FORT KNOX MINE

TAILING FACILITY
CLOSURE MANAGEMENT PLAN

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2603/R1

Prepared for:

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PLANS

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1 INTRODUCTION

This document presents the Closure Management Plan for the Fort Knox Tailing Storage Facility (TSF) located near Fairbanks, Alaska. This plan outlines the closure objectives, the technical components of the closure plan, and the expected long-term performance of the closed facility. This document is an update to the existing Fort Knox Mine Reclamation Plan that focuses on the physical issues of closure and reclamation.

1.1 Purpose

The purpose of this document is to provide a detailed description of the closure approach for the Fort Knox TSF, including:

- a site-wide conceptual model with respect to the facility configuration, hydrology, hydrogeology, and water quality at closure;
- a site-wide water management plan;
- prediction of closure performance with respect to background water quality and applicable water quality criteria at the monitoring point; and
- preliminary engineering design of key closure elements such as the spillway, wetland system, and seepage management system.

1.2 Site location

The Fort Knox mine is located approximately 15 miles northeast of Fairbanks, Alaska. The site includes several sections in T2N, R2E and T2N, R3E, Fairbanks Meridian near the head of the Fish Creek drainage. The site is located on and owned by the State of Alaska, the Alaska Mental Health Trust, and private parties. Figure 1.1 illustrates the site location.

1.3 Existing reclamation plan

The initial closure strategy for the TSF was contained in the March 1994 Reclamation Plan. The existing Fort Knox Mine Reclamation Plan (Fairbanks Gold Mining, Inc. (FGMI), 2001) presents the closure strategy for the site and reflects changes to the plan made in 2001.

Two closure scenarios were originally presented for the TSF in the 2001 Reclamation Plan in recognition of the potential for variability in the water quality. One scenario focuses on reducing the amount of standing water on the tailing in the TSF to minimize seepage. As part of this approach, tailing would be deposited in a configuration that would allow drainage to a pond located in the northeastern portion of the TSF against the north abutment of the dam. A spillway would be constructed that would pass all water (including extreme events) to the wetlands located below the TSF.

As part of the second alternative, the tailing surface would be configured with areas of standing water on the tailing surface to provide physical stabilization as well as habit for avian and terrestrial wildlife. A spillway would be constructed but would be significantly smaller than the one in the first alternative.

1.4 General technical approach

The overall technical approach for the tailing Closure Management Plan focuses on the second alternative and includes the following:

- Widen the beach on the upstream side of the dam to move the TSF pond away from the dam face.
- Create a permanent wetland area behind the beach with the objective of: 1) reducing pore pressure in the upper filter to the degree possible; 2) minimizing seepage through the seal layer; 3) physically stabilizing the tailing.
- Manage the tailing deposition to optimize water storage, wetland development and maximize the area of inundation.
- Manage the short-term site-wide water balance to minimize inventory as quickly as possible, which may involve pumping water to the pit in the short term.
- Increase the area that can be successfully re-vegetated; using pit outflow and leach discharge as sources of irrigation.
- Optimize the spillway design based on the short- and long-term water balance.
- Optimize the long-term water balance to maintain background conditions and meet water quality criteria at the monitoring points.
- Streamline the monitoring plan and include monitoring points only in locations that provide meaningful measures of quality.

1.5 Closure strategy

In light of the key issues and technical approach outlined above, a revised closure strategy has been defined for the tailing storage facility:

Reduce short-term water inventory: In order to reduce the amount of process water requiring management, the plan will incorporate reduction measures to be implemented as part of pre-closure activities. Reducing water inventory at closure will include minimizing makeup water additions, gradual shut down of the interception system, and utilizing the pit for pond water storage subsequent to mill shut down.

Optimize the post-closure site water balance: Aside from direct precipitation, inflow to the tailing facility will originate from upgradient watershed areas (both undisturbed and disturbed), discharge from the heap leach pad and pit outflow (once water levels have recovered). By optimizing the quality and quantity of inflow to the tailing facility, maintaining compliance with background and regulatory standards will be facilitated.

Manage surface water through storage and attenuation: The final tailing surface will be constructed to provide storage capacity for normal inflows and the ability to attenuate peak storm events prior to discharge from a spillway. This approach will eliminate the need for construction and maintenance of extensive diversion structures and simplify surface stabilization of the tailing. A significant portion of the tailing surface will remain saturated under this option. Stabilization of the surface will be achieved by establishing upland vegetation on the margins surrounding the wetland areas. Within the wetland area, the surface stabilization is achieved through a combination of vegetation and inundation.

Improve water quality: The water quality in the pond will be optimized at closure by minimizing it's size. By minimizing the size of the pond, the influence of subsequent dilution by clean inflows can be increased. As the quality of the pond improves through time, the possibility of surface discharges exceeding standards is reduced. As the quality of pond water improves the seepage reporting to the underflow system will also improve. Monitoring points will be located downgradient of the passive treatment works (which includes a wetland component).

1.6 Sources of information

Numerous studies have been performed at the Fort Knox site in support of the mining operation. Documents pertinent to the Closure Management Plan for the TSF were reviewed, evaluated and integrated into this report. The major sources of information and the data that were used for this report are listed below in chronological order.

- Dames and Moore, 1991 - *Fort Knox Gold Mine Baseline Water Resource Evaluation Report*. As part of the mine feasibility study, Dames and Moore conducted a study of the water resources at the mine site. The report contains detailed information on the watersheds around the mine, stream flow data, surface water quality, groundwater quality, the surface and groundwater flow regimes, and climatic conditions.

- American North, 1992 - *Fort Knox Project, Water Resources Report, 1989 – 1991*. A second water resources study was conducted in support of the Fort Knox mine in 1989, 1990, and 1991. The report describes the baseline conditions for the surface water, precipitation and groundwater systems. Information is also provided on surface water flow (hydrographs), storm runoff volumes, and ground and surface water quality.

- *John C. Halepaska and Associates, 1992a (March) - Summary of Preliminary Operational Study Runs for a Surface Water Storage Facility to Meet the Fort Knox Project Water Demand*. Based on the anticipated water requirements of the mill, JCHA performed a feasibility study of potential water storage facilities. Information presented in the report includes climate data (precipitation and evaporation) and surface water flow data.

- John C. Halepaska and Associates, 1992b (December) - *Surface and Ground Water Hydrology for the Fort Knox Project.* This report was generated to collate and summarize all available data on surface water and groundwater hydrology at the proposed mine site. Information in the report includes: watershed and aquifer characteristics; water level data and maps; surface water data; climate data; and estimates of groundwater recharge.

- CH2MHill, 1993. *Fort Knox Mine Environmental Assessment* - As part of the permitting process for the mine, CH2MHill performed an environmental assessment. The report provides an overview of proposed mine operations, site conditions and potential environmental impacts. The report includes storm water runoff volumes and surface water quality data.

- Knight Piésold, 1994 - *Fort Knox Project Design of Tailing Storage Facility and Water Reservoir*. The design document for the TSF and freshwater reservoir includes information on performance of the TSF embankment, TSF infilling curves, and the characteristics and behavior of the tailing (density, grain size distribution, and permeability).

- John C. Halepaska and Associates, 1996 - *Tailing Storage Facility Interceptor Well Collection System, Fort Knox Mine, Fairbanks, Alaska*. The design summary report for a system to collect drainage through the tailing into the underlying aquifer included information (in the vicinity of the TSF) on extraction/monitoring well locations and design; aquifer characteristics; water level data and groundwater surfaces; and discharge/groundwater flow characteristics.

- Montgomery Watson Harza, 2004 - *Conceptual Chemical Stabilization Closure Plan*. The preliminary closure plan provides a comprehensive overview of site conditions during mine operations and updates to several data sets collected prior to mine development. The report includes: historical and future water quality of groundwater; surface water (in the mine pit), TSF pond water and seepage; the geochemistry of the mill feed; mill processing chemistry; and chemistry of precipitation. The report also presents conceptual water balance models for the mine pit, TSF, and waste rock facilities.

- Doubek HydroLogic, 2004 - *Fort Knox Mine, Fairbanks Alaska, Ultimate Pit Lake Infilling Study*. The infilling study evaluated the time for the pit to fill, the final water level, and the estimated outflow from the pit after it fills. The report provides information on climatic conditions (precipitation and evapotranspiration), groundwater levels in the vicinity of the pit, and bedrock aquifer characteristics.

In addition to the studies performed by consultants, FGMI provided a large body of data, including: maps, databases of surface water and groundwater quality, chemical data on tailing and mill effluent, surface water flow data, estimates of storm runoff volumes, and watershed characteristics. FGMI also supplied copies of their quarterly monitoring reports. Five-year environmental audits for Fort Knox (TRC, March 1999 and Golder, 2004) were reviewed. Geochemical data related to the True North Project were also reviewed (SRK, 2003).

1.7 Acknowledgements

WMC would like to thank Delbert Parr, Larry Jackson, and Stacy Staley for their support and assistance with this project. Their efforts were of great value in helping to gather the large quantity of information required to complete this work.

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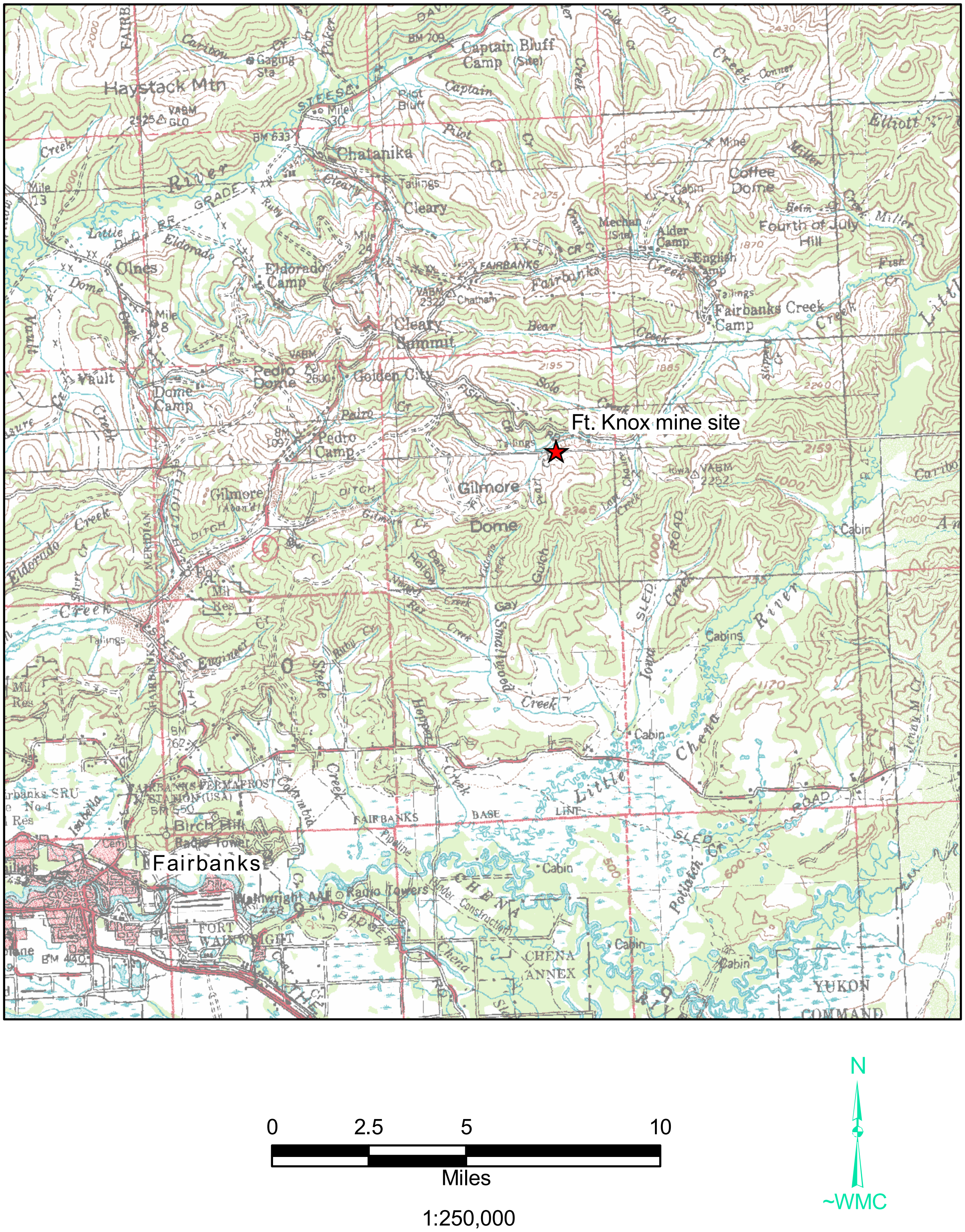
Figure 1.1 Regional location map



2 PROJECT SETTING AND DESCRIPTION

2.1 General setting and facility layout

The Fort Knox site is located in the Chena River basin within the Yukon-Tanana Uplands physiographic province. The site is situated within the Fish Creek subbasin, which is tributary to the Chena River. Ridges with gentle slopes characterize the higher elevations ranging between 1,200 and 1,300 feet above mean sea level (ft amsl). The broad flat drainages are elongated east-west to southwest-northeast. The average width of the bottom of the Fish Creek valley is between approximately 1,000 and 2,000 ft. The ore body is centered on the north flank of Gilmore Dome on a ridge between Melba Creek and Monte Cristo Creek. The open pit occupies approximately 33 percent of the drainage area of these two creeks, which are tributaries of Barnes Creek. The remaining site facilities including the waste rock pumps, TSF, water reservoir, mill and plant are located within the Barnes Creek and Fish Creek drainages. The Barnes, Melba, and Monte Cristo Creeks as well as the smaller tributaries of Walter, Pearl, Yellow Pup, Solo, and Last Chance all flow to Fish Creek. Figure 2.1 shows the primary facility locations at the site.

2.2 Ore processing

Crushed ore is conveyed to the mill and fed into the semi-autogenous grinding (SAG) circuit. From the SAG mill the ore is gravity-fed into two ball mills. The milled concentrate slurry is then pumped into the first of seven flow-through leach tanks where the gold is extracted and subsequently adsorbed onto activated carbon. Once the gold has been removed from solution onto the carbon, the resulting spent solution is recirculated in the process. The tailing are sent to thickeners where water is recovered. The thickened tailing are then brought up to a higher water content for pumping by adding water from the TSF pond. The tailing are then discharged to the TSF. The tailing are processed through an INCO cyanide detoxification circuit if needed to meet permit limits.

2.3 Tailing facility description

The TSF has three major design elements; the embankment, the conveyor crossing embankment, and the seepage collection system. Each component is described briefly below. Detailed engineering design information can be found in Knight Piésold, 1994. In addition, Section 4 provides a more complete description of the design and operation of the TSF as it relates to closure.

The tailing embankment has been designed as a zoned earthfill/rockfill structure capable of withstanding full hydrostatic load. The structure includes a starter embankment which was constructed in two phases. Annual construction to raise the embankment was scheduled to occur over an 11-year period, resulting in a final crest elevation of 1,494 ft amsl. The ultimate embankment will be approximately 328 ft higher than the downstream toe.

The conveyor crossing embankment (see Figure 2.1) is a homogeneous rockfill structure designed to provide access across the Barnes Creek drainage for conveyor routing to the mill site. The final construction consists of a 120 ft crest width with 1.5H:1V slopes. All fine-grained alluvial materials were removed prior to construction.

Slurried tailing are currently discharged sub-aerially from pipes located at the upstream margin of the TSF facility. Approximately 36,000 tons per day (tpd) are processed and deposited in the TSF. To date, approximately 123 million tons (Mt) of tailing have been placed in the facility. A pond covers an area of approximately 175 acres and serves as the source of makeup water to the mill. Section 4 provides a detailed description of the embankment design and TSF operation as they relate to closure.

Seepage from the TSF reports to a collection sump located at the downgradient toe of the TSF embankment. The sump is connected to the foundation drain in the dam. Solutions collected in the sump are continuously pumped out and returned to the TSF pond.

2.4 Site-specific constraints affecting closure

The work program for completing the tailing facility Closure Management Plan for Fort Knox reflects the following key site-specific conditions:

- **Post-closure facility size:** The surface area of the facility at closure will require the final stabilization to include a combination of upland vegetation and wetlands. This will be achieved by optimizing the tailing management and facility water balance.

- **Site wide water balance:** The tailing facility, heap leach pad, and open pit are key components of the short- and long-term, site-wide water balance. The pit may provide flexibility in managing short-term water inventory.

- **Tailing deposition:** Slurried tailing is currently discharged sub-aerially from pipes located at the upstream margin of the facility. The fine-grained fraction (slimes) accumulates adjacent to the upstream face of the embankment beneath the TSF pond.

- **Tailing management:** During operations the tailing management must protect the mill water supply and achieve the desired final surface topography.

- **Water quality:** The background surface water and groundwater quality exceeded regulatory standards for several parameters. Parameters with naturally-occurring, elevated concentrations include arsenic, cadmium, copper, iron, manganese, selenium, and zinc. The elevated metals concentrations reflect the mineralization that occurs in the bedrock and alluvium within the Fish Creek drainage. The Closure Management Plan considers a range of alternatives including passive treatment to meet water quality standards or reduce concentrations to background levels.

- **Surface water:** Significant diversion of surface water around the tailing facility is not a practical long-term component of the Closure Management Plan. Management of surface water will be optimized through the tailing deposition plan and the facility water balance.

- **Habitat:** The southern margin of the Fish Creek drainage between the embankment and freshwater reservoir is grayling habitat, and it will remain undisturbed as part of the closure design.

- **Historical mining activities:** The morphology of the Fish Creek drainage has been altered significantly as a result of historical placer mining. In addition, the disturbance of the mineralized alluvial materials prior to construction has likely altered water quality conditions.

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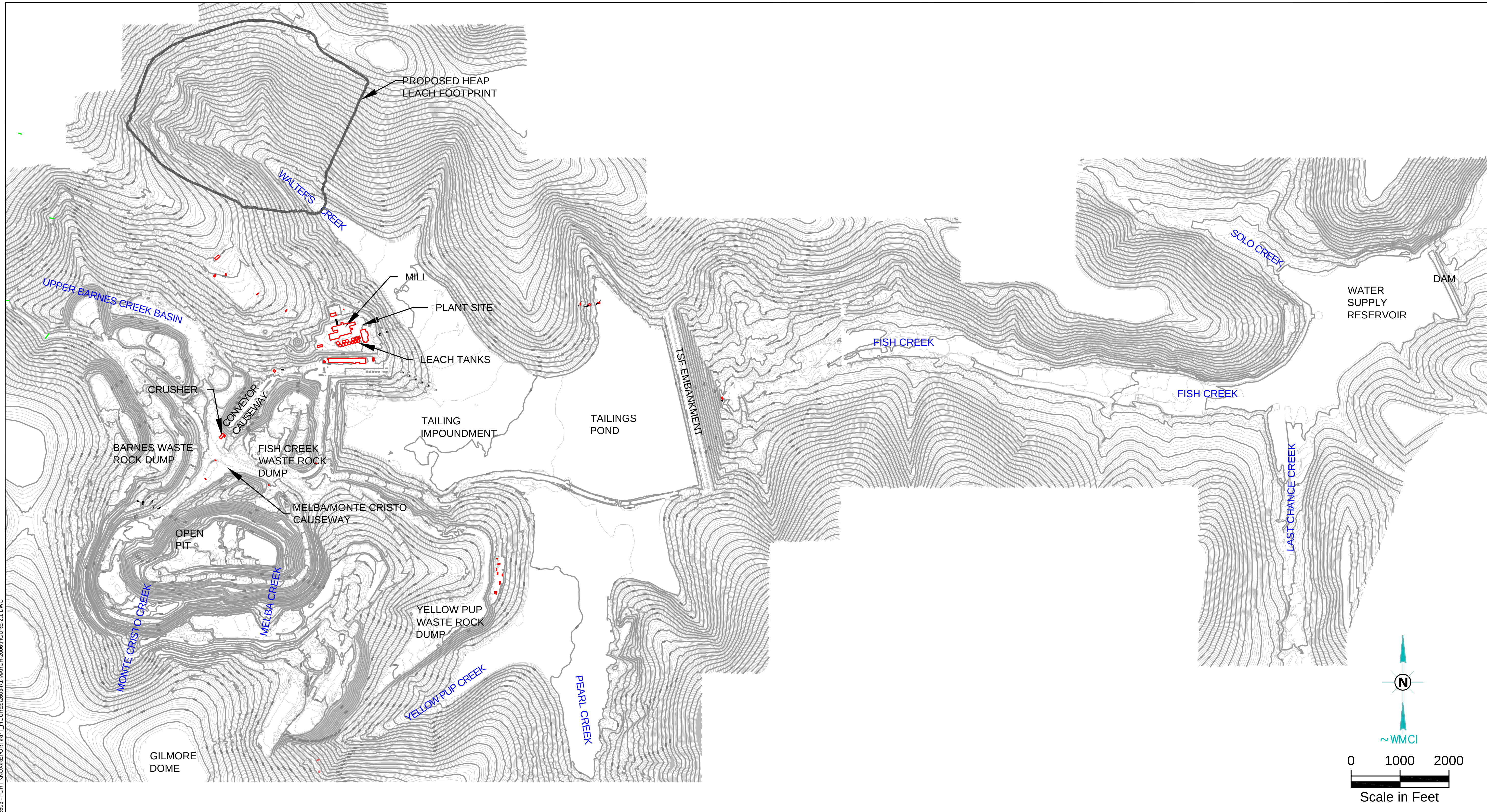


Figure 2.1 General facility layout map

3 HYDROLOGY

3.1 Climate

The climate at the site is continental sub-arctic with the majority of precipitation occurring during the months between May and September. Precipitation has been measured continuously at the mine site and has averaged approximately 20 inches per year with a low of 14.5 inches per year in 2001 and a high of 23.1 inches per year in 2002. The precipitation station at the mine is located in the parking lot on the east side of the administration building at an approximate elevation of 1,640 ft amsl. Previous studies have compared the precipitation at the site to Gilmore Creek Station (Station Index No. 3275), located approximately 4 miles west of the mine at an elevation of 973 ft amsl. The Gilmore Creek Station has a period of record dating back to 1969 and precipitation averages about 20 inches per year with 30 percent falling as snow (Dames and Moore, 1992). The temperatures on site range from highs above 90°F to lows of minus 50°F. Table 3.1 summarizes the monthly precipitation based on the entire period of record at the site. Figure 3.1 illustrates these data.

Table 3.1 Mine site precipitation data

Month	1998	1999	2000	2001	2002	2003	AVG
January	0.10	0.93	2.11	0.39	1.03	0.36	0.82
February	0.14	0.19	0.00	0.49	0.70	1.03	0.43
March	0.11	0.67	0.03	0.40	0.15	0.13	0.25
April	0.11	0.63	0.00	0.21	3.14	0.01	0.68
May	1.66	1.06	2.13	1.05	0.87	0.30	1.18
June	1.51	1.73	1.57	2.09	2.69	1.20	1.80
July	4.93	3.38	2.41	3.38	4.96	7.70	4.46
August	4.23	2.78	6.42	3.59	5.22	3.59	4. 31
September	2.76	3.13	3.66	0.27	1.98	2.68	2. 41
October	0.16	2.64	1.73	1.83	1.85	1.42	1.61
November	0.73	2.26	0.83	0.14	0.02	2.78	1.13
December	1.24	1.56	0.38	0.61	0.53	1.49	0. 97
ANNUAL	**17.68**	**20.96**	**21.27**	**14.45**	**23.14**	**22.69**	**20.04**

Various reports have cited a range of free-water evaporation rates. Evaporation rates used for water balance analyses completed by Halepaska range from 7.31 inches to 15.45 inches per year (John C. Halepaska and Associates, Inc. (JCHA), 1992). Knight Piésold (1994) used a value of 17.02 inches per year. Dames and Moore maintained a Class A evaporation pan at the mine site for the months of June through September, 1990. Based on these data the total annual actual evaporation was estimated to be between 6 and 9 inches per year. Currently, FGMI uses annual values of approximately 10.4 inches for the TSF operational water balance.

3.2 Geologic setting

3.2.1 Bedrock

The Fort Knox mine is located in the Fairbanks Mining District, in the northeast part of the Yukon-Tanana Upland. The mining district is divided into four metamorphosed stratigraphic groups; the Chatanika sequence, the Fairbanks Schist, the Chena River sequence, and the Birch Hill sequence.

The area of the mine is underlain by the Fairbanks Schist unit and the Cleary Sequence of the Fairbanks Schist unit (Knight Piésold, 1994). The Fairbanks Schist consists largely of muscovite-quartz schist and micaceous quartzite. The Cleary Sequence consists of calcareous actinolitic greenschist, impure marble, muscovite quartz schist, and potassium feldspar white schist. The schist is host to younger granitic intrusions, such as the one outcropping at the mine site. The Fairbanks Schist and other metamorphic rocks range in age from late Precambrian to lower Paleozoic. The intrusive granodiorites and quartz monzonite are most likely Cretaceous to Tertiary in age (Knight Piésold, 1994).

The Gilmore Dome pluton, which consists of granodiorite and quartz monzonite is present in the pit area of the mine site. Prior to opening the pit, granodiorite outcropped in the Melba and Monte Cristo Creeks and is the main host rock for the gold mineralization of the Fort Knox deposit. This pluton has intruded into the Fairbanks Schist, which makes up the upper portion of the pit wall.

Gold occurs in and along the margins of pegmatites, quartz veins and veinlets, quartz-filled shears, and fractures within the granite. Pre-mineralization fractures, which resulted from magmatic doming, provided conduits for mineralizing fluids within the stockwork and shear zones. The stockwork veins strike predominantly east-west and dip randomly. Vein density decreases with depth. Shear zones generally strike northwest to southeast and dip moderately to the southwest.

The upper 100 to 300 ft of the bedrock is highly weathered. The degree of weathering depends on the original mineral content of the bedrock and exposure. Weathering characteristics consist of intense fracturing and alteration of primary minerals to clay and oxide. Based on drilling completed in the area of the TSF, the greatest fracturing and depth of weathering occurs in the valley floor where the maximum depth of effective fracturing has been estimated to be between 300 and 500 ft (JCHA, 1992).

3.2.2 Alluvium

The alluvium consists primarily of a thin layer of organic soil and unconsolidated silt, sand, and gravel. In the larger valleys there is a basal gravel, which has grain sizes between sand and gravel size and may contain boulders as large as 1 to 2 ft in diameter. This basal unit between the surficial materials and the bedrock has been extensively placer mined in the area. Based on drilling completed to support the design of the seepage collection system and fresh water reservoir, the average thickness of alluvium downgradient of the TSF is approximately 30 to 35 ft.

3.2.3 Geologic structure

The mine is situated on the southeast flank of a broad asymmetric synform structure with an east-northeast trending axis. Fish Creek parallels the general strike of the foliations. Several shear zones appear to have controlled the development of drainages in the area. The dominant structural trend of the district is expressed by numerous northeast trending faults and shear zones, which were important to the localization of gold mineralization.

3.3 Surface water hydrology

The principal surface water features in the mine area include:

- Solo Creek
- Last Chance
- Fish Creek
- Barnes Creek
- Pearl Creek
- Monte Cristo Creek
- Melba Creek
- Walter Creek

Figure 3.2 illustrates each of the creeks and their respective subbasins. Fish Creek is the major stream in the area and all the other streams are tributary to it. As a result of the extensive placer mining that has occurred, the morphology of the drainages from the confluence of Solo and Fish Creeks to Monte Cristo Creek has been significantly altered.

Solo Creek has a contributing area of approximately 5.1 mi^2 and flows eastward from an elevation of 2,400 ft amsl at the western watershed boundary to an elevation of about 1,015 ft amsl at its confluence with Fish Creek. Barnes Creek drains from about 2,400 ft amsl through small tributaries from the western edge of the Fish Creek watershed. Walter Creek, where the proposed heap leach facility is located, is tributary to Barnes Creek. Upper Barnes Creek (1.32 mi^2), Melba Creek (0.38 mi^2), and Monte Cristo Creek (0.89 mi^2) meet at about 1,375 ft amsl. Pearl Creek drains south to north and meets Barnes Creek; Fish Creek begins at their confluence.

3.3.1 Streamflow

Continuous and instantaneous discharge measurements were collected on Fish Creek as part of baseline characterization. Figure 3.2 illustrates the location of the gaging stations used as part of the baseline characterization. Surface water flow characteristics were defined by American North, Inc. (1992) in 1990 and 1991, using instantaneous discharge measurements, gage readings, and continuous instream measurements. Flow data were collected for Fish, Solo, Upper Barnes, Lower Barnes and Pearl Creeks. Figures 3.3 through 3.5 illustrate the streamflow measurements collected prior to construction for Fish Creek, Upper Barnes Creek, and Lower Barnes Creek, respectively. Data from 1990 and 1991 were quite different because record-breaking snowfalls occurred in 1991. In 1990, flow in mid-May ranged from 0.2 cfs in Upper Barnes Creek to approximately 6 cfs in Fish Creek. Flow during the same time period in 1991 was 4.5 cfs in Upper Barnes Creek and about 50 cfs in Fish Creek.

In July, prior to the summer rains, base flow was approximately 0.2 cfs in Upper Barnes Creek, 0.7 cfs in Lower Barnes Creek and 1 cfs in Fish Creek. During the same time the following year, flow was 4 to 11 times higher (1.5 cfs in Upper Barnes Creek, 3 cfs at Lower Barnes Creek and 11 cfs in Fish Creek).

3.3.2 Flood hydrographs

Using rainfall-frequency data for Alaska (Miller, 1963), Halepaska developed flood hydrographs for the 100-year, 24-hour storm (Halepaska, 1992b) for the TSF. The 100-year, 24-hour precipitation depth is estimated to be 3.6 inches for the project area. Using this rainfall amount and the Soil Conservation Service unit hydrograph methodology, Halepaska developed flood hydrographs for key facilities including the TSF (Figure 3.6).

The peak flow and runoff volume from the 100-year, 24-hour storm event at the TSF is summarized in Table 3.2 below (Halepaska, 1992b).

Table 3.2 100-year, 24-hour runoff volumes

	Peak instantaneous flow (cfs)	Total storm runoff (acre-ft)
Fish Creek Tailing Facility	1,960	310

According to the U.S. Department of Commerce Weather Bureau, the probable maximum precipitation (PMP) for the site is 11.2 inches (Miller, 1963; Appendix A, Figure A-1). Using rainfall-frequency data for Alaska (Miller, 1963), and a Type I storm distribution (USSCS, 1986; Appendix A, Figure A-3), WMC developed flood hydrographs for the PMP storm event for the TSF. Inflow Design Floods for Dams and Reservoirs states that, "Reservoir inflow unit hydrographs for IDF determinations should be peaked 25 to 50 percent to account for the fact that unit hydrographs are usually derived from smaller floods" (USACE, 2001). The Type I unit hydrograph was peaked by 25 percent for the PMP storm, which resulted in a flood depth of 14.0 inches. The storm hydrograph is included in Appendix A, and results are discussed in Section 6.1.4 along with spillway design criteria.

3.3.3 Spring breakup

A large portion of the annual surface water flow occurs during the spring breakup period. Analysis of the relationship between mean monthly flows and total annual flows indicates that as much as one fifth to one quarter of the total annual flow occurs during the month when spring breakup occurs. This suggests that the precipitation falling between approximately October and May in the form of snow runs off as a single event averaged over one month (i.e., seven to eight months of precipitation averaged over one month). For purposes of evaluating spring breakup volume, it is defined as the average of the peak monthly flow in each year for the period of record.

Halepaska (1992b) evaluated flow records at the Caribou Creek station near Chatanika to estimate runoff volumes that could be expected from spring breakup in Fish Creek. Based on the records available, spring breakup volumes were estimated by Halepaska (1992b) and are presented in Table 3.3.

Table 3.3 Summary of estimated spring breakup volumes

	Average spring breakup volume (acre-ft)	Maximum spring breakup volume (acre-ft)
Fish Creek Tailing Facility	550	950

3.4 Groundwater hydrology

The groundwater conditions across the site have been evaluated through various investigations prior to and during operations. Preliminary work was completed during pre-feasibility (EBA Engineering, 1990) and initial design activities (JCHA, 1992a, 1992b, and 1996). The following discussion is based on the hydrogeologic data compiled during these investigations. Figure 3.7 illustrates the borehole locations from each phase of work.

3.4.1 Hydrostratigraphy

The two principal hydrostratigraphic units in the mine area are the alluvium that underlies stream valleys and the fractured bedrock. The following sections provide a detailed description of each unit.

Alluvium

In its undisturbed state, the alluvium typically consists of a thin layer of organic soils, moss and vegetation, underlain by organic silts with occasional channel deposits of sand and gravel, which is then underlain by a layer of poorly-sorted gravel.

Underlying the surficial layer is a 25- to 35-ft thick layer of organic silt with occasional channel deposits of sand and gravel. This deposit of organic silt is also restricted to the valley floor and ranges in width from approximately 400 to 1,800 ft. The organic silt has an estimated thickness of up to 35 ft, which pinches out at the valley margins.

Grain sizes in the underlying gravel material range from as large as 1- to 2-ft diameter boulders, to sand and gravel in a matrix of fine silts and clay overlying an erosional, mineralized surface of weathered bedrock. Restricted to the valley floor, this mineralized, gold-bearing gravel deposit varies in width from an estimated 200 ft up to 1,200 ft and has an estimated thickness of up to 25 ft along the valley axis. The basal gravel layer pinches out along the valley edges. It is reported that both the basal gravel and the overlying organic silts were mostly permanently frozen in their undisturbed state.

As the basal gravel deposits have historically been the primary economic placer gold-bearing deposit in the region, most of the valley fill described above has been modified. Soils and organic silts have been removed to access the gold-bearing gravels. The gold-bearing gravels in turn were reworked and washed to remove the gold. The tailing produced from this procedure was deposited in the mined-out portions of the valley. In many places the tailing was used to construct settling ponds to separate silt and clay from placer mining discharge. As a result, much of the modern-day alluvium consists of a heterogeneous mix of poorly-sorted material grading from coarse gravel to fine silts and clay often found in a somewhat inverted stratigraphy where the course-grained gravels overlie fine-grained silts and sands. Numerous pockets of predominantly fine-grained materials from the old settling ponds exist throughout the valley. Similarly, local lenses of well-sorted and well-stratified sands and gravel deposited by streamflow are also present. Much of this re-worked valley fill may now be thawed and subject only to seasonal frost action.

Based on aquifer tests performed by JCHA (1992a) the permeability of the basal gravel ranges between 10^{-4} to 10^{-5} cm/sec. Hydraulic conductivity values for the alluvial material are estimated to range between 10^{-2} to 10^{-5} cm/sec with an average of 7×10^{-3} cm/sec).

Bedrock

The underlying bedrock aquifer consists primarily of schist (referred to as the Fairbanks schist) and is interpreted to be a pre-Cambrian Age. This schist is host to younger granitic intrusions, such as the one outcropping at the Fort Knox mine site.

The upper portion of the bedrock (ranging up to 100 ft in thickness) is highly weathered. The degree of weathering depends on the original lithologic content of the bedrock and exposure. Weathering characteristics consist of intense fracturing, alteration of primary minerals to clays and oxides (such as iron oxide), dislocation from soil creep and the filling of fractures with sand, silt, and clay.

Movement of groundwater in the bedrock aquifer occurs in open fractures. The degree of fracturing observed during the drilling of bedrock monitoring wells was variable, as indicated by the range of hydraulic conductivities calculated from pump test data ranging from 10^{-2} to 10^{-5} cm/sec.

The greatest fracturing and, hence, higher hydraulic conductivities are found in the valley floor locations. Hydraulic conductivities are observed to be lower in wells completed at the hillside locations. This is related to two factors; 1) the greater degree of fracturing observed in the valley floors is related to the shallow depth to bedrock and more intense weathering, and 2) the greater degree of fracturing observed in the valley floors is likely related to shear zones that control the development of local drainages. Based on drilling completed as part of initial site characterization the estimated depth of effective fracturing below the permafrost in the bedrock is expected to be 300 to 500 ft. Below this depth, fracture frequency and permeability decrease significantly.

Data from pumping tests also indicate that the bedrock fracture systems at most of the locations are directly connected with the overlying alluvial aquifer system. Water level declines observed in alluvial wells completed adjacent to bedrock pumping wells were relatively instantaneous and similar in magnitude, suggesting a strong hydraulic connection between the alluvial system and the underlying fractured bedrock.

Tests by JCHA (1992a) indicate that the hydraulic conductivity for the upper 300 ft of bedrock is approximately 1×10^{-3} cm/sec.

3.4.2 Permafrost

Data collected from exploration boreholes and thermistors installed in the area of the embankment prior to construction indicate the presence of localized permafrost. Temperature surveys of the monitoring wells indicate that frozen conditions exist mostly on north-facing slopes and in shaded areas on the valley floor. Thermistor readings indicated that temperatures ranged from 1 to 10°C. The majority of soil and rock temperatures in frozen areas ranged from 0 to 1°C indicating warm permafrost. Data collected during drilling suggests that at some locations the bedrock aquifer may be frozen to significant depths (in excess of 100 ft). Frozen bedrock in the embankment area was left in place prior to construction. Because the permafrost was warm the rate of thaw was likely rapid once seepage from the facility began (Knight Piésold, 1994).

3.4.3 Groundwater flow

Pre-mining groundwater flow

Pre-mining groundwater elevations in the alluvium ranged from about 1,700 ft amsl in the upper reaches Barnes and Walter Creeks to 1,000 ft amsl in the vicinity of the freshwater reservoir. Hydraulic gradients within the alluvium present in the upland areas average approximately 0.06 ft/ft. Along the axis of Fish Creek the hydraulic gradient is approximately 0.01 ft/ft. The groundwater flow direction in the alluvium is from west to east and follows the topography. Plan 3.1 illustrates the pre-mining groundwater elevations within the alluvium.

Pre-mining groundwater flow directions in the bedrock generally followed surface topography, with potentiometric elevations ranging from greater than 1,750 ft amsl on the northern flank of Gilmore Dome to 1,550 ft amsl at the northern edge of the current pit. In the upland areas, hydraulic gradients in the bedrock ranged from 0.08 to 0.10 ft/ft prior to mining. Along the axis of Fish Creek the pre-mining gradient was approximately 0.015 reflecting the lower topographic gradient and higher hydraulic conductivity. Prior to mining, groundwater flow in the bedrock reported to the overlying alluvial aquifer or discharged directly to the surface water system. Plan 3.2 illustrates the pre-mining bedrock groundwater elevations.

Current groundwater flow

The current influences on groundwater flow include pit dewatering, seepage from the TSF, and the interception system downgradient of the TSF. Plan 3.3 illustrates the current groundwater elevations.

Groundwater levels in the pit are managed through a system of dewatering wells located adjacent to and within the pit. There are currently 16 production dewatering wells completed within the bedrock aquifer. The present abstraction rate ranges from approximately 550 to 750 gpm depending on the time of year and maintenance requirements. Water levels are being measured in approximately 50 piezometers in the vicinity of the pit. Water from all of the production wells is conveyed in HDPE pipelines to a discharge point at the northeast corner (downgradient toe) of the Melba/Monte Cristo Causeway.

The elevation of the TSF pond is currently about 1,423 ft amsl. The tailing beneath the TSF pond are saturated. Therefore, the phreatic surface upgradient of the tailing dam is about the same elevation (i.e. 1,423 ft amsl). As a result of the drain system within the TSF embankment, the phreatic level drops to an elevation at or slightly below the alluvial/bedrock contact downgradient of the TSF.

Below the downstream toe of the TSF, the seepage from the facility is collected in a series of sumps and interceptor wells. Figure 3.7 illustrates the location of the seepage collection system. The total pumping rate from the seepage collection system is approximately 2,000 to 2,200 gpm. As a result of pumping groundwater from the interception system, water levels have dropped 110 ft to more than 200 ft relative to pre-mining conditions. The cone of depression appears to extend to wells MW-5, MW-6, and MW-7.

Groundwater throughflow

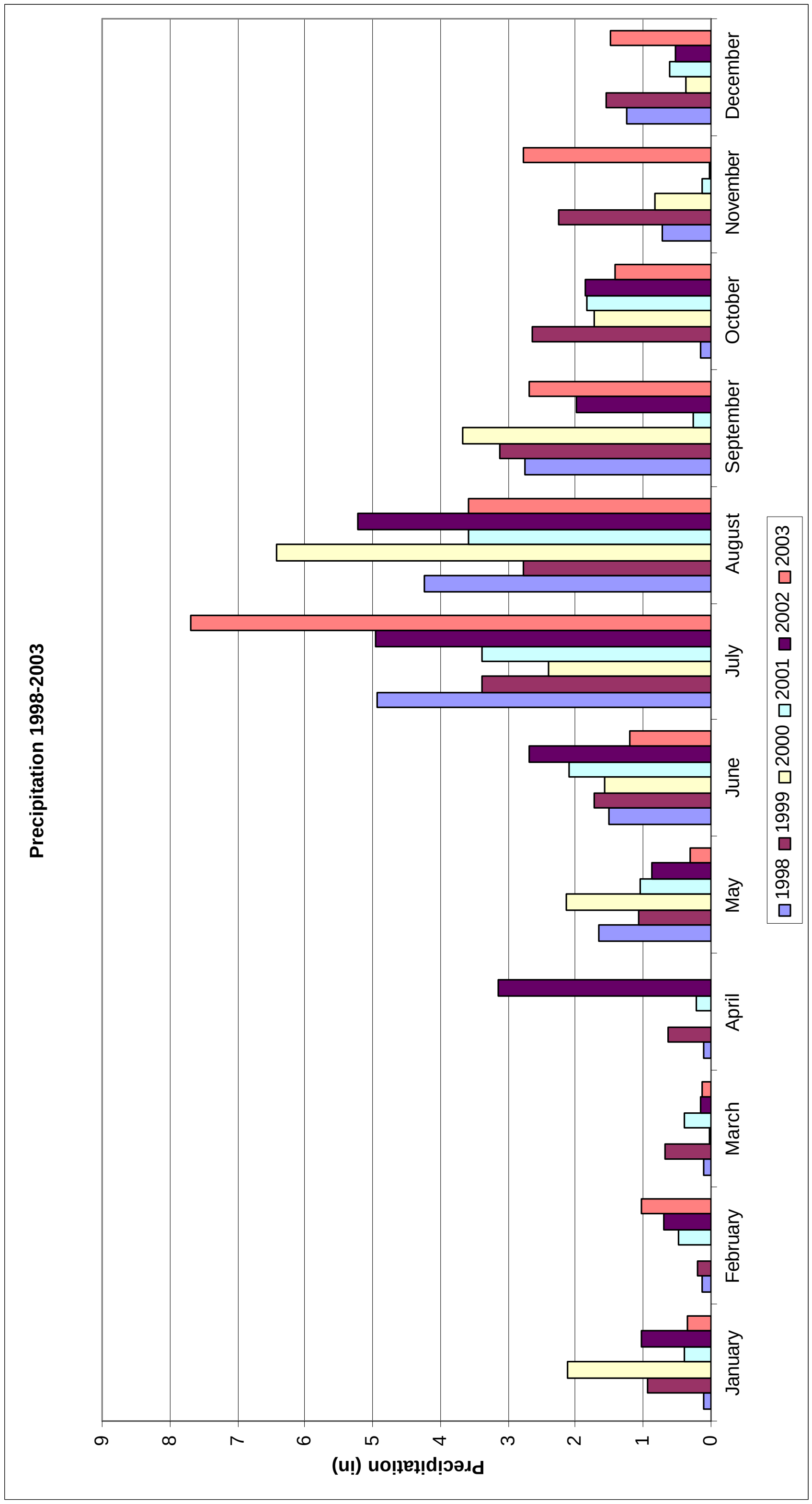
Groundwater underflow occurs in both the weathered bedrock and saturated alluvium. Estimates of underflow in the alluvium prior to mining range from approximately 40 to 50 gpm (JCHA, 1992b). This assumes that the entire saturated thickness is thawed. Underflow in the alluvium is derived from local infiltration and interflow within the colluvium present on the adjacent valley walls.

JCHA estimated the underflow within the weathered bedrock to be on the order of 300 to 320 gpm (JCHA, 1992b). This estimate was based on an aquifer width of 4,000 ft corresponding to the crest length of the embankment which likely represents an overestimate of aquifer dimensions in the area of the TSF. Based on the geologic cross-section presented in Figure 3.8 the width of the aquifer beneath the TSF is estimated to be between approximately 1,800 and 2,000 ft. Using the weighted hydraulic conductivity for the bedrock aquifer and an effective porosity of 10 percent, the corresponding throughflow estimate is approximately 175 gpm.

Further downgradient near the confluence with Last Chance Creek the total throughflow (i.e., alluvium and bedrock) is estimated to be approximately 270 to 300 gpm based on the increased catchment area and aquifer width.

