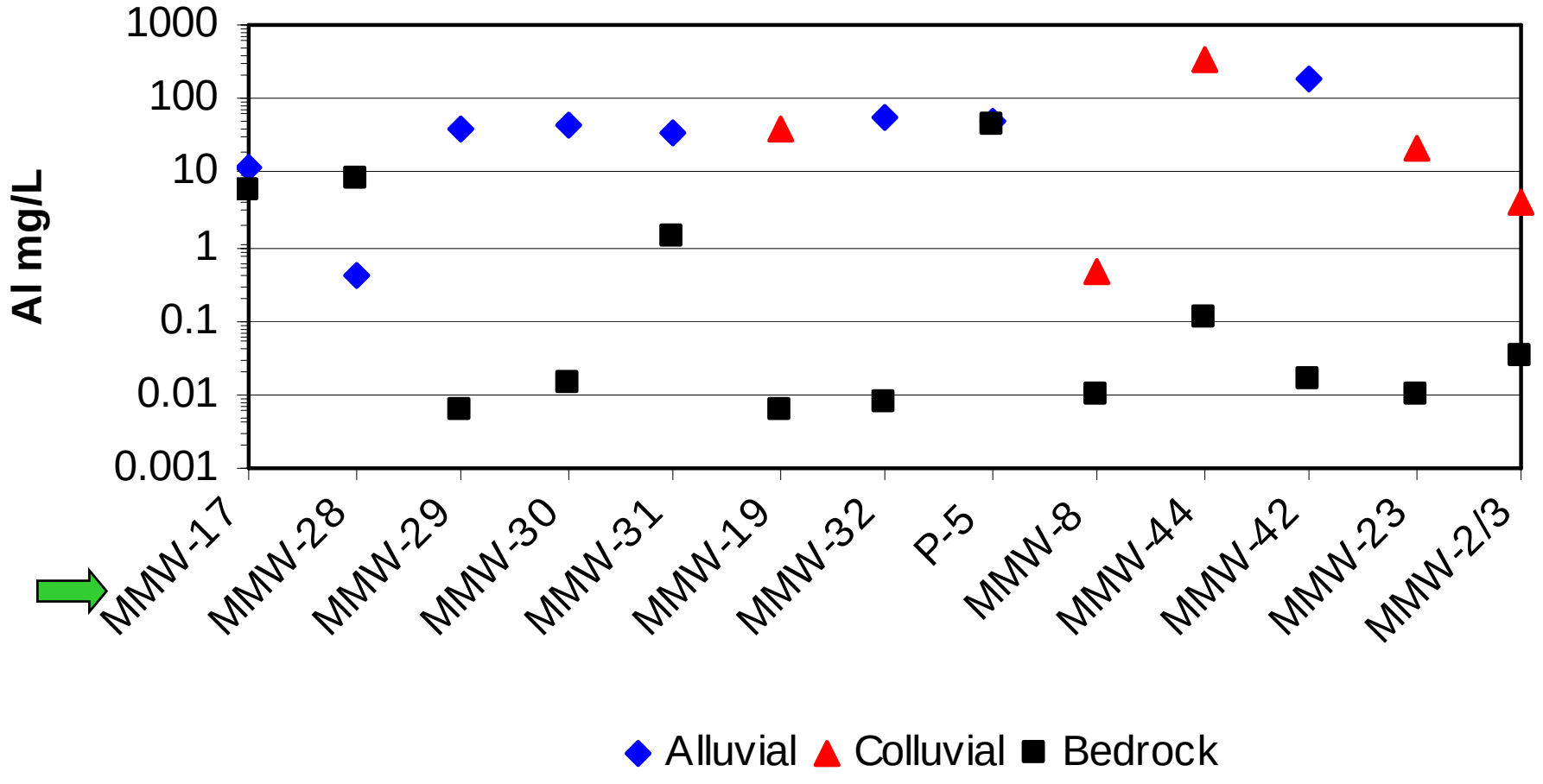
Fall 2002 data

pH in Springs



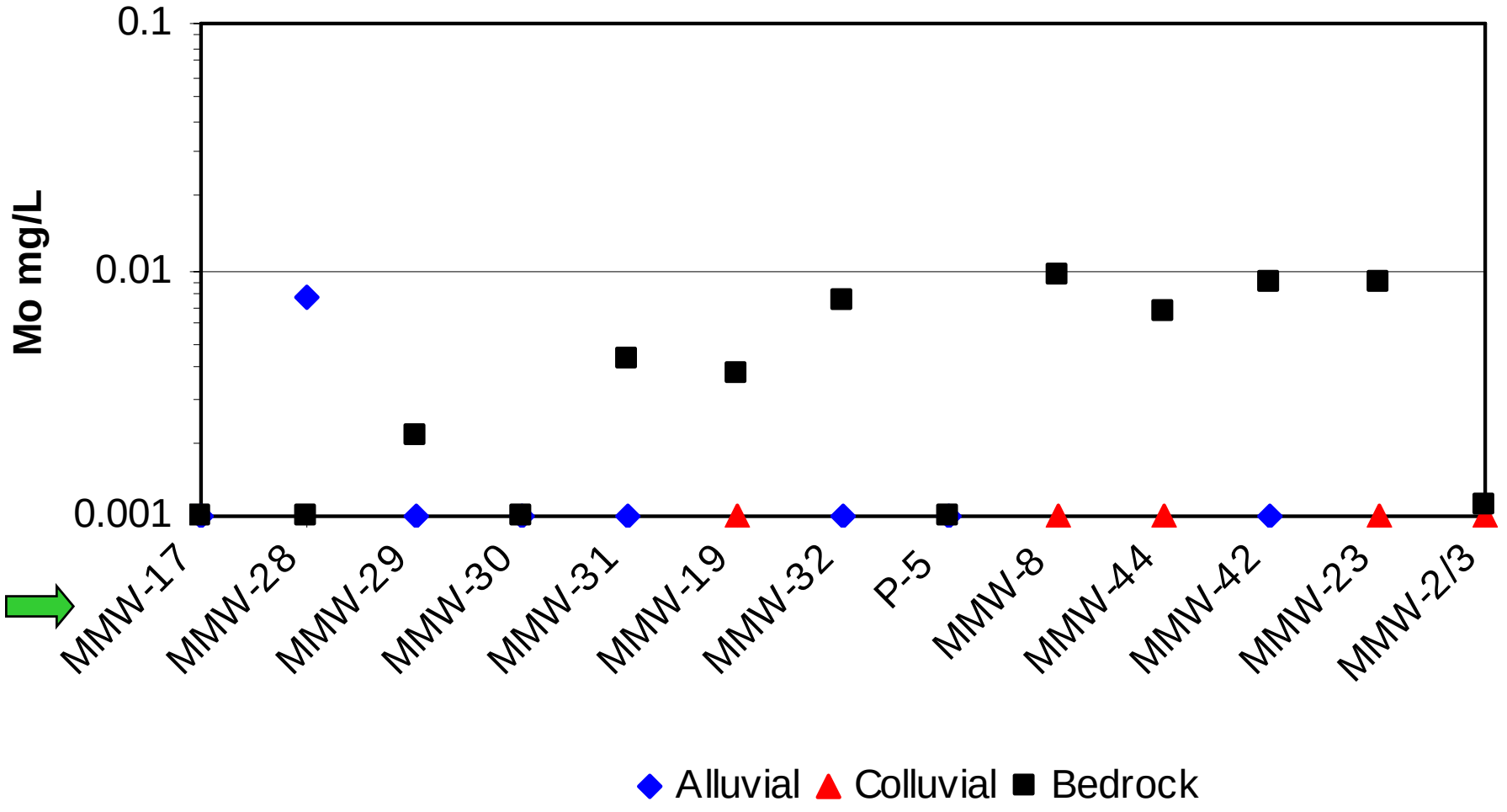
Fall 2002 data

Dissolved Aluminum in Paired Monitoring Wells



Fall 2002 data

Molybdenum in Paired Monitoring Wells



Fall 2002 data

Concentrations in Water from Underground Workings

mg/L	Total	Dissolved
Aluminum	7.81	0.21
Arsenic	0.0014	0.0005
Boron	0.0129	0.0137
Cadmium	0.0039	0.0035
Cobalt	0.168	0.069
Copper	0.03	0.02
Iron	8.72	1.2
Lead	0.0034	0.0002
Manganese	40.6	39.6
Molybdenum	5.3	5.3
Nickel	0.263	0.26
Selenium	0.0057	0.0015
Zinc	3.22	2.39
Sulfate	2030	
Alkalinity	170	
Fluoride	10.9	
pH (su)	6.98	

