
KENNECOTT GREENS CREEK MINING COMPANY

SITE 23/D HYDROGEOLOGY AND GEOCHEMISTRY ANALYSIS



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1.0 Executive Summary

Long term storage of production rock from underground mining operations at Kennecott's Greens Creek Mine is actively taking place at a storage facility referred to as Production Rock Site 23 (Site 23). Located just west of the mine and mill area, Site 23 and the now inactive Site D (collectively Site 23/D) are adjacent production rock disposal sites designed for long-term development rock management. This report presents recent interpretations of data acquired through drilling and monitoring over the life of the waste disposal site. These data have led to continued progress in understanding the site geology and hydrology which is in turn useful in interpreting the site geochemistry, and assessing the need for and effectiveness of water management facilities.

Site 23/D is underlain by a highly variable, slide rock/colluvial unit. The geology beneath the site is a mix of slide material, glacial till and alluvial material resulting in a highly anisotropic water-bearing matrix. Within this slide zone there are lenses of low permeable material overlying and underlying water bearing zones resulting in multiple semi-confined perched water tables. Such conditions are evidenced by excavations, drilling and monitoring data showing varying hydraulic pressures between wells, intermittent seeps/springs, and highly variable saturated thickness.

Surface and groundwater are managed to enhance site stability, minimize contact with production rock, and convey water that contacts the production rock to containment and treatment as necessary. Surface water is managed using runoff collection ditches and ponds. Groundwater is managed with a subsurface drain network underlying the Site 23 production rock and the curtain drain interceptor constructed into the colluvium at the toe of Site 23. Empirical data and modeling computations suggest that these structures are effective at collecting, conveying and containing production rock contact water for treatment. Under current operating conditions, it is estimated that the curtain drain captures 75 gpm of a total colluvial system discharge beneath the pile of approximately 102 gpm for an approximate 74% capture of the groundwater flux through the colluvium.

The finger drain system is estimated to capture approximately 17% of the infiltration through the waste rock material in an uncovered condition. The combined capture efficiency of the finger drains and curtain drain, results in an estimated production rock contact water capture volume of 11 to 15 gpm. The non-contact water total in the same system is estimated to be approximately 136 gpm.

The hydrologic conditions and water management needs of the site post closure are substantially different than under the current conditions of active operations. Under closure plans, the site will be covered with an engineered multi-layer water balance cover system (O'Kane Consultants, 2001). The design of the cover system is to result in a significant reduction in the infiltration rates and oxygen ingress. A cover is currently in operation on a portion of the Site 23 pile, and data acquisition is actively occurring. The actual cover data results will be used to adjust the cover design to optimize the closure of the site and the long-term hydrologic and geochemical management of the site.

Geochemical conditions of production rock, surface water, groundwater and collected water at Site 23/D are monitored on a regular schedule and vary both seasonally, spatially and compositionally. In general, production rock has net acid producing potential and metals values are higher than crustal averages, however, a significant carbonate component inhibits acid generation and provides for neutralization. Surface water from Bruin Creek and Greens Creek shows natural seasonal fluctuations, and comparisons between upstream and downstream sites indicates activities from site 23/D are negligible. Groundwater electrical conductivities range from 200 to 800 uS/cm and show little difference between up-gradient and down-gradient groundwater locations at Site 23/D. This demonstrates the effectiveness of collection and management of contact water at the site.

Finger drain compositions also vary seasonally, but little increase in dissolved concentrations are apparent from basal drains. While increases in curtain drain dissolved compositions have been measured, the primary reason for this is the inclusion of surface drainage from Site D and the continued growth of Site 23.

Representative water quality sample results from various sources monitored at the site provided basic data for modeling of post closure conditions. Twelve scenarios were examined in the model that assumes full build-out of Site 23 and uses a number of variables accounting for percolation rates, rainfall, and quantities of contact water and non-contact native groundwater. Due to the relationship between projected concentrations and water quality standards, cadmium is the constituent that may constrain cover performance requirements. Recently reduced cadmium water quality standards are met under conditions with 2% percolation rates through the cover and production rock. These predictions do not consider natural attenuation processes, such as oxidation, reduction, and sorption, which could occur in the system following closure of the facility. Further refinement of the model is dependent upon additional hydrologic and water quality data collection as well as data associated with assessment of cover performance.

2.0 Introduction and Background

The Kennecott Greens Creek Mine (KGCMC) is a precious and base metal mine producing gold, silver, zinc and lead from underground mining operations. The mine is located approximately 18 miles southwest of Juneau, Alaska on Admiralty Island. As a necessary part of the mining process, underground operations extract non-ore bearing rock, referred to as production rock. Some of this retained material cannot be placed back underground due to materials placement constraints consistent with the progression of the mine plan. Therefore, the production rock must be placed in facilities on the surface that are engineered for storage of this material. Production Rock Site 23 and the adjacent Production Rock Site D are two such facilities. These facilities are engineered and managed for geotechnical stability, geochemical stability, and appropriate water management. Site D was operational from approximately 1987 to 1995, but is no longer an active placement area. Site 23 was constructed in 1995 and is currently the only active surface placement facility for production rock besides the tailings area.

2.1 Report Purpose

The purpose of this report is to provide an updated assessment of existing hydrologic and geochemical conditions at the Site 23 and adjacent Site D rock storage facilities by examining recently acquired and historic hydrologic and geochemical data from the sites. Understanding the hydrology and geochemistry is important in assessing the effectiveness of the hydrologic control structures and in optimizing the site management with respect to hydrologic controls and protection of water quality. A detailed discussion for overall KGCMC site water management is beyond the scope of this report. A separate report addresses water management for the entire site (EDE, 2003).

This report is based upon drilling exploration, hydrologic monitoring, water quality monitoring and data gathering that began more than a decade ago, and has resulted in a progressively better understanding of site hydrology, geology, and geochemistry. Key components to this understanding include geologic and stratigraphic information derived

from drilling and seismic work; water quality data from well, spring and stream sampling; aquifer properties from aquifer testing; hydraulic head measurements from well monitoring, and estimated groundwater flow quantities. From these various types of data, a conceptual and qualitative assessment of site hydrology and geochemistry is presented.

2.2 Report Organization

This report covers two main topics; 1) surface and groundwater hydrology, 2) site geochemistry. These two disciplines are inter-related and they each provide clues to the conditions and functioning of the site as a system.

The report structure includes the following main sections:

- Section 1 - report summary
- Section 2 - site history, background and operations.
- Section 3 - site description and examination of available data.
- Section 4 - site hydrology and engineered structures.
- Section 5 - site D relocation alternatives
- Section 6 - closure and post closure hydrology
- Section 7 - hydrology summary and conclusions
- Section 8 - geochemistry
- Section 9 – geochemistry summary and conclusions.

3.0 Site Description and Operation

3.1 General Site Description

The general site plan, surface water hydrologic features and the hydrologic control structures of Site 23/D are displayed on Figure 1 while monitoring points utilized at the site are depicted on Figure 1B. The Production Rock Site 23/D is situated on the south-southeast facing slope of the Greens Creek Valley. Site 23 is located immediately adjacent to and uphill of the main mine/mill access road (the “B” road) while Site D is located immediately adjacent to and downhill of the “B” road at mile post 8.0 or approximately ¼ mile down valley from the mill/office complex. Site 23 and Site D combined, occupy a total of 19.0 acres.

Both Site 23 and Site D are bounded on the east by Bruin Creek. Site D is also bounded on the south by Greens Creek and adjacent/contiguous to Site 23 on the north, essentially only separated by the “B” access road. Due to this close proximity

Table 3.1 – Site Size/Volume (12/31/03)

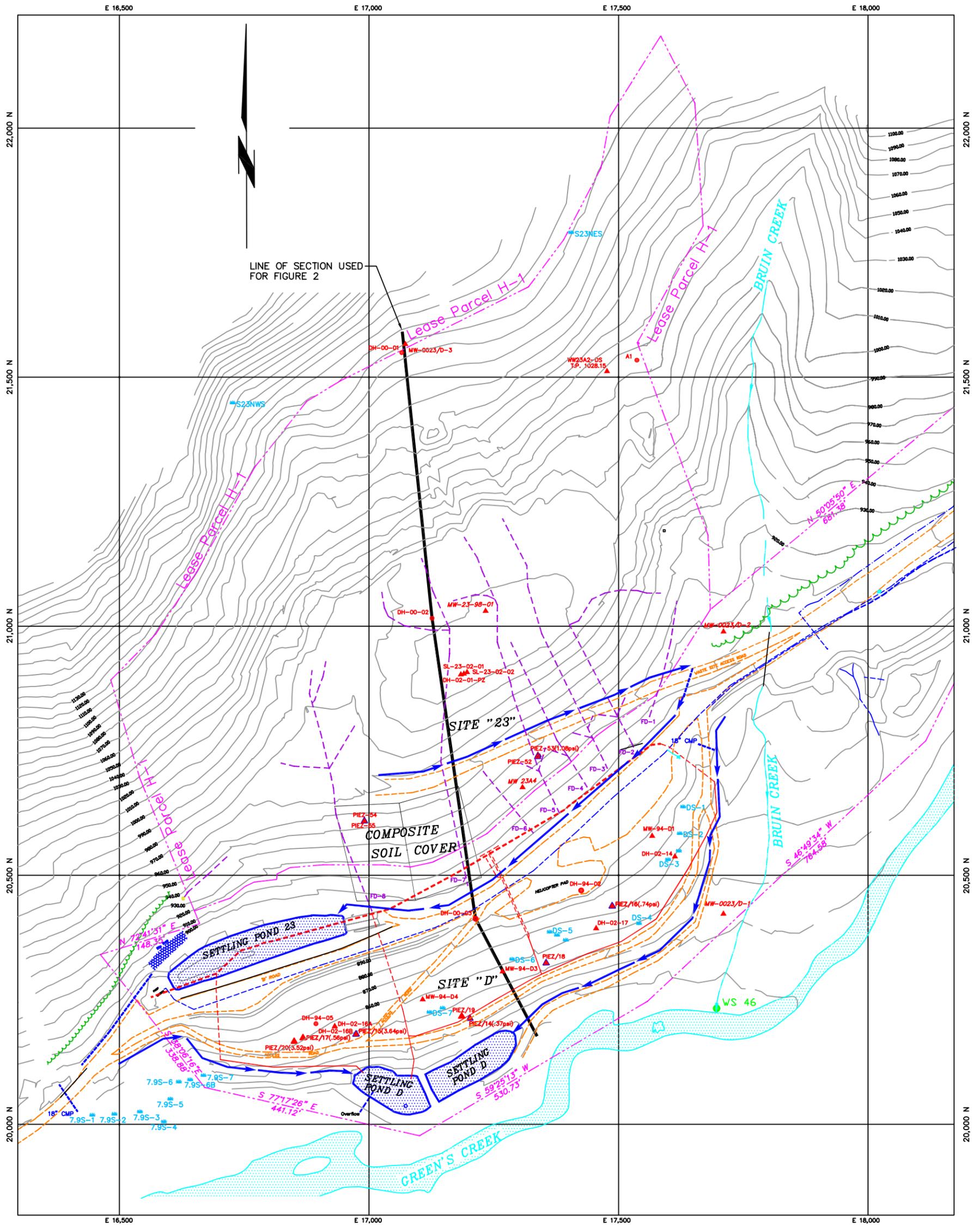
Site	Footprint Area (acres)	Volume (cubic yds)	Tons	Active years
D	8.0	89,208	151,010	1987 - 1995
23	11.0	445,756	754,571	1995 - Present

and many shared hydrologic conditions, Site 23 and Site D are treated as one entity with regard to hydrology and will be referred to as Site 23/D throughout this report. Table 3.1 summarizes basic characteristics of the Sites D & 23.

3.2 Site Operations and Monitoring

At site D, placement of native glacial till excavated from the mill site during construction and mine production rock began in 1987. Site D is no longer receiving any material, and the site is now at final grade and has been re-vegetated. The construction of Site 23 began in 1995 with back slope excavation (excavation of the slope toward the north/northeast and uphill), and the installation of hydrologic controls including finger

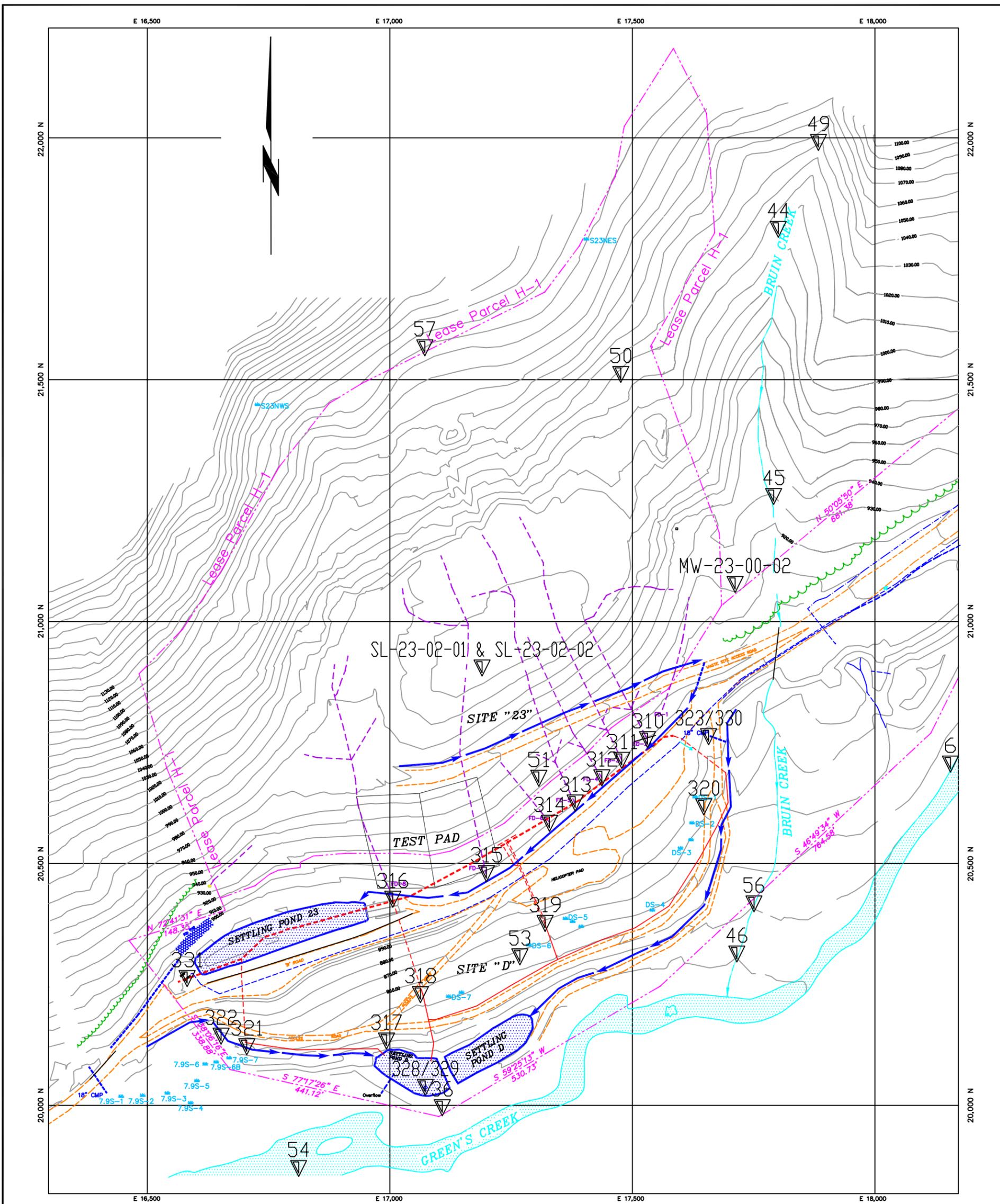
and curtain drains. Site 23 is currently the active production rock placement site and is anticipated to have sufficient capacity for the currently estimated life-of-mine plan.



