Report No. 052010/2

SURFACE EROSION AND STABILITY ANALYSIS
QUESTA TAILINGS FACILITY, NEW MEXICO

Prepared for

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(MINE CLOSEOUT PLAN PROGRAM TASK B – SUBTASK B1)

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1.0 INTRODUCTION

Molycorp, Inc. (Molycorp) owns and operates tailings impoundments located adjacent to the town of Questa, New Mexico. These impoundments contain the tailings from the Questa molybdenum mine, which is located 3.5 miles east of Questa. It is anticipated that these tailings facilities will be operated for at least another 20 years. However, provision must be made for the eventual reclamation and closure of these tailings impoundments.

Under the terms of the approval granted by the Groundwater Protection and Remediation Bureau of the New Mexico Environment Department (NMED) for Molycorp's Discharge Plan (DP-933), Molycorp was required to prepare a Revised Closure Plan (RCP) for the Questa tailings impoundments. A RCP was prepared and submitted to the NMED, as well as the New Mexico Energy, Minerals and Natural Resources Department – Mining and Minerals Division (MMD), in April 1998 (RGC 1998).

The MMD granted an extension to Molycorp for approval of the Questa Tailings Facility closure plan on December 30, 1999. The extension included tasks yet to be completed to support the RCP, one of which was a surface erosion and stability analysis. A Work Plan for this analysis was submitted January 21, 2000 (Molycorp 2000a) and subsequently modified, at the request of the MMD, on March 30, 2000 (Molycorp 2000b). The Work Plan indicated that the work would take place from March 1 to April 30, 2000, with the report submitted May 31, 2000. The deadline for submission of the report was subsequently extended to June 23, 2000.

A surface erosion and stability analysis of the Questa Tailings Facility has been completed. This report describes the methodology used to conduct the analysis and presents and discusses the results of the analysis, which was performed between May 15 and June 20, 2000.

1.1 Purpose

The surface erosion and stability analysis at the Questa tailings impoundments is designed to ensure that long-term stability of all structures will be achieved and a self-sustaining ecosystem will be in place at the tailings facility upon final closure. The current tailings facility is well suited to this analysis because in some areas the vegetation has been in place for over twenty years and will be a good representation of post-closure conditions. Monitoring of the stability of the various structures has been a requirement by the State Dam Safety Engineer throughout the operating life of the structure.

The objective of the surface erosion and stability analysis, as stated in the original Work Plan submission (Molycorp 2000a), is:

- for erosion, to quantify, where possible, evaluate, and set-up test plots to determine the surface erosion potential and identify measures to minimize post-closure erosion; and
- for stability, to demonstrate the long-term stability (post-closure) of all embankments (dams) and diversion structures that form the tailings facility.

1.2 Scope of Work

The scope of work for the Questa Tailings Facility surface erosion and stability analysis is specified in the original Work Plan submission (Molycorp 2000a), as well as amendments to the Work Plan (Molycorp 2000b). The major components of the scope of work are listed below, with additional details provided later in this report.

<u>Evaluation of the Erosion Potential of the Tailings Surfaces and Dam Slopes:</u>

- Perform a reconnaissance survey of the tailings surface area and dam faces of concern, as well as the diversion ditches, to describe any areas where erosion is observed.
- Set-up test plots to visually evaluate erosional conditions or potential erosion on dam slopes of concern, in an older, revegetated tailings area (Dam 1) and in tailings areas covered and seeded in 1993 and 1998.
- Predict the potential for future erosion using the Revised Universal Soil Loss Equation (RUSLE 1.06) and the methods and techniques developed by Abt et al (1998).
- Evaluate alternative measures for erosion control on dam slopes of concern.

<u>Evaluation of the Stability of the Tailings Dam Slopes:</u>

- Submit the two most recent quarterly reports provided to the State Engineers Office (SEO) regarding stability of the dams to the NMED and MMD.
- Perform stability analyses of the long-term post-closure conditions of the tailings embankments, using conventional circular arc and block failure analyses methods, for both static and pseudo-static conditions applicable to the site.

Section 2 of this report provides background information for this study, including the general environmental setting of the Questa Tailings Facility and a brief description of the various areas and structures analyzed. Observations from the reconnaissance surveys and a description of the methods and techniques used in the field and laboratory investigations are provided in Section 3. Section 4 reviews existing information and provides requirements for additional analysis for the stability portion of this study. The results of this study are presented and discussed in Section 5, followed by a summary and conclusions in Section 6.

2.0 BACKGROUND

The general environmental setting of the Questa Tailings Facility and the various components of the facility evaluated in this study are described in this section. The majority of this background information is taken from RGC (1998).

2.1 General Environmental Setting

The Questa Tailings Facility is located near the village of Questa in Taos County, New Mexico (Figure 1). The village of Questa lies in an alluvial plain at an elevation of about 7600 feet a.s.l., bordered by the Sangre de Cristo Mountains to the east and the Guadalupe Mountains to the west. The Red River and its tributary, Cabresto Creek, have cut a prominent valley 100 to 200 feet below the level of the alluvial plain to the south of Questa. The piedmont alluvial plain extends past the village of Cerro, and into Sunshine Valley, to the north of Questa. The tailings impoundments were constructed in two deeply incised "arroyos" (channels cut in the alluvial plain), which run in a southwesterly direction towards the Red River valley.

The climate of the study area is semi-arid. The nearest weather station to the Questa Tailings Facility is located at Cerro, only three miles north of Questa in the alluvial plain (altitude 7665 feet a.s.l.). Annual precipitation at Cerro averages 12.24 inches per year with much of this precipitation occurring as summer thundershowers (43% of total precipitation occurs from July to September). The summers are generally pleasant, with maximum daily temperatures in the low 80s and minimum temperatures in the low 40s. The winters are long with temperatures dropping below freezing almost every night from October through to April. However, typically clear skies bring sunshine during most days with temperatures rising to above the freezing point.

The 1976 Soil Survey of Taos County identified three major soil types at the Questa Tailings Facility. The three types are identified as Sedillo-Silva Association (SED), Fernando Cobbly Loam (FaC), and Rock Outcrop-Raton Complex (RRE). The SED soil type is a very gravelly loam and makes up about 55% of the association and is found on side slopes in the region. The FaC soil type is found on alluvial fans at the base of mountains and is generally cobbly loam (5%), loam and clay loam (33%), and loam (62%). The last major soil type (RRE) includes areas of rock outcrop and Raton very stony silt loam intermingled.

The vegetation in the tailings facility area has been identified as primarily pinon-juniper woodland in combination with sagebrush (*Artemesia spp.*) and rabbitbrush (*Chrysothamnus nauseosus*). Sagebrush as well as rabbitbrush dominates the site, with the understory made up of wheatgrass (*Agropyron spp.*) and blue grama (*Bouteloua gracilis).* In general, the pinon-juniper woodland occupies the rocky or rough terrain, while sagebrush or other species occupy the gentle portions. Some species found in association with pinon-juniper, particularly in well-developed (12 inches) soils, include big sagebrush, cliffrose, bitterbrush, western or crested wheatgrass, blue grama, and Indian ricegrass.

2.2 Tailings Facility Overview

RGC (1998) describe in detail the historic and future development of the Questa Tailings Facility. The following sub-sections provide an overview of the tailings facility and in particular, background information relevant to the surface erosion and stability analysis.

2.2.1 Dams

The locations of the dams that have been constructed to develop the Questa Tailings Facility are shown in Figure 2. As they currently exist they comprise three impoundment systems:

i) The first system is located in Section 36 and currently consists of Dams 1 in the south, Dams 1C, 1B, and 2A on the east and a separator dyke between this impoundment and that for the Dam 4 complex on the west.

ii) The second system is located in Section 35 and consists of Dam 4 in the south, Dam 3A in the north and a discontinuous containment dyke along the west.

iii) The third system, also in Section 35, consists of Dam 5A in the south and impounds against Dam 3A. This system is currently receiving tailings.

All the dams have been designed, constructed and operated under the permitting control and regulatory overview of the New Mexico State Engineer. Construction and operation have been in accordance with the designs and specifications as permitted. Regular dam inspections have been performed by New Mexico Registered Professional Engineers in accordance with the National Dam Safety Act. Deficiencies identified during inspections and operation, and any concerns expressed by the State Engineer, have been addressed, and remediation or repairs made as appropriate. No outstanding issues or concerns currently exist.

<u>Dam 1 Complex:</u>

Dam 1 was constructed in 1966 as an earthfill dam across an arroyo. It contains a blanket and chimney drain and was raised by downstream construction using earthfill in stages from its original crest elevation (El) of 7460 to El of 7500. The last raise from El 7500 to El 7525 was by upstream construction using earthfill. The dam includes a 120 ft wide toe berm installed in 1981, which was required for stability. Dam 1 is approximately 175 ft high and has a downstream slope of about 27° (2 horizontal to 1 vertical, 2:1).

“Old” Dam 1C was constructed in 1975 of cycloned sand 650 ft upstream of Dam 1 to El 7560. Dams 1B and 2A were also constructed to El 7560 using earthfill to provide containment along the east side, next to the diversion ditch.

“New” Dam 1C was constructed at its present location in 1981 to its current elevation of 7584. This ‘new’ dam replaced the ‘old’ dam, which is contained within the tailings deposited behind “New” Dam 1C. The new dam was designed to achieve appropriate static and dynamic stability criteria. It incorporates a chimney and blanket drain and includes a downstream berm to provide adequate stability and provide for future downstream raisings. Dam 1C is approximately 50 ft high and has a downstream slope of about 27° (2:1).

Dams 1B and 2A were raised at the same time to the same elevation (El 7584). Dam 1B was raised with earthfill by downstream construction and includes a chimney and blanket drain, and a downstream stabilizing / construction berm. Prior to raising Dam 2A, a cycloned tailings dam had been constructed inboard of the dam and the tailings immediately upstream from the dam were excavated to allow for the raising of Dam 2A. Chimney and blanket drains were installed. Dams 1B and 2A are approximately 50 ft high and have downstream slopes of about 27° (2:1).

Dam 4 Complex:

The initial embankment of Dam 4 was constructed in the arroyo in Section 35 in 1971 to El 7460. It was constructed of earthfill and incorporates a chimney and blanket drain. An upstream asphalt membrane controls seepage through the embankment. Subsequent raisings have been substantially constructed by centreline construction methods. Some changes in construction concept have occurred, which led to changes in the location and nature of the chimney and blanket drain. The material for the seepage cut-off was changed to a high-density polyethylene (HDPE) geomembrane during the most recent raise to El 7520. Dam 4 is approximately 200 ft high and has a downstream slope of about 27°.

Dam 3A is an earthfill dam that was constructed in 1973 to El 7532. It served to retain tailings placed behind Dam 4 from flowing further north and west. This dam will cease to function as a dam with the placement of the tailings currently occurring behind Dam 5A.

Dam 5A Complex:

Dam 5A was constructed in 1990 in the old west decant channel on the north side of Dam 3A. It was made of earthfill and reached an elevation of 7525. It was subsequently raised in 1996 to El 7545 as a zoned rockfill dam. Tailings are currently being placed in the impoundment formed by this dam.

2.2.2 Diversion Ditches

Surface runoff from the upstream catchment had to be diverted around the tailings impoundments with the development of the tailings dams. A drainage ditch was constructed in 1973 to divert water around the west side of the impoundments. The run-on water to the eastern arroyo (Dam 1) was also diverted to this ditch. The diversion ditch at the toe of Dams 1B and 2A were filled in with the development of the expanded tailings structures in 1975 and as a result, new diversion facilities were required.

The current East and West Diversion Ditches were designed and installed at the location shown on Figure 2 following the completion of a comprehensive hydrology analysis (Vail 1975). Both ditches were designed to pass the one in one hundred year frequency storm over the entire catchment basin, with three feet of freeboard. To-date, no flow has been observed in the West Diversion Ditch and only minor flows, which appear to be associated with irrigation water discharges to the catchment rather than storm water flows, have been observed in the East Diversion Ditch.

2.2.3 Interim Covers

Drying of the tailings beaches following the shutdown of tailings operations in the early 1990s resulted in wind erosion and dust from the tailings beaches. A program of interim cover placement was implemented to control the dusting problem. This consisted of placing 9 inches of alluvial gravel material onto the tailings beaches, followed by the establishment of vegetation on these covers. The interim covers were seeded with crested wheatgrass (*Agropyron desetorum*) and yellow sweetclover (*Melilotus officinalis*) using a standard agricultural seed drill. The most recent interim covers were placed on tailings surfaces in early 2000 and seeded in May 2000.

The seed mix used for this area was western wheatgrass (*Pascopyrum smithii*) and blue grama (*Bouteloua gracilis*). The tailings surface between Dam 1 and Dam 1C had been capped in a similar manner prior to 1974.

The cover materials are alluvial gravels borrowed from the impoundment area, and are typical of the extensive deposits of this nature available locally. The gravel content of the cover material renders it very effective for the long-term control of both wind and water erosion. The small clay content gives sufficient cohesiveness to prevent dust erosion and the gravel content provides physical protection from both forms of erosion. The problem with dust was entirely eliminated with the placement of these interim covers.

3.0 SURFACE EROSION ANALYSIS

The surface erosion analysis consisted of three major components; namely, reconnaissance surveys, a field investigation, and a laboratory investigation. Observations from the reconnaissance surveys are provided below, followed by a description of the methods and techniques used in the field and laboratory investigations. The results of the field and laboratory investigations are presented and discussed in Section 5.1.

3.1 Reconnaissance Surveys

Reconnaissance surveys were performed in this study as specified in the Work Plan (Molycorp 2000a, 2000b). Mr. David Christensen, a Masters of Science graduate student at the University of Saskatchewan, Canada, carried out the surveys with assistance from RGC and Molycorp personnel. The purpose of the surveys was to visually evaluate and document the nature and extent of any observed erosion, including descriptions of the vegetation and surface materials, as well as the cause (i.e. water, wind, etc.) and type (i.e. rill, sheet, etc.) of erosion. Several photographs were taken during the surveys and are included in the Photo Log at the back of this report. Observations from reconnaissance surveys performed on tailings dam slopes of concern, along the diversion ditches and on different tailings area surfaces are provided below.

3.1.1 Tailings Dam Slopes

Tailings dam slopes of concern with respect to surface erosion include the downstream slope of Dams 1, 1B, 1C, 2A, 3A, and 4. However, reconnaissance surveys were only performed on the downstream slopes of the two major dams (Dam 1 and 4); the other dams are much smaller compared to Dam 1 and 4 and are of the same construction (earthfill). Although Dam 5A is constructed of rockfill (i.e. not a concern with respect to surface erosion), a reconnaissance survey was performed on its downstream face and abutments.

<u>Dam 1 Downstream Slope:</u>

A reconnaissance survey of the downstream slope of Dam 1 was performed on June 11, 2000. The surface of the slope was visually inspected by walking the crest and toe of each of the bottom two benches of the dam. The bottom two benches are quite similar in physical appearance and erosional characteristics (Photo 1). Coarse rock exists sporadically on the surface of the entire downstream face (Photo 2). Some evidence of minor surface erosion from water was observed during the survey; no evidence of surface erosion from wind was observed.

Two relatively small gullies were found on the downstream face of each bench of Dam 1. These gullies are similar in nature with the apparent cause of the erosion being water; however, water channels do not lead to the top of the area. Vegetation has established in the gullies and the gullies have coarse rock distributed within them, but do not appear to be deeper than 6 to 8 inches and 18 inches wide (Photo 6).

Vegetation including shrubs, grasses and scattered pinons exist intermittently across the entire downstream slope of Dam 1 (Photo 1). The vegetation species observed on the embankment include rabbitbrush, sagebrush, wheatgrass and yellow sweetclover (*Melilotus officinalis*). Photo 5 shows the different vegetation types and species on the downstream slope of Dam 1.

Dam 4 Downstream Slope:

A reconnaissance survey of the downstream slope of Dam 4 was performed on June 11, 2000. The surface of the slope was visually inspected by walking 40 feet below the crest and 40 feet above the toe across the entire dam face. A wide view of the entire downstream face of Dam 4 and a close-up view of the middle section of the downstream dam face are shown in Photos 7 and 8, respectively. No evidence of surface erosion from wind or water was observed during the survey.

Coarse rock exists sporadically on the surface of the downstream face of Dam 4 (Photo 9), with the exception of the dam toe (Photo 10). Excluding the layer of coarse rock along the toe of Dam 4, the coarse rock coverage is only about half that observed on the downstream slope of Dam 1. In addition, the average size of coarse rock on the slope surface is smaller compared to the coarse rock observed on the Dam 1 slope surface.

Vegetation observed on the downstream slope of Dam 4 is very similar to that observed on the downstream slope of Dam 1; however, the overall coverage of vegetation on Dam 4 is much less compared to the coverage on Dam 1. The vegetation species observed on the embankment include rabbitbrush, sagebrush, wheatgrass and yellow sweetclover. Photo 12 provides a good view of the different vegetation types and species on the downstream slope of Dam 4.

Dam 5A Downstream Slope and Abutments:

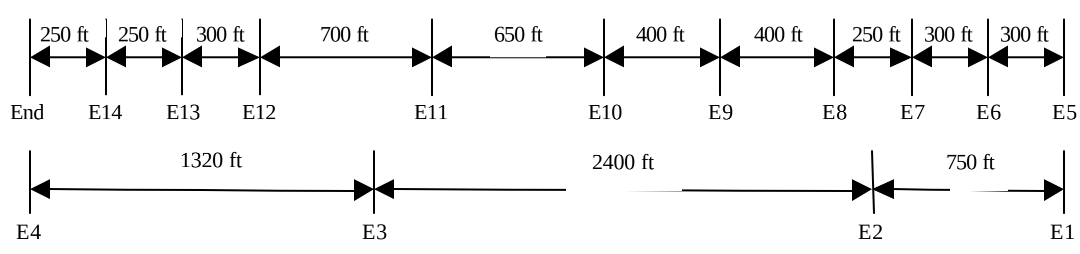
A reconnaissance survey of the downstream slope and abutments of Dam 5A was performed on June 11, 2000. The downstream face of Dam 5A and the east and west abutment walls of the rockfill dam are shown in Photos 14, 15, and 16, respectively. No evidence of surface erosion from wind or water was observed during the survey, even at the contact between the rockfill and granular abutment walls. Considering the construction of Dam 5A and the minimal potential for future surface erosion, Dam 5A is not considered any further in the surface erosion analysis.