Fall 2002 data

Capulin and Goathill Springs

Constituent	Concentrations (diss)	
	Capulin Spring (mg/L)	Goathill Spring (mg/L)
Aluminum	1,060	1,470
Iron	243	631
Manganese	524	427
Nickel	8.15	8.06
Zinc	109	98.4
Fluoride	114	143
Sulfate	12,900	13,600
pH	2.7	2.6

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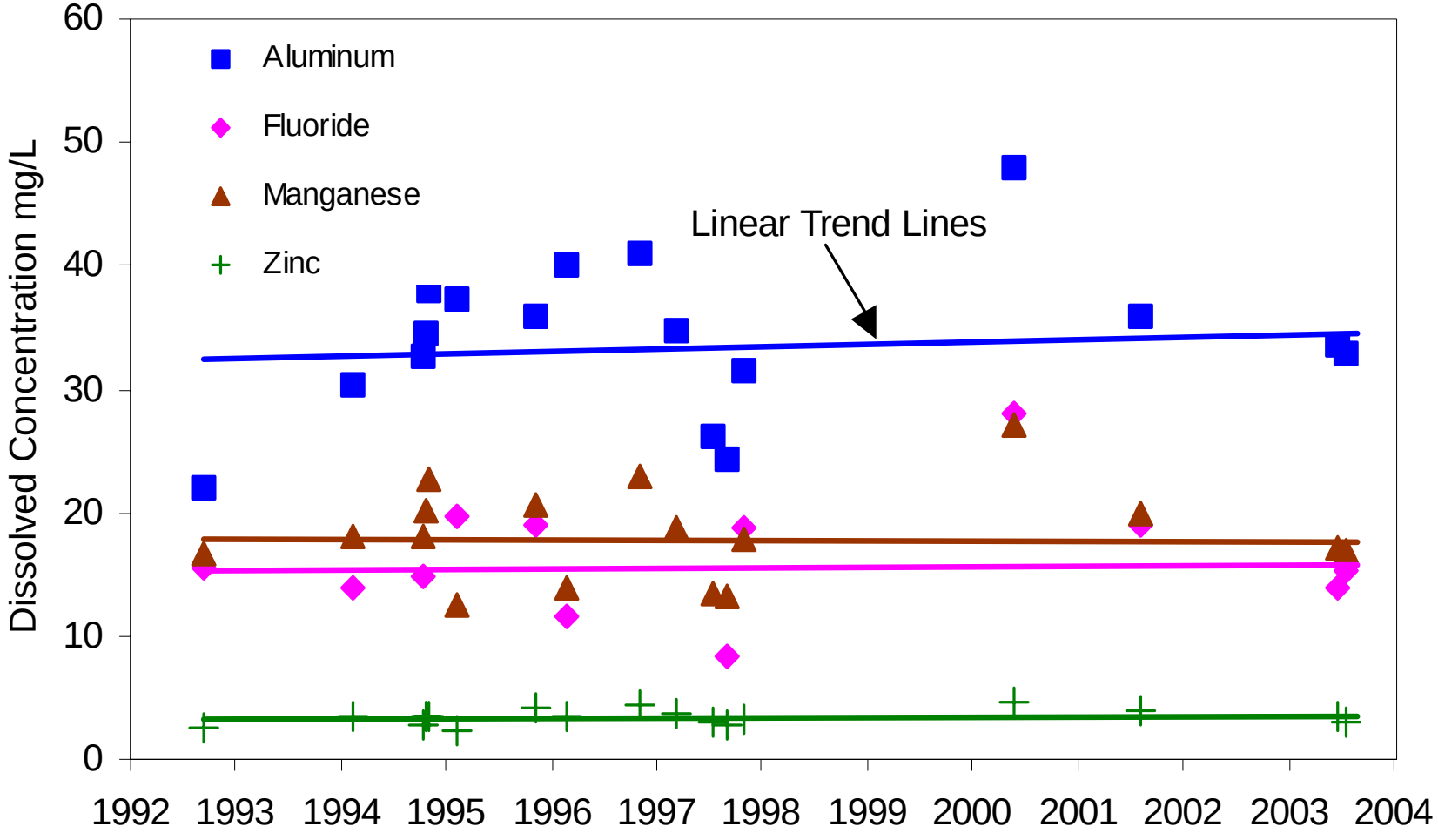
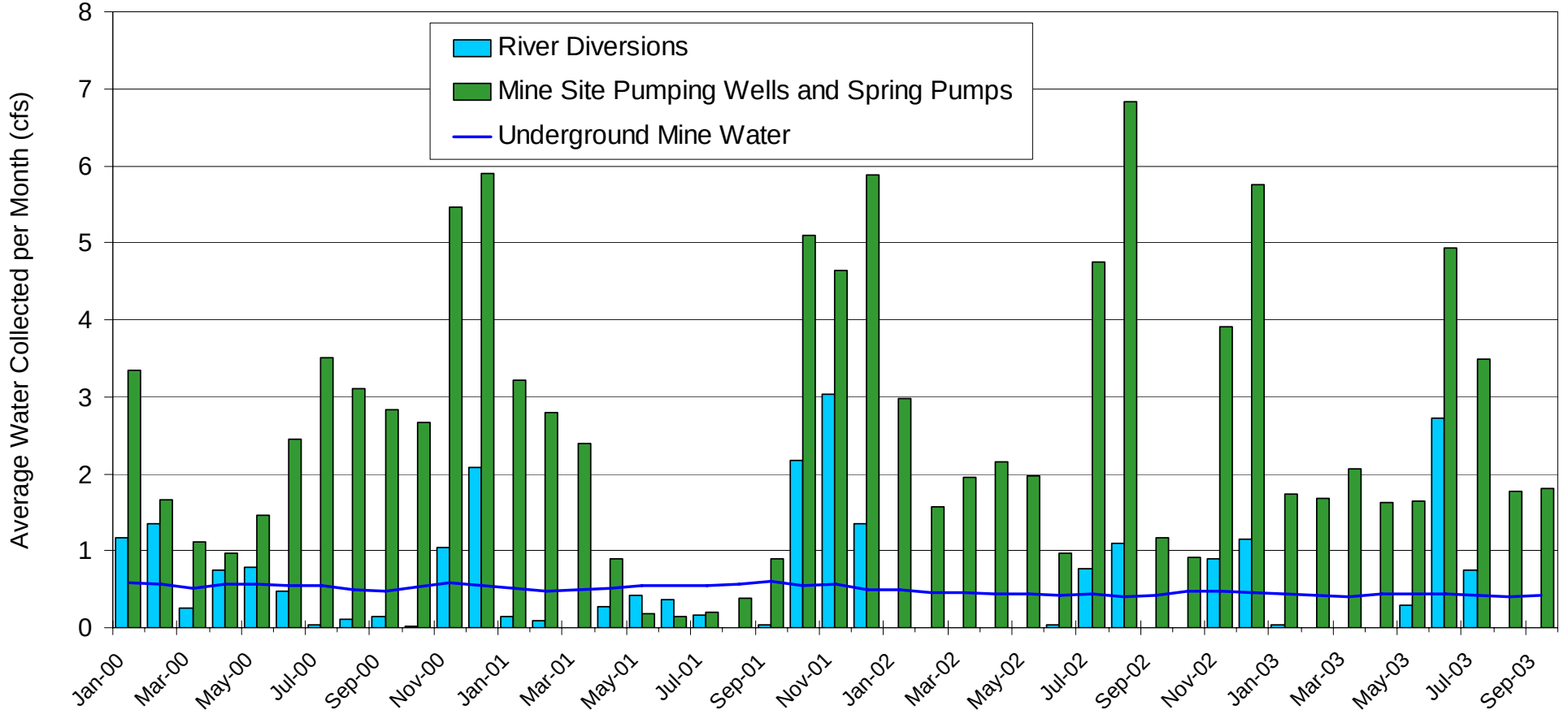
February 2003 data