- LEGEND:**
- RIP RAP
 - CULVERT
 - FINGER DRAIN
 - PIEZOMETER/WELL
 - LEASE BOUNDARY
 - 10' CONTOUR LINE
 - STREAM CHANNEL
 - ROAD
 - DRILLHOLE/BOREHOLE
 - CURTAIN DRAIN
 - CURTAIN DRAIN OUTFALL
 - RUNOFF DITCHES
 - SEEPS/SPRINGS

FIGURE 1

KENNECOTT GREENS CREEK MINE ADMIRALTY ISLAND, ALASKA	
SITE 23/D 2003 GENERAL SITE MAP & HYDROLOGIC CONTROLS	
DATE: 07/17/03 DRAWING BY: RWH & SLN DESIGN BY: BJS REVIEWED BY: BNN & BJS PROJ OR REF: GCM0203 - 23/D	 Environmental Engineering Hydrology Water Resources Engineering 23 North Scott St., #23 Sheridan, WY 82801 PHONE: (307) 672-3793 EDE DWG FinalFig1.dwg
SCALE: 1" = 200'	SHEET: 1 OF 1



MONITORING SITE NAMING CROSS REFERENCE	
Numeric Site Name	Alternate Designation
6	Middle Greens Creek (MGC)
36	D Pond Outfall (OP)
44	Old Upper Bruin Creek (UBC)
45	Middle Bruin Creek (MBC)
46	Lower Bruin Creek (LBC)
49	New Upper Bruin Creek (UBC)
50	MW A2-D (MW23A2-D)
51	Monitor Well (MW-A4)
53	Monitor Well (MW-D3)
54	Lower Greens Creek (LGC)
56	MW-D-00-01 (MW-0023/D1)
57	MW-23-00-03 (MW-0023/D3)
MW-23-00-02	MW-23-00-02 (MW-0023/D2)
SL-23-02-01	Suction Lysimeter (SL-23-02-01)
SL-23-02-02	Suction Lysimeter (SL-23-02-02)
310	Finger Drain (FD-2)
311	Finger Drain (FD-3)
312	Finger Drain (FD-4)
313	Finger Drain (FD-5)
314	Finger Drain (FD-6)
315	Finger Drain (FD-7)
316	Finger Drain (FD-8)
317	Corrugated Metal Pipe (D-1 CMP)
318	Mid West Curtain Drain (D-2 MidWCD)
319	Mid East Curtain Drain (D-3 MidECD)
320	East Corrugated Metal Pipe (D-4 ECMP)
321	West Curtain Drain (D-5 WCD)
322	Pump House (D-6 23PH)
323	East Corrugated Metal Pipe D-7 E CMP (CD-4)
328	Curtain Drain (CD-2)
329	Curtain Drain (CD-3)
330	East Corrugated Metal Pipe (CD-4 ECMP)
331	Wet Well (D Pond WW)

- LEGEND:**
- RIP RAP
 - CULVERT
 - FINGER DRAIN
 - PIEZOMETER/WELL
 - LEASE BOUNDARY
 - 10' CONTOUR LINE
 - STREAM CHANNEL
 - ROAD
 - DRILLHOLE/BOREHOLE
 - CURTAIN DRAIN
 - CURTAIN DRAIN OUTFALL
 - RUNOFF DITCHES
 - SEEPS/SPRINGS

FIGURE 1-B

KENNECOTT GREENS CREEK MINE
ADMIRALTY ISLAND, ALASKA

SITE 23/D
2004 HYDROLOGIC MONITORING
SITE LOCATION MAP

DATE: 3/4/04	
DRAWING BY: RWH & SLN & BNN	23 North Scott St., #23 Sheridan, WY 82801
DESIGN BY: BJS & BNN	PHONE: (307) 672-3793
REVIEWED BY: BNN & BJS & PC	EDE DWG: FinalFig1-B.dwg
PROJ OR REF: GCMO203 - 23/D	

SCALE: 1" = 200' SHEET: 1 OF 1

The following is a brief discussion of the current Site 23 construction and operations of the combined Site 23/D. A complete detailed description of the construction and operation of Site 23 is contained in the KGCMC General Plan of Operations (GPO), Appendix 11, Attachment B "Site Specific Plan, Site 23", August 31, 2000.

Production rock is placed at Site 23 following excavation of native colluvium/slide rock. Colluvium/slide rock is excavated from the site working uphill and to the north. Excavated colluvium/slide rock is used as borrow/fill material for general construction throughout the surface facilities and support facilities area as well as cover material at the Production Rock Site 23 reclamation cover. In addition, the colluvium/slide material removal prepares the site for production rock placement and provides additional placement capacity.

As of January 1, 2004, approximately 754,751 tons of production rock had been placed at Site 23, with approximately 34,316 tons placed in 2003 (KGCMC, Tailings and Production Rock Site, 2003 Volume Report). Production rock is dumped, spread in 1 ft. to 2 ft. lifts and then compacted with a vibratory drum compactor. KGCMC manages the site to promote runoff and minimize infiltration by placement of these thin, compacted lifts at the proper drainage angle (GPO, 2001). Side slopes of the repository are placed at an overall maximum of 3H:1V.

Following back-slope excavation and prior to production rock placement, finger drains are extended to intercept water at the base of the waste rock, as necessary. Similarly, as the production rock surface elevation increases from sequential placement of material, the casing of stand pipes and piezometers installed on the active placement areas are extended from the surface to an appropriate height above land surface to maintain access to these monitoring devices.

The hydrologic monitoring system shown on Figure 1 and Figure 1B consists of pneumatic piezometers, stand pipe piezometers, monitoring wells, finger drains, a curtain drain, as well as surface water sites on Bruin Creek and Greens Creek. The monitoring sites address both groundwater and surface water quality and quantity. The

majority of the listed sites are utilized for internal monitoring needs as addressed in ADEC (2003) and KGCMC (2000) while sites 6, 54, 49, 46, 57, and 56 are monitored for compliance under the requirements of the Fresh Water Monitoring Program (GPO Appendix 1) as well as KGCMC (1996). Monitoring locations and equipment for the two monitoring programs were installed at various times in 1987-1988, 1994, 1998, 2000 and 2002. This phased development of the monitoring network progressed as the site developed and additional data revealed further information about the site geology/hydrology.

3.3 Site Geology

The underlying geology of Site D and Site 23 as it pertains to hydrology are similar in that they are dominated by unconsolidated materials, principally colluvium, but differ from one another in significant ways. The geologic materials collectively involve intact and fractured/blocked bedrock, glacial deposits, alluvial deposits, land-slide debris, and placed fill material. The geologic structure is relatively complex with respect to how it influences the hydrologic regime, both with respect to surface water and groundwater and is an important aspect of the hydrology and geochemistry. The following describes the geology of the site both in terms of describing the individual units involved and the collective structure at the sites.

A total of six distinct lithologic and hydrologic units make-up the Site 23/D area stratigraphy. These are, in order of increasing depth where present:

- 1) Production Rock
- 2) Fill material (Site D only)
- 3) Alluvium (Site D mainly)
- 4) Colluvium
- 5) Till
- 6) Bedrock

Previous geologic and hydrologic technical information is presented in:

- “Geotechnical Investigations at Potential Waste Rock Sites-Greens Creek Mine” (SRK, 1992),
- “Environmental Assessment for Additional Waste Rock Disposal Capacity at Greens Creek Mine, Admiralty Island National Monument, Alaska”, (USDA, National Forest Service, November, 1992)
- Internal report titled “Kennecott Greens Creek Mine Production Rock Characterization Study” (KGCMC, 1995),
- Internal Memorandum by Peter Condon titled “The Results of the 1998 Drilling at Site 23”, (KGCMC, 1998),
- Internal documentation by Peter Condon titled “Synopsis of Waste Site 23 Structural Geology”, (KGCMC, 2001),
- “Greens Creek Mine East Tailings Expansion and Waste Rock Site 23/D Drilling and Well Installation Summary for Summer 2000”, (EDE, 2000),
- Tailing and Production Rock Site 2001 Annual Report (KGCMC, 2002), and
- Tailing and Production Rock Site 2002 Annual Report (KGCMC, 2003).

The following discussion briefly describes these units, their hydrologic properties, thickness and extents. Figure 2 portrays a generalized hydrogeologic cross-section through the area.

Production Rock

KGCMC production rock is typically comprised of sericitic phyllites, chloritic schist and argillite, usually with a coarse fraction dominated by the 2-6” diameter range as described by Vos (1993). This material overlies the majority of the site. The matrix between production rock clasts can consist of clays, iron oxide clots as well as small rock fragments. Production rock moisture content varies horizontally and vertically, though the rock normally comes to the site from the underground in a dry condition and is compacted relatively quickly after placement to minimize the sorption of moisture.

The maximum thickness of the production rock exceeds 60’ on Site 23 while the maximum observed on Site D is approximately 23 ft. at DH-02-16. Observations from



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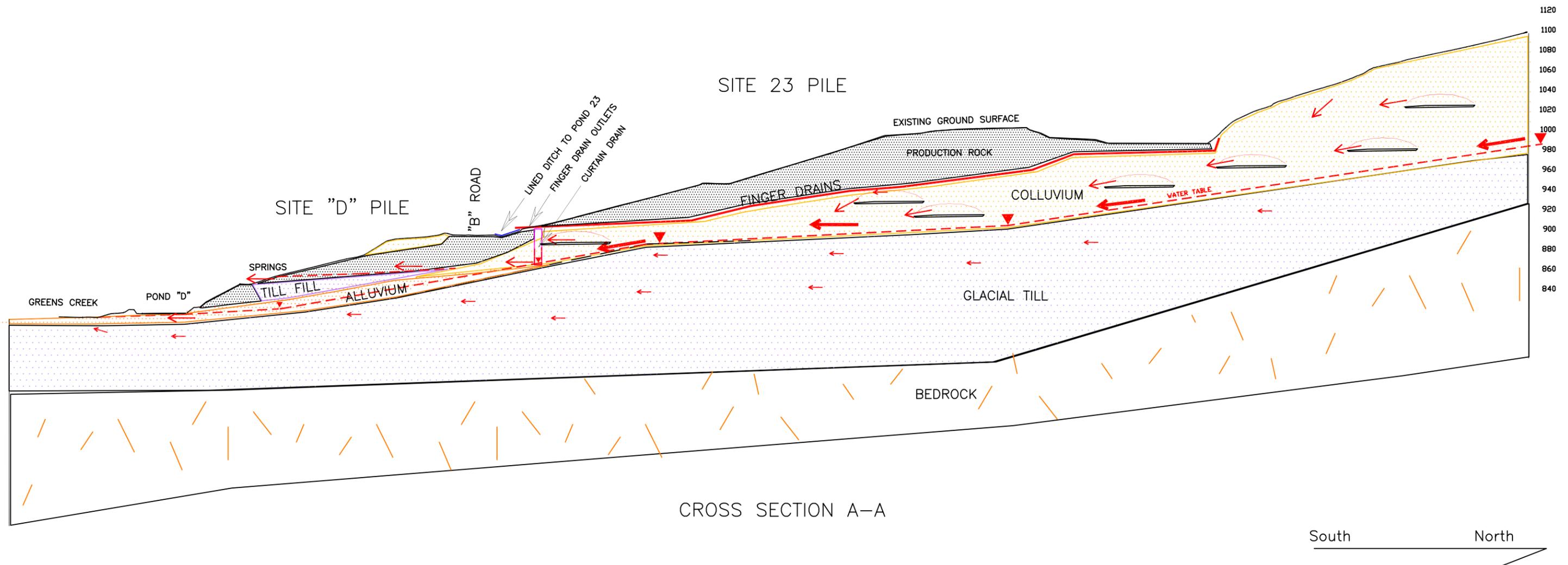
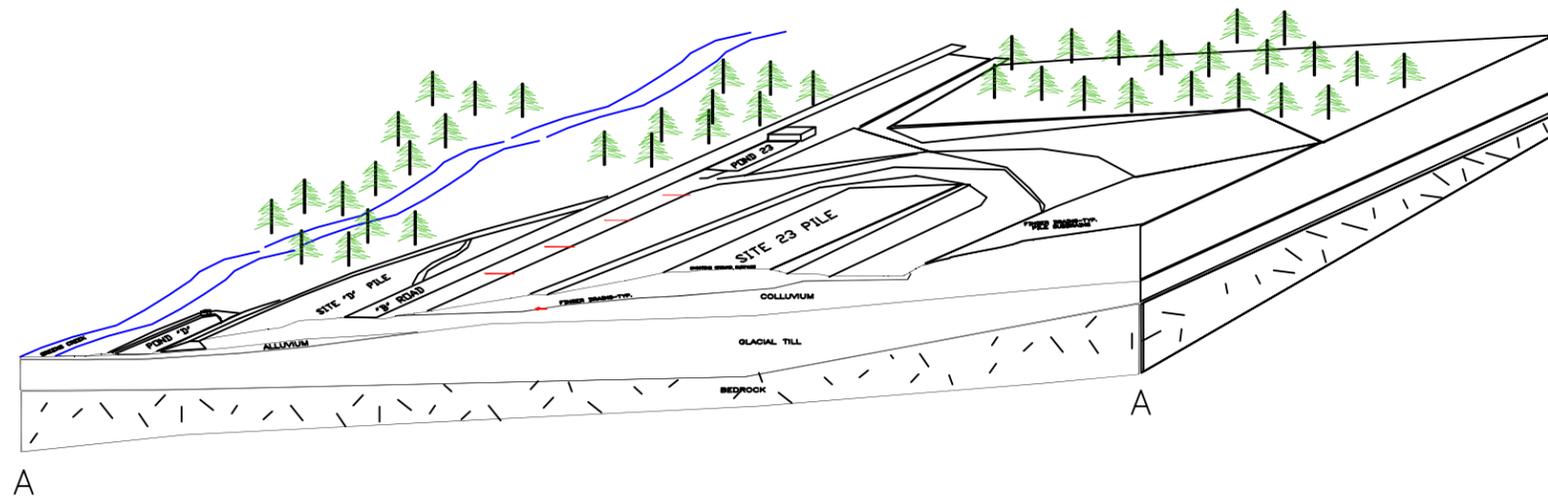
DATE: 4-30-03
DRAWING BY: TZ
DESIGN BY: PC
REVIEWED BY: ----
PROJ OR REF: EDE-Site 23/D Hydrology

TITLE:
SITE 23/D CONCEPTUAL
GROUNDWATER FLOW

LEGEND:

	CLAY LENSES WITH PERCHED WATER		EXISTING GROUND
	WATER TABLE		PRODUCTION ROCK FILL
	WATER FLOW VECTORS - FLOW RATE PROPORTIONAL		FINGER DRAINS TYPICAL
			COLLUVIUM
			ALLUVIUM
			GLACIAL TILL LAYER
			BEDROCK

FIGURE 2



South North

drilling indicate that where water saturation zones are present in the production rock, it exists as isolated, discontinuous, perched water tables/lenses.

Fill Material

Fill material consists of material excavated during mill site construction in 1988 possibly combined with some production rock. This material normally underlies production rock at Site D but is not present within Site 23. The fill is comprised of silty clay till with slaty argillite clasts and ranges in thickness from less than 2.5' to approximately 33'. Some drilling logs note sporadic occurrence of organics in the form of peat and woody matter while in-situ moisture conditions range from wet to saturated.

Alluvium

Alluvial deposits in the form of gray to gray black silty sands to gravelly sands have been observed primarily underlying Site D. At one lower location on Site 23 (MW23-A4), a thickness of 8' of sand/gravel was observed during drilling, though this remains the only borehole to display this material on Site 23. Stratigraphically below (or possibly equivalent to) the colluvium and overlying the glacial till in most locations, the highly variable alluvium ranges up to 36' in thickness at DH-00-03, and appears to thin to the northeast and southwest under Site D to 5' or less.

Colluvium/Slide Rock

Colluvium and/or slide material consisting of a brown to gray, silty to sandy matrix with abundant angular rock fragments overlies glacial till under Site 23. Exposures of the unit form the back-slope or excavation area of Site 23. Colluvium fragments are generally greenish-grey chloritic rock or talcy schists with sporadic slickensides evident and occasional thin clay seams. Many larger rock blocks maintain internal structures and due to talcy alteration are very friable. The unit thins from north to south and at the periphery of the area, with thickness ranging from 17' to over 114'. Water bearing zones are often perched and confined while also responding quite quickly to precipitation.

Glacial Till

Glacial till, consisting of blue/gray silty clay underlies the entire site at thickness up to 130'. Trace sand and gravel seams have been noted and are normally the water bearing zones within this formation. Water appears to be confined at MW-23-00-2 with a positive head of 11' above the top of the unit.

Bedrock

Underlying the entire site is bedrock at depths often greater than 200'. Generally composed of sericitic phyllite or argillite, little is known about aquifer characteristics due to a lack of wells or instruments installed in the unit. However, underground mine workings provide excellent exposure of bedrock physical characteristics near the site. Rock quality designations (RQD) for the cored intervals vary across the site. RQD values from the northernmost borehole (DH-00-01) were consistently 0% (highly fractured) while those at DH-00-02 and DH-00-03 ranged from 47% (less fractured) to 100% (not fractured).

Re-evaluation of existing and newly acquired data for the Site 23/D area, has resulted in reinterpretation of the site geology and groundwater hydrology. Previously, pre-excavation slopes were described as 'moderately sloping' at 20-25% (SRK, 1992) and noted a 'scarp-like' feature at the 950 ft. and 1000 ft. elevations, possibly a relict fault enhanced by glacial excavation. Follow-up drilling and re-interpretation by KGCMC technical staff led to a revised understanding of this feature. Today, it is believed that a unit of semi-coherent rock and colluvial/slide material exists below Site 23 and overlies in-tact glacial till and bedrock in the area. This revised interpretation to a rock slide scenario prompted KGCMC to re-evaluate the geotechnical stability and groundwater hydrologic characteristics of the site. A final report is expected 2004.