WATER MANAGEMENT CONSULTANTS

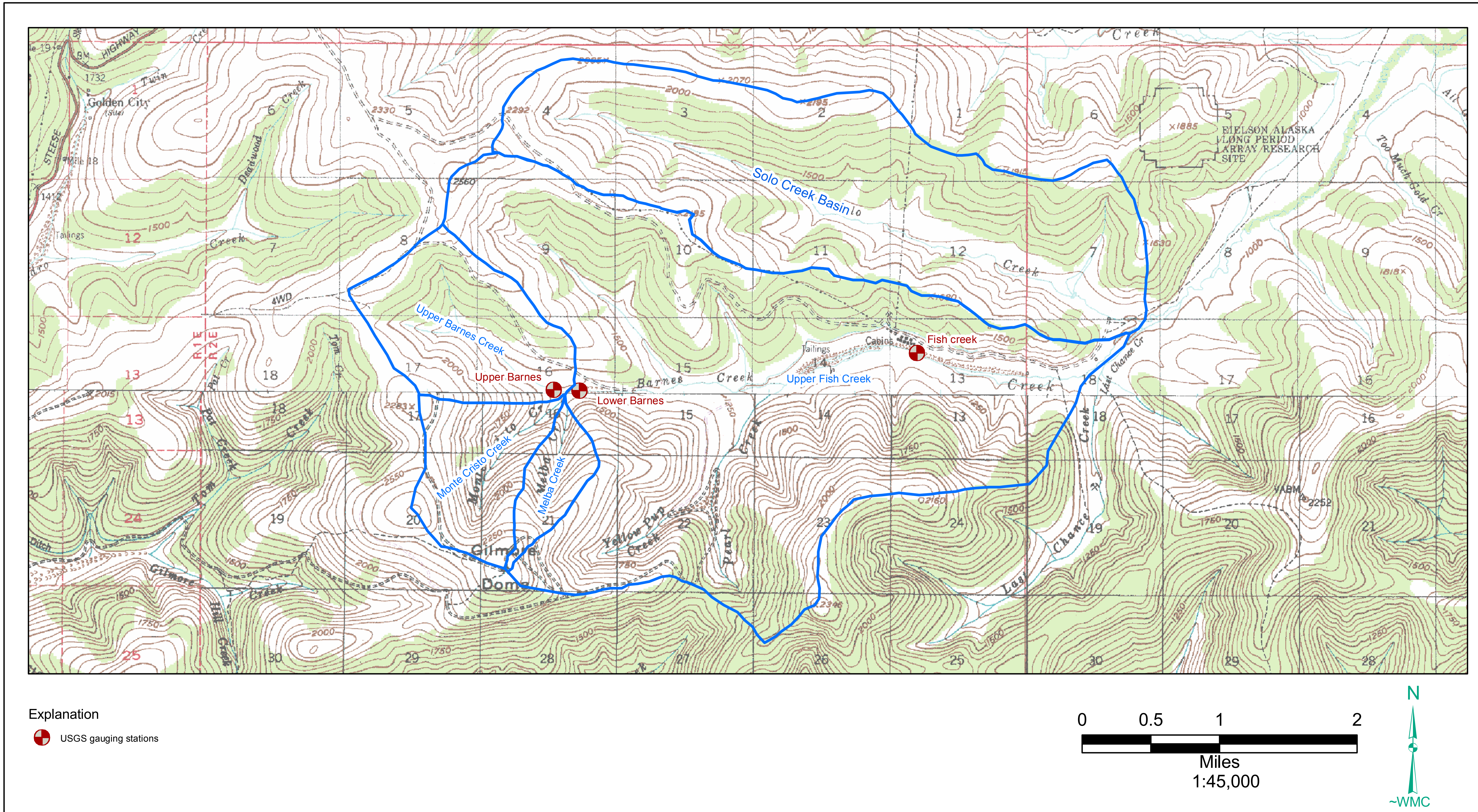
Figure 3.1 Monthly data precipitation



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-3.1.DWG

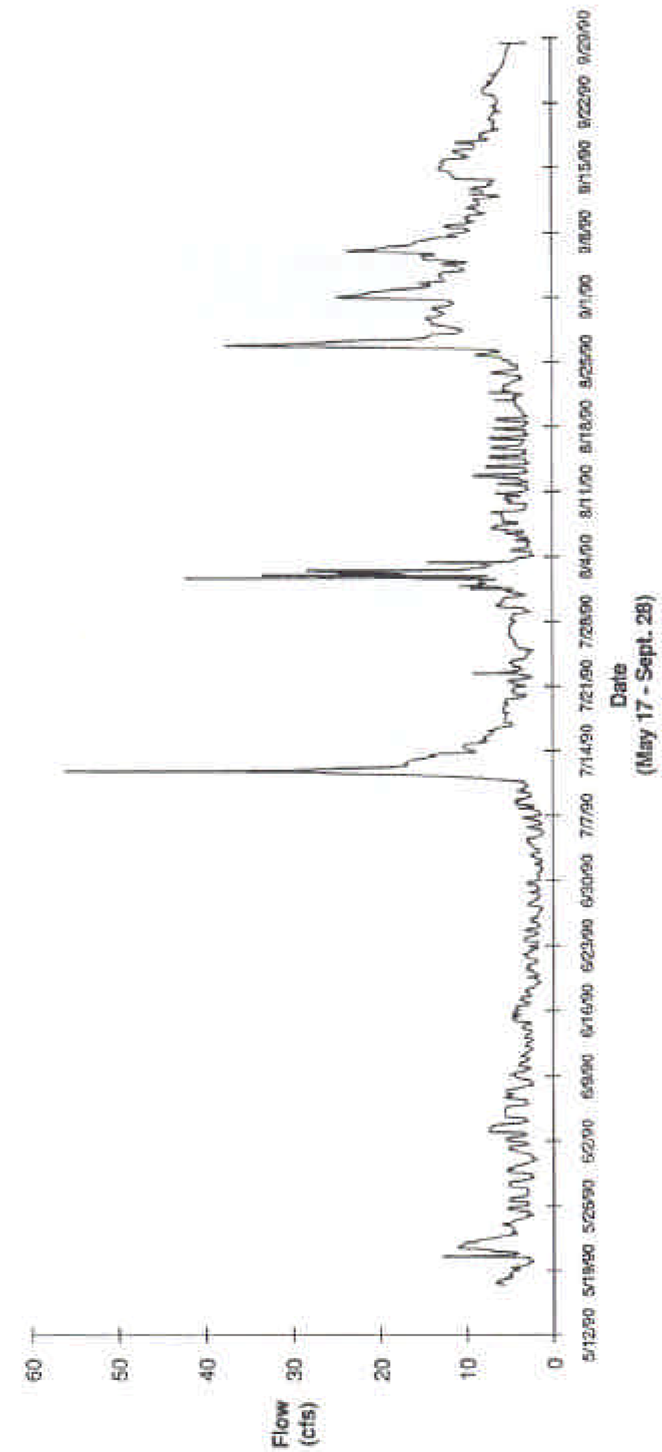
WATER
MANAGEMENT
CONSULTANTS

Figure 3.2 Local watershed boundaries and gauging stations



WATER MANAGEMENT CONSULTANTS

Figure 3.3 Continuous discharge measuremens - Fish Creek, 1990

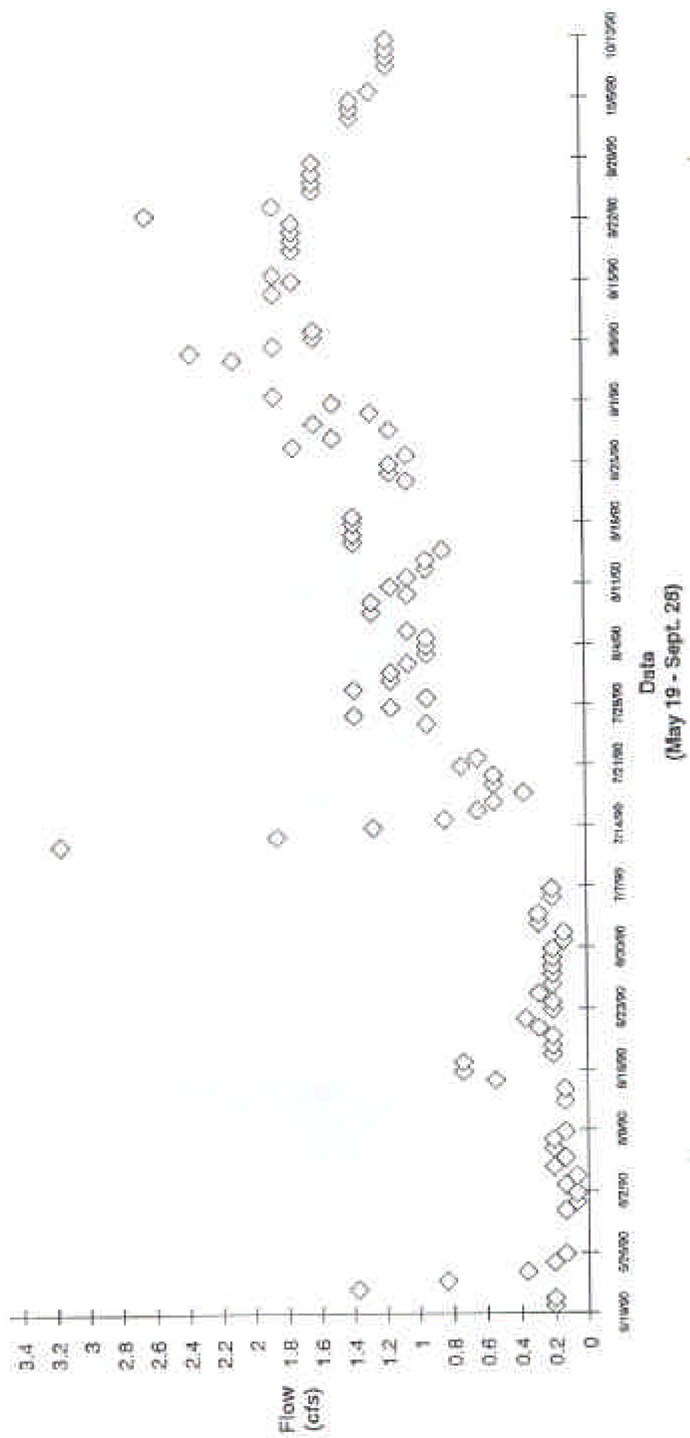


SOURCE: AMERICAN NORTH INC., 1992

F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-3.3.DWG

WATER MANAGEMENT CONSULTANTS

Figure 3.4 Instantaneous discharge measurements - Upper Barnes Creek, 1990

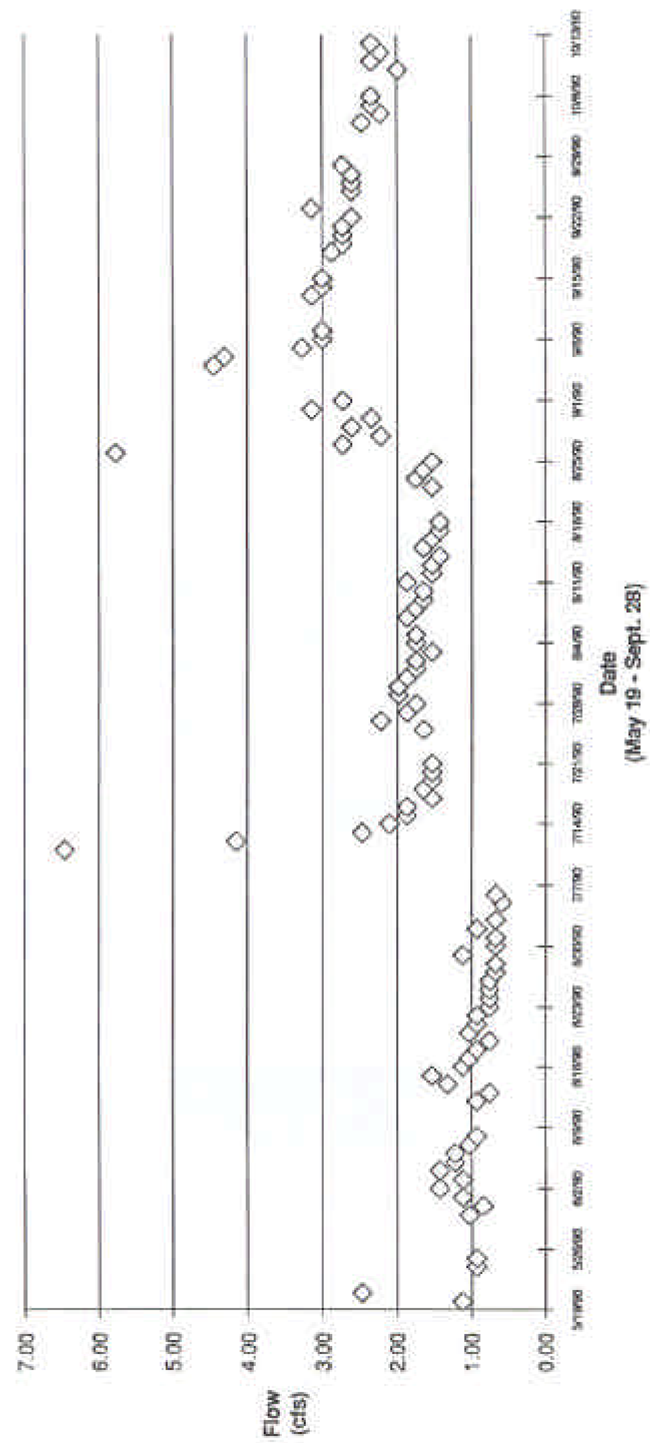


SOURCE: AMERICAN NORTH INC., 1992

F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-3.4.DWG

WATER MANAGEMENT CONSULTANTS

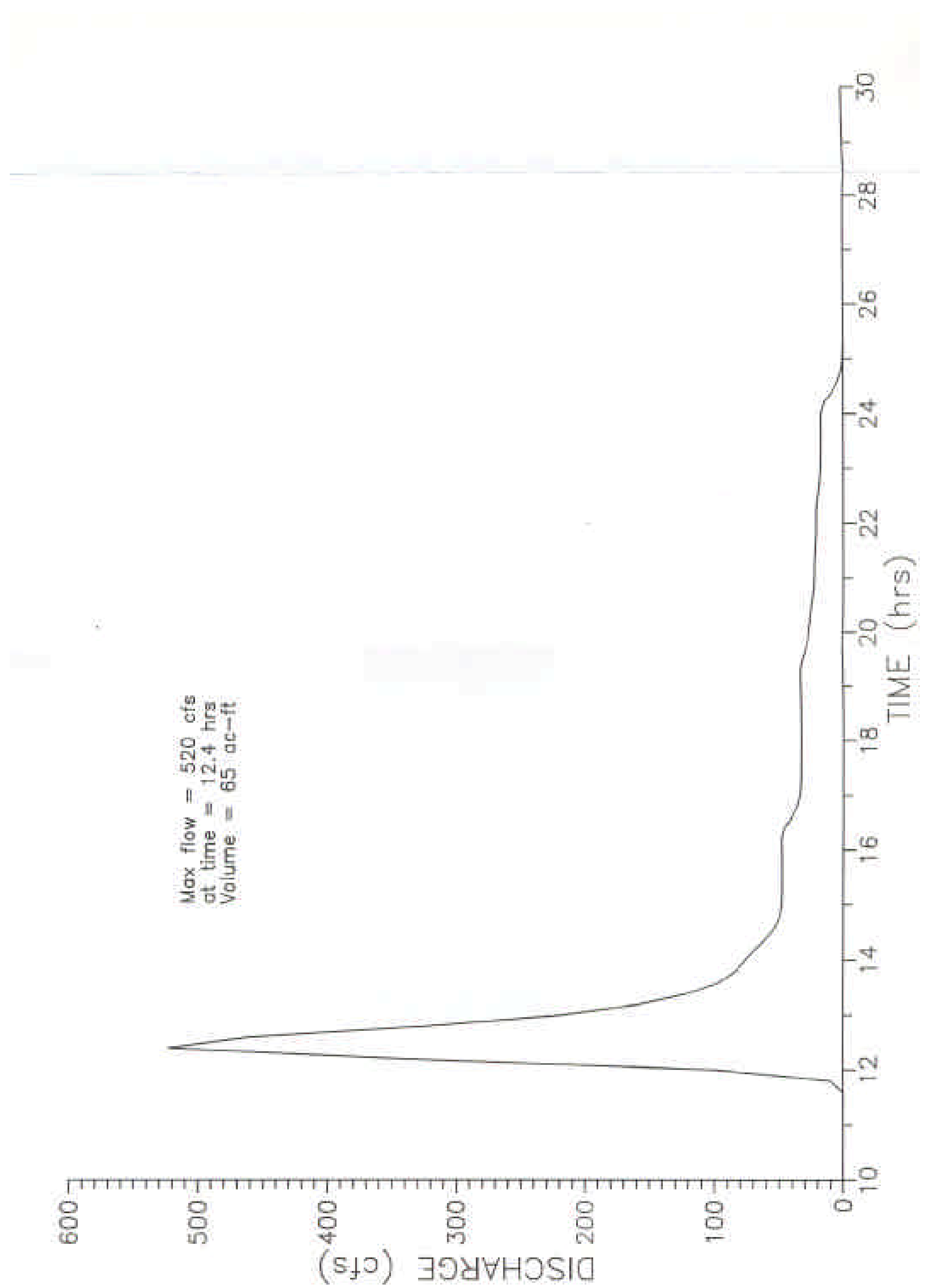
Figure 3.5 Instantaneous discharge measurements - Lower Barnes Creek, 1990



SOURCE: AMERICAN NORTH INC., 1992

WATER MANAGEMENT CONSULTANTS

Figure 3.6 Flood hydrograph for TSF

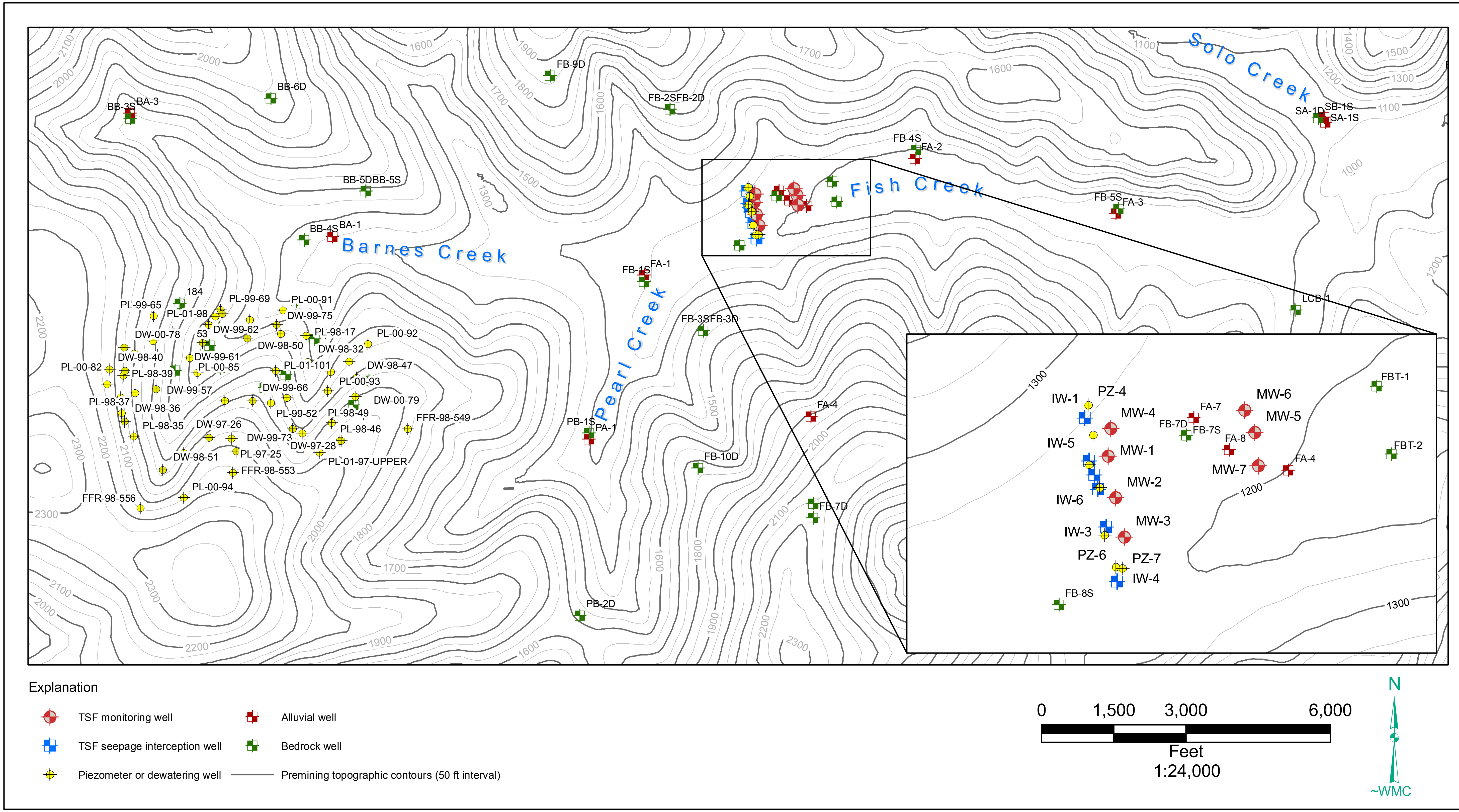


SOURCE: AMERICAN NORTH INC., 1992

F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-3.6.DWG

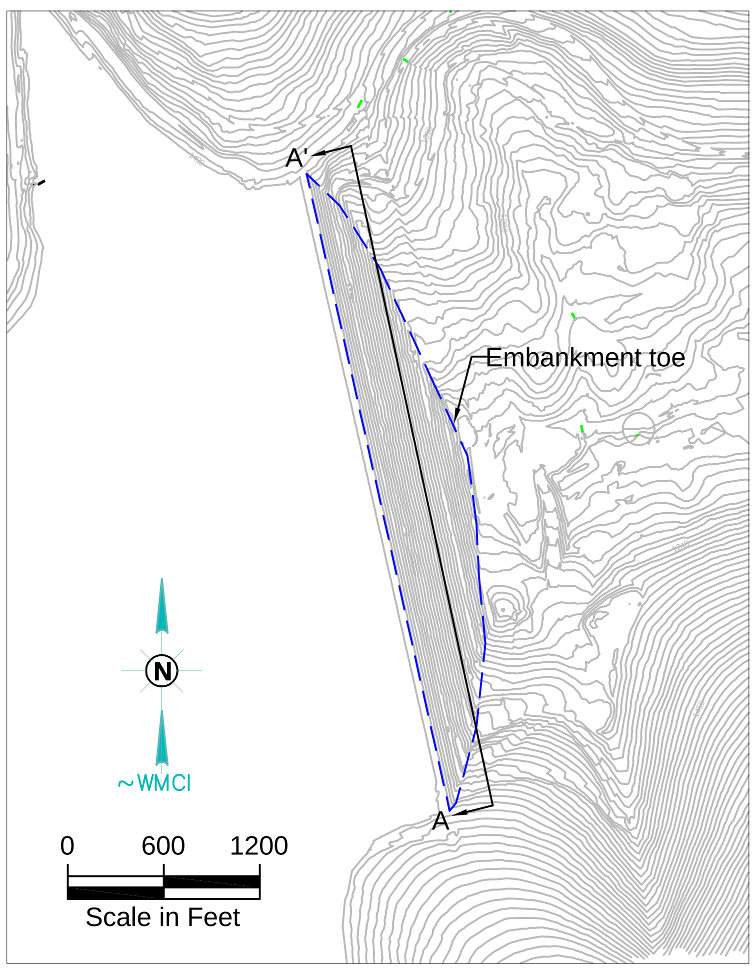
WATER
MANAGEMENT
CONSULTANTS

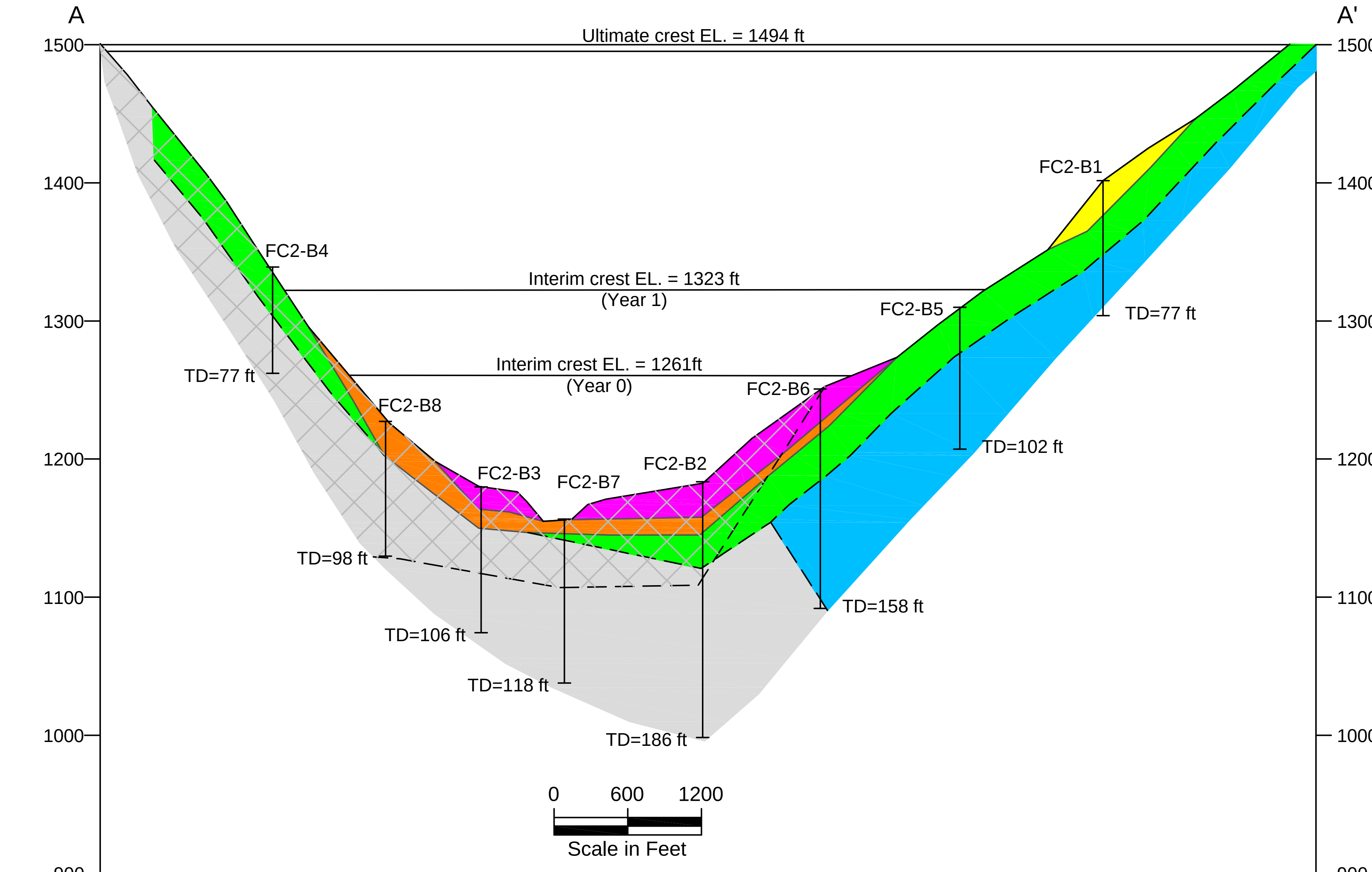
Figure 3.7 Well location map



WATER MANAGEMENT CONSULTANTS

Figure 3.8 Geologic cross section in area of TSF embankment





TAILING STORAGE FACILITY
GEOLOGIC CROSS SECTION

LEGEND

- L — Loess deposits (Wind blown silt) on valley north side slope
- S — Silt, gray to black, highly organic, generally frozen; may contain local sand and/or gravel lenses
- G — Silty gravel and sand with occasional silt lenses, generally frozen where buried but thawed near surface, dense; includes thin gravelly colluvial deposits on south side of valley
- WS — Highly weathered schist bedrock, soil-like in consistency, dense, excavates easily
- FS — Fairbanks schist bedrock, moderately hard to hard, well foliated, moderately to highly fractured, tends to break up into medium hard to soft subangular fragments
- CS — Cleary schist bedrock, hard, brittle, moderatelyto highly fractured, tends to break up into resistant angular fragments
- Frozen soil or rock (Permafrost)

NOTES:

1. Vertical exaggeration 5 times horizontal scale
2. Geology along starter embankment expected to be similar to geology along lines of exploration boreholes
3. Existing monitoring wells (Halepaska, 1992) and geotechnical instrumentation (KP, 1992) to be preserved or replaced

SOURCE: KNIGHT PIESOLD, 1994

F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-3.8.DWG

4 TAILING FACILITY CONSTRUCTION AND OPERATION

4.1 Facility construction

As mentioned in Section 2, the TSF embankment has been constructed as a zoned earthfill/rockfill structure capable of withstanding full hydrostatic load. Construction of the starter embankment began in late 1995 and was completed in two stages. The starter embankment was used to impound water to meet mill startup requirements.

All alluvial materials in the foundation footprint were removed to expose sound bedrock prior to embankment construction. The geometry of the embankment includes a 2.25H:1V upstream slope and a 1.8H:1V downstream slope. The embankment consists of a 30-ft wide rock fill zone on the upstream face, which serves as a riprap/ice protection zone on the upstream face. This zone is bedded on 25 ft of well-graded filter sand adjacent to a seal zone, a sand filter zone, a transition zone, and random rock fill zones (in upstream to downstream order). A foundation drain was constructed at the downstream toe to intercept seepage. Figure 4.1 illustrates the general embankment construction. All construction materials were generated from the embankment footprint or local borrow sources in the pit and Pearl Creek areas (Knight Piésold, 1994).

The low permeability seal zone is founded on competent (but relatively permeable) bedrock. Because of its relatively high permeability, the bedrock functions as part of the drain system for the embankment. Filter and transition zones within the embankment were designed to meet graded filter criteria. Specific construction specifications are presented in Knight Piésold, 1994. A summary of the hydraulic conductivity values for each of the materials is provided in Table 4.1.

The basin upstream of the embankment where tailing is stored is generally blanketed by a layer of silt, silty sand, and gravel with an effective vertical permeability of 7×10^{-3} cm/s. Highly fractured bedrock occurs beneath this zone and has an effective permeability of approximately 2×10^{-3} cm/s (Knight Piésold, 1994). Thus the materials directly below the tailing act as part of the drain system and allow continuous effective drainage. Seepage emanating from within the basin that is not collected by the reclaim system within the embankment foundation is captured by the interception system located downstream of the facility.

Seepage is collected in a sump connected to the foundation drain. Two 63-inch diameter high-density polyethylene (HDPE) pipes were founded in concrete at the base of the sump and act as caissons for the vertical-shaft turbine pumps which convey solution to the TSF pond. The toe drain pipes also discharge to the caissons. The sump is filled with drain rock and wrapped in non-woven geotextile. The downstream face was constructed with a geosynthetic clay liner keyed into bedrock. The foundation drain and sump system have been sized to accommodate a maximum flow of 12,200 gpm (Knight Piésold, 1994). The pump system is designed to cycle on and off between elevations of 1,155 and 1,141 ft amsl, respectively. The residual storage volume in the sump is approximately 14.5 Mgal above an elevation of 1,155 ft amsl. The elevation of the invert for the emergency drainage channel is approximately 1,162 ft amsl.

Annual construction occurred through the first 9 to 10 years to raise the embankment. The crest elevation of the TSF embankment in April 2005 was approximately 1,465 ft amsl. The final raise planned to occur during the 2006/07 construction season and will result in a final crest elevation of 1,494 ft amsl. The elevation of the top of the seal zone is expected to be approximately 1,488 ft amsl (Figure 4.1).

Table 4.1 Summary of hydraulic conductivity values for embankment construction materials

Material type	Hydraulic conductivity (cm/sec)
Highly fractured bedrock (upper 300 ft)	2.1×10^{-3}
Fractured bedrock (below highly fractured zone)	1.0×10^{-5}
Alluvium	7.1×10^{-3}
Rockfill zone	2.0×10^{-1}
Transition zone	1.8×10^{-1}
Filter zone	6.0×10^{-5}
Seal zone	4.8×10^{-6}
Drain	3.6×10^{-1}
Tailing	1.0×10^{-5}

4.2 Facility operation

Tailing deposition began in 1996 at a rate of approximately 40,000 to 45,000 tons per day (t/d). Tailing is discharged from open pipes located at five positions around the facility. Figure 4.2 illustrates the tailing discharge locations. Tailing is discharged at a solid:liquid ratio of approximately 50:50 by weight.

To date, approximately 123 Mt of tailing have been placed in the TSF. Figure 4.3 illustrates the actual and projected filling curve developed by Knight Piésold (1994). The maximum tailing elevation is projected to be approximately 1,488 ft amsl and the total amount of tailing to be placed is approximately 223 Mt.

Reclaimed water is transferred from the TSF pond to the mill using four barge-mounted vertical turbine pumps. The pumps have a total capacity of approximately 9,500 gpm.

To assess the performance of the TSF embankment drain system, vibrating wire piezometers were placed within the embankment during construction. Table 4.2 provides a summary of the location of the piezometers. Figure 4.4 illustrates the locations in plan view. Data are collected from the piezometers on a monthly basis. Figures 4.5 through 4.8 illustrate the pore pressure records for the filter layer, seal zone, and random fill.

Table 4.2 Summary of piezometer installations

Piezometer no.	Location and zone	Station	Elevation
P-1	Seal Zone	10+04.9	1,144.01
P-2	Seal Zone	10+05	1,145.68
P-3	Seal Zone	10+05	1,190.00
P-4	Seal Zone	10+05	1,190.00
P-5	Seal Zone	10+05	1,190.00
P-6	Seal Zone	10+05	1,200.96
P-7	Seal Zone	10+05	1,224.35
P-8	Filter Zone	10+05	1,140.55
P-9	Filter Zone	10+02.4	1,141.94
P-10	Random Fill	10+02.6	1,138.69
P-11	Random Fill	10+04.2	1,138.07
P-12	Seal Zone	10+05	1,155.00
P-13	Seal Zone	10+05	1,155.00
P-14	Seal Zone	10+05	1,155.00
P-15	Seal Zone	14+28.9	1,143.86
P-16	Seal Zone	14+25	1,151.56
P-17	Seal Zone	14+25	1,190.26
P-18	Seal Zone	14+23.3	1,192.01
P-19	Seal Zone	14+22.8	1,191.90
P-20	Seal Zone	14+25.2	1,204.61
P-21	Seal Zone	14+25	1,225.20
P-22	Filter Zone	14+25	1,152.55
P-23	Filter Zone	14+22	1,143.02
P-24	Random Fill	14+27.7	1,144.86
P-25	Random Fill	14+31	1,141.26
P-26	Seal Zone	14+22.2	1,159.25
P-27	Seal Zone	14+24	1,160.45
P-28	Seal Zone	14+15.9	1,160.59

The data indicate that the seal and drainage system are functioning as designed. Key points illustrated by the data include:

- Pressures within the filter layer on the upstream face are increasing as the elevation of the TSF pond increases through time.
- There is little to no head buildup in the filter at the base of the embankment indicating that the drainage system is functioning properly.
- There is a significant head drop across the seal zone indicating that the low permeability layer is effectively controlling the flow rate through the impoundment and allows higher permeability layers located downstream of the seal zone to drain.
- There is no increase in pressure within the random fill downstream of the drainage system indicating that the underlying bedrock has sufficient permeability to dissipate pressure.

4.3 Tailing hydraulic and geotechnical properties

4.3.1 Hydraulic properties

The hydraulic properties of the tailing were characterized as part of the original design (Knight Piésold, 1994) and, more recently, by WMC as part of this report. The test work completed to date includes saturated hydraulic conductivity testing and moisture release characterization. Two samples of tailing were collected by FGMI personnel in March, 2005, and shipped to the WMC hydraulic testing laboratory. Sample #104 was collected from the slurry line near the plant, and sample #106 was collected from the tailing surface midway to the TSF pond. The sampling locations are illustrated on Figure 4.2. No samples were collected from within the TSF pond area.

As a means of estimating the hydraulic properties of the fine fraction, a split was generated from sample #106 consisting of the –200 mesh material. This fraction is assumed to be similar in nature to the slimes present below the TSF pond.

Table 4.3 summarizes the saturated hydraulic conductivity values generated from the various test programs. The tailing were tested over bulk density values ranging from 70.4 to 100.0 pounds per square foot (psf). The range of densities represents variations in grain-size distributions and test conditions. The range is generally consistent with estimated in-situ density based on material reconciliation calculations completed by FGMI. Estimated hydraulic conductivity values range from 1.2×10^{-5} to 3.0×10^{-6} cm/s.

The test work suggests that the hydraulic conductivity of tailing material would be expected to decrease with continued consolidation. However, the magnitude of the decrease will likely be variable depending on the textural characteristics at any given location. The data suggest that there will be an overall decrease in hydraulic conductivity (and hence seepage) between one-half and one-order of magnitude as consolidation occurs. In addition, the fine fraction deposited beneath the pond has a hydraulic conductivity about one order of magnitude lower than the coarser tailing in the beach area.

Table 4.3 Results of falling-head permeability tests

Sample	Initial solids content (%)	Dry density (lb/ft^3)	Saturated hydraulic conductivity (cm/s)	Source
Bulk tailing	39.9	70.4	2.7×10^{-5}	Knight Piésold (1994)
Bulk tailing	44.1	74.0	1.4×10^{-5}	Knight Piésold (1994)
Bulk tailing	49.8	75.6	1.2×10^{-5}	Knight Piésold (1994)
104	59.8	99.3	9.33×10^{-5}	WMC(2005)
106	59.8	99.3	2.26×10^{-5}	WMC (2005)
106	59.8	100.0	3.3×10^{-4}	University of Colorado (2005)
106 (-200M)	NA	100.0	3.0×10^{-6}	University of Colorado (2005)

NA = Not applicable

Moisture release characteristics were defined through Tempe cell testing completed on the two samples collected in March 2005. The moisture characteristic curves are presented in Figure 4.9. The release characteristics are typical for fine materials and show a gradual decrease in moisture content with increasing suction. The total porosity ranges between 0.43 and 0.49. The residual moisture content at the highest suction applied ranges from approximately 3 to 5 percent by volume. The moisture release data were used to estimate the unsaturated hydraulic conductivity function for the tailing materials illustrated in Figure 4.10. The results indicate that the hydraulic conductivity changes relatively gradually with decreases in moisture content. At saturation the hydraulic conductivity is approximately 1×10^{-5} cm/s and decreases to about 1×10^{-6} cm/s at a moisture content of 30 percent by volume.

4.3.2 Geotechnical properties

The geotechnical testing completed on the tailing for the Closure Management Plan included particle-size distribution and consolidation analyses. Test work was completed as part of the initial design and is summarized in the Knight Piésold engineering report (Knight Piésold, 1994). The Knight Piésold testing program included determination of drained and air-dried densities, flow cone viscosity estimates, specific gravity and particle-size distributions. All test work performed by Knight Piésold was completed on laboratory generated tailing samples.

Particle-size distribution

Sieve and hydrometer tests were run on samples #104 and #106 to determine whether the tailing at the two locations were substantially different, potentially requiring two different consolidation tests. The samples varied in that #106 contained slightly more fines than #104. This indicates some initial settlement of coarse material between the beach and the main pool area. However, the difference was not considered significant enough to warrant two consolidation tests. Therefore, the more fine-grained of the two samples (#106) was selected for the Seepage Induced Consolidation Test (SICT) discussed below. The gradation curves for each sample are presented in Appendix B. In summary, sample #106 is characterized as a silty sandy material with 100 percent of the particle size passing the No. 10, approximately 76 percent of the particle sizes passing the No. 100 sieve size and approximately 53.6 percent passing the No. 200 sieve size (all percentages are based on dry solids weight).

Consolidation testing

Tailing consolidation testing was completed to provide an estimate of the tailing condition subsequent to deposition. This information was used to correct the final tailing surface elevation to account for consolidation and estimate the volume of consolidation water that will report to the pond over time.

The SICT is used for determining the consolidation characteristics of soft soils and soil-like materials (such as mine slurry waste, dredged spoils, sludge from waste treatment plants, etc.). The basis of the test is to characterize consolidation induced by subsequent deposition of material and self-loading over time. A summary of the SICT and the test results for the Fort Knox tailing sample is presented in Appendix B. The following is a brief discussion of the SICT results.

The SICT results indicate that the tailing material is relatively stiff and permeable. As a result, the magnitude of consolidation is estimated to be small following initial settlement of the solids from the slurry (i.e., the majority of consolidation occurs over a short period of time). It is estimated that measurable consolidation of the tailing mass will be complete within 6 to 10 months following the cessation of tailing deposition. The data suggest this will be the case regardless of tailing thickness in any area of the impoundment.

The data plots for *e-log p* (void ratio vs. log of applied effective stress) and permeability vs. void ratio of the SICT are presented in Appendix B. These plots illustrate the stiffness and relative permeability of the tailing material. The initial settled density of the tailing (the settled density at zero effective stress – referred to as the start of consolidation) was determined to be 85.95 pcf with an initial void ratio of 0.92.

Figures 4.11 through 4.13 and Table 4.4 summarize a series of data comparisons generated from the test results.

Several assumptions were required for the analysis of the consolidation test data:

- The material tested is representative of the in-place tailing mass currently in the impoundment;
- The material tested is representative of future tailing material to be deposited into the impoundment;
- Tailing placement and distribution methods are not subject to change in the future;
- The tailing always remain saturated such that drying and desiccation do not increase the estimated effective stresses applied to the underlying layers of tailing;
- The maximum depth of tailing are estimated at 250 ft in the central area of the impoundment in the vicinity of the upstream toe of the dam; and
- The project life is 16 years beginning in July 1996.

The summary of consolidation characteristics listed below are based on the laboratory test data and analytical analysis:

- The material tested exhibits relatively high hydraulic conductivity (3.3×10^{-4} cm/s) even with a fines content of plus 50 percent by weight;
- The settled density of the tailing prior to the start of consolidation is estimated at 85.95 pcf at a void ratio of 0.92;
- The average density of the tailing deposited over a six-month period is 93.44 pcf;
- Most of the water released from consolidation of a freshly deposited layer occurs over a 6- to 12-month period following deposition;
- Vertical drainage consolidation of water will occur upward to the surface and downward into the foundation;
- The hydraulic conductivity of the tailing are such that there will be a net downward flow component from the water stored on the tailing surface over the long term; and
- Once tailing deposition is completed in an area, measurable consolidation will cease within a 6- to 10-month period.

Release of consolidation water

The water released during consolidation of the tailing occurs as two components. The first is defined as ‘free’ water. This is water that immediately drains upon initial settlement of solids to a density under no self-weight induced effective stresses (i.e., the point defined as the settling out of the tailing from solution and the start of tailing consolidation). The second component is the water released from the tailing as consolidation occurs. This includes water released during both primary and secondary consolidation. Primary consolidation releases water from the near surface tailing. Secondary consolidation releases water from lower tailing as deposition continues.

The reported slurry density at discharge ranges from 45 to 60 percent and averages 50 percent solids by weight making the total water content in the slurry 1 ton per ton of ore (240 gal per ton of ore). Based on the SICT results, the initial settled density of the tailing are estimated to be 85.95 pcf. The ‘free’ water draining to the pond is approximately 156 gallons per ton of ore, leaving 84 gallons per ton of ore retained in the ore.

Based on the SICT data analysis, the primary consolidation likely occurs from tailing deposited up to about 80 ft in depth. Once deposition of tailing in an area exceeds 80 ft in depth, the release of consolidation water from tailing is greatly reduced.

Table 4.5 presents a summary of tailing consolidation, water released from the tailing over time, and the depth of tailing deposited based on the SICT results. Figure 4.14 illustrates these data and the incremental increase of consolidation water with subsequent tailing deposition. Assuming no additional tailing deposition after Year 16, the release of consolidation water is expected to decrease to negligible levels within about a 6- to 12-month period.

4.4 Tailing geochemistry

4.4.1 Meteoric water mobility testing

FGMI has collected quarterly Meteoric Water Mobility Procedure (MWMP) data from the tailing solids since operation began. These data are reported in the quarterly reports for Solid Waste Permit #0031-BA008. Table 4.5 provides a summary of these data and is based on information presented in the MWH report (2004). The information is presented relative to pre-True North ore processing. Milling of the True North ore ended in early 2005. Therefore, the final tailing surface will be comprised of tailing from the Fort Knox deposit only. The data in Table 4.5 illustrate the constituents that have the highest potential to be mobilized but are not indicative of the actual concentrations that will occur in the runoff. This is because the solid:liquid ratio used in the MWMP test is much higher than that which occurs in the field during a runoff event. The results indicate that arsenic, antimony, iron, cadmium, copper, and manganese may be mobilized during runoff events. The actual concentrations of constituents present in the runoff will diminish with time as the upper profile of the tailing gets sequentially flushed. The rate of flushing will be rapid because of the high proportion of surface water relative to the amount of pore water in the near surface tailing.

Table 4.4 Average tailing and consolidation water vs. time and height

Time (years)	Average tailing column consolidated height (ft)	Average dry density (pcf)	Total dry weight (lbs/ft^2)	Average void ratio	Average porosity	Water retained (gal/t)	Consolidation water (gal/t)	Increase consolidation water (gal/t)	Average increase per year (gal/t)
0.5	8.76	93.44	818.52	0.76	0.43	69.6	13.97	0	0.00
1	17.00	95.77	1628.25	0.72	0.42	65.7	17.85	3.88	7.76
2	33.33	98.14	3271.26	0.68	0.40	61.9	21.62	3.77	3.77
3.2	52.33	99.84	5224.69	0.65	0.39	59.3	24.22	2.60	2.17
5	80.51	101.45	8168.22	0.62	0.38	56.9	26.60	2.38	1.32
6.4	102.17	102.35	10456.84	0.61	0.38	53.7	27.89	1.29	0.92
9.6	151.02	103.83	15680.36	0.59	0.37	53.6	29.98	2.08	0.65
12.8	199.18	104.88	20890.44	0.57	0.36	52.1	31.42	1.44	0.45
16	246.85	105.69	26090.71	0.56	0.36	51.1	32.51	1.10	0.34

Table 4.5 Summary of tailing solids MWMP chemistry[(1)]

	Average	Minimum	Maximum
pH	8.4	6.6	10.0
TDS	583	80	3210
Sulfate	44	0.45	191
Iron[(2)]	0.58	0.01	2.43
Manganese[(2)]	0.095	0.003	0.651
Antimony[(2)]	0.013	0.003	0.092
Arsenic[(2)]	0.022	0.003	0.087
Cadmium[(2)]	0.0028	0.0003	0.0082
Copper[(2)]	0.012	0.005	0.076
Selenium[(2)]	0.003	0.003	0.008
Nitrate	1.4	0.50	3.6
Nitrite	0.02	0.01	0.04
Ammonia	1.4	0.1	4.6
Cyanide[(3)]	0.009	0.005	0.020

Notes:
(1) Units in mg/l, except for pH (S.U.) based on information provided in MWH, 2004.
(2) Dissolved values used for metal constituents.
(3) Cyanide reported as WAD.

4.4.2 Acid-base accounting

Tailing samples have been analyzed on a quarterly basis for acid base characteristics since 2000. The values for acid neutralizing potential (ANP) range from 23 to 78 tons $CaCO_3$/kT. The values for acid generation potential (AGP) range from below detectable levels to 2.2 tons $CaCO_3$/kT. The ANP:AGP ratios range from 30 to over 300 indicating that the neutralization potential of the tailing are significantly higher than the sulfide content. In general, ANP:AGP ratio values of 3 or greater are indicative of materials with low net acid generation potential. Based on the results of testing completed to date, the Fort Knox tailing have an insignificant potential for acid generation.

4.4.3 Preliminary column testing

The evolution of the tailing pore water quality was qualitatively evaluated using column test results. Preliminary column testing was performed by the FGMI metallurgical lab in 2004 to simulate the effect of clean water passing through tailing. Three columns were constructed to simulate Fort Knox/True North blended ore in series between Fort Knox unblended ore. Approximately 2,000 grams of tailing were placed in each column and covered with fiberglass. Water, with an initial pH of approximately 5.7, was passed through the columns. Effluent from each pore volume collected from the last column in series was submitted for chemical analysis.

For most constituents, concentrations drop rapidly with an increasing number of pore volumes. Analytes that decreased rapidly included TDS, copper, manganese, sulfate, and ammonia. Decreases from the first to the twelfth pore volume varied from a factor of 2.3 for nitrate to 40 for ammonia. Concentrations for several analytes (antimony, cyanide, and arsenic) increase by as much as a factor of ten within two to four pore volumes, and then drop to below their initial concentrations.

The results indicate that the rate of flushing from the tailing are rapid and that the magnitude of decrease in concentrations will be significant. Concentrations will likely begin to decrease in the seepage very quickly once the TSF pond composition begins to improve at the start of closure. Given the testing protocols and methodology, estimates of the number of pore volumes required to reach acceptable discharge quality are uncertain. However, the preliminary data suggest acceptable discharge quality could be met after 5 to 7 pore volumes.

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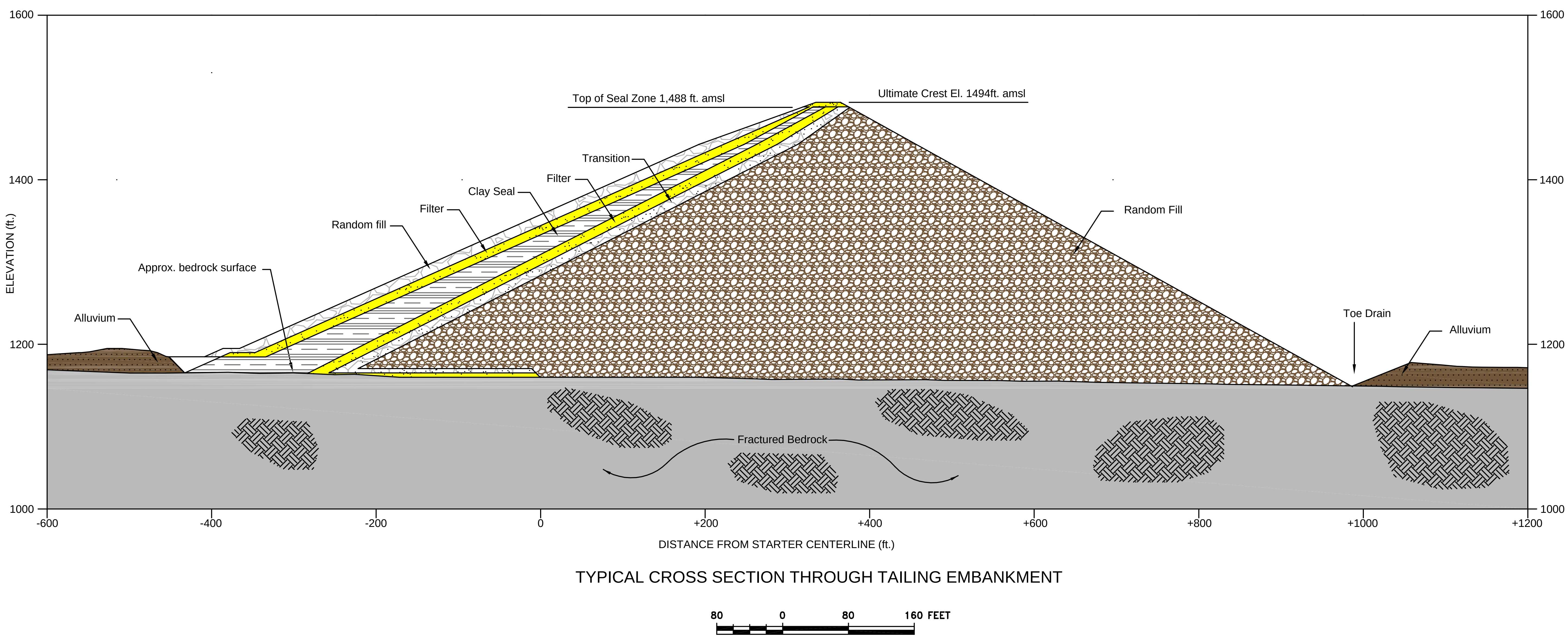
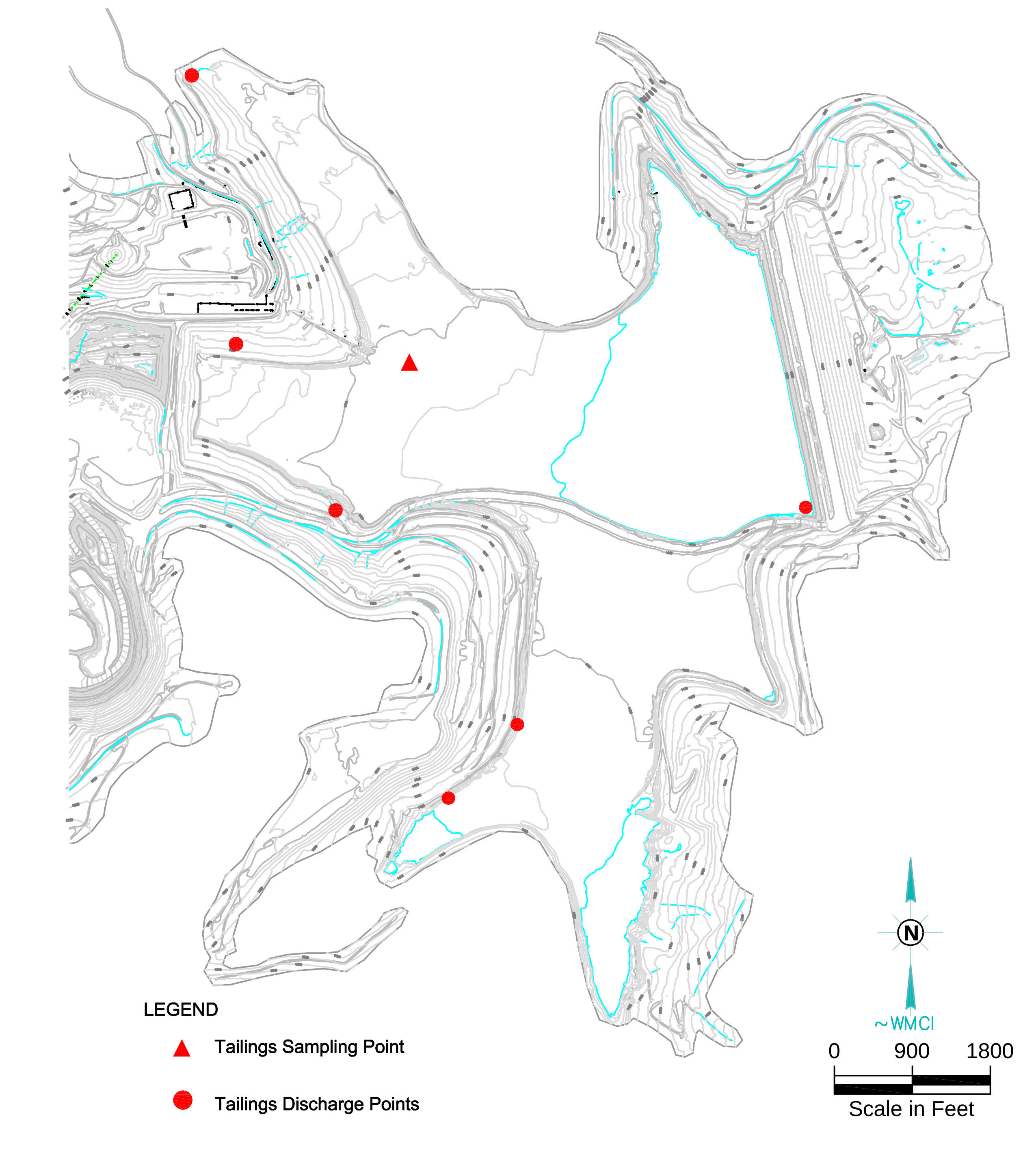
Figure 4.1 TSF embankment construction schematic