Historical Metals Concentrations for Cabin Springs

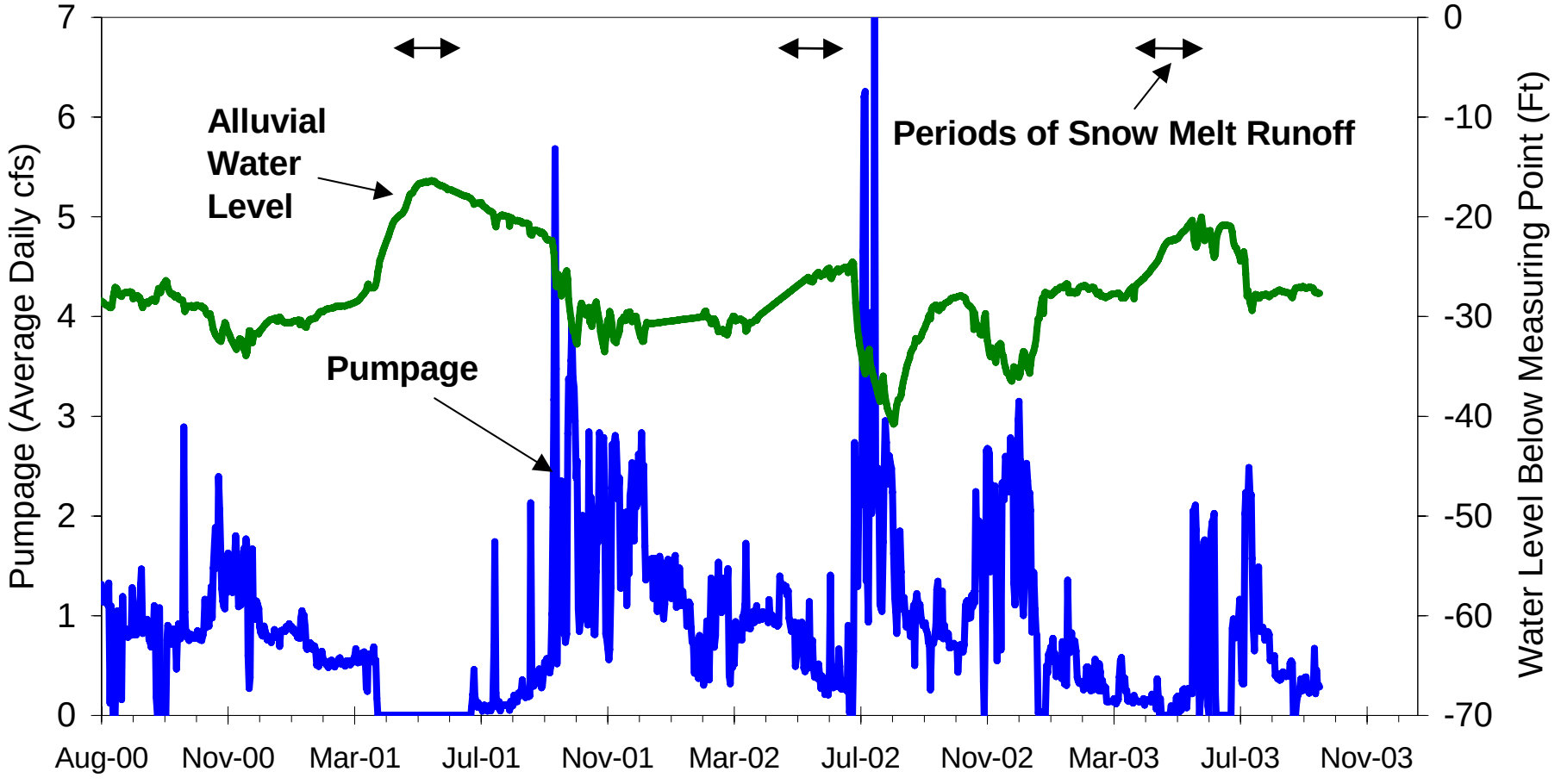


Operational Pumping

Operational Pumping 2000 to 2003



Columbine No. 2 Pumping and Groundwater Level Responses in P-1



Note: water levels are from Vail Engineering

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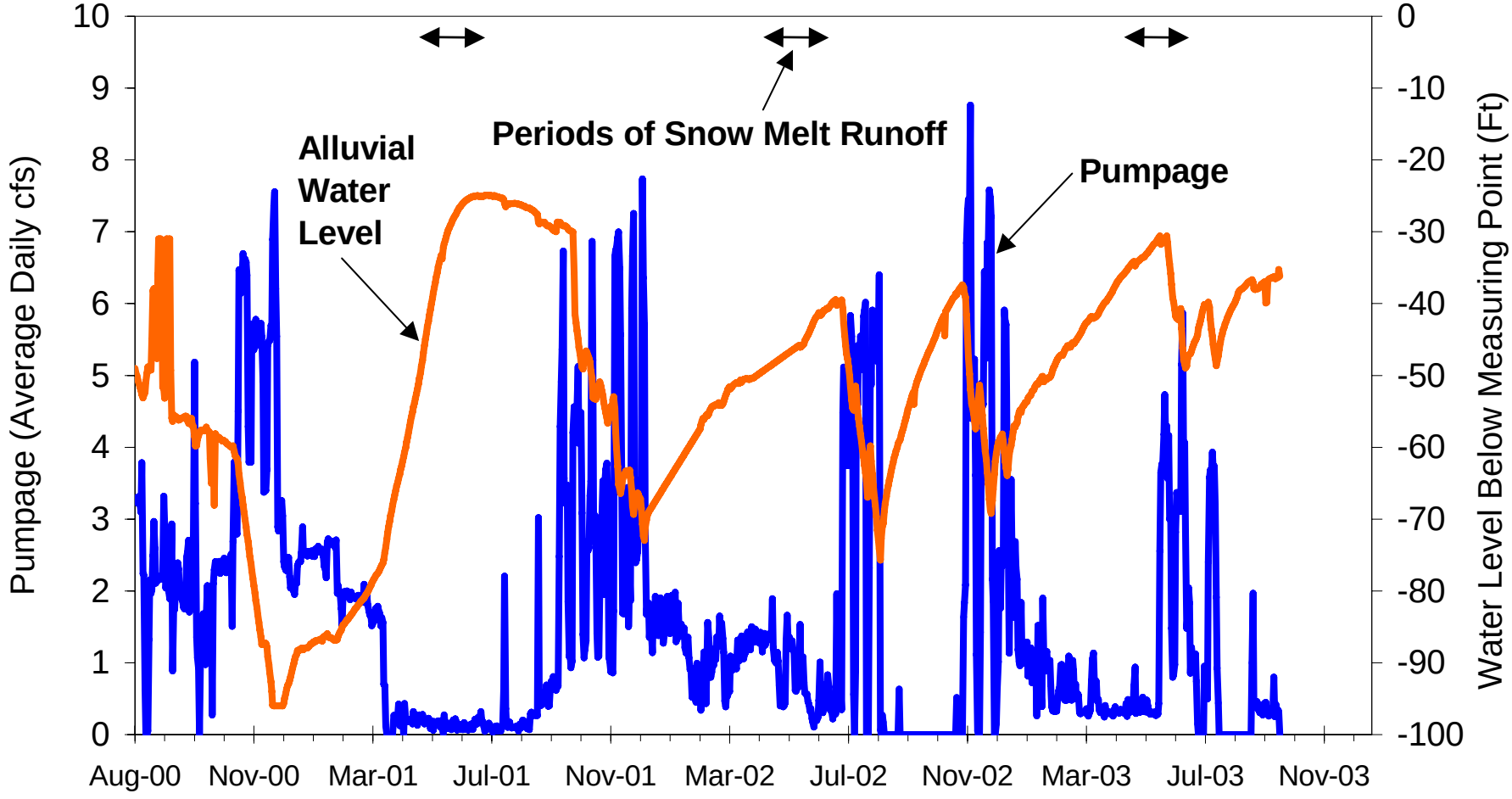
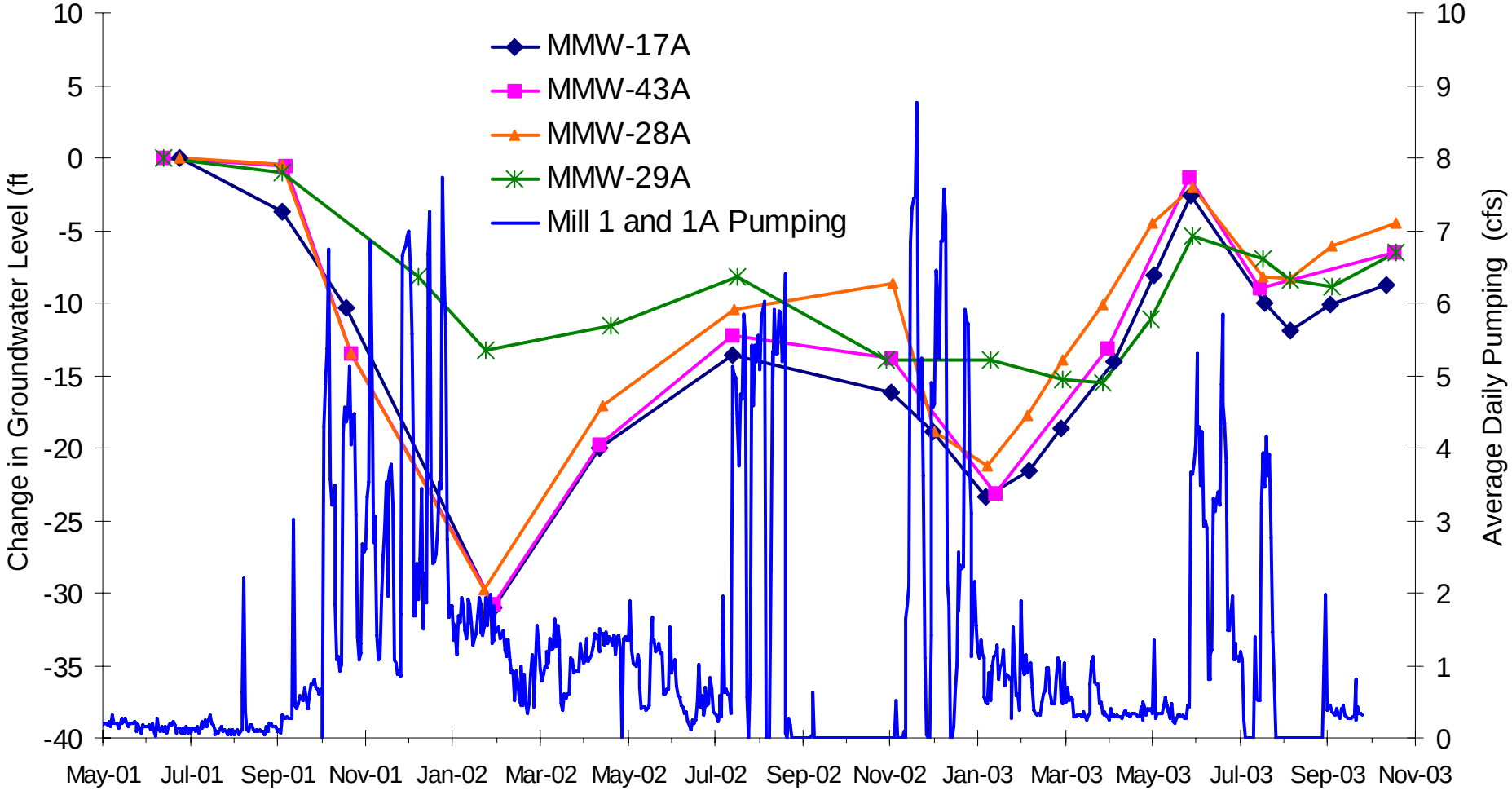
Mill Well Pumping and Groundwater Level Responses in Mill Area



Note: water levels are from Vail Engineering's test well

Mill Pumping and Change in Alluvial Groundwater Levels



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Extent of Operational Pumping Influences and Capture

- Map of showing area influenced and captured by pumping (ArcView)

Summary of Operational Pumping

- Pumping influences groundwater flowpaths near Mill and Columbine Park areas
- Pumping potentially influences both groundwater and surface water quality
- Interpretations regarding alluvial groundwater quality need to account for operational pumping