Bedrock geology of the immediate area around Site 23/D is very complex. Northwest striking, southwest dipping fault zones bound the Triassic marine meta-sediments and meta-volcanics. With the Maki Fault zone on the northeast periphery of the site and the Gallagher Fault on the southwest, significant structural implications are apparent. The meta-sediments and meta-volcanics that comprise the bedrock in the

area are made up of chloritic greenstones, sericitic phyllites and talcy schists as well as a slatey, graphitic argillite to the east. The complex geology has prompted a review of the hydrology and the previous interpretations of the hydrologic regime. The site hydrology is discussed below.

4.0 Site Hydrology

4.1 Regional Hydrology

A significant hydrologic feature both regionally and locally is the large amount of precipitation received at the site. Precipitation data from the mill area, Site 23 and tailings area from the last several years is summarized below. Considered a temperate rain forest, recent annual precipitation levels at the mill area and Site 23 range from 53.9 inches in 1998 (Mill) to a high of 80.2 inches in 1999 (Mill) and averages 64.7 inches (based on 1997-2003 data). The tailings area (4.5 miles north, northwest and 800 ft. lower in elevation) values range from 43.5 inches in 1998 to 64.3 inches in 1999. Orographic influences in the mountainous terrain account for the significant differences, for comparison, the National Weather Service Climate Database indicates that Juneau (with the longest single station period of record) reports an average of 56.6 inches while Auke Bay, just north of Juneau reports an average of 62.4 inches (over 37 years). This indicates that values observed in the relatively short period of record for the Mill and Site 23 area are well within reasonable ranges for precipitation in the region.

Surface water hydrology includes two local streams, Bruin Creek and Greens Creek. Bruin Creek is a direct tributary of the much larger Greens Creek (Figure 1). Bruin Creek flows approximately parallel to the eastern boundary of the 23/D site. Greens Creek runs approximately parallel to the south boundary of the site. These streams are typical of the mountainous regions of Southeast Alaska, with relatively small watersheds and flows that respond quickly to precipitation and have a perennial flow component based on snow pack melt and local groundwater discharge.

No regional aquifer systems have been identified in the area of Site 23/D. The presence of groundwater that may be of interest with respect to Site 23/D appears to be restricted to local groundwater systems. Groundwater is resident in the slide materials, glacial and fluvial-glacial sediments and structurally isolated bedrock units. These units are not discrete and distinct aquifers at site 23/D and are best described as water bearing formations. Water within these units varies in response to precipitation

recharge and the presence/absence of water varies vertically and horizontally suggesting discontinuous flow paths and zones of highly varying permeability.

4.2 Local Hydrology

4.2.1 Surface Water Hydrology

Significant surface water features are presented on Figure 1. The Site 23/D lease area is bounded by Bruin Creek on the east and Greens Creek on the south. Flow within Bruin Creek, running from north to south, is thought to be predominantly runoff supplemented by bedrock groundwater in the upper reaches, and seeps from colluvial/slide material adjacent to the creek on the west along the middle and lower reaches. Historic flow data for Bruin Creek is limited. Flow rates measured in July 2002 at the 'B' Road culvert indicate base flow conditions are in the range of 0.85 to 1.83 cubic feet per second (cfs). Discharge measurements collected in September (after significant precipitation) produced a flow estimate of 5.98 cfs. Observations from mine personnel indicate that the section of Bruin Creek below the 'B' Road culvert is a losing reach, especially in winter.

Bruin Creek is a tributary to Greens Creek with the confluence at the southeastern edge of the Site 23/D area. Greens Creek flows east to west at the southern edge of Site 23/D. Greens Creek is a much larger stream than Bruin Creek, and has a USGS gauging station located just upstream of the mine portal, or approximately 0.5 miles upstream of the Bruin Creek confluence. Mean daily flows taken at this station range from 1.9 to 465 cfs and averaged 43.3 cfs from 1990-2001 (USGS, 2003). Drainage area above Site 23/D for the Greens Creek watershed is approximately 8.6 square miles (USGS, 2003).

Surface water flows within the Site 23 and Site D areas result from precipitation and groundwater discharge as springs. The heavily vegetated/forested nature of the hill slope above Site 23/D (typical of the Admiralty Island temperate rain forests), retains nearly all precipitation under normal precipitation conditions by infiltration and vegetative consumption. Surface water originating from within the site is captured in toe ditches around the production rock piles and is collected in one of the two containment ponds,

Pond 23 and Pond D (Figure 1). A lined ditch system conveys runoff from Site 23 along the toe of the facility to Pond 23. A similar, but unlined ditch conveys water collected from Site D to Pond D.

Other surface water features consist of a number of low volume non-contact water springs or seeps, both perennial and intermittent. The locations of the largest springs have been surveyed and are labeled on Figure 1 and Figure 1B. A single perennial spring has been documented within the northeast corner of the Site 23 lease area (Figure 1 - S23NES). Flow from this spring does not contact production rock placement areas and was estimated at 5-10 gpm in July 2002. Flow from the S23NES spring discharges into Bruin Creek.

Eleven springs have been observed on the placed production rock/fill on Site D. Discharges from these Site D seeps are captured in the Site D toe ditch and routed to Pond D. Seven of these springs have been assigned identifying designations. The locations of these springs are designated DS-1 through DS-7 on Figure 1. Within 200 feet of the Site D disturbance limit, to the west side of the Site D production rock pile; another eight springs have been mapped. These native springs (designated 7.9S-1 through 7.9S-7) flow unrestricted to Greens Creek. In addition to the springs shown on Figure 1, during/after significant precipitation events, springs have been noted at a number of locations on the unexcavated back-slope of Site 23. These ephemeral springs flow for several days following rainfall and then gradually decrease as the precipitation charged shallow perched aquifer is depleted. These ephemeral springs are an artifact of storage and re-release of water in the shallow peat and colluvium layers.

4.2.2 Surface Water Management

In general, non-channelized surface water runoff flows at Site 23/D are from north to south. Water that contacts development rock (contact water) is captured, conveyed, and contained for treatment. Non-contact water is allowed to flow following natural drainage features to Bruin Creek or Greens Creek.

Pond 23 and Pond D were constructed primarily as storm water retention structures, but Pond 23 also assists as a holding/storage facility for water from the mill site while Pond D serves a similar function with respect to Site D. Within Pond D, the curtain drain discharge reports to a wet well than conveys the combined Pond D flows and curtain drain flow to the 23 Pump House. From the 23 Pump House the combined Pond D wet well flow is either directed back to the mine/mill complex as a fresh water source for the mill process and/or is ultimately directed to the Pit 5 water treatment plant. These ponds are normally operated at about 30% or less of their capacity, leaving 70% available for storm water runoff from large events. Water collected in these two ponds is pump discharged down to the Tank 6/Pond 6 holding and water treatment facilities at the surface tailings impoundment site via two HDPE pipelines that parallel the main access road (B road), or is pumped back up to the mill for re-use. Following conveyance to Tank6/Pond 6, the water is treated at the Pit 5 water treatment plant and discharged under the approved NPDES permit into Hawk Inlet via the sub-sea discharge diffuser.

Pond 23 also collects water from the finger drains beneath the Site 23 production rock pile. The finger drains are charged by precipitation events and display a relatively rapid time to concentration for waters infiltrating through the production rock pile. This is apparently due to the relatively high vertical hydraulic conductivity of the development rock material estimated at $2.4E^{-4}$ cm/sec. Consequently, it requires a relatively large storm event to produce runoff surface flow from the pile itself except along the access road where continued repeated traffic has increased compaction and fines have effectively sealed much of this traveled surface.

4.3 Groundwater Hydrology

The groundwater flow regime at the site is relatively complex. However, the monitoring well network, long term monitoring data and stratigraphic information derived from exploration, geotechnical and seismic data have provided a means of developing a picture of the groundwater flow dynamics.

The following discussion presents two types of analysis: 1) First, a conceptual examination of groundwater flow at the site. This conceptual model forms the basis for the second step. 2) A quantitative or numeric assessment using potentiometric data, aquifer test results and measured flows from the site. Due to the complexities of the groundwater flow system and geology it was judged that, at this time, a three dimensional groundwater flow model would be difficult to construct and being based primarily upon assumptions and conjectures, it would provide little understanding of the Site 23/D groundwater system.

4.3.1 Groundwater Flow Concepts

An important objective of understanding the groundwater flow regime and dynamics is to use the information for water management considerations. This includes assessing the effectiveness of existing water management features of the site and as a basis for design and construction of future water management features. Among these are the man made structures that control or otherwise convey surface water that contacts the production rock stored at the site, as well as control structures and water management measures that minimize the amount of groundwater that contacts the production rock. This section of the report examines the hydrologic control features that have been implemented and are discussed along with the natural water bearing units that underlie the area.

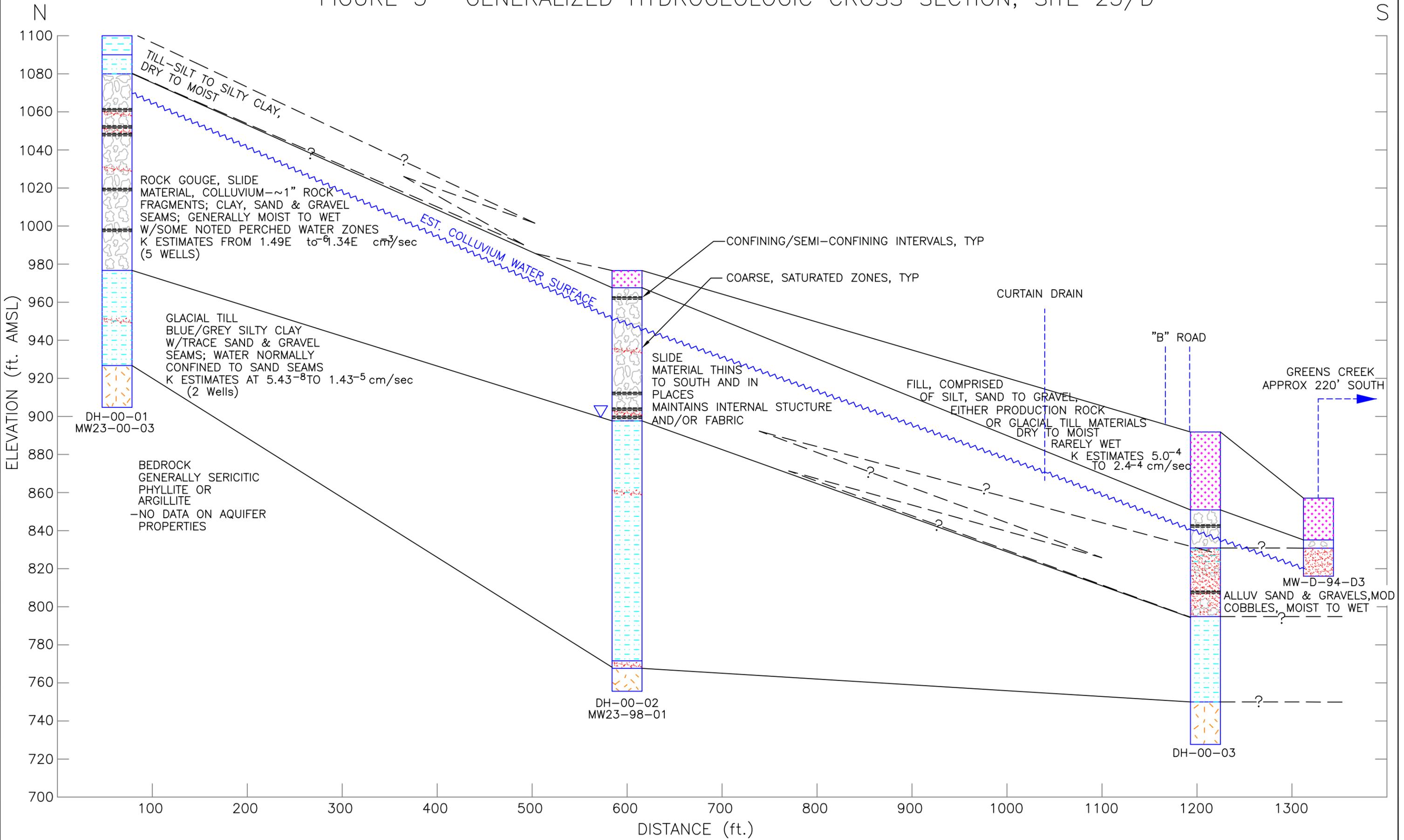
Numerous geotechnical drilling investigations of the sediments underlying Site 23/D have led to a complete lithological classification scheme which has been placed into a robust stratigraphic interpretation. In addition, water quality and piezometric data collection has spanned nearly 15 years at Site D and nearly 10 years at Site 23. The synthesis of these data has led to the identification of six distinct lithological units of which three are of primary importance to understanding flow at the site: the production rock, the colluvium/slide material and underlying glacial till.

The colluvium/slide material underlies the production rock at Site 23 and is thought to have originated on the hill slope above the site. The colluvium forms a lobate feature both beneath and behind the production rock. The colluvium is comprised of

rock fragments that range in size from 4" to house sized blocks. The supporting material consists of lenses of clay to silt/fine sand that provide the sub-confinement of the majority of groundwater in the unit resulting in the characteristic of the colluvium of perched and/or semi-confined water bearing zones, separated by non-continuous lenses of clay material. The most transmissive zones, where the majority of the mass water movement occurs, are in the layers occupied by the coarser intervals. The significance of these perched zones is that the water can move much more easily in the horizontal plane versus vertical movement due to the clay lenses. The result is that the colluvium isolates independent perched layers of water from both above and below. These perched layers are not continuous, which limits the degree of hydraulic connection. The evidence of this perched condition/isolation is observed in the seeps/springs above the site where these zones intercept the surface. It is also observed in monitoring wells completed in different water bearing zones of the slide unit as well as in a number of boreholes that have been observed to display alternating wet and dry intervals through the profile.

In general, groundwater flow in the colluvium is from north to south paralleling/sub-paralleling the mountain slope topography. The apparent recharge area occurs on the mountain slopes above Site 23 through the peat that overlies the colluvium. Groundwater flows laterally along discontinuous perched layers. Where these layers are truncated or pinch out, vertical flow occurs and probably dominates. The vertical flow continues, possibly interrupted by additional laterally limited perching layers, down to a continuous sub-confining layer. This continuous sub-confining layer occurs at the base of the colluvial unit at the contact with the low permeability till stratum. Drilling data suggests that the bulk of the groundwater movement beneath 23/D occurs at this interface. Figure 3 is a conceptual groundwater flow diagram for the area. This figure depicts the flow vectors and thinning nature of the unit from north to south and assists with the concept of alternating lateral and vertical flow to the fully saturated zone at the till/colluvium contact.

FIGURE 3--GENERALIZED HYDROGEOLOGIC CROSS SECTION, SITE 23/D



TILL-SILT TO SILTY CLAY,
DRY TO MOIST

ROCK GOUGE, SLIDE
MATERIAL, COLLUVIUM--~1" ROCK
FRAGMENTS; CLAY, SAND & GRAVEL
SEAMS; GENERALLY MOIST TO WET
W/SOME NOTED PERCHED WATER ZONES
K ESTIMATES FROM $1.49E^{-9}$ to $1.34E^{-9}$ cm^3/sec
(5 WELLS)

GLACIAL TILL
BLUE/GREY SILTY CLAY
W/TRACE SAND & GRAVEL
SEAMS; WATER NORMALLY
CONFINED TO SAND SEAMS
K ESTIMATES AT $5.43E^{-8}$ TO $1.43E^{-5}$ cm/sec
(2 Wells)

BEDROCK
GENERALLY SERICITIC
PHYLLITE OR
ARGILLITE
-NO DATA ON AQUIFER
PROPERTIES

SLIDE
MATERIAL THINS
TO SOUTH AND IN
PLACES
MAINTAINS INTERNAL STRUCTURE
AND/OR FABRIC

FILL, COMPRISED
OF SILT, SAND TO GRAVEL,
EITHER PRODUCTION ROCK
OR GLACIAL TILL MATERIALS
DRY TO MOIST
RARELY WET
K ESTIMATES $5.0E^{-4}$
TO $2.4E^{-4}$ cm/sec

MW-D-94-D3
ALLUV SAND & GRAVELS, MOD
COBBLES, MOIST TO WET

GREENS CREEK
APPROX 220' SOUTH

100 200 300 400 500 600 700 800 900 1000 1100 1200 1300

DISTANCE (ft.)

ELEVATION (ft. AMSL)

1100
1080
1060
1040
1020
1000
980
960
940
920
900
880
860
840
820
800
780
760
740
720
700

S

N

EST. COLLUVIUM WATER SURFACE

CONFINING/SEMI-CONFINING INTERVALS, TYP

COARSE, SATURATED ZONES, TYP

CURTAIN DRAIN

"B" ROAD

?

?

?

?

?

?

?

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?