TYPICAL CROSS SECTION THROUGH TAILING EMBANKMENT

Figure 4.2 Location of tailing discharge points



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-4.2.DWG

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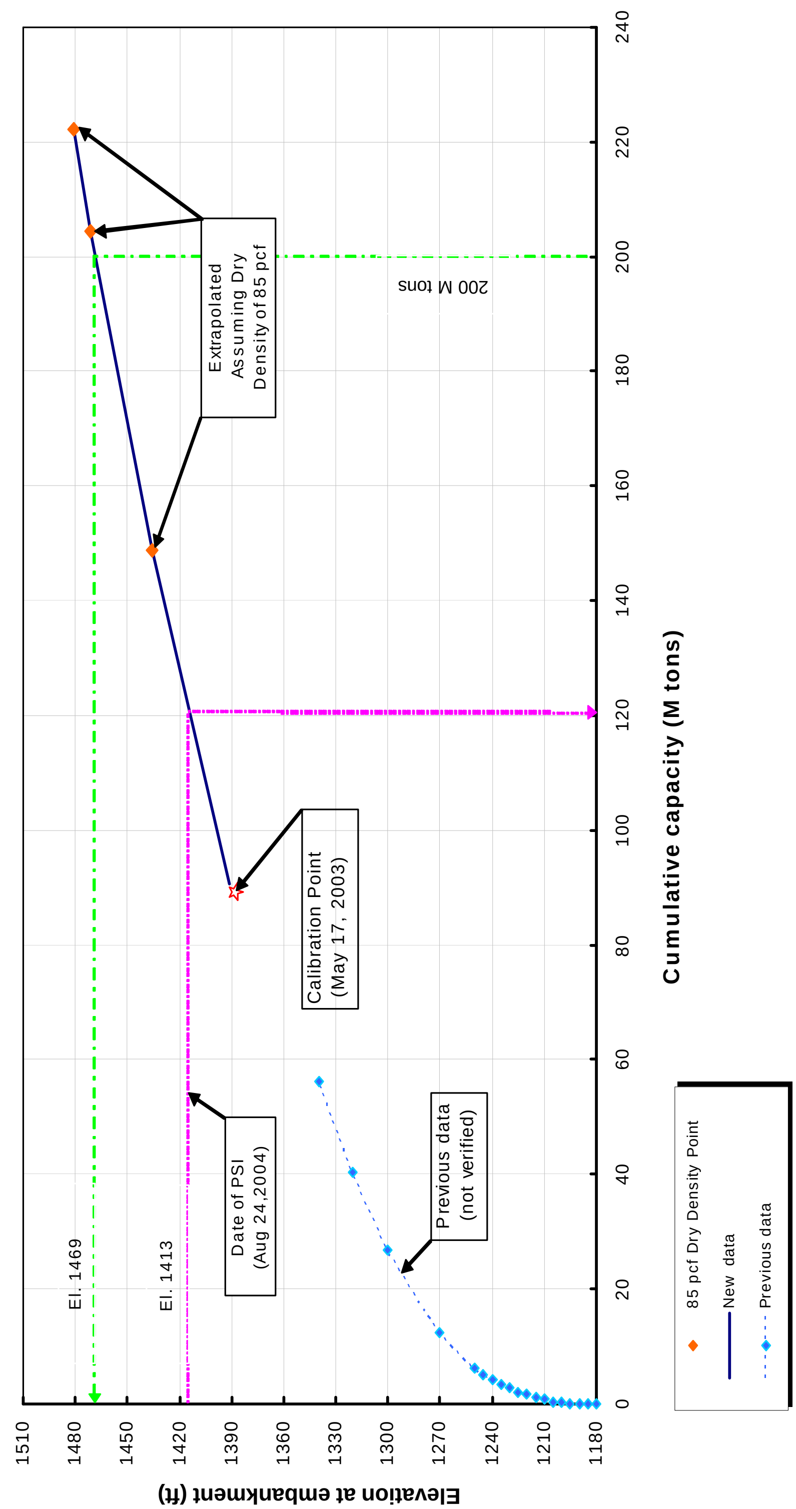
Figure 4.3 TSF filling curve



SOURCE: KNIGHT PIESOLD, 2004

F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-4-3.DWG

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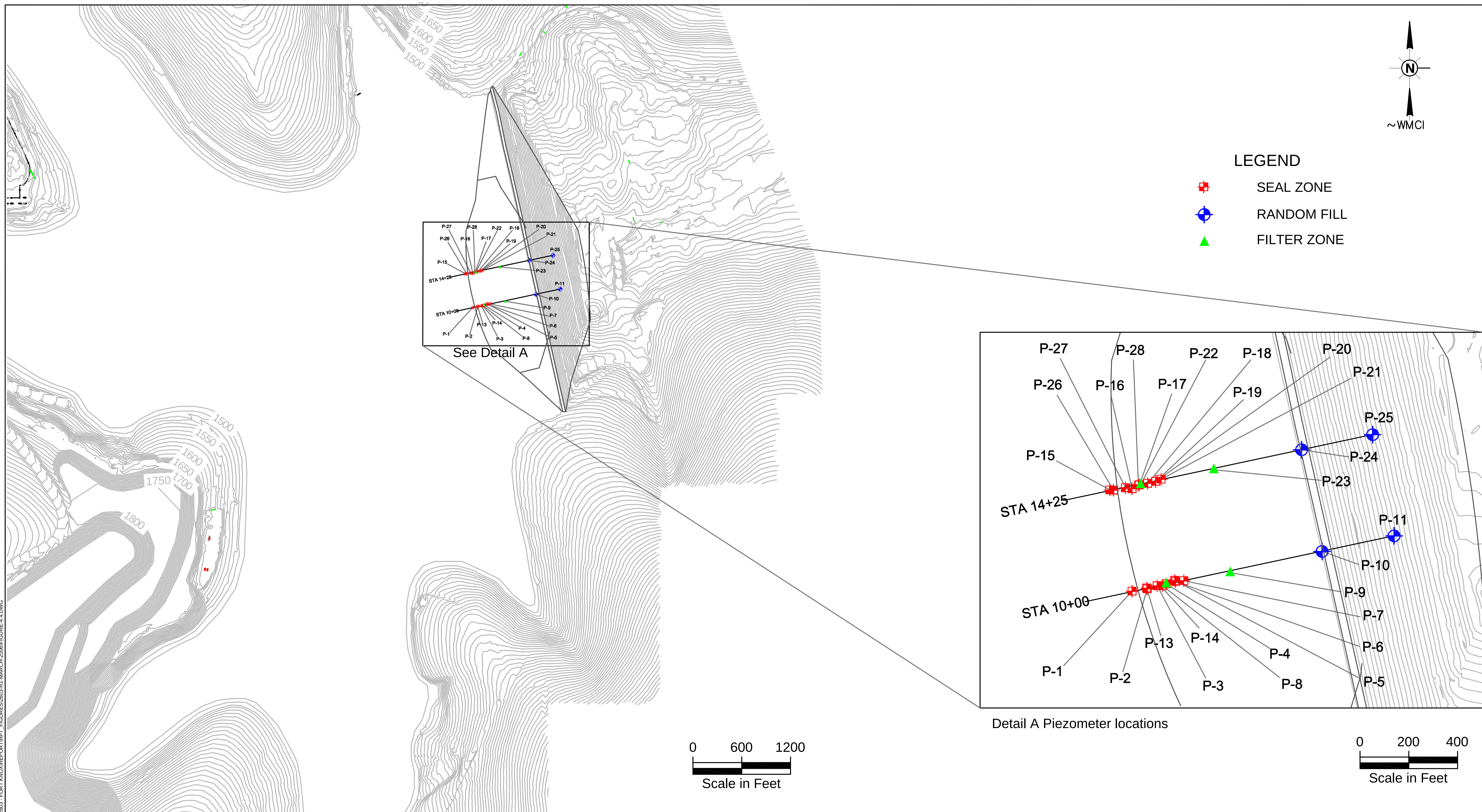
Figure 4.4. Vibrating wire piezometer locations



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-4.4.DWG

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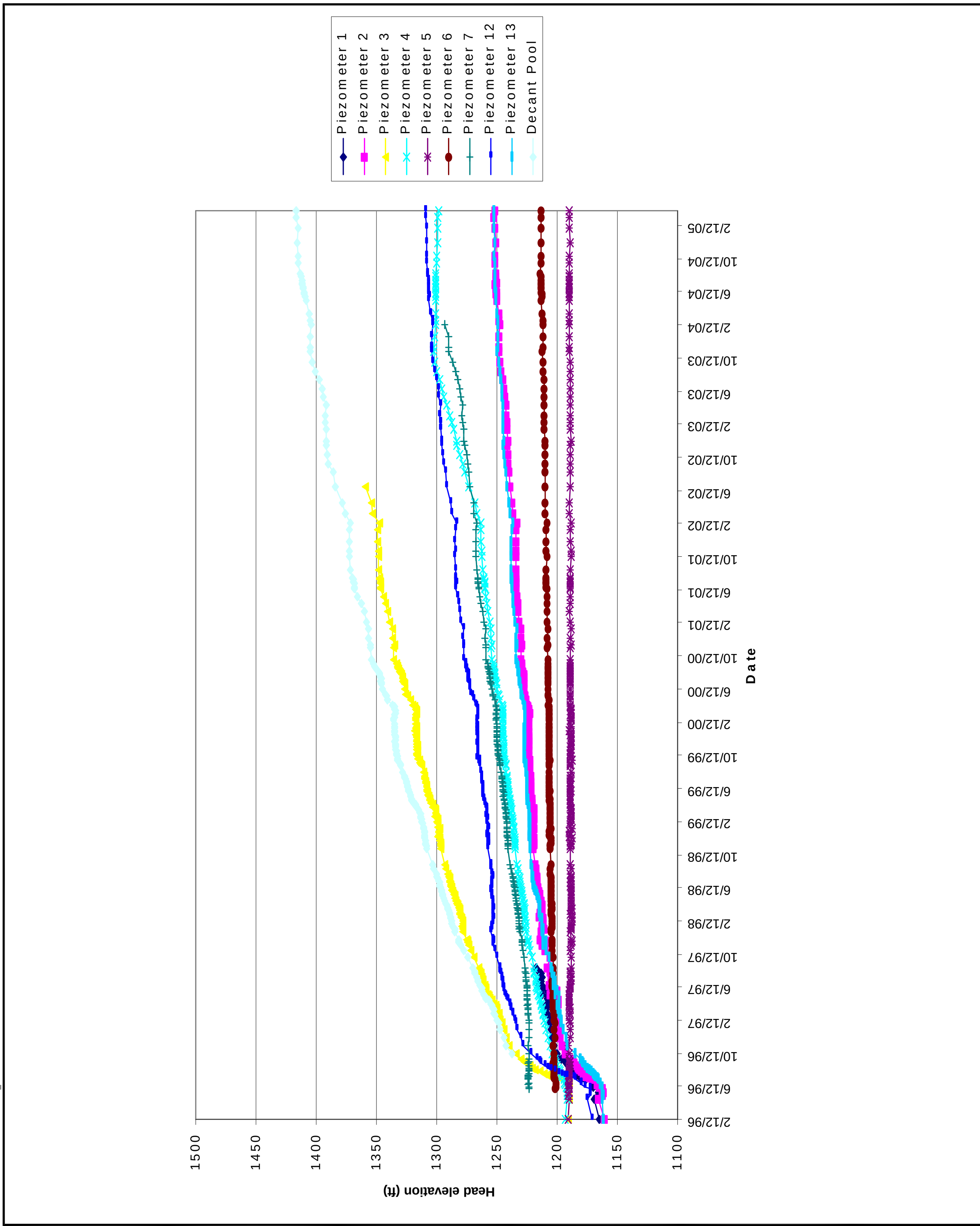
Figure 4.5 Pore pressure record for piezometers in filter layer



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-4.5.DWG

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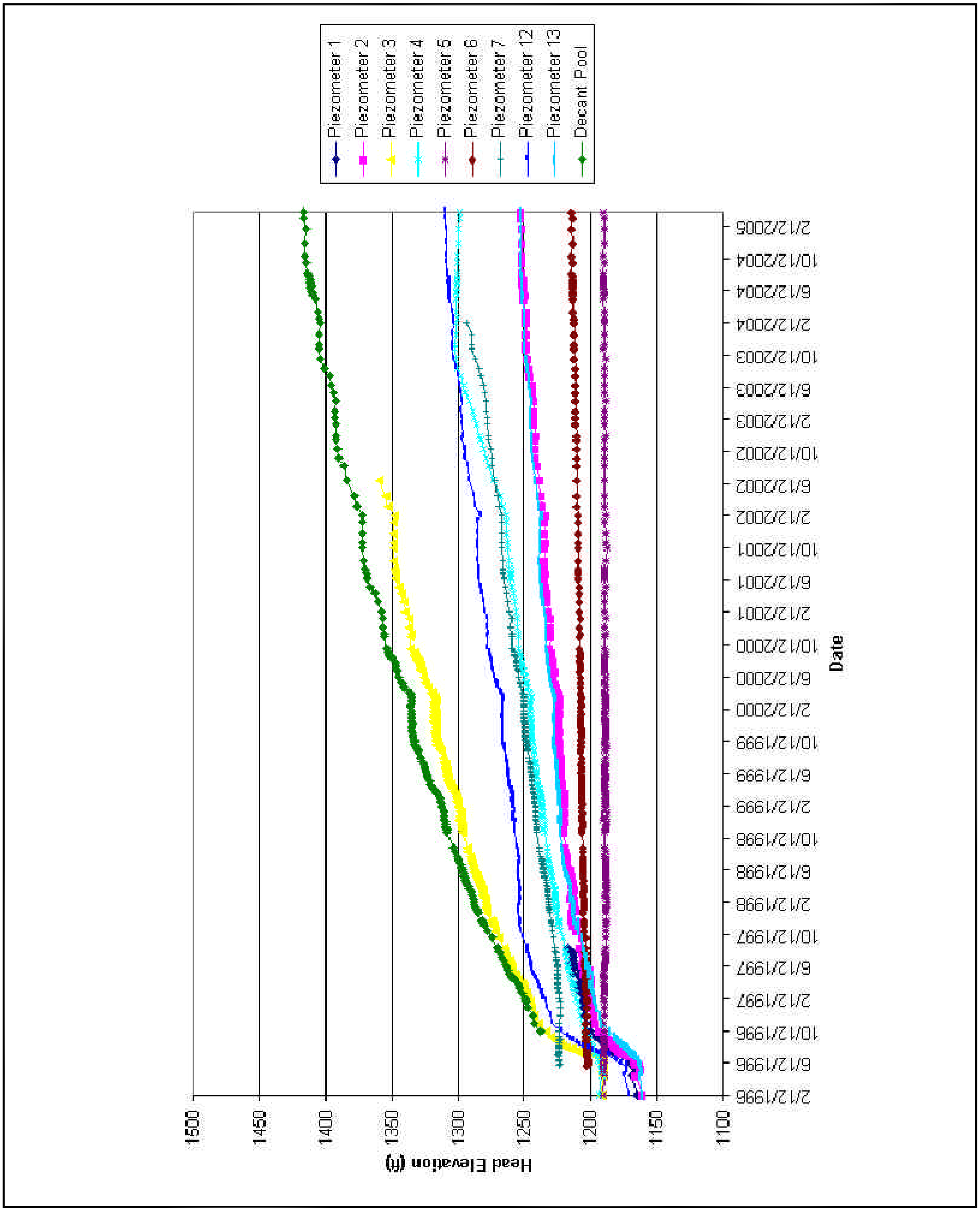
Figure 4.6 Pore pressure record for piezometers in seal zone (PZ1 - PZ14)



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-4.6.DWG

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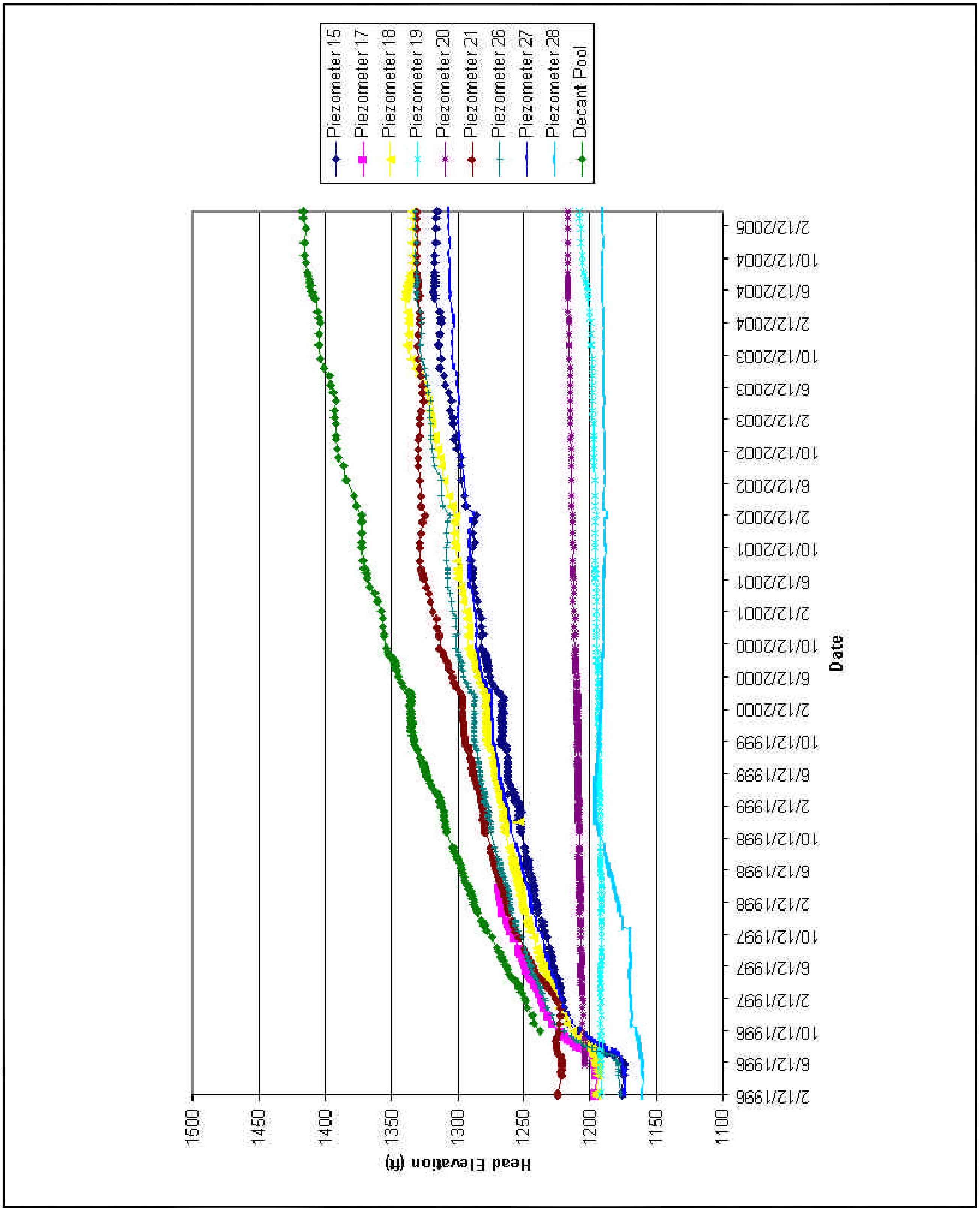
Figure 4.7 Pore pressure record for piezometers in seal zone (PZ15 - PZ28)



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-4.7.DWG

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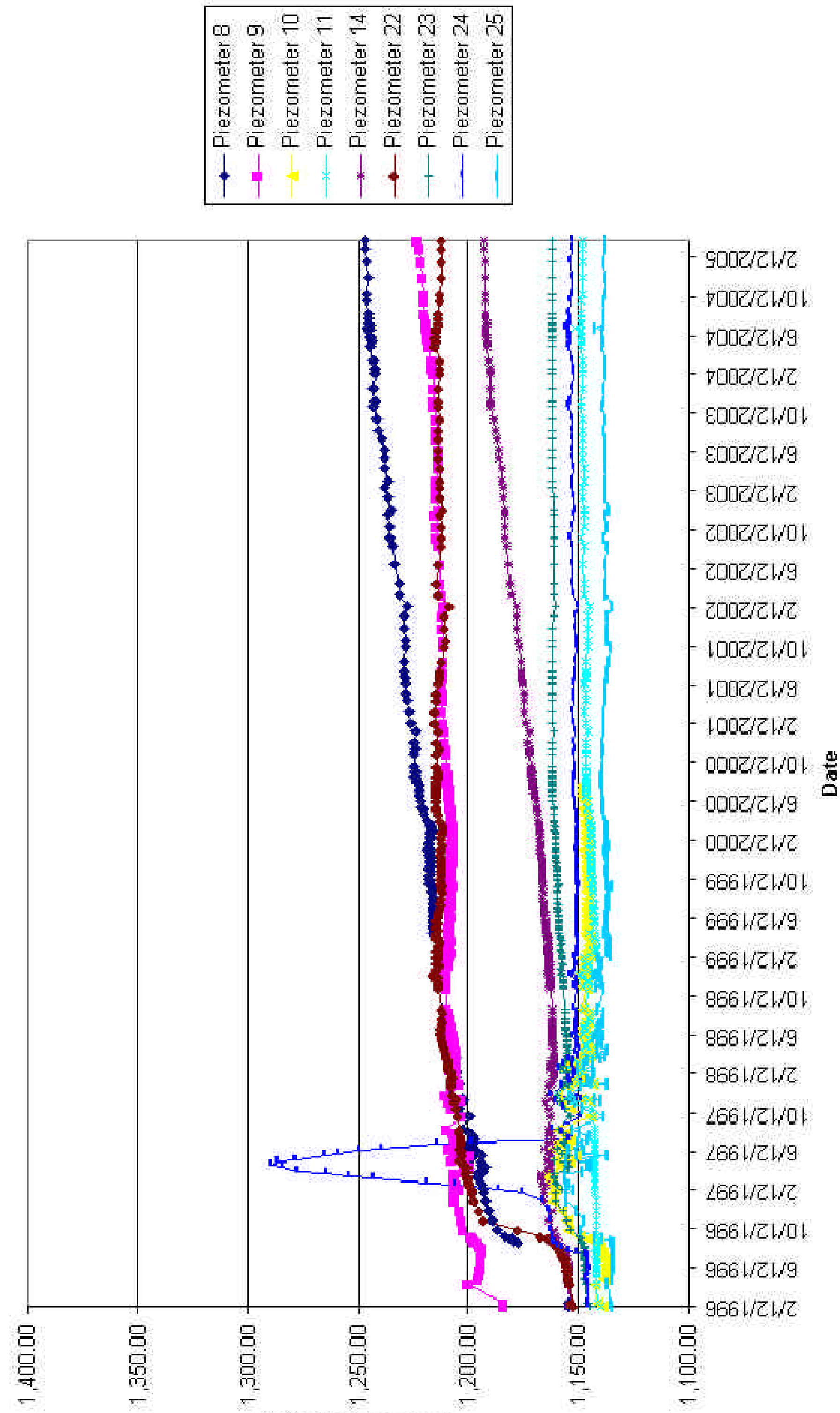
Figure 4.8 Pore pressure record for piezometers in random fill



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-4.8.DWG

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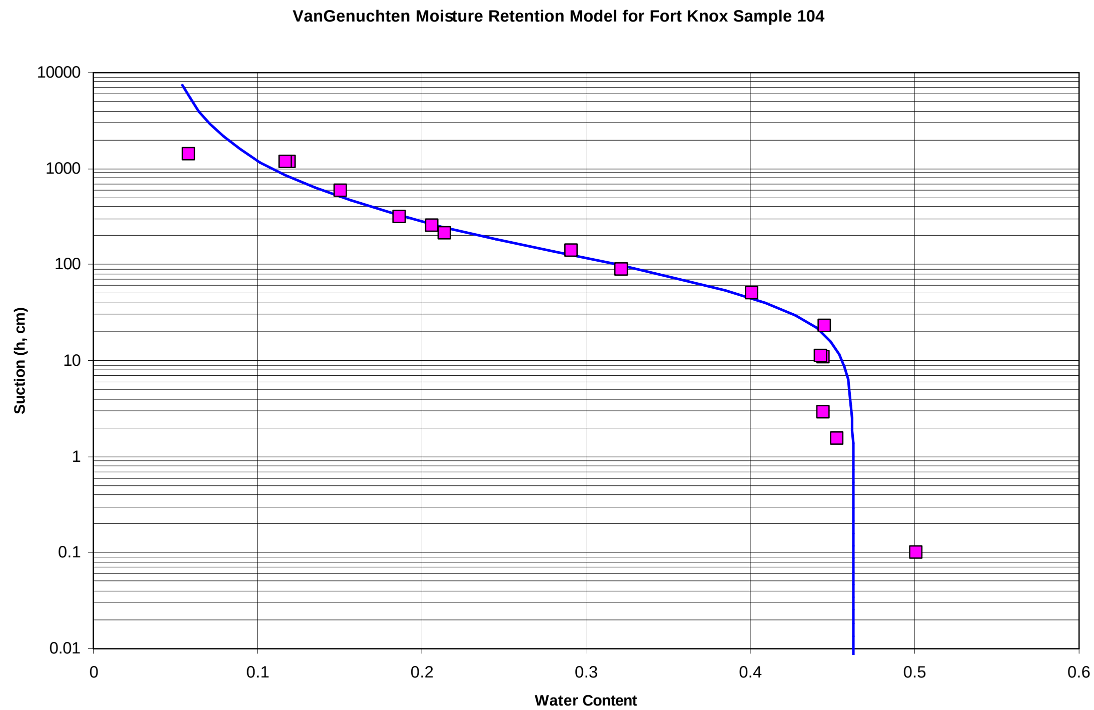
Figure 4.9 Tailings material moisture characteristic curves



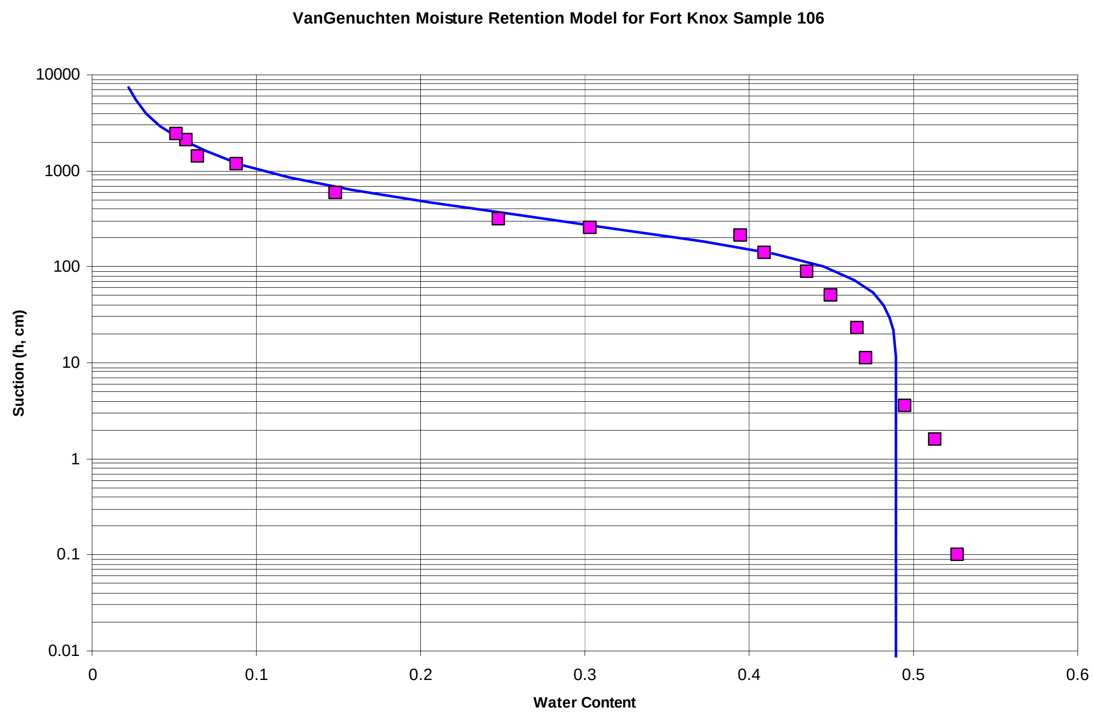


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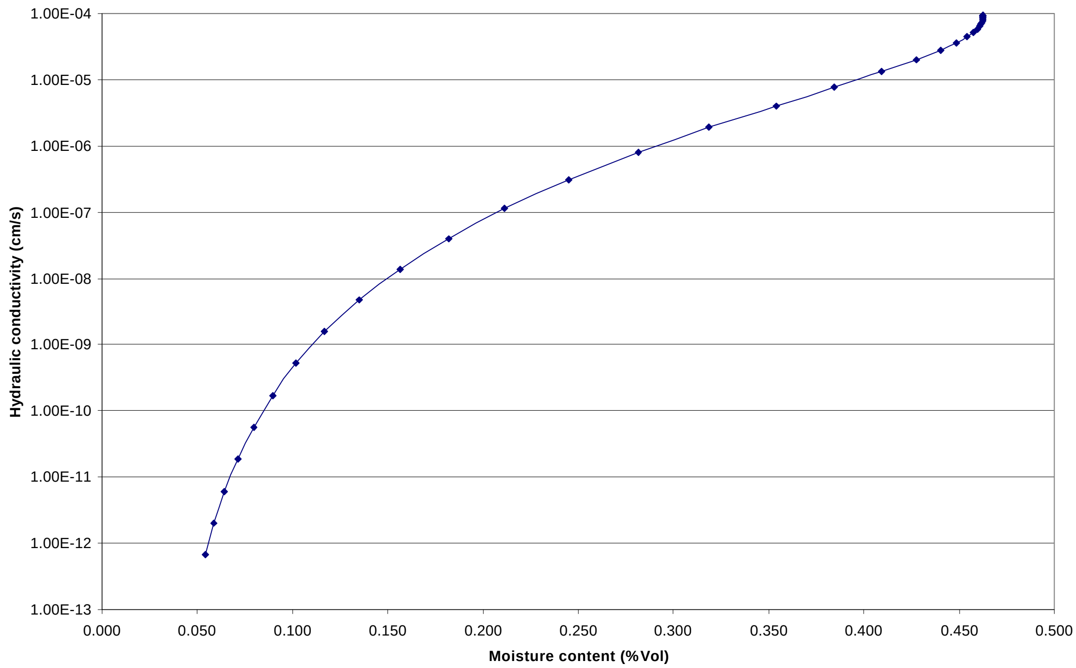
Figure 4.10 Tailings material hydraulic conductivity functions

Tailings discharge at pipe



Tailing half-way to decant pool

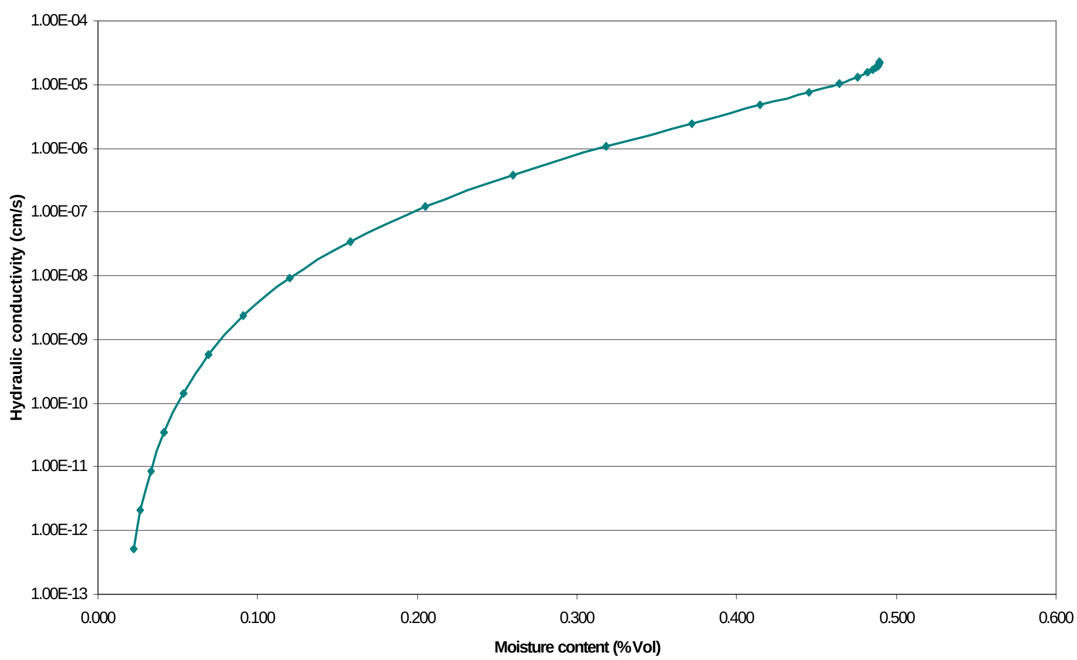


Figure 4.11 Tailing height vs. time

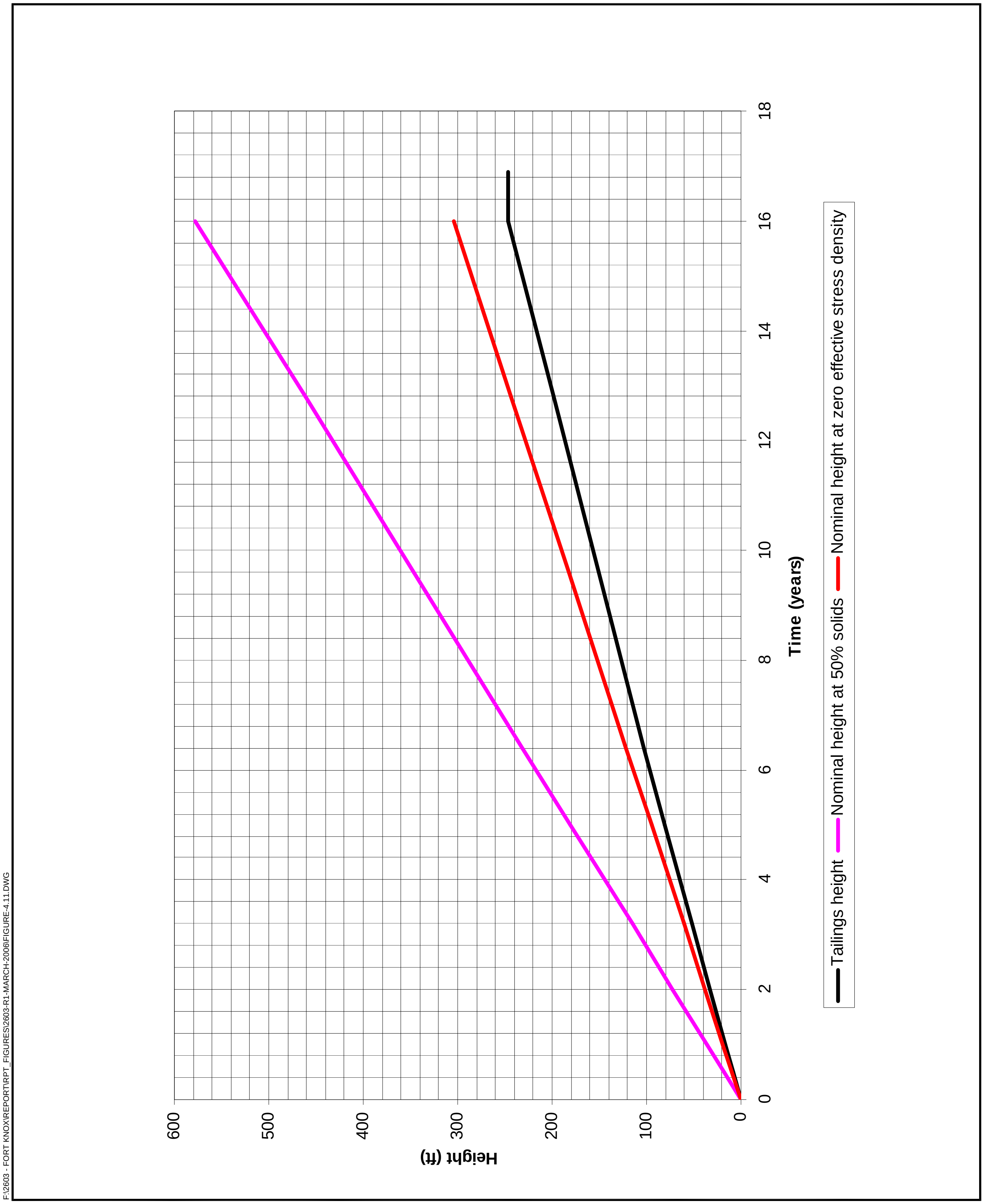
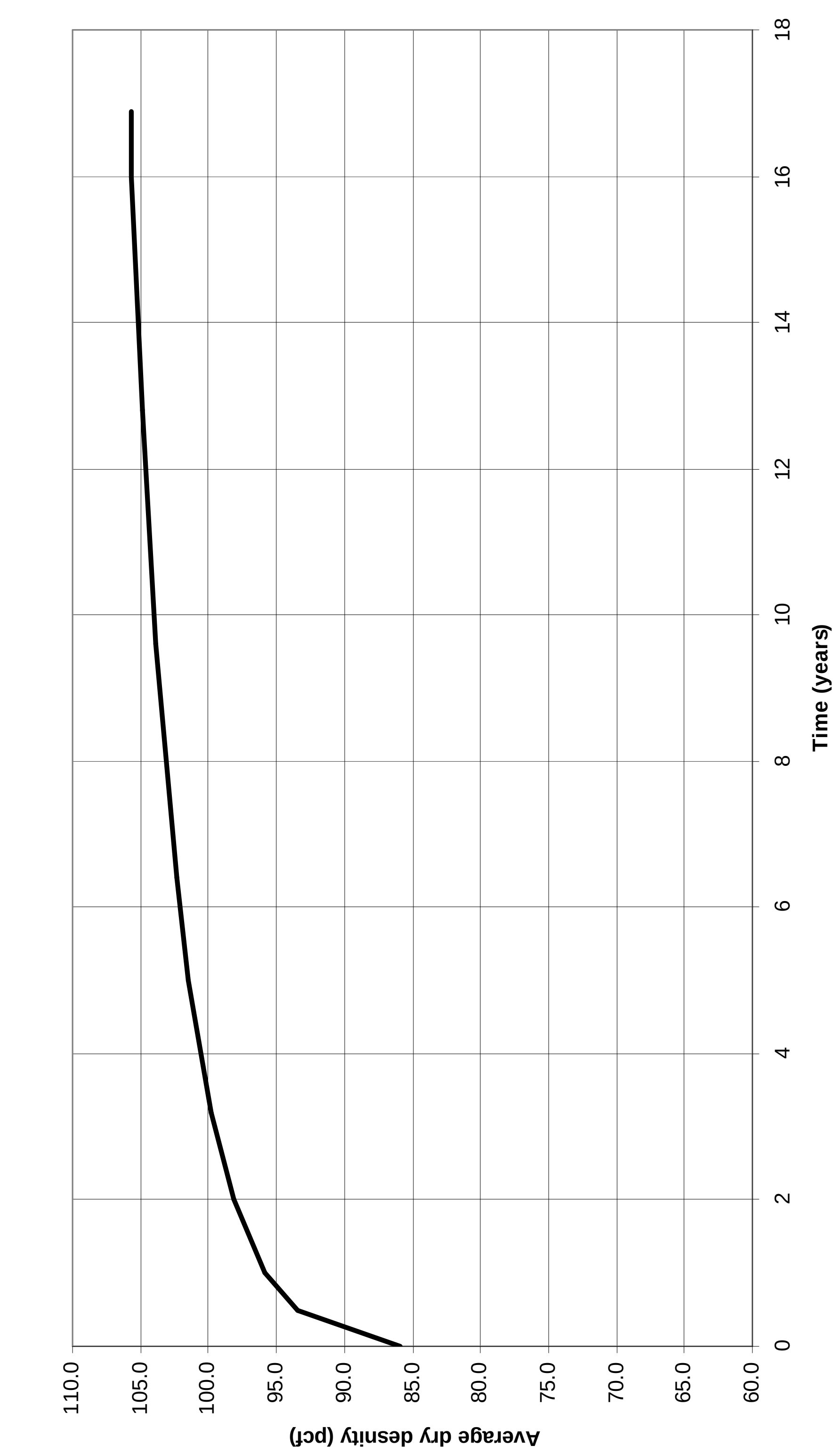


Figure 4.12 Dry density vs. time since deposition



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-4.12.DWG

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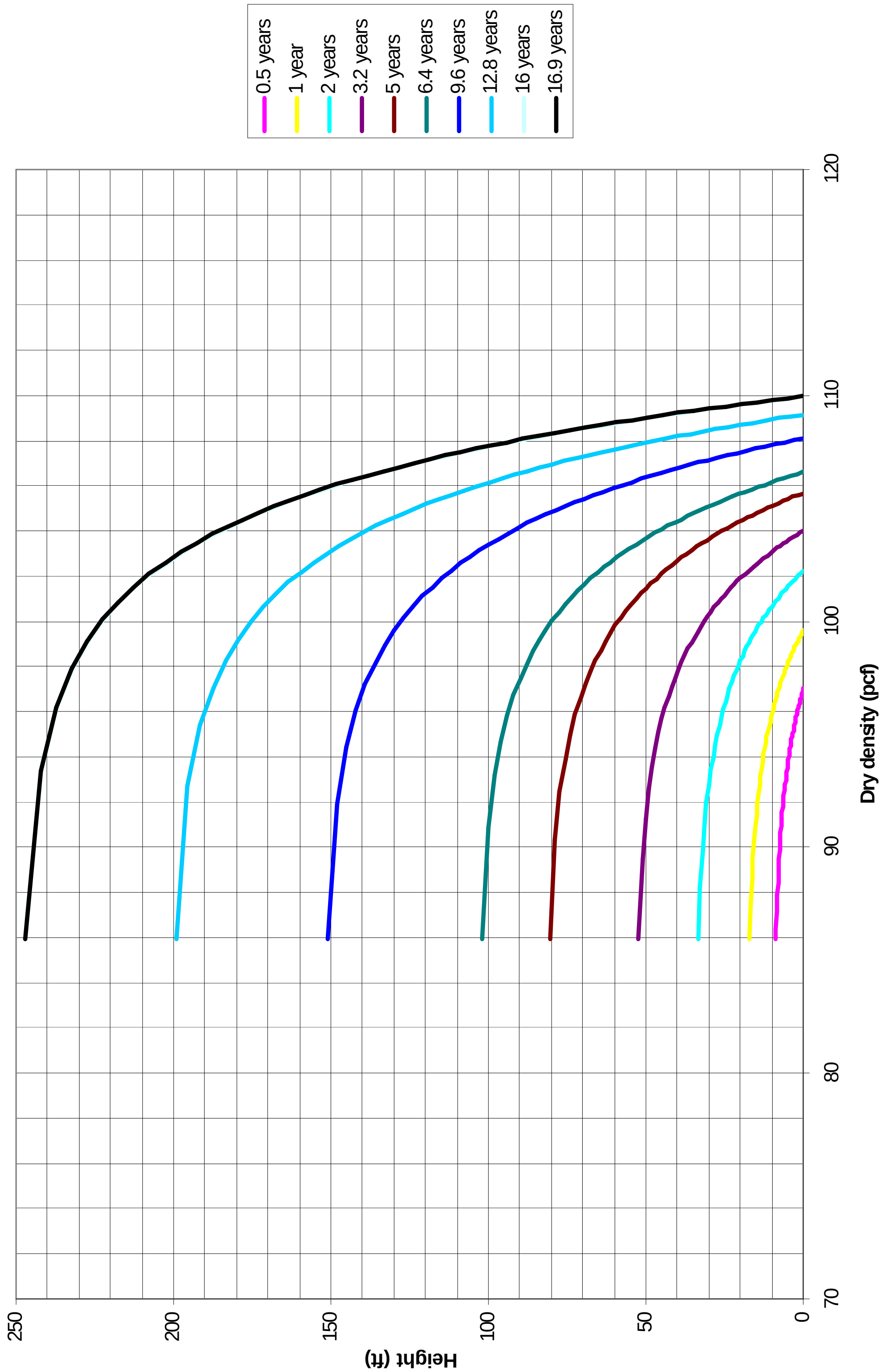
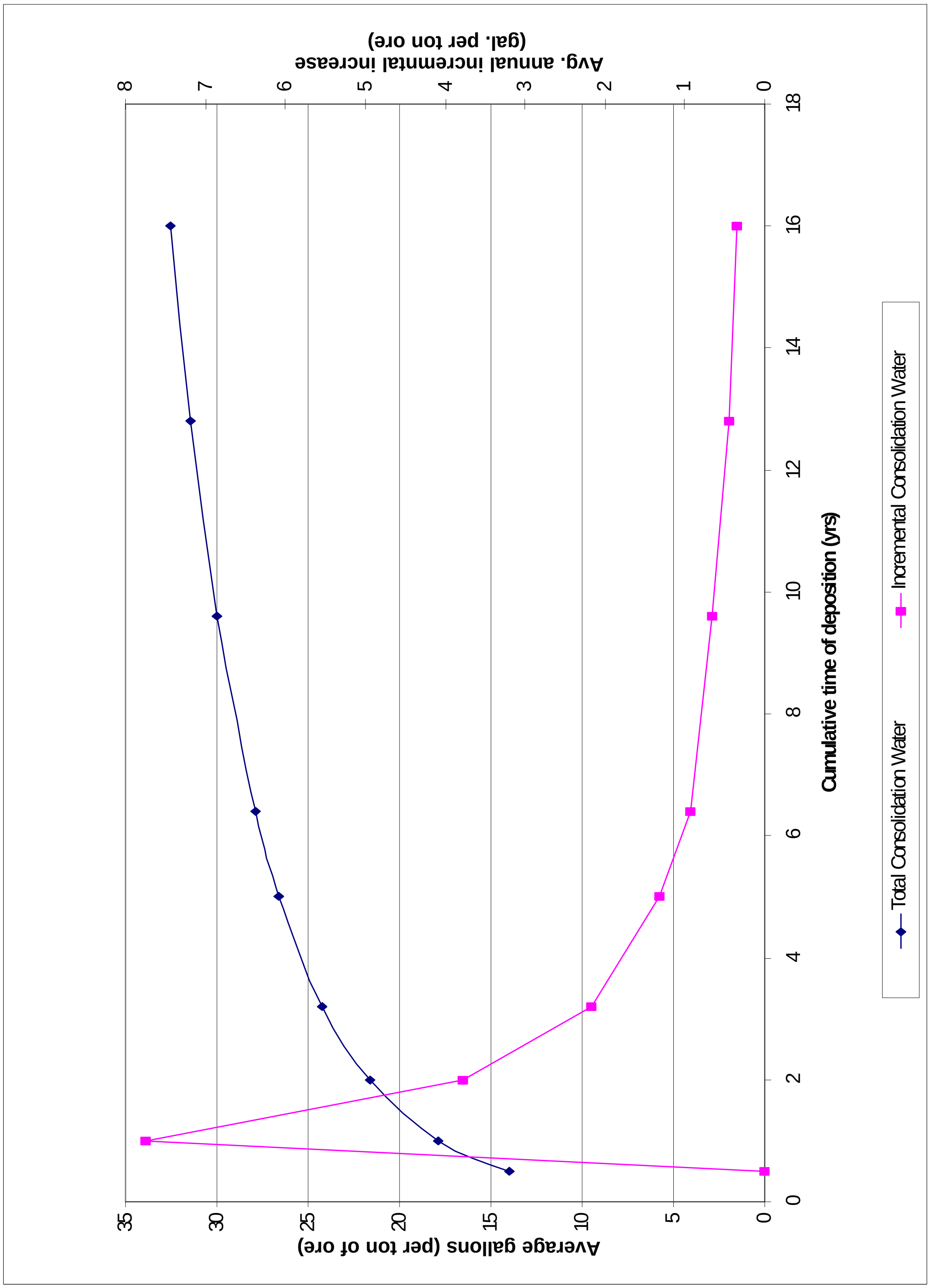
Figure 4.13 Dry density vs. height



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-4.13.DWG

Figure 4.14 Average consolidation water per ton of ore



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-4.14.DWG

5 HYDROCHEMISTRY

The hydrochemistry of various waters at the mine site was evaluated to characterize the range of baseline and current compositions relevant to closure management. Historical and current water quality data were evaluated to determine pre-mining conditions and the historical trends in water quality during the course of normal operations. Data were reviewed for the following components of the site hydrochemistry.

- surface water,
- groundwater,
- TSF pond, and
- TSF seepage.

To focus the evaluation of the water quality on potential constituents of concern during closure, the background and operational water quality data were compared to applicable water quality standards outlined in Section 5.1 below.

5.1 Applicable water quality standards

The applicable standards have been defined based on review of Title 18, Chapter 70 and Chapter 80 of the Alaska Administrative Code (18 AAC 70, 18 AAC 80) . The standards set forth in 18 AAC 70 specify the degree of degradation that may not be exceeded in a water body as a result of human activity. Under these regulations freshwater is protected for the following uses: water supply; water recreation; and growth/propagation of fish, shellfish, other aquatic life, and wildlife. Water that is protected for more than one use is subject to the most stringent water quality criteria for all of the designated uses (18 AAC 70.0-40). Therefore, the limits used to evaluate closure performance represent the most stringent water quality standards for fresh water based on maximum contaminant levels and criteria for aquatic life and human health.

As discussed in more detail in the following sections, baseline water quality data collected prior to construction of Fort Knox demonstrate that the natural condition of the groundwater and surface water in Fish Creek is of lower quality for several constituents relative to the criterion defined above. As a result, definition of tolerance interval based criteria that take into account natural conditions as outlined in 18 AAC 60.830 may be appropriate. Under the Solid Waste Disposal Permit #0031-BA008 an owner/operator of a solid waste facility must establish an appropriate method for evaluating changes in groundwater quality. One approved method (18 AAC 60.825) includes establishing tolerance intervals for specific parameters based on background data that reflect natural conditions within the groundwater system. Preliminary analysis of the data for selected parameters such as iron, manganese, antimony and arsenic suggest that the tolerance intervals calculated using baseline data will be above the criteria outlined in Table 5.1. FGMI will be working with Alaska DEC to establish the most appropriate criteria for the site prior to initiating closure activities.

Based on the evaluation of process water composition, the constituents with the potential to exceed water quality standards include arsenic, antimony, copper, sulfate, iron, TDS, cyanide, manganese, and selenium. Applicable water quality standards for constituents that have to be managed during closure are listed in Table 5.1, as well as the sources of each of the criterion. Hardness-based criteria were calculated based on available surface water data collected from the lower wetland directly above the freshwater reservoir.

5.2 Background chemistry

Background surface water and groundwater quality data are available from various studies performed prior to construction of the mine in 1996. The spatial distribution of data for water quality extends from Upper Barnes Creek to the current location of the freshwater reservoir.

5.2.1 Baseline surface water

Background surface water quality downgradient of the mine site was derived from samples collected at the Upper and Lower Fish Creek monitoring stations. Samples were collected monthly from 1992 to 1995 by FGMI. The locations of the surface water sampling stations are shown on Figure 5.1. The ranges of the total concentrations, as well as their average values, are presented in Table 5.2. Concentrations of total metals were generally higher than the dissolved fraction.

Table 5.1 Applicable water quality criteria

Constituent	Standard (mg/l)	Standard source
PH (standard units)	6.5 – 8.5. May not vary more than 0.5 pH from natural conditions	18 AAC 70
TDS	500$^{(1)}$	SDWR
Sulfate	250$^{(1)}$	SDWR
Iron	1	Table III chronic
Manganese	0.05	Table Va
Antimony	0.006	MCL
Arsenic	0.01	MCL
Cadmium$^{(3)}$	0.0003$^{(2)(3)}$	Table III chronic
Copper	0.009$^{(2)(3)}$	Table III chronic
Selenium	0.005	Table III chronic
Zinc	0.12$^{(2)(3)}$	Table III chronic
Nitrate	10	MCL & Table I
Nitrite	1	MCL & Table I
Ammonia	2.43 – 6.67$^{(4)}$	Table VIIa (chronic), temperature and pH dependent
WAD Cyanide	0.0052 $^{(2)(5)}$	Table III chronic

Notes:

(1) = Criteria for water supply
(2) = Four day average
(3) = Hardness based. Hardness = 103.7 mg/l as CaCO3, based on average Ca and Mg concentrations in the lower wetland surface water samples collected between February 2000 and November 2005.
(4) = Based on temperature <14^{o} C and a pH range of 8.0 to 6.5
(5) = Standards are based on free cyanide measured as weak acid dissociable (WAD) cyanide.