3.1.2 Diversion Ditches

Reconnaissance surveys were performed along the entire length of the East and West Diversion Ditch on June 11, 2000. Observations from these surveys are provided below.

East Diversion Ditch:

The East Diversion Ditch reconnaissance survey consisted of 14 stops (i.e. points of observation), as illustrated in the schematic below. The survey commenced at the north end and proceeded to the south, ending at the downstream slope of Dam 1.



Stop E-1: The ditch is approximately 15 feet deep at the starting point (Photo 17). Heavy vegetation exists on both sides of the ditch; grass dominates the side-slopes and bushes and shrubs line the channel bottom. Coarse rock is visible on the side-slopes, covering about 20-30% of the area. No signs of erosion were observed in this area.

Stop E-2: A small gully is visible in the east slope of the diversion ditch (Photo 18). It occurs in well-vegetated gravelly soil; coarse rock can be seen in and around the gully. No other signs of erosion are visible to either side.

Stop E-3: The eastern slope is not as well vegetated compared to the previous two stops (Photo 19). No signs of erosion were observed. Possibly, small rills can be seen at mid-slope (only 2 feet long and 2 inches deep at most). The east slope is not as coarse as the slope has been to this point. The west slope is coarser and holds more vegetation. The channel bottom is sandy and dry.

Stop E-4: This stop occurs on the road crossing over the diversion ditch (Photo 20). The area is a continuation of Stop E-3 and has similar characteristics. The ditch is still approximately 15 feet at this point.

Stop E-5: The slopes of the diversion ditch 300 feet to the south of the road are 20% coarse material in a brown sandy matrix. Both sides are vegetated; wheatgrass and sagebrush cover approximately 30-40% of the slope. No signs of erosion appear on either slope; the side-slope appearance is much like the downstream slopes of Dams 1 and 4 (Photo 21). The channel has some boulders that have rolled down the side-slopes.

Stop E-6: This area is much the same as Stop E-5; the east slope has more grass and the slope is slightly flatter. Grass is growing on the channel bottom (Photo 22). No signs of erosion were observed.

Stop E-7: A small gully was observed in the coarse rock face in the east slope (Photo 23). No vegetation exists next to the gully, which is the only one encountered in the area. No other signs of erosion were observed around the gully.

Stop E-8: The east slope has moderate rills, with very sparse vegetation, and coarse rock covering about 40% of the surface (Photo 24). The moderate gullies are spaced 6 to 10 feet apart, and are about 6 inches deep and 1 foot wide. They are all over the slopes 150 feet in each direction. The debris fans are a mixture of coarse and fine material. Coarse rock is on the bottom of the channel. The west slope shows no signs of erosion and has more vegetation than the east slope.

Stop E-9: The area shows no signs of erosion. The diversion ditch is now closer to 30-40 feet in depth.

Stop E-10: This area also shows no signs of erosion. The slope surfaces have approximately 40-50% coarse material covering the slope. There is more vegetation on the west slope than the east slope, which is the trend throughout the length of the diversion ditch.

Stop E-11: No evidence of erosion was observed in this area. This is the start of the riprapped diversion ditch channel bottom with large volcanic rock. The ditch is now back to 25 feet in depth.

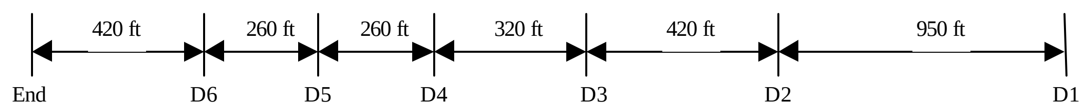
Stop E-12: This area, which is halfway through the riprapped slope, shows no signs of erosion.

Stop E-13: No evidence of erosion was observed in this area (Photo 25).

Stop E-14: This is the end of the East Diversion Ditch. Small to moderate erosion gullies are present on the east/south slope for 150 feet in each direction (Photo 26). The surface material is quite fine, only 15% is covered with coarse rock; it is the finest material found in the survey of the East Diversion Ditch. Gullies are 4-6 inches deep and 8 inches wide, spaced every 2-3 feet. The debris fans have both coarse and fine material. The west/north slope shows no signs of erosion. Minimal vegetation was observed on either slope at this stop.

<u>West Diversion Ditch:</u>

The West Diversion Ditch reconnaissance survey consisted of six stops (i.e. points of observation), as illustrated in the schematic below. The survey commenced at the north end and proceeded to the south, ending at the downstream slope of Dam 1. The cross-section of the ditch, which is quite consistent throughout its length, ranges from 10 to 15 feet deep.



Stop D-1: Both slopes are unvegetated except for some small forbs at the starting point; the slope of the channel walls is similar for each side (Photo 27). The top two feet of the slope are almost vertical; the bottom part has a concave shape. Some fines collected from the top part of the slope are present at the bottom of the slope. There are no rills or gullies within sight on either slope. The upper west slope has some moderate gullies, up to 1 foot in depth (Photo 28). The channel bottom is lined with bushes.

Stop D-2: The ditch slopes have the same shape as discussed in Stop D-1. Small surface failures or “cave-ins” were observed on the west slope (Photo 29). The small cave-ins extend to the top of the slope and consequently, clumps of grass exist in the channel bottom. The channel bottom has large boulders; most likely the boulders were within the matrix of the channel walls and the fines around them were removed causing the boulders to fall.

Stop D-3: The ditch slopes show no signs of erosion in this area. To the south, the east slope has the upper vertical, then bottom concave shape as discussed in Stop D-1. A layer of coarse rock exists in the upper layer of the ditch; it is standing without any signs of erosion. The west slope stands nearly vertical, and appears to be a conglomerate of material (a fine matrix with large boulders extending out of the slope).

Stop D-4: The area has a small earth flow from the east side of the diversion ditch (Photo 30). The debris fan is somewhat hummocky indicating more than one event. The debris fan does not reach the west side of the diversion ditch; however, it does constrict the channel, reducing it to only 6 feet at the base.

Stop D-5: The area is in bedrock outcrops with the slopes standing close to vertical (Photo 31). Loose fill has accumulated at the toe of the slope as a result of falling material from the upper part of the slope. Another possible theory is that wind has deposited some of the fill due to sediment being picked up as the wind descends the mountains to the west. Only weeds are present on the dry channel floor.

Stop D-6: The next area extends from the road that intersects the diversion ditch to the end of the ditch at the face of Dam 4. This area is similar to Stop D-5; bedrock outcrops exist and the slopes stand close to vertical.

3.1.3 Tailings Areas

Reconnaissance surveys were performed on the surface of three different tailings areas with respect to the time of placement of an interim cover. The three areas surveyed were: 1) tailings area covered and revegetated prior to 1974 (between Dam 1 and 1C); 2) tailings area covered and revegetated in 1993 (areas behind both Dam 1 and 4); and 3) tailings area covered and revegetated between 1998 and 2000.

<u>Tailings Area Covered and Revegetated Prior to 1974:</u>

A reconnaissance survey of the tailings area surface between Dam 1 and 1C was performed on June 13, 2000. This area is relatively small compared to the other tailings areas and as a result, the entire area was walked and visually inspected. The area shows no signs of erosion from water or wind. There is no visually measurable slope in the area (i.e. nowhere for water to collect or runoff).

In general, the surface of this tailings area is covered with a sandy-gravel matrix (interim cover borrow material) and well-established vegetation (Photo 32). An area close to Dam 1C has greyish-white tailings on the surface (Photo 33), with interim cover material about three inches beneath the tailings.

<u>Tailings Area Covered and Seeded in 1993:</u>

Reconnaissance surveys of the tailings area covered and revegetated in 1993 behind Dam 1 and Dam 4 was performed on June 12 and 13, 2000, respectively. Each area was traversed and visually inspected for about ten minutes; this was sufficient time considering the homogeneity of the surface features of each area. No evidence of surface erosion from water or wind was found and there is no visually measurable slope in either area.

The surface of these two tailings areas (covered and seeded in 1993) consist of a sandy-gravel matrix (interim cover borrow material) and relatively well-established vegetation (Photo 36 and 38). In general, the vegetation in the Dam 4 tailings area is less dense than that observed in the Dam 1 tailings area. This could be a result of the winter grazing of sheep that occurs in this area.

<u>Tailings Area Covered and Seeded in 2000:</u>

A reconnaissance survey of a tailings area covered and seeded in 2000 was performed on June 12, 2000. The area was traversed and visually inspected for about ten minutes; this was sufficient time considering the homogeneity of the surface features in the area. No evidence of surface erosion from water or wind was found, and there is no visually measurable slope in the area.

The surface of the area surveyed consists of a sandy-gravel matrix (interim cover borrow material) and virtually no vegetation (seeding of the area occurred in May 2000), as shown in Photo 43.

3.2 Field Investigation

The field investigation component of the surface erosion study consisted of developing test plots on tailings dam slopes of concern, and historic and more recent covered and revegetated tailings areas. The purpose of the test plots was to visually evaluate erosional conditions or potential erosion by collecting information such as estimated percent coverage of cobble and/or gravel and vegetation, as well as vegetation type and species and estimated slope. Physical measurements of the surface profile of the various test plots were collected. In addition, samples of soil material on the surface of the embankments and tailings areas were collected and analyzed as described in Section 3.3. The results of the surface erosion field investigation are presented and discussed in Section 5.1.1.

The approved Work Plan for this study specifies that the test plots should be about 30 ft by 30 ft, and should be situated in areas of both “typical” and “more advanced” erosive conditions (Molycorp 2000a, 2000b). The Work Plan also states that two transects of 30 ft by 3 ft are to be placed in each plot to measure vegetation type and species. The results of this evaluation are presented and discussed in Section 5.1.1.

3.2.1 Tailings Dam Slopes

A total of four large-scale test plots were developed on Dam 1 and 4 to evaluate surface erosion on embankments at the Questa Tailings Facility. A 30 ft by 15 ft test plot was created just below the crest and just above the toe, in vertical alignment with one another, on the downstream slope of each dam as specified in the amendments to the Work Plan (Molycorp 2000b). The downstream face of Dam 4 was chosen to represent “typical” erosive conditions, while the downstream face of Dam 1 was selected to represent “more advanced” erosive conditions. This decision was based on the fact that more signs of surface erosion were observed on Dam 1 as compared to Dam 4.

<u>Dam 1 Downstream Slope:</u>

The locations of the test plots developed on the downstream slope of Dam 1 are shown in Figure 3. The test plots were situated over small gullies observed during the reconnaissance survey of the downstream slope to evaluate “more advanced” erosive conditions. The surface of the upper and lower test plots are very similar in appearance. Photo 5 shows the lower test plot.

A small-scale, 3 ft x 3 ft test plot, was developed on the downstream face of Dam 1 as shown in Figure 3 (not specified in the approved Work Plan). The purpose of this exercise was to better assess the coarse rock present on the downstream face; the test plot was selected to be representative of the coarse rock on the slope and not necessarily vegetation. Photos 3 and 4 show the small-scale test plot on Dam 1.

Dam 4 Downstream Slope:

The locations of the test plots developed on the downstream slope of Dam 4 are shown in Figure 3. The test plots were situated based on observations from the reconnaissance survey of the downstream slope to evaluate "typical" erosive conditions. The surface of the upper and lower test plots are very similar in appearance. Photo 13 shows the upper test plot.

A small-scale, 3 ft x 3 ft test plot, was developed on the downstream face of Dam 4 as shown in Figure 3 (not specified in the approved Work Plan). The purpose of this exercise was to better assess the coarse rock present on the downstream face; the test plot was selected to be representative of the coarse rock on the slope and not necessarily vegetation. Photos 11 and 12 show the small-scale test plot on Dam 4.

3.2.2 Tailings Areas

A total of eight large-scale test plots were developed in this study to evaluate surface erosion on historic and more recently covered and revegetated tailings areas at the Questa Tailings Facility. Test plots 30 ft by 30 ft were created on the various tailings areas to evaluate both "typical" and "more advanced" erosive conditions. Note however, that during the reconnaissance and survey of the areas, no differences could be found across the tailings. Therefore, while an attempt to identify "typical" and "more advanced" erosion was undertaken, there is essentially no difference between the plots in terms of erosional status. The plots were selected to represent a visually flat area and an area with slightly more relief (i.e., the cover was not smoothed as well during construction).

Tailings Area Covered and Revegetated Prior to 1974:

The locations of the test plots developed on the tailings area covered and revegetated prior to 1974 (between Dam 1 and 1C) are shown in Figure 3. The test plots are very similar in appearance, as illustrated in Photos 34 and 35.

Tailings Area Covered and Seeded in 1993:

The locations of the test plots developed on the tailings areas covered and seeded in 1993 (behind Dam 1 and 4) are shown in Figure 3. The test plots are very similar in appearance, as illustrated in Photos 36, 38, 39 and 41.

Tailings Area Covered and Seeded in 2000:

The locations of the test plots developed on the tailings area covered and seeded in 2000 are shown in Figure 3. The test plots are very similar in appearance. Photo 43 shows the one of the two test plots.

3.3 Laboratory Investigation

The laboratory investigation component of the surface erosion study consisted of determining the distribution of particle sizes larger than 0.075 mm in samples collected during the field investigation. A mechanical sieve analysis was performed on each sample as specified in ASTM D422-63 (ASTM 1990). The results of each analysis are presented and discussed in Section 5.1.

3.4 Potential for Future Erosion

The approved Work Plan for this study indicates that the potential surface erosion on tailings areas and dam slopes will be predicted using the Revised Universal Soil Loss Equation (RUSLE 1.06) for mined lands, construction sites and reclaimed lands (Molycorp 2000a). The use of alternative erosion assessment methods, such as those developed by Abt et al (1998), will also be considered to best estimate the potential for future erosion and the benefits of alternative erosion control measures.

A preliminary assessment was completed using the RUSLE program to assess the potential for future erosion. Background information for data input was taken from the RGC (1998). Four options were reviewed, two for the tailings at slopes of 0.5% and 1%, and two for Dams 1 and 4, at a slope of 50%. The difference between Dams 1 and 4 was that the flow path was shorter for Dam 4, and the amount of rock coverage was higher for Dam 1. A fine and coarse cover material was modelled for each of these options, based on the particle size analysis shown in Figures 4 and 11. For each option reviewed, the percentage of vegetation cover was varied from 10% to 100%. The maximum weight of biomass for any given vegetative cover amount was assumed be constant (the amount of biomass that can be supported is determined by the soil type and the vegetative matter). Default climate characteristics for Albuquerque were assumed for completion of the comparative modelling.

Figures 18 and 19 show the erosion rates for the four options reviewed. Figure 18 presents the results when using the fine-grained cover material. The model predicted that the erosion rates using the fine-grained cover material might range from 1.4×10^{-5} kg/m^2/yr for the tailings at a slope of 0.5%, to a maximum of 7.4×10^{-2} kg/m^2/yr for the downstream slope of Dam 1. Figure 19 presents the predicted erosion using the coarse-grained material. The predicted results for the coarse-grained cover material indicate that the amount of erosion occurring ranges from 1.3×10^{-4} kg/m^2/yr for the tailings at a slope of 0.5%, to a maximum of 6.6×10^{-1} kg/m^2/yr for the downstream slope Dam 1. Assuming a bulk density of 1800 kg/m^3 the highest predicted erosion rate of 6.6×10^{-1} kg/m^2/yr works out to about 0.36mm/yr mass loss. In fifty years this erosion would amount to a soil loss of less than 2 cm. Clearly, the erosion occurring for each of the different options is minimal to insignificant.

The model predicted that the coarser cover material produced more erosion than the finer textured material. This was attributed to the fact that the finer grained cover material comparatively more well-graded than the coarser textured material, with grain sizes from clay to cobbles. In contrast, the coarser grained cover material is more uniform. Hence, the finer grained cover material is comparatively more self-armouring, and ultimately results in less erosion. In addition, the finer grained material has a higher content of clay materials, and the model predicts that these materials tend to be resistant to detachment. In contrast, the model predicts that uniform soils with little to no clay content result in higher mobility rates.

The RUSLE model should not be taken as a quantitative prediction of erosion. Rather, it should be used to qualitatively compare differing conditions for a given set of fixed conditions. The predicted model results compared to each other indicate that the steeper slopes require vegetation coverage of 30% to 40% to achieve only minimal erosion. In comparison, the model predicted that the tailings surface would exhibit essentially no erosion, regardless of vegetation cover and slope angle. The latter predictions agree very well with that observed in the field for the actual tailings surface.

Additional predictions of potential future erosion at the Questa Tailings Facility will be carried out, and submitted as an addendum to this report once cover types and vegetation programs have been finalized. If, based on these predictions, the implementation of alternative erosion control measures, such as slope reduction to 3H:1V and the use of surface armouring and slope breaks, are found to be necessary, they will be evaluated. Preliminary assessments indicate that the erosion that has occurred over several decades is not measurable on most surfaces and minimal where encountered. Much of the measurable erosion probably occurred shortly after slope construction when surface soils were lose and readily erodable, and before an erosion resistant surface (due to gravel particles and vegetation establishment) occurred. The potential for future erosion is clearly minimal and no remediation, maintenance or repair is considered necessary. The Closeout Plan will provide for additional monitoring and, if required, maintenance, but no long-term maintenance requirements are anticipated.

4.0 STABILITY ANALYSES

All the dams have been designed and permitted under the permitting control and regulatory overview of the New Mexico State Engineer. Regular dam inspections have been performed by New Mexico Registered Professional Engineers in accordance with the National Dam Safety Act. Copies of the two most recent Inspection Reports for the last quarter of 1999 and the first quarter of 2000, performed Vail Engineering of Santa Fe, are included as Appendix A.

4.1 Stability Analyses

Stability analyses for static and pseudo-static conditions, and where a concern exists, also block failure, have been performed for all dams during design. The dams have been built in accordance with the designs and these analyses remain applicable. The design stability parameters required were (Geocon, 1991):

i) Under static loading conditions the factor of safety should be not less than 1.5.

II) Under seismic (Pseudo-static loading) conditions the factor of safety should be not less than 1.1.

These stability criteria are also suitable for long term post closure conditions.