Best Management Practices (BMPs)

Groundwater Withdrawal Wells

- Required Best Management Practices under NPDES Permit
- Startup February 2, 2003
- GWW-1 = ~100 gpm
- GWW-2 = ~80 gpm
- GWW-3 = ~240 gpm
- Total from wells = 420 gpm (more than double the approximate accretion along north side of river from Mill to above Columbine Creek)
- Water is delivered to mill for pipeline maintenance

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Spring 39 and 13 Collection Systems

- Required by Best Management Practices under NPDES Permit
- System startup on February 2, 2003
- Spring 39: 300 ft long drain (~20 to 30 gpm)
- Spring 13: 1,000 ft long drain (~20 to 30 gpm)
- Water is delivered to the mill for pipeline maintenance

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Spring 39 Collection System

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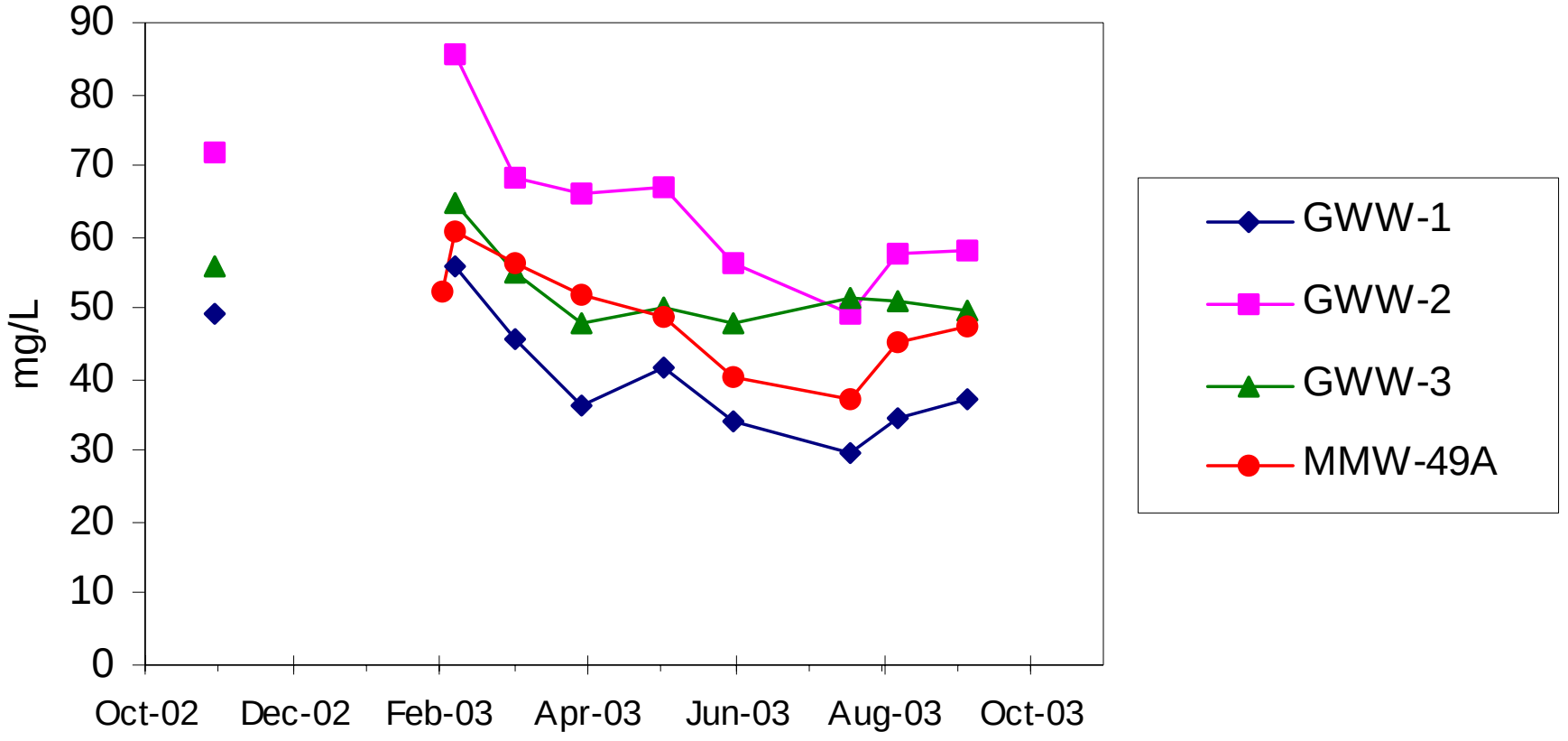
Dissolved Aluminum Concentrations for Withdrawal Wells