Standard Definitions

18 AAC 70 = Alaska Department of Environmental Conservation Water Quality Standards for fresh water uses, growth and propagation of fish, shellfish and other aquatic life, and wildlife.
MCL = Maximum Contaminant Concentration (USEPA, 2004)
SDWR = Secondary Drinking Water Regulation (USEPA, 2004)
Tables I –VIIa = Water Quality Criteria for Toxic and Other Deleterious Organic and Inorganic Substances [Title XVIII, Chapter 70, Alaska Administrative Code (18 AAC 70)]
Table I – Drinking water maximum contaminant levels (MCL)
Table III – Criteria for freshwater aquatic life
Table V – Human health criteria for noncarcinogens: (a) consumption of water + aquatic organisms, and (b) aquatic organisms only.
Tables VI and VIIa – Specific criteria for ammonia

Table 5.2 Baseline surface water quality

	Water quality criteria	Upper Fish Creek			Lower Fish Creek		
		Min	Max	Average	Min	Max	Average
PH	6.5-8.5	6.8	7.2	7	6.6	10.1	7.5
TDS	500	58	137	82	58	160	106
TSS		22	6,500	151(1)	5.1	1,300	58.6(1)
Calcium		9.02	40.3	17.4	9.3	23.9	18.4
Magnesium		2.46	30.5	6.9	3.15	12.8	6.0
Sodium		2.14	5.97	3.79	1.83	5.67	3.97
Potassium		0.45	13.1	2.82	0.45	13.3	2.58
Chloride		0.11	1.5	0.37	0.1	1.27	0.44
Sulfate	250	6.09	28.8	11.4	7.3	64.9	18.4
Alkalinity		18	55	38	20	91	52
Arsenic	0.01	<0.001	0.056	0.016	<0.001	0.054	0.0100
Antimony	0.006	<0.003	-	-	<0.003	-	-
Cadmium	0.0003	<0.0001	0.0003	0.0003	<0.0001	0.0007	0.0006
Copper	0.009	<0.07	0.153	0.024	<0.006	0.063	0.019
Iron	1	1.85	117	16.9	1.03	41	9.5
Manganese	0.05	0.103	1.88	0.43	0.148	0.788	0.29
Selenium	0.005	<0.002	0.005	0.0014	<0.002	0.005	0.002
Zinc	0.12	<0.006	0.284	0.048	<0.001	0.127	0.026
Nitrate	10	<0.03	0.4	0.24	<0.03	1.24	0.28
Nitrite	1	<0.03	0.05	0.031	<0.02	0.1	0.036
Ammonia	2.43-6.67	<0.05	-	-	<0.05	-	-
Cyanide		<0.01	-	-	<0.01	-	-
WAD cyanide	0.0052	<0.01	-	-	<0.01	-	-

Notes:
All concentrations reported as total recoverable.
All units in mg/l, except for pH (standard units) and alkalinity (mg/l as $CaCO_3$).
Averages calculated using one-half the reporting limits for values below their respective reporting limits.
Hardness = 103.7 mg/l as $CaCO_3$ (see note on Table 5.1).
(1) = Geometric mean used due to asymmetric distribution of samples.

Water quality of the surface water prior to mining is characterized by TDS of approximately 100 mg/l. The water is a calcium-bicarbonate type, as shown in Figure 5.2. The pH at Upper Fish Creek is near neutral with limited variability (6.4 to 7.2). At the downgradient location, the average pH is slightly higher (7.5), but pH varies widely over time (6.6 to 10.1). The water quality in Fish Creek reflects the fact that the mineralized alluvium was mined previously as an ore body. Concentrations for arsenic, cadmium, copper, iron manganese, selenium, and zinc exceeded the water quality standards prior to construction of the TSF. The consistent presence of metals in elevated concentrations prior to construction of the Fort Knox Mine reflects the mineralized nature of the entire Fish Creek drainage.

Pre-mining surface water mass loading in Fish Creek was calculated using the synthetic hydrograph for Fish Creek generated by Andrews (1992), based on flow measurements from 1990. Monthly averages of constituent concentrations were calculated from data for the Lower Fish Creek sampling location. The monthly mass loading of the Lower Fish Creek valley surface water is shown in Table 5.3. Constituents that were consistently at or below their reporting limits are not listed.

Table 5.3 Mass loading at Lower Fish Creek

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow	1.5	1.0	1.0	2.5	12.0	6.0	6.0	7.0	6.5	3.0	2.0	2.0
TDS	842	658	633	1,537	6,021	2,411	4,024	4,104	4,190	162	1,144	1,047
Calcium	141	111	119	286	777	579	588	661	745	1,529	218	224
Magnesium	28	33	34	93	268	283	229	239	271	298	55	50
Sodium	30	23	24	64	165	123	147	165	147	111	44	48
Potassium	8	5	8	48	124	145	96	210	126	61	13	12
Chloride	3	3	3	5	32.6	23.8	10.0	10.1	10.9	47.4	4.4	3.8
Sulfate	140	102	108	247	1,493	387	580	498	456	11	227	209
Arsenic	0.01	0.02	0.02	0.13	0.28	0.90	0.57	0.79	0.81	4.64	0.04	0.01
Cadmium	0.001	0.004	0.001	0.001	0.086	0.002	0.036	0.048	0.013	0.089	0.007	0.001
Iron	20.7	16.2	11.6	127.2	403.4	698.5	537.9	624.0	649.2	11.7	49.8	26.1
Manganese	1.8	1.3	1.7	5.2	15.2	15.1	9.7	10.6	10.8	179.1	2.7	2.6
Nitrate	2.5	1.3	1.2	4.5	12.0	6.1	7.7	8.8	8.8	318.0	3.8	2.7

All values in lbs/month, except for flow (cubic feet/second)

5.2.2 Baseline groundwater

Baseline groundwater quality in the area of the current mine pit was characterized during three sampling events completed in 1989, 1990, and 1991. The samples were collected from exploration boreholes converted to monitoring wells (EBA Engineering, 1990).

Values of pH for groundwater upgradient of the TSF range from 6.6 to 7.8. TDS concentrations range from 37 to 520 mg/l. The groundwater composition is calcium-bicarbonate type. In general, the groundwater quality reflects the mineralization present in the area of the orebody. Metals present in detectable concentrations include antimony, arsenic, cadmium, copper, iron, lead, manganese, mercury, and selenium. Most of these analytes were above the water quality standards for one or more of the sampling events. The maximum antimony concentration was 0.049 mg/l. Arsenic concentrations range from below detectable limits to 0.57 mg/l. Cadmium concentrations range from below detectable limits to 0.0002 mg/l. Copper concentrations range from 0.034 to 0.086 mg/l. Iron concentrations range from 0.37 to 4.6 mg/l. Lead was present in detectable concentrations ranging from 0.003 to 0.01 mg/l. Selenium concentrations present above the detection limit range from 0.003 to 0.004 mg/l.

Pre-mining groundwater data in the Fish Creek drainage downgradient of the TSF were obtained from three alluvial wells (FA-7, FA-8, and FA-3) and three bedrock wells (FB-7S, FB-7D, and FB-5S). Four of the wells (FA-7, FA-8, FB-7S, and FB-7D) are located just below the TSF embankment while FA-3 and FB-5S are located approximately 1.5 miles below the TSF (Figure 5.1). The FA wells were screened in the alluvium. In the upgradient well cluster, FA-8 and FA-7 were screened across the upper and lower portions of the alluvium, respectively, to provide vertical delineation of groundwater quality. The FB wells are screened in the underlying bedrock. Vertical delineation of the bedrock groundwater quality was provided FB-7S and FB-7D, which were screened in the upper and lower portions of the bedrock aquifer, respectively. Well FA-3 is screened in the upper alluvium. The wells were sampled between May 1992 and April 1994. Sampling of FA-8 continued until February 1995.

Groundwater quality in both the alluvium and bedrock is characterized by neutral pHs, and low TDS (average of approximately 200 mg/l). Based on their major ion chemistries, groundwater from the alluvium and bedrock is a calcium-bicarbonate type (Figure 5.2). Summary statistics (range and average) of the principal constituents are presented in Table 5.4 for each of the six monitoring wells.

Groundwater quality varies slightly with depth, lithology, and location. Immediately downgradient of the TSF, TDS concentrations increase with depth in the alluvium and upper bedrock and then decrease in the lower bedrock. TDS concentrations in baseline groundwater ranged from 150 to 271 mg/l. Average TDS concentrations in the upper alluvium increase downgradient. In the bedrock wells, TDS decreases downgradient. As shown on Figure 5.2 and Table 5.1, sulfate concentrations increase downgradient. Concentrations of trace metals in groundwater reflect the mineralized nature of the area with arsenic, cadmium, copper, iron, and manganese present in detectable quantities.

Arsenic was detected at a maximum concentration of 0.038 and 0.039 mg/l in FA-7 and FA-8, respectively. Arsenic is present in most wells at concentrations above the standard. Cadmium and copper are also present at levels that exceed the standard, which is consistent with site-wide groundwater composition. Iron and manganese both exceed the numerical standards, which is consistent with both groundwater and surface water trends across the site. Nitrate concentrations are generally low (less than 0.06 mg/l), and nitrite was below reporting limits. Ammonia was detected in all wells, with the highest concentrations (5 mg/l) below the TSF in the lower alluvium.

Similarities in the hydrochemistry between groundwater and surface water (Figure 5.2) are indicative of a high degree of mixing. The scatter of points on the tri-linear diagram is primarily due to a combination of temporal variations in sample collection.

Table 5.4 Baseline groundwater quality

		FA-7			FA-8			FD-7S			FD-7D			FA-3			FB -5S		
	Water quality criteria	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
pH	6.5-8.5	6.0	7.0	6.8	6	7	6.3	6.0	7.0	6.8	7.0	7.0	7.0	6.0	8.0	6.6	7.0	8.0	7.2
TDS	500	239	336	271	131	197	167	238	298	262	190	248	230	182	444	292	136	156	150
TSS		0.45	400	143.9	0.45	400	53.53	1.2	370	185.6	1.8	7.4	4.6	18	510	123.3	0.45	26	5.87
Calcium		38.8	60.6	50.1	23.8	37.5	31.7	45.4	70.7	61.2	55.1	67.8	59.6	42.1	92.4	67.0	30.8	34.0	32.9
Magnesium		7.48	16.1	13.5	4.9	13.1	8.68	8.26	15.7	12.0	7.31	12.6	10.4	11.1	28.1	19.8	4.86	6.15	5.48
Sodium		6.08	26.2	19.7	4.84	7.56	6.07	5.28	20.9	7.6	5.99	7.52	6.69	4.46	7.61	5.94	5.5	6.63	5.88
Potassium		2.74	10.7	6.2	0.45	4.66	1.46	1.91	6.85	2.9	1.55	2.63	2.03	2.56	11.2	4.61	0.71	1.25	0.88
Chloride		0.4	1.6	0.72	0.05	1	0.48	0.26	1.1	0.47	0.25	0.7	0.43	0.5	1.45	0.89	0.1	1.8	0.53
Sulfate	250	0.2	11.1	3.5	0.1	11	3.03	0.18	1.4	0.71	0.31	3	1.29	4.74	52.7	25.20	27	33.9	31.4
Alkalinity		194	211	203	111	156	128	191	218	202	181	218	193	102	326	217	82	85	84
Arsenic	0.01	0.005	0.039	0.015	0.019	0.038	0.030	0.006	0.016	0.010	<0.003	0.005	0.003	0.002	0.026	0.012	<0.003	0.005	0.003
Antimony	0.006	<0.003	-	-	<0.003	-	-	<0.003	-	-	<0.003	-	-	<0.003	-	-	<0.003	-	-
Cadmium	0.0003	<0.0001	0.0006	0.0002	<0.0001	0.0001	0.0004	<0.0001	0.0001	0.0001	<0.0001	0.0006	0.0001	0.0001	0.0017	0.0006	<0.0001	0.0002	0.0001
Copper	0.009	<0.006	0.052	0.022	<0.006	0.024	0.0075	<0.006	0.021	0.007	<0.006	0.026	0.009	<0.007	0.295	0.046	<0.006	0.009	0.005
Iron	1	5.32	55.9	33.1	23.4	46.1	34.0	4.06	31.1	8.67	1.28	2.92	2.21	3.77	49.5	22.31	0.033	0.568	0.165
Manganese	0.05	0.767	1.96	1.44	0.839	1.3	1.15	0.66	1.57	0.84	0.42	0.5	0.46	1.36	2.4	1.68	0.194	0.226	0.212
Selenium	0.005	<0.002	-	-	<0.002	-	-	<0.002	-	-	<0.002	-	-	<0.002	-	-	<0.002	-	-
Zinc	0.12	<0.002	0.092	0.050	<0.002	0.039	0.010	<0.002	0.028	0.007	<0.002	0.012	0.005	0.017	0.148	0.046	0.004	0.014	0.007
Nitrate	10	<0.03	0.25	0.058	<0.03	0.4	0.073	<0.03	0.2	0.047	<0.03	0.05	0.0322	<0.03	0.07	0.064	<0.03	0.05	0.036
Nitrite	1	<0.03	-	-	<0.03	-	-	<0.1	-	-	<0.1	-	-	<0.1	-	-	<0.1	-	-
Ammonia	2.43-6.67	<0.9	5	2.9	<0.9	2	0.98	<0.9	3	0.91	<0.9	1	0.51	<0.9	2	0.71	<0.9	-	-
Cyanide		<0.1	-	-	<0.1	-	-	<0.1	-	-	<0.1	-	-	<0.1	-	-	<0.1	-	-
WAD cyanide	0.0052	<0.01	-	-	<0.01	-	-	<0.01	-	-	<0.01	-	-	<0.01	-	-	<0.01	-	-

All units in mg/l, except for pH (standard units) and alkalinity (mg/l as $CaCO_3$)
Average calculated using one-half the reporting limits for values below their respective reporting limits.
Reported values are for dissolved concentrations.

The groundwater baseline loading of constituents was derived using the average concentrations for the downgradient well cluster and a calculated groundwater flow volume of approximately 175 gpm (Knight Piésold, 1994). Table 5.5 lists the solute loading of the aquifer in pounds per day.

Table 5.5 Mass loading of groundwater in Lower Fish Creek

	Average concentration (mg/l)	Loading (lbs/day)
TDS	221.3	465
Calcium	49.9	105
Magnesium	12.6	27
Sodium	5.9	12
Potassium	2.7	6
Chloride	0.7	1.5
Sulfate	28.3	60
Nitrate	0.1	0.11
Copper	0.025	0.053
Iron	11.2	26.4
Manganese	0.9	1.99
Zinc	0.0	0.056

5.2.3 Summary of background chemistry

Background chemistry for surface water and groundwater reflects the mineralized nature of the rocks within the Fish Creek drainage and the historical placer mining activity that occurred in the area.

Pre-mining groundwater within the Fish Creek drainage has circum-neutral pH values and is generally a calcium-bicarbonate compositional type. Values of TDS and alkalinity are low to moderate. Shallow bedrock and alluvial groundwater compositions are generally similar as a result of the hydraulic connection between the two systems. Deep bedrock groundwater tends to be more variable in composition as a result of compartmentalization. Background sampling indicates that metals present in concentrations above the standards include arsenic, cadmium, copper, iron, manganese, and zinc.

Because of the inter-connection between the surface water and groundwater systems, the pre-mining chemical character of the two are similar. Background surface water is characterized by circum-neutral pH values, low TDS values, moderate alkalinity, and the presence of trace metals in relatively high concentrations. Metals that are present in background concentrations that exceed numerical standards include arsenic, cadmium, copper, iron, manganese, selenium, and zinc.

The observed background metal concentrations in the groundwater and surface water reflect naturally occurring mineralization in the area. Exceedances of standards for parameters such as arsenic, cadmium, copper, iron, manganese, selenium, and zinc prior to construction of Fort Knox suggest that evaluation of the performance of the closure strategy should be relative to background concentrations. As mentioned previously, guidelines set forth in 18 AAC 60.825 outline appropriate methods for establishing criteria to evaluate changes in water quality for a solid waste disposal permit. FGMI will evaluate the most appropriate method to establish water quality criteria in conjunction with Alaska DEC prior to initiating closure activities.

5.3 TSF pond

Water is used to slurry tailing to the TSF and accumulates in the pond where it is ultimately pumped back to the mill. Water quality in the TSF pond is controlled by the following factors:

- chemistry of the mill feed (ore),
- chemical reagents used to process the ore,
- effluent treatment processes,
- dilution by the freshwater reservoir when makeup water is added,
- upgradient run-on,
- direct precipitation,
- geochemical processes, and
- seasonal effects (ice cover and evaporation).

The tailing facility is considered a treatment works during operation and through closure until discharge occurs. As a result, water quality standards for the designated use are not applicable prior to discharge. However, for the purposes of discussion, the following paragraphs reference the standards defined in Section 5.1 as part of the assessment of current operational water quality.

5.3.1 Historical TSF pond water quality

Samples for total metal concentrations have been collected since late 1996 as required for the Solid Waste Permit. Dissolved metal concentrations were characterized from late 1996 until August 2003. The water quality of the TSF pond (total concentrations) is summarized in Table 5.6 and displayed graphically in a tri-linear diagram (Figure 5.3). Changes over time for dissolved and total concentrations of the major constituents are shown in Figures 5.4 through 5.16.

Table 5.6 Water quality in the TSF pond and seepage

	Water quality criteria	TSF pond			Seepage		
		Min	Max	Avg	Min	Max	Avg
pH	6.5-8.5	7.5	10.7	8.8	6.3	9.8	7.3
TDS	500	180	1170	805	132	886	641
Calcium		18	233	128.7	0.158	157	98.0
Magnesium		0.94	12.7	5.9	7.9	120	23.5
Sodium		9.6	119	84.5	6.3	83.2	53.4
Potassium		5.2	34.6	15.9	1.7	13.6	7.1
Chloride		4	92	35.9	3	54	23.7
Sulfate	250	55	637	385	34	475	320
Alkalinity		37	92	64	52	110	79
Arsenic	0.01	<0.005	1.09	0.31	0.0005	0.009	0.003
Antimony	0.006	<0.005	2.42	0.60	0.00075	0.06	0.016
Cadmium	0.0003	<0.0001	0.009	0.001	<0.0005	-	-
Copper	0.009	0.039	3	0.83	<0.004	0.082	0.009
Iron	1	<0.05	5.15	0.46	<0.05	1.24	0.22
Manganese	0.05	0.012	0.307	0.068	0.04	0.99	0.55
Zinc	0.12	<0.01	0.04	0.008	<0.01	0.04	0.01
Selenium	0.005	<0.003	0.065	0.016	<0.003	0.018	0.006
Nitrate	10	0.5	20.6	8.5	0.4	13.2	8.4
Nitrite	1	<0.1	10	1.3	<0.01	8.7	0.50
Ammonia	2.43-6.67	4.4	50.1	20.6	0.025	21.3	2.4
Cyanide		<0.002	3.15	0.68	<0.004	0.21	0.031
WAD cyanide	0.0052	<0.01	2.58	0.48	0.002	0.052	0.012

Notes:
All units in mg/l, except for pH (standard units) and alkalinity (mg/l as $CaCO_3$).
Average calculated using one-half the reporting limits for values below their respective reporting limits.

Water in the TSF pond is a calcium/sodium-sulfate solution (Figure 5.3) with an alkaline pH of approximately 8 (Figure 5.4) and an average TDS concentration of 690 mg/l (Figure 5.5). In general, the dissolved and total concentrations of metals in the pond were approximately the same, indicating that metals occur principally in the dissolved phase. The one exception to this trend is iron, where the total concentrations were higher than the dissolved concentrations (Figure 5.6).

Water quality in the TSF pond has changed over time due principally to the mill feed. From 1996 until early 2001, the mill feed was exclusively Fort Knox ore. Water quality in the pond during this period was characterized by an alkaline pH of 8.8 (Figure 5.4), TDS concentration of approximately 800 mg/l (Figure 5.5),and relatively low concentrations of metals.

From early 2001 until January 2005, the mill processed a mixture of ore from the Fort Knox deposit as well as ore from the nearby True north deposit. True North tailing contained higher concentrations of antimony, selenium, and arsenic (Figures 5.7 through 5.9, respectively) relative to historical levels (Table 5.4). The True North ore required additional cyanide to process the ore, which resulted in higher concentrations in the tailing slurry (Figure 5.10). To minimize the concentrations of free and WAD cyanide concentrations in the TSF pond, the INCO cyanide detoxification unit was used more frequently. This process is catalyzed by copper ions, which are added to the detoxification unit as copper sulfate and resulted in increased copper concentrations in the TSF pond (Figure 5.11). INCO treatment for the blended ore also increased the sulfate and nitrate concentrations in the TSF pond (Figures 5.12 and 5.13).

In 2001, FGMI minimized the use of the detoxification unit and managed cyanide through the use of tailing thickeners and volatilization. As shown in Figure 5.14, this led to a reduction in ammonia concentrations.

Concentrations within the TSF pond also change over time as the volume of impounded water changes. During the winter, dilution from surface water run-on and rainfall is at a minimum, which results in increased analyte concentrations. During the spring, breakup concentrations tend to decrease in response to dilution from surface water run-on. After breakup, concentrations vary with the amount of makeup water added from the freshwater reservoir.

5.4 Seepage

Seepage from the TSF is collected by two sumps located at the foot of the TSF and pumped back to the TSF pond for use as makeup water. Seepage that bypasses the sumps is collected by six downgradient interceptor wells. Groundwater quality below the seepage collection system is monitored at three wells (MW-5, MW-6, and MW-7).

Composite seepage water quality samples for total concentrations have been collected quarterly for the solid waste permit since the TSF went into operation in 1996. Samples for dissolved concentrations were collected from 1996 until August of 2003. Total concentrations of constituents in the seepage are presented in Table 5.6. Variations in compositions over time are illustrated in Figures 5.4 through 5.16.

Based on a comparison of the seepage and TSF pond chemistries, the bulk of the water entering the seepage recovery system originates from the TSF. A comparison of the chloride concentrations in the TSF pond water and seepage (Figure 5.15) suggests that very little dilution is occurring due to groundwater flow under the TSF. The high degree of correlation between temporal variations in chloride chemistry also indicate a relatively short travel time. This suggests that any differences between the seepage and TSF pond chemistries are due principally to geochemical processes such as precipitation and sorption as opposed to the effects of dilution.

Water in the seepage has an average pH of approximately 7.3 (versus 8.8 in the TSF pond) and an average TDS of 655 mg/l. Seepage water is a calcium/sodium-sulfate type solution. A summary of the major constituents (range and average) in the seepage is provided in Table 5.6.

As shown in Figures 5.4 through 5.15, the water quality of the seepage is generally better than the TSF pond water. The difference in concentrations between the TSF pond and the seepage for a given constituent vary considerably. Several of the constituents are attenuated through the tailing, including arsenic, ammonia, antimony, copper, cyanide (total and WAD), nitrite, and selenium.

Arsenic concentrations in the seepage decrease by almost an order of magnitude as a result of attenuation. Increases in arsenic present in the TSF pond associated with processing of True North ore had only minor effects on seepage quality, indicating significant attenuation capacity within the system possibly as a result of co-precipitation with iron hydroxides. Selenium and antimony showed similar characteristics with decreases of 80 and 90 percent, respectively. Constituents with variable or minimal attenuation include iron, nitrate, sulfate, and TDS.

Manganese concentrations in the seepage increase relative to the TSF pond water concentrations (Figure 5.16). Manganese concentrations in the TSF pond average 0.053 mg/l (dissolved), while the average concentration in the seepage was more than ten times higher at 0.56 mg/l. This is likely a result of contributions from the groundwater underflow, which has naturally occurring elevated concentrations and geochemical reactions within the tailing material.

5.5 Downgradient groundwater chemistry

Groundwater quality downgradient of the TSF is monitored by three monitoring wells (MW-5, MW-6, and MW-7). The locations of the wells are shown on Figure 5.1. Groundwater quality samples have been collected quarterly from the wells since August 2000. A summary of water quality from these wells is provided in Table 5.7.

Table 5.7 Groundwater quality in the TSF monitoring wells

	Water quality criteria	MW-5			MW-6			MW-7	
		Min	Max	Avg	Min	Max	Avg	Min	Max
pH	6.5-8.5	6.9	7.8	7.3	7.0	8.1	7.5	7.1	8.8
TDS	500	450	640	548	350	580	470	105	159
TSS		<0.9	34.0	14.1	10.3	252	55.1	<5	-
Calcium		101	184	143	81.8	168	121	9.6	12.6
Magnesium		13.0	24.0	19.9	16.4	25.5	22.6	0.6	0.86
Sodium		19.9	29.0	24.1	16.1	23.4	20.1	25.6	32
Potassium		1.3	2.01	1.7	1.1	2.7	2.0	0.9	2.2
Chloride		<0.5	1.6	0.71	<0.9	0.9	0.58	<0.5	0.8
Sulfate	250	1.0	20	10.7	4.8	20.3	14.8	21.6	24.5
Alkalinity		351	566	484	272	524	413	61	85
Arsenic	0.01	<0.005	-	-	<0.005	0.0013(1)		<0.005	-
Antimony	0.006	<0.0013	-	-	<0.0013	-	-	<0.0013	-
Cadmium	0.0003	<0.0002	-	-	<0.0002	-	-	<0.0002	-
Copper	0.009	<0.01	-	-	<0.01	-	-	<0.01	-
Iron	1	0.47	14	7.7	0.77	8.32	3.8	<0.03	0.1
Manganese	0.05	0.448	2.07	1.5	0.287	1.6	0.638	0.026	0.038
Selenium	0.005	<0.005	-	-	<0.005	-	-	<0.005	-
Zinc	0.12	<0.01	-	-	<0.01	0.0006(1)	-	<0.01	-
Nitrate	10	<0.01	0.15	0.056	<0.01	0.15	0.036	<0.01	0.13
Nitrite	1	<0.01	0.43	0.059	<0.01	0.22	0.039	<0.01	0.05
Ammonia	2.43-6.67	<0.05	0.72	0.23	<0.05	0.61	0.12	<0.05	0.5
Cyanide		<0.004	-	-	<0.004	-	-	<0.004	-
WAD cyanide	0.0052	<0.01	-	-	<0.01	-	-	<0.01	-

Notes:
All units in mg/l, except for pH (standard units) and alkalinity (mg/l as $CaCO_3$).
Average calculated using one-half the reporting limits for values below their respective reporting limits.
(1) = One value above reporting limit

Groundwater at wells MW-5 and MW-6 have average TDS of approximately 450 to 550 mg/l, average pHs of 7.2 and 7.6, respectively, and are classified as calcium-bicarbonate waters (Figure 5.3). Concentrations of sulfate, chloride, sodium, and potassium are low (less than 25 mg/l). As shown on Figure 5.3, the groundwater chemistry of MW-5 and MW-6 are very similar to background groundwater chemical conditions from wells FA-7, FA-8, FB-7S, and FB-7D (Figure 5.2). Groundwater at MW-7 is very different from the other two wells, with an average TDS 121 mg/l, a pH of 8.5, and a sodium-bicarbonate water type. Sulfate concentrations are approximately twice as high as in MW-5 and MW-7 (average of 23 mg/l) with little variation over time. This is likely a reflection of compartmentalization of the fractured bedrock.

In all the monitoring wells, the concentrations of arsenic, cadmium, arsenic, zinc, antimony, and cyanide have been consistently below reporting limits. Groundwater in the monitoring wells only exceeds the water quality standard for iron and manganese (Table 5.7).

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Figure 5.1 Water quality sampling locations

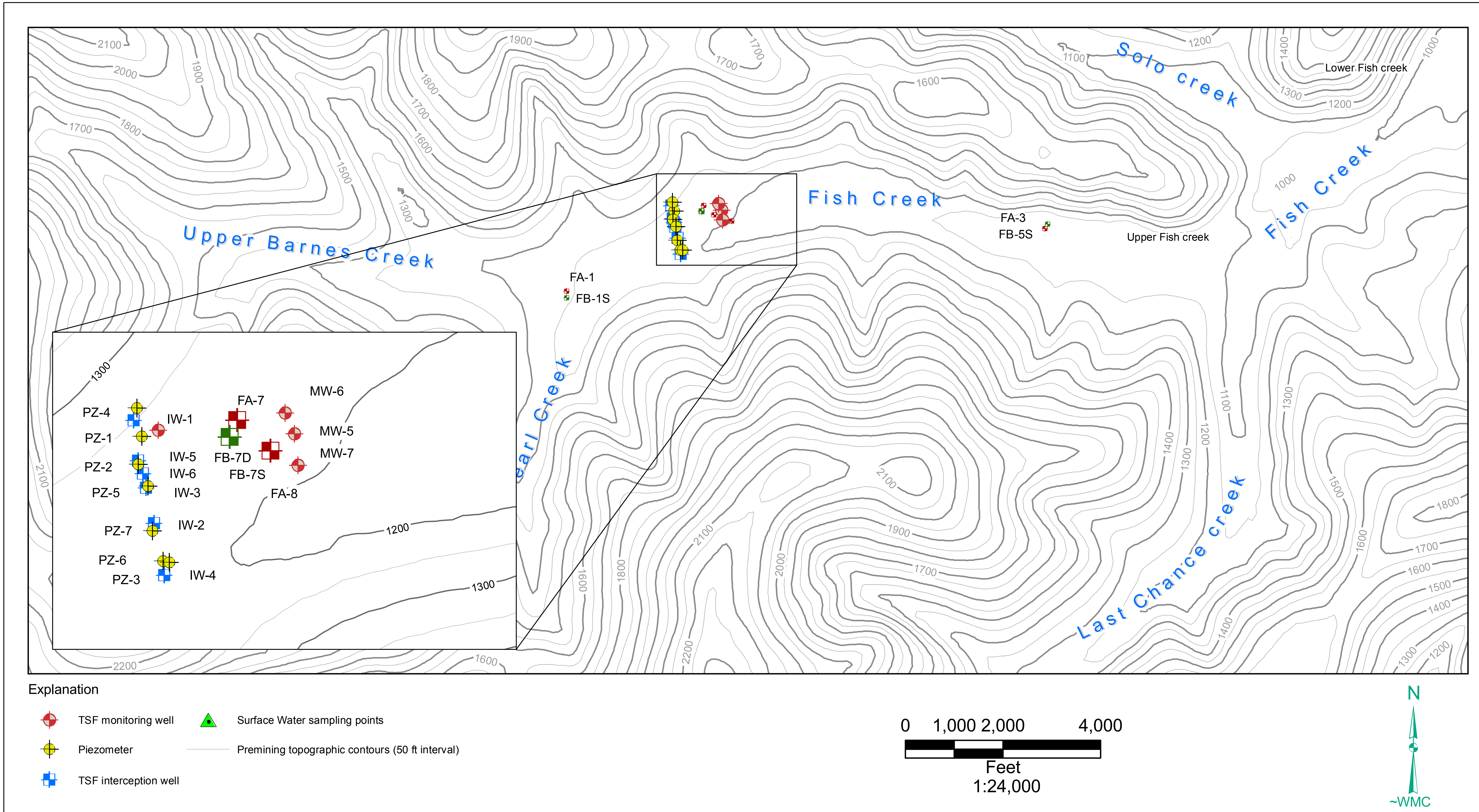

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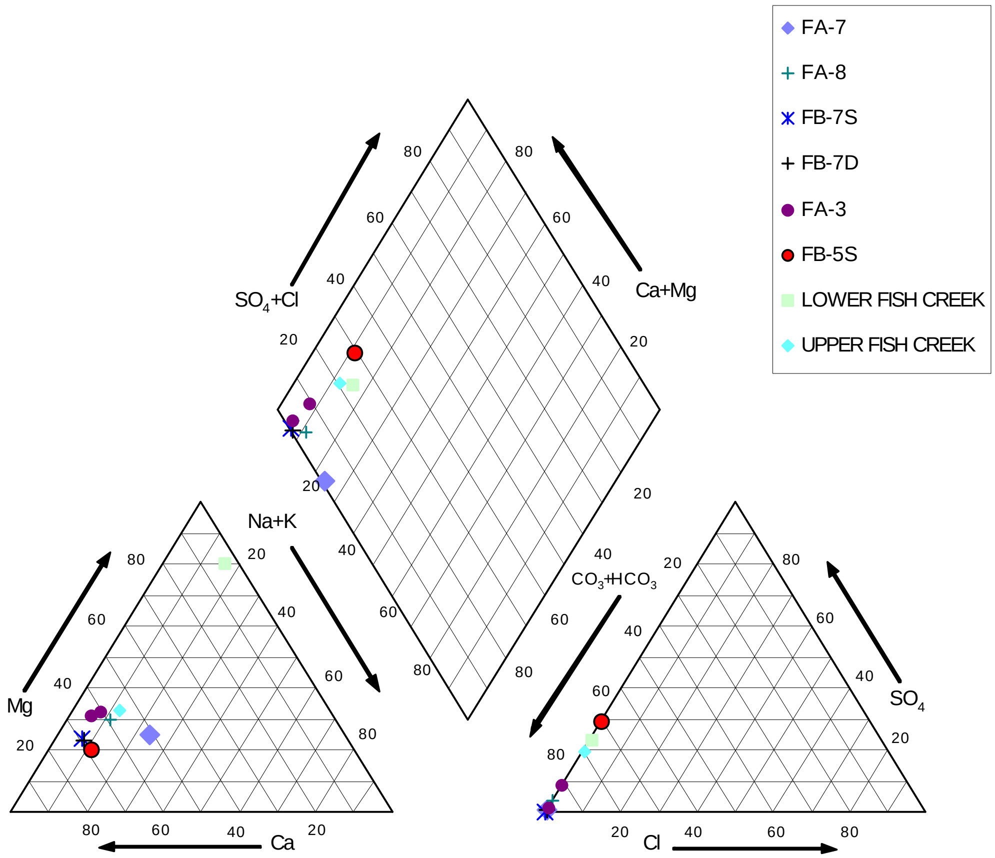
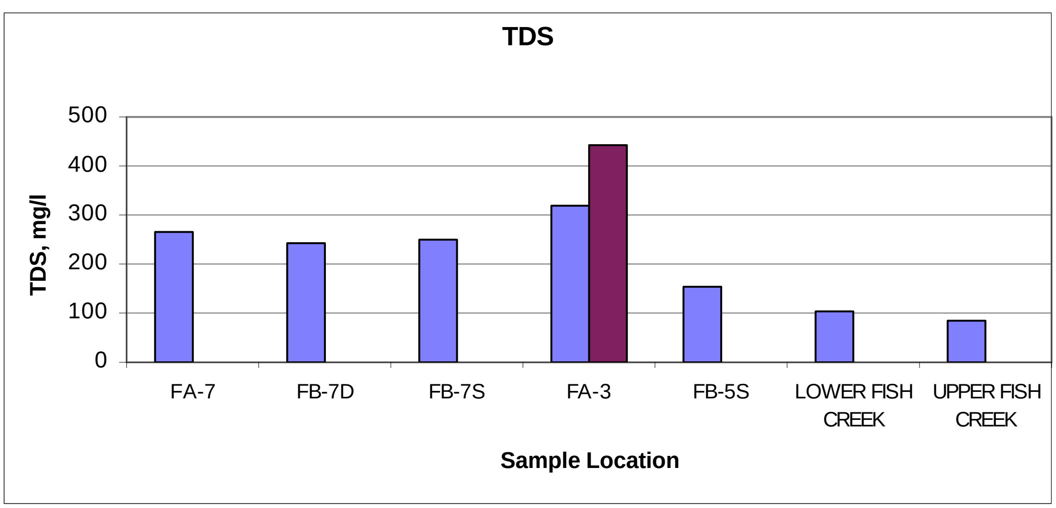
Figure 5.2 Inorganic chemistry of background surface water and groundwater





F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-5.2.DWG

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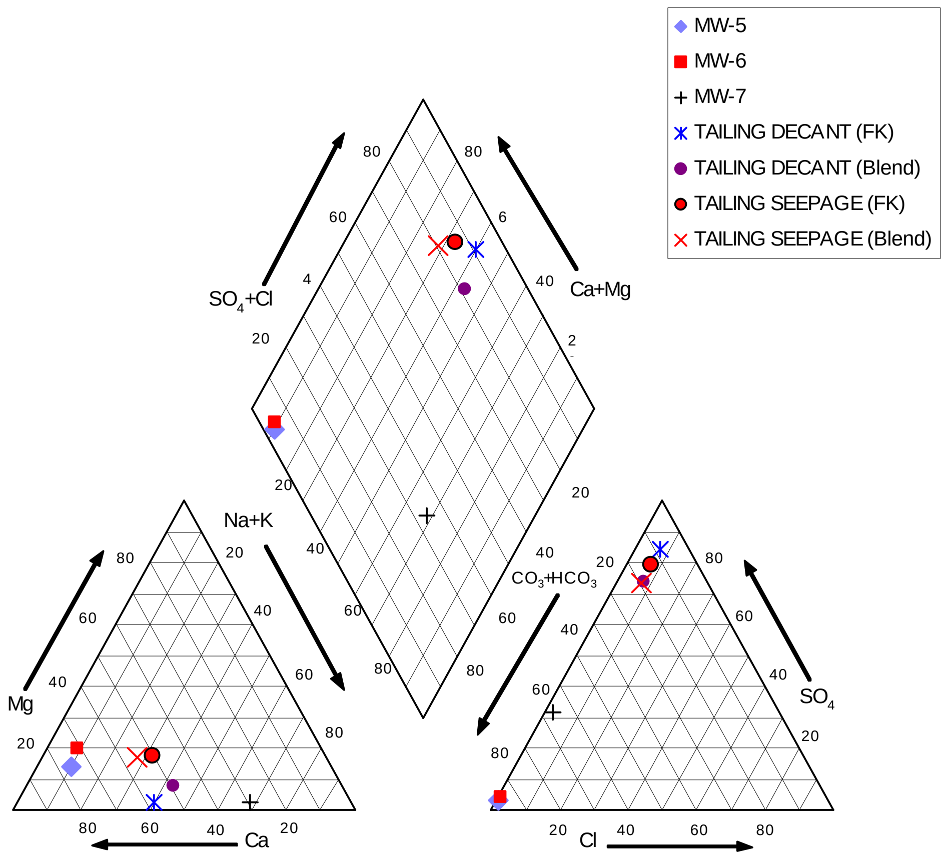
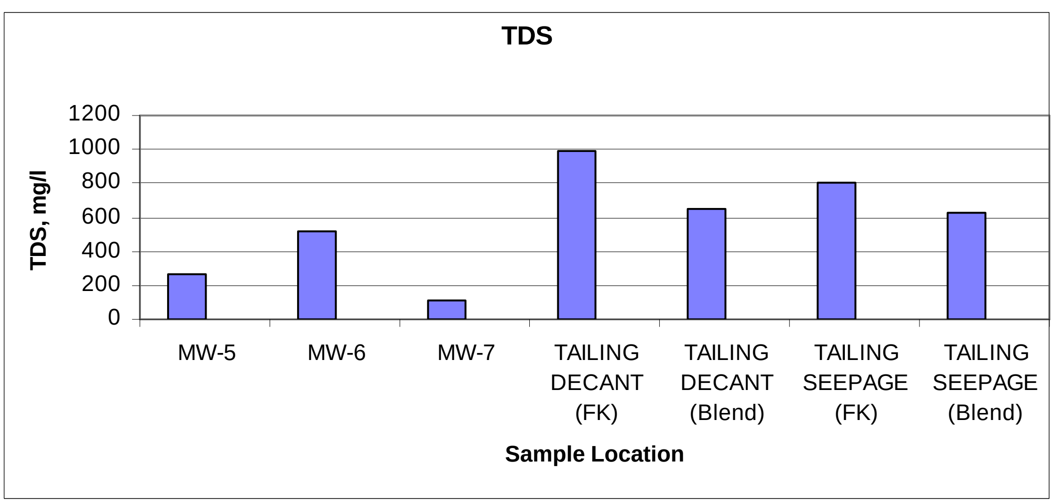
Figure 5.3 Inorganic chemistry of pond water, seepage and TSF monitoring wells





F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-5.3.DWG

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Figure 5.4 pH in TSF pond and seepage

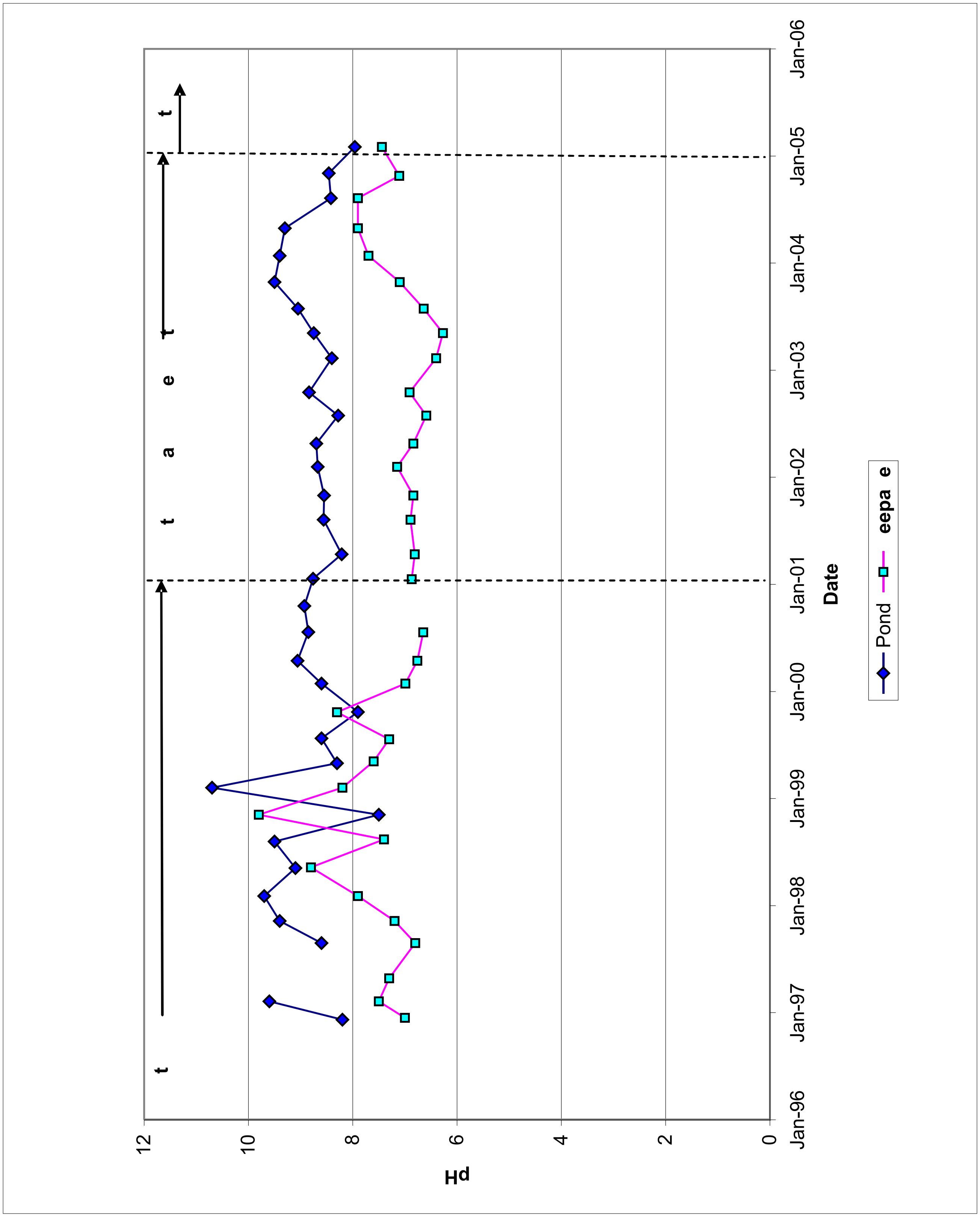

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Figure 5.5 TDS concentrations in the TSF pond and seepage

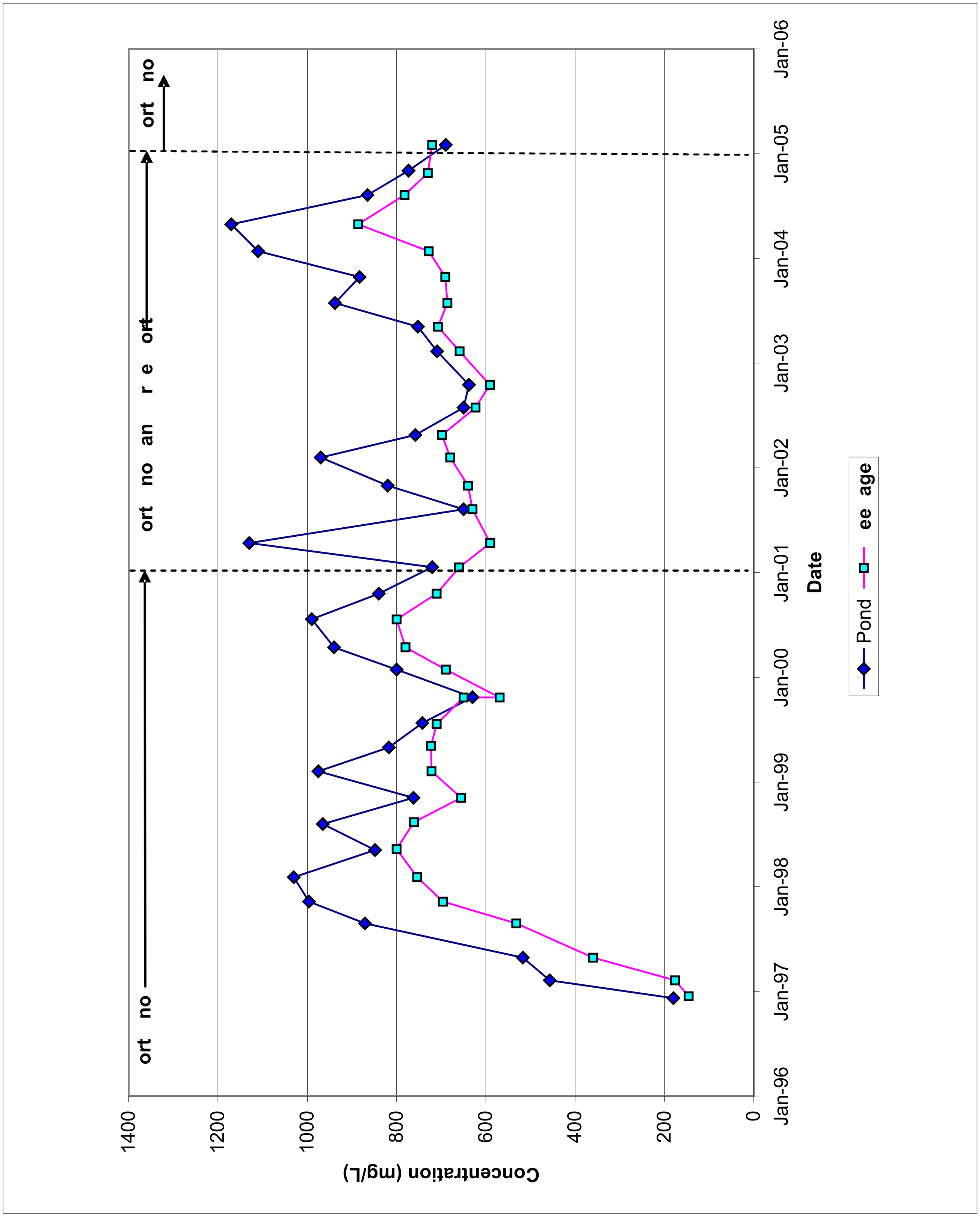

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Figure 5.6 Iron concentrations in the TSF pond and seepage

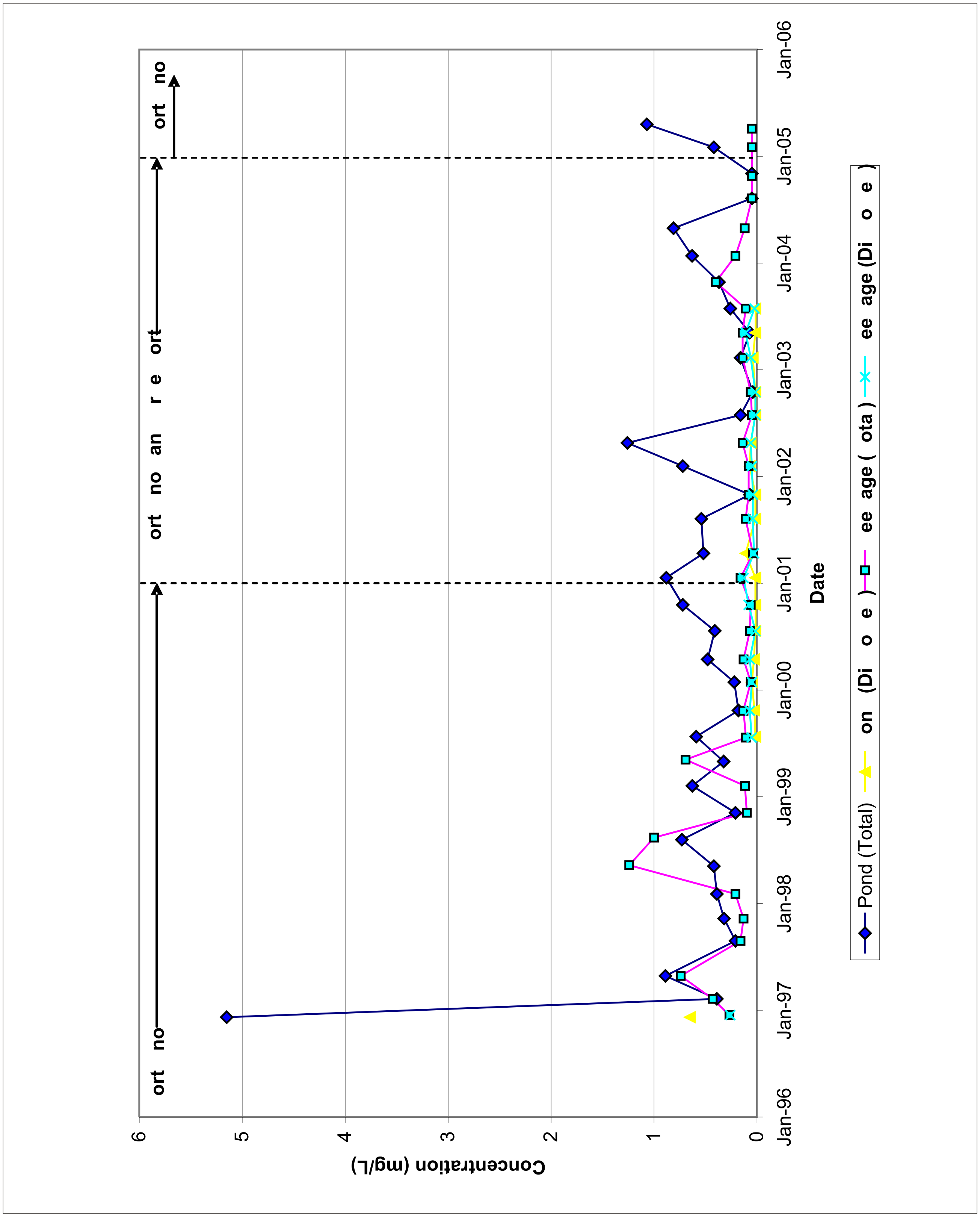

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Figure 5.7 Antimony concentrations in the TSF pond and seepage