Piezometers installed in and under the dams allow the monitoring of pore pressures that develop within the dams. A review of the piezometer results (see latest dam inspection reports) indicate that the phreatic surface is well below assumed design values. Thus, the actual factors of safety against failure currently existing in the field are greater than those determined in the original stability analyses. Post closure, there will be no storage of water on the dams and there will be a further decline in the phreatic surface, with a corresponding increase in stability.

It is not feasible to determine the stability of the dams at closure since the final designs have not been prepared. However, since future designs and construction will be to the same design parameters the final factors of safety will be no less.

The stability analyses for the various dams are reviewed below:

i) Dam 5A

The original design for Dam 5A, to elevation 7540 is described in Geocon (1990). The seismic loading for pseudo-static analysis assumed was 0.1g, the design value used for all the dams. The static and pseudo-static factors of safety determined were 1.6 and 1.15 respectively. The block failure analysis for the dam yielded a factor of safety of 2.4 against mass sliding. Generally, in the absence of a low shear strength horizontal layer, the factor of safety for block failure is much greater than the factor of safety for circular arc failures in granular tailings dams of this form. This implies that if adequate factors of safety for circular arc failures are predicted, it will also indicate adequate factors of safety for block failure. On tailings dam closure there will be a reduction of the phreatic surface in the dam as the tailings drain due to the more permeable underling alluvial soils. Thus, there will be increases in the stability, post closure.

ii) Dam 1

The current Dam 1 was stabilized with a berm designed in 1981. The design and stability analyses are described in Mine Tailings International 1981. With the addition of the berm, the static and dynamic factors of safety against circular slip failure were determined to be 1.5 and 1.24, respectively. The assumed phreatic surface used in the analyses was higher than the value of the current surface and the current factors of safety are therefore higher than these values.

iii) Dam 1C

Dam 1C is constructed on tailings and in the 1981 stability review, the potential for liquefaction of both the dam foundation and retained tailings was addressed. A conservative assumption was made that there may be full liquefaction of the tailings retained by the dam, and a reduction of the shear strength of the tailings under the dam for dynamic conditions. The computed static and pseudo-static (dynamic) factors of safety were 2.5 and 1.2, respectively using these assumptions.

iv) Dam 1B

Static and pseudo-static factors of safety for circular arc failure determined in the 1981 study for Dam 1B were computed on the same basis as for 1C yielding values of 2.2 and 1.1, respectively.

v) Dam 2A

Static and pseudo-static factors of safety for circular arc failure determined in the 1981 study for Dam 2A were computed on the same basis as for 1C yielding minimum values of 1.55 and 1.1, respectively.

vi) Dam 4

MAJA Corporation Ltd. 1998 performed stability analyses for the 1998 raising of Dam 4 to El 7525. The results of these analyses were minimum factors of safety for static and pseudo-static analyses of 2.19 and 1.69, respectively.

vii) Separator Dyke

The separator dyke was reinforced with a stabilizing berm in 1991, and the stability analyses are presented in Geocon (1991). The static and pseudo static factors of safety were no less than 1.65 and 1.33, respectively. An analysis was also performed for liquefaction of tailings under the dyke (dynamic conditions), and the resulting minimum factor of safety was 1.18.

5.0 PRESENTATION AND DISCUSSION OF RESULTS

5.1 Surface Erosion Analysis

5.1.1 Field Investigations

Vegetation was difficult to identify in some cases as a result of the prolonged dry period Questa has experienced this year. The vegetation will be re-surveyed later in the summer, probably August or September to capture the change in vegetation as a result of precipitation events.

<u>Dam 1 Downstream Slope</u>

The slope of the downstream face of Dam 1 was measured at between 26° and 28° (2 horizontal and 1 vertical).

The sagebrush, rabbitbrush and grass are much thicker on Dam 1 than they were on Dam 4; the coverage of the clover is the same or a little less. Overall coverage by vegetation is approximately 30-40%. The cover is a visual estimate.

The coarse rock covers 30-40% of the overall dam face area.

The majority of the rock within the study area is gravel sized ½ to 1" rock. Additionally there are rocks up to 5-6 inches and one rock close to 10". The coarse rock covers 50-60% of the study area, higher than the estimated coverage of the entire slope. A representative surface soil sample (Sample #2) was taken immediately to the east of the 3 ft x 3 ft plot. The results of the grading determination of this sample are shown on Figure 4.

The vegetation covers about 15% of the study area. Only grass is present in the area. Other plant species nearby but not necessarily in the plot include yellow sweetclover, rabbitbrush and sagebrush (intermittent across slope).

The "more erosive" test plot was placed on the face of Dam 1. Dam 1 had a few small signs of erosion. The 30 ft x 30 ft plot was placed over one of the small gullies to get a good profile. The gully is difficult to see because of the vegetation. It is shallow and wide (approximately 8 inches deep and 2 feet wide). The gully is in the same material as the rest of the dam, which is not showing any signs of erosion. There does not seem to be any source of water, no channels along the bench lead to the top of the gully. The debris fan has coarse materials mixed in a fine matrix, and extends four feet past the toe of the slope.

The horizontal profiles measured across the two parts of the "more advanced erosion" plot are provided in Figures 5 and 6. These profiles will be re-surveyed in future years to evaluate whether additional erosion occurs, and to determine erosion rates.

<u>Dam 4 Downstream Slope</u>

The slope of the downstream face of Dam 4 was measured at between 26° and 28°.

The slope is not heavily vegetated covering approximately 5-10% of the slope, sagebrush, rabbitbrush, grass, and yellow sweetclover.

The slope has small cobbles covering 15 to 20% of the slope area; larger (up to 2 feet) boulders appear intermittently.

The majority of the rock within the study area is gravel-sized ½ to 1" rock. Additionally there are rocks up to 2 - 4 inches. Coarse rock covers 20-30% of the study area, slightly higher than the estimated coverage of the entire slope. A representative surface soil sample was taken immediately to the east of the 3 ft x 3 ft plot. The results of the grading test on this sample are provided in Figure 4.

The vegetation covers only a small part (<10%) of the study area. Plant species include yellow sweetclover and standing dead annual vegetation, such as asters. Other vegetation nearby but not necessarily in the plot are sagebrush and rabbitbrush (intermittent across slope) and a bunchgrass (unidentified).

The "typical" erosion test plot was set up on Dam 4. The typical erosion in this case is no erosion. The two areas on Dam 4 have smooth faces, there are no gullies or depressions. The horizontal profiles measured across the two parts of the test plot are provided in Figures 7 and 8. These profiles will be re-surveyed in future years to whether additional erosion occurs, and to determine erosion rates.

<u>Tailings Area Covered and Revegetated Prior to 1974:</u>

Flat Test Plot

The vegetation is well established in this area. Vegetation covers approximately 38% based on a point intercept transect (Table 1). Species within the test plot area are rabbitbrush, yellow sweetclover, cactus (*Opuntia spp.),* a fescue, tentatively identified as Arizona fescue (*Festuca arizonica*), and a forb that could not be identified but is likely an aster.

Table 1. Summary of species and percent coverage for the flat test plot revegetated prior to 1974 in the two 3 ft x 30 ft point intercept transacts (points every 1 ft).

	Gravel	Litter	Grass	Yellow Sweetclover	Shrub	Bare
Transect 1	1	6	11	0	0	12
Transect 2	0	8	11	1	0	10
Average (%)	2	23	37	2	0	37

Note: species identified include, Rabbitbrush (*Chrysothamnus nauseosus*)*,* Arizona fescue (tentative) (*Festuca arizonica*)*,* Yellow sweetclover, (*Melilotus officinalis*), Cactus (*Opuntia spp.*), Aster (tentative) (*Aster spp.*).

The material is light brown and similar to the other soils found in the covers. However, this soil is finer and was classified as silty sand. The coarse rock (1/2" and greater) covers only 5-10% of the surface. The maximum rock size observed is 3".

Relief Test Plot

This area has more relief than the flat test plot. It is not due to erosion; most likely the cover surface wasn't completely levelled during construction. The depression and ridges allow for collection of water and possibly runoff, which is why it is chosen as the more advanced plot. However, no erosion was observed in the test plot area.

The test plot area is not as homogeneous as the other test plots have been; there are areas of greater coarse rock at surface, and there are areas where tailings are at the surface. The vegetation is fairly consistent throughout the test plot. Overall, the area has no measurable slope.

The vegetation on the plot is similar to the flat test plot. There is more yellow sweetclover present in this area, and the live vegetation is estimated at 40% based on a point intercept transect (Table 2).

Table 2. Summary of species and percent coverage for the relief test plot revegetated prior to 1974 in the two 3 ft x 30 ft point intercept transacts (points every 1 ft).

	Gravel	Litter	Grass	Yellow Sweetclover	Shrub	Bare
Transect 1	1	10	9	4	0	6
Transect 2	7	7	11	0	0	6
Average (%)	13	28	33	7	0	20

Note: species identified include, Rabbitbrush (*Chrysothamnus nauseosus*), Wildrye (tentative), (*Leymus spp.*), Yellow sweetclover, (*Melilotus officinalis*), Indian Ricegrass (*Oryzopsis hymenoides*), Aster (tentative) (*Aster spp.*).

The material is still the light brown material, similar enough that another soil sample was not taken. The small area of tailings, is a light grey, fine material. The coarse rock is not consistent on the plot; overall, it covers 15-20% of the surface area.

Profiles measured across the test plot are shown on Figures 9 and 10. These profiles will be re-surveyed in future years to evaluate whether additional erosion occurs, and to determine erosion rates.

<u>Tailings Area Covered and Seeded in 1993:</u>

Flat Test Plot (#1)

Wind erosion is most likely not a concern in the area – there is sufficient vegetation and surface gravel to mitigate wind effects. Gusts up to approximately 40-mph wind were experienced during the measurement of the test plot and no clouds of dust were observed.

There is no measurable slope in the area – a waterbody (the current water area for the tailings) is present 100 m to the south. There are no drainage channels to the impoundment.

The area vegetation includes yellow sweetclover, indian ricegrass (*Oryzopsis hymenoides*), bottlebrush squirreltail (*Elymus elymoides*), and rabbitbrush. Vegetation covers 35% based on the point intercept transect (Table 3).

Table 3. Summary of species and percent coverage for the flat test plot revegetated in 1993, in the two 3 ft x 30 ft point intercept transacts (points every 1 ft).

	Gravel	Litter	Grass	Yellow Sweetclover	Shrub	Bare
Transect 1	2	16	10	1	0	1
Transect 2	1	15	10	0	0	4
Average (%)	5	52	33	2	0	8

Note: species identified include, Rabbitbrush (*Chrysothamnus nauseosus*), Indian Ricegrass, (*Oryzopsis hymenoides*), Yellow sweetclover, (*Melilotus officinalis*), Bottlebrush squirreltail (*Elymus elymoides*), Aster (tentative) (*Aster spp*.).

The surface material is light brown sandy gravel with a high silt content. Coarse rock is imbedded in the surface material, 10-20% of the area is covered by ½" and greater rock. The maximum rock size is 4". A soil sample was taken to the south of the plot. The results of a grading test on this sample are provided on Figure 11.

Relief Test Plot (#1)

The relief test plot is similar to the flat test plot. The test plot is 400 m to the southeast of the flat test plot.

The ground has a little bit of relief – the small ridges and depressions are not caused by erosion; they are likely an effect of construction. The area around the waterbody was investigated but no erosion was observed next to it. This area has been picked as the comparison plot because of its relief; if extreme water events do occur, runoff in the depressions will be more likely than in a flat area.

There is more vegetation in this area as compared to the flat plot. The vegetation is made up of yellow sweetclover, Indian ricegrass, crested wheatgrass (*Agropyron desertorum* – tentative identification), rabbitbrush, Arizona fescue (tentatively identified), aster (tentatively identified) and alfalfa (*Medicago sativa)*. Overall, vegetation covers 57% based on the point intercept transect (Table 4).

The soil is the same light brown sandy gravel with high silt content. Coarse rock covering the surface is approximately the same at 10-20% coverage.

Profiles measured across the test plot are shown in Figures 12 and 13. These profiles will be re-surveyed in future years to evaluate whether additional erosion occurs and to determine erosion rates.

Table 4. Summary of species and percent coverage for the relief test plot revegetated in 1993, in the two 3 ft x 30 ft point intercept transacts (points every 1 ft).

	Gravel	Litter	Grass	Yellow Sweetclover	Shrub	Bare
Transect 1	2	9	13	2	0	3
Transect 2	2	6	18	1	0	3
Average (%)	7	25	52	5	0	10

Note: species identified include, Rabbitbrush (*Chrysothamnus nauseosus*), Wheatgrass (Crested?), (*Agropyron desertorum*), Yellow sweetclover, (*Melilotus officinalis*), Indian Ricegrass (*Oryzopsis hymenoides*), Aster (tentative) (*Aster spp.*), Alfalfa (*Medicago sativa*).

Flat Test Plot (#2)

The test plot was set up on the east side of the waterbody in Dam 4. The vegetation as a whole is less dense than vegetation encountered on Dam 1. Ten minutes of walking through the area found no signs of erosion on the tailings surface. The flat plot and the more relief plot are therefore quite similar. The area has no measurable slope, there is no course for runoff to follow and create erosion.

The area adjacent to the waterbody was investigated and no signs of erosion were observed – it was not selected because it had slightly thicker vegetation than its surroundings. There are barren areas (> 50 ft^2) where no vegetation exists. The soil in these areas is still intact. There are no signs of smooth surfaces swept clean by wind erosion. The soil is lightly crusted on top.

Vegetation in the area is sparse covering only 20-25% of the ground surface. Within the test plots there is wheatgrass, sporadic rabbitbrush, but no yellow sweetclover. Yellow sweetclover is found near the test plot area. Additionally, an unidentified forb was found in the plot.

The cover material is the same light brown sandy gravel with high silt content. This is expected because the borrow material used to cover the tailings area in 1993 came from the same source in the north area of the pit. There is not much coarse rock at the surface, the ½" and greater rock covers 10-15% of the surface – the maximum rock size is 3". A soil sample was taken directly south of the test plot.

Relief Test Plot (#2)

The relief test plot is similar to the typical test area. There are no signs of erosion. The test plot is located east of the waterbody, approximately 1,200 ft south-east of the typical test plot. The results of a grading test on this sample are provided on Figure 11.

It is designated as the comparison plot because the vegetation is less dense, increasing its risk of erosion, and it has a depression running along the east side of the plot. The depression is not likely an effect of runoff because it does not have a smooth channel bottom, there is no slope in the test plot to encourage runoff, and piles of fine tailings lie undisturbed in the depression. Most likely the depression was a construction error.

The vegetation covers 15-20% of the land area; rabbitbrush is the most common species. There is litter including dead grass and dried forbs still rooted in the soil.

The cover material is similar to light brown material of the typical plot. The test plot has a slightly higher coarse rock on the surface (15-20%) and the maximum rock size is 3”.

Profiles measured across the test plot are shown in Figures 14 and 15. These profiles will be re-surveyed in future years to monitor if any additional erosion occurs and to determine erosion rates.

<u>Tailings Area Covered and Seeded in 2000:</u>

Flat Test Plot

Wind erosion is a definite possibility – the soil is dry and winds gust to high values. While working on the test plots wind gusts up to 40 mph were common. However, the wind erosion cannot be quantified; the soil has no obvious effects on the appearance of the cover surface. The wind is most likely picking up fine material uniformly across the slope resulting in the deflation of the fine particles until a "pavement" of coarser; wind resistant particles are formed. Observations of older, re-vegetated tailings, demonstrate that such erosion ceases once a vegetative cover has developed.

There is no measurable slope in the area. No rills were found in our investigation.

Vegetation has not been established on the cover. There are areas of darker soil with tree roots where trees were removed to place the cover. Some annuals and yellow sweetclover sporadically appear on the cover surface.

The cover is a sandy gravel with a high silt content, the material is light brown. There is some coarse rock (¾” and greater) incorporated in the soil matrix. The coarse rock covers 10-20% of the soil area; the maximum size of rock encountered is six inches. A soil sample was taken south of the test plot. The results of a grading test on this sample are provided on Figure 11.

Relief Test Plot

The relief test plot is similar to the flat test plot. The test plot is 500 m NNE of the first plot in the northwest corner of the tailings impoundment. There are no signs of rills or erosion in the area. There is little relief in the test plots; the entire area has been graded to level.

Vegetation is not established in this test plot, although there are some annuals and yellow sweetclover beginning to grow.

The material is a light brown sandy gravel with a high silt content. Coarse rock content is the same covering, approximately 10-20% of the area. A soil sample was not taken, as the soil type is similar to the soil sample taken at the typical test plot.

The horizontal profiles measured across the two parts of the test plot are provided in Figures 16 and 17. These profiles will be re-surveyed in future years to evaluate whether additional erosion occurs, and to determine erosion rates.

5.1.2 Laboratory Investigations

This section presents and discusses the results of standard sieve analyses performed on samples collected during this study. Figure 4 shows the particle size distribution of the samples collected from the surface of the downstream slopes of Dam 1 and Dam 4. As expected, the distribution of particle sizes for the two embankment surface materials are very similar. These materials are classified as GM, silty gravels (small percentage of fines), based on the Unified Soil Classification System (USCS). This type of material is considered satisfactory to good in terms of erosion resistance, minimizing the loss of material during storm events.

Figure 11 shows the particle size distribution of the samples collected from the surface of the various tailings areas assessed in this study. As expected, the distribution of particle sizes for the four tailings area surface materials are very similar. These materials are classified as GM-GC, silty to clayey gravels, based on the Unified Soil Classification System (USCS). This type of material is considered satisfactory to good in terms of erosion resistance for minimizing the loss of material during extreme storm events.