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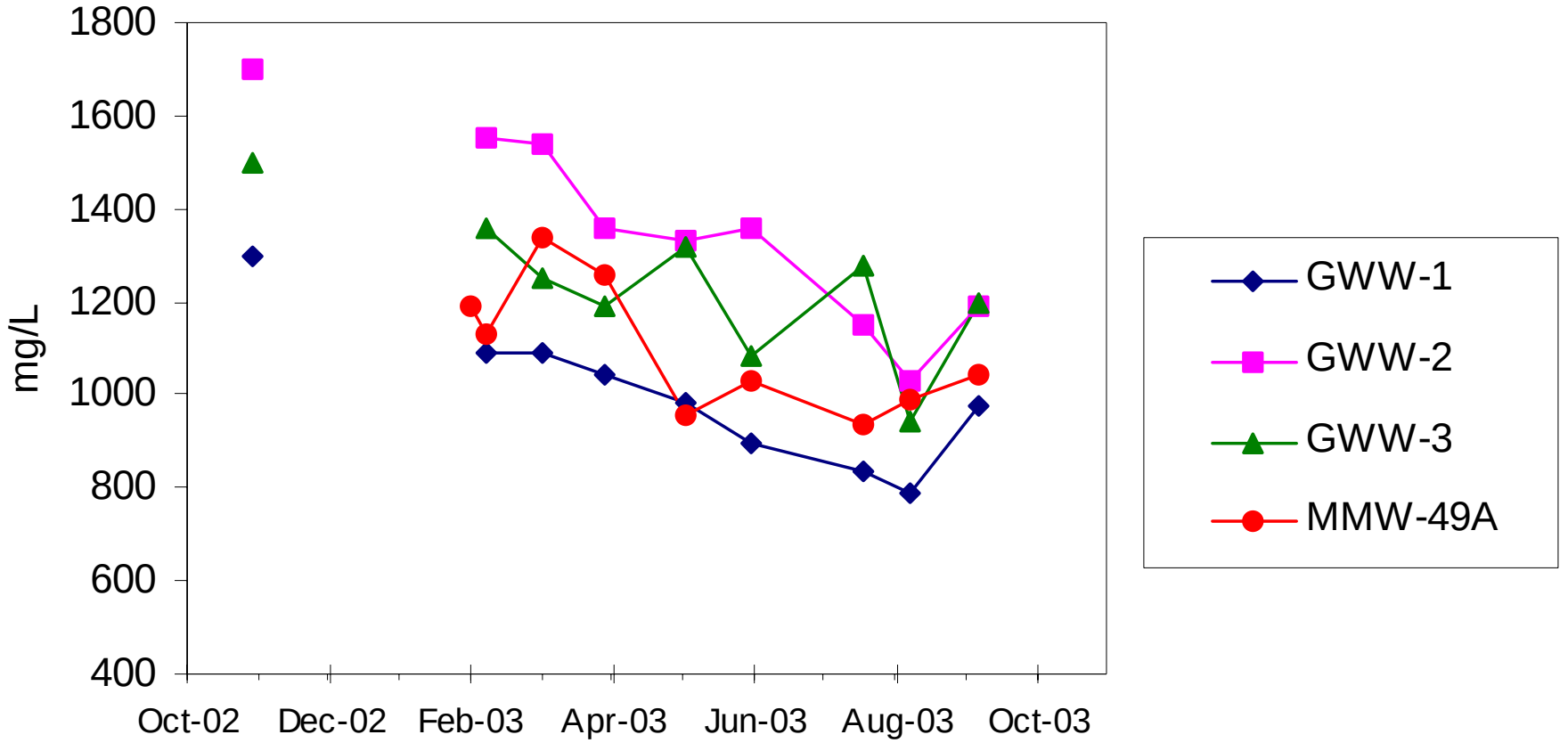
Sulfate Concentrations for Withdrawal Wells



Concentrations from Spring 39 and 13 Pumps

Constituent	Concentrations (dissolved)	
	Spring 39 Pump (mg/L)	Spring 13 Pump (mg/L)
Aluminum	22	81.3
Iron	ND	11.2
Manganese	1.97	11.7
Nickel	0.39	0.26
Zinc	0.95	2.96
Fluoride	5.4	3.8
Sulfate	843	1,060
pH	4.78	3.58

March 2003 data

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Preliminary Loading Calculations for Red River Alluvial Aquifer Along Mine Site

Loading Estimate Methodology

- Used July 2003 groundwater levels, concentrations, and pumping rates
- Used Darcian approach (Q=KIA) to estimate flow through colluvium/debris flow
  - Average value for hydraulic conductivity
  - Measured gradients between wells
  - Cross sectional areas based on geologic cross sections near the base of each drainage
- Loadings for surface water/groundwater interactions were from July 2003 sampling event
- Calculations do not account for chemical transformations or precipitation