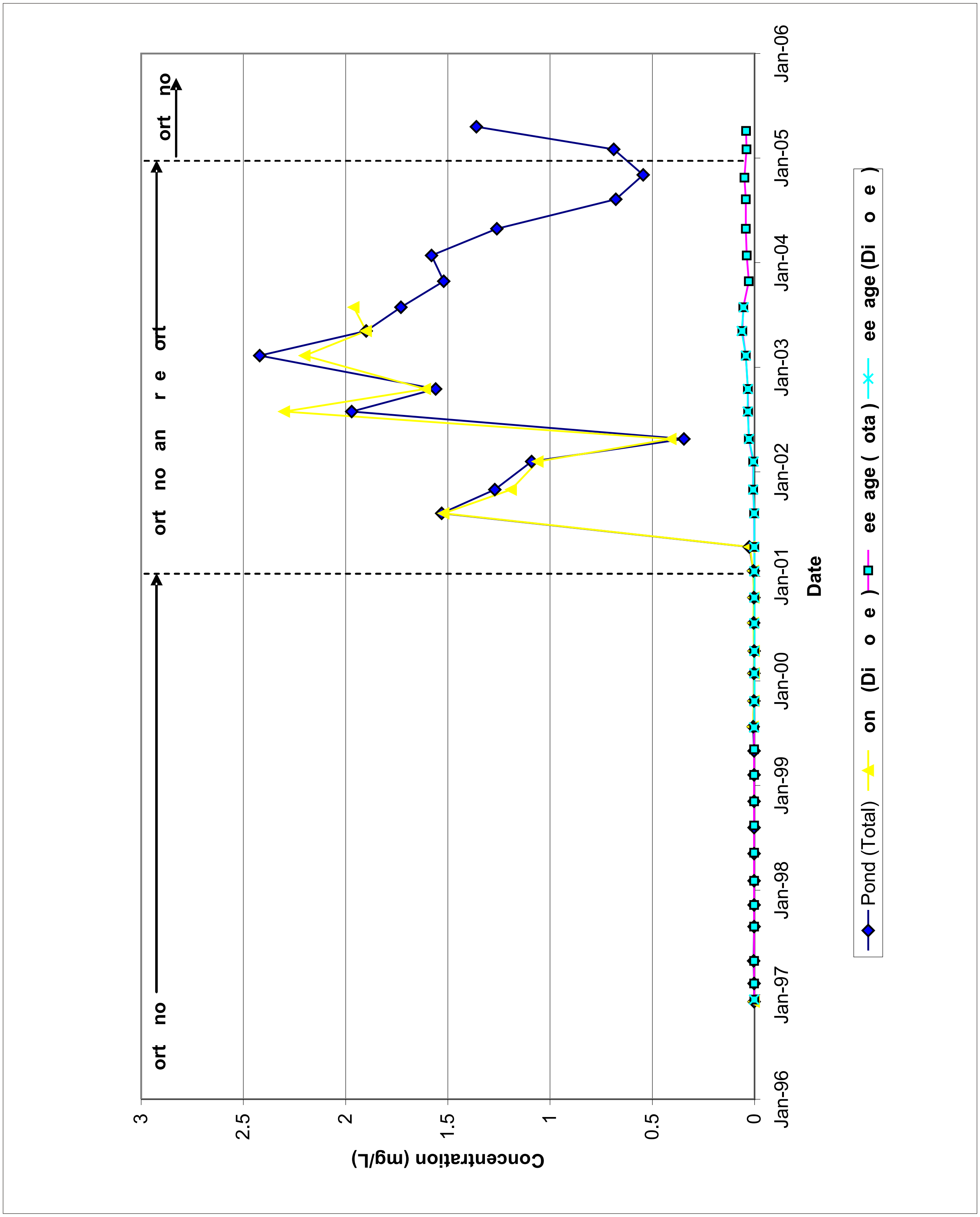

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Figure 5.8 Selenium concentrations in the TSF pond and seepage

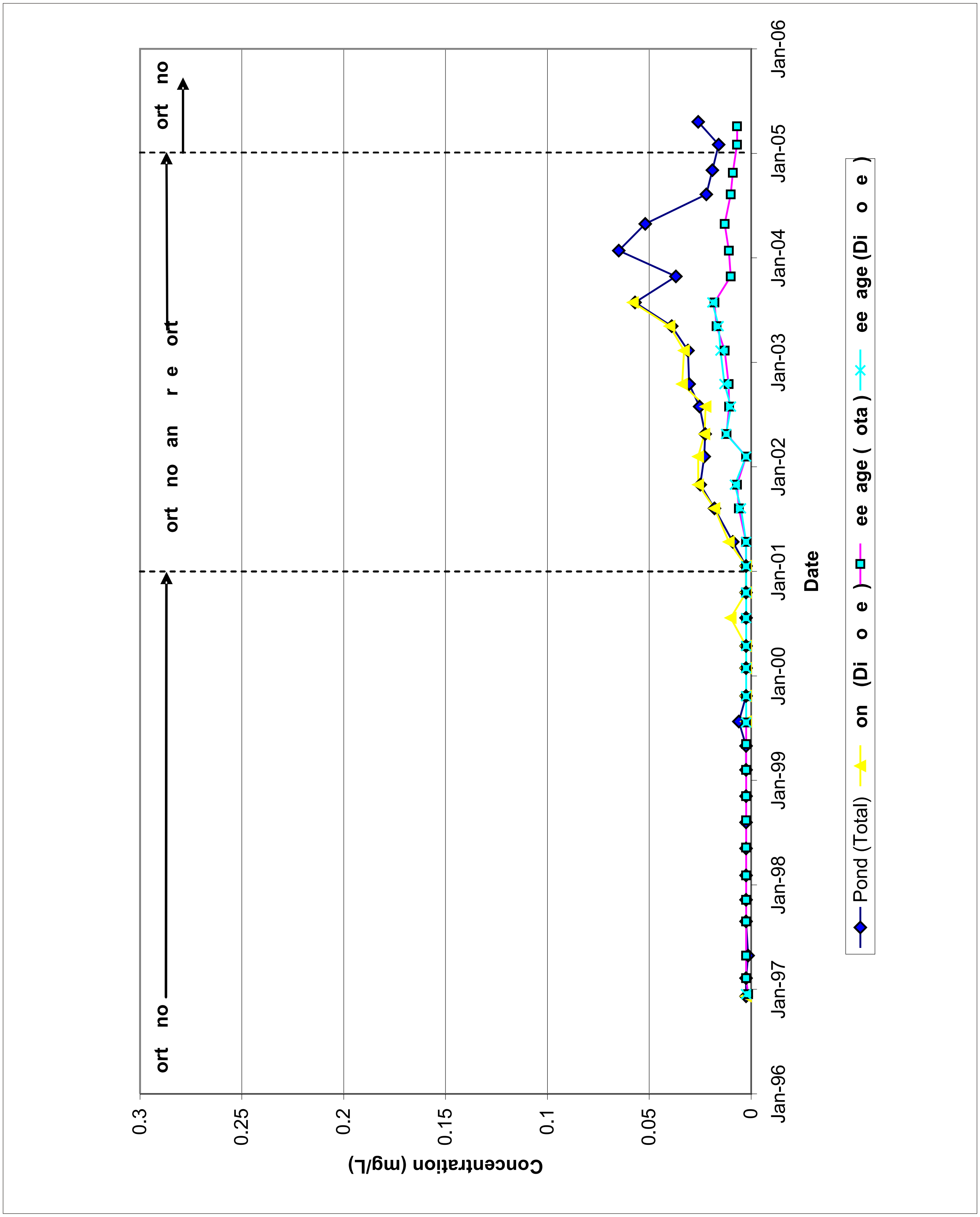

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Figure 5.9 Arsenic concentrations in the TSF pond and seepage

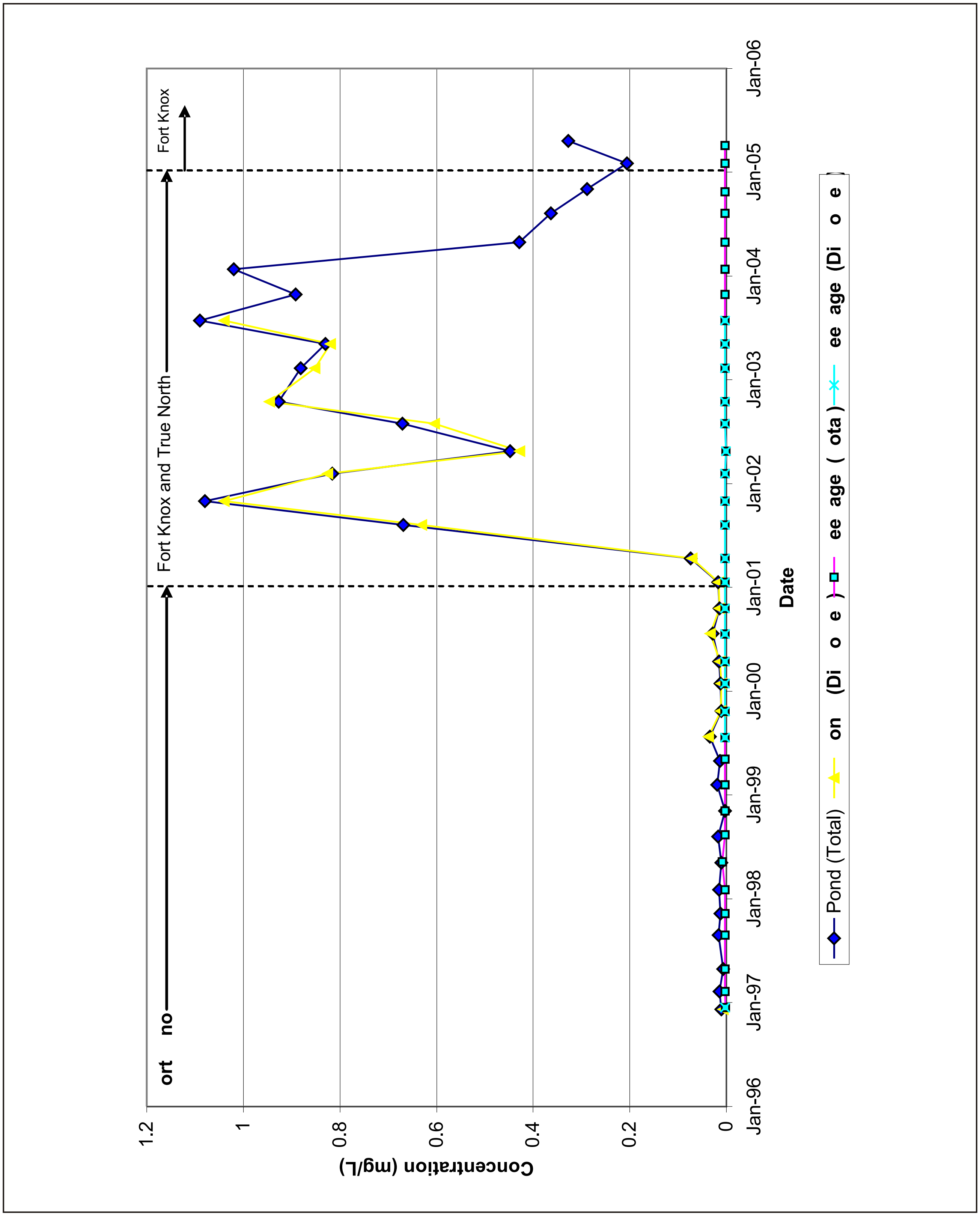

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Figure 5.10 WAD Cyanide concentrations in the TSF pond and seepage

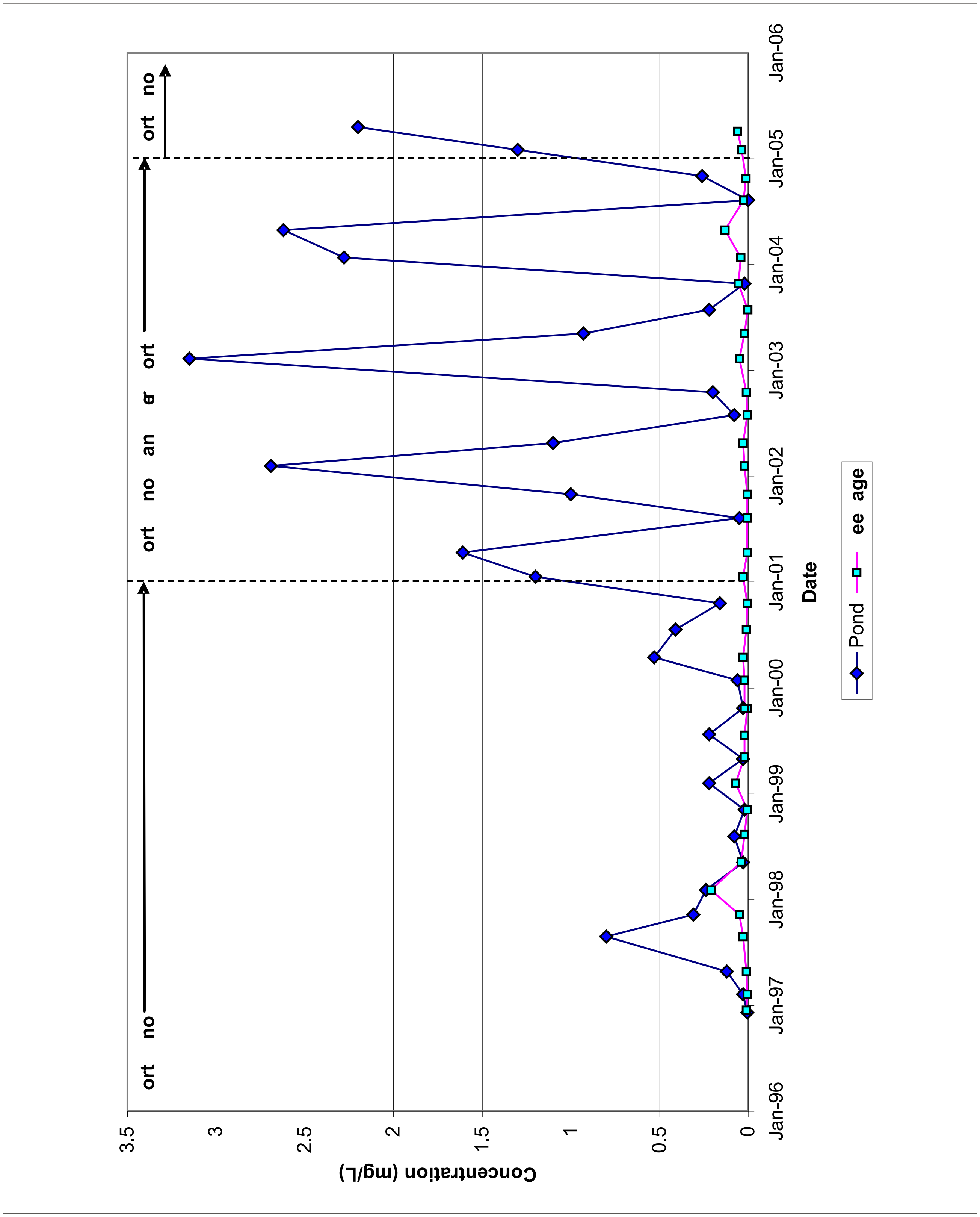

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Figure 5.11 Copper concentrations in the TSF pond and seepage

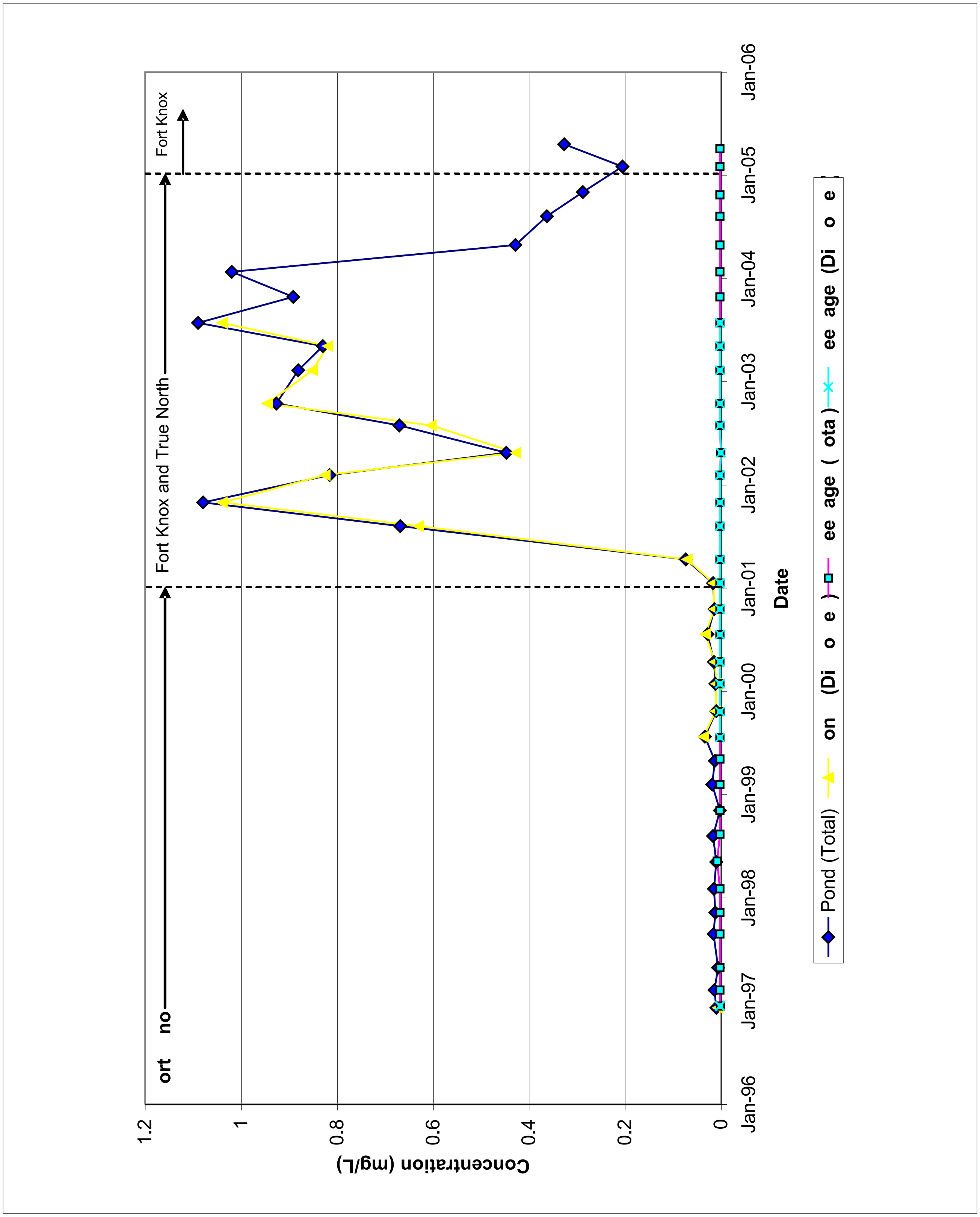

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Figure 5.12 Sulfate concentrations in the TSF pond and seepage

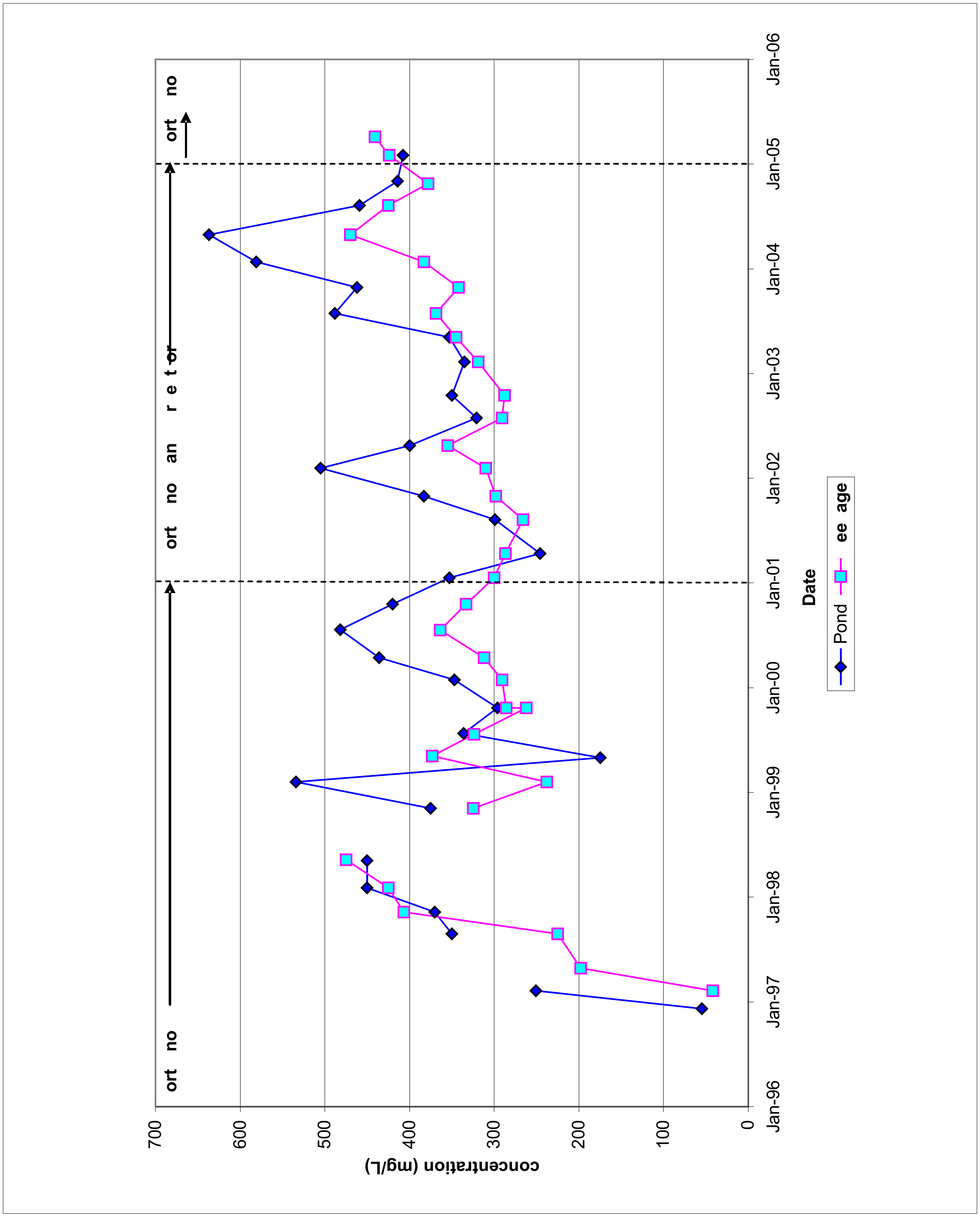

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Figure 5.13 Nitrate concentrations in the TSF pond and seepage

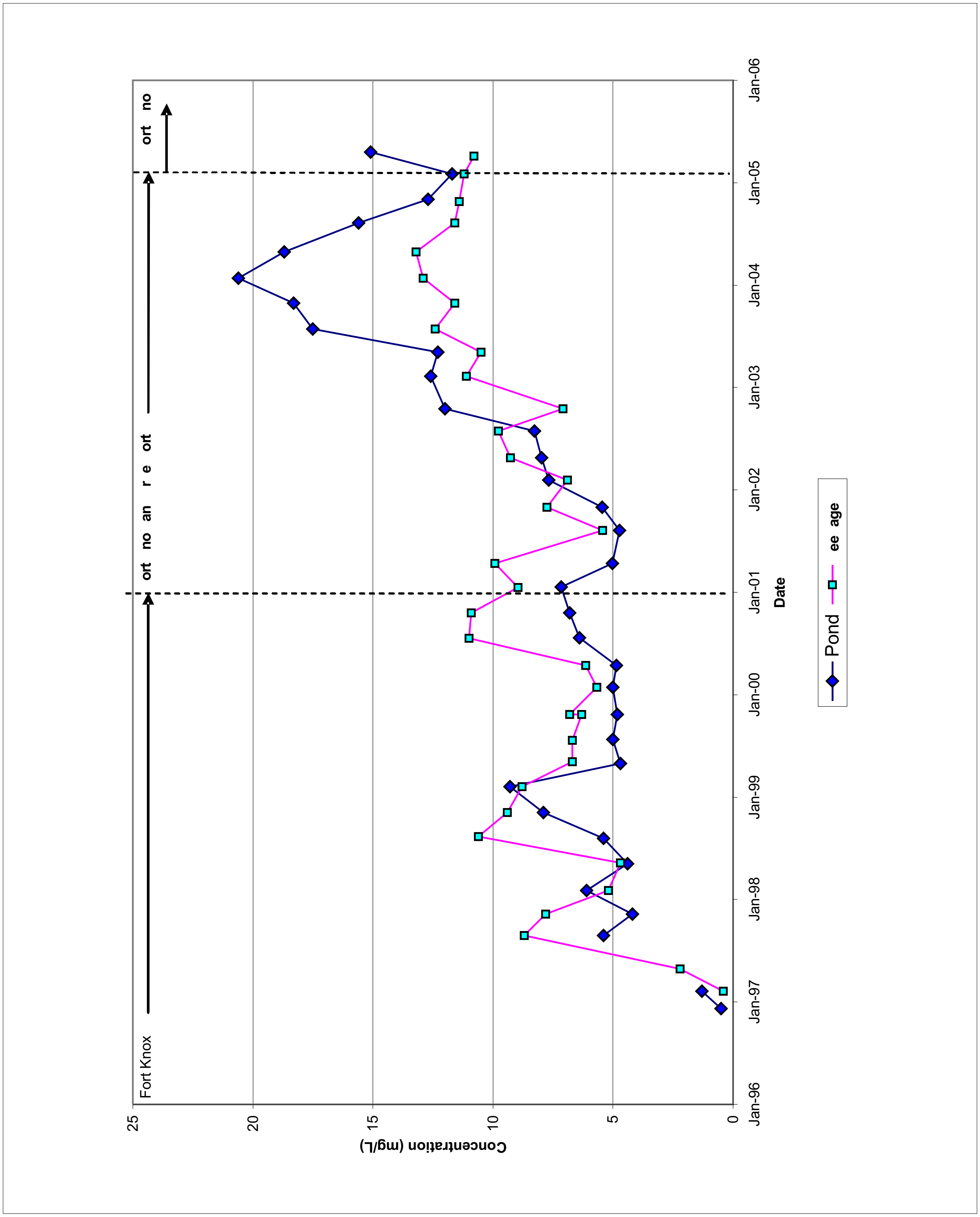

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Figure 5.14 Ammonia concentrations in the TSF pond and seepage

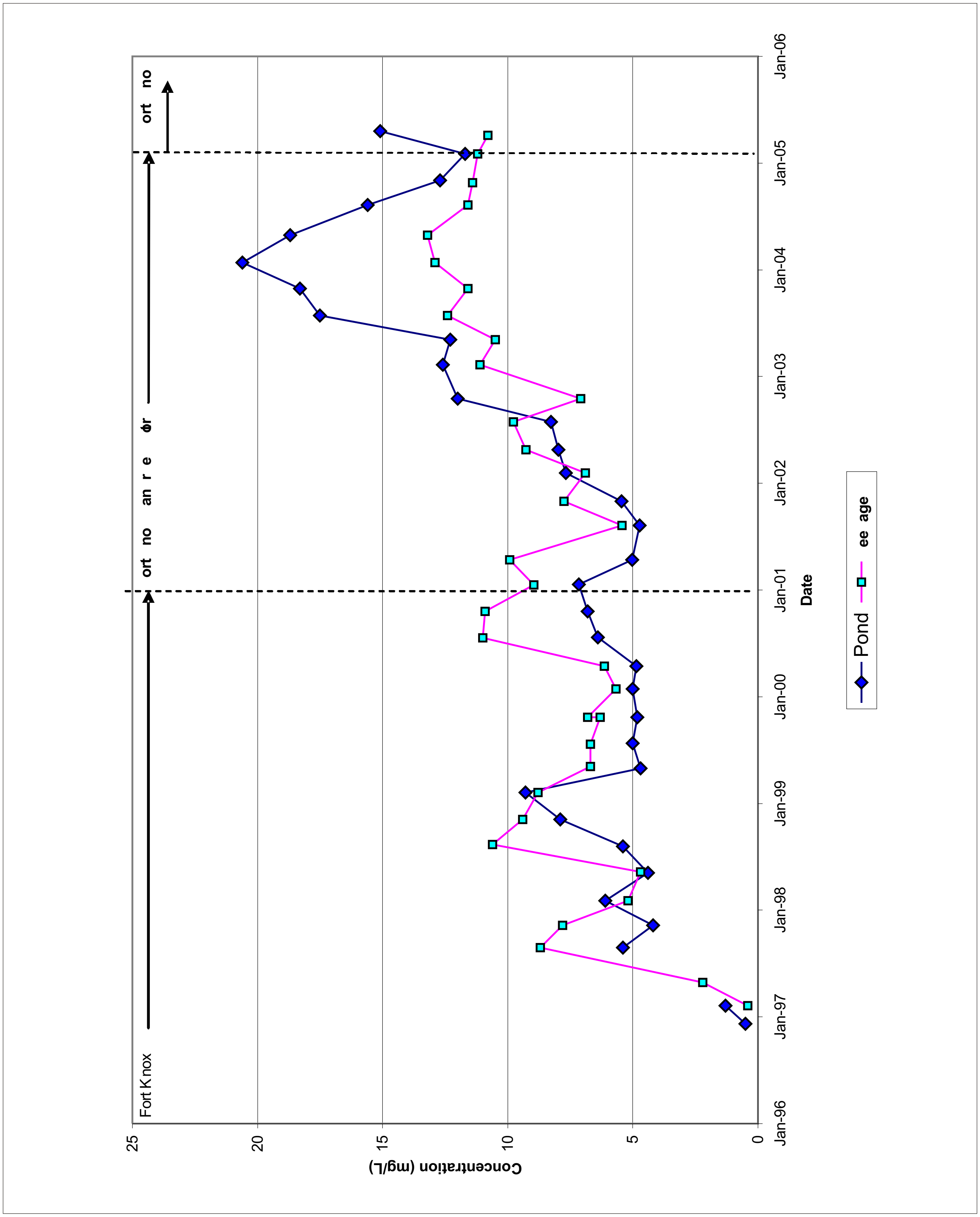

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Figure 5.15 Chloride concentrations in the TSF pond and seepage

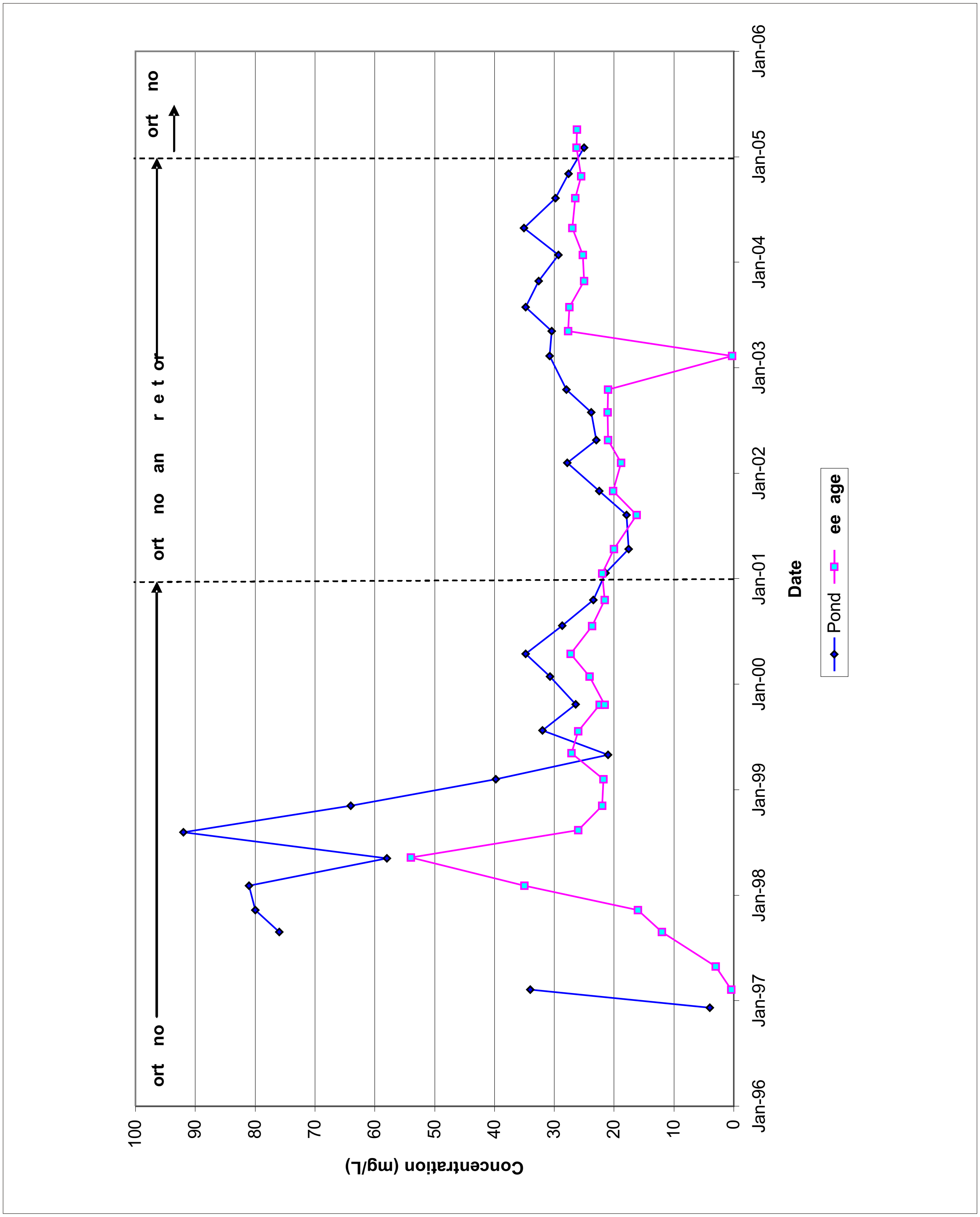

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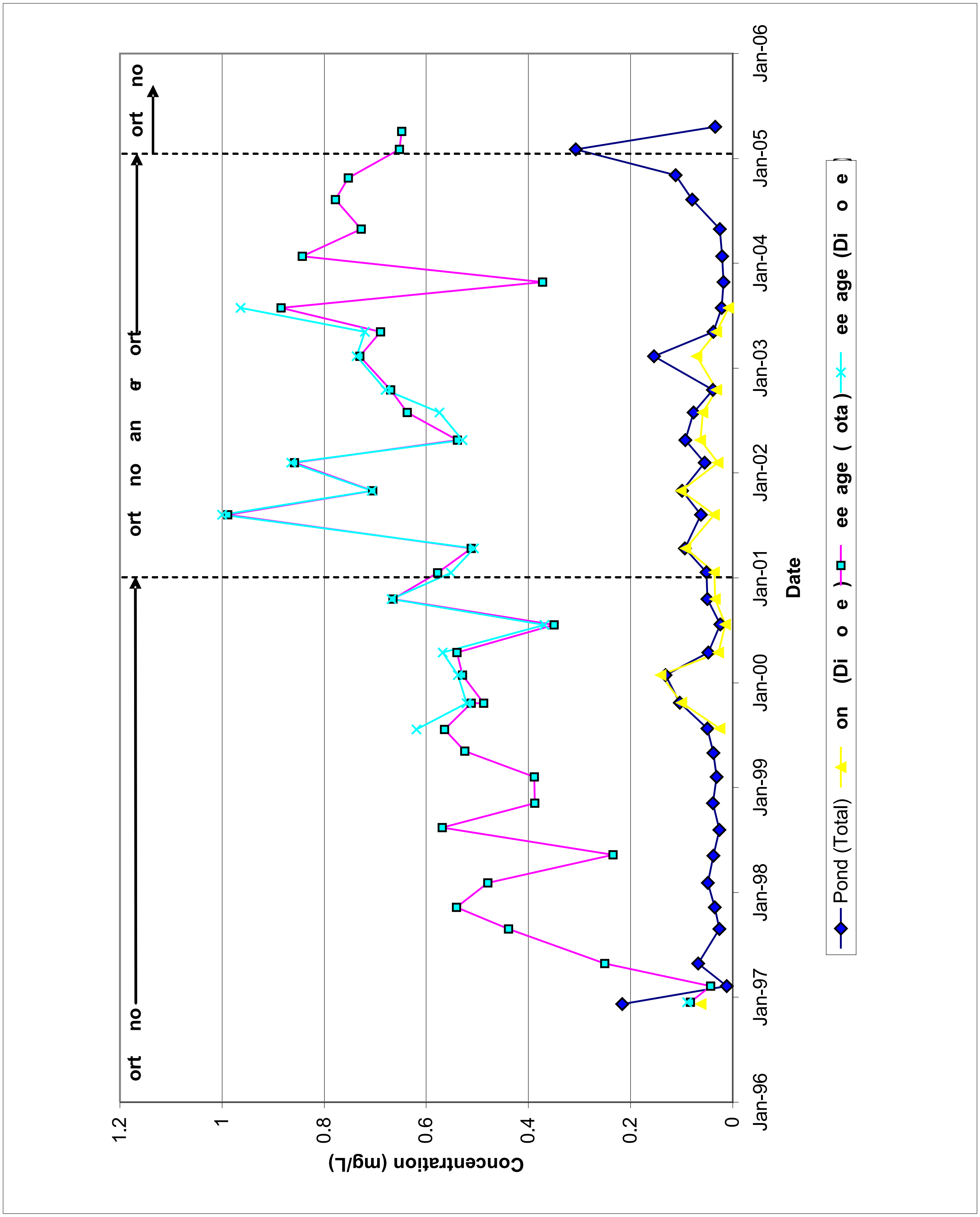
Figure 5.16 Manganese concentrations in the TSF pond and seepage



6 PRELIMINARY CLOSURE DESIGN AND MODELING

The closure elements requiring design include the final tailing surface, the spillway, the conveyance channel, and the engineered wetlands system. A preliminary design of the final tailing surface has been developed to optimize the long-term water balance and estimate the relative proportion of the various stabilization alternatives being considered. The preliminary spillway and channel layouts have been defined based on the design storm event and the anticipated layout of the engineered wetland system which will receive seasonal surface water flow.

Modeling of the proposed closure alternative was completed for the purpose of estimating long-term seepage rates, optimizing the site-wide water balance, and predicting water quality at the monitoring points. The water balance and water quality model included all elements of the proposed closure approach as well as the influence of related facilities such as the heap leach pad and mine pit. The elements of the proposed closure approach incorporated in the modeling include:

- minimizing short-term inventory of process water,
- operating the seepage collection system,
- pumping seepage and short-term inventory to the mine pit over a two-year period, and
- establishing an engineered wetland system to manage seasonal surface water outflows.

The objective of the modeling was to assess the performance of the closure approach and identify key elements of the site-wide water balance that could be used to optimize short- and long-term water quality. The following sections provide a description of the preliminary closure design and performance modeling.

6.1 Preliminary closure design

6.1.1 Final tailing surface topography

As discussed in Section 4, approximately 223 Mt of tailing will be deposited in the TSF prior to closure. The final tailing surface has been designed to meet the following criteria:

- ensure that the required tailing storage volume is available,
- protect mill water supply during the final years of tailing deposition,
- provide the surface storage capacity required to handle the design flood volume,
- maintain free water surface away from the embankment face to minimize impacts of potential erosion and maintain pore pressures as low as possible within the embankment, and
- create conditions necessary to develop sustainable physical stabilization of the tailing.

The information used to design the final tailing surface included:

- the current mine production schedule,
- the physical characteristics and consolidation properties of the tailing, and
- the depositional characteristics of the tailing (i.e., slope and consolidation).

Figure 6.1 illustrates the final tailing surface. The maximum elevation of tailing against the upstream face of the embankment is approximately 1,488 ft amsl and grades to a central low point which corresponds to the location of the barge pump. Currently, the final tailing surface assumes that a beach with a width of between 300 and 500 ft will be constructed adjacent to the upstream face of the embankment. The beach will function to:

- reduce the pressure head in the upper filter layer and within the seal zone,
- isolate the free water surface from the crest of the seal zone, and
- provide physical protection from erosion for the embankment crest and downstream face.

The lowest elevation on the principal portion of the final tailing surface is approximately 1,454 ft amsl. The final surface was generated under the assumption that tailing deposition would be managed to preserve the necessary TSF pond volume through the end of mine life.

The total storage volume on the final tailing surface is approximately 5,500 acre-ft. The stage-storage curve for the final surface is presented in Figure 6.2. Currently, it is assumed that the initial TSF pond at the time of closure will have been pumped down to the minimum volume practical. This will provide almost the entire storage capacity of the final tailing surface.

6.1.2 Preliminary spillway and channel design

The spillway for the tailing impoundment will be a trapezoidal, broad-crested weir designed to safely pass the design storm event (1.25PMP). The spillway location is located in the north abutment of the dam based on existing dam layouts and the optimal route in competent native rock for the spillway channel. Plan 6.1 illustrates the spillway alignment.

6.1.3 Design criteria

The Alaska Department of Natural Resources states, "Standard design procedures such as Corps of Engineers, Bureau of Reclamation, and Soil Conservation Service [sic] are acceptable for use in designing dams" (AK DNR 2003). Spillway configuration and discharge channel design parameters were determined in accordance with the United States Army Corps of Engineers (USACE), as referenced below.

The following criteria were set for the preliminary design of the closure spillway design.

- **Tailings Dam Parameters -** as taken from the "Project Data Sheet" supplied by FGMI:
  - Tailings dam crest = 1494 ft amsl
  - Crest width = 30 ft
  - Snowmelt plus 100-yr, 24-hr flood volume = 1,085 ac-ft
  - 100-yr, 24-hr rainfall = 3.6 inches
  - ½ probable maximum precipitation (PMP) = 5.6 inches
- **Alignment -** The spillway and discharge channel will be cut into native bedrock.

- **Design Event** - The tailing facility spillway and discharge channel were designed to Standard 1 as defined by the *Inflow Design Floods for Dams and Reservoirs*, "…structural designs will be such that the dam will safely pass an inflow design flood (IDF) computed from probable maximum precipitation (PMP) occurring over the watershed above the dam site" (USACE 1991). Therefore, the spillway height and cross-section and the discharge channel alignment and cross-section were determined based on the peak flow and volume reporting to the tailing facility from contributing subbasins. The IDF curve determination is described in Section 3.3.2 of this report. The design event was modeled using HEC-HMS software (2003) in accordance with Alaska dam safety guidelines (Revision 1, 2005) and the calculations are described in detail in Appendix A. WMC modeled the spillway elevation (and the starting water elevation) in the tailing dam reservoir at 1,485.5 ft amsl (full to spillway elevation 1,484.5 plus one foot of additional storage due to ice or debris blockage in the spillway) when the 1.25PMP storm event hit. Therefore, peak flow, peak volume, and minimum freeboard design values are conservative.
    - ***Peak Flow*** - The spillway and spillway discharge channel leading to Fish Creek were designed to convey the peak flows resulting from the 1.25PMP (USACE, 1991). Spillway and channel capacity and erosion protection were determined based on these peak flow criteria. "Spillway and outlet capacity must be sufficient to prevent overtopping of the embankment" (USACE, 2004).

- **Spillway and Channel Peak Design Flow = 178 cfs**
    - ***Volume*** - The volume from the 1.25PMP, 24-hour storm was estimated at 2,236 ac-ft as reported in the HEC-HMS output (Appendix A). The peak design volume was considered when setting the spillway elevation and used in the HEC-HMS model to calculate maximum flood elevation.

- **Spillway and Channel Peak Design Volume = 2,236 ac-ft (inflow)**

- **Freeboard -** The spillway elevation was set so that the peak flow elevation for the 1.25PMP storm event does not rise above the crest of the seal zone in the dam (1488ft amsl) in the event that the tailings reservoir is full when the design storm event occurs. Several levels of conservancy were included in this design to be consistent with state and federal guidelines and to account for site conditions, especially the mountainous terrain and climatic conditions.

The Guidelines for cooperation with the Alaska dam safety program reference the Federal Emergency Management Agency's (FEMA) Federal Guidelines for Dam Safety: Selecting and Accommodating Inflow Design Floods for Dams (FEMA, 2004) recommendations for freeboard allowances. While FEMA states that it is, "generally not necessary to prevent splashing or occasional overtopping of a dam by waves under extreme conditions," (emphasis added) they go on to provide guidelines for determining freeboard. The guidelines are listed below with a discussion and calculations used to meet the criteria.

For minimum freeboard combinations, the following components, when they can reasonably occur simultaneously, should be added to determine the total minimum freeboard requirement:

1. Wind generated wave runup and setup

Design of Small Dams (USBR 1977) states that freeboard calculations should include a consideration to, "prevent overtopping of the embankment by abnormal and severe wave action of rare occurrence that may result from unusual sustained winds of high velocity from a critical direction." USBR goes on to state that, "…no locality is safe from an occurrence of winds of up to 100 miles per hour at least once during a period of many years, although a particular site may be topographically sheltered so that the reservoir is protected from sustained winds of high velocity. Under these conditions, velocities of 75 mph may be used." USBR provides the guidance summarized in Table 6.1 below.

Table 6.1 Wave height as a function of fetch and wind velocity

Fetch (miles)	Wind velocity (mph)	Wave height (ft)
1	50	2.7
1	75	3.0
2.5	50	3.2
2.5	75	3.6
2.5	100	3.9

The Ft Knox Tailing Facility peak water surface elevation during the 1.25PMP is approximately 1488 ft, with a maximum fetch of approximately 9000 ft, or 1.7 miles.

Accordingly, a conservative wind generated wave runup freeboard allowance range is between 3.0 and 3.9 feet.

2. Possible malfunction of the spillway and/or outlet works during the design storm event

WMC chose the spillway elevation (1484.5ft) so that the 1.25PMP storm event peak flow elevation did not rise above the seal zone assuming that one foot of the spillway was blocked by ice buildup and or debris. Regular maintenance will be needed to ensure that the spillway functions properly, but in the event of an extreme event, an additional 1.0 foot of freeboard allowance has been included below the sealed zone elevation.

3. Settlement of embankment and foundation not included in the crest camber

Settlement calculations and the resulting camber allowance are included in the tailing dam design as provided by Knight Piesold in the design of tailing storage facility and water reservoir (Knight Piesold 1994). Based on their calculations, Knight Piesold states, "…that in the event of the design earthquake, no large deformations will occur in the embankment structures." Therefore, additional reductions in crest elevation due to earthquake induced settlement.

4. Landslide-generated waves and/or displacement of reservoir volume associated with the design storm

Landslides associated with the design storm event are assumed to be negligible during the 1.25PMP storm event in the areas around the tailing reservoir because the soils consist of deposits of colluvium and loess, ranging in composition from silt and sandy silt to silty gravelly sand on the valley slopes (Knight Piesold 1994) and are known to be well-drained based on the field investigations.

In summary, the freeboard allowance includes 1.0 foot below the seal zone to account for spillway blockage, and 6.1 feet (1494 ft-1487.9 ft) above the seal zone to account for wave runup (3.0 ft – 3.9 ft), embankment settlement (negligible), and landslide impacts (negligible during the 1.25PMP).

- **Spillway Freeboard (max water elevation to dam/channel crest)**

  Freeboard = 1,494.0 dam crest – 1,484.5 spillway elevation = **9.5** ft
  Residual freeboard = 1,494.0 dam crest – 1,487.9 peak water elev. = **6.1** ft

- **Channel Freeboard** is the vertical distance between the water surface and the channel crest during the design storm event. The 1.25PMP storm event was used for design of the tailing dam spillway consistent with Standard 1 design criteria. Because the discharge channel is located away from the toe of the tailing dam embankment, wave runup, splash, and turbulent flow in the channel bed will not jeopardize its integrity. Therefore, the discharge channel leading from the spillway to the receiving stream was designed to carry the 1.25PMP storm event without freeboard. During the 100-year storm event, the channel provides a minimum freeboard allowance of 1.1 ft (Appendix A).

- **Channel Freeboard (max water elevation to channel crest)**

  Freeboard during the 1.25PMP event = **0.0** ft
  Freeboard during the 100-yr, 24-hr event = **1.1** ft

6.1.4 Preliminary spillway design

Design invert and flow capacity

The spillway invert was initially set at an elevation of 1,484.5 ft amsl to minimize the required cut for the spillway and discharge channel and to keep the peak water surface elevation during the design flow event below the tailing dam seal zone peak elevation of 1,488 ft amsl. The 1.25PMP storm event was routed through the spillway to estimate required size and freeboard allowances. The following assumptions were made in the routing calculations:

- The exit slope of the spillway was set at 1 percent and the spillway width was set to 14 ft to provide positive drainage through the spillway and control the erosion potential while minimizing the depth of cut through the embankment.
- The spillway will be located in the left dam abutment and cut through bedrock to provide safety against erosion of the embankment.

Plans 6.1 through 6.5 illustrate the spillway and discharge channel design details. The discharge channel routes the flow from the spillway down the slope to the stilling basin. The alignment was selected to avoid unsuitable ground, maintain a smooth transition of the centerline alignment, and minimize grade changes in the invert. Once the alignment was set, the centerline profile and required channel depths were determined for the design flow capacity. The alignment and centerline profile were then adjusted to reduce flow velocities, minimize excavation, and place the channel in native ground. The channel sizing was based on design flow estimates using Manning’s equation. A V-shaped section was selected for preliminary design. Final design may include a shallower, trapezoidal profile if field conditions dictate.

Because the channel is constructed in natural ground (and not the tailing dam embankment) the channel’s slope varies along its length. Some steep portions of the channel are followed by shallow sections, and may cause hydraulic conditions to fluctuate (from sub- to super-critical flow during some flow events). There are five locations where the reduction in slope is greater than 4 percent in successive channel sections. A wider, shallow-sloped area protected against erosion (bedrock-lined or grouted, riprap-lined) will likely be required downstream of the channel transitions. Final design will provide exact dimensions of the necessary structures, and a typical basin design is provided in this report; Plan 6.5, Detail 2.

A transition section containing a stilling basin-type structure will be constructed where the discharge channel merges into the receiving stream. General specifications are provided on Plan 6.5.

6.1.5 Engineered wetland treatment system

The engineered wetland treatment system will receive underflow from the TSF and surface water flow conveyed from the embankment spillway. The wetland treatment system will provide final polishing to any seepage or discharge from the facility so that the water quality standards, including any site-specific criteria, are met at the outlet. Subsequent to decommissioning the seepage collection system, flow will be routed from the TSF to the engineered wetland treatment system via an underdrain system. The underdrain will be constructed by excavating through the downstream face reclaim sump liner in at least three locations.

The underdrain system will have the capacity to handle an inflow of 1,300 gpm which is the maximum predicted discharge after closure (see Section 6.2.2). The design will include a minimum of three channels to distribute flow within the alluvial system. Final design will be completed once actual field conditions have been determined. The top of the underdrain will remain approximately 10 ft bgs to prevent uncontrolled discharge to surface water. Figure 6.3 illustrates the conceptual design for the underdrain system.

The channel conveying flow from the spillway will be routed to a point just downstream of the embankment toe and discharge into the engineered wetland treatment system. The wetland system will be constructed on the north side of Fish Creek where placer mining has completely disturbed the original stream morphology. Currently, little to no surface water flow occurs in the area planned for construction of the wetlands.