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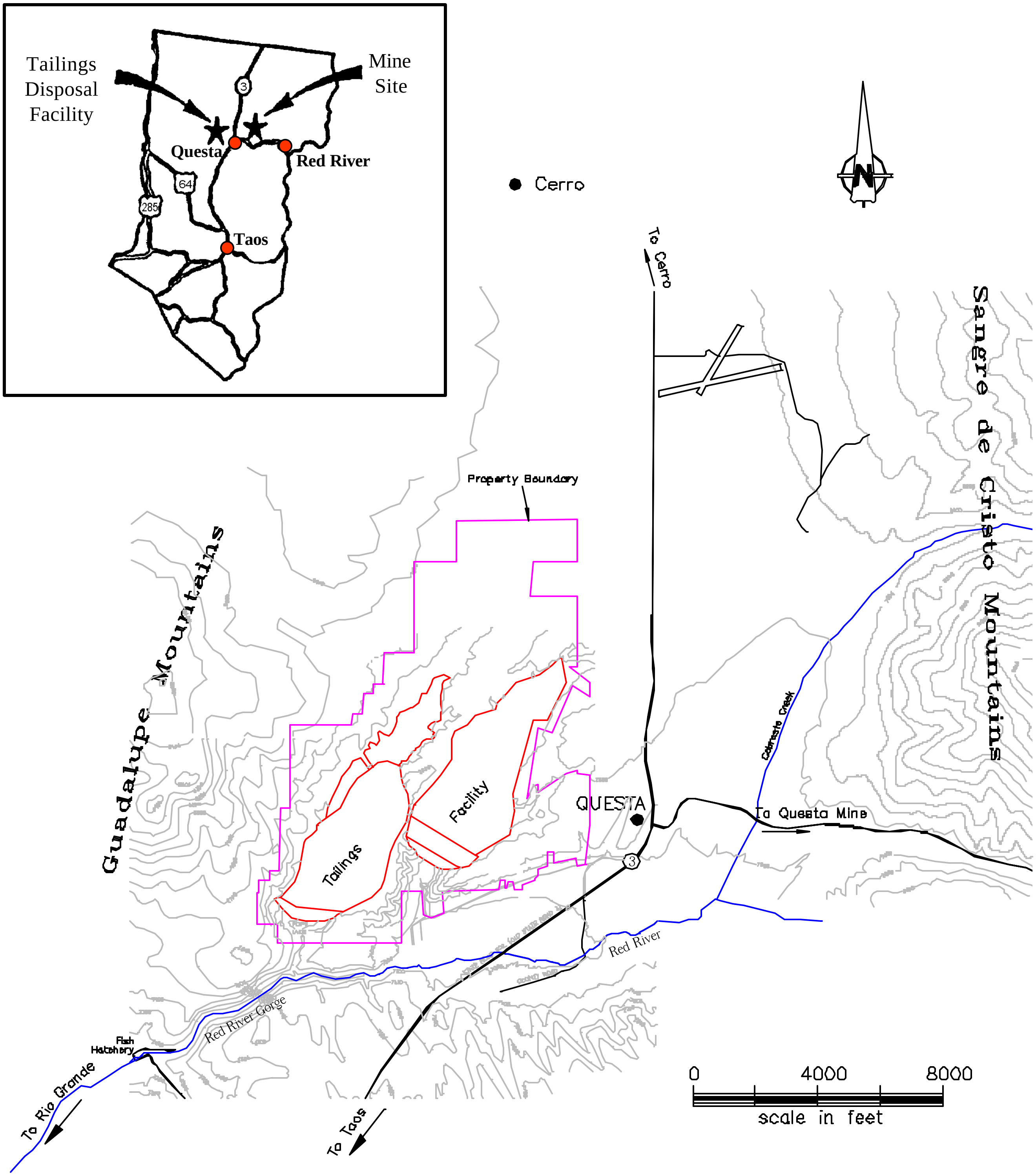
Figures

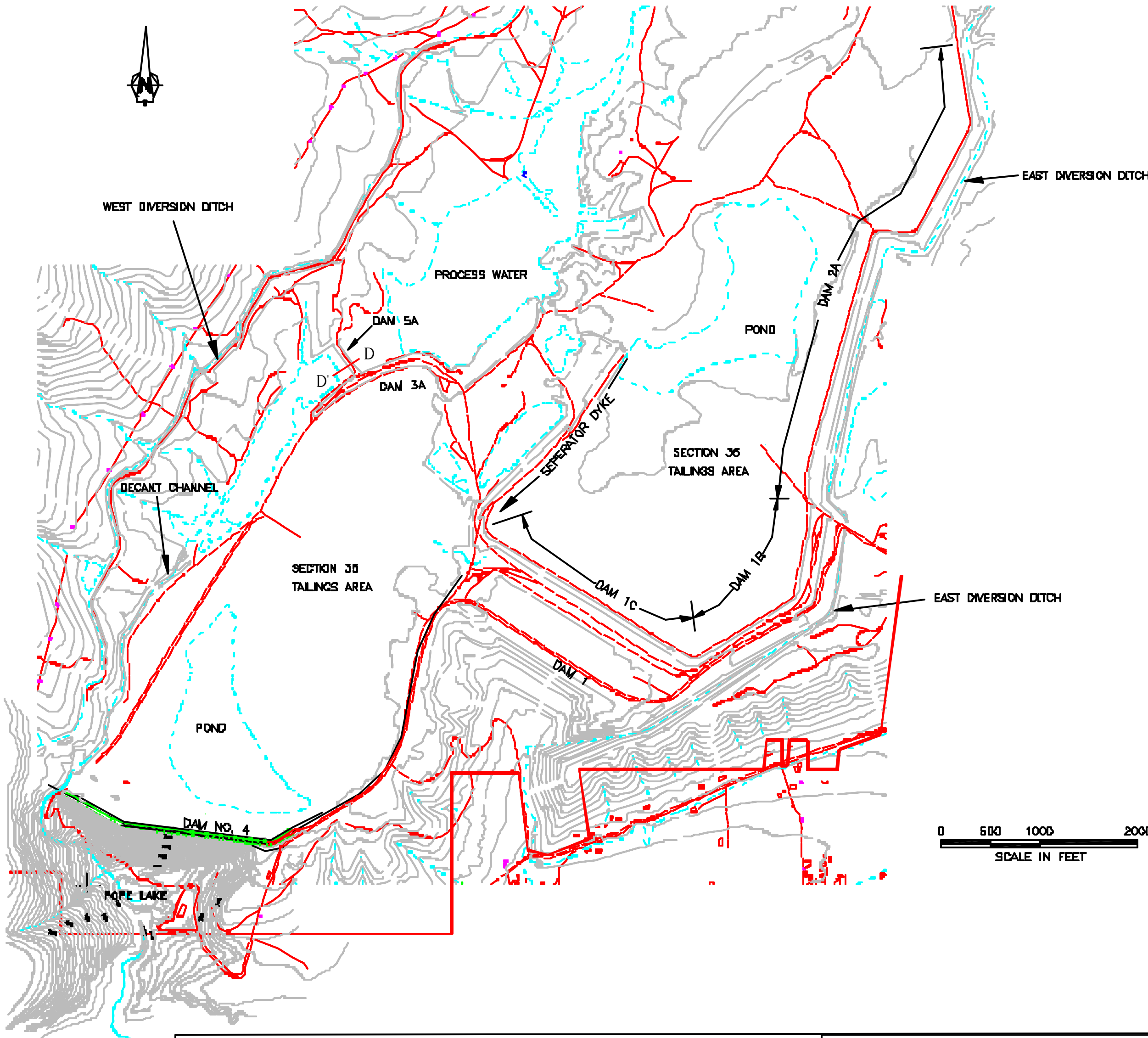


CLIENT:	MOLYCORP, INC
PROJECT No	052010
PROJECT:	Surface Erosion and Stability Analysis
LOCATION:	QUESTA TAILINGS FACILITY NEW MEXICO, USA

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

Location map

DATE:	DRAWN BY:	FIGURE:
June 2000	JG	1



CLIENT:	MOLYCORP, INC
PROJECT No	052010
PROJECT:	SURFACE EROSION AND STABILITY ANALYSIS
LOCATION:	QUESTA MINE NEW MEXICO, USA

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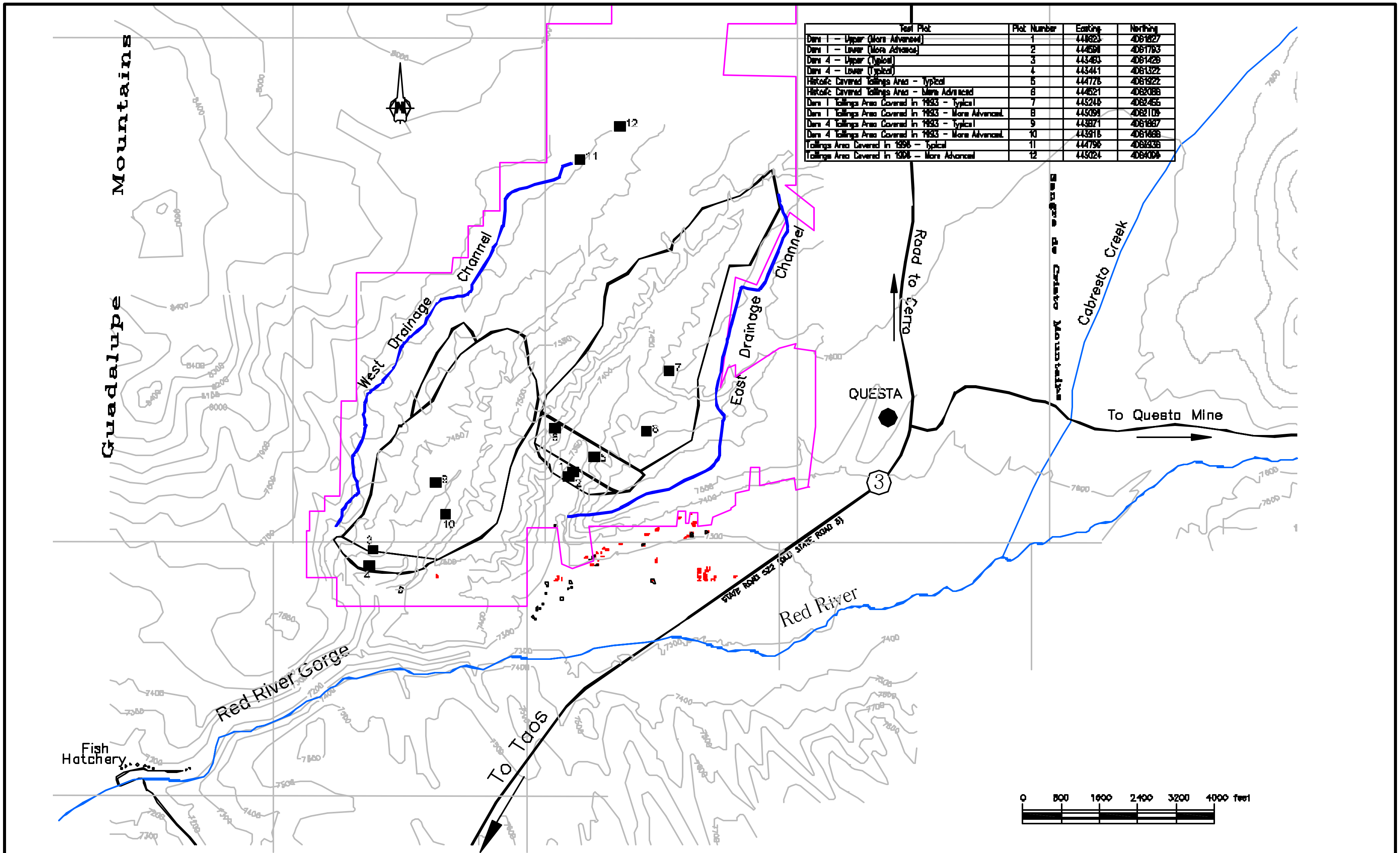
Consulting Geotechnical and Environmental Engineers

Tailings Facility Overview

DATE:	DRAWN BY:	FIGURE:
June 2000	JG	2



Test Plot	Plot Number	Easting	Northing
Dam 1 – Upper (More Advanced)	1	444623	4061827
Dam 1 – Lower (More Advanced)	2	444591	4061793
Dam 4 – Upper (Typical)	3	443463	4061426
Dam 4 – Lower (Typical)	4	443441	4061322
Historic Covered Tailings Area – Typical	5	444776	4061922
Historic Covered Tailings Area – More Advanced	6	444521	4062086
Dam 1 Tailings Area Covered in 1993 – Typical	7	445240	4062455
Dam 1 Tailings Area Covered in 1993 – More Advanced	8	445091	4062109
Dam 4 Tailings Area Covered in 1993 – Typical	9	443871	4061867
Dam 4 Tailings Area Covered in 1993 – More Advanced	10	443916	4061666
Tailings Area Covered in 1996 – Typical	11	444790	4063936
Tailings Area Covered in 1996 – More Advanced	12	445024	4064094

CLIENT:	MOLYCORP, INC
PROJECT No	052010
PROJECT:	SURFACE EROSION AND STABILITY ANALYSIS
LOCATION:	QUESTA MINE NEW MEXICO, USA

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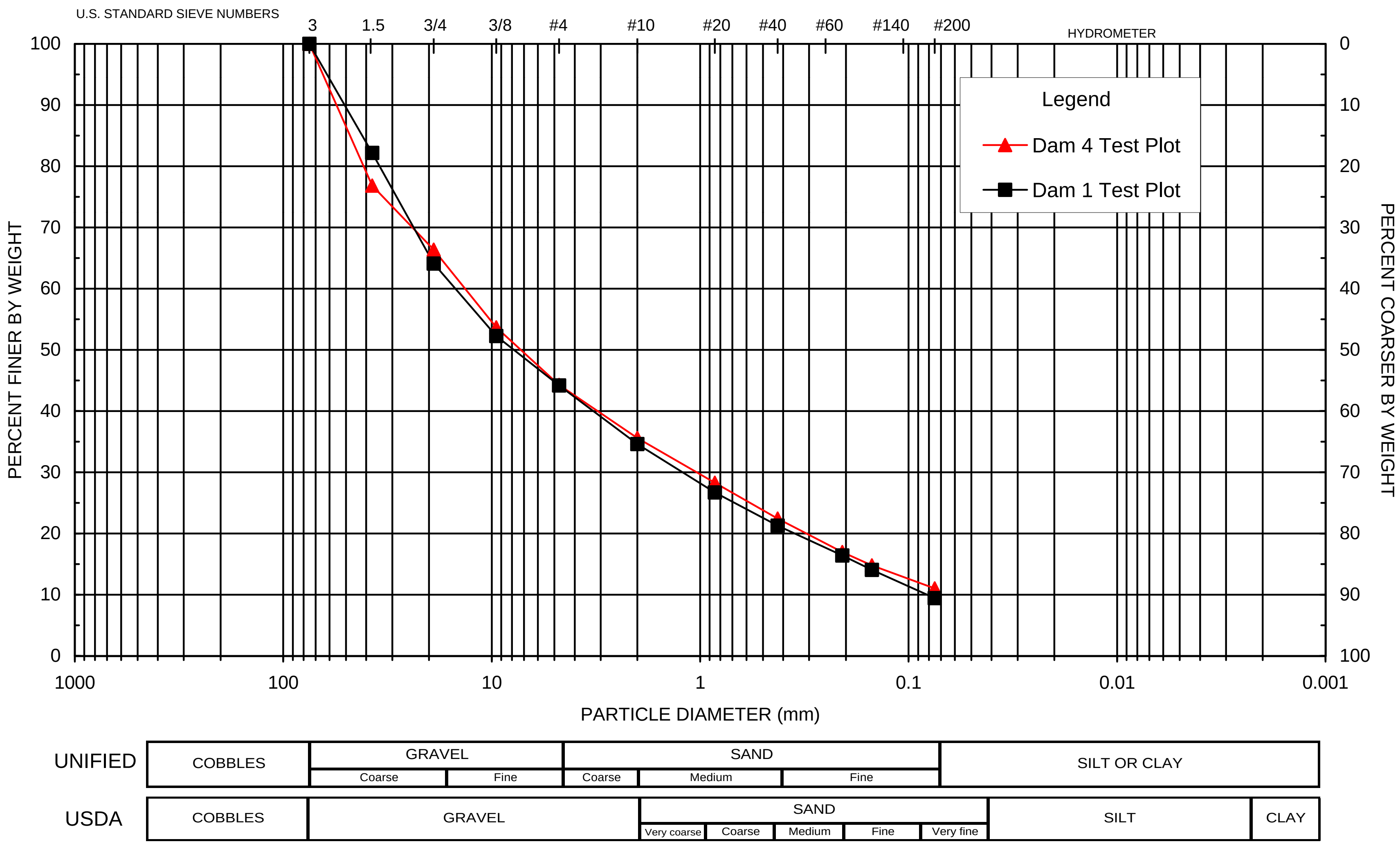
Surface Erosion Test Plots

DATE:	DRAWN BY:	FIGURE:
June 2000	JG	3



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PROJECT No. 52010	SURFACE EROSION AND STABILITY ANALYSIS
Questa Tailings Facility Surface Erosion Study	Figure 4. Particle size distributions of samples collected from surface erosion test plots on downstream slopes of Dam 1 and Dam 4.