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Overlying the colluvium at Site 23 is the production rock removed from the underground operations. Consisting of phyllite and argillite fragments, the production rock is fairly homogeneous by rock class and normally dry. Hydrologically, the production rock does not have a saturated zone and does not behave as an “aquifer”. The production rock may transmit water vertically as unsaturated flow to the colluvium where it may encounter the lenses of low permeability material thus forming localized perched water tables as beneath the rock pile described above. Vadose zone flow in the production rock (from infiltration of precipitation) is downward to the finger drain system, which was constructed to prevent the formation of a saturated zone at the contact of the production rock and the colluvium. Water captured by the finger drains is conveyed to storage/transfer at Pond 23 and subsequent treatment at the Pit 5 water treatment plant.

Underlying the colluvium/slide rock at the site is a thick section of glacial till. The till forms a significant barrier to vertical groundwater movement as it is comprised of blue/gray silty clay to thicknesses above 130 feet. The till contains only sporadic, thin intervals of water bearing zones of low hydraulic conductivity and hydraulic pressures that are above the top of the unit. Vertical groundwater flow from the overlying colluvial material is restricted by the low hydraulic conductivity of the till and the groundwater movement then tends to be dominated by a down-slope component along the base of the colluvium/top of till rather than a vertical component through the till.

Several other stratigraphic units at the site include the bedrock which underlies the entire area, and fill material that underlies the production rock at Site D. Though little hydrologic information is available for the bedrock, water is thought to occupy faults and highly fractured zones based upon conditions found throughout the KGCMC mine workings. The thick, low permeability, till sequence isolates the bedrock from the site related groundwater system, therefore no further hydrologic investigative focus has been placed on the bedrock.

Fill material underlies the production rock at Site D and consists of clays, silts and matter excavated in 1987 during the construction of the mill. The colluvium/slide

material thins down-slope to the south, and a transition to alluvial sands of Greens Creek occurs under Site D. This transition, observed in the drilling logs, does not appear to influence water movement at the site and the Greens Creek alluvial system.

Two primary engineered structures manage groundwater at Site 23/D; the curtain drain and the finger drain systems. Both water management structures are shown on Figures 1 and 3. The curtain drain was designed to intercept non-contact groundwater from the underlying colluvium and divert it away from the production rock of Site D. The Site 23 finger drain system receives water that infiltrates through the production rock pile and from springs in the pile foundation. Due to the decreased thickness of colluvium/slide rock under Site D, water that travels past the curtain drain probably flows into the fill/production rock at Site D where it is managed as contact surface water. The springs documented on Site D may be evidence of this phenomenon.

4.3.2 Groundwater Quantitative Analysis

Quantitative analysis of groundwater flows and movement requires data consisting of hydraulic characteristics such as hydraulic conductivity, transmissivity and storage coefficient as well as information about the head levels and gradients. Such data have been collected in wells and piezometers at both Site D and Site 23. Table 4.3 summarizes aquifer testing completed at Site 23/D in 2000 and 2002.

Production Rock

Where water is present in the production rock it exists as transient infiltration and/or isolated perched water table/lens. Head levels are measured in the production rock using 2 pneumatic piezometers and 2 suction lysimeters however, head measurements are consistently at zero. Due to these conditions, aquifer tests were not conducted. The production rock is not an aquifer, nor a feature with continuous saturated thickness that may be monitored or tested as an aquifer.

Fill

Well D-1, completed in both the fill and alluvial sand/gravel, has hydraulic conductivity values of $5.0E-4$ cm/sec. Well D-4, completed in fill and production rock has conductivity values of $2.4E-4$ cm/sec. Since both these wells are multiple

completions, they do not reflect the conductivity of the fill material exclusively, but present a combined conductivity of the units within the screened completion zone. Therefore, the conductivity values cannot be assigned exclusively to the fill material. The behavior of the material by virtue of the presence of springs on Site D that appear to be due to the barrier effect of the fill material forcing groundwater to the surface, suggests that the conductivity of the fill material is significantly lower than the conductivity of the overlying/adjacent production rock.

Alluvium

A single well (D-3) installed in 1994 yielded a hydraulic conductivity estimate of $2.3E-4$ cm/sec. This is a fairly transmissive material and capable of conveying significant amounts of water under nominal gradients.

Colluvium/Slide Rock

Five aquifer tests conducted in 2000 and 2002 within colluvium indicate an average hydraulic conductivity of $2.8E-3$ cm/sec, with a range of $1.5E-6$ to $7.8E-3$ cm/sec. The lowest measured hydraulic conductivity was from a well completed in a shallow or perched zone of the colluvium (MW23-A2S). The colluvium is typically the most permeable material tested at the site.

Glacial Till

Aquifer tests conducted on the two wells completed in the till indicate an average hydraulic conductivity of $7.15E-6$ cm/sec and range from $5.4E-8$ cm/sec to $1.4E-5$ cm/sec. The higher estimate is from MW-98-01 and may be considered in the upper range for the aquifer, similar units at the tailings basin portray much lower conductivities, similar to those seen at MW-00-23-2. The values of E-6 to E-8 cm/sec are at or less than permeabilities associated with engineered, compacted clay liners typically used for wastewater ponds and other structures intended to prevent/minimize water migration.

Bedrock

No aquifer test data are available for the bedrock material, but RQD values ranging from 0% to 100% suggest a wide range of hydraulic conductivities may be

present and preferential pathways in fracture zones would control flow rates and direction. As mentioned earlier, the bedrock is hydraulically isolated by the glacial till, therefore it has not been the focus of groundwater investigation in the Site 23/D area.

Table 4.3 - Site 23/D Aquifer Test Data Summary

WELL	AQUIFER	ESTIMATED AQUIFER THICKNESS	ESTIMATED HYDRAULIC CONDUCTIVITY		ESTIMATED TRANSMISSIVITY	
		feet & cm	cm/s	ft/s	cm ² /s	ft ² /s
MW-94-D-1	Fill/sand & gravel	1.25	5.0E-04	1.6E-05	1.9E-02	2.0E-05
		38.10				
MW-94-D-3 (Site 53)	Alluvium	5.37	2.3E-04	7.5E-06	3.8E-02	4.0E-05
		163.68				
MW-94-D-4	Fill & Waste Rock	6.30	2.4E-04	7.8E-06	4.6E-02	4.9E-05
		192.02				
MW-23-00-2	Till	17.03	5.4E-08	1.8E-09	2.8E-05	3.0E-08
		519.07				
MW-23-98-01	Till	6.02	1.4E-05	4.7E-07	2.6E-03	2.8E-06
		183.49				
MW23A2S	Colluvium	4.19	1.5E-06	4.9E-08	1.9E-04	2.0E-07
		127.71				
MW23A4	Colluvium/Alluvium	12.78	1.3E-03	4.4E-05	5.2E-01	5.6E-04
		389.53				
MW23A2D (Site 50)	Colluvium	17.33	7.8E-03	2.6E-04	4.13	4.5E-03
		528.22				
MW-23-00-3 (Site 57)	Colluvium	42.02	3.7E-03	1.2E-04	4.73	5.1E-03
		1280.77				
MW-23-00-1	Colluvium/Alluvium	8.71	1.4E-03	4.4E-05	3.6E-01	3.8E-04
		265.48				

Hydraulic heads in the production rock and fill material are minimal. Pneumatic piezometers and wells installed in the units indicate little to no saturation/pressure in Site 23 production rock and very low pressure in Site D production rock. Drilling demonstrates no saturated zone in the production rock of Site 23. Appendix A contains life-of-well hydrographs for wells and piezometers at Site 23/D. Contour maps of water elevation in the fill material were unnecessary due to the absence of water.

Water levels measured in wells completed in the alluvium; D-1, D-3, MW23-A4, and DH-02-16A show hydraulic heads from as little as several feet (D-1 & D-3) to as much as 21 feet in DH-02-16A. Head differences are often reflective of differing completion depths. Figure 4 shows the potentiometric surface of the alluvium and colluvium at the site. These units were contoured together due to stratigraphic and hydraulic similarities as well as potential communication.

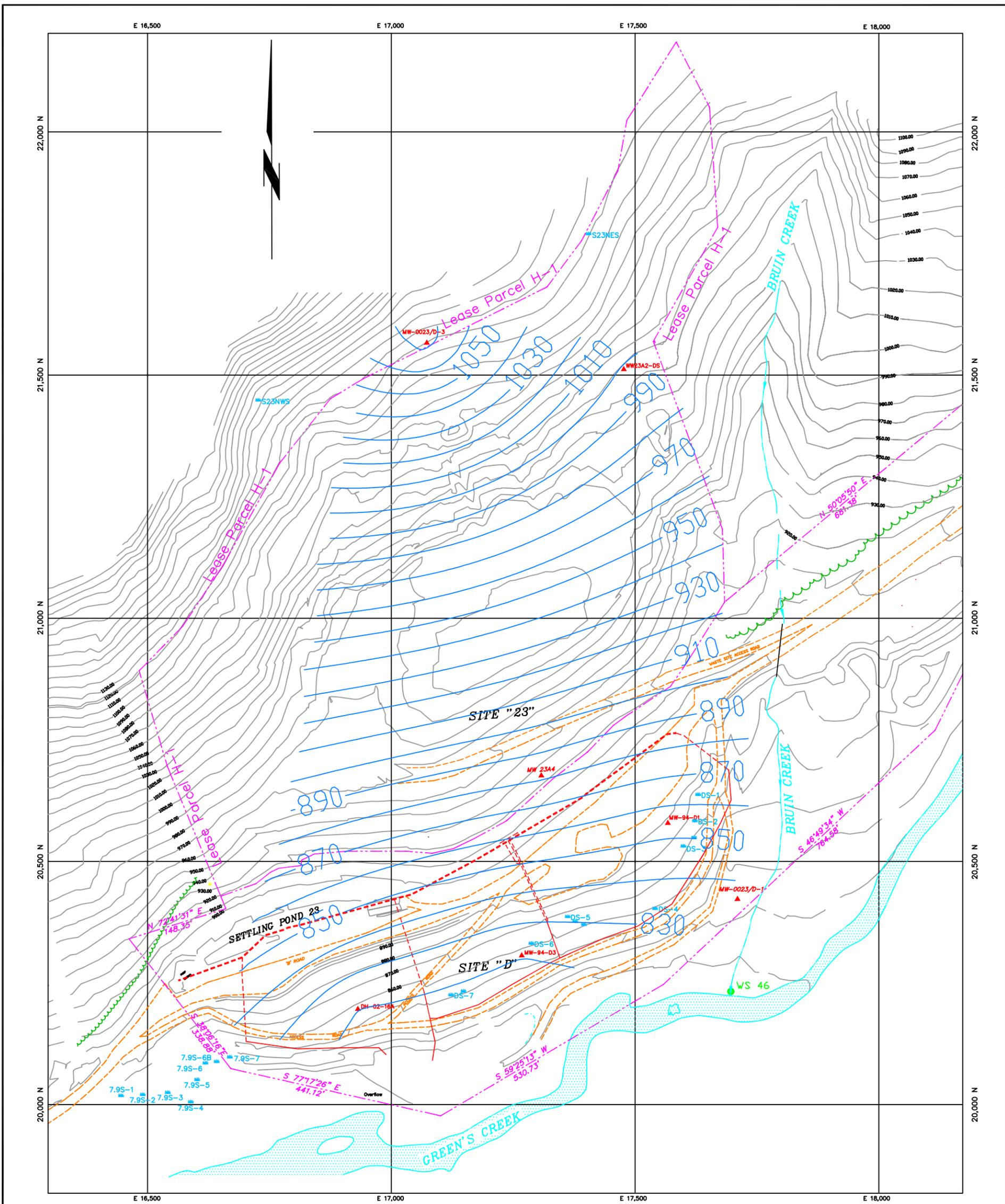
Hydraulic properties of the colluvium are highly variable, which is a reflection of the variability of the lithology of the material itself. Well MW0023-3, upslope from Site 23, indicates substantial pressure, with nearly 40 feet of head within the unit. This is not to say that the pressure is 40 ft. above the unit, but that there is a confined layer within the unit exhibiting this degree of pressure due to confinement by overlying and underlying low permeability materials. Well MW0023-3 water levels have varied approximately 5 ft. over the life of the well, potentially due to influence from surface water infiltration due to precipitation. Though showing less pressure head, MW23A2D displays substantial fluctuation, with more than 8' of variation over the life of the well. The shallow colluvial offset well, MW23A2S, shows nearly 4.3' of water level fluctuation over the life of the well, again most likely from recharge rate fluctuations from surface water combined with the perched water table conditions. Examination of the life of well hydrographs (Appendix A) show that between wells MW23A2D and A2S (upslope from Site 23) there is approximately 15' of head difference. This is another indicator of semi-confined perched zones.

With only two wells completed in the till, potentiometric contouring is not possible; however, both data points indicate confining pressure within the unit (ie: the pressure head is above the top of the till/colluvial contact elevation). Well MW0023-2, on the east side of Site 23 (Figure 1), has over 24' of confining head, while BH23-98-01 on the pile indicates several feet of confining head. These pressures combined with very low permeabilities again suggest the till is a significant barrier to downward groundwater movement.

Hydrologic Control Structures

Curtain Drain

The colluvium is a complex hydraulic system. As described above, discontinuous layers of saturation due to vertical segregation by low permeability



LEGEND:

- ▲ PIEZOMETER/WELL
- LEASE BOUNDARY
- 10' CONTOUR LINE
- STREAM CHANNEL
- ROAD
- CURTAIN DRAIN
- CURTAIN DRAIN OUTFALL
- 7.9S-4 SEEPS/SPRINGS
- COLLUVIUM POTENTIOMETRIC ISOPLETHS C.I. = 10'

FIGURE 4

KENNECOTT GREENS CREEK MINE
ADMIRALTY ISLAND, ALASKA

SITE 23/D
COLLUVIUM POTENTIOMETRIC
SURFACE 2003

DATE: 03/04/04
DRAWING BY: RWH
DESIGN BY: RWH
REVIEWED BY: RWH
PROJ OR REF: ----

EDE Consultants
Environmental Engineering / Hydrology / Water Resources Engineering
23 North Scott St., #23 Sheridan, WY 82801
PHONE: (307) 672-3793

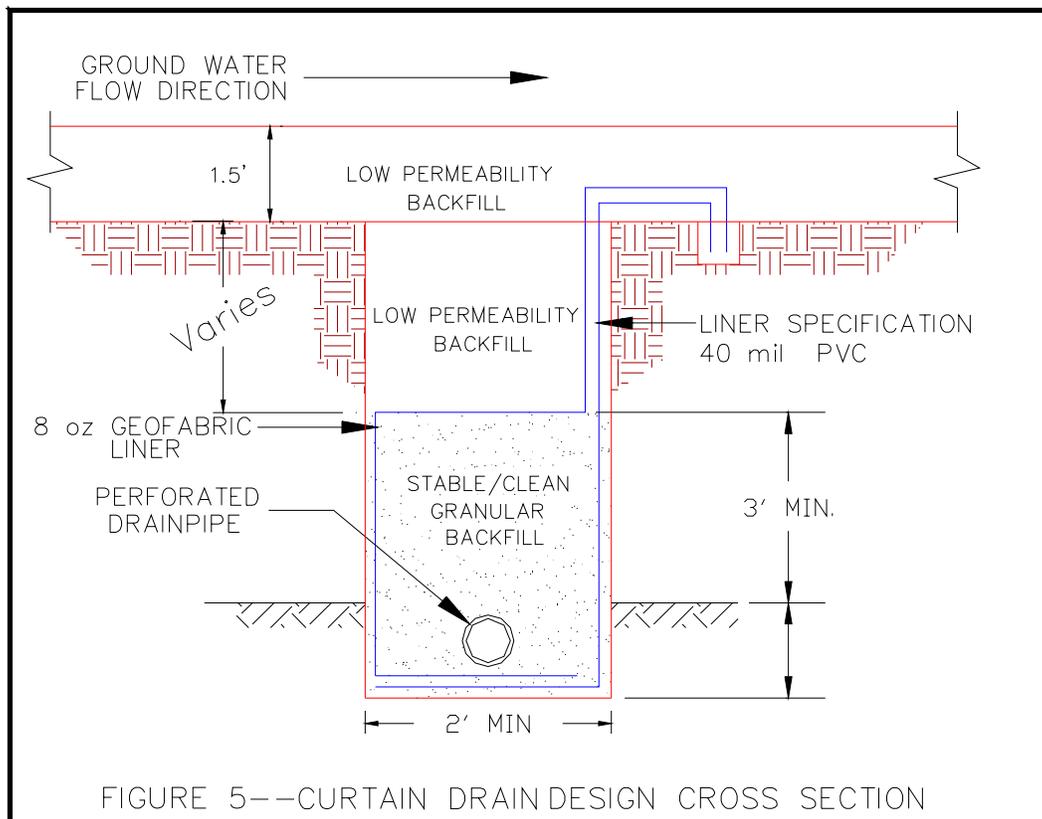
EDE DWG: site 23 base map.dwg

SCALE: 1" = 200'