During periods of discharge, water will flow from the stilling basin to the existing pond located at the toe of the TSF. The wetland system will consist of a series of interconnected detention basins, which will ultimately terminate above the freshwater reservoir. Plan 6.6 illustrates the conceptual layout of the engineered wetland system. The constructed wetlands will be designed to provide final treatment to any seepage or discharge from the facility so that the water quality standards (including site-specific criteria) are met at the outlet.

The basins will be constructed in the alluvium disturbed by placer mining on the north side of the Fish Creek basin. The wetland system will be separated from the grayling ponds on the south side of the drainage by a ridge developed during placer mining. The total storage capacity of the detention basins is approximately 5 to 7 acre-ft. The geometry of the basins has been defined based on the existing topography and the gradient of the drainage. The basins will be excavated to depths ranging from 3 to 6 ft depending on the local topographic gradients.

The conveyance channel interconnecting the basins will be approximately 14-ft wide with a trapezoidal section. The channel side slopes will be 3H:1V. It is likely that the channel bottom will be comprised of placer tailing (coarse gravel to cobbles) and will not require significant armoring or erosion control. Rip rap will be placed where local ground conditions require stabilization and erosion control.

6.2 Closure modeling

Performance modeling was completed for the proposed TSF closure approach. The evaluation incorporates the key components of the site-wide conceptual model. This includes the closure elements that involve water management as part of pre- and early-closure activities. The purpose of the model is to assess the performance of the Closure Management Plan relative to background water quality conditions and/or meeting water quality criteria at the proposed monitoring points.

The modeling consisted of estimating long-term seepage from the facility and development of a Dynamic Systems Model (DSM) that incorporated all of the relevant components of the conceptual model. The data used for the modeling were generated from existing information collected as part of previous investigations, the engineering design report for the embankment (Knight Piésold, 1994), operational data provided by FGMI, laboratory data generated as part of this program, and water quality monitoring data collected by FGMI for normal environmental reporting requirements.

6.2.1 General conceptual model

Figures 6.4 and 6.5 illustrate the general conceptual model of the site-wide water balance as it relates to the TSF at closure. The components of the water balance include:

- Inflows
  - Direct precipitation
  - Surface water run-on from upgradient areas
  - Discharge from the mine pit
  - Discharge from the heap leach facility
  - Consolidation water
  - Groundwater underflow
  - Pumpback water
- Outflows
  - Evaporation/Sublimation
  - Surface water discharge
  - Seepage
  - Groundwater outflow

Precipitation and evaporation

Direct precipitation (as snow and rain) will occur on upgradient watershed areas, the tailing surface and directly on the pond. Rainfall on the tailing adjacent to the inundated area will runoff and report to the pond. A small percentage of rainfall on the vegetated tailing surface will infiltrate (<3 percent). During winter, water will accumulate as snow and ice. Water stored as snow/ice will be released during the spring breakup. Evaporation occurs from the pond surface and the near surface tailing (when sufficient water is available). During the winter, water from the snowpack will be lost to sublimation.

Surface water

The upgradient Fish Creek drainage area encompasses approximately 7.3 mi^2. Yellow Pup Creek, Pearl Creek, Walter Creek and Barnes Creek watersheds provide inflow to the TSF. The majority of surface water flow occurs during the spring breakup period in April and May. Downgradient of the TSF, the undisturbed watershed to the confluence with Last Chance Creek contributes additional water to Fish Creek. This area provides additional flow between the TSF and the fresh water reservoir. When the water level in the pit recovers to an elevation of approximately 1,480 ft amsl, seasonal discharges will occur via the ancestral Monte Cristo drainage through the Fish Creek dump and ultimately report to the TSF. Discharge from the heap leach pad will also be directed to the TSF as surface water. Long-term seepage rates are expected to range from 2 to 7 gpm. During the spring, breakup discharge rates would be expected to increase to approximately 10 gpm (WMC, 2005b).

Groundwater

Groundwater flow occurs in the alluvium and upper fractured bedrock unit. Recharge to the uppermost groundwater system occurs upgradient of the TSF. Currently the cone of depression created by dewatering activities intercept deep recharge to the fractured bedrock in the vicinity of the mine pit. Shallow groundwater flow mixes with seepage from the TSF and is captured by the interception system located at the embankment toe.

Pump-back water

Water that is pumped back to the tailing pond from the interception system is a mixture of groundwater and seepage from the tailing pond. Current pumping rates range from approximately 1,700 to 1,900 gpm. At closure, the interception system will be operated only as long as necessary to ensure water quality criteria are met at the monitoring point.

Consolidation water

As mentioned in Section 4.3.2, the ‘free’ water draining to the surface water pool area is approximately 156 gallons per ton of tailing. The SICT results show that most of the consolidation of freshly deposited tailing occurs in the first 6 to 12 months following deposition. Minor consolidation occurs as subsequent tailing are deposited. During later periods of secondary consolidation a portion of the water will be forced to the surface and report to the pool (approximately 50 percent) and the balance will migrate vertically downward and report as seepage.

6.2.2 Closure strategy conceptualization

The performance modeling reflects the proposed closure strategy which includes short-term inventory management, operation of a seepage management system, surface water management, and interim and long-term water quality monitoring. The following paragraphs describe the closure strategy as conceptualized for the performance modeling. Figure 6.6 illustrates a general timeline for the various pre-closure and closure activities.

6.2.2.1 Pre-closure activities

During the latter stages of tailing deposition, the facility water balance will be actively managed to reduce the short-term inventory. During this period, the TSF pond volume will be reduced to the extent practical. The seepage interception system will remain operational during this period but will be optimized to maintain hydraulic containment at the lowest pumping rates possible.

6.2.2.2 Closure activities

While the duration and schedule of the closure activities proposed in this section are necessary for planning, the actual duration and dates will be determined by the mine plan, performance of the systems in meeting the appropriate water quality and permit requirements. The following schedule should be considered a general guideline based on the existing mine plan.

Step 1 (2010 through 2013; early-closure)

Establishment of the final tailing surface and cessation of mill operations will mark the beginning of Step 1 closure activities. The following will be completed during this period:

- The spillway and channel will be constructed.
- The underdrain and engineered wetlands system will be constructed.
- Remaining TSF pond water will be pumped to the pit.
- Seepage collected from the interception system will be pumped to the pit for a period of two years.
- Monitoring of groundwater will occur at the current monitoring points (or others established further downgradient).
- Mining operations in the pit will cease
- Operation of the heap leach will continue with remaining stockpiled ore and continued leaching
- After a period of two years, pumping to the pit will cease and water will begin to accumulate on the surface of the TSF.

Step 2 (2013+; pre-stabilization)

The time period of Step 2 will be determined by the predicted time required for the pond to reach the spillway invert. During this period, the following will be completed:

- The seepage management system will be gradually shut down. The system will remain intact in the event further operation is required to achieve water quality standards or meet background conditions.

- The existing groundwater monitoring wells will be gradually phased out at the end of active seepage management and moved further downstream to coincide with the surface water monitoring point.
- Monitor decant pond elevation and quality
- Monitor pit lake elevation and quality

Step 3 (Post-stabilization)

- Seasonal surface water flows will be routed to the engineered wetland treatment system.
- Monitoring of surface water and groundwater quality will occur at the final locations (described below).

Water quality monitoring

A key component of the closure approach is the definition of the monitoring points referenced above. The purpose of these monitoring points is to evaluate performance of the closure approach in a manner that reflects site-specific and post-closure conditions. Site-specific considerations used to define monitoring points include the following:

- The area downgradient of the TSF has been intensely disturbed by placer mining.
- The alluvium in Fish Creek represents a mineralized orebody with naturally-occurring, elevated metals concentrations.
- The north side of Fish Creek currently does not carry water. Seasonal surface water flows may flush metals out that should be monitored below the TSF in both surface water and groundwater.

Prior to the end of the pre-stabilization period (Step 2), a surface water monitoring points will be established at the terminus of the engineered wetland treatment system (Plan 6.6). The anticipated location of the wetland treatment system on the north side of Fish Creek currently does not carry surface water. Therefore, the monitoring location has been established directly upgradient of the freshwater reservoir. The final groundwater monitoring point will be moved to a similar location.

6.2.3 Seepage modeling

Seepage modeling was completed to evaluate the optimal beach width and estimate the long-term drainage quantity from the TSF. A finite element code (SEEP/W) was used to build the model. The model was also utilized to assess the potential impact of reduced drain permeability on pore pressures within the embankment. The following sections outline the modeling methodology and results.

6.2.2.3 Model description

Model configuration

A two-dimensional finite element model of the embankment was constructed based on the design prepared by Knight Piésold. Figure 6.7 illustrates the zones included in the model for the embankment, and Figure 6.8 presents the entire finite element mesh. The model included the bedrock foundation, alluvium, tailing, random fill, transition zone, filter zone, and toe drain.

Material properties (i.e., permeability and porosity) were assigned to the various zones based on values presented in the Knight Piésold design report and results of field characterization completed by Halepaska and Associates (JCHA, 1992a). The values provided in the Knight Piésold design report were based on field and laboratory test results.

The crest of the embankment was set at an elevation of 1,494 ft amsl, and the facility was assumed to be full of saturated tailing. The total base width of the embankment structure was defined to be approximately 1,470 ft. The alluvium beneath the tailing are assumed to be in direct contact with the overlying tailing.

To evaluate the influence of beach widths on pressure within the upstream filter layer, widths of 100, 250, and 500 ft were evaluated. The beach surface was assumed to slope away from the upstream face at about a 0.45 percent grade. The influence of drain performance was modeled assuming reductions in permeability of 50 percent and one order of magnitude. Long-term seepage from the facility was evaluated assuming areas of inundation ranging from 400 to 500 acres. Seepage quantities were estimated assuming a constant head on the tailing surface for pond elevations ranging from 1,482 to 1,484.5 ft amsl (the spillway invert elevation).

Boundary conditions

The downstream boundary condition was defined as a constant head of 1,148 ft amsl equal to the alluvium/bedrock contact. The bottom of the domain was defined as a no flow boundary. On the upstream side of the bedrock domain, the boundary condition was set at a constant flux of 175 gpm. Full hydrostatic head was specified on the tailing surface representing stored water on the tailing surface.

6.2.2.4 Model results

Calibration

The model was calibrated by comparing predicted heads in specific zones within the embankment against measured values at various TSF pond elevations. Heads were compared in the rock fill near the toe, within the filter extension, and in the sealed zone. Each point corresponds to the location of a vibrating wire piezometer.

Constant heads of 1,336, 1,393, and 1,414 ft amsl were defined at the tailing surface to represent the elevation of the TSF pond at specific times during facility operation. The predicted and measured heads were then compared at each of the various zones within the embankment to determine how well the model was able to represent measured conditions. Figure 6.9 illustrates the results of the calibration.

The model was able to reasonably predict measured pore pressures with no modification of the initial parameter values. The calibration indicates that the model is able to adequately represent the observed head drop across the seal zone and is consistent with the lack of increased pressure measured in the foundation.

Evaluation of beach width

In order to move impounded water away from the upstream face of the embankment, a beach will be established during the final stages of tailing deposition. The beach will serve to reduce the hydraulic head in the upper filter layer and within the sealed zone. The magnitude of these reductions will be dependent on the width of the beach and the ultimate beach slope at the time of closure.

The maximum head is for the condition with no beach and corresponds to a pressure of 1,484.5 ft amsl, which is the maximum elevation of the impounded water. Based on the simulation results, the pressure in the upper filter layer decreases to a minimum of approximately 1,430 ft for a beach width of 500 ft. This provides approximately 58 ft between the water elevation in the upper filter layer and the top of the sealed zone. The pressure head within the seal zone is predicted to be about 1,426 ft amsl which is approximately 44 ft less than would be predicted with no beach.

Long-term seepage estimates

Post-closure, the TSF will hold water on the surface. The area of inundation will depend on the amount of water on the facility at the beginning of breakup, the breakup volume, and the final stage-area curve for the tailing surface. Vertical drainage will report to the underlying bedrock aquifer and to the drain system within the embankment. Long-term seepage estimates are predicted to range from 700 to 900 gpm depending on the elevation of the pond. This corresponds to an average flow of approximately 1.8 cfs.

There is not anticipated to be a significant amount of seasonal variation in seepage rates due to the hydraulic characteristics of the tailing materials. Therefore, the seepage rate will be relatively constant subsequent to closure.

Influence of drain performance

The results of the drain performance evaluation presented in Figure 6.10 illustrate the changes in pore pressures in the various zones for 50 percent and one order of magnitude reduction in drain permeability. The results indicate that while some increase in pore pressure would result from decreases in drain permeability, the magnitude of increase would not be significant in terms of compromising dam stability. For example, with a one order of magnitude decrease in drain permeability, the increase in pressure in the seal zone is predicted to be less than 10 ft with a 500 ft beach width. The increase in the upper filter zone is predicted to be of a similar magnitude.

One of the reasons the pore pressures in the embankment are not particularly sensitive to decreases in drain performance is because of the high permeability of the underlying bedrock. The bedrock is estimated to have a hydraulic conductivity on the order of 10^{-3} cm/s, which allows the upper portion to function as part of the embankment underdrain system. This provides additional contingency capacity in the event degradation of the drain materials would occur resulting in a loss in permeability.

6.2.3 Water balance modeling

The water balance model was run for the following closure scenario:

- TSF pond water, run-on, and seepage collected from the interception system would be pumped to the pit for a period of two years or as long as required to meet water quality criteria.
- The TSF pond would be pumped as low as possible subsequent to shutting down the seepage collection system minimizing the amount of water on the surface.
- The discharge from the pit would occur after approximately 80 years and report to the TSF.
- The groundwater monitoring point is the same as that currently monitored.
- All water balance components were assigned compositions based on the water quality data presented in Sections 4 and 5.

6.2.4 Operational calibration

In order to confirm that the model was capable of representing the general water balance for the TSF, a calibration was completed against the existing water balance used by FGMI. The results of the calibration are presented in Figure 6.11. The basis for the calibration is the change in pond volume over the course of a 12-month period. The results indicate that the model is able to adequately represent the monthly changes in pond volume. The model incorporates all climatological and operational components of the existing TSF water balance.

6.2.5 Post-closure water balance predictions

The water balance for the TSF consists of two periods:

- Pre-stabilization: beginning at the start of closure. During this period, the pond elevation (and size) gradually increases from the initial condition to the steady-state, long-term condition.
- Long-term steady-state: variations in the water balance during this time result from seasonal fluctuations in spring breakup volumes and climatological conditions (temperature, precipitation, evaporation, and sublimation).

The predictions for each period are discussed briefly below.

Pre-stabilization

Figure 6.12 illustrates the pond elevation over the first 20 years following cessation of pumping to the pit. The results indicate that the pond elevation increases from an initial value of 1,466 to 1,484.5 ft amsl in about 2 to 3 years. The seasonal variations in pond elevation during this period range from approximately 1 to 2 ft. After about 2 to 3 years, the average water level elevation is about 1,484 ft amsl slightly below the spillway elevation. Regular, seasonal discharges mark the beginning of the long-term, steady-state condition. It is important to note that the time required for the pond to reach the spillway elevation will depend on the actual final tailing surface and the initial pond volume. These may vary from the conditions assumed in the current model.

Long-term steady state

Figure 6.13 illustrates the steady-state pond elevation. Seasonal variations range from 1,483 to 1,484.5 ft amsl (spillway invert elevation). The magnitude of the seasonal discharges ranges from 2.5 to 33 cfs. The average discharge rate is approximately 9 cfs. Discharge is predicted to begin after approximately 2 to 3 years. Figure 6.14 illustrates the predicted annual variations in flows in Fish Creek relative to baseline conditions. The results indicate that the Fish Creek hydrologic system will return to similar conditions as those that existed prior to mining once stable conditions are established.

6.2.6 Post-closure water quality predictions

Water-quality predictions

Water-quality predictions have been made for the TSF pond and at the surface water and groundwater monitoring points. The evaluation of post-closure water quality at the monitoring point is relative to the standards presented in Section 5.1 and the background concentrations in surface water and groundwater, which were discussed in Section 5.2.

TSF pond

Concentration changes for selected constituents in the TSF pond are illustrated in Figures 6.15 through 6.20. The results for all analyzed constituents are presented in Appendix C.

Values of pH in the TSF pond are predicted to vary between 7.5 and 8.0. The variations result from seasonal inflow of freshwater. The results are presented in Appendix C.

Arsenic concentrations are predicted to decrease from an initial value of 0.31 mg/l to an average of approximately 0.006 mg/l after approximately one year following pumping to the pit (Figure 6.15). After five years, the concentration varies slightly but remains at or below the water quality standard.

Cadmium concentrations are predicted to average approximately 0.0002 mg/l following pumping to the pit (Figure 6.16). After the first two years following pumping, the concentration varies but decreases steadily to values below the water quality standard.

Figure 6.17 illustrates the changes in antimony concentrations with time within the TSF pond. Concentrations decrease from an initial value of approximately 0.10 mg/l to 0.002 mg/l after approximately five years. The predicted concentration is below the water quality standard after discharges to surface water are predicted.

Selenium concentrations are predicted to decrease from a maximum value of 0.01 mg/l to an average of approximately 0.001 mg/l after approximately seven years following pumping to the pit (Figure 6.18). The predicted concentration remains below the standard when discharges to surface water begin.

Manganese concentrations are predicted to decrease from a maximum value of 0.5 mg/l to an average of approximately 0.16 mg/l after approximately six years after water begins to accumulate on the surface (Figure 6.19). The predicted concentration remains above the water quality standard during the post-closure period, but is consistent with observed pre-mining concentrations.

WAD cyanide concentrations are predicted to decrease from an initial value of 0.25 mg/l to an average of approximately 0.002 mg/l after approximately two years following the beginning of pond development (Figure 6.20). The predicted concentration remains below the water quality standard during the post-closure period.

Monitoring locations

Figures 6.21 through 6.26 illustrate the predicted water quality for selected parameters at the surface water and groundwater monitoring locations. The results for all analyzed constituents evaluated are presented in Appendix C.

Values of pH for groundwater and surface water are predicted to average approximately 7.7 which is consistent with current conditions. The results are presented in Appendix C.

As discussed in Section 5, pre-mining arsenic concentrations in groundwater ranged from 0.003 to 0.57 mg/l with most occurrences above the water quality standard. Arsenic concentrations in groundwater are predicted to average approximately 0.007 mg/l at the monitoring point during post-closure (Figure 6.21). Surface water concentrations are also predicted to average about 0.007 mg/l. Based on the model results, the arsenic standard will not be exceeded at the monitoring points.

Cadmium concentrations in groundwater are predicted to average about 0.0002 mg/l at the monitoring point (Figure 6.22). Background cadmium concentrations in groundwater ranged from 0.0001 to 0.0006. The model results suggest that post-closure concentrations will be similar to pre-mining conditions. Groundwater concentrations for cadmium are predicted to be below the standard at the monitoring point. Cadmium concentrations in surface water are predicted to average approximately 0.00035 mg/l. Surface water concentrations are predicted to vary seasonally but are predicted to remain below the freshwater aquatic life standard.

Figure 6.23 illustrates the changes in antimony concentrations in both groundwater and surface water. Groundwater concentrations are predicted to average approximately 0.002 mg/l during the post-closure period while surface water concentrations average approximately the same. Prior to mining, antimony concentrations exceeded the MCL standard in the vicinity of the mine pit with a maximum reported value of 0.049 mg/l.

Selenium concentrations in groundwater are predicted to average approximately 0.0025 mg/l at the monitoring point after approximately two to three years. Surface water concentrations decrease to 0.002 mg/l (which is below the 0.005 mg/l aquatic life standard) after approximately the same amount of time (Figure 6.24). The decrease through time reflects the continued improvement of seepage and pond quality.

Manganese concentrations in groundwater at the monitoring point are predicted to average approximately 0.12 mg/l, which is above the human health (consumption of water and aquatic organisms) water quality standard (Figure 6.25). However, average pre-mining groundwater concentrations for manganese range from 0.02 to 1.7 mg/l indicating post-closure conditions will be similar to baseline conditions. Surface water concentrations are estimated to average about 0.20 mg/l at the monitoring point. This compares well with the baseline manganese concentration at the Lower Fish Creek location of 0.30 mg/l.

WAD cyanide concentrations in groundwater are predicted to average approximately 0.0025 mg/l after approximately one year following closure (Figure 6.26). The predicted concentration in surface water at the monitoring point averages 0.002 mg/l, which is below the numerical standard for human health (consumption of water and aquatic organisms).

6.3 Discussion of results

The water balance results indicate that the time required for the hydrologic system to reach steady-state is on the order of approximately 2 to 3 years. During the pre-stabilization period, the pond elevation increases steadily from its initial level to the elevation of the spillway invert. During this period, the outflows from the facility consist of evaporation, sublimation, and seepage. Seepage is the principal outflow and remains consistent throughout the pre-stabilization period. The primary source of seepage will be vertical drainage from the pond. Variations in pond levels during stabilization are predicted to be on the order of 1 to 2 ft.

Once the pond elevation reaches approximately 1,484.5 ft amsl, seasonal discharges will begin. Seasonal variations in the pond elevation are predicted to be on the order of 1 to 2 ft. Once the system becomes stable, seasonal variations in surface water flow will be similar to those prior to construction of the facility. There will be some attenuation resulting from the available storage between elevations of 1,483 and 1,484.5 ft amsl.

Because the TSF will receive run-on from upgradient areas of the Fish Creek watershed, a portion of the annual breakup that would normally report to surface water will be captured in the pond and ultimately discharge to the shallow groundwater system. At the terminus of the wetland treatment system, much of the surface water will be made up of discharge from shallow groundwater. Therefore, while the relative proportion of groundwater and surface water may differ from pre-mining conditions, the total flow within the Fish Creek system will be approximately the same.

The results of the mass balance modeling indicate that the quality of the TSF pond will progressively improve over about a one- to two-year period as a result of active management and continued mixing. By the time discharges to surface water begin after about 2 to 3 years, most of the constituents are predicted to be below their respective numerical standards. Exceptions to this include iron and manganese which are predicted to remain above the standard for the entire post-closure period but at levels that are consistent with measured pre-mining concentrations.

The results indicate that the magnitude of improvement in TSF pond water quality will be influenced to a significant degree by the quality of the surface water originating from upgradient of the facility and the quality of runoff from the tailing surface. The initial quantity of water in the TSF pond at the time of closure will be an important factor for constituents such as copper and antimony. Concentrations for manganese and iron in the pond will likely return to levels close to their pre-mining surface water concentrations, which were above the numerical standards. Cyanide concentrations decrease to below the water quality standard after about two years; well before surface water discharges are predicted to occur. Because the rate of release for consolidation water is expected to be relatively rapid, the influence of pore water quality is most significant over the first two years of closure. During this time, the majority of pore water released through consolidation will occur and most will report to the TSF pond and subsequently be pumped to the pit. Through time, the influence of pore water quality on the composition of the TSF pond diminishes significantly.

Downgradient surface water flow at the monitoring point is predicted to be similar in magnitude to pre-mining conditions once the system stabilizes. During the pre-stabilization period, much of the upgradient surface water is intercepted by the TSF. The water accumulates on the surface, and the pond continues to increase in size. Seepage reporting to the shallow groundwater system becomes part of the total underflow and a portion discharges to surface water further downgradient.

Following the pre-stabilization period, seasonal surface water discharges from the TSF provide additional flow from the upgradient portions of the catchment previously intercepted by the facility. Flow will be managed by the engineered wetland treatment system located on the north side of Fish Creek. Currently, no water actively flows in this portion of the drainage. Depending on the magnitude of flow during the first few seasons after discharges begin, it may take several years for the entire system to reach hydraulic equilibrium. Therefore, water will not be present at the monitoring point on a consistent basis during this time.

The results of the water quality modeling indicate that the post-closure conditions will return to those present prior to construction of Fort Knox. Pre-mining water quality in surface water and groundwater reflected the mineralized nature of the Fish Creek drainage. Predictions of post-closure water quality indicate iron, and manganese may be present at concentrations that exceed the numerical standards but are well within the range of values measured prior to mining. Therefore, the proposed closure approach is predicted to effectively return the system to pre-mining conditions.

The iron standard is based on secondary drinking water criteria, respectively. The manganese standard is based on the human health criteria for consumption of water and aquatic organisms.

Predicted post-closure mass loading rates are consistent with estimates of pre-mining loading presented in Section 5. None of the key parameters are predicted to exceed pre-mining loading rates post closure. Because long-term, predicted concentrations and flow rates are similar to those measured prior to construction of the TSF, the proposed closure strategy will allow the system in Fish Creek drainage to return to background conditions.

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Figure 6.1 Final tailing surface topography

F:\2603 - FORT KNOX\REPORTS\RPT_FIGURES\2603-R1-JUNE-2006\FIGURE-6.1-R.DWG

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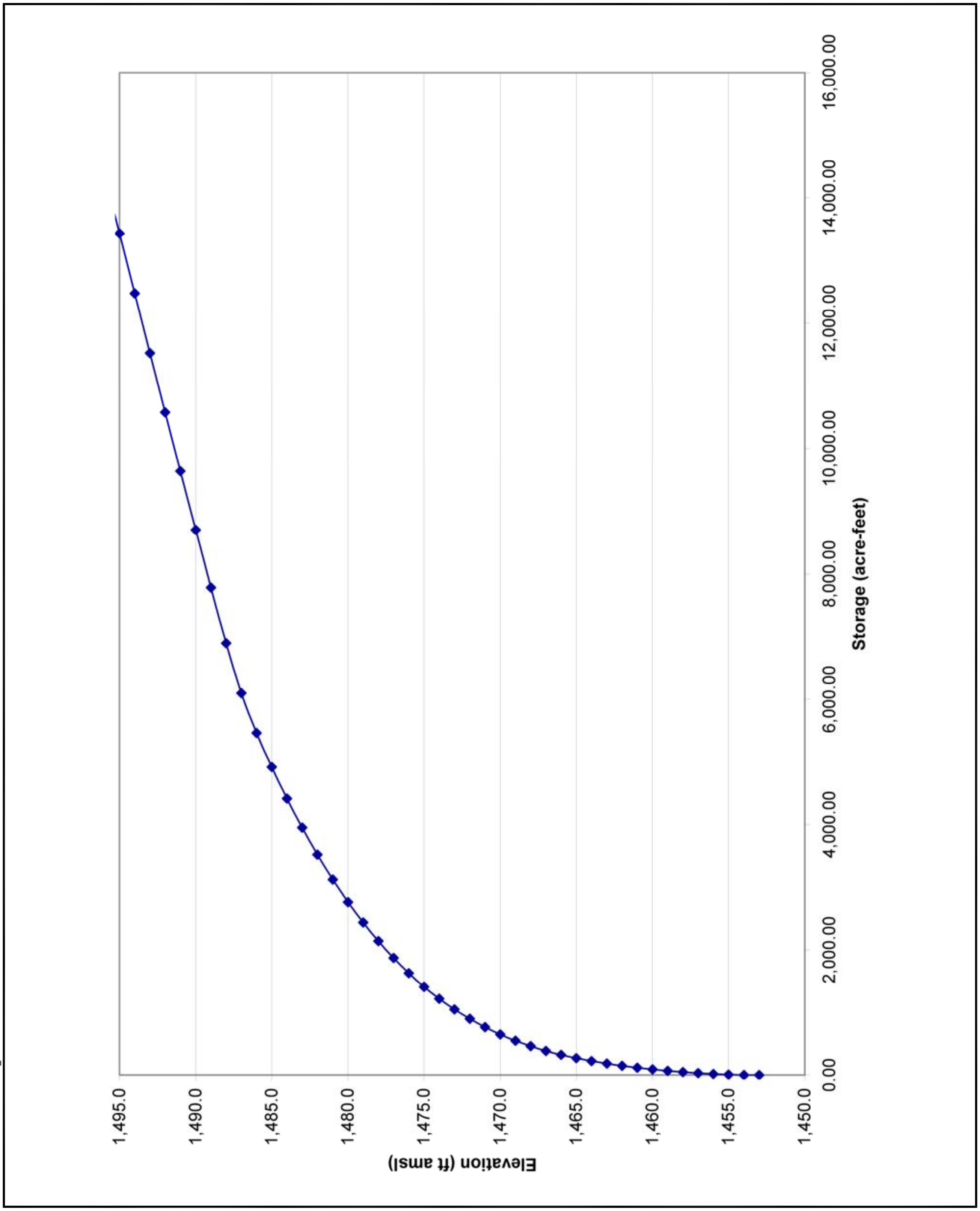
Figure 6.2 Stage storage curve for the final tailing surface



F:\2603 - FORT KNOX\REPORTS\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-6.2-R.DWG

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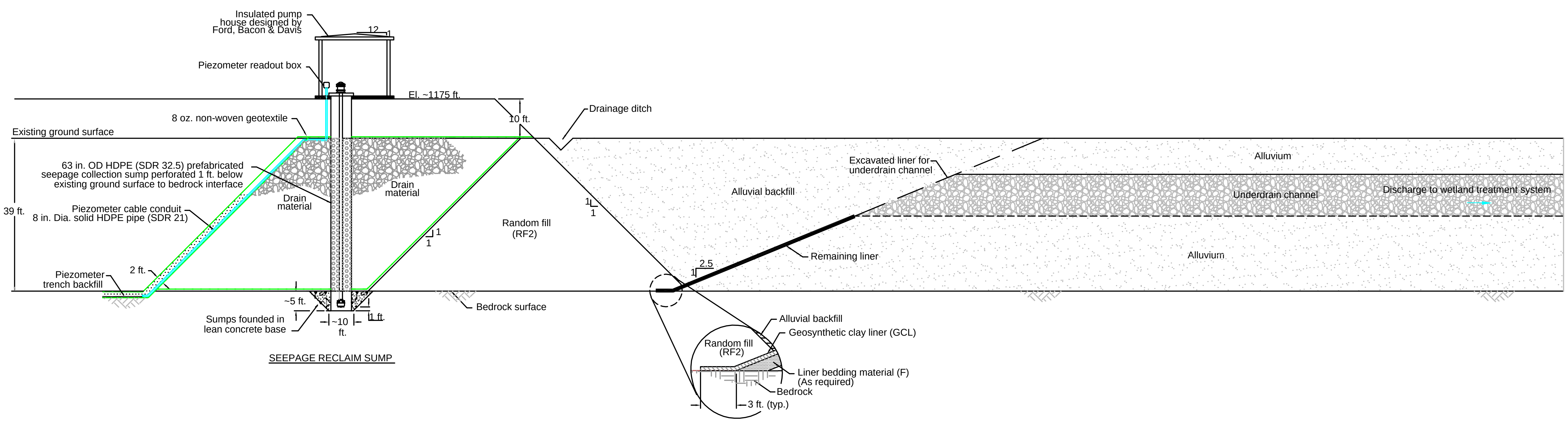
Figure 6.3 Conceptual design for the underdrain system



LEGEND

- Drain material
- Alluvium
- Woven geotextile

NOTE: Based on as-built provided by Knight Piesold.

F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-6.3.DWG

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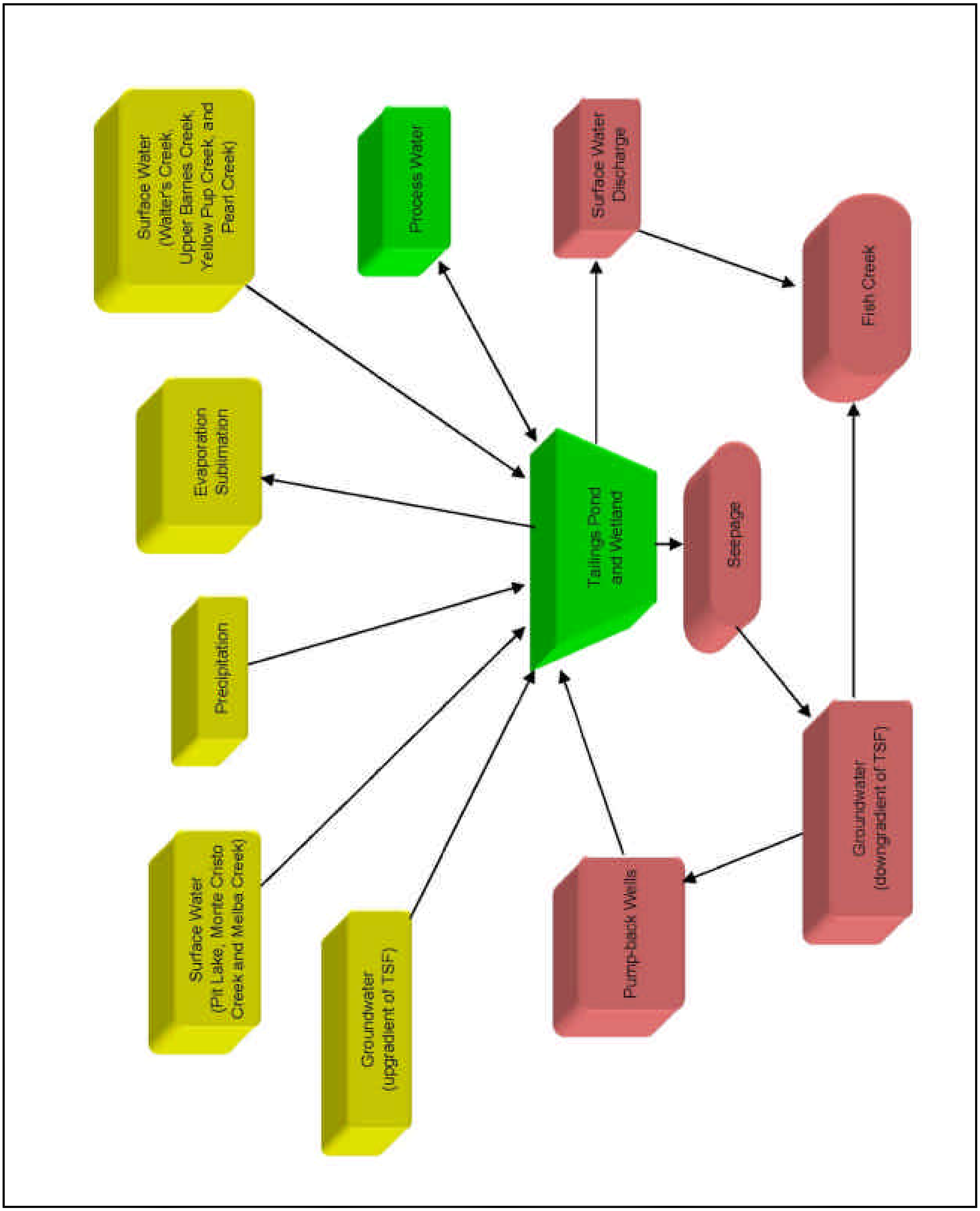
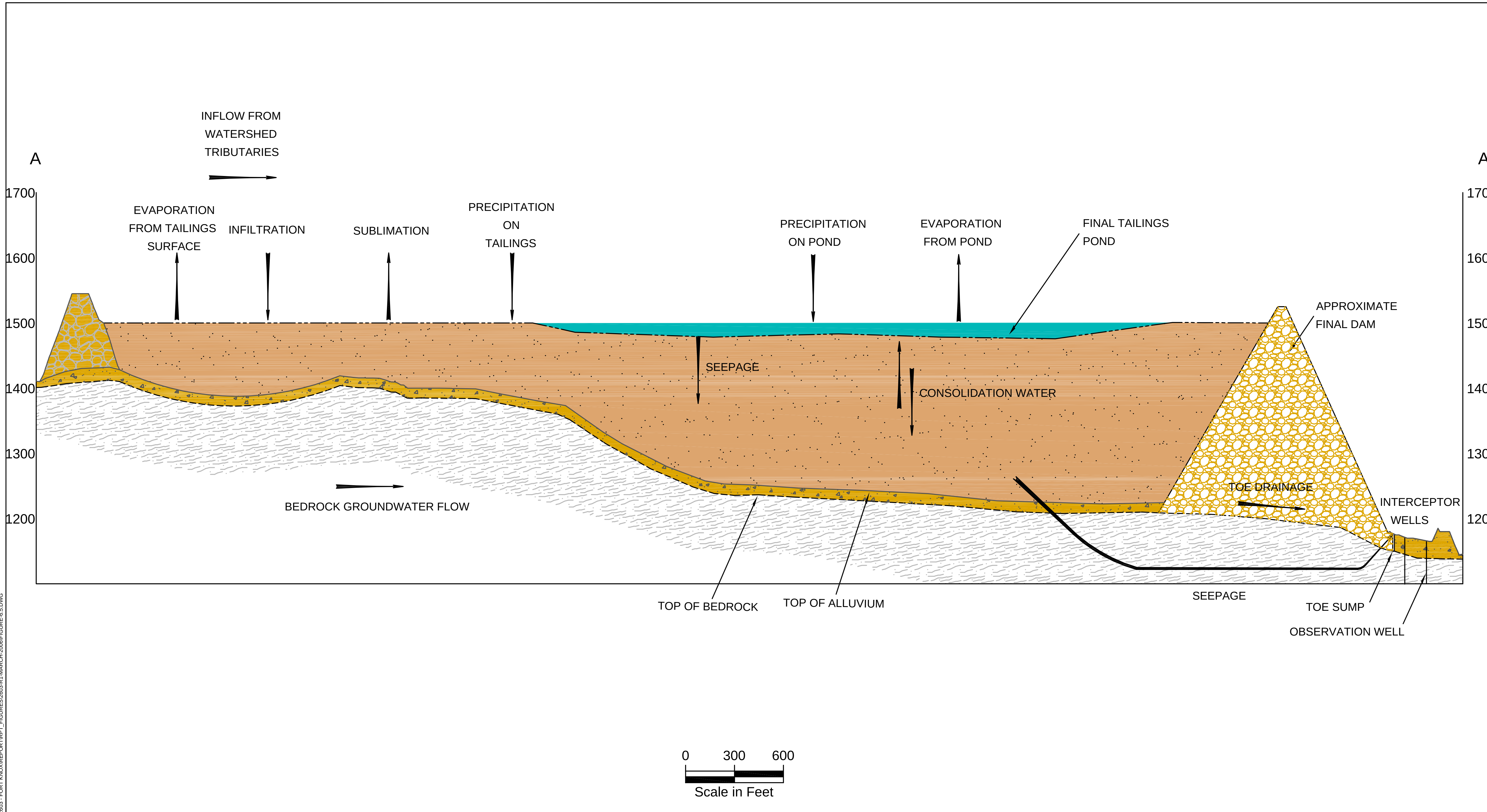
Figure 6.4 Fort Knox TSF water balance conceptual model



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-6.4.DWG

Figure 6.5 Schematic cross section with water balance components



F:\2603 - FORT KNOX\REPORT\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE 6.5.DWG

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Figure 6.6 General timeline for closure activities

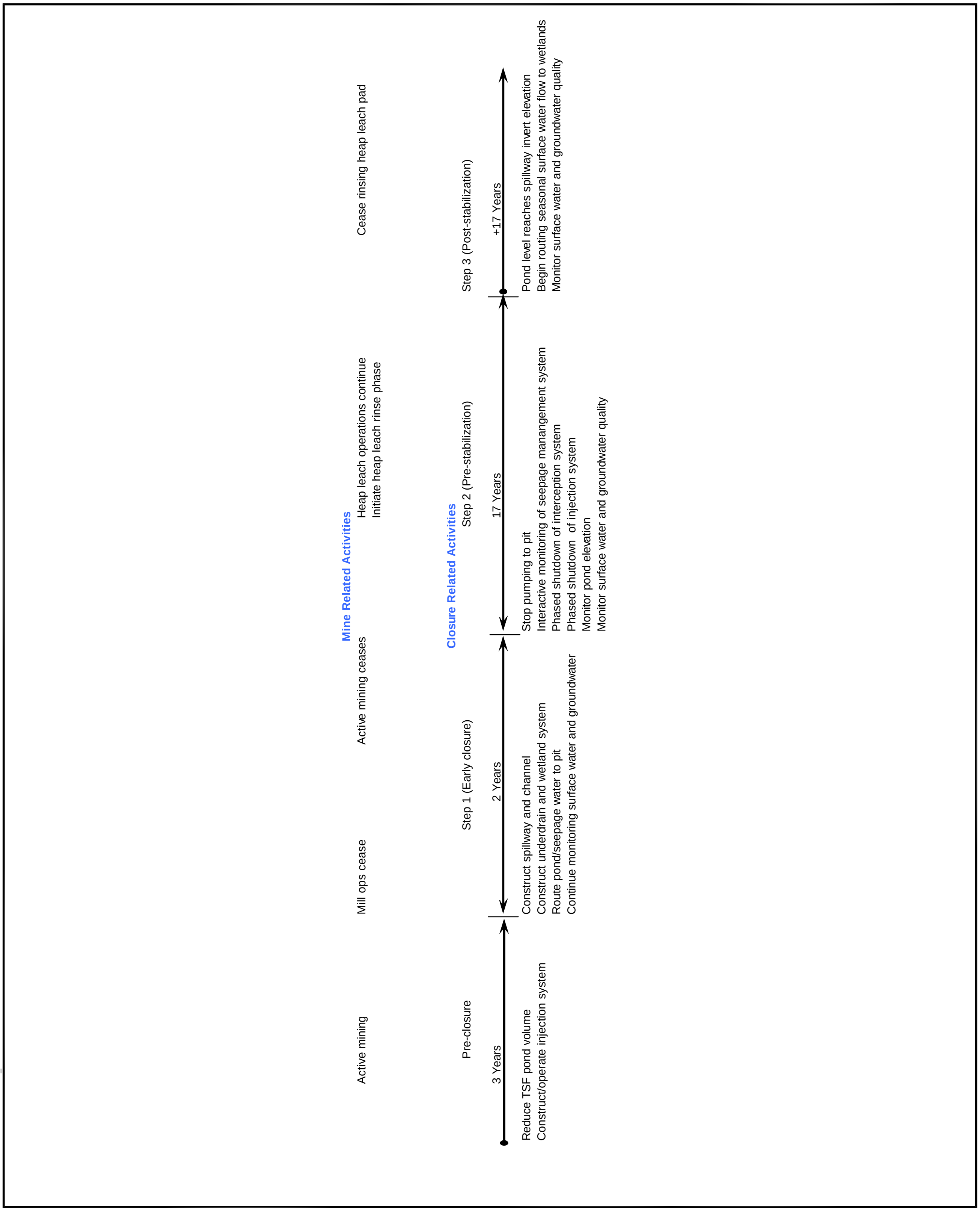

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Figure 6.7 Model domain for the embankment

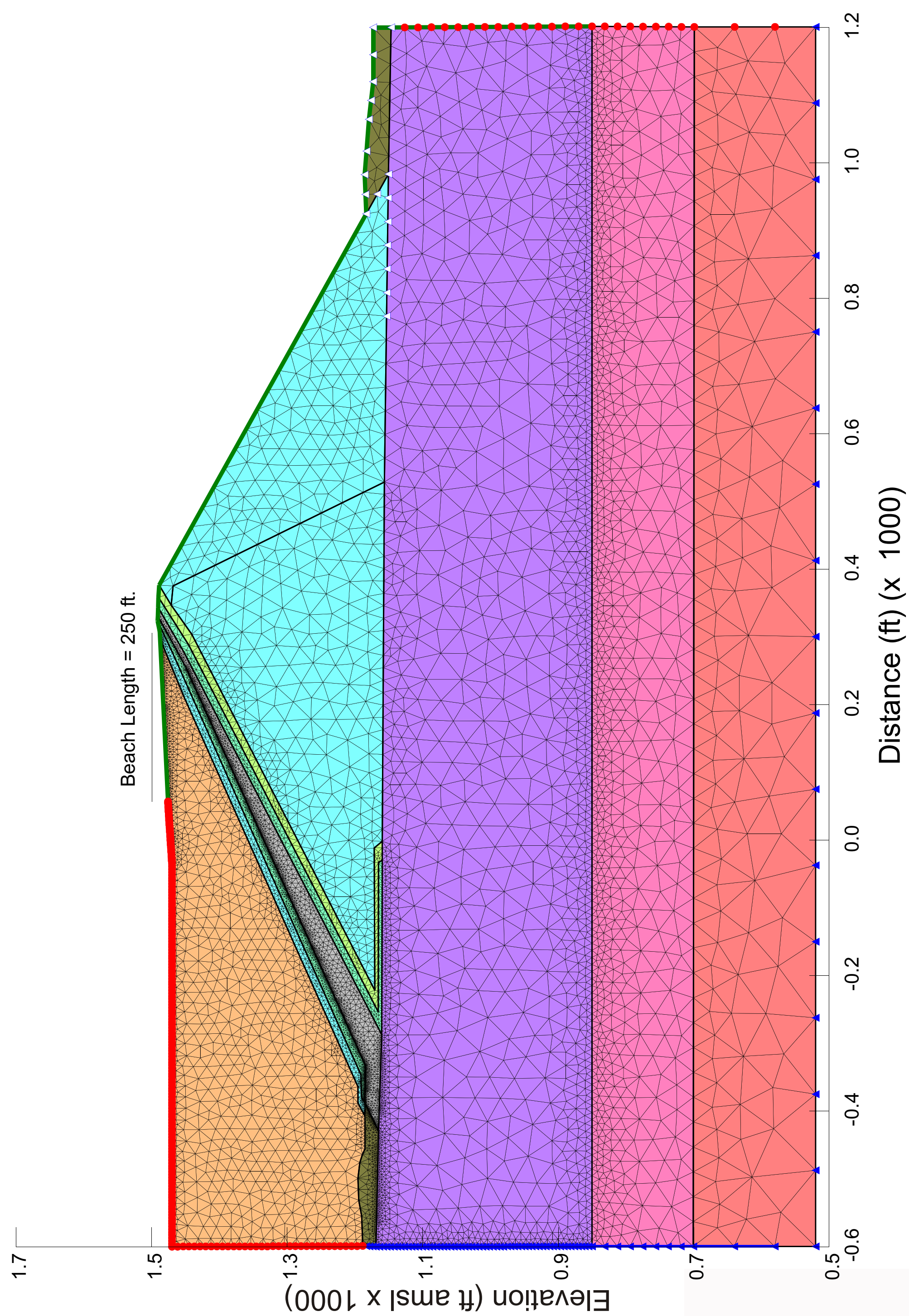

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Figure 6.8 Model domain for seepage analysis

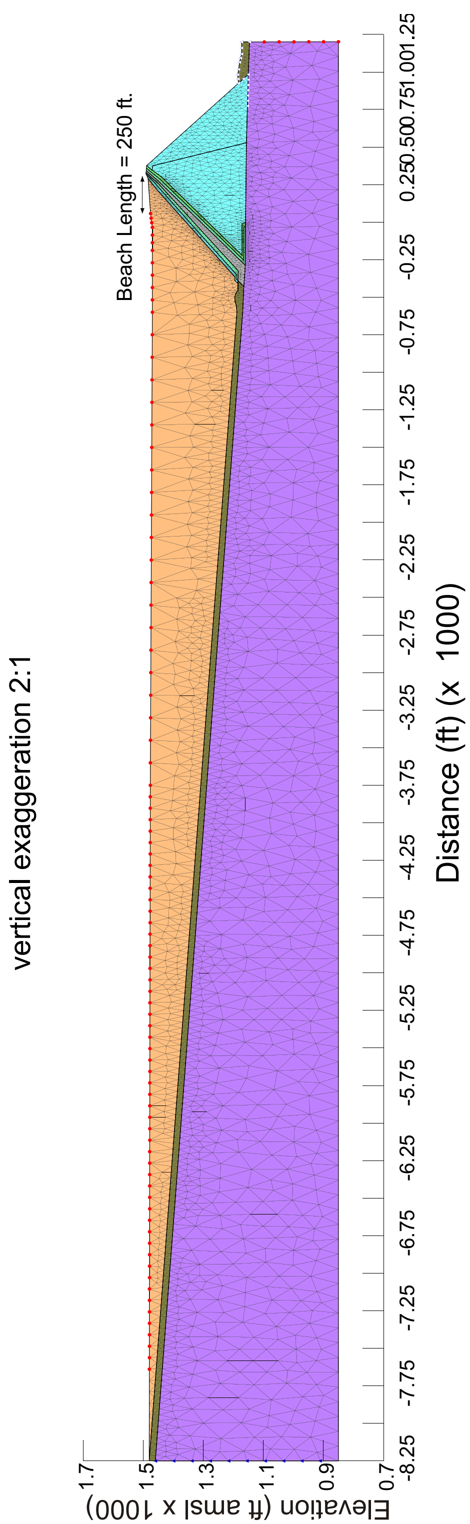

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Figure 6.9 Seepage model calibration results