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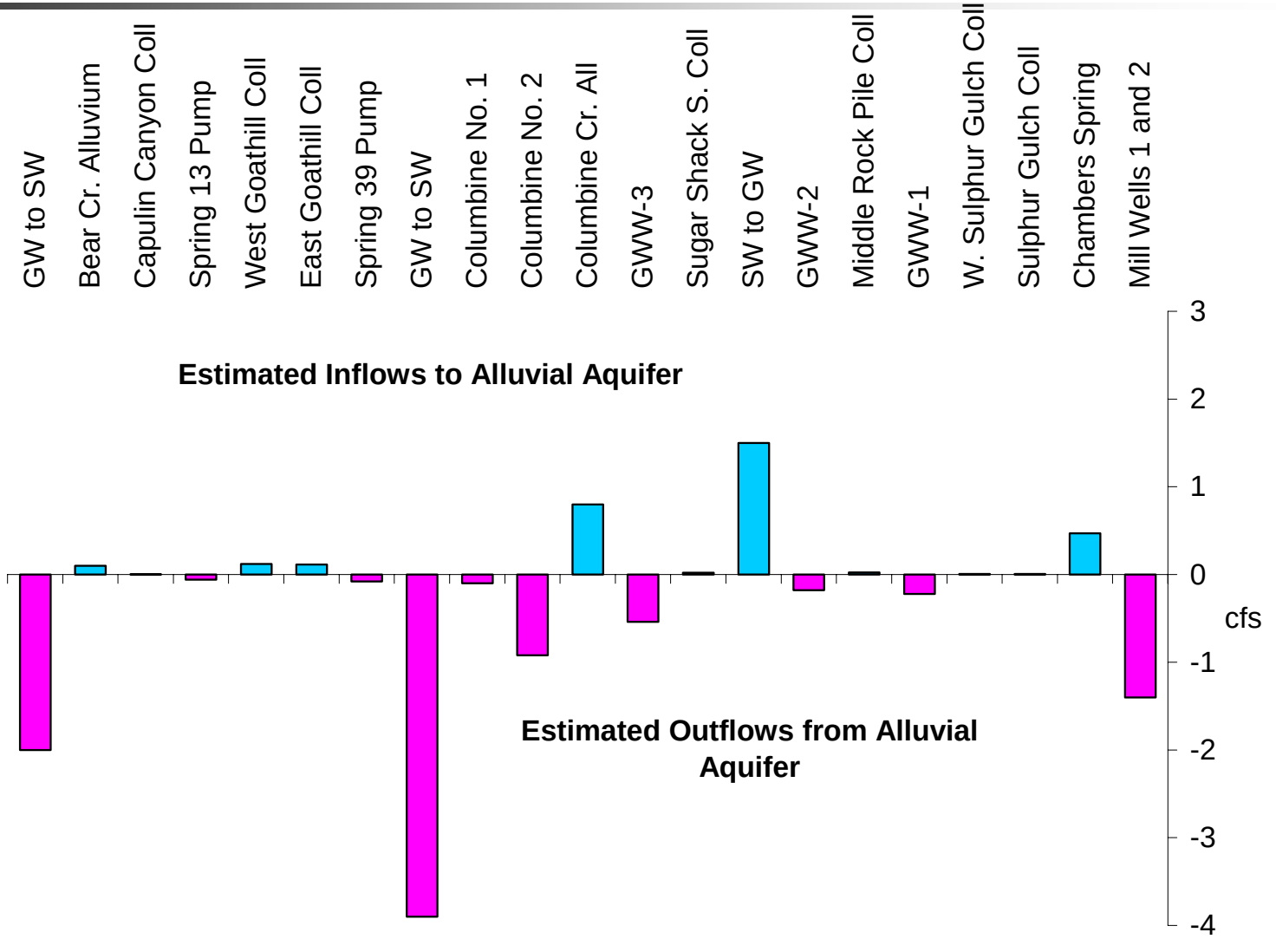
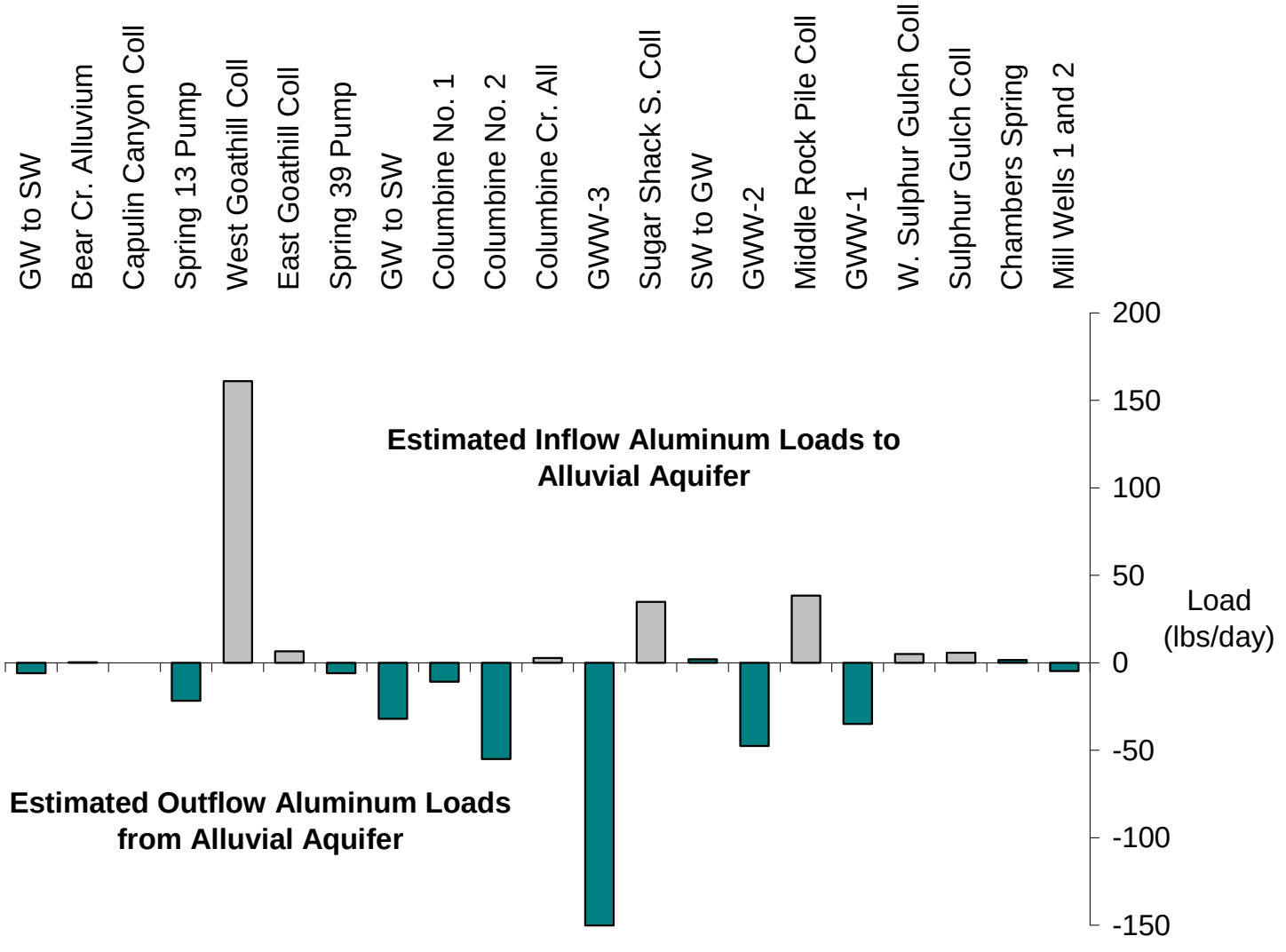
Inflow/Outflow to/from Alluvial Aquifer