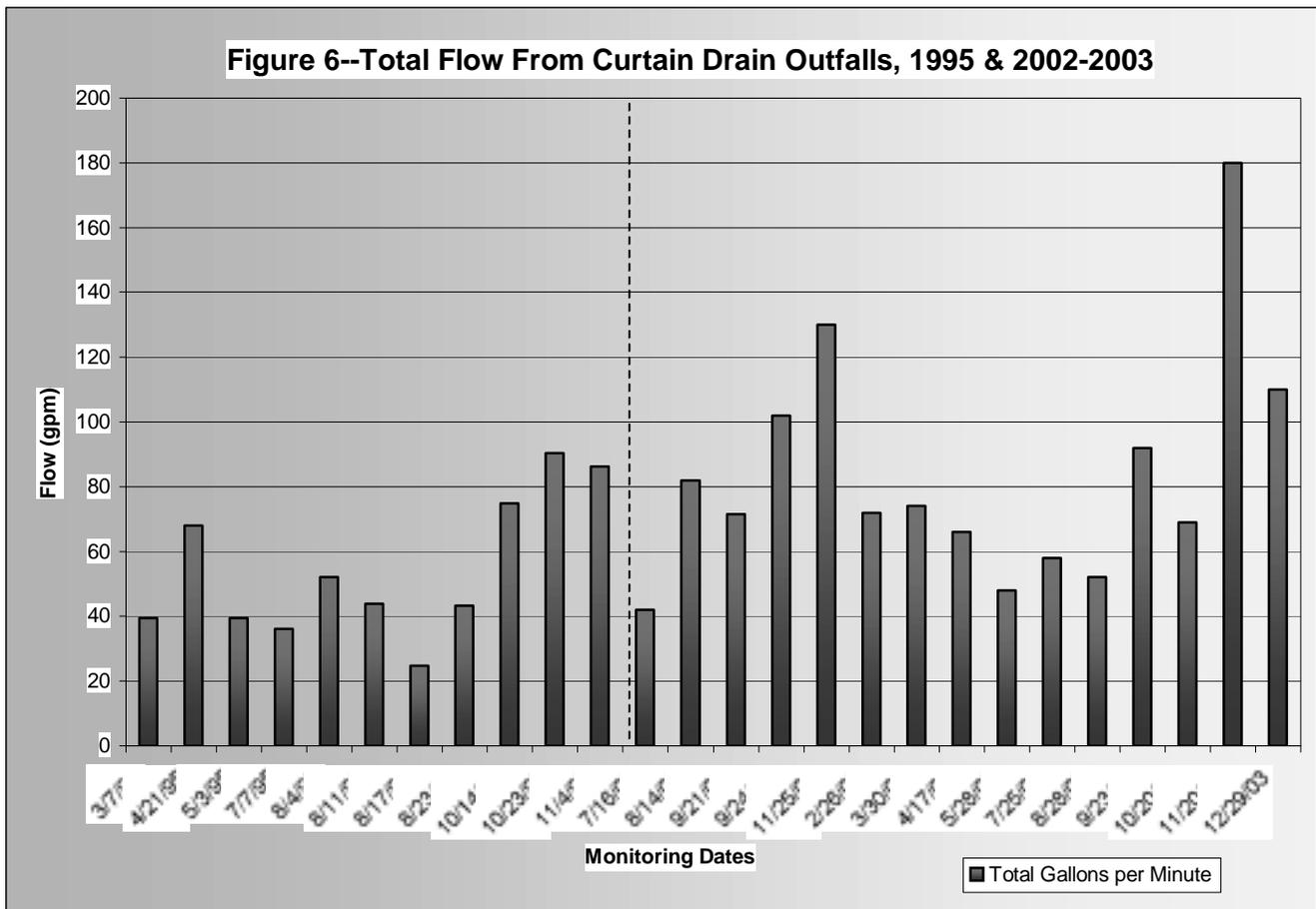
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layers characterize the colluvium/slide material. Conceptually, full vertical saturated thickness cannot be assumed. If one were to assume full saturation, then the associated flow volumes would be grossly over estimated. To assess curtain drain function, a quantitative assessment of curtain drain flow was conducted and compared against measured drain discharges. This computation requires establishment of some fundamental attributes of the system.

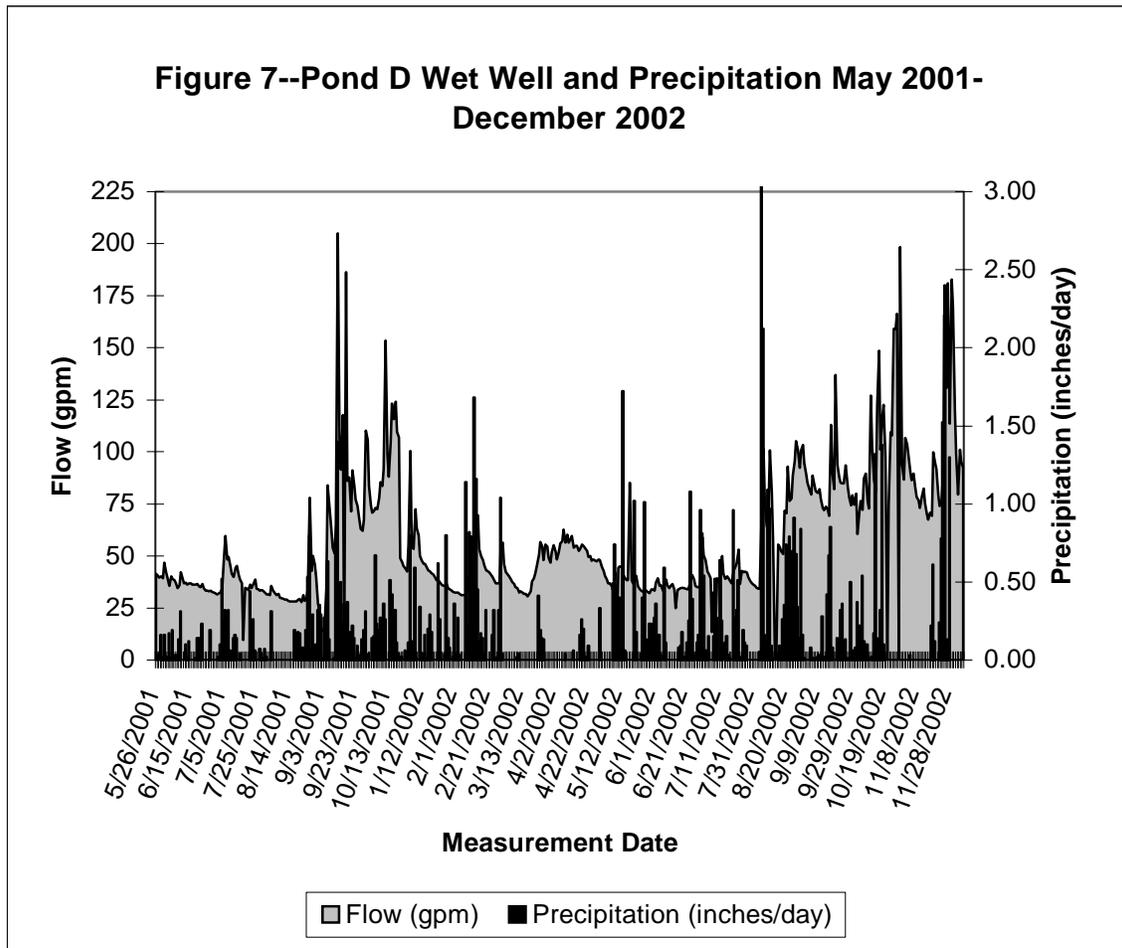
Constructed in 1994, the curtain drain under the toe of Site 23 and up-gradient of Site D, controls groundwater under the pile. The curtain drain consists of an excavated trench, lined with filter fabric and backfilled, first with clean granular backfill, then with a mixture of low permeability colluvium, till & production rock material, the granular backfill surrounds an 8" perforated corrugated metal pipe (CMP). Drainage from the pipe is handled by 6" or 8" HDPE outfall pipelines tied into the CMP at the four low points along the structure. Down-gradient tie-ins were constructed of 40 mil PVC liner, and the entire structure was covered with 1.5 ft. of low permeability backfill. Figure 5 is a design cross-section through a typical portion of the curtain drain.



Following installation of the curtain drain, KGCMC personnel closely monitored flow and water quality from the drains. Figure 6 portrays total flow measurements from the drains in 1995 and 2002. Flow increased in the fall of 1995 and was very consistent with flows measured in 2002. Today, the drains are piped together so that individual flows cannot be measured. However, the consistency seen between 1995 and 2002 would indicate that the system is intact and continues functioning as designed. Average flow for the curtain drain outfalls from 1995 and 2002-2003 was 71 gpm while the peak observed flow was 180 gpm. Similar to the upslope colluvium wells, the curtain drain outflow responds rapidly to precipitation events. Drain discharge measurements were taken in July 2002 following 6.9 inches of precipitation over the previous 28 days and showed a flow rate of 42 gpm. Measurements in August after 10.43 inches of precipitation in the previous 28 days showed the flow rate nearly doubled to 82 gpm.



Flows from the Pond D (the curtain drain flows discharge to Pond D) wet well, also increase after precipitation. There are other contributions to the wet well influent other than curtain drain flow (i.e. flow from Pond D, D pile finger drains), however, the majority of flow into the well comes from the curtain drain outlet. Figure 7 is a time series plot of Pond D wet well flow and precipitation during 2001 and 2002. Examination of the data shows that with a number of rainfall events (especially those exceeding 0.40 inches), flow from the wet well increased, and often after very little lag time (<24 hours). This response pattern suggests a competent system that intercepts the shallow groundwater flow and conveys it for treatment and discharge in response to seasonal recharge rate fluctuations.



Another indication of system effectiveness is the continued lack of hydraulic head in Site 23/D wells and piezometers that are completed in

production rock or underlying colluvium/alluvium units. The low head demonstrates a free draining pile and well drained conditions beneath.

A total of 14 flow measurements, 11 in 1995 and 15 in 2002-2003 are available to assess the effectiveness of the drain. The base flow rate appears to be between 25 gpm and 40 gpm, and the average is about 71 gpm as discussed above. Due to the limited number of measured flows from the drain, system performance/efficiency was estimated/verified by computation. The estimate was developed by applying Darcy's Equation to the aquifer up gradient of the drain. Darcy's equation states: $(Q = KIA)$, where: (Q) = Flow rate, (K) = hydraulic conductivity, (I) = aquifer gradient, (A) = cross-sectional area of saturated zone. First some basic assumptions and computations were made. These assumptions are stated below with the computations. Then, the gradient was computed from the potentiometric surface maps, the aquifer cross sectional flow area was computed from the drain length and average saturated thickness of the aquifer (as determined from drilling and piezometer data), and the hydraulic conductivity was derived from aquifer test data. The calculated flow/flux through the aquifer system is then compared to the measured discharge rates from the curtain drain to determine the capture efficiency of the drain. The capture efficiency is determined under the presumption that the computation accurately estimates the total groundwater flux rate, and the drain flow rate reflects the capture of some portion of that total.

Aquifer Mass Flow Rate

This computation assumes a scenario without the curtain drain, to determine the total average flow rate through the colluvium beneath Site 23/D. This flow rate will be compared to the mean measured flow rate from the curtain drain. From this an estimated capture efficiency of the drain is computed.

This computation uses the following input values:

Hydraulic Conductivity: The hydraulic conductivity is based upon the average of 5 aquifer tests conducted on wells at Site 23. The average colluvial hydraulic conductivity used was $7.6E-5$ ft./sec.

Hydraulic Gradient: The gradient was computed from the potentiometric surface map of the colluvium and determined to be 0.18 ft/ft.

Area: The cross sectional flow area is the saturated thickness of aquifer material multiplied by the section distance perpendicular to the flow path-lines beneath the development rock pile (1150 ft.) and the apparent average saturated thickness of approximately 14.4 ft.

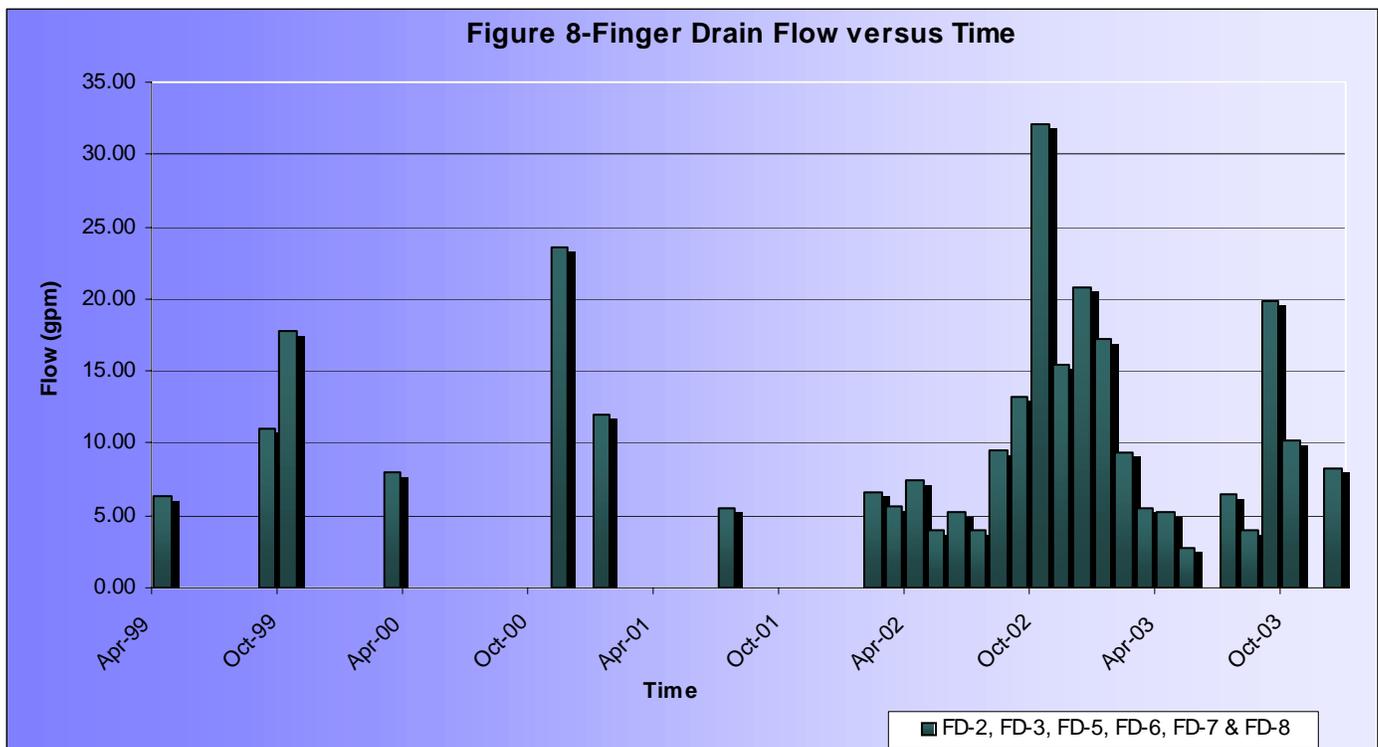
Using the above assumptions and numeric inputs the mean colluvial flow is estimated by using Darcy's equation to be approximately 102 gpm. Compared to the mean measured flow of 71 gpm from the curtain drain, this is a reasonable match. It may suggest that some portion of flow may not be captured by the curtain drain; however the computed capture efficiency is approximately 70%. It is recognized that the computation is a gross estimate, but is based on field measured values for gradient, length, and hydraulic conductivity. The component of flow not collected by the Curtain Drain is intercepted at the D site by the D pond at the toe of the D site pile. Documentation of no significant influence from Site 23/D at monitoring points in Greens Creek down-gradient from the site supports this conclusion (FWMP, 1998).

Finger Drains

Underlying the production rock at Site 23 is a system of finger drains. The locations of the finger drains are shown on Figure 1 and 1B. The locations of the drains are designed to prevent water accumulation in the production rock pile and to intercept groundwater flow into the overlying rock material at the contact of the production rock ($K= 2.4E-4$ cm/sec) and apparently somewhat less

permeable colluvium (1.5E-6 cm/sec to 7.8E-3 cm/sec). This acts to enhance geotechnical stability. The finger drains are constructed concurrently with back-slope excavation using 6" slotted HDPE pipe bedded in gravel/rock and added in sections progressively upslope from the active placement area. There are currently a total of 8 finger drains, of these; six are constructed with lateral lines to increase effectiveness. Collectively, the length of these drains is currently approximately 4,500 ft. These drains all have alpha-numeric designations of FD-1 through FD-8 for management and sampling purposes.