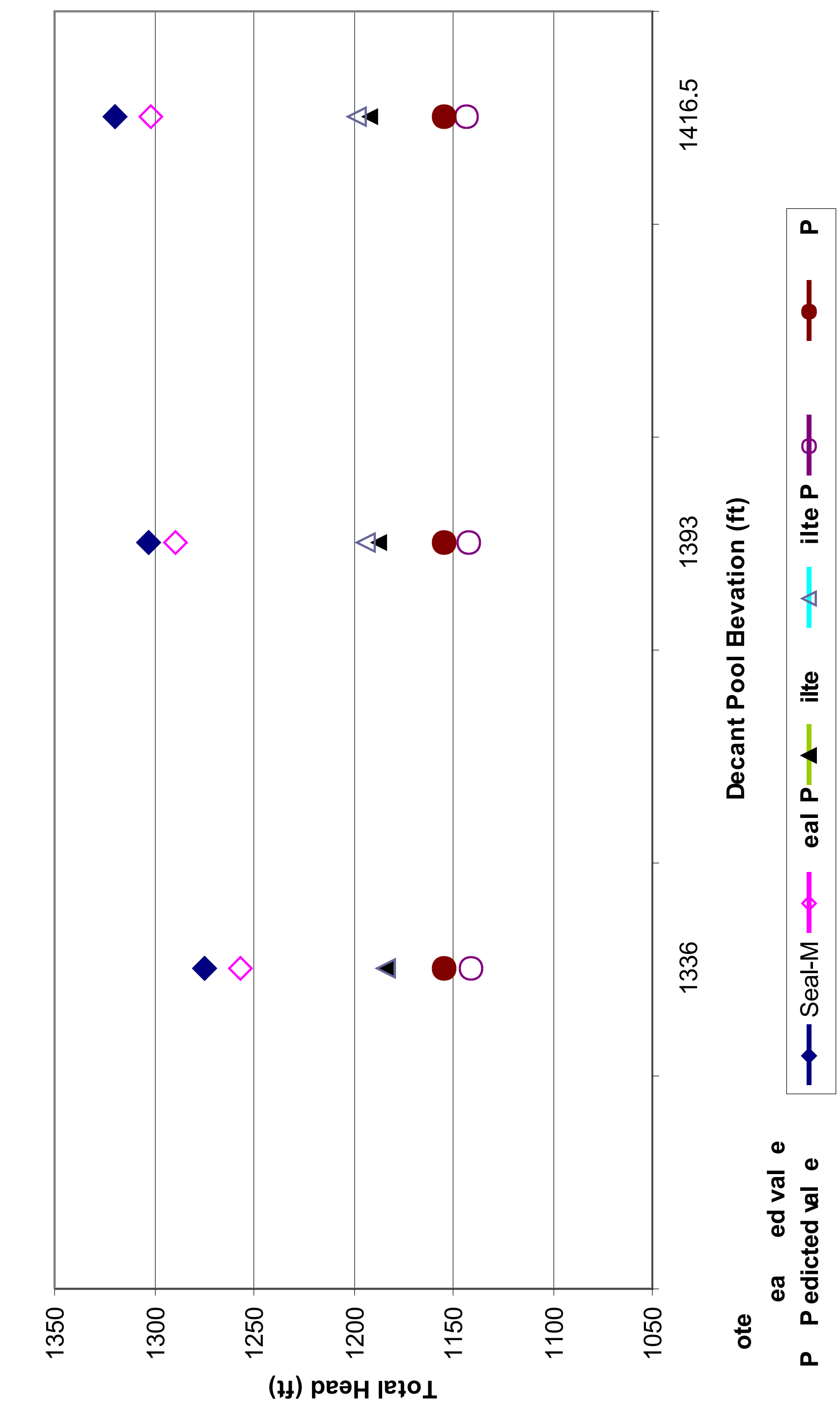

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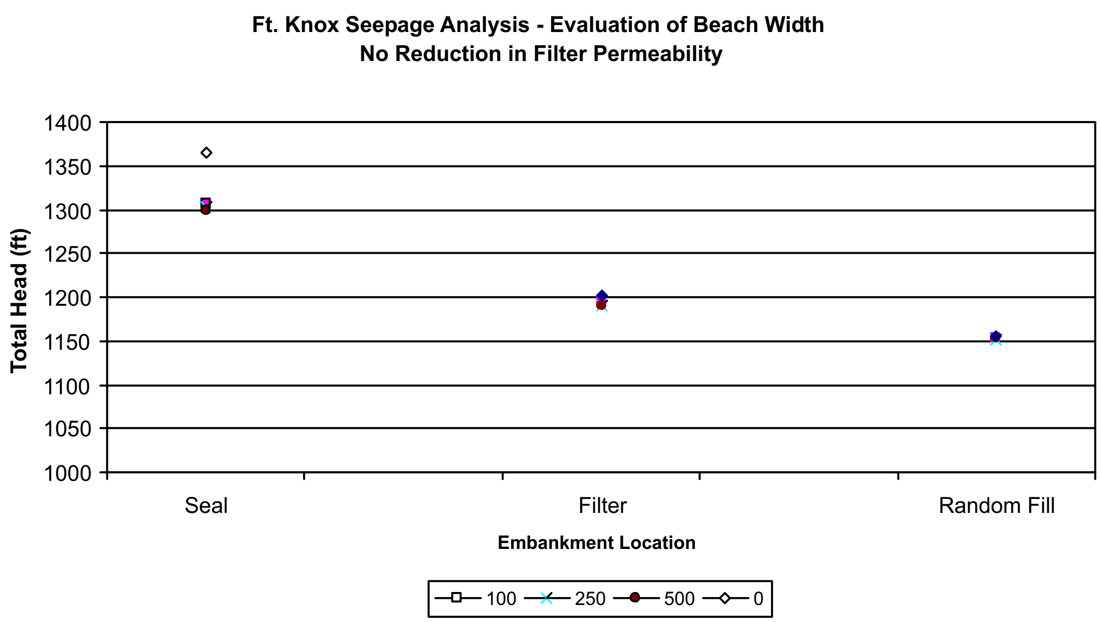
Figure 6.10 Embankment drain performance evaluation



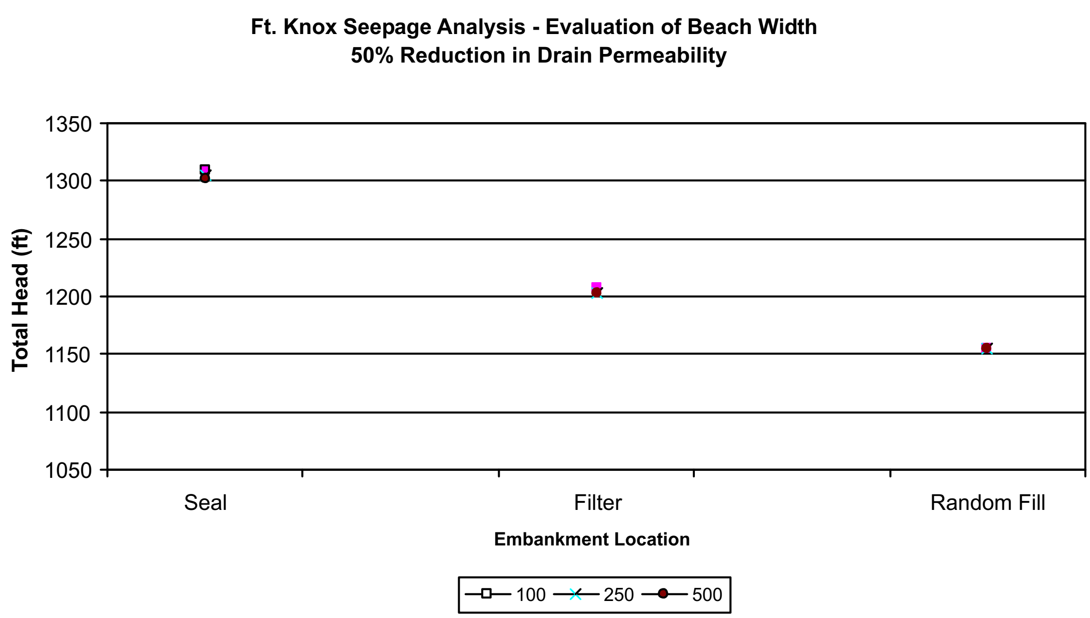


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Figure 6.11 Water balance calibration

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Figure 6.12 TSF pond elevation - 20 years following closure

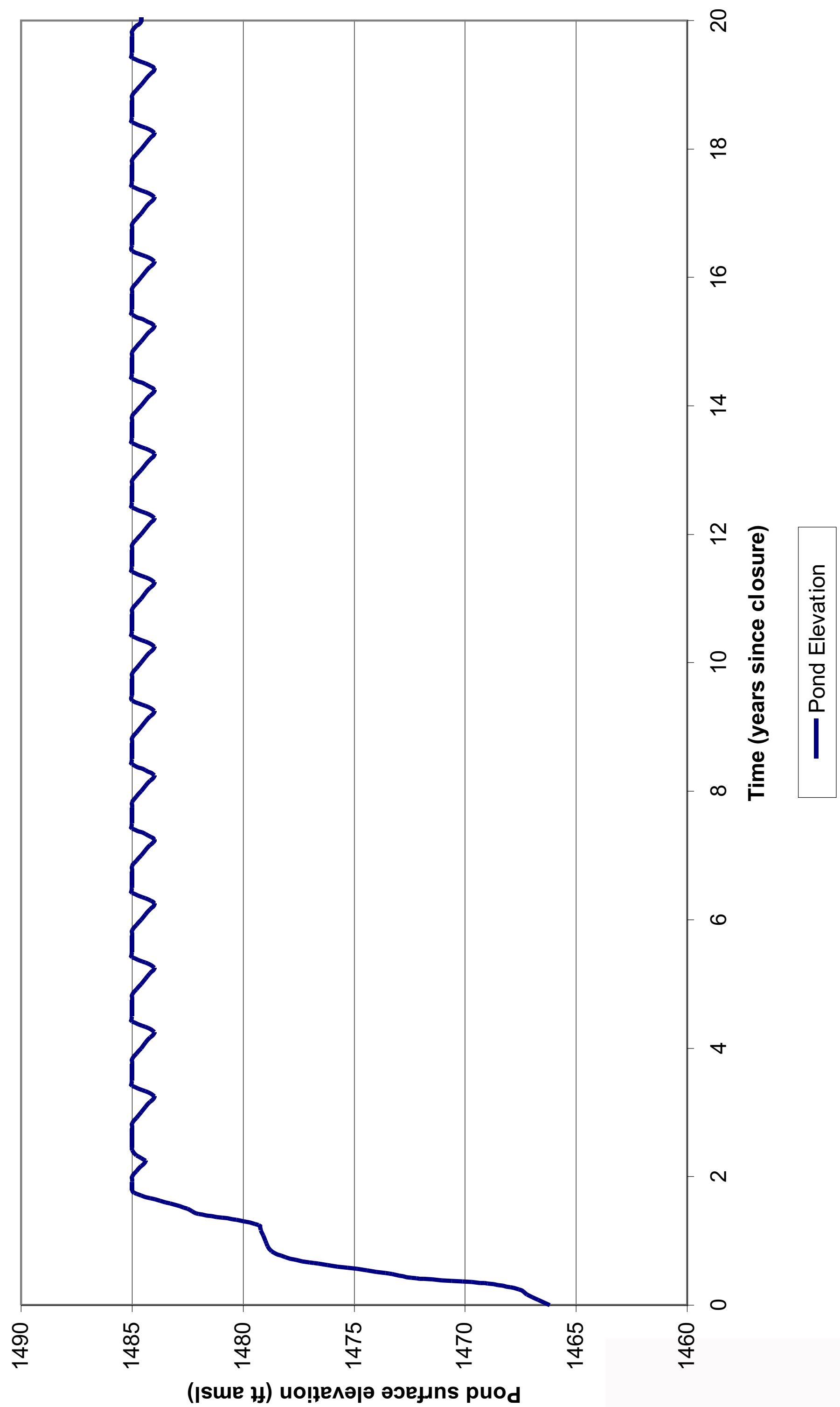

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Figure 6.13 Post-closure steady- state TSF pond elevation

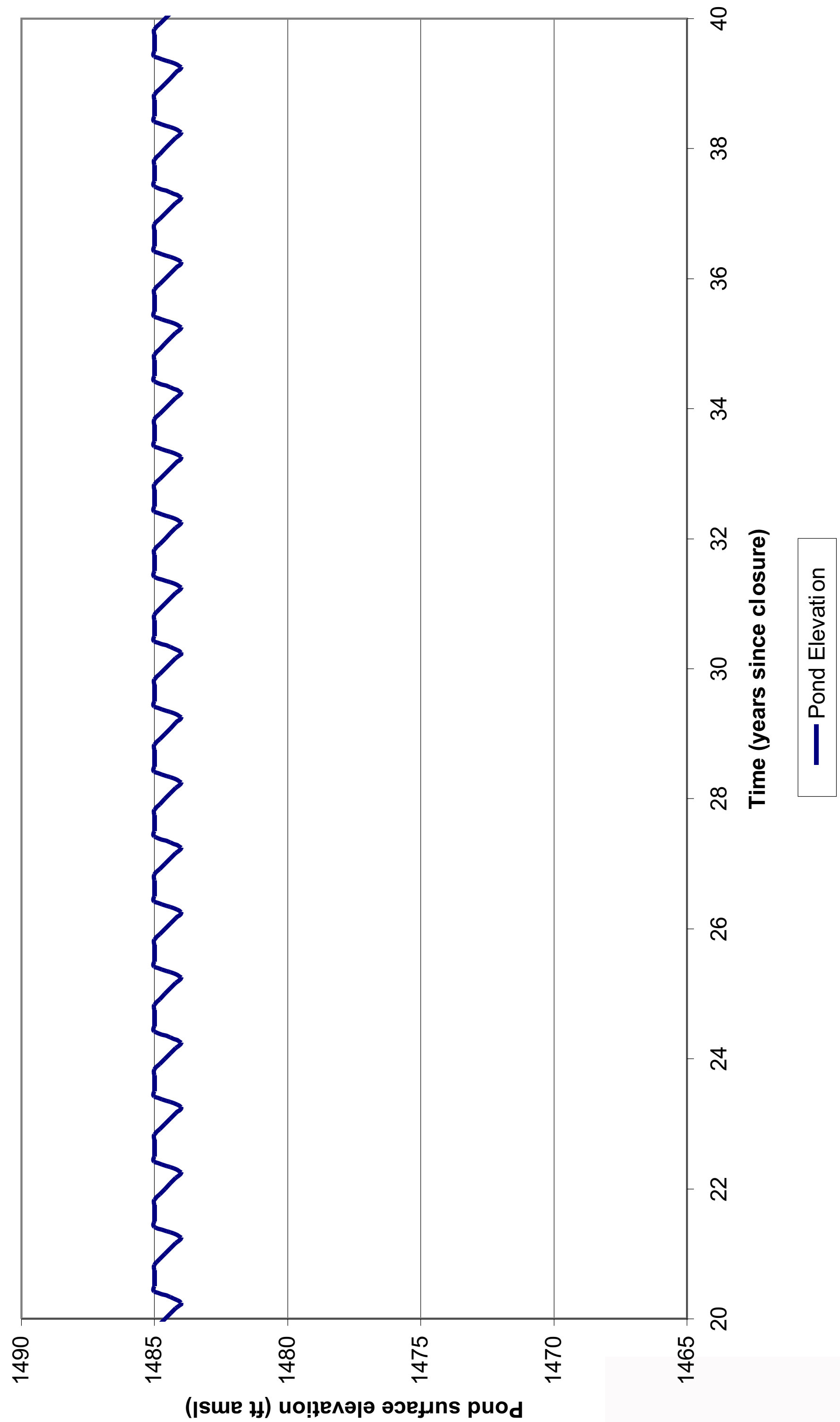

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Figure 6.14 Predicted and measured surface water flow in Lower Fish Creek

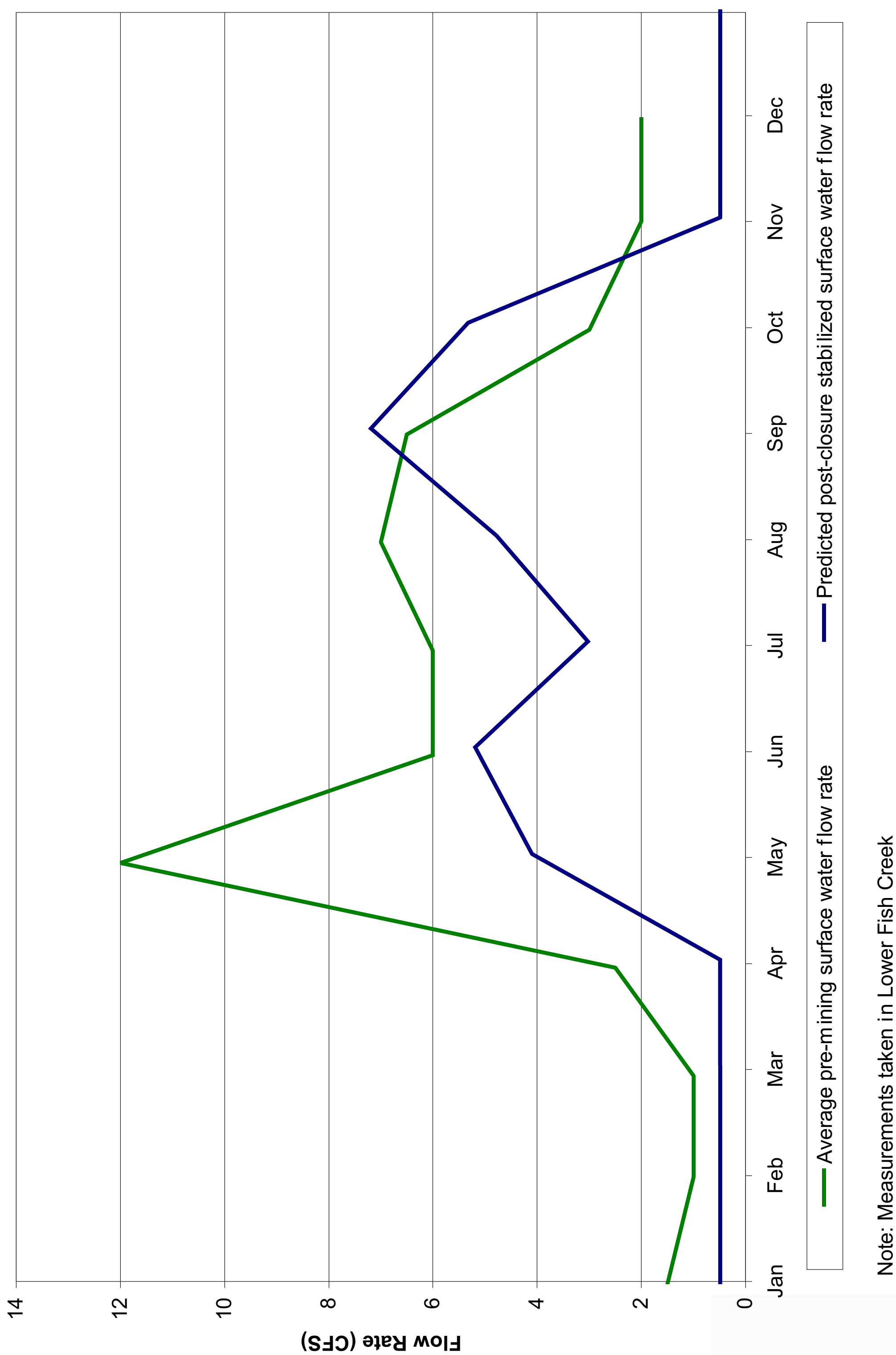

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Figure 6.15 Predicted post-closure arsenic concentrations in the TSF pond

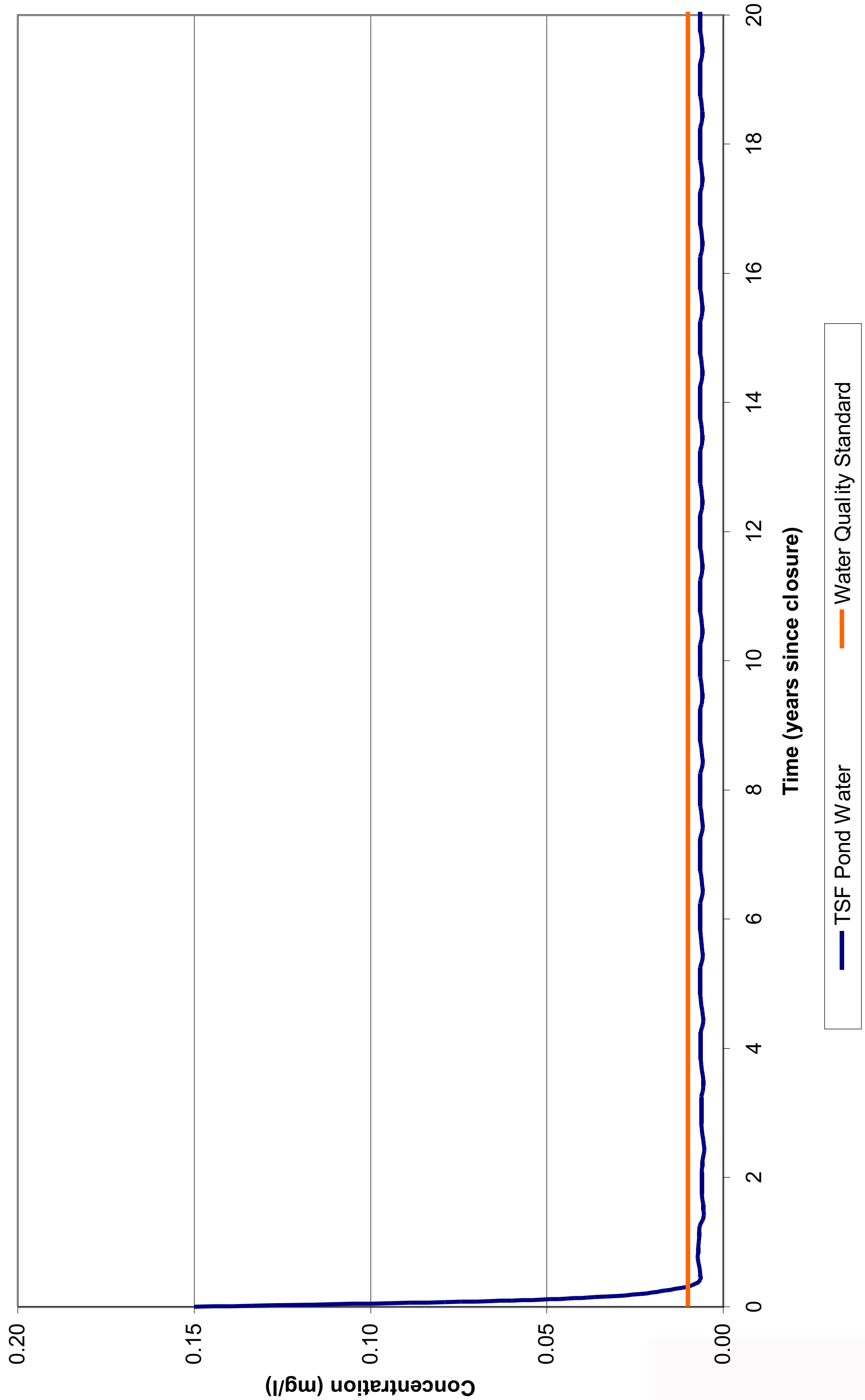

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Figure 6.16 Predicted post-closure cadmium concentrations in the TSF pond

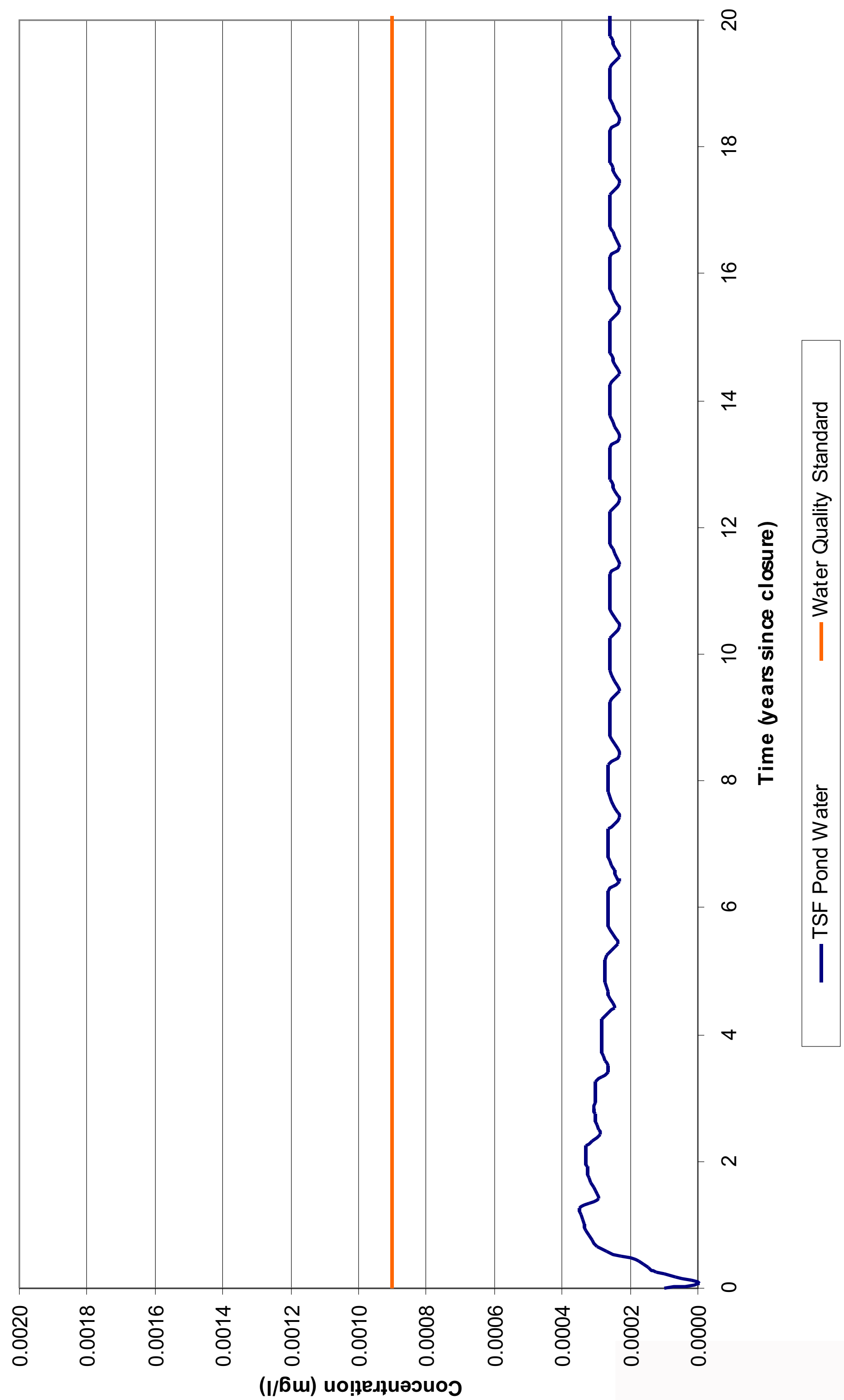

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Figure 6.17 Predicted post-closure antimony concentrations in the TSF pond

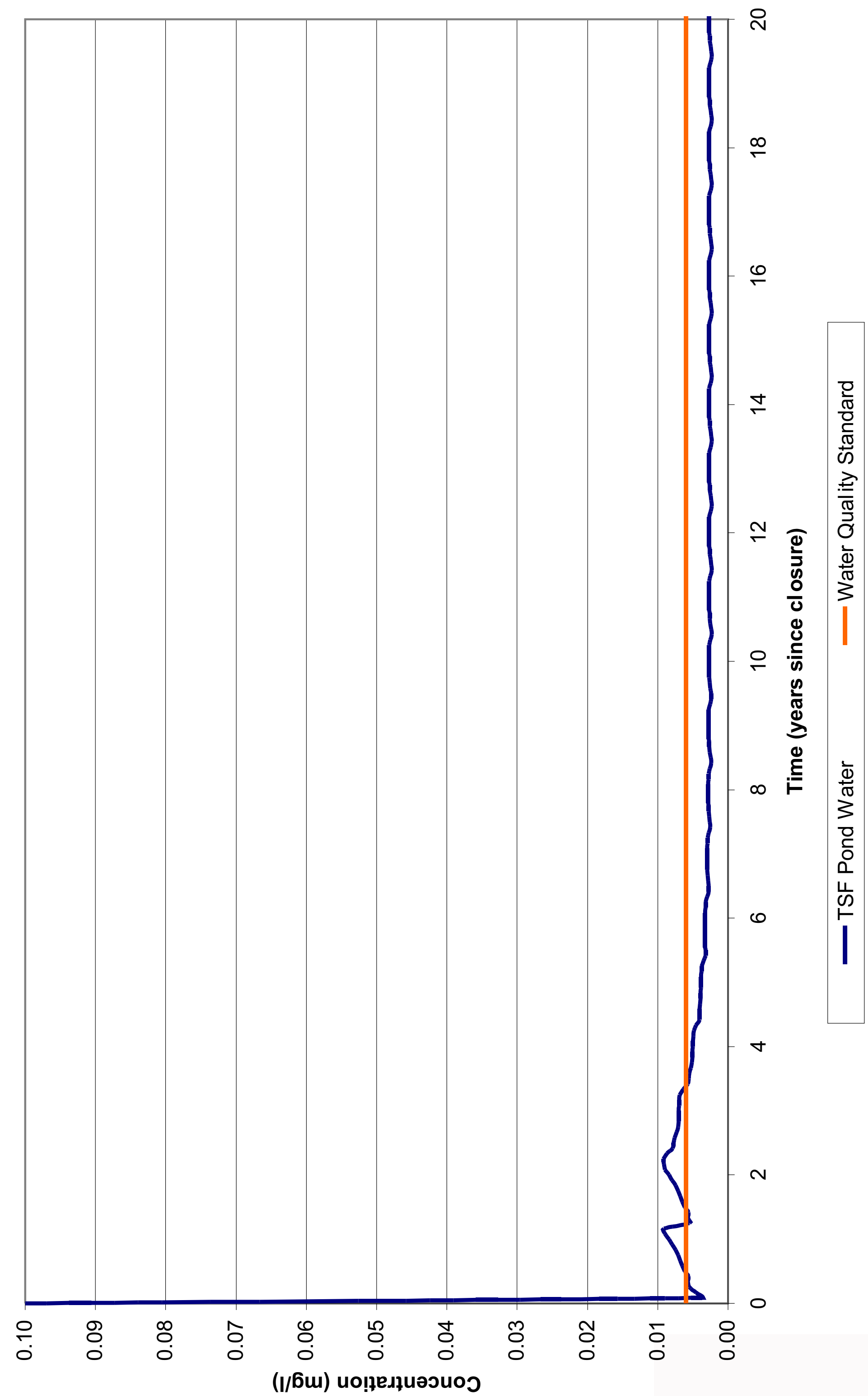

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Figure 6.18 Predicted post-closure selenium concentrations in the TSF pond

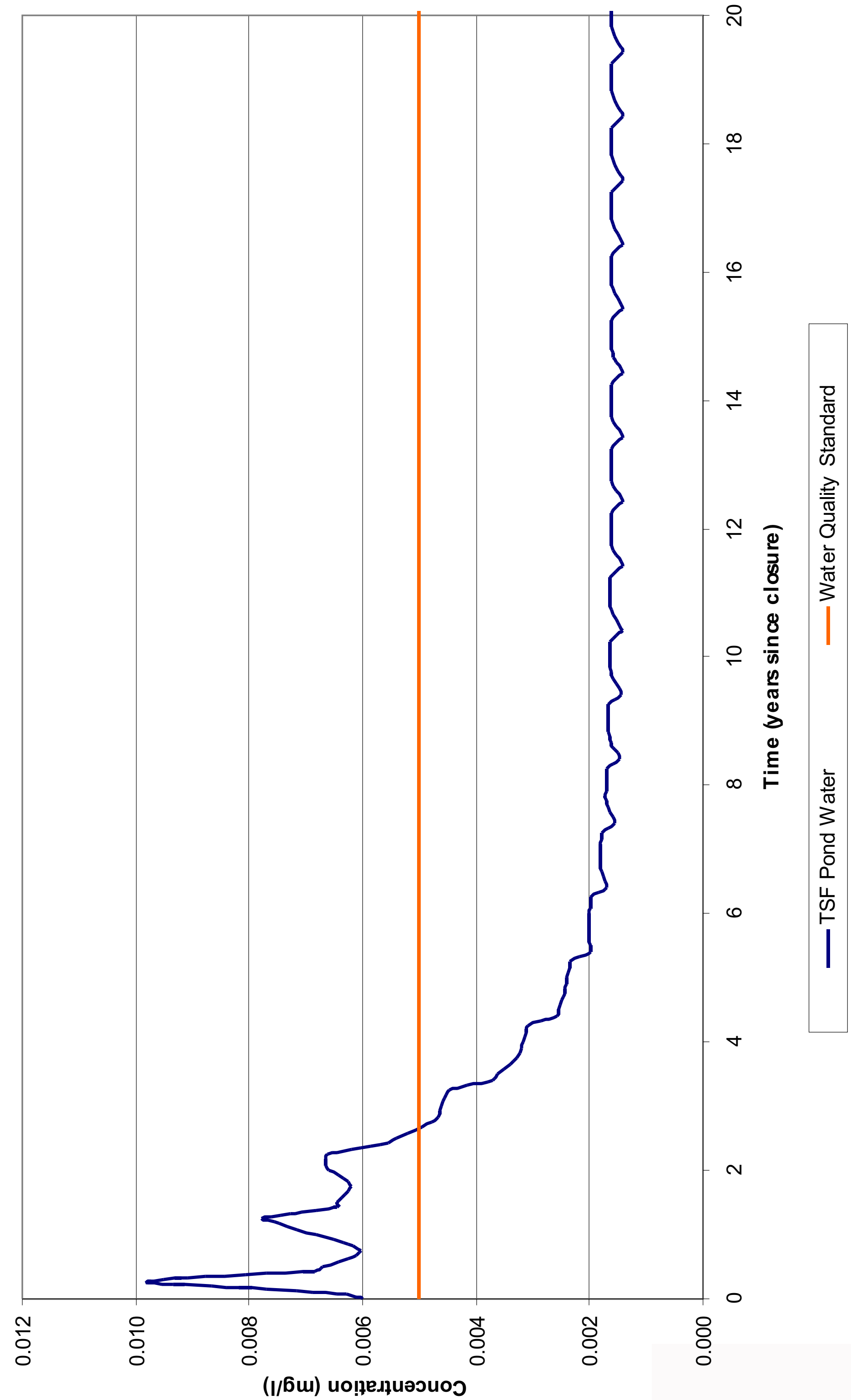

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Figure 6.19 Predicted post-closure manganese concentrations in the TSF pond

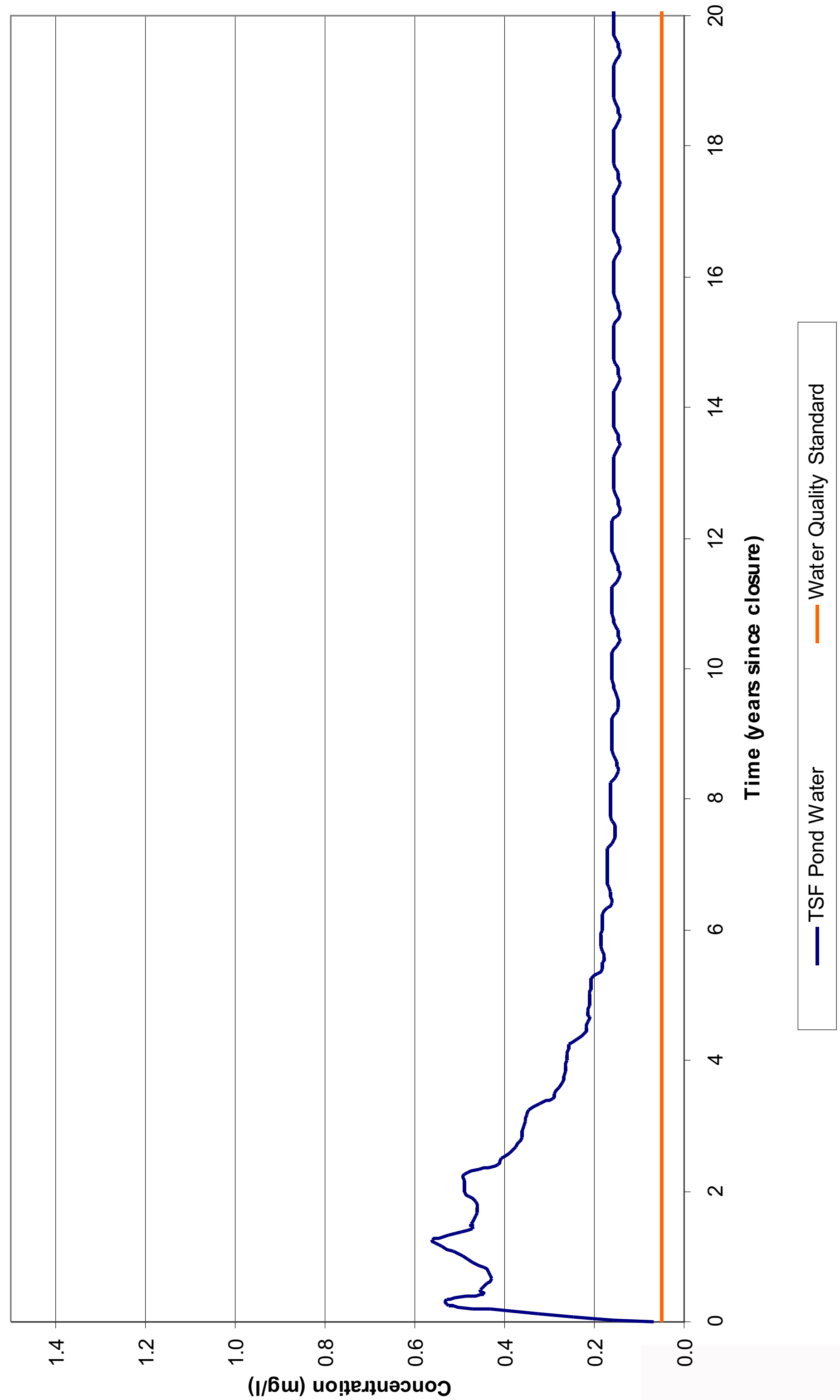

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Figure 6.20 Predicted post-closure WAD cyanide concentrations in the TSF pond

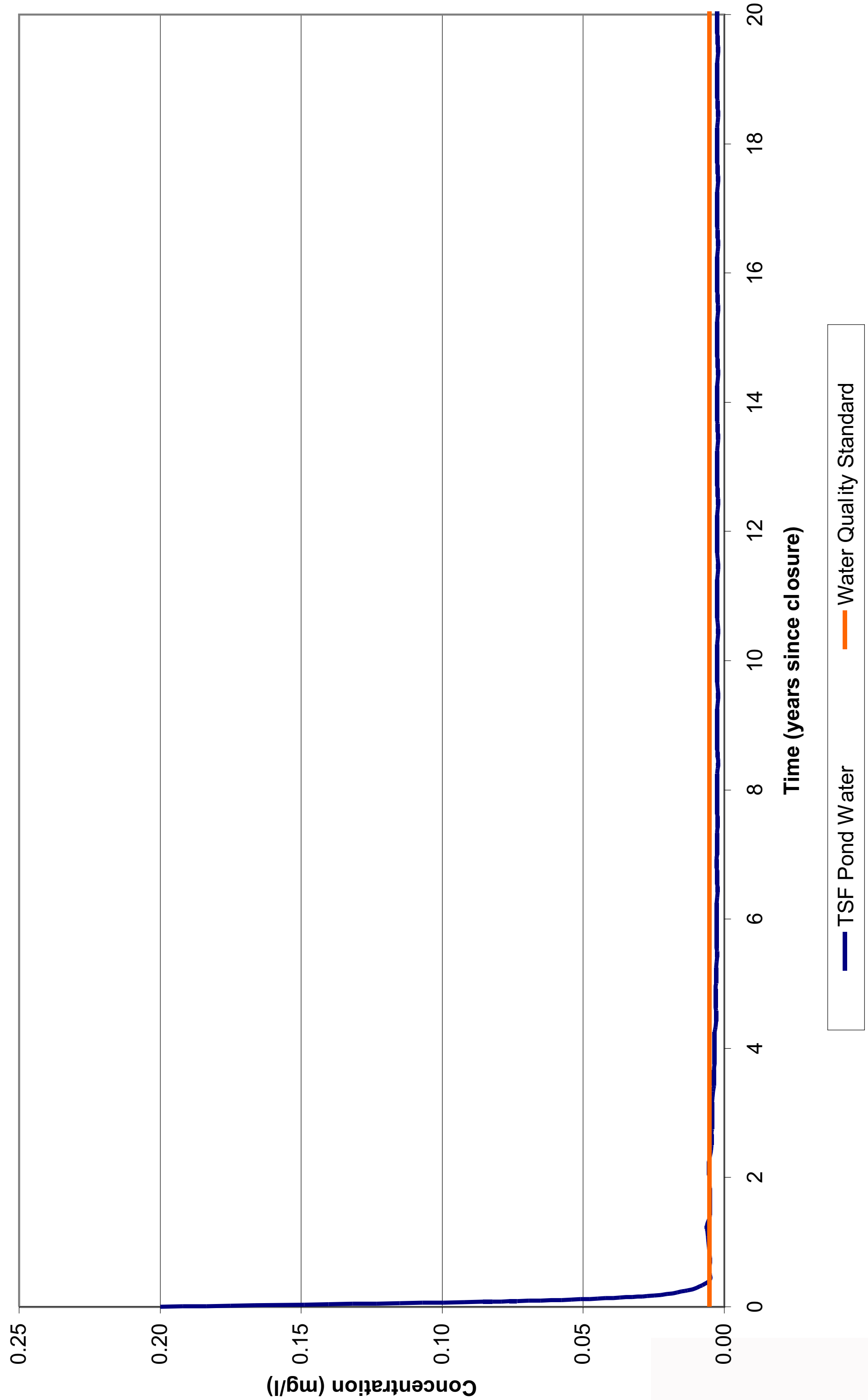

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Figure 6.21 Predicted post-closure arsenic concentrations in surface water and groundwater at the monitoring point

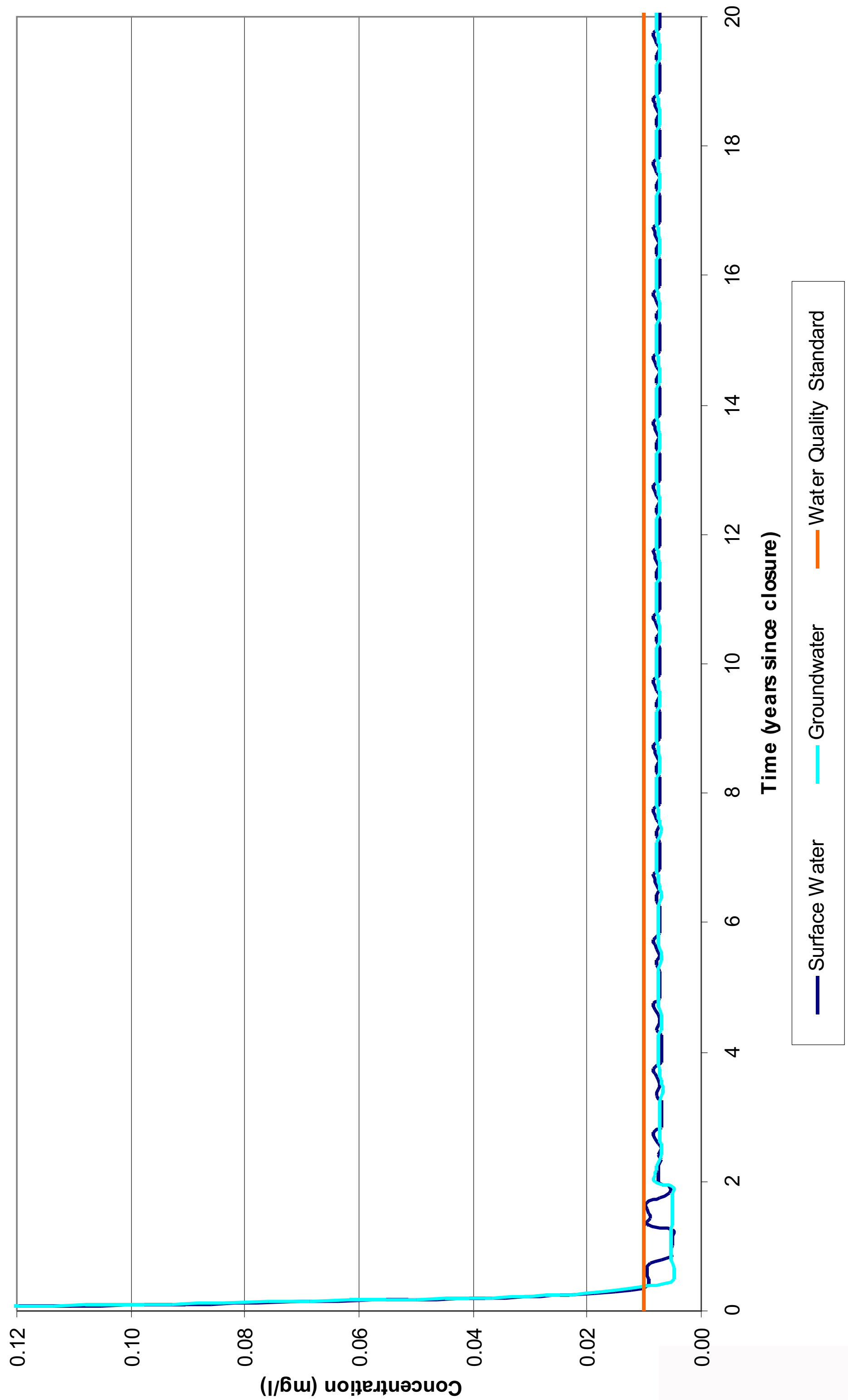

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Figure 6.22 Predicted post-closure cadmium concentrations in surface water and groundwater at the monitoring point

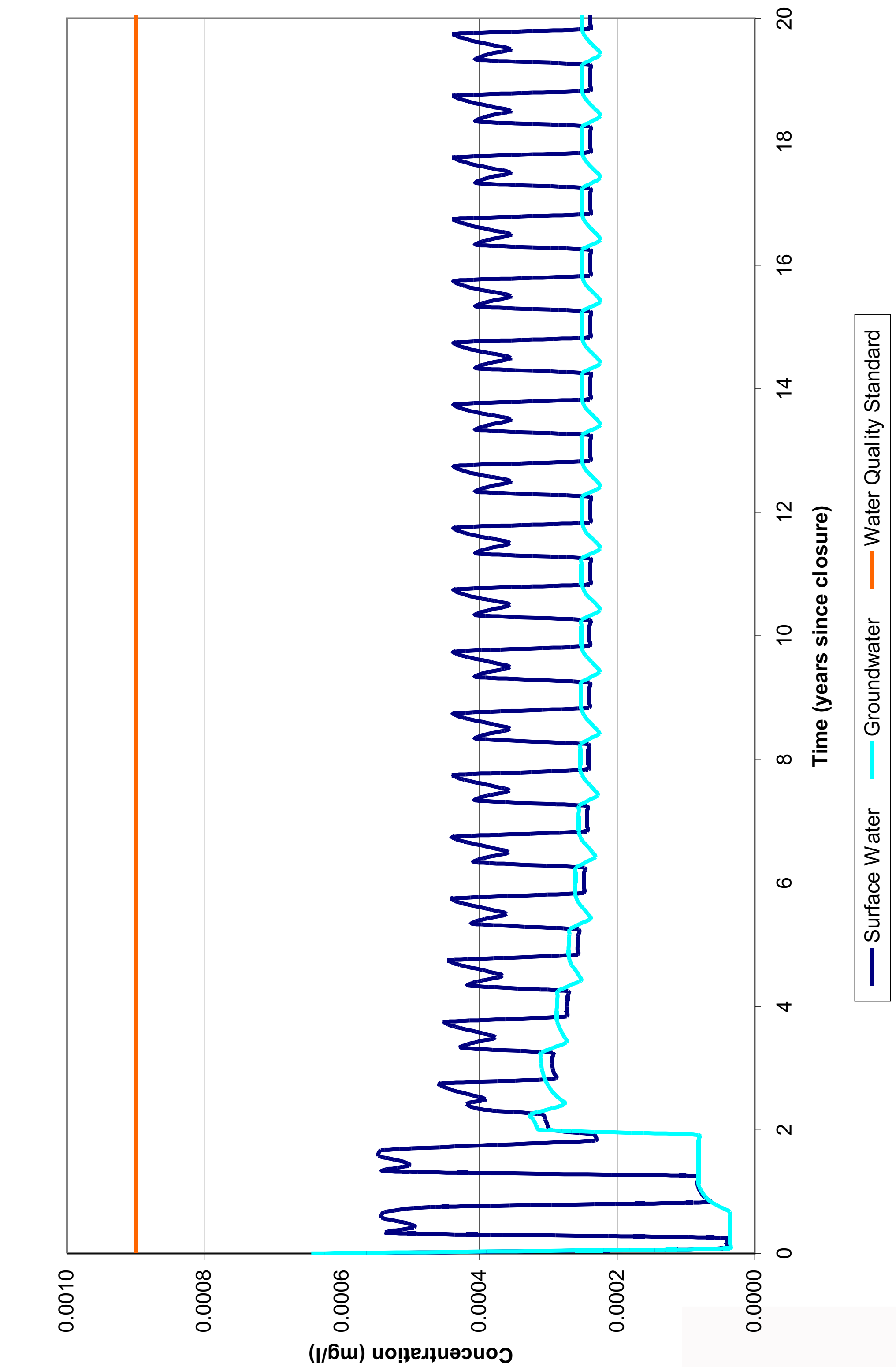

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Figure 6.23 Predicted post-closure antimony concentrations in surface water and groundwater at the monitoring point

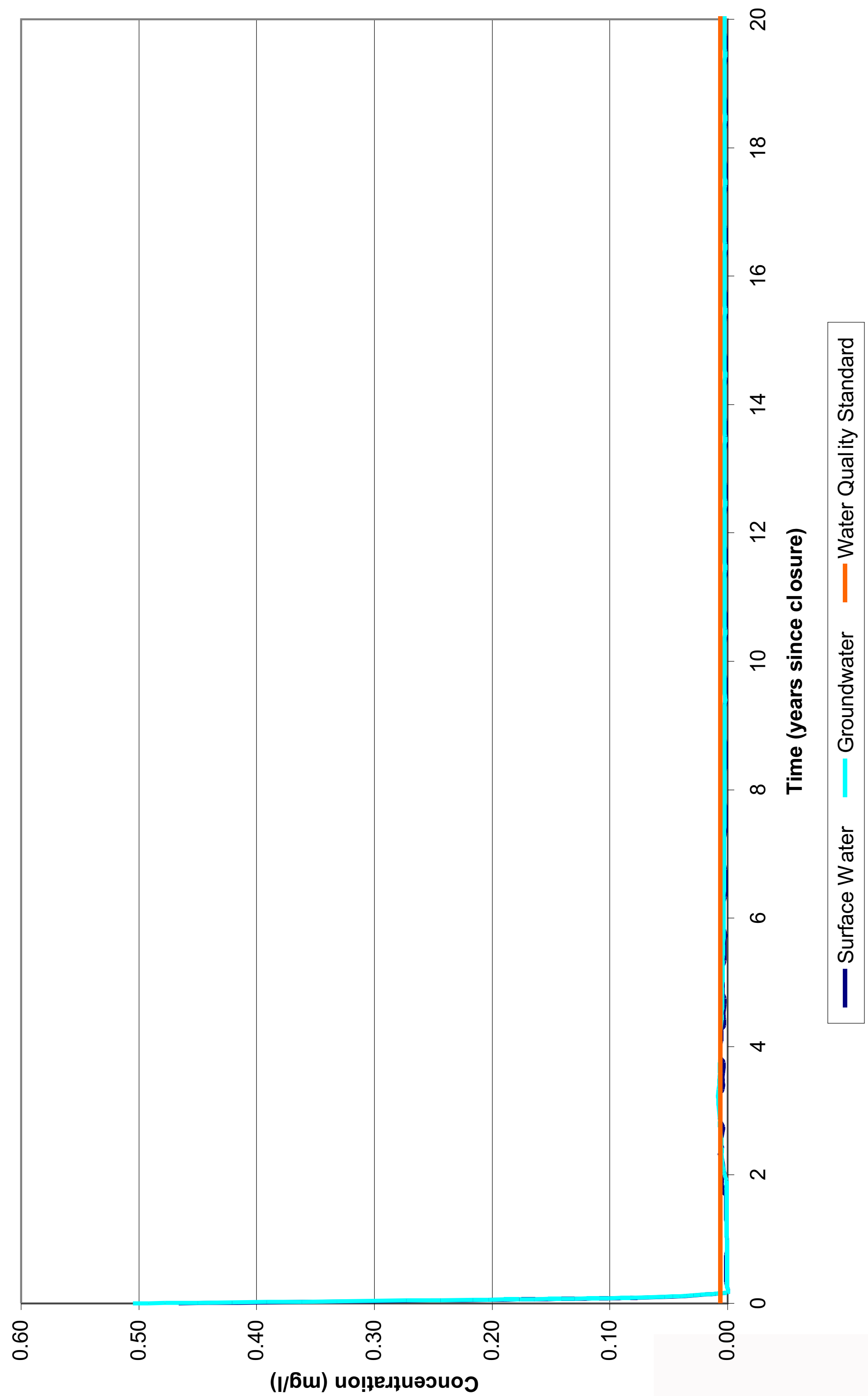

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Figure 6.24 Predicted post-closure selenium concentrations in surface water and groundwater at the monitoring point