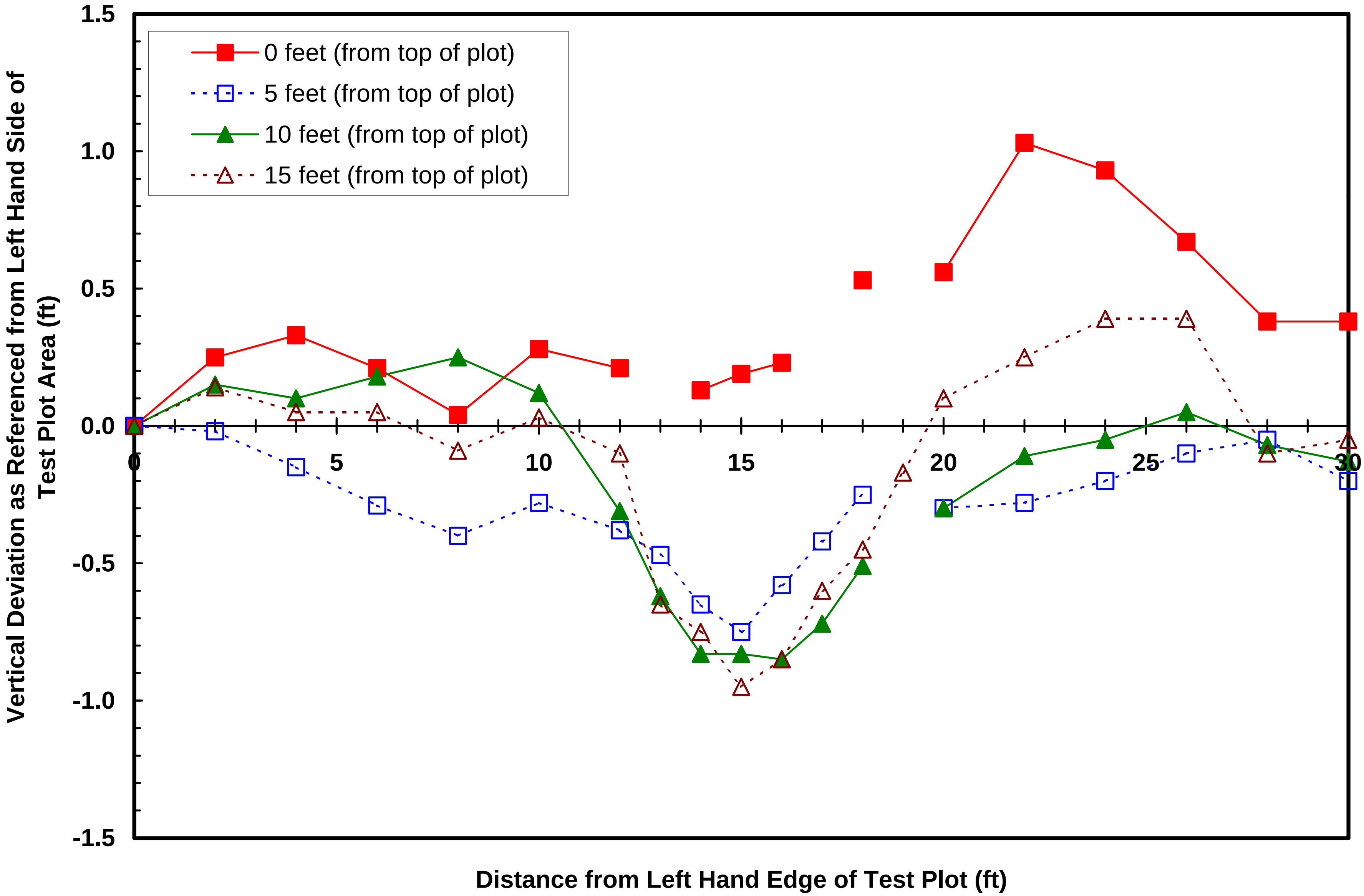


Figure 5.
Profile of Dam 1 Upper Slope Test Plot Surface ("more advanced" erosion characteristics).

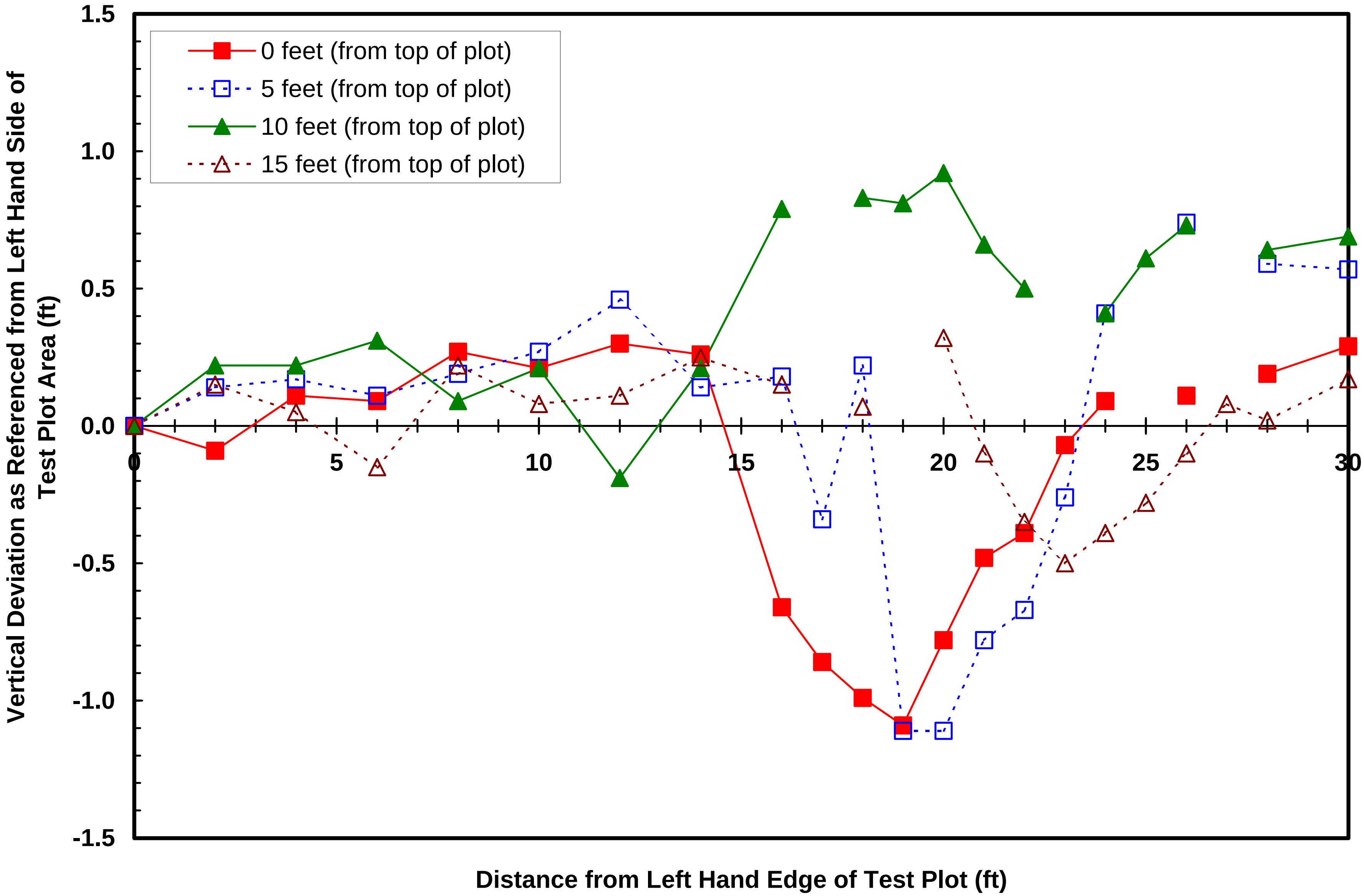


Figure 6.
Profile of Dam 1 Lower Slope Test Plot Surface ("more advanced" erosion characteristics).

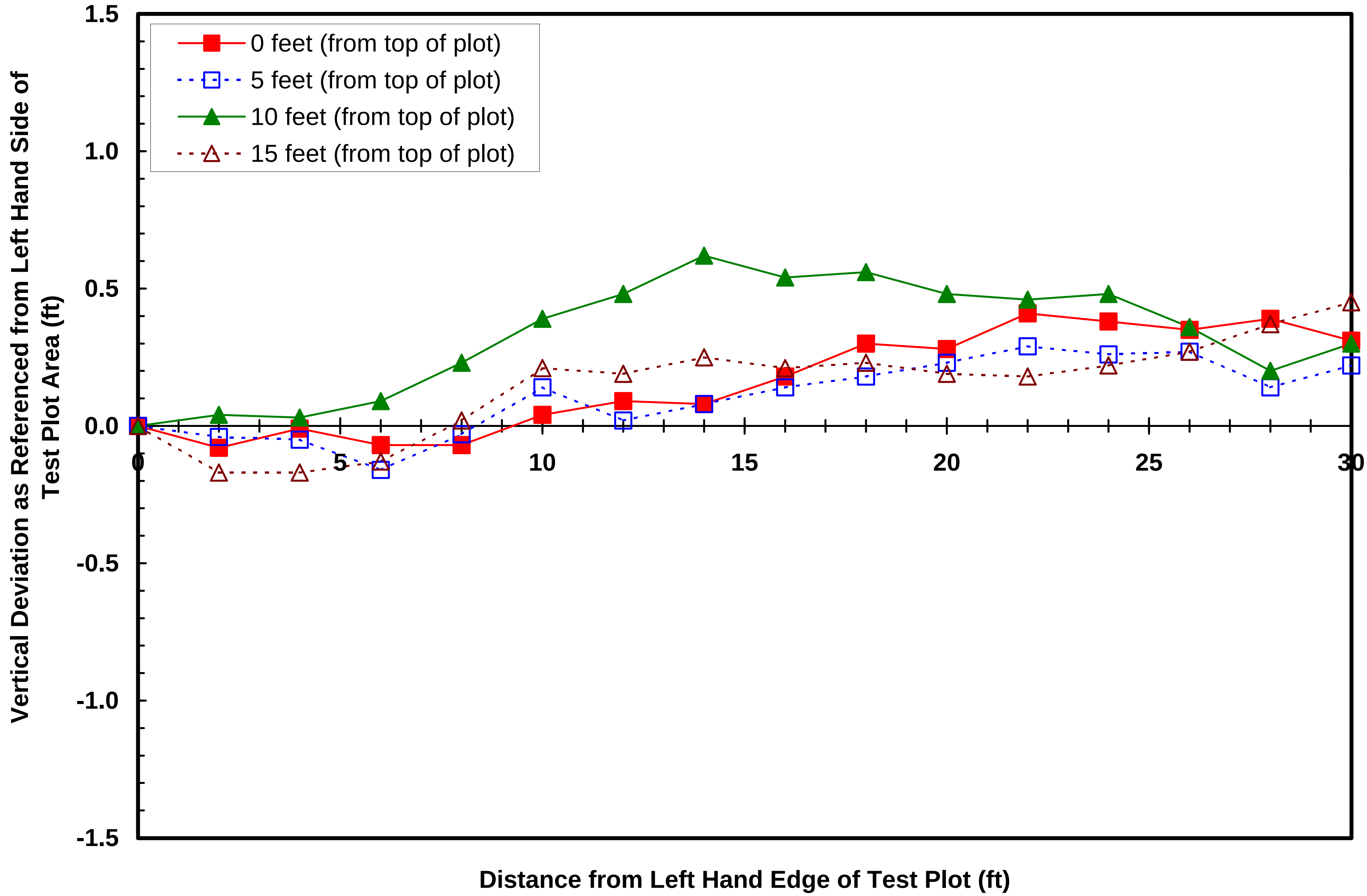


Figure 7.
Profile of Dam 4 Upper Slope Test Plot Surface ("typical" erosion characteristics).

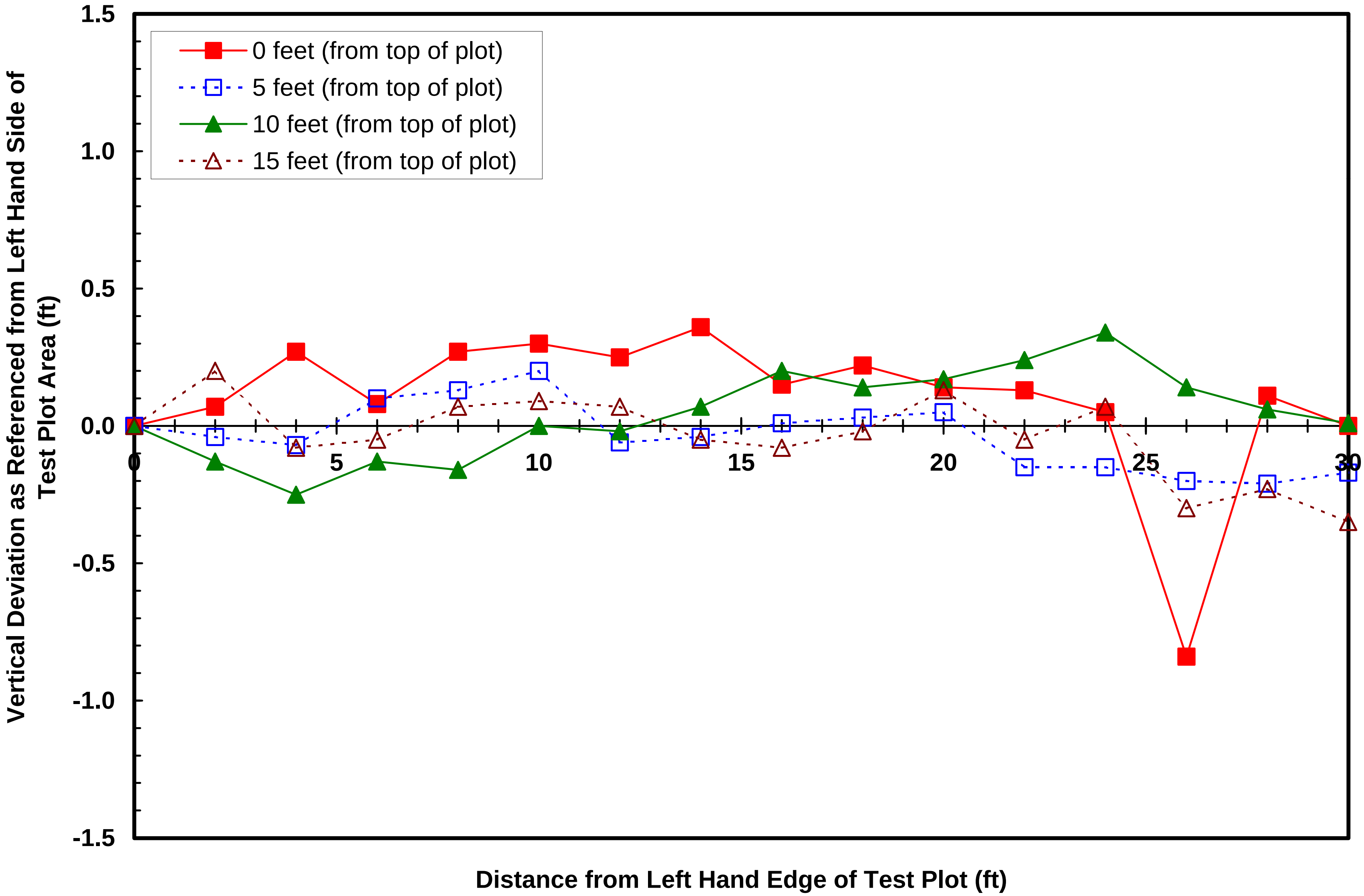


Figure 8.
Profile of Dam 4 Lower Slope Test Plot Surface ("typical" erosion characteristics).

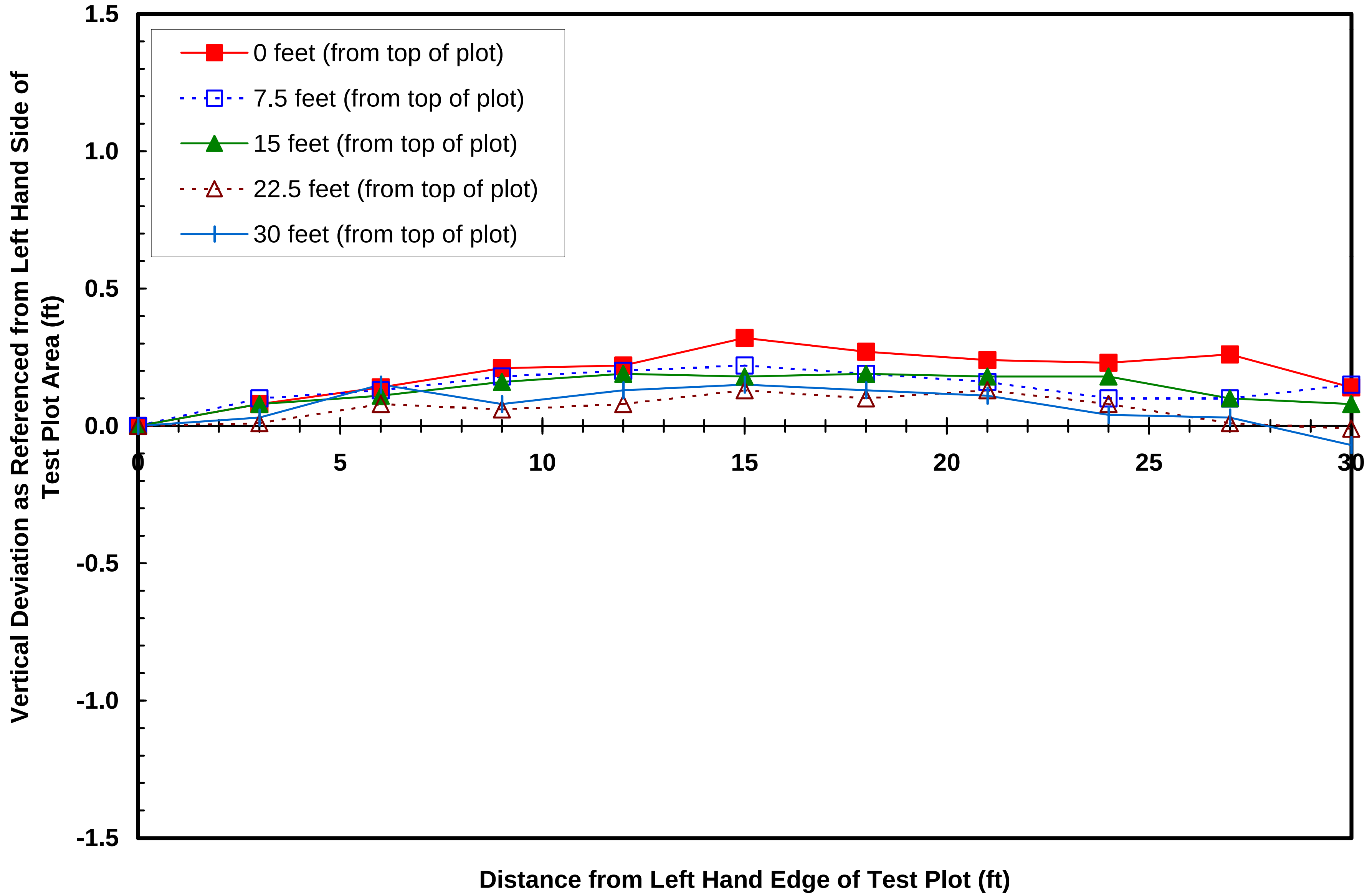


Figure 9.
Profile of Historic Covered Tailings Area Test Plot Surface ("typical" erosion characteristics).