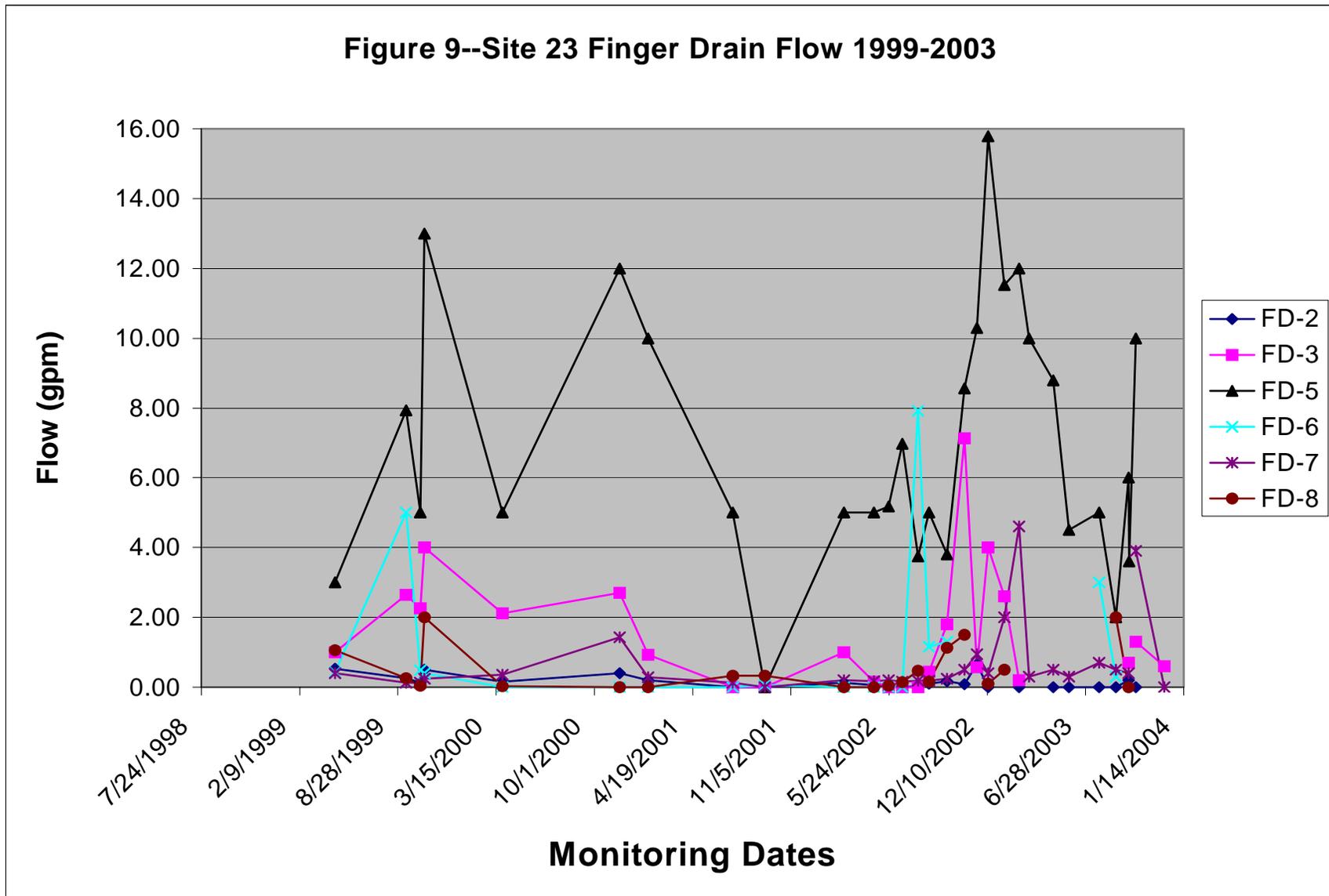
These drains discharge to the lined ditch paralleling the "B" access road at the toe of Site 23, through which the flow is conveyed to Pond 23. Flows from the drains are normally quite low (less than 2 gpm), with the exception of FD-5, which collects water from an excavated spring. Discharges from FD-5 average approximately 7 gpm, but has ranged from zero flow prior to tying in the spring flow to a peak of 16 gpm. Historic flow monitoring of the drains indicates total flow ranges from 4 gpm to 32 gpm, with an average of 10.5 gpm. Figure 8 plots total finger drain flow over time while Figure 9 shows individual finger drain flows



over time. Similar to other aspects of the site, the finger drain system responds rapidly to precipitation.

Infiltration through the production rock, runoff from the back-slope and an increasing groundwater component during and after rainfall events result in an increase flow response in the finger drains.

The finger drain flow measurements were modeled by conducting a simple computation of the flow using the production rock site surface area and precipitation. Based on the 11 acres of exposed production rock (2003 surface area) and an annual 2.2 feet (26.4 inches) of infiltration (40% of annual precipitation of 66 inches), an annual average flux of 15.0 gpm is expected. The conservative assumption of 40% infiltration is based upon an estimated runoff coefficient (curve number) of 60 derived from published industry standard references for estimating surface condition and runoff coefficients (B.J. Barfield, R.C. Warner, C.T Hahn, 1981). It is known that FD-5 contributes a large portion of this flow and that FD-5 was constructed such that it intercepts a known spring (now buried). To correct the captured flows to reflect infiltration/contact water flows, it is necessary to subtract the known spring water flows from the total modeled flow rate (15.0 gpm – 8 gpm = 7 gpm). Correcting the flows yields a modeled flow of approximately 7 gpm contact water from the drains as compared to the average total monitored/measured flow of 10.5 gpm. Adjusting the measured flows to account for approximately 8 gpm of non-contact spring water, the total measured contact water is approximately 2.5 gpm. This suggests that the finger drains capture approximately 17% of the estimated infiltration. The absence of water or pressure build-up in piezometers monitoring the production rock indicates free draining conditions, which, although capture appears to be 17% of total infiltration, suggests that the finger drains function sufficiently to prevent the formation of a saturated water table within the production rock. Life of well hydrographs plotted for the monitoring piezometers are presented in Appendix A.



5.0 Site D Relocation Alternatives

Recent investigative field work and data analysis associated with hydrology, geochemistry and geotechnical stability suggest that there may be long term advantages to relocating the production rock placed at Site D. These considerations include:

- The ability to recover the Site D glacial till fill material, which may be suitable reclamation/cover material for Site 23.
- Creation of additional buffer distance between production rock placement (Site D) and Greens Creek.
- Creation of additional area between Site 23 and Greens Creek for reclamation features. (Closure/Post-closure conditions are addressed in Section 6 of this report).
- Elimination of potential geotechnical stability risk associated with Site D fill (glacial till) material.

Field work and data analysis is continuing to identify potential risks and benefits associated with either leaving the site at the current location or moving the material elsewhere. The decision as to whether Site D will be relocated is at the discretion of KGCMC based upon the results of technical and economic factors not fully quantified and evaluated in this report. However, should Site D material be relocated, some aspects of the hydrologic regime associated with the site will be altered and this is addressed below.

Should the decision be made that it is advantageous to move the Site D production rock, the fill material underlying it could be separately handled. Depending upon the physical and chemical quality/suitability of this material, it may be used for reclamation materials as appropriate. The alluvial sands underlying both the fill material and the production rock are not anticipated to be disturbed.

The potential hydrologic changes if Site D is relocated involve both surface water and groundwater aspects of the site. With respect to surface water, the amount of runoff from the surface area of reclaimed production rock

would be expected to decrease, but the total runoff from the site would not change measurably as the unchanged Site D area footprint will still generate runoff. The reclaimed surface of the alluvium underlying Site D would be expected to have similar vegetation, topsoil/growth medium conditions as the cover materials now present at the site and therefore similar infiltration and runoff characteristics. Differences might include an increase in infiltration due to flattening of the topography, which results in proportionately lower runoff volumes. The removal of overlying compacted production rock and the cover materials would “unload” the alluvium and tend to eliminate potential confining or semi-confining conditions associated with the overburden on the alluvium.

Potential water quality changes associated with the relocation of Site D material may not be measurable with respect to actual or detectable effects on Greens Creek or the Greens Creek alluvium. Currently, environmental monitoring of Greens Creek water quality (Sites 6 and 54) demonstrates that effects from Site 23/D are negligible. The removal of the production rock would not be anticipated to have any negative water quality effects and may reduce the risk of water quality effects by eliminating water contact and transport through the production rock and potentially to Greens Creek and the Greens Creek alluvium.

As discussed previously, Site D has approximately 7 seeps down the lower half of the slope toward Greens Creek. These seeps (DS-1 through DS-7, Figure 4) are present along the southern and eastern side of Site D. Examination of Figure 4 and comparison of the intersection of the water table with the elevation isopleths at the location of the seeps show that they are approximately 30 ft. to 40 ft. elevationally higher than the apparent water table as depicted in Figure 4. The discharge from these seeps from the elevational relationships is clearly not colluvial water, it is most likely local infiltration into the production rock and horizontal migration along a compacted or low permeability layer such as the fill/production rock interface or a truck haulage roadway or similar feature, now incorporated into the core of the pile. Removal and relocation of the Site D production rock would eliminate the existence of these local seeps. Additional natural springs have been mapped just west of Site D at

the toe of the hill slope within the Greens Creek channel flood plain. These springs appear to be native colluvial aquifer discharge. The relocation of the production rock from Site D would not be expected to affect these seeps.

6.0 Closure and Post Closure Hydrology

Upon full build-out of the Site 23 production rock area, which is not anticipated to occur before the ultimate cessation of underground mining, the site will under-go a transition from active placement, to active closure construction activity, to a post-closure steady state condition with respect to hydrology and geochemistry. The following discussion is not intended to provide a detailed closure plan or closure schedule. The following provides a narrative of the expected hydrologic regime changes during the transition from active site to full closure. The changes in hydrology include the surface water hydrologic regime and the groundwater hydrologic regime. With respect to Site 23/D, one affects the other.

Following the completion of production rock placement activities, the site will be graded and contoured to establish the closure/post closure geometry for the pile. An earthen cover layer is to be constructed covering all production rock. The cover system currently being monitored at Site 23 is designed to be a water balance cover. It is a multiple layer cover that has many purposes and objectives. The principal objectives are to maintain a saturated soil barrier that is in balance with infiltration, and evapo-transpiration such that it minimizes the infiltration and provides an oxygen influx barrier by virtue of the maintenance of a saturated zone within the cover clay layer. The specific physical construct of the cover and the projected performance along with a detailed discussion of the functioning of a water balance cover is presented in (USEL 1998 and O'Kane, 2002). The upper layer of the cover will be constructed as the growth media layer. The growth layer will be seeded with a select seed mixture for the site. The initial cover has demonstrated that rapid and vigorous vegetative establishment may be expected. The hydrologic response during reclamation and following reclamation is discussed below.

6.2 Surface Water

The surface water hydrology of the production rock pile is determined by the grading plan and the establishment of vegetation. The conveyance and quantity of runoff is dictated to a great degree by the soil type, vegetative cover,

slope shape, slope steepness and slope length. During the re-grading phase and prior to the completion of the cover, the runoff rate in the relatively coarse production rock may be relatively low owing to higher infiltration. Upon completion of the cover but prior to establishment of vegetation, the runoff volumes would be higher than raw production rock due to the finer grained nature of the soils, the surface/slope grading and the minimization of depressional water storage/catchment. During the short period of bare growth media, it would be expected that the runoff water quality may be slightly higher in sediment (though this has not been observed with the existing cover) and would require capture and sedimentation, but otherwise of acceptable chemical quality.

Finally, upon establishment of a vigorous and self sustaining stand of vegetation, the runoff volumes would be reduced compared to bare soil, but much greater than raw production rock. The vegetation provides soil stability and transpiration of soil water from the root zone. The stabilization of the soil will reduce the sediment concentrations to be equal to native runoff of undisturbed meadow areas. Chemical water quality would be improved over water that has contacted production rock and is expected to be equal to adjacent native meadow areas. No capture and treatment would be required at this post closure stage.

The annual runoff yield from the cover is expected to be the total annual rainfall amount, minus the infiltration, minus the evapo-transpiration. The maximum infiltration is expected to be 15%. The evapo-transpiration would account for an additional approximately 15%. The runoff volume would then be approximately 70% of the annual rainfall or about 46" (3.8 ft.) per year. From the full build-out Site 23 pile geometry of 20.7 acres, this is approximately 25.6 million gallons of runoff or approximately 78 acre-ft. Converted to a mean daily flow value this is approximately 49 gpm of non-contact runoff water.

6.2 Ground Water

The ground water hydrology of the production rock pile under closure and post closure conditions may be altered somewhat from current conditions. This may be due to the amount of water that will contact the production rock via

infiltration. The current infiltration rate of raw, placed as-is, or compacted production rock has not been directly measured. Observations at the site imply that the infiltration is relatively high as evidenced by relatively low runoff volumes reporting to settling pond 23 from the pile. This estimate is, however, a non-quantitative observation. To quantify the current infiltration rates and assess the potential effect of reducing the infiltration rate on the colluvial aquifer due to covering, it is necessary to make assumptions based upon the characteristics of the raw production rock. The raw production rock is relatively coarse ranging in size from clay size to small boulders up to 18", but is dominated by materials in the 2" to 8" range. Such materials have very high hydraulic conductivity and therefore high infiltration potential. The exceptions to this are the roadways that are traveled by large loaded trucks and result in mechanical crushing and compaction of the rock. The permeability and infiltration rates on these travel routes are likely to be several orders of magnitude less than areas outside of haulage truck roadways.

The piezometric data from wells show the free draining nature of the production rock, also an indication that water moves freely within this material. Post closure infiltration rates are determined by the effectiveness of the cover soils/materials, and the establishment of vegetation. The cover is designed with the objective of achieving between 5% and 15% net infiltration of precipitation through the cover into the production rock. It is expected that the annual infiltration rate of the completed and vegetated cover will be between 5% and 15% of annual precipitation. The average annual precipitation for the 920 area, immediately up the B road and adjacent to Site 23/D, is approximately 66 inches per year. At 5% increments from 5% to 15% of that amount is:

5% = 3.3" per year net infiltration

10% = 6.6" per year net infiltration

15% = 9.9" per year net infiltration

The area of Site 23 at full build-out is planned to be approximately 20.7 acres. The current area of Site D is 7.7 acres. Using these values as inputs for the

computation of the water flux through pile, and covered production rock pile, the flux rates are estimated to be:

Table 6.2—Calculated, Post-Closure Infiltration Volumes for Site 23/D

infiltration %	annual ppt (in)	depth (in)	area (acres)	volume (gal per year)	flux (gpd/sqft)	discharge (gpm)	
5	66	3.3	28.45	2,549,203.07	0.01	4.85	Site 23 and D Combined
10	66	6.6	28.45	5,098,406.15	0.01	9.70	
15	66	9.9	28.45	7,647,609.22	0.02	14.55	
5	66	3.3	20.73	1,857,468.53	0.01	3.53	Site 23 only
10	66	6.6	20.73	3,714,937.06	0.01	7.07	
15	66	9.9	20.73	5,572,405.59	0.02	10.60	

The discharge values above are the theoretical continuous flow rate of water that would exit the production rock and be captured by either the finger drains or the curtain drain. Maximum case is 15 gpm. Under the scenario of Site D relocation, the Site 23 flow range is 4 gpm to 11 gpm. It is estimated that the finger drains capture approximately 17% of infiltration prior to entering the colluvium and therefore potentially the colluvial aquifer. That reduces the respective discharge values above to a range of 3 gpm and 12.5 gpm. The 17% capture of infiltration water via the finger drains is contact water and may require additional water management. Note also that post closure infiltration rates may be too low to promote flow into drains.

The remaining 83% of net infiltration will progress through the colluvium and encounter the curtain drain. The colluvial groundwater flux beneath the pile was estimated at a mean of 102 gpm. Assuming complete mixing with the production rock infiltration water that evades capture by the finger drains the mixing ratios are:

- 102 gpm freshwater to 12.5 gpm contact water and;
- 102 gpm freshwater to 3 gpm contact water.

The curtain drain was estimated (Section 4.3.2) to capture approximately 74% of the groundwater flux through the colluvium. By proportion then, there may be slightly more than 1 gpm of the infiltrative water remaining in the aquifer

system; however this will be blended with native colluvial waters, not as discrete discharge water.

The water components of the hydrologic system including the annual runoff volume and rate, colluvial underflow, finger drain captured infiltration, colluvial commingled infiltration and curtain drain captured commingled colluvial water are all quantified above. In summary, waters in direct contact with the production rock amount to a maximum of 3 gpm to 12.5 gpm. Non contact waters (102 gpm total – 12.5 gpm contact + 49 gpm surface) total approximately 138.5 gpm (including the surface water runoff component).

7.0 Hydrology Summary and Conclusions

In summary, the Site 23/D area encompasses 6 geologic and hydrologic units including the production rock. Five of these units play a role in the management of water at Site 23/D. The most significant of these are the production rock, the colluvium and the glacial till. Understanding the hydrologic characteristics of these units is critical to site water management. Greens Creek Mining Company has constructed a hydrologic monitoring system that has been progressively phased with site development. This system includes surface water monitoring sites, wells, and piezometers. Current understanding from recent additional data acquisition has provided an understanding of the hydrology and the performance of water management efforts.

The production rock is free draining and contains no apparent saturated zone. The colluvium contains perched tables of water and semi-confined discontinuous water bearing zones in the upper profile. The lower colluvium is underlain by very low permeability glacial clays which form a sub-confining layer resulting in a basal saturated zone in the colluvium. Groundwater, if any, in the bedrock plays no role at the site due to the confining glacial clays, and as such, has not been investigated. The production rock and the colluvium respond rapidly to hydrologic events such as snowmelt and rainfall, indicating very local recharge and discharge.