Aluminum Loading to/from Alluvial Aquifer



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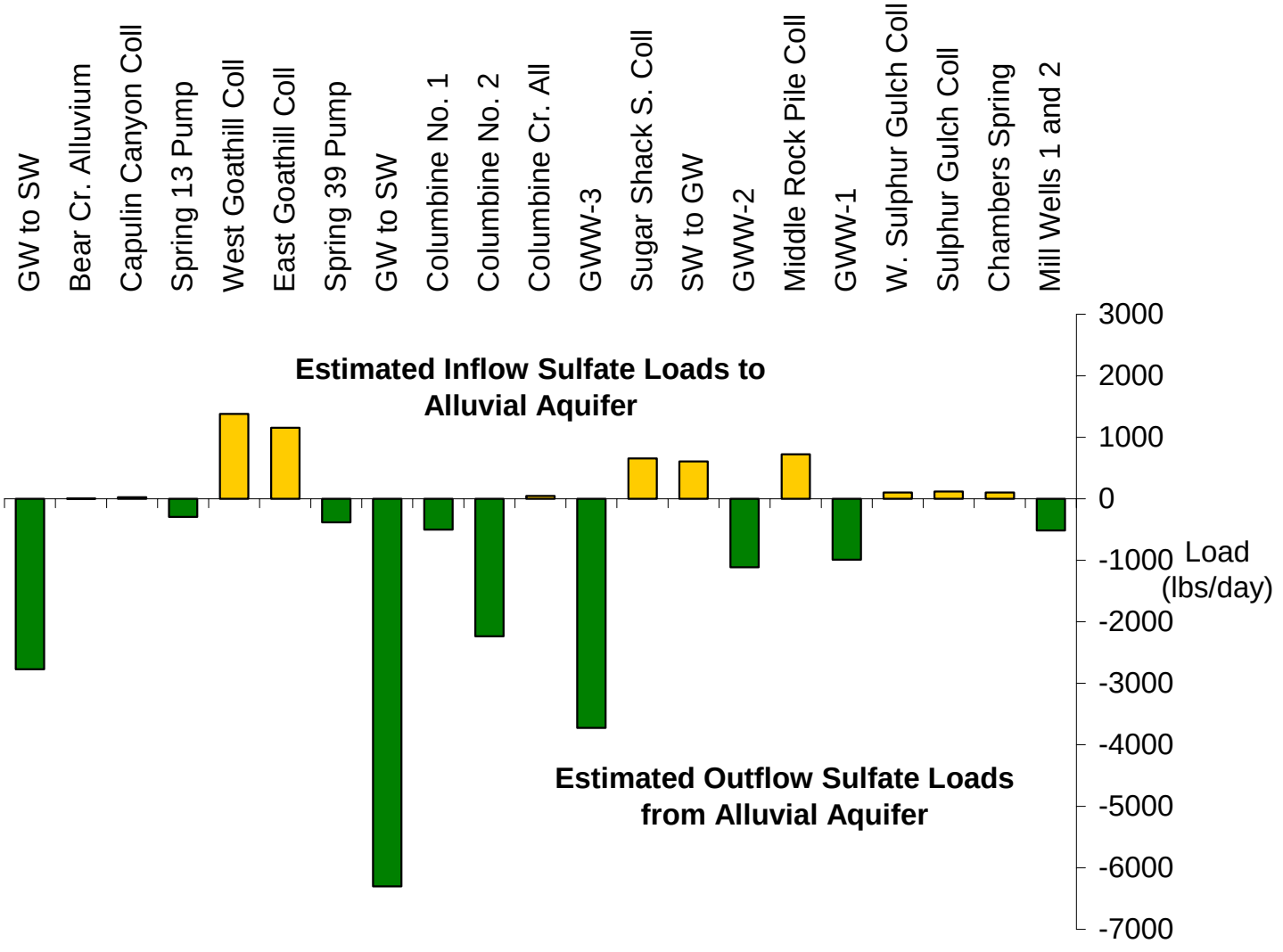
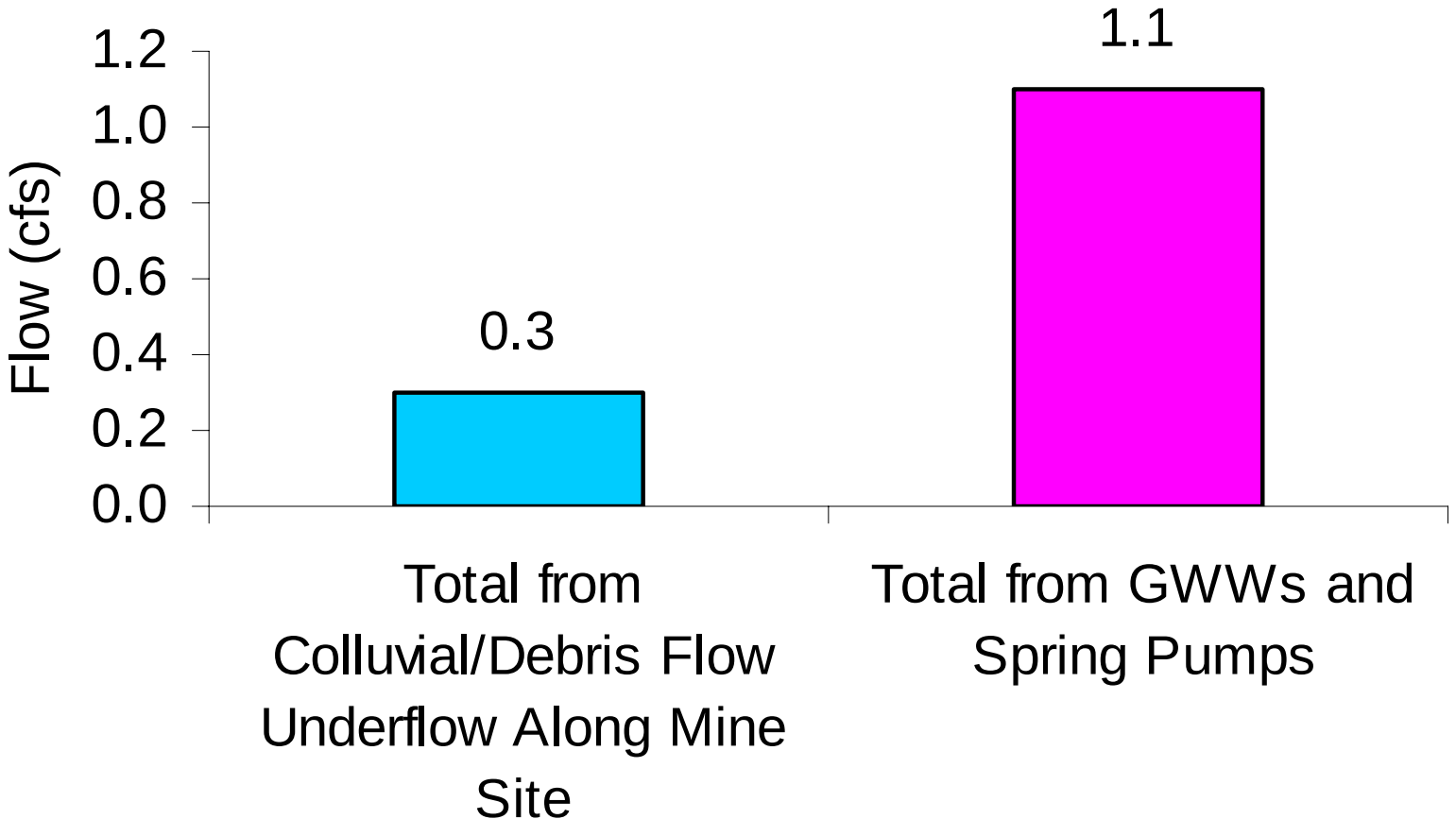
Sulfate Loading to/from Alluvial Aquifer