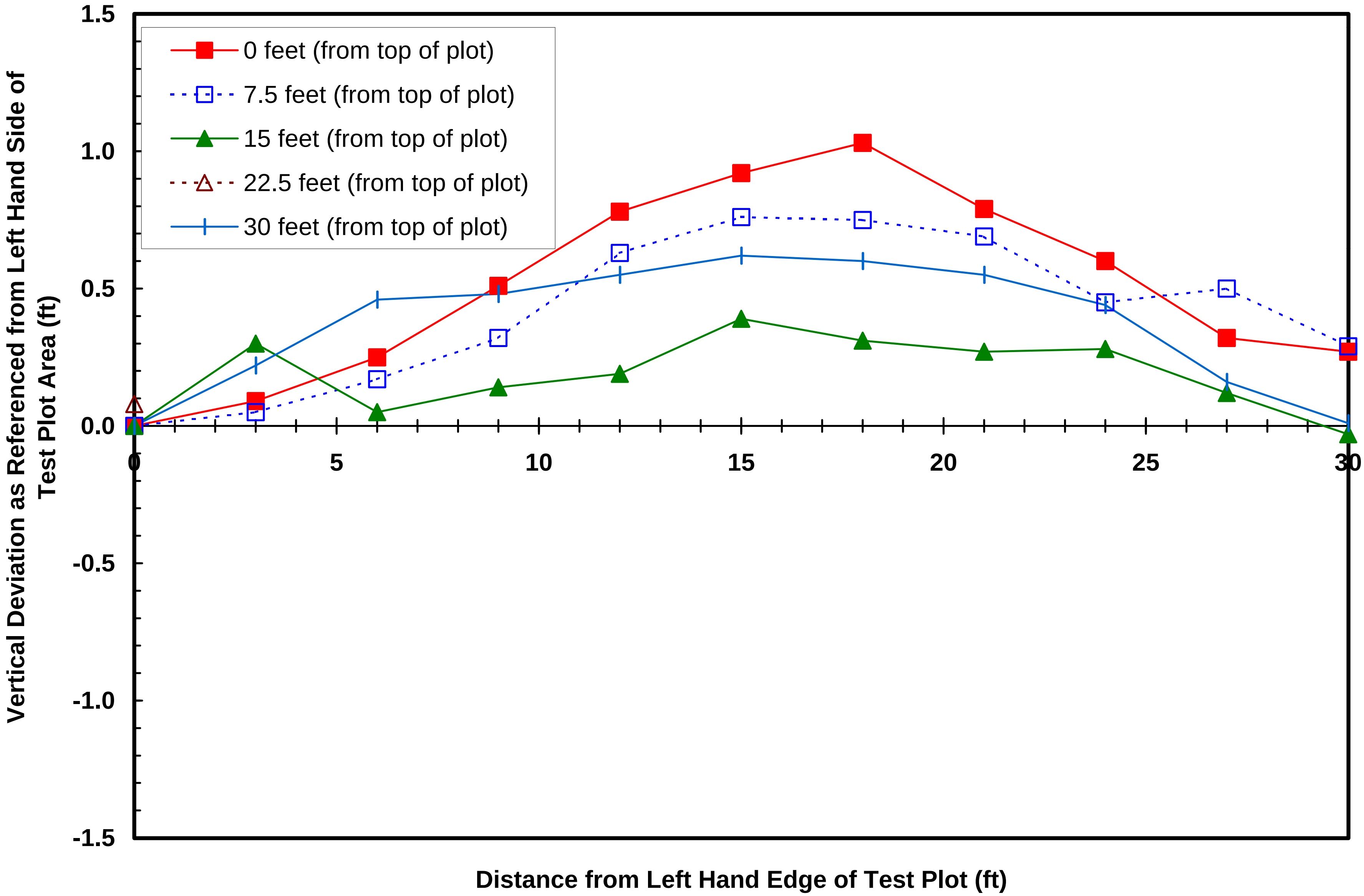
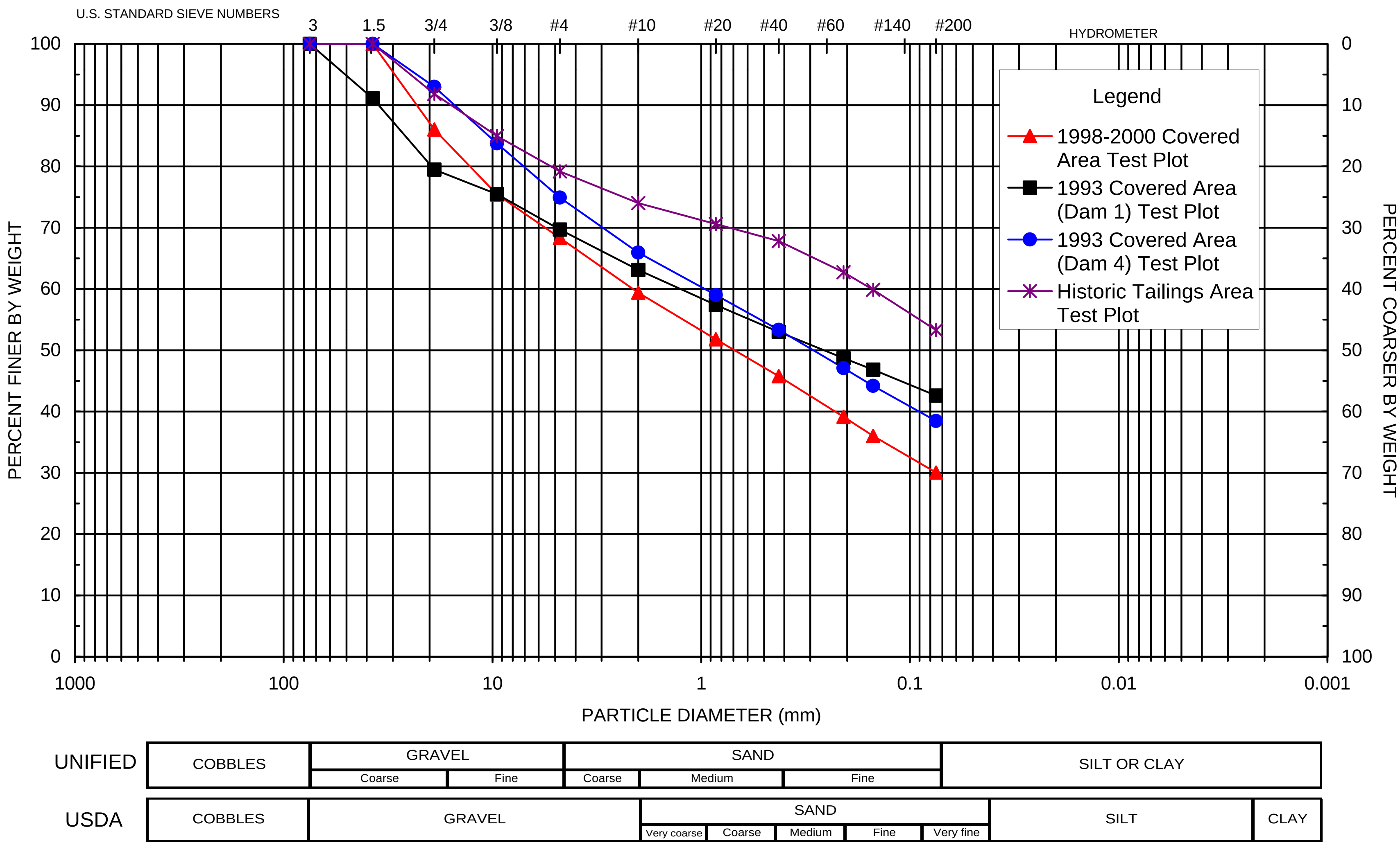


Figure 10.
Profile of Historic Covered Tailings Area Test Plot Surface ("more advanced" erosion characteristics).



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PROJECT No. 52010

SURFACE EROSION AND STABILITY ANALYSIS

Questa Tailings Facility
Surface Erosion Study

Figure 11. Particle size distributions of samples collected from surface erosion test plots on various covered and revegetated tailings area.

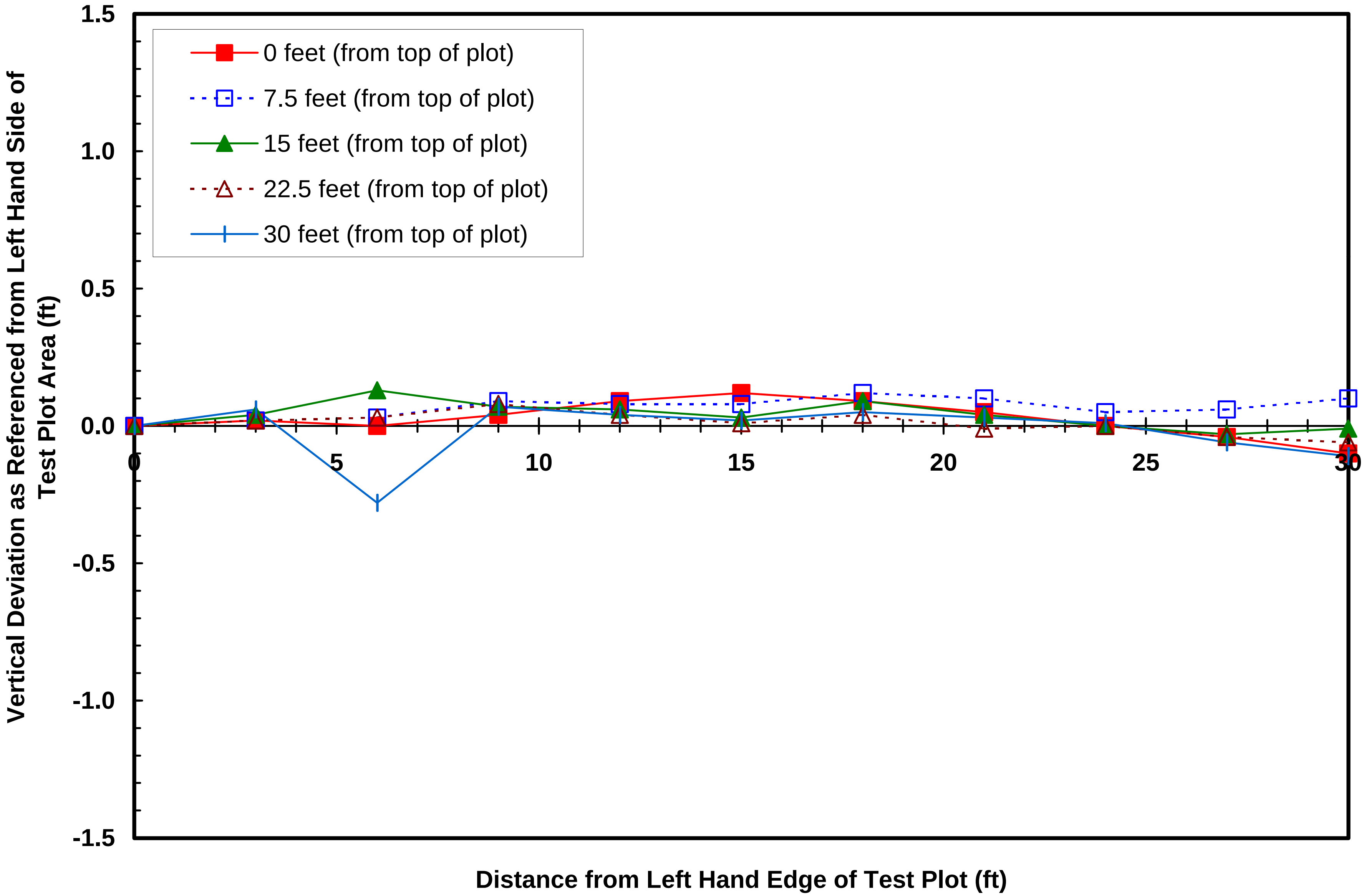

Figure 12.
Profile of Tailings Area Covered in 1993 Test Plot 1 Surface ("typical" erosion characteristics).

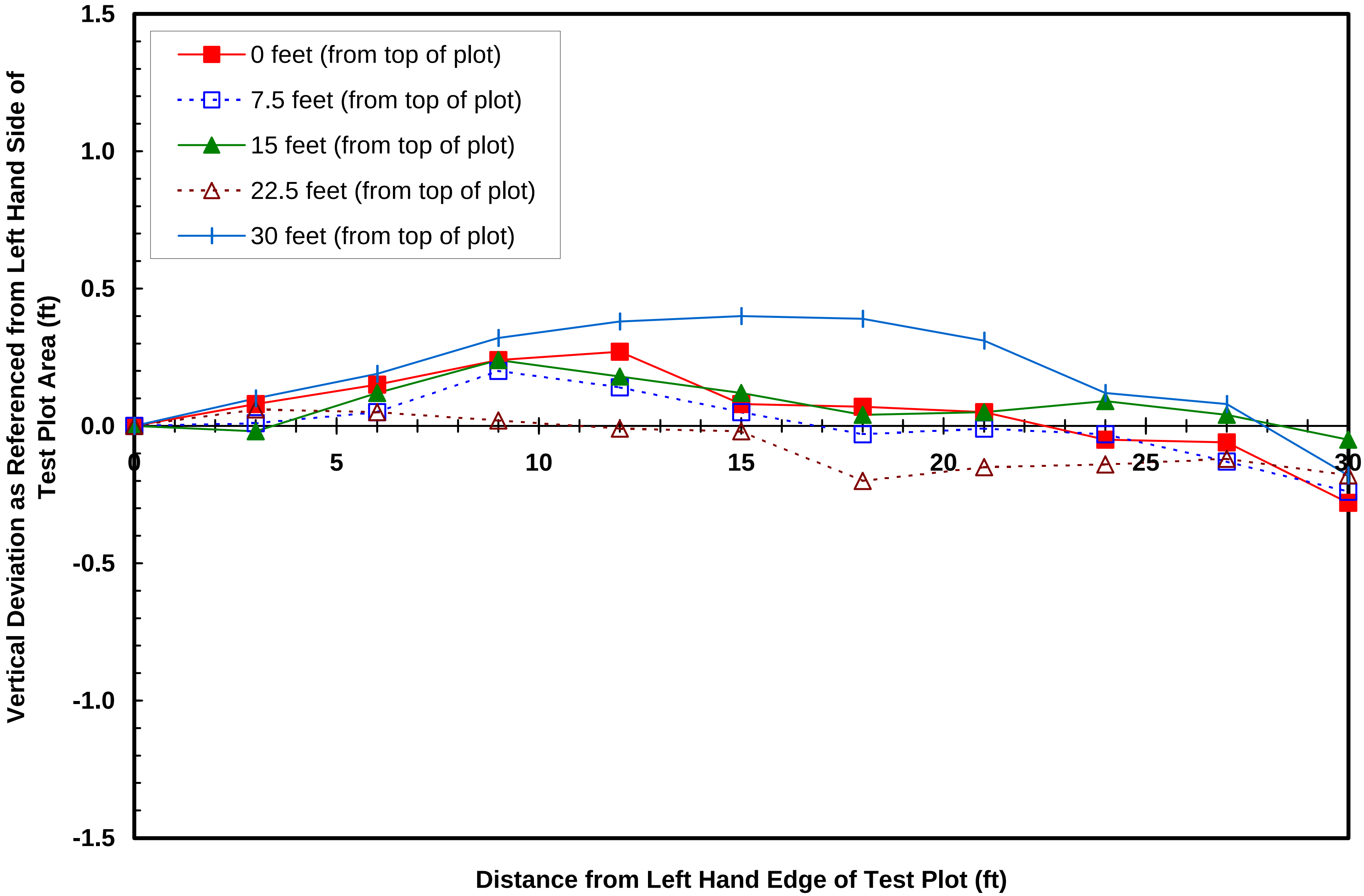

Figure 13.
Profile of Tailings Area Covered in 1993 Test Plot 1 Surface ("more advanced" erosion characteristics).

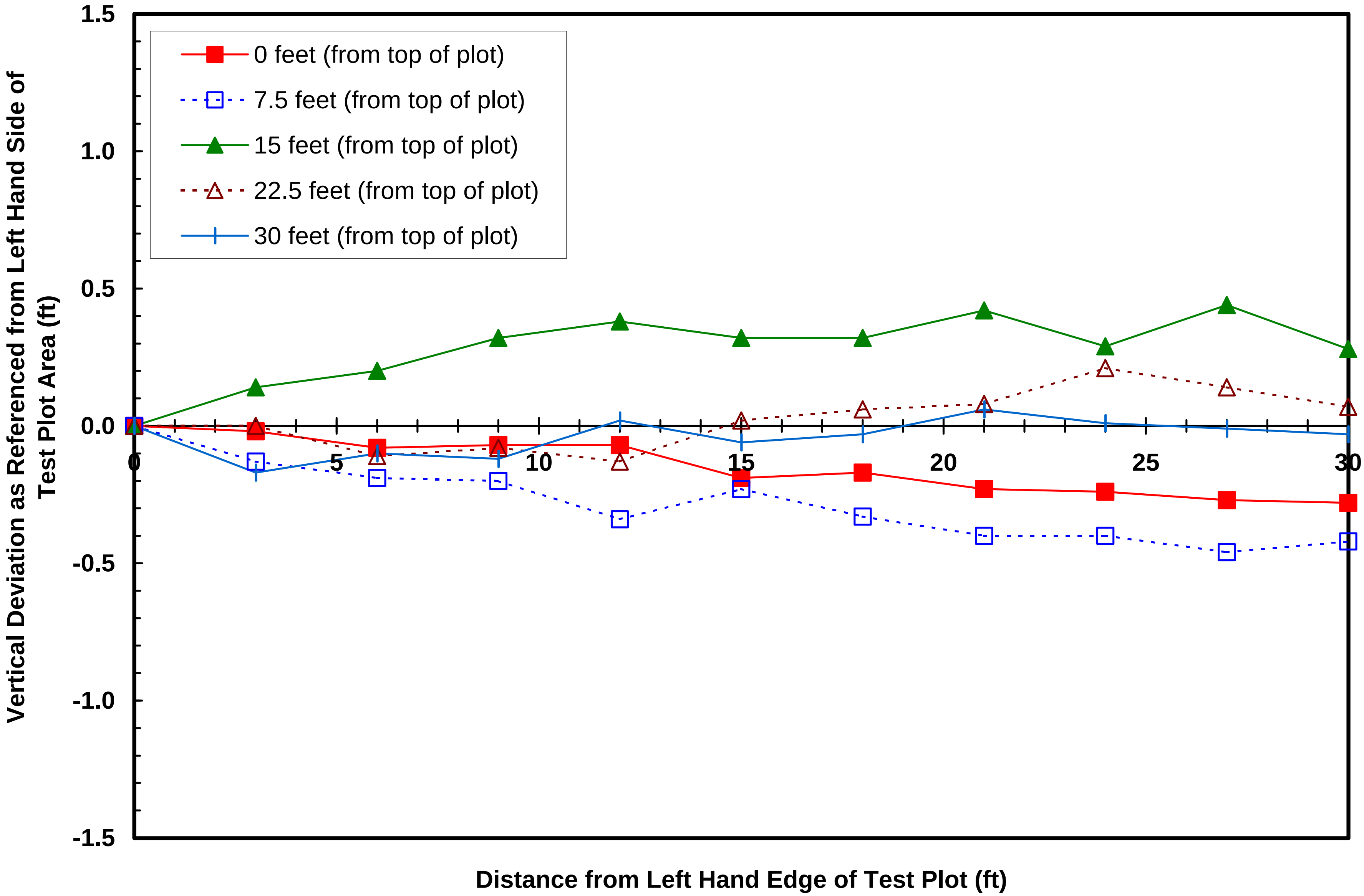

Figure 14.
Profile of Tailings Area Covered in 1993 Test Plot 2 Surface ("typical" erosion characteristics).