Direct precipitation runoff from the production rock is captured and conveyed by a system of lined ditches. Groundwater ingress to the site is captured and managed by a curtain and finger drain system. Infiltration through the production rock is captured and managed by the finger drains. Comparison of historic versus modeled flow from the finger drains and the curtain drain indicate they are performing as designed and as necessary. On going monitoring of the hydrology and the water management system will continue to gather information about the hydrologic regime in and around the site.

8.0 Geochemistry

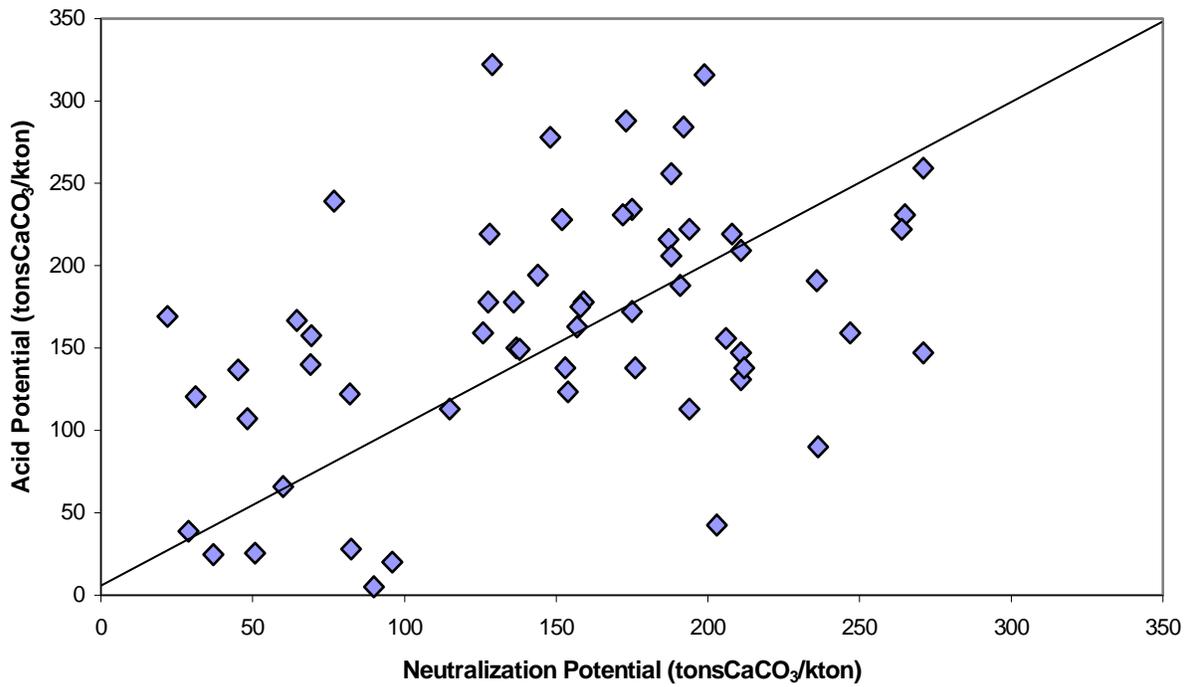
This section provides an overview of the chemical composition of Site 23/D production rock, surface water and groundwater. It includes a description of existing conditions and predictions on how water compositions are expected to evolve following closure of the site.

8.1 Solids Characterization

Materials in Site D below (south of) the B Road consist of relocated till from excavation of the mill site, un-segregated production rock and quarry rock. The relocated till occurs as a wedge-shaped panel, which is buttressed at its toe by a rock containment berm. The containment berm forms the up-hill (north) flank of Pond D, which is encircled by a smaller rock berm. Both berms are comprised of a mixture of inert and pyritic rock types. The till is covered by a layer of production rock that is about five feet thick near the top of the containment berm and reaches a maximum thickness of approximately 30 feet up-slope near the B Road. The production rock is overlain by a two foot layer of grass covered till and colluvium.

A summary of the geochemical characteristics of the relocated till, colluvium and production rock is presented in Table 8.1. Figure 10 summarizes the acid base accounting data for 44 samples of production rock collected from Site D while Figure 11 indicates the acid base accounting for 213 samples collected from the underground mine workings at Site 23. The results of the geochemical analyses described here and in Shepherd Miller 2000, KGCMC 1995a, KGCMC 2003b indicate that the production rock has net acid generating potential, but has a significant amount of carbonate, which retards the onset of acid generation. Trace metal concentrations of the production rock are enriched relative to crustal averages. The combination of acid generation potential and potential for metal mobility necessitates reclamation objectives that minimize oxygen and water contact.

Figure 10--Site D Acid Base Accounting Data

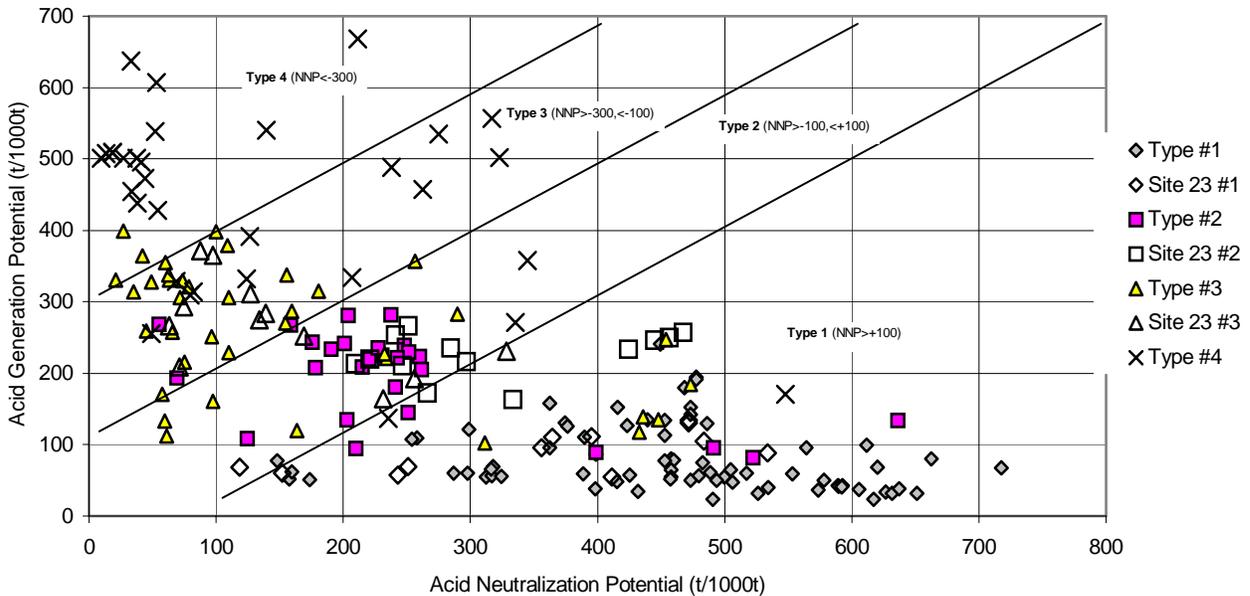


Materials in Site 23 above the B Road consist primarily of segregated production rock. This portion of the site contains approximately 754,571 tons of Class 1, Class 2 and Class 3 production rock placed through December 31, 2003. Table 8.1 presents the average composition of each of the production rock classes.

Table 8.1—Average Composition of Till, Colluvium/Slide Material and Production Rock

Parameter	Till	Colluvium	Site D Production Rock	Class 1		Class 2		Class 3		Class 4
				Site 23	Rib	Site 23	Rib	Site 23	Rib	Rib
Number (n)	1	1	59	13	73	14	27	13	38	35
Acid Potential (t/1000t CaCO ₃)	11	2	164	88	79	225	196	260	261	463
Neutralization Potential (t/1000t CaCO ₃)	50	19	150	359	455	310	248	154	157	134
Net Neutralization Potential (t/1000t CaCO ₃)	39	17	-14	271	375	85	52	-106	-105	-329
Lead (wt%)	0.005	0.004	0.18	0.22	0.15	0.54	0.14	0.44	0.38	0.29
Zinc (wt%)	0.016	0.005	0.29	0.28	0.21	1.20	0.06	0.98	0.70	0.91

**Figure 11--2001-2003 Underground Rib Samples
 & 2002-2003 Site 23 Quarterly Samples**



8.2 Surface Water and Groundwater Compositions

The characteristics of the site's surface and groundwater hydrology are presented in Section 4. For detailed discussions of the monitoring of surface and groundwater sites associated with Site 23/D see the 2002 KGCMC Freshwater Monitoring Plan Annual Report (KGCMC 2003a) and the Tailings and Production Rock Site 2002 Annual Report (KGCMC 2003b). The following sections provide an overview of the site's geochemical conditions and provide supplemental information to that discussed in the annual reports.

The conductivity of waters from several sites is discussed below because it serves as a good indicator parameter for evaluating temporal changes at a site and differences between sites. Other geochemical constituents are used where necessary to test or support conclusions drawn from the conductivity data.

8.2.1 Surface Waters

Bruin Creek and Greens Creek bound the site to the east and south, respectively and do not receive surface drainage from Site 23/D. Conductivity data for sample sites on Bruin Creek and Greens Creek are shown in Figures 12 to 14. Figure 12 compares the conductivities recorded in Bruin Creek above Site 23/D (Sites 44 and 49) and below it (Site 46). Note site locations are portrayed on Figure 1B. Values range seasonally between 50 and 225 uS/cm, and there is little difference between the up-gradient and down-gradient sites. This indicates that effects from Site 23/D on Bruin Creek are negligible. Gaps in the lower site record reflect periods of insufficient flow to obtain a sample at that site, where water infiltrates into alluvial gravels of the Greens Creek flood plane.

Figure 12--Bruin Creek Conductivity

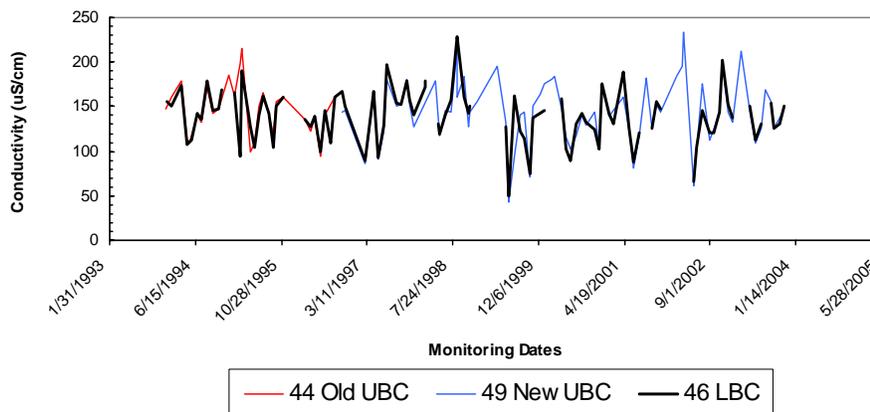
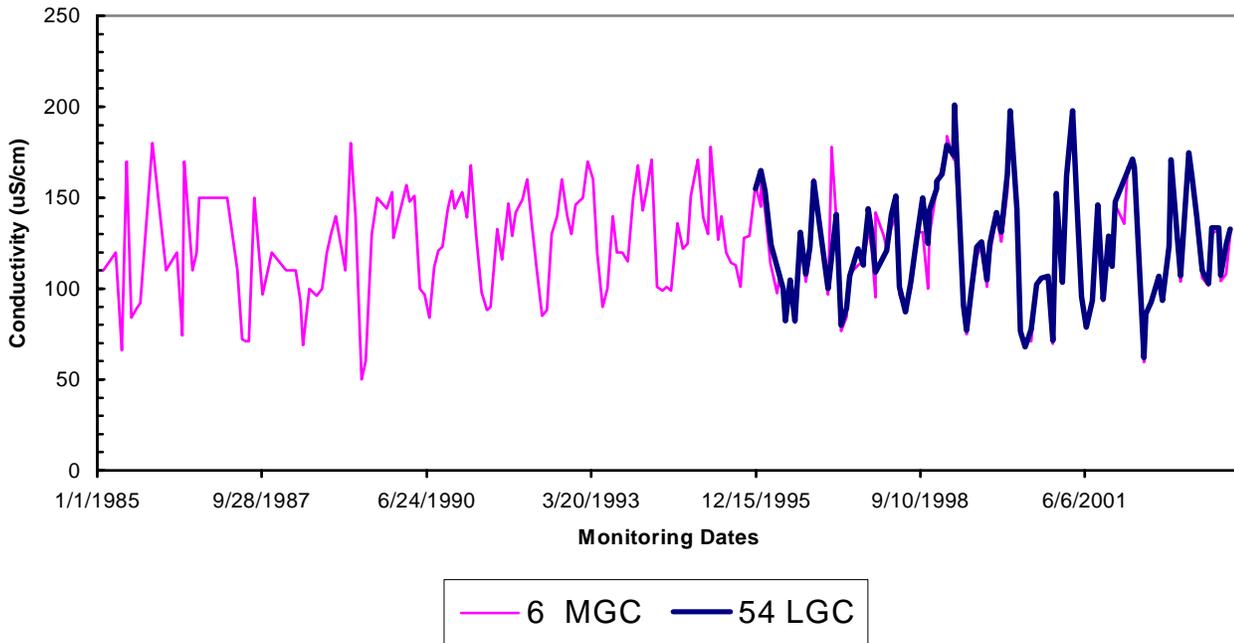
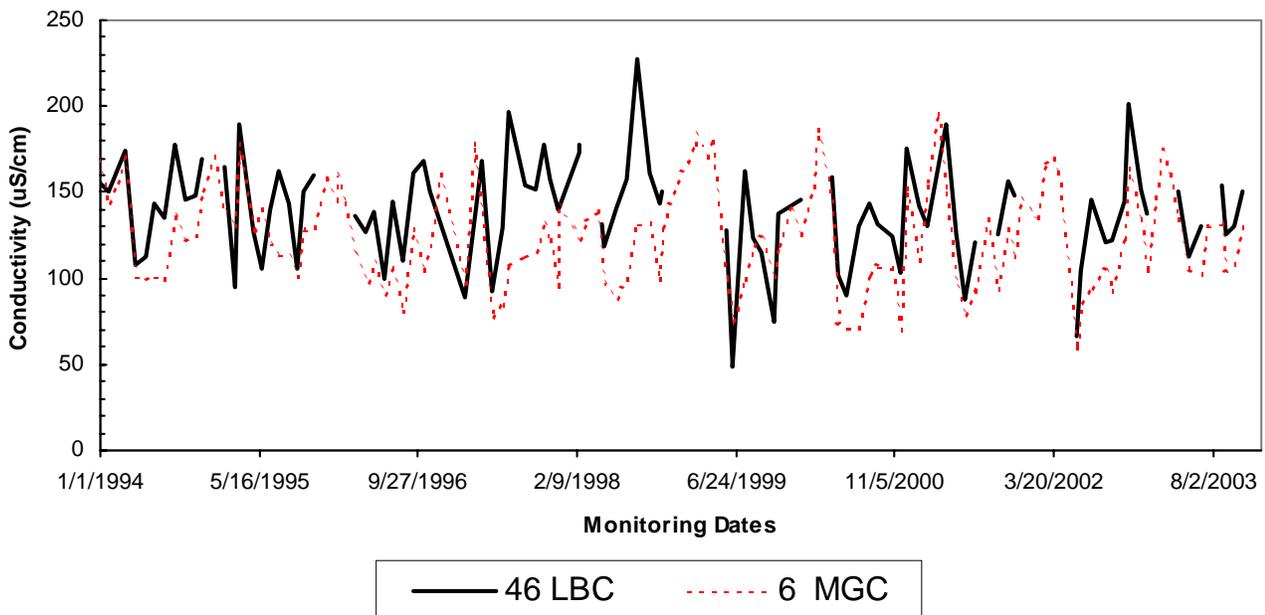


Figure 13--Greens Creek Conductivity



A comparison of Bruin Creek (Site 46) and Greens Creek (Site 6) is shown in Figure 14. Bruin Creek consistently has a higher conductivity than Greens Creek, which could be a result of Bruin Creek's smaller, lower elevation watershed and different bedrock lithology.