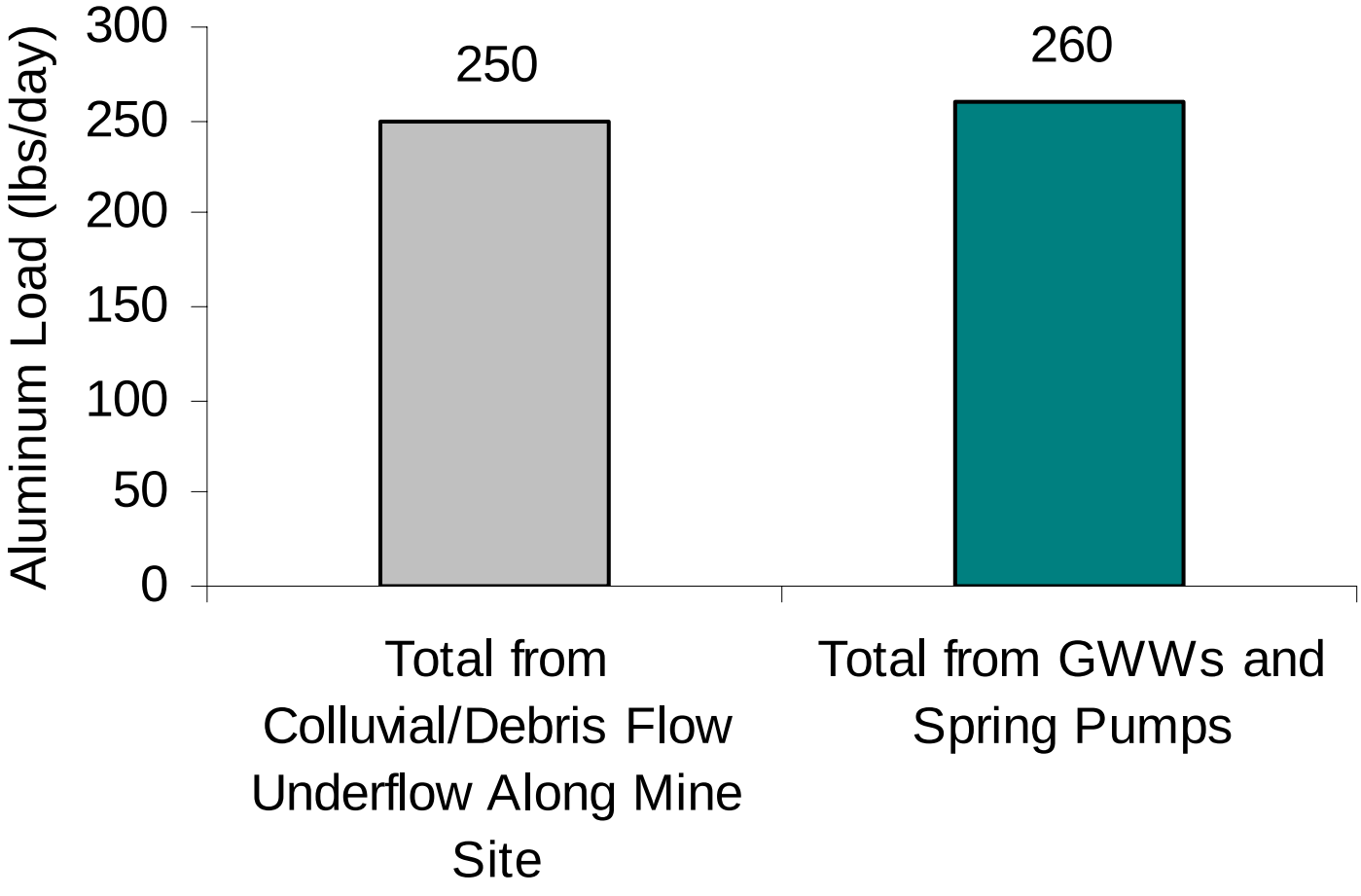


Comparison Between Colluvial Underflow and BMPs



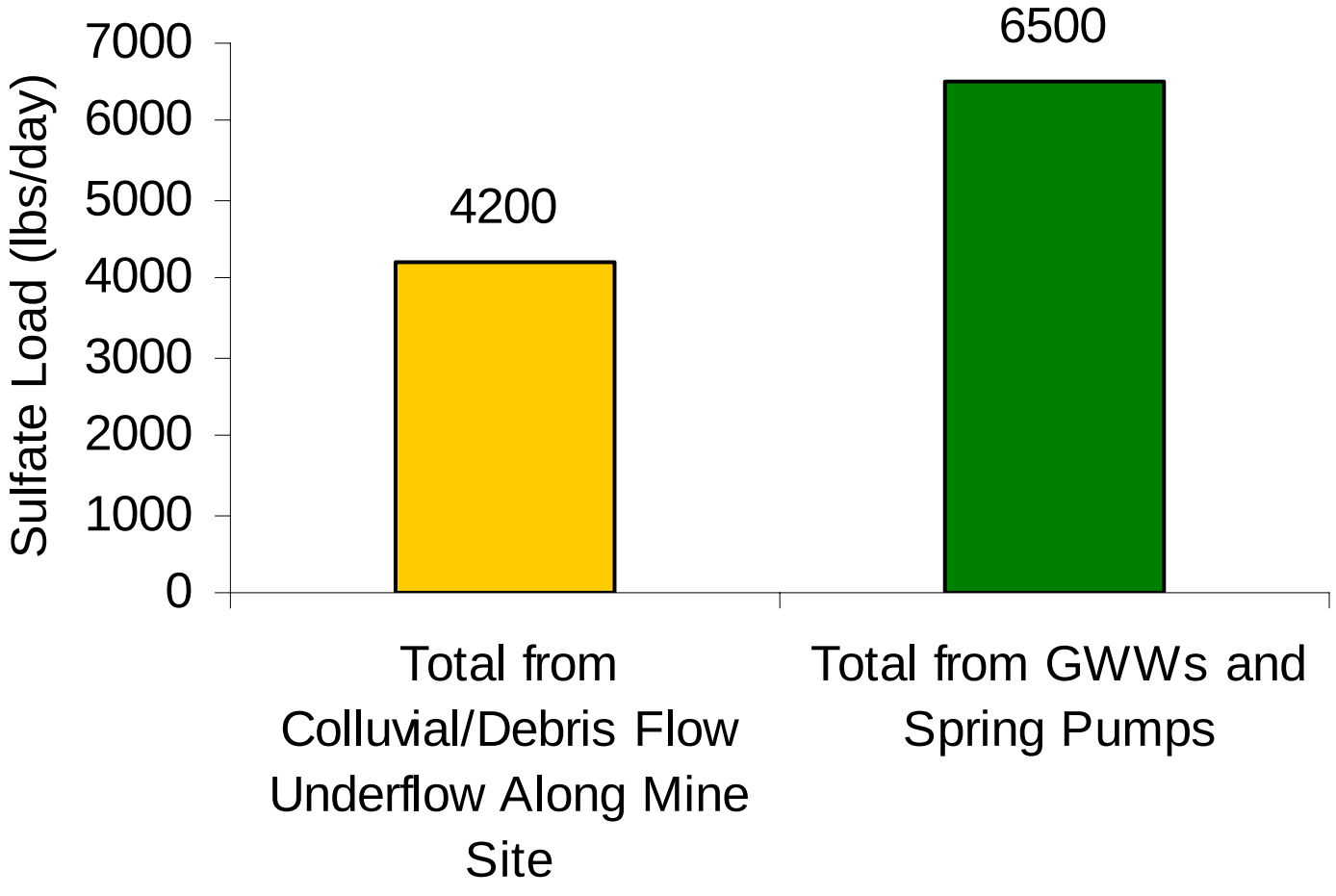
July 2003 data

Comparison of Aluminum Load Between Colluvial Underflow and BMPs



July 2003 data

Comparison of Sulfate Load Between Colluvial Underflow and BMPs



July 2003 data

Summary of Alluvial Loading Analysis and BMPs (Based on July 2003 Data)

- BMPs are removing metals/inorganics from alluvial aquifer; the amount removed is equal to or greater than the amount estimated in the colluvial underflow
- Another loss of alluvial groundwater load is due to the groundwater to surface water discharge due to the Goathill Gulch debris fan constriction and near the downstream mine boundary due to bedrock valley constrictions
- Loading estimates will be re-calculated after additional hydraulic testing is complete

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Nature and Extent

Isoconcentration Contour Maps (GIS)

- Mine site and reference areas
  - Aluminum October 2003
  - Sulfate October 2003

Summary

- The alluvial aquifer is considerably more transmissive (3 orders of magnitude) than the colluvial/debris flow unit and bedrock aquifer
- Available borehole data suggests that mine rock is not saturated along the front rock piles, except for at MMW-38A (<5 ft) in the Middle Rock Pile
- Goathill debris fan and bedrock constrictions at the downstream mine boundary create areas of strong groundwater to surface water discharge

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Summary (cont)

- Metals concentrations are highest at Capulin and Goathill Springs. High concentration also occur at the M&E area and at lower Goathill debris fan
- Elevated metals also occur in the alluvium, colluvium and bedrock groundwater in the upstream reference area
- Operational pumping influences (lowers) alluvial water table from the Mill to Columbine Park area, where surface water infiltrates into the underlying alluvial aquifer

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Summary (cont)

- BMPs are removing metals mass equal to or greater than the amount from colluvial groundwater underflow along the mine site
- Nature and Extent:
  - Concentrations in colluvium/debris flow groundwater within mine site drainages and pre-existing drainages decrease toward Red River as mixing with alluvial groundwater occurs
  - Poorer quality alluvial groundwater tends to flow along the northern portion of the alluvial aquifer due to colluvial/debris flow underflow
  - A similar pattern of metals concentrations and acidity also occurs upstream of the mine

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