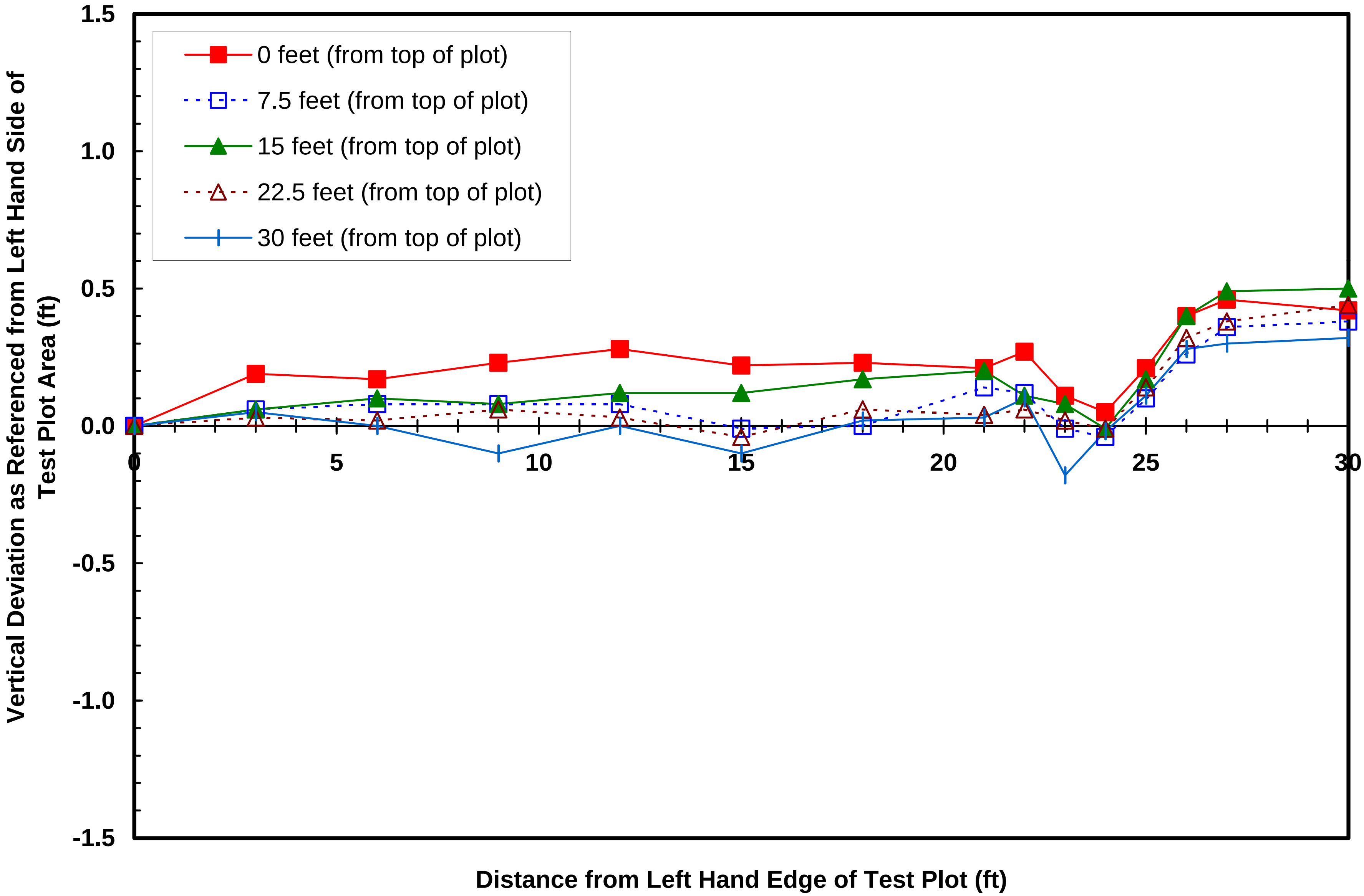

Figure 15.
Profile of Tailings Area Covered in 1993 Test Plot 2 Surface ("more advanced" erosion characteristics).

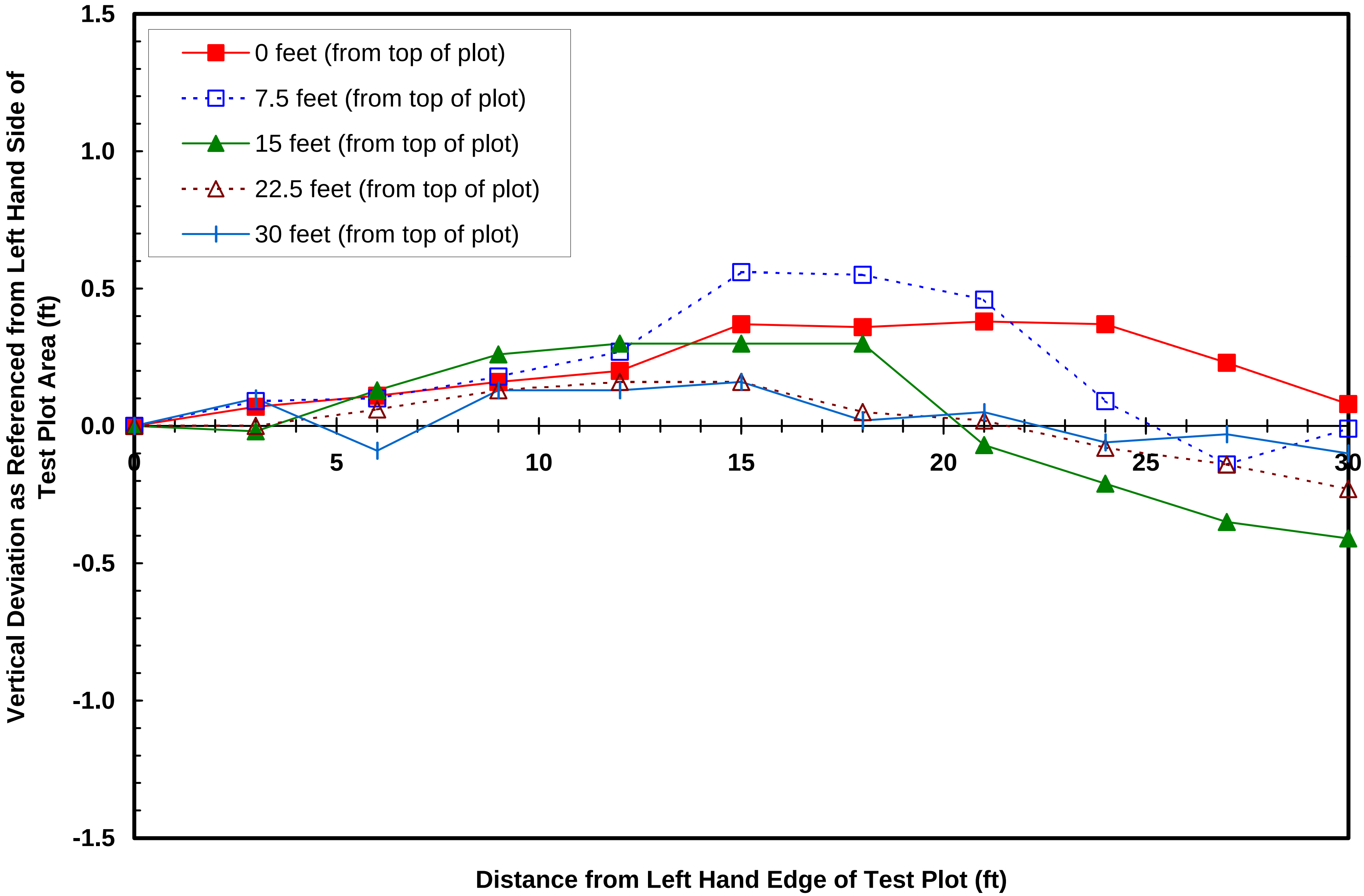

Figure 16.
Profile of Tailings Area Covered in 1998-2000 Test Plot Surface ("typical" erosion characteristics).

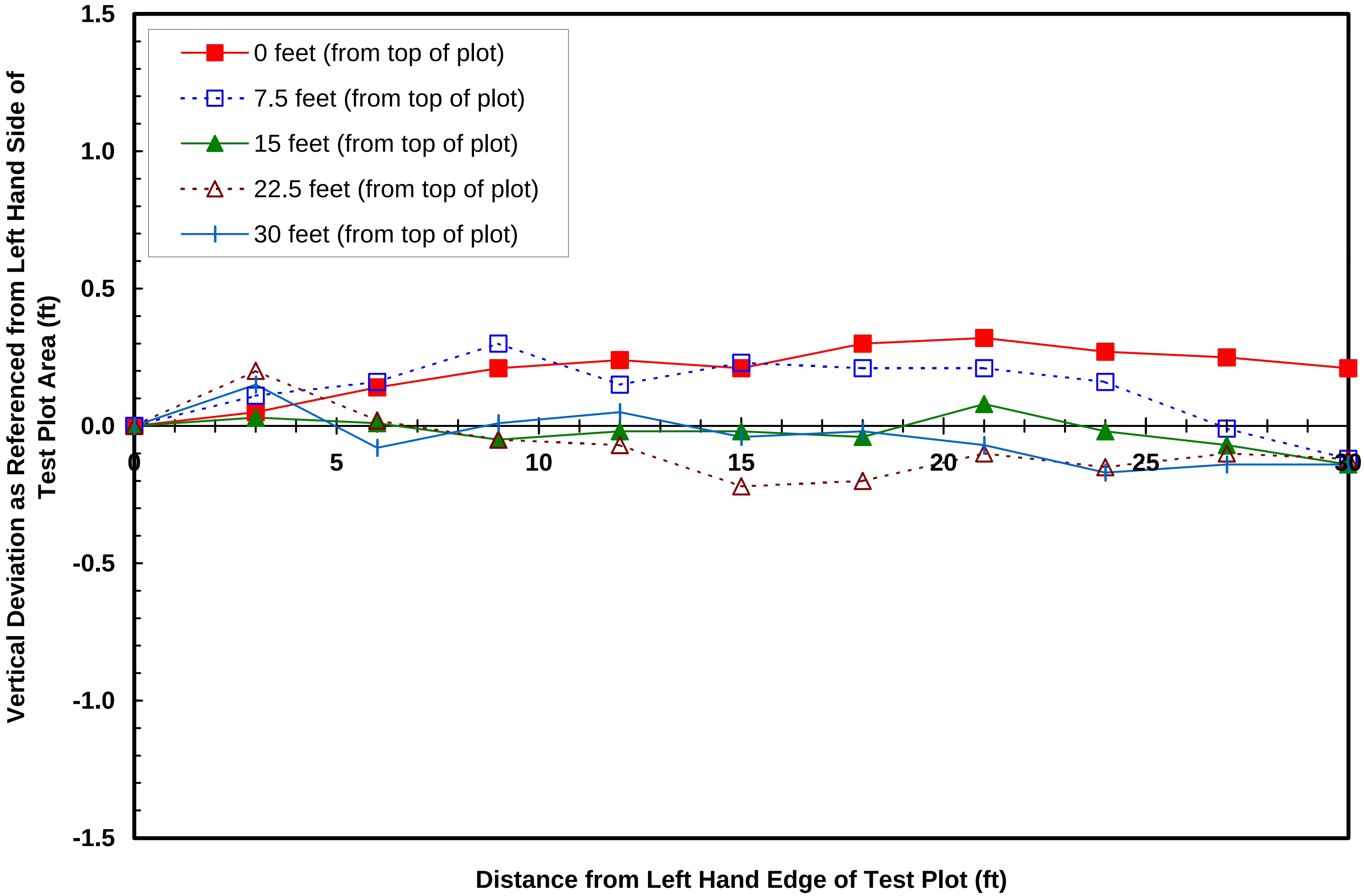

Figure 17.
Profile of Tailings Area Covered in 1998-2000 Test Plot Surface ("more advanced" erosion characteristics).

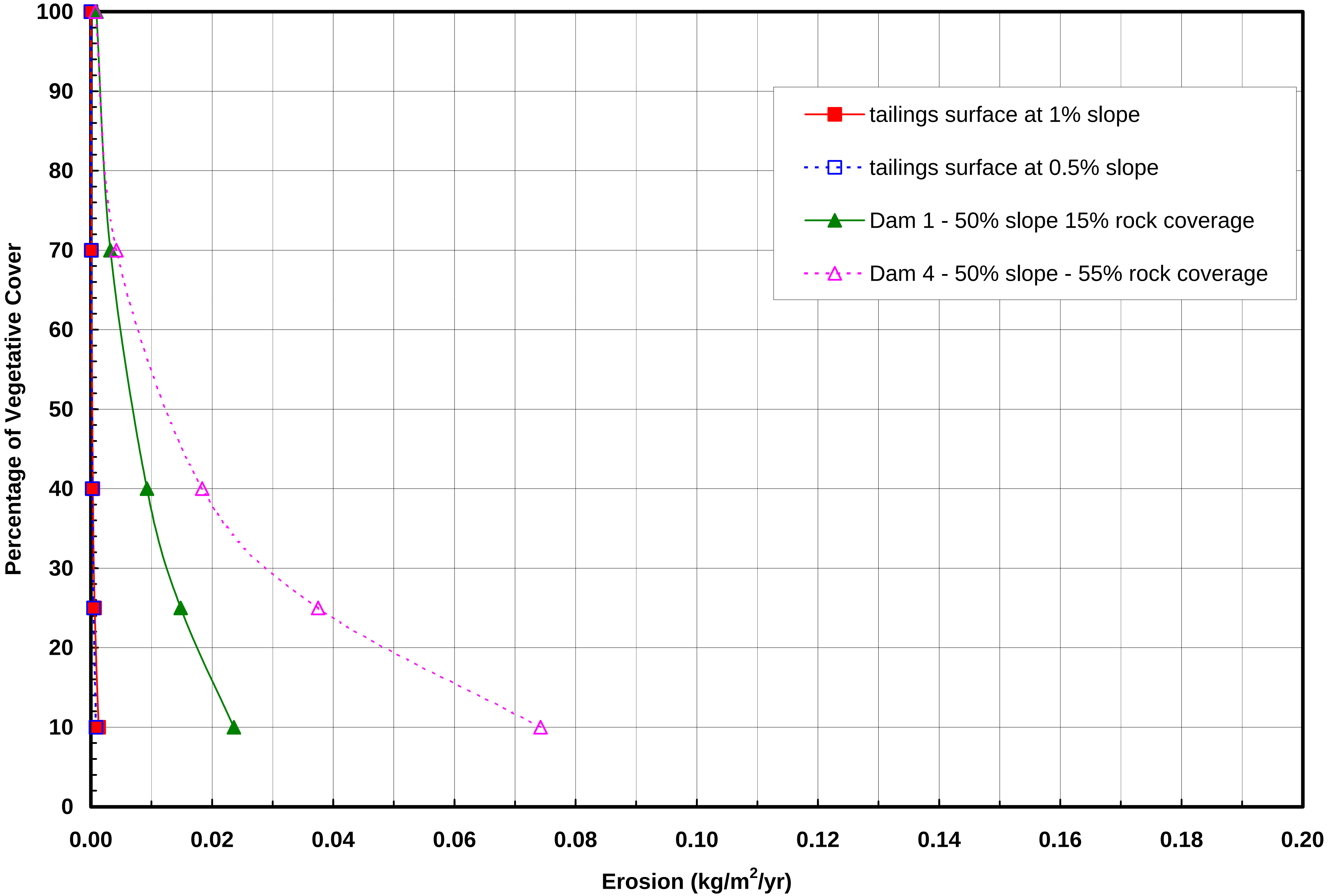

Figure 18: Predicted Erosion (RUSLE) for Fine Cover Material as a Function of Vegetation Cover

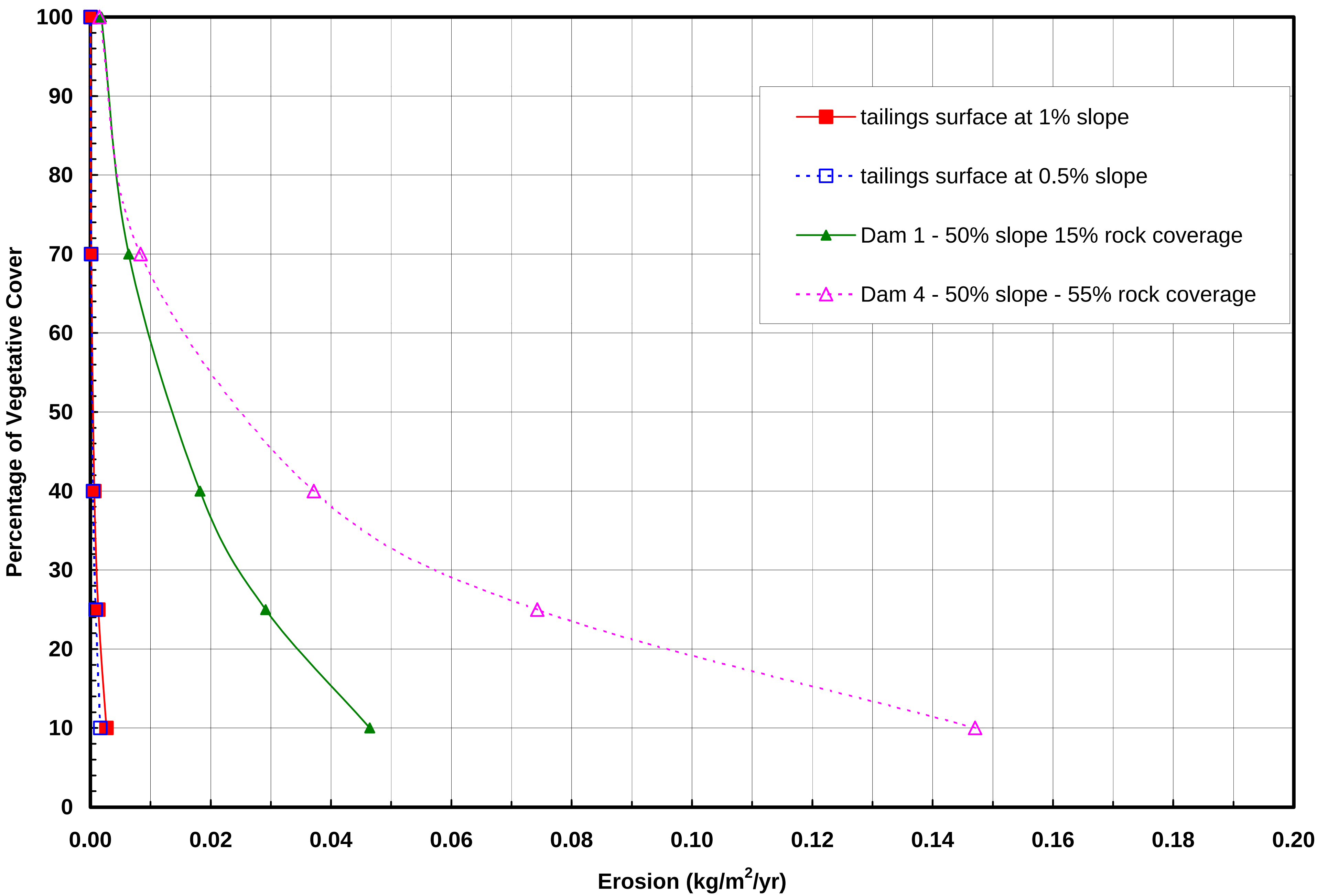

Figure 19: Predicted Erosion (RUSLE) for Coarse Cover Material as a Function of Vegetation Cover

Photos

Photo 1: Looking north showing the downstream face of Dam 1.