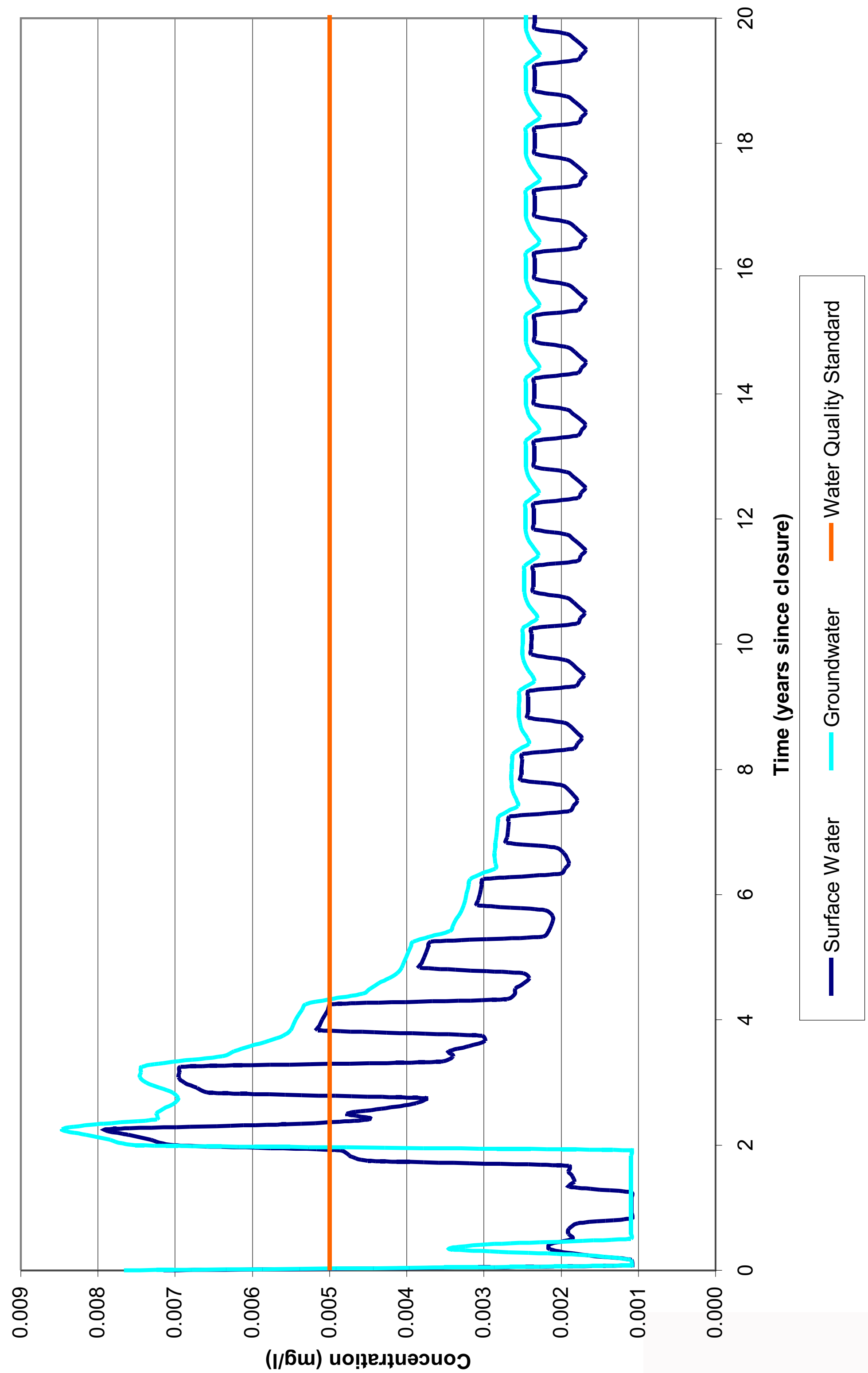

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Figure 6.25 Predicted post-closure manganese concentrations
In surface water and groundwater at the monitoring point

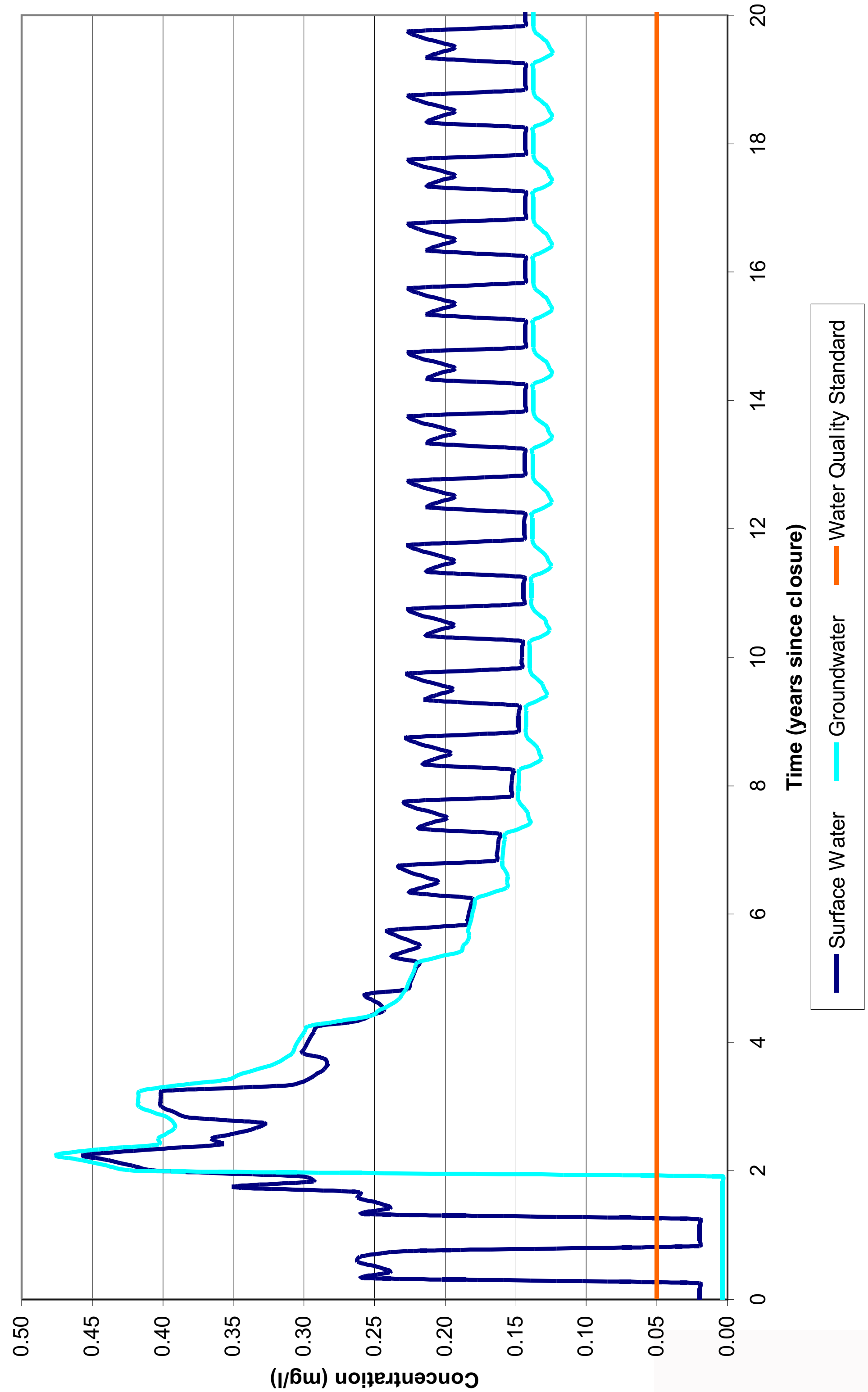

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Figure 6.26 Predicted post-closure WAD cyanide concentrations
In surface water and groundwater at the monitoring point

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7 CLOSURE MANAGEMENT PLAN

This section outlines the steps comprising the Closure Management Plan for the Fort Knox TSF. It reflects the approach outlined in the previous chapter. The schedule of implementation is based on the predicted short- and long-term water balance and quality predictions. Specifically, the Closure Management Plan includes the following steps:

- Pre-closure,
- Closure Step 1 (early closure),
- Closure Step 2 (pre-stabilization), and
- Closure Step 3 (post-stabilization).

The following paragraphs outline the objectives of the Closure Management Plan and presents the activities that will be completed during each step.

The objectives of Closure Management Plan are as follows:

- Define a strategy for closure of the TSF that promotes adequate physical stabilization and allows pre-mining water quality conditions to be achieved.
- Ensure the Closure Management Plan is supported by existing technical information.
- Provide a monitoring plan, including monitoring points and water quality criteria.

The Closure Management Plan reflects the general strategy outlined in Section 1 regarding the facility closure strategy and objectives. Briefly these include:

- minimization of short-term water inventory,
- optimization of the post-closure site water balance,
- management of surface water through storage and attenuation, and
- optimization of water quality.

The following sections describe the management plan components, schedule of implementation, and the monitoring program.

7.1 Closure plan and schedule

Based on the analyses presented in the previous sections, a closure plan has been developed which describes the activities that will be performed to allow final stabilization of the TSF. The schedule is based on the anticipated start date for closure activities (October 1, 2012) and the pre- and post-stabilization periods discussed in Section 6.2. The closure steps, and activities comprising them, reflect the anticipated water balance and improvement in water quality over time.

7.1.1 General description of closure activities

While the duration and schedule of the closure activities proposed in this section are necessary for planning, the actual duration and schedule will be determined by the time required to meet the appropriate water quality and permit conditions.

As part of pre-closure activities, the final tailing surface will be established through managed deposition. As the final tailing surface is being developed, the mill makeup water supply will be monitored closely to ensure no disruptions occur. This will be critical due to the reduction in the size and volume of the pond that will occur during the final stages of deposition. It is anticipated that the pond will be reduced to the lowest volume practical prior to cessation of mill operations.

Once mill operation is complete, the remaining pond water will be pumped to the pit. During this time, the seepage collection wells will remain operational and the discharge will be pumped to the pond and ultimately report to the pit. It is anticipated that the seepage collection wells will be operational for about two years after mill operations cease. Pumping rates from the seepage collection system will be gradually reduced during this period to minimize the gradient from the facility to the underlying aquifer in order to minimize the amount of seepage derived from the facility. The reduction of pumping rates will be controlled by the rate at which seepage quality improves and may vary from current estimates.

Model predictions suggest that the pre-stabilization period will be on the order of 2 to 3 years. During this time, water will accumulate on the surface of the tailing until it reaches the elevation of the spillway invert (1,484.5 ft amsl). Once the pond reaches an elevation of 1,484.5 ft amsl, seasonal outflow from the spillway will occur and the pond elevation will become relatively stable except for seasonal variations.

During the post-stabilization phase, seasonal surface water flows will be routed from the spillway to an engineered wetland treatment system located on the northern margin of Fish Creek. The wetland system will be comprised of a series of interconnected detention basins, which will provide final polishing for water quality. During the post-stabilization period, active management, such as pumping, will take place until seepage quality is suitable for discharge.

Physical stabilization of the tailing surface will be achieved through a combination of revegetation and ponded water. A combination of upland and wetland vegetation will be established through time as surface conditions allow.

7.1.2 Pre-closure activities

Establish final tailing surface

Establishment of the final tailing surface was initiated in June 2005, when one of the tailing discharge spigots was moved to the eastern end of the causeway in order to begin establishing the beach adjacent to the upstream face. The central portion of the beach area will be established by moving the discharge point progressively further north. The final tailing surface will have elevations ranging from about 1,488 ft amsl to a low point of 1,454 ft amsl. The overall slope on the surface will depend on tailing discharge characteristics (i.e., particle size distribution and solid:liquid ratio). The beach on the upstream face of the embankment will vary between 300 and 500 ft wide depending on location. The total storage volume of the final surface is approximately 5,500 acre-ft at an elevation of 1,484.5 ft amsl (elevation of spillway invert).

Pond water management

Management of the TSF pond volume will begin at the close of mill operations (October 2012). The volume of the pond will be reduced by pumping water to the mine pit at a rate of about 5,000 gpm. At the same time, the seepage collection system will be pumped to the pond at a maximum rate of about 1,700 gpm resulting in a peak net discharge of about 2,300 gpm. Pumping will continue for at least two years to remove inflows derived from spring breakup and to transfer production from the seepage collection system to the pit. Pumping will continue until as much of the water from the TSF pond has been removed as practical.

The water from the TSF pond will be routed via pipeline to the pit where it will be discharged. The discharge will be directed down the haul road in a location that will not compromise slope stability. The total volume of water to be pumped to the pit includes the water, seepage, and natural runoff. Over a two-year period, the total volume of water that will be pumped to the pit is approximately 8,900 acre-ft. The total storage volume of the pit is approximately 58,650 acre-ft or about 6.5 times the volume planned to be pumped. Based on the estimated water quality in the pond after two years and the anticipated pit inflow quality, the final pit lake is expected to meet quality standards by the time discharge occurs. Exceptions will likely include copper, manganese, and iron, which have background concentrations above standards. Pre-mining iron concentrations in surface water ranged from 9.5 to 17 mg/l. Current concentrations measured in the wetlands ranged from 2 to 30 mg/l. Manganese concentrations ranged from 0.3 to 0.4 mg/l in Fish Creek prior to mining. Current concentrations are similar in magnitude; therefore, these constituents will not degrade existing water quality. Table 7.1 provides a summary of the expected pit lake quality at the time of closure. The estimates are based solely on conservative mixing calculations and do not account for stratification or chemical reactions that would likely reduce concentrations even further.

Table 7.1 Predicted pit lake quality at full recovery

Parameter	Standard (mg/l)	Pit lake concentration (mg/l)
As	0.01	0.009
Sb	0.006	0.005
CN (free)	0.0052	0.002
SO_4	250	50
TDS	500	145
Cd	0.0003	0.0002
Cu	0.009	0.007
Se	0.005	0.005
Zn	0.12	0.009

7.1.3 Closure Step 1

Cessation of mill operations will mark the beginning of Step 1 closure activities. The following will be completed during this period:

- The spillway, channel, and wetland system will be constructed.
- Remaining pond water will be pumped to the pit.
- Seepage collected from the interception system will be pumped to the pit.
- Interim sampling of groundwater will occur at the current monitoring points (or others established further downgradient).

The seepage interception system will be operated for a period of approximately two years during which time all production will be routed to the pit for disposal. Initially the production from the interception system will be on the order of 1,700 gpm. Gradually the pumping rate will be decreased in response to improved water quality and in order to minimize the gradient from the facility to the groundwater system. Assuming an average pumping rate of 1,200 gpm over the entire period of operation, a total of about 3,870 ac-ft of seepage will report to the pit.

Once the interceptor wells have been shut down, the cone of depression will begin to recover and natural groundwater gradients will be re-established.

7.1.4 Closure Step 2

The duration of Step 2 is predicted to be approximately 2 to 3 years, which is the time required for the pond to reach the spillway invert. During this period, the following will occur:

- After two years, pumping to the pit will cease and water will begin to accumulate on the surface of the TSF.
- The seepage management system will shut down at the start of this step. The system will remain intact in the event further operation is required.
- The current groundwater monitoring location will be gradually phased out beginning with the end of active seepage management and moved further downstream to coincide with the surface water monitoring point.

Because of the size of the facility and upgradient catchment area, diversion of surface water around the facility is not a viable, long-term option for managing surface water. Therefore, management of upgradient surface water will involve allowing all flows (including discharge from the heap leach facility and mine pit) to run-on to the tailing surface.

Construction of the wetland treatment system will begin during Closure Step 2. The system will utilize existing basins currently located downstream of the TSF but above the grayling habitat. Flow from the uppermost basins will be routed to the north side of Fish Creek along an existing ancestral diversion.

7.1.5 Closure Step 3

Closure Step 3 will entail:

- Subsequent to the pond elevation stabilizing at the spillway invert elevation, seasonal discharges will occur during the spring breakup period.
- Seasonal surface water flows will be routed to the engineered wetland treatment system.
- Monitoring of surface water and groundwater at the final locations (described in Section 7.3).

Water will be discharged to the Fish Creek drainage via a conveyance channel. The conveyance channel alignment is illustrated in Plan 6.1. Surface water will flow to a stilling basin and ultimately to the existing wetland system located directly below the TSF. Water will be routed to the north side of the Fish Creek drainage and discharged to the engineered wetland treatment system. The conceptual layout of the wetland treatment system is illustrated on Plan 6.6. The system consists of a series of interconnected detention basins, which terminate above the fresh water reservoir.

7.2 Surface stabilization

Stabilization of the tailing surface will include a combination of upland vegetation, wetlands, and water cover. Surface management activities will begin during the pre-stabilization phase. Upland vegetation will be established along the margins of the facility where tailing have dewatered sufficiently to allow access. Wetland species will be established where water will be present for the majority of the year after the pond elevation stabilizes. Revegetation will continue through the pre-stabilization phase as surface conditions allow access for placement of growth media and nutrients.

Based on the current water balance, the stable pond area will have an area on the order of 481 acres. The majority of the area will have less than 3 ft of ponded water. The revegetated area is expected to be around 400 to 450 acres. Figure 7.1 illustrates the distribution and relative proportions of the various surface types.

7.3 Monitoring plan

The monitoring plan will include water quality sampling, water level measurements, and observations of the success of revegetation. A complete description of the closure monitoring is presented in *Fort Knox Reclamation and Closure Plan (FGMI, 2006)* and *Fort Knox Mine Monitoring Plan (FGMI, 2006).* The frequency of sampling events will be adjusted as appropriate between the pre- and post-stabilization phases based on observed improvements in water quality. Table 7.2 summarizes the monitoring program.

7.3.1 Monitoring points

The program will include monitoring points for both surface water and groundwater. A discussion of the rationale for the proposed monitoring point locations was presented in Section 6.2.2.

During Step 1 of the closure process, monitoring of groundwater quality will occur at the existing monitoring wells.

Prior to the end of Closure Step 2 (pre-stabilization), surface water and groundwater monitoring points will be established near the terminus of the engineered wetland system. Figure 7.2 illustrates the location of the monitoring points.

Water quality monitoring

During the pre-stabilization phase, the pond will be sampled on a quarterly basis. Once surface water discharges begin, quality will be monitored on a monthly basis during active flow for the first two years. Monthly samples will be analyzed for the indicator parameters summarized in Table 7.3.

The interceptor and monitoring wells will be sampled on a monthly basis for the first two years. Quarterly sampling will occur between Years 3 and 5. Quarterly samples will be analyzed for analytes in Table 7.3. Annual samples will be collected from the monitoring wells between Years 6 and 10.

The water quality in the pit will be monitored on an annual basis throughout the closure period.

Table 7.2 Summary of closure monitoring

Monitoring location	0 to 2 years		3 to 5 years		+ 6 years	
	Frequency	Parameter list	Frequency	Parameter list	Frequency	Parameter list
TSF pond	Quarterly	Complete	Quarterly	Complete	Quarterly	Complete
Pit lake	Annual	Complete	Annual	Complete	Annual	Complete
Seepage collection system	Monthly	Indicator	Quarterly[1]	Complete	NA	NA
Groundwater monitoring wells	Monthly	Indicator	Quarterly	Complete	Annual	Complete
Surface water monitoring point	NA	NA	NA	NA	Monthly[2]	Indicator[3]
Dam safety monitoring	Annual	Annual	Annual	Annual	Annual	Annual

Notes:
1 Only if operational
2 Discharges predicted to begin after about 2 to 3 years
3 Indicator parameters are the same as Monthly parameters in Table 7.3

Table 7.3 Summary of monthly and quarterly analyte lists

Monthly samples	Quarterly samples
pH	pH
TDS	TDS
Sulfate	TSS[1]
Alkalinity	Calcium
Arsenic	Magnesium
Antimony	Sodium
Cadmium	Potassium
Copper	Chloride
Iron	Sulfate
Manganese	Alkalinity
Selenium	Arsenic
Cyanide	Antimony
WAD cyanide	Cadmium
	Copper
	Iron
	Manganese
	Selenium
	Zinc
	Nitrate
	Nitrite
	Ammonia
	Cyanide
	WAD cyanide

Note: [1] Surface water only

Water level monitoring

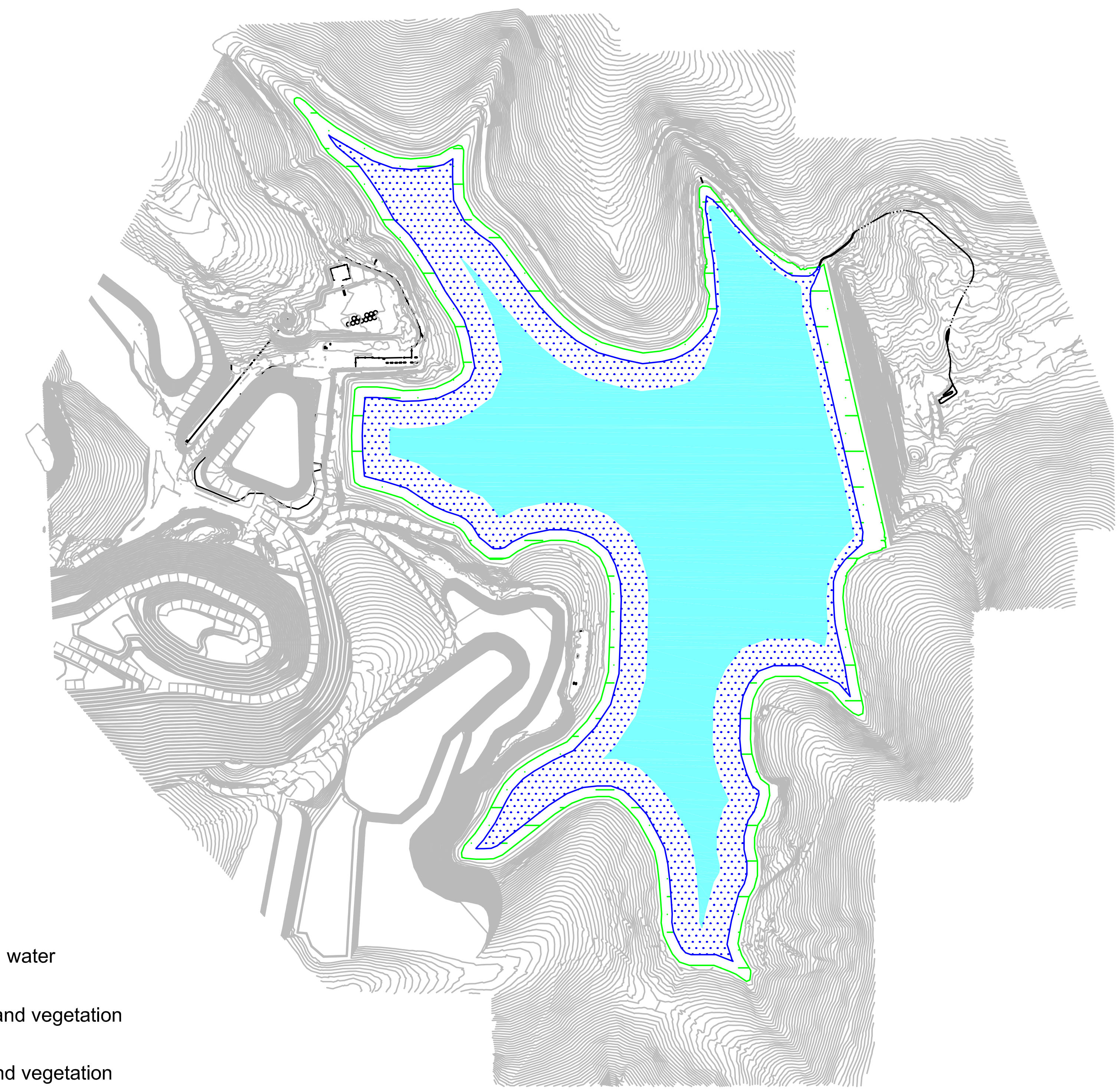
Groundwater levels will be monitored in the interceptor wells and monitoring wells on a quarterly basis to track the performance of the hydraulic containment system during operation. Subsequent to decommissioning the interception system, water levels will be monitored concurrent with each water quality sampling event.

Inspection of surface stabilization

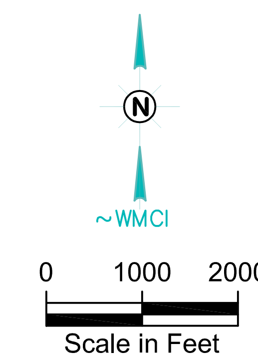
Visual observation of revegetation success will be performed on a quarterly basis during the pre-stabilization phase. Inspection for erosion and formation of gullies will be completed at the same time. Pond elevations will be measured on a quarterly frequency until the spillway invert elevation is reached.

WATER MANAGEMENT CONSULTANTS

Figure 7.1 Revegetation layout of TSF



	Calculated areas (acres)	Elevation from final tailing surface topography (ft amsl)
Upland vegetation	166	1490
Wetland vegetation	286	1486
Open water	481	1484

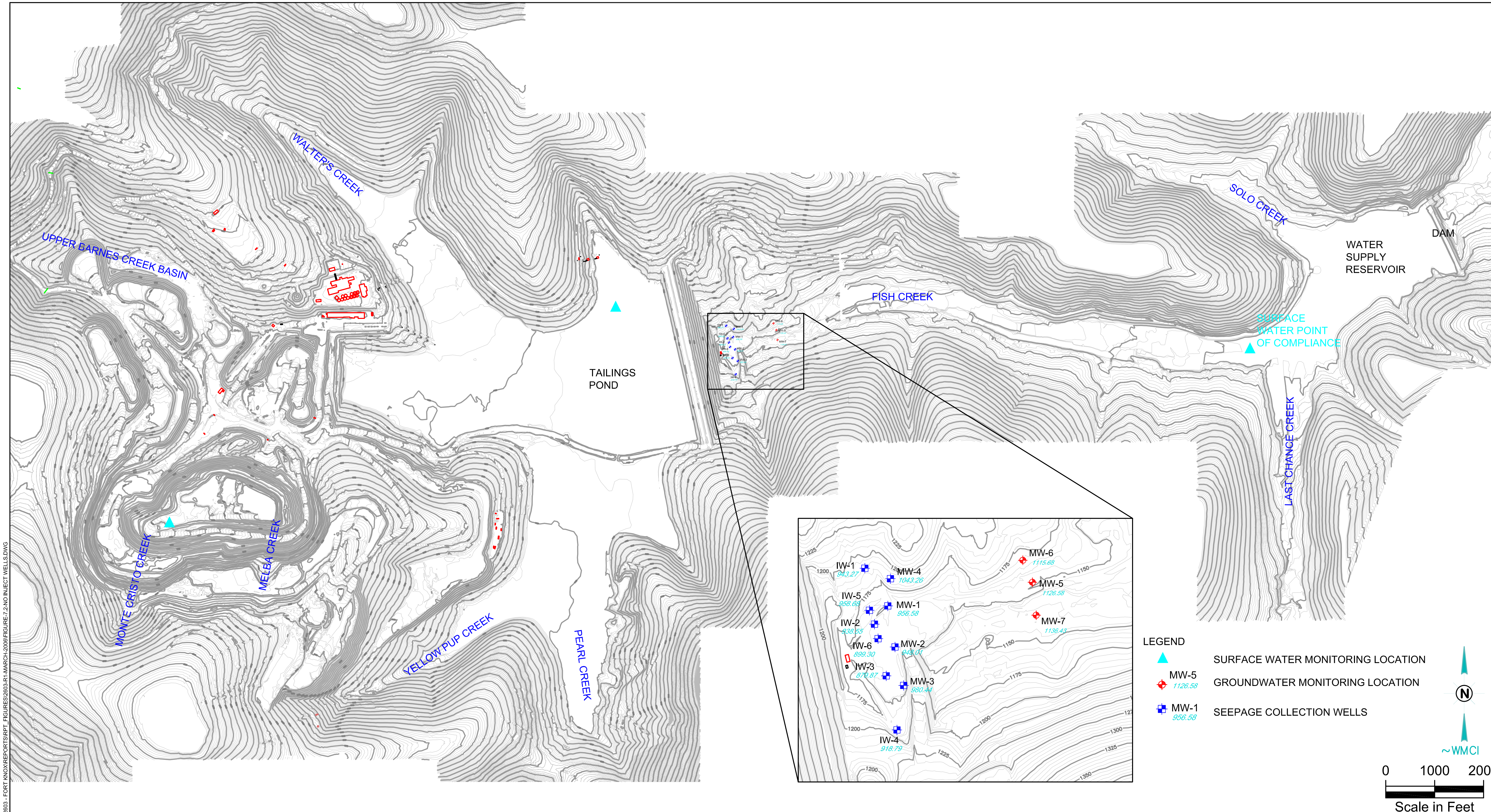


EXPLANATION

- Open water
- Wetland vegetation
- Upland vegetation

F:\2603 - FORT KNOX\REPORTS\RPT_FIGURES\2603-R1-MARCH-2006\FIGURE-7.1-R.DWG

Figure 7.2 Water quality monitoring locations



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PLANS

LEGEND

— — — — OUTLINE OF MAIN ALLUVIAL AQUIFER SYSTEM

■ FA-4 1274 ALLUVIAL WELL AND DESIGNATION WITH STATIC WATER LEVEL IN FT MSL

— 1000 — EQUIPOTENTIAL LINE
CONTOUR INTERVAL IS 50 FT
CONTOURS ARE DASHED WHERE INFERRED

DIRECTION OF GROUNDWATER FLOW

NOTES:

WATER LEVEL CONTOURS ARE DRAWN ASSUMING THAT THERE ARE NO DISTURBANCES TO ALLUVIAL AQUIFER.

WATER LEVELS PROVIDED BY HALEPASKA AND ASSOCIATES. MEASUREMENTS WERE TAKEN SEPTEMBER 1992.

N
~WMCI

0 500 1000
Scale in Feet

Pre-mining alluvial groundwater conditions

CLIENT: Ft. Knox	WATER MANAGEMENT CONSULTANTS	SCALE: 1"=1000'
JOB: 2603		DRAWN: RN CHECKED: JC
DRAWING: Plan 3.1		DATE: March 2006

LEGEND

FBT-1 1136 / FB-7D 1144 — BEDROCK WELL AND DESIGNATION WITH STATIC WATER LEVEL IN FT MSL

1000 — EQUIPOTENTIAL LINE
CONTOUR INTERVAL IS 100 FT
CONTOURS ARE DASHED WHERE INFERRED

DIRECTION OF GROUNDWATER FLOW

NOTES:

WATER LEVELS FOR ALL NUMBERED WELLS (#164)
PROVIDED BY FAIRBANKS GOLD MINE PERSONNEL.
MEASUREMENTS WERE TAKEN AUGUST 1992.

WATER LEVELS FOR ALL LETTERED WELLS (FB-4)
PROVIDED BY HALEPASKA AND ASSOCIATES.
MEASUREMENTS WERE TAKEN SEPTEMBER 1992.

N
~WMCI

0 500 1000
Scale in Feet

Pre-mining bedrock groundwater conditions

CLIENT: Ft. Knox	WATER MANAGEMENT CONSULTANTS	SCALE: 1"=1000'
JOB: 2603		DRAWN: RN — CHECKED: JC
DRAWING: Plan 3.2		DATE: March 2006

LEGEND

PL-98-37 1671	PIEZOMETER
DW-98-36 1575 (ESTIMATED)	DEWATERING WELL
IW-1 943.27	INTERCEPTION WELLS
PZ-1 1055.20	PIEZOMETER
MW-1 956.58	MONITORING WELLS
1800	EQUIPOTENTIAL LINE CONTOUR INTERVAL IS 100 FT IN THE VICINITY OF THE PIT CONTOURS INTERVAL IS 50 AT THE TSF EMBANKMENT
→	DIRECTION OF GROUNDWATER FLOW

NOTES:

WATER LEVELS DATA FOR TSF PROVIDED BY FGMI. MEASUREMENTS WERE TAKEN JUNE 2005.

WATER LEVELS FOR MINE PIT PROVIDED BY DOUBEK HYDROLOGIC. MEASUREMENTS WERE TAKEN FEBRUARY 5, 2003.

N
~WMCI

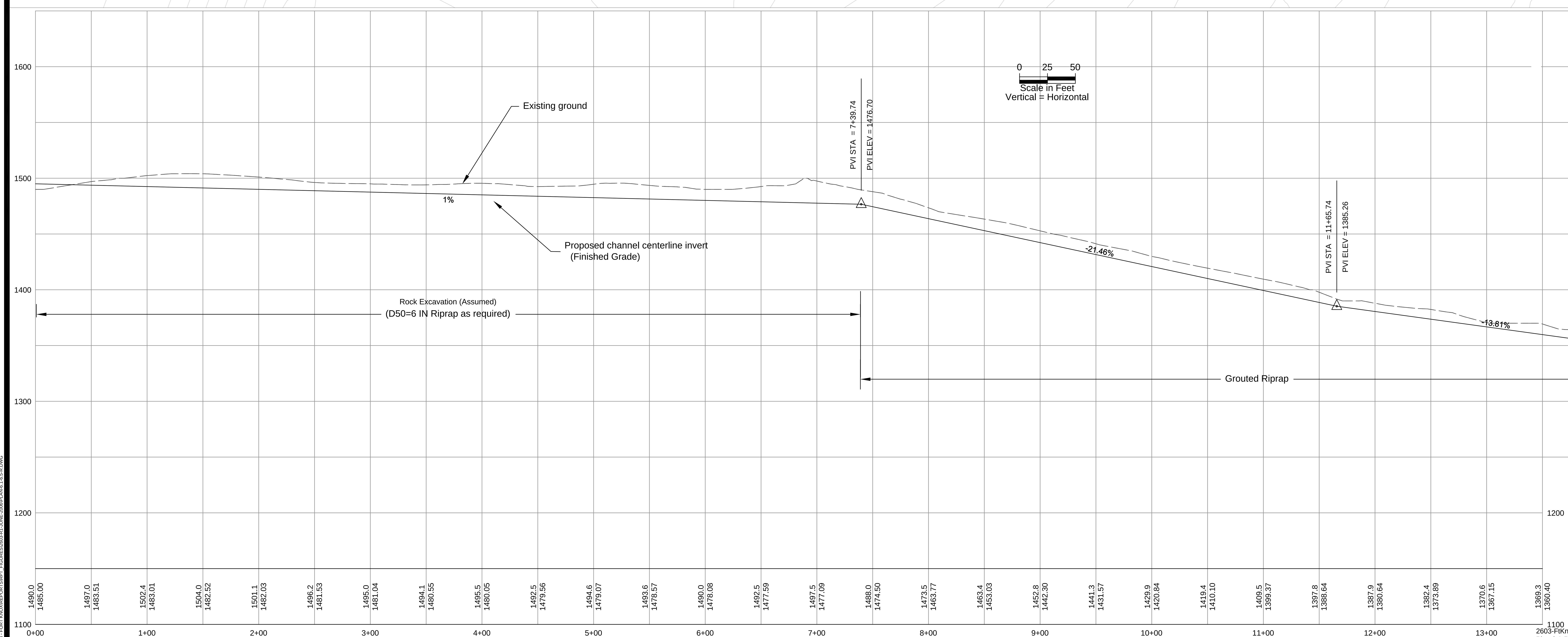
0 250 500
Scale in Feet

Current bedrock groundwater conditions

CLIENT: Ft. Knox	WATER MANAGEMENT CONSULTANTS	SCALE: 1"=500'
JOB: 2603		DRAWN: RN / CHECKED: JC
DRAWING: Plan 3.3		DATE: March 2006

Spillway and channel general arrangement map
Fort Knox Closure Management Plan

CLIENT: Fairbanks Gold Mining	WATER MANAGEMENT CONSULTANTS	SCALE: AS SHOWN
JOB: Fort Knox		DRAWN: PGQ — CHECKED: JC
DRAWING: Plan 6.1		DATE: March 2006



2603-FtKnox Plan 6.1-5

Preliminary spillway and channel design STA 0+00 to 16+00
Fort Knox Closure Management Plan

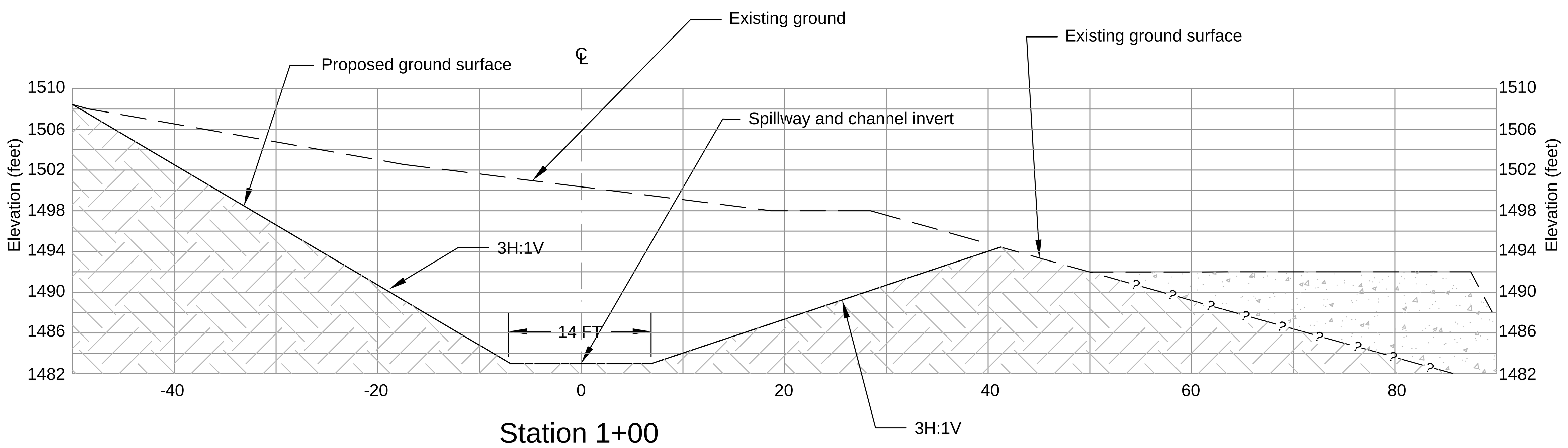
CLIENT: Fairbanks Gold Mining	WATER MANAGEMENT CONSULTANTS	SCALE: AS SHOWN
JOB: Ft Knox		DRAWN: PGQ / CHECKED: JC
DRAWING: Plan 6.2		DATE: March 2006

Preliminary spillway and channel design STA 16+00 to 29+00 Fort Knox Closure Management Plan	
CLIENT: Fairbanks Gold Mining	SCALE: AS SHOWN
JOB: Ft Knox	DRAWN: PGQ — CHECKED: JC
DRAWING: Plan 6.3	DATE: March 2006

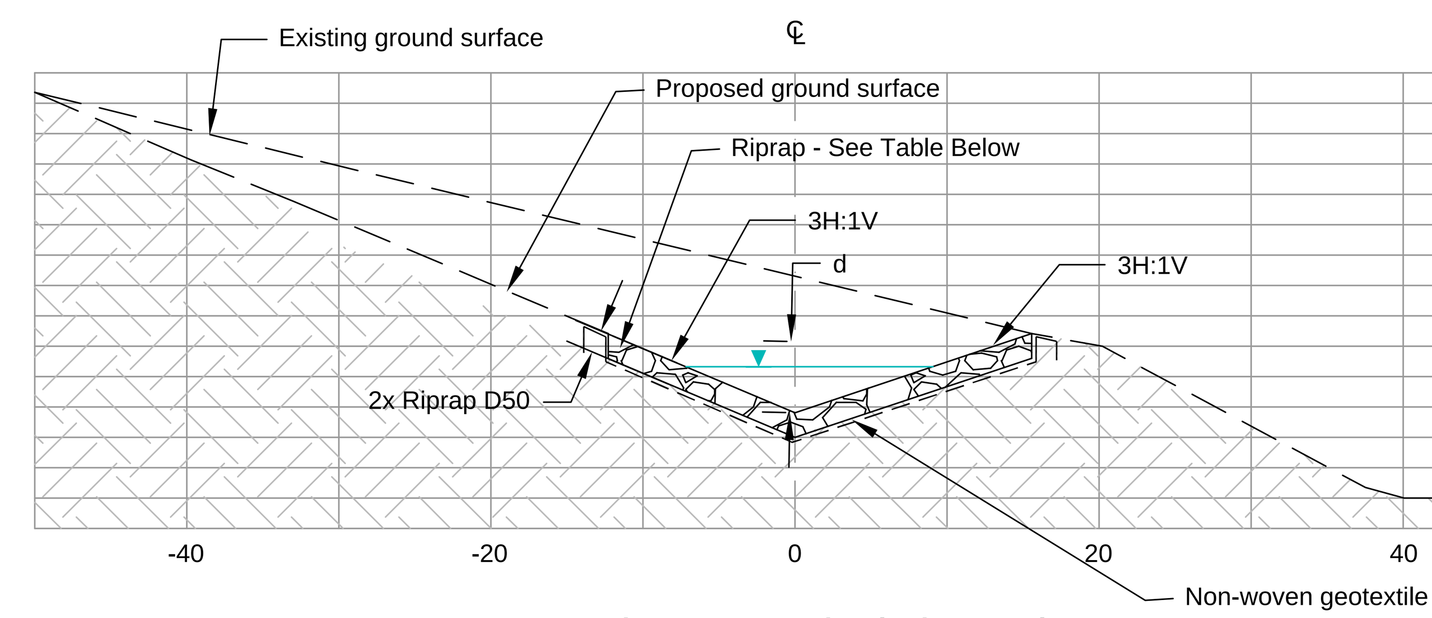
WATER MANAGEMENT CONSULTANTS

Preliminary spillway and channel design STA 29+00 to 45+49.61
Fort Knox Closure Management Plan

CLIENT: Fairbanks Gold Mining	WATER MANAGEMENT CONSULTANTS	SCALE: AS SHOWN
JOB: Ft Knox		DRAWN: PGQ / CHECKED: JC
DRAWING: Plan 6.4		DATE: March 2006



Station 1+00
Spillway cross-section at dam
Horizontal Scale: 1 IN = 10 FT
Vertical Scale: 1 IN = 5 FT

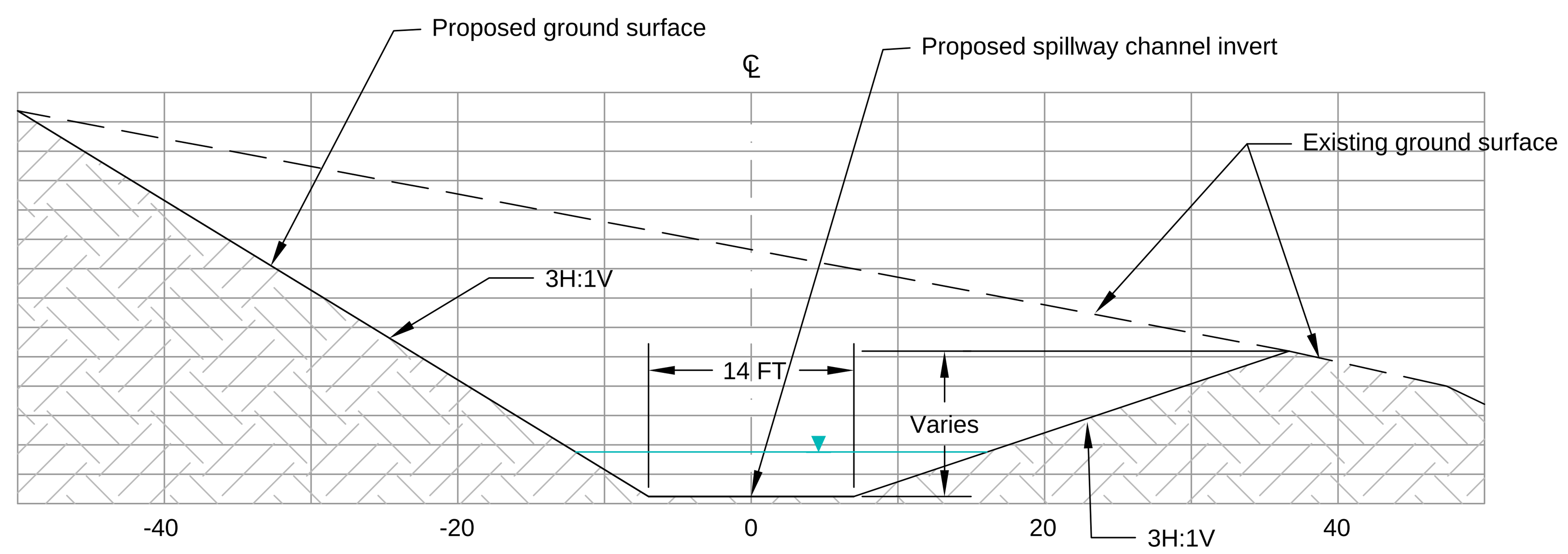


Section B: Typical channel
Horizontal Scale: 1 IN = 10 FT
Vertical Scale: 1 IN = 5 FT

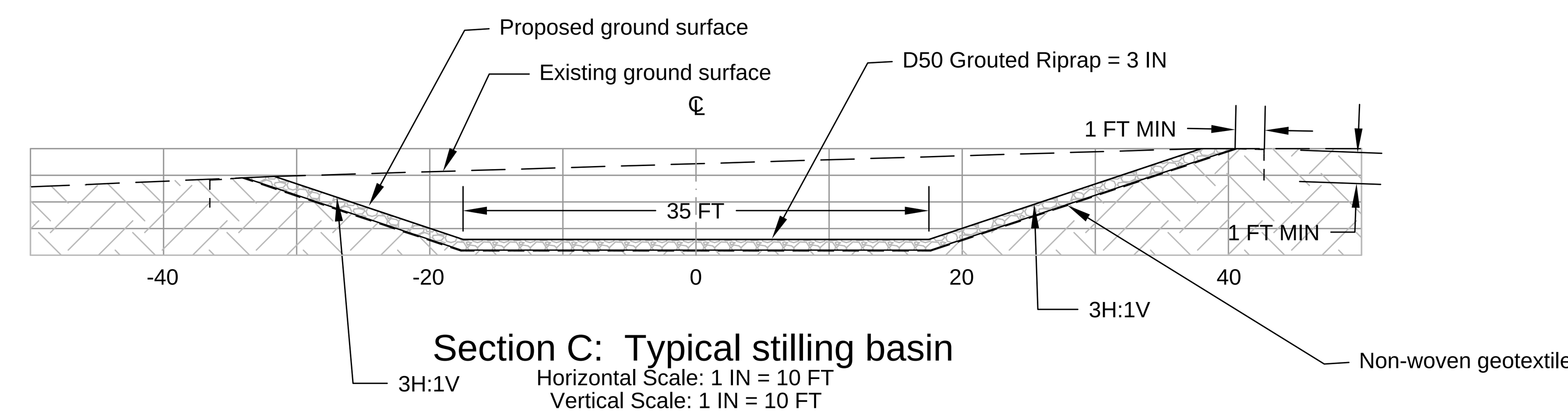
Table 6.5-1 Channel lining schedule

Slope	Depth "d" (FT)	Riprap
Spillway	3	Rock Excavation
0-2%	5	D50=6 IN (3,4)
2-8%	4	D50=12 IN (3,4)
>8%	3	Grouted Riprap D50 = 3 IN

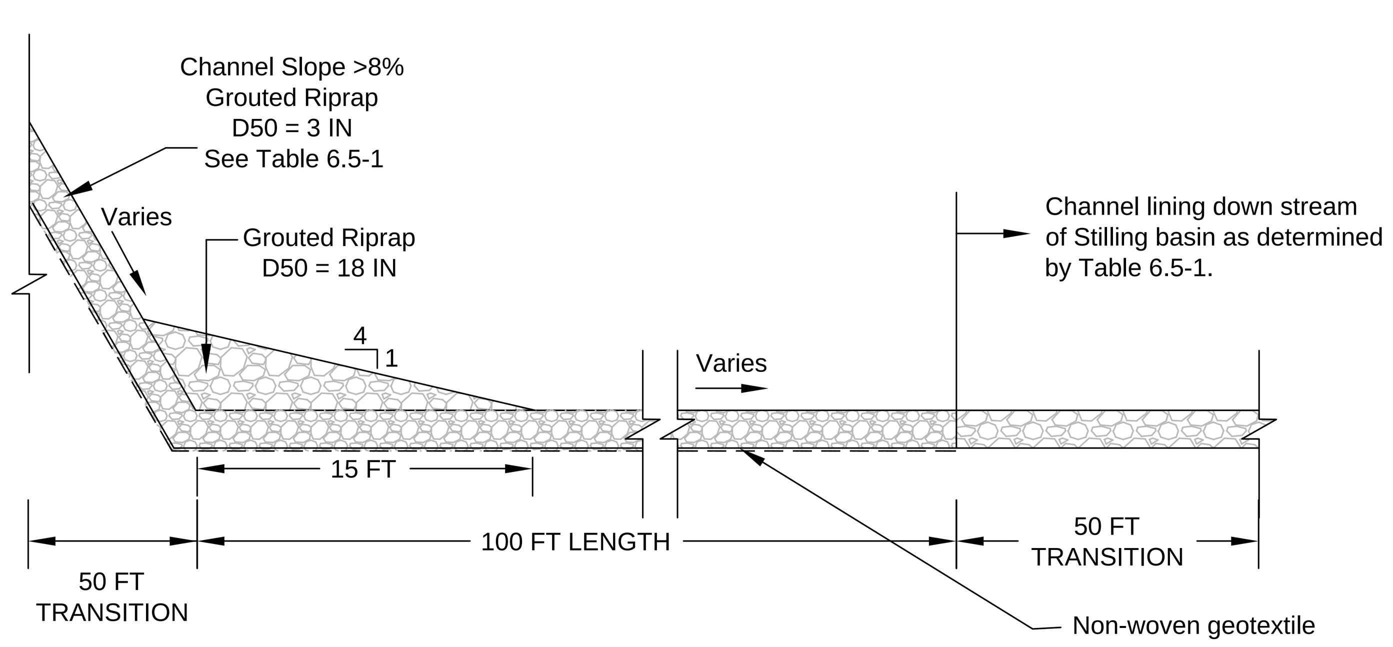
Note 1: Grouted D50=12 IN Riprap
Note 2: Grout mix - Flowable Fill (2000 psi, high slump, C-33 sand/cement mix)
Note 3: Assumes erodable channel subgrade; No armor required if rock cut.
Note 4: Riprap size per chart estimates.



Section A: Typical spillway cross-section
Horizontal Scale: 1 IN = 10 FT
Vertical Scale: 1 IN = 10 FT



Section C: Typical stilling basin
Horizontal Scale: 1 IN = 10 FT
Vertical Scale: 1 IN = 10 FT



Detail 1: Typical stilling basin
Not to Scale

Note: D50=12 IN Riprap to extend 15 Ft into Stilling Basin

Preliminary spillway and channel design details
Fort Knox Closure Management Plan

CLIENT: Fairbanks Gold Mining
JOB: Fort Knox
DRAWING: Plan 6.5

WATER MANAGEMENT CONSULTANTS

SCALE: AS SHOWN
DRAWN: PGQ
CHECKED: JC
DATE: March 2006

~WMCI

0 200 400
Scale in Feet

Conceptual layout of engineered wetland system		
CLIENT: Fairbanks Gold Mining	WATER MANAGEMENT CONSULTANTS	SCALE: As shown
JOB: 2603		DRAWN: PGQ / CHECKED: JC
DRAWING: Plan 6.6		DATE: March 2006