Photo 2: Upper slope of Dam 1 looking west.

Photo 3: A 3 ft x 3 ft test plot created on the lower slope of Dam 1; representative only of the coarse rock (i.e. not vegetation) on the dam slope.

Photo 4: Looking upslope of the 3 ft x 3 ft test plot on the lower slope of Dam 1.

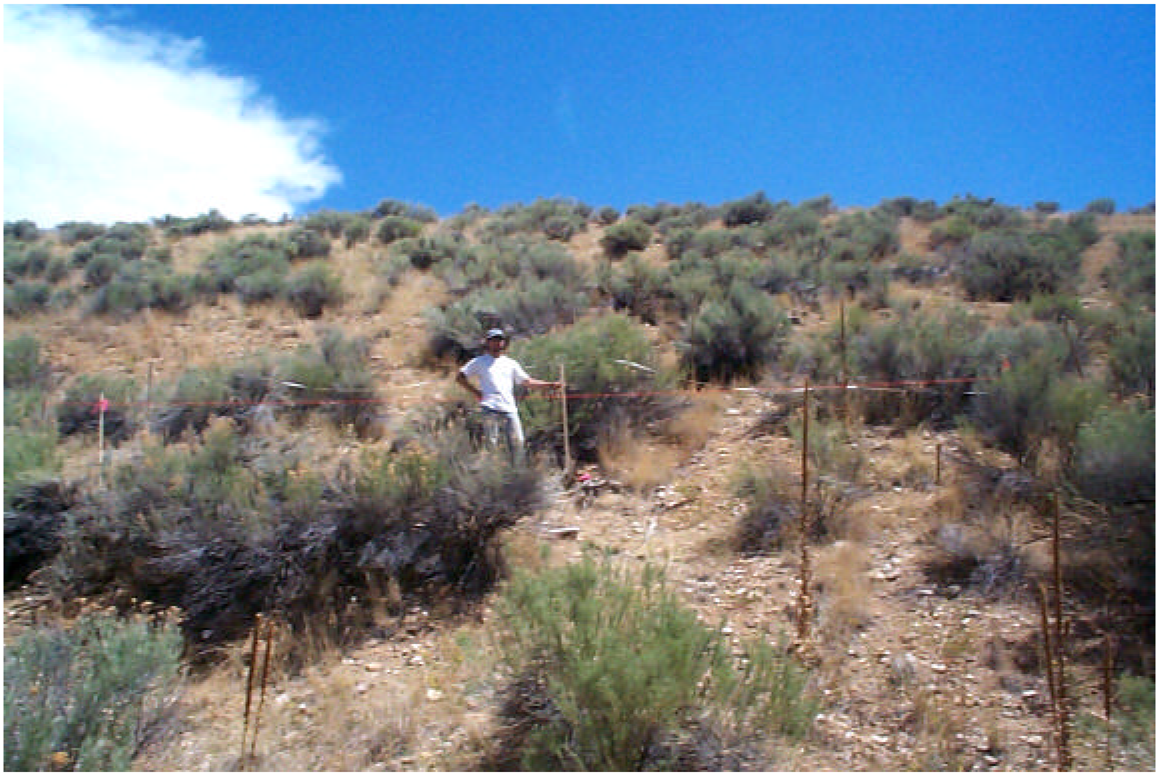

Photo 5: The 30 ft x 15 ft test plot near the toe of Dam 1.

Photo 6: Small gully near the toe of Dam 1; pink flagging tape at the edge of the gully.

Photo 7: Looking north showing the downstream face of Dam 4.

Photo 8: Middle section of the downstream face of Dam 4; coarse rock layer at the toe.

Photo 9: Mid-slope of Dam 4 looking west.

Photo 10: Close-up of the coarse rock layer at the toe of Dam 4.

Photo 11: A 3 ft x 3 ft test plot created on the lower slope of Dam 4; representative only of the coarse rock (i.e. not vegetation) on the dam slope.

Photo 12: Looking upslope of the 3 ft x 3 ft test plot on the lower slope of Dam 4.

Photo 13: The 30 ft x 15 ft test plot near the crest of Dam 4.

Photo 14: Looking north showing the downstream face of Dam 5A.

Photo 15: East abutment wall of Dam 5A.

Photo 16: West abutment wall of Dam 5A.

Photo 17: Looking north at the north end of the East Diversion Ditch from the tailings area (survey stop E-1).

Photo 18: Small gully in the east slope of the East Diversion Ditch at survey stop E-2.

Photo 19: East slope of the East Diversion Ditch at survey stop E-3 (no erosion; dry channel bottom).

Photo 20: East Diversion Ditch looking north from the road crossing at survey stop E-4.

Photo 21: West slope of the East Diversion Ditch at survey stop E-5 (no erosion).

Photo 22: Looking north at the east slope of the East Diversion Ditch from survey stop E-6.

Photo 23: Small gully in the east slope of the East Diversion Ditch at survey stop E-7.

Photo 24: Moderate gullies in the east slope of the East Diversion Ditch at survey stop E-8.

Photo 25: East/south slope of the East Diversion Ditch at survey stop E-10 (no erosion).

Photo 26: Small to moderate gullies in the east/south slope of the East Diversion Ditch at survey stop E-14.

Photo 27: West Diversion Ditch looking south from the north end of the ditch (survey stop D-1).

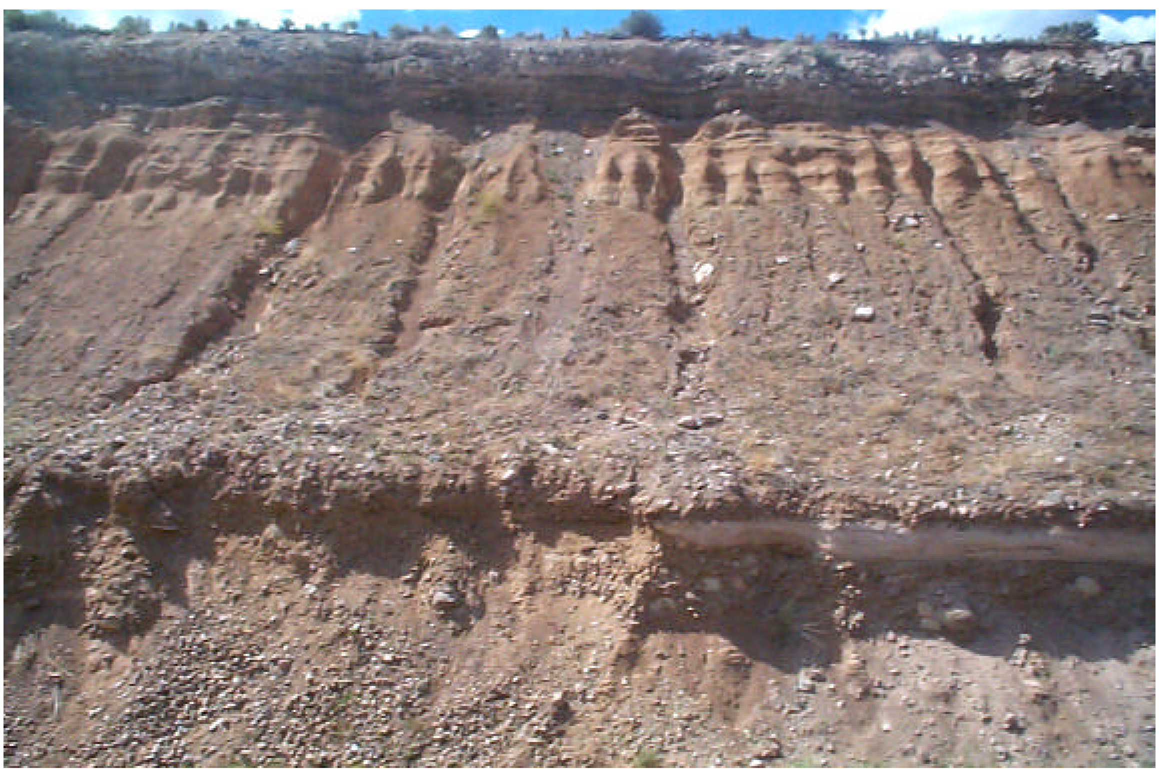

Photo 28: Moderate gullies in the west slope of the West Diversion Ditch at survey stop D-1.

Photo 29: Cave-ins on the west slope of the West Diversion Ditch and fallen debris in the channel bottom at survey stop D-2.

Photo 30: Earth flows originating from gullies in the east slope of the West Diversion Ditch at survey stop D-4.

Photo 31: West Diversion Ditch looking south near survey stop D-5 (near vertical side-slopes).

Photo 32: Example of the vegetation and cover material on the tailings area surface between Dam 1 and 1C.

Photo 33: Tailings on top of interim cover material near the toe of Dam 1C.

Photo 34: The 30 ft x 30 ft test plot representative of "typical" conditions on the surface of a tailings area covered and revegetated prior to 1974 (between Dam 1 and 1C).

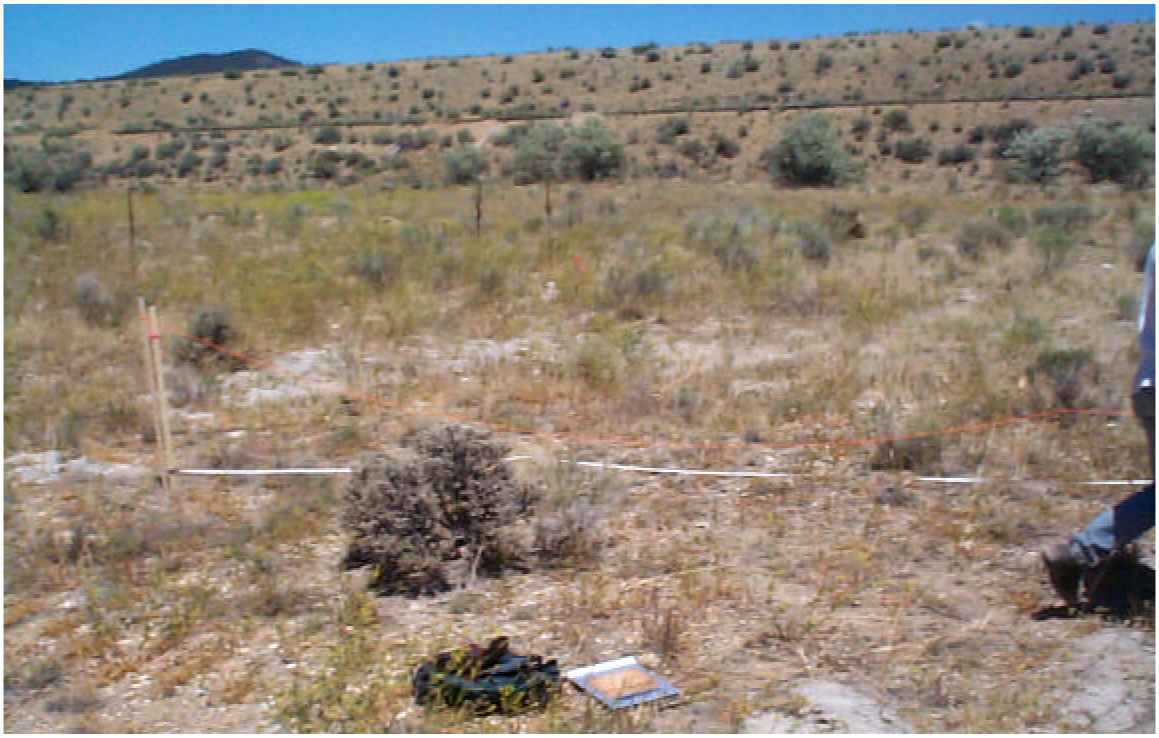

Photo 35: The 30 ft x 30 ft test plot representative of “more erosive” conditions on the surface of a tailings area covered and revegetated prior to 1974 (between Dam 1 and 1C).

Photo 36: The 30 ft x 30 ft test plot representative of “typical” conditions on the surface of a tailings area covered and revegetated in 1993 (Dam 1 tailings area).

Photo 37: Close-up of the surface of the "typical" test plot on the surface of a tailings area covered and revegetated in 1993 (Dam 1 tailings area).

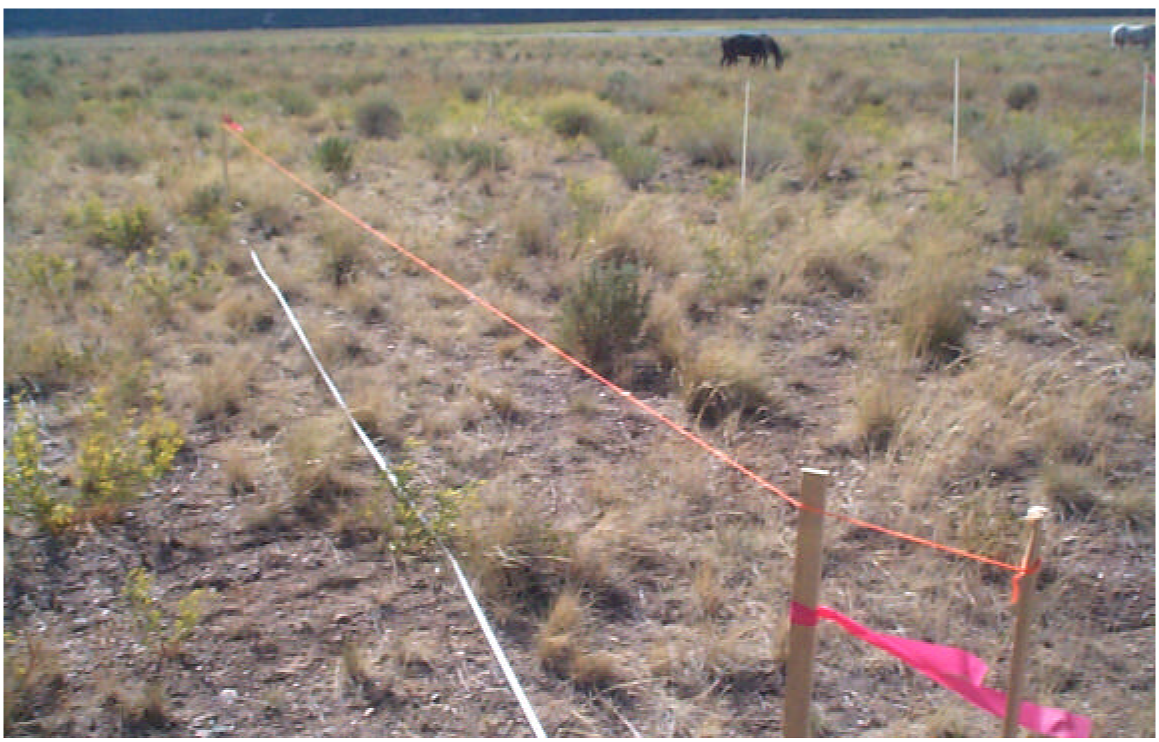

Photo 38: The 30 ft x 30 ft test plot representative of "more erosive" conditions on the surface of a tailings area covered and revegetated in 1993 (Dam 1 tailings area).

Photo 39: The 30 ft x 30 ft test plot representative of "typical" conditions on the surface of a tailings area covered and revegetated in 1993 (Dam 4 tailings area).

Photo 40: Close-up of the surface of the "typical" test plot on the surface of a tailings area covered and revegetated in 1993 (Dam 4 tailings area).

Photo 41: The 30 ft x 30 ft test plot representative of "more erosive" conditions on the surface of a tailings area covered and revegetated in 1993 (Dam 4 tailings area).

Photo 42: Close-up of the surface of the "more erosive" test plot on the surface of a tailings area covered and revegetated in 1993 (Dam 4 tailings area).

Photo 43: The 30 ft x 30 ft test plot representative of "typical" conditions on the surface of a tailings area covered and revegetated between 1998 and 2000.

Photo 44: Close-up of the surface of the "typical" test plot on the surface of a tailings area covered and revegetated between 1998 and 2000.