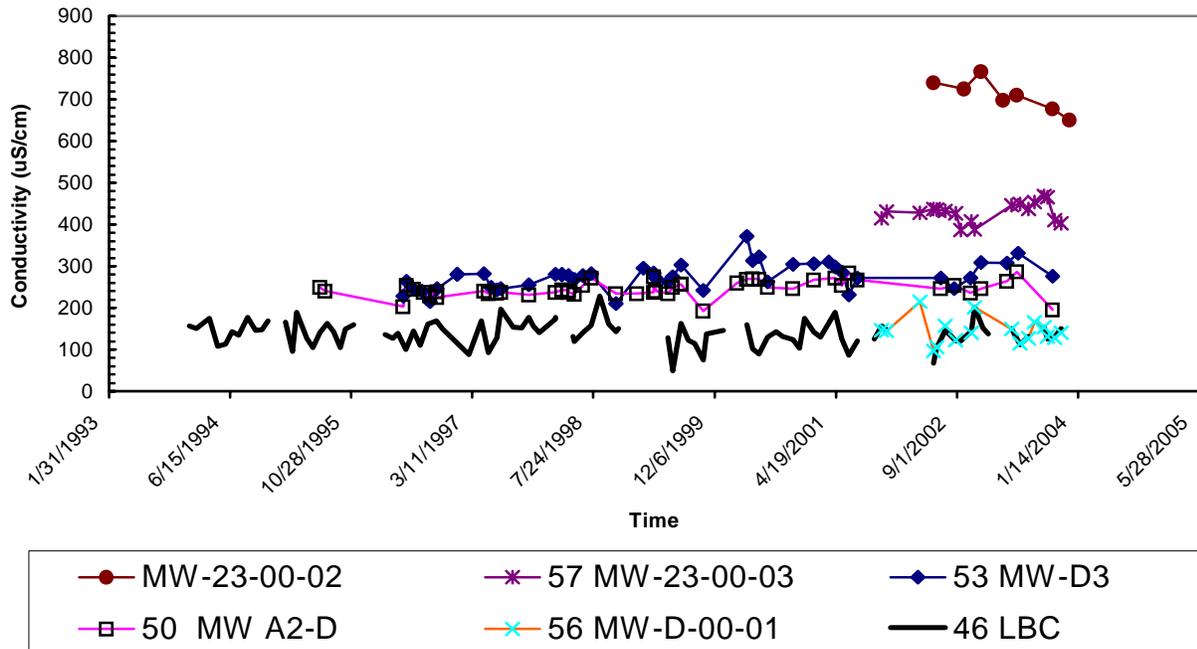
Figure 14--Bruin Creek and Greens Creek Conductivity



8.2.2 Groundwater

Conductivity data for background groundwater sites are shown in Figure 15. See Figure 1B for sample locations. Data for the Lower Bruin Creek surface water site are presented for reference. Sites 57 (MW-23-00-03) and 50 (MW-A2D) are up-gradient of the Site 23/D production rock placement area. Sites 56 MW-D-00-01 and MW-23-00-02 are down-gradient and east of the placement area. Site 53 (MW-D3) is completed in alluvial sands underneath Site D. These down-gradient sites are included in the background discussion because they do not appear to show influences from site activities. Background groundwater conductivities vary seasonally and between sites, ranging between 200 and 800 uS/cm. MW-23-00-02, which is completed in glacial till has conductivity values that are substantially higher than the other sites. However trace metal and major ion data and low permeability values suggest that the water is isolated formation water that is not interacting with surface waters. The lack of seasonal variation observed in other groundwater wells and an upward hydrologic gradient support this conclusion.

Figure 15--Background Groundwater Conductivity



Site 57 has conductivity values (450 uS/cm) that are higher than those observed at Site 50 (250uS/cm). Both wells are up-gradient of the production rock placement area and are completed in the colluvial/slide unit but at different depths. The difference in conductivity supports the assertion that the slide unit hosts a series of disconnected, perched water tables. Internal variability in lithology in the slide may account for the range of background water compositions in the unit.

Sites 50 and 53 are completed in different units (slide and alluvium, respectively), but have similar conductivities (~250 uS/cm) and show similar seasonal fluctuations. The slightly higher conductivity at Site 53 could be a result of the different unit lithologies. The average conductivity of several springs that emanate from the colluvial/slide unit west of Site 23/D is 306 uS/cm, comparable to Site 53 and the other background groundwater sites.

Site 56 and Bruin Creek have nearly the same conductivities (150 uS/cm). The close proximity of Site 56 to Bruin Creek and the observation that Bruin Creek flow is lost to the alluvium in which the well is completed is a reasonable explanation for the similarity.

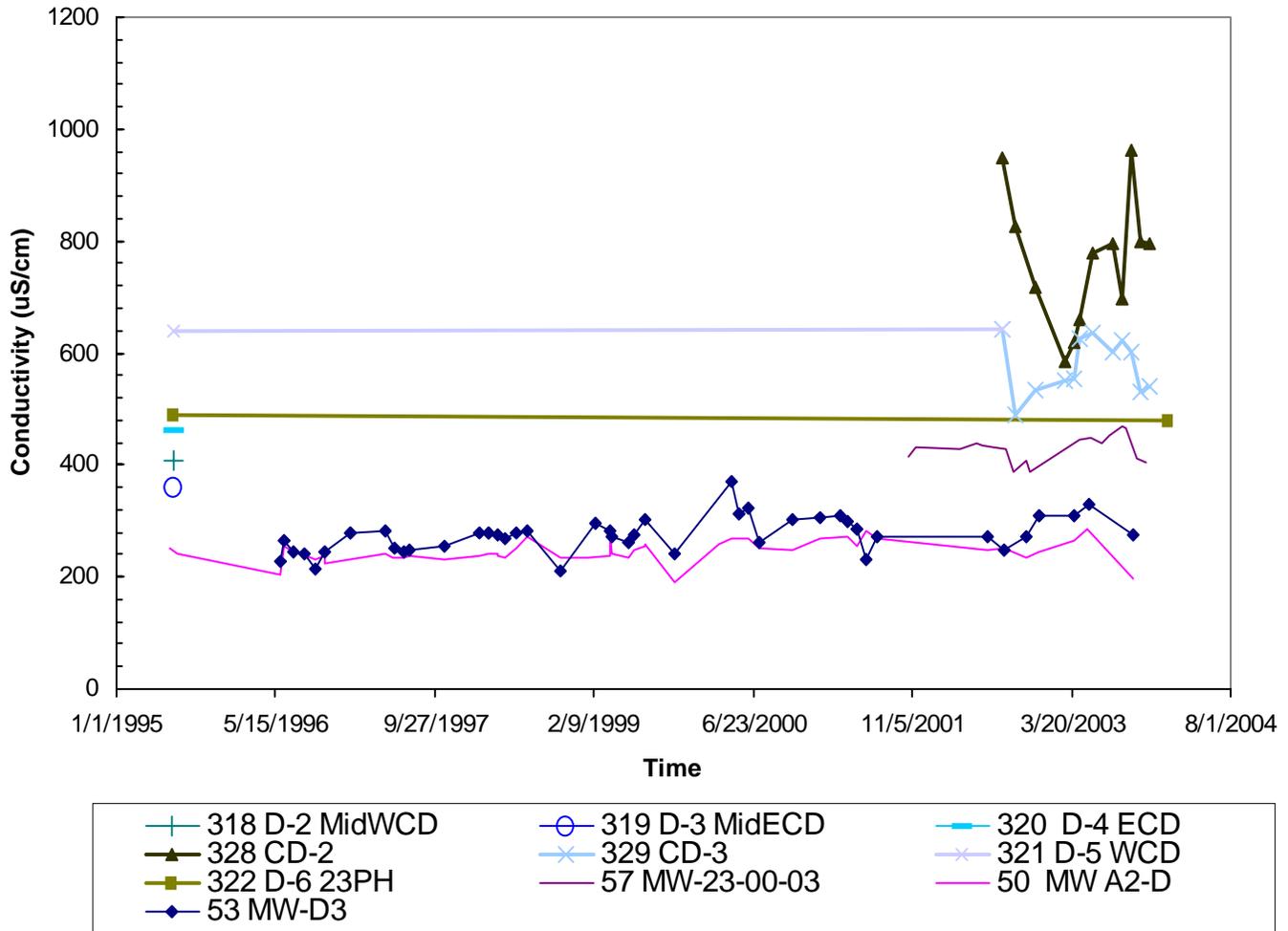
The lack of conductivity anomalies beneath Site D or in creeks and springs along the down-gradient perimeter of the site supports the conclusion that collection of contact water is effective and that the effects from Site 23/D are negligible.

8.2.3 Drains

The conductivity of samples from the curtain drain installed between Site 23 and Site D is shown in Figure 16. See Figure 1B for drain locations. Note that while several drain outlets are located at Site D, the source for the water in the drains is the foundation up-gradient of Site D. Sites 50, 53 and 57 are included in Figure 16 for reference. Samples from the curtain drains and other sub-drains collected in 1995 ranged from 350 to 650 uS/cm. These conductivity values are higher than those from background sites 50 and 53 and are in the range of those from background Site 57. Subsequent to the 1995 sampling the curtain drain outlets were combined and routed directly to the Pond D wet well. Under the

present configuration only the west curtain drain outlet (Site 321 and 329) and the Pond 23 pump house drain (Site 322) sample the same water they did in 1995. Both of these sites show little difference in conductivity between past and current sampling (500 to 600 uS/cm).

Figure 16–Curtain Drain Conductivity



The two central drains (Sites 318 and 319) and the east drain outlet (320) were combined with near-surface drainage and are now sampled collectively as Site 328, which currently has the highest conductivity of the curtain drains, ranging from approximately 600 to 1000 uS/cm. The drains show the same seasonal fluctuations observed in the background waters. The increase in conductivity observed at Site 328 relative to Sites 318-320 resulted from changes

in the curtain drain influent chemistry and from the incorporation of near-surface Site D water into the flow. Construction of Site 23 since 1995 has increased the dissolved load in the water collected by the curtain drains. This was anticipated given the permeability of the foundation.

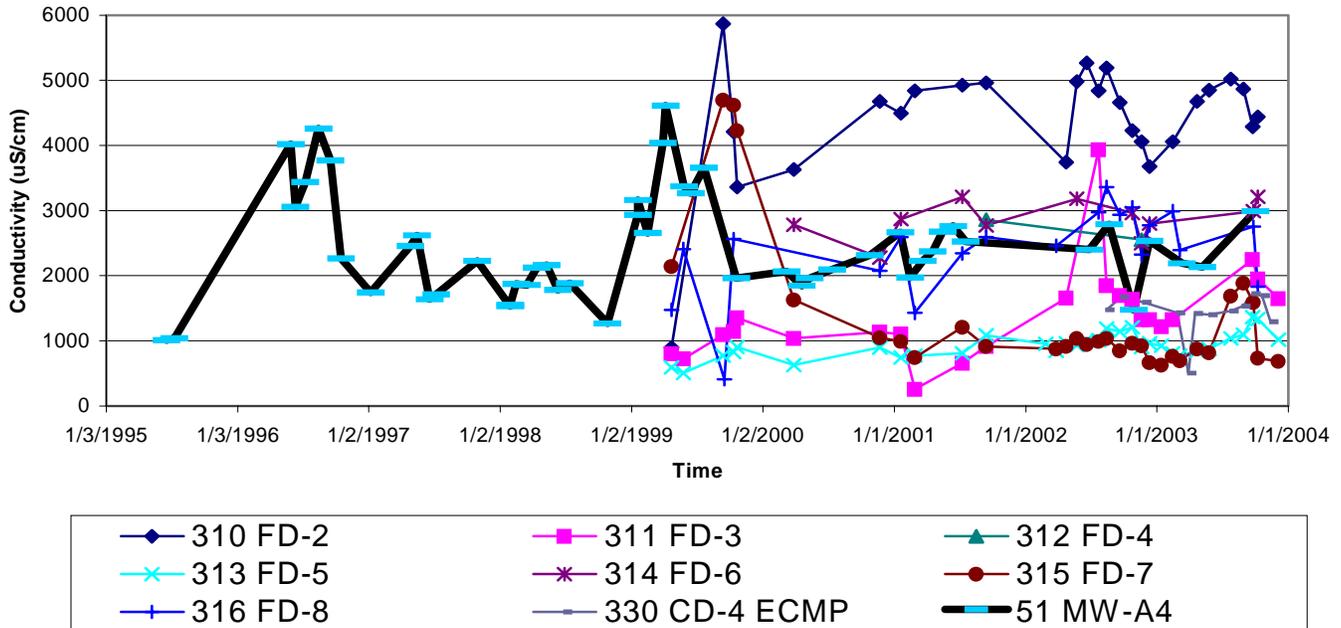
Data available from 1995 indicate that the curtain drains (Sites 318, 319, 320) and other foundation drains (Sites 322, 317, 330) represented approximately 80% of the flow from Pond D (72 gpm of 90 gpm). Assuming the average background groundwater conductivity was 275 uS/cm, the relative increase in loading in Pond D relative to background was 1.6X in 1995. This was based on Pond D's mean value of 440 uS/cm. The conductivity of the Pond D effluent has increased another 1.6X to 710 uS/cm since 1995, and flow has remained about the same (~100 gpm). Since the conductivity of water draining Site D has actually decreased (1460 uS/cm versus an average of 2820 uS/cm for Site 317), the increase in conductivity observed at Pond D has to be a result of the dissolved load from Site 23. Pond D effluent is pumped up to the Pond 23 pump house where it is routed either into the mill or directly to the tailings facility for treatment and discharged in accordance with the NPDES permit.

Basal drains constructed near the base of Site 23 provide an indication of the dissolved load produced by Site 23. See Figure 1B for drain locations. Figure 17 shows the conductivity data for each of the finger drains (Sites 310-316), a toe drain that daylights just below the B Road near the entrance ramp to Site D (Site 330) and a well completed in the foundation below Site 23 (Site 51).

Conductivity values for the finger drains range from 260 to 5870 uS/cm. Drains with lower conductivities (Sites 313 and 315) have the larger flow - a result of incorporation of foundation water into drains. Site 310 consistently has the lowest flow and the highest conductivity (typically near 4500 uS/cm) and reflects the maximum dissolved concentrations produced by the pile. The remaining drains and Site 51 plot between the values of Sites 310 and 313, reflecting intermediate dissolved concentrations. Site 51 plots closer to pile-derived dissolved concentrations than to a mixture of foundation and pile waters (Sites 313 and 315). This suggests that the Site 51 well is completed in a zone

of the foundation that is somewhat isolated from the flow paths that contribute the majority of the flow received by the curtain drain (Figure 16). Water that reports to the curtain drain is more similar to water produced by Sites 313 and 315.

Figure 17--Site 23 Finger Drain Conductivity



All of the basal drains and the Site 51 well show seasonal conductivity fluctuations, yet there is no indication of increasing dissolved concentrations in waters exiting the pile. The drains that are a mixture of pile water and foundation water (e.g. Site 313) show a slight increasing trend, which is expected because as the pile footprint grows the proportion of contact water in the mixture increases. This is analogous to the increase in dissolved load observed in the curtain drain and Pond D since Site 23 construction began in 1995.

8.2.4 Suction Lysimeters

Two suction lysimeters were installed in the unsaturated production rock of Site 23 in 2002. See Figure 1B for lysimeter locations. SL-23-02-01 is completed at a depth of 37 feet and SL-23-02-02 is completed at a depth of 16 feet. Water collected from the suction lysimeters is not indicative of water that exits the pile because it is water that is held in small pores and as films on particle surfaces, often isolated from flow paths. Capillary forces (surface

tension) exceed gravitational forces, preventing the downward movement of this interstitial water. The suction lysimeter applies a vacuum that exceeds the capillary forces, thus promoting flow into the lysimeter. Though not indicative of water that drains from the pile, the lysimeter data is useful because it provides additional information about the chemical processes occurring in the pile. The average conductivity of SL-23-02-01 and SL-23-02-02 is 4900 uS/cm and 5273 uS/cm, respectively. Potential reasons the shallower lysimeter has higher conductivity include:

- The shallower lysimeter is closer to the surface where evaporation can increase the dissolved load of the pore water
- The shallow lysimeter receives water from argillite, which produces higher dissolved loads than phyllite
- Oxidation and dissolution processes are greatest near the surface and contribute more salts to the pore water than at depth.

8.2.5 Dissolved Load Analysis

Electrical conductivity increases with increasing dissolved load (TDS), however site-specific correlation is required to determine the quantitative relationship between the two parameters. Conversion of conductivity values to TDS permits linear scaling between sites (i.e. a site with a TDS of 800 mg/l has twice the dissolved load as one with a TDS of 400 mg/l, yet its conductivity is not twice as high). A conversion equation was fit to the data set derived from water analysis that had both conductivity and TDS results. Calculated TDS values are shown in Figure 18 and are compared with the analytical values used to derive the conversion equation. The average TDS values for the sites are grouped by type in Figure 19. As discussed in Section 8.2.4, suction lysimeter samples have the highest dissolved load, approximately twice that of water produced by typical finger drains without a groundwater component. Finger drains with a groundwater component (e.g. Site 313) are up to five times less concentrated than typical drains lacking a groundwater component. The lower dissolved load

from curtain drains and Site D reflects a further increase in the groundwater component in these waters.

Table 8.2 presents the average TDS values for major Site 23/D water types and shows a percentage matrix derived from the distribution of TDS data. The difference between the average TDS of each potential source and the average groundwater TDS (185 mg/l) was used to create the source matrix. For example, the average TDS values for Site 313 (FD-5) and typical finger drains (Sites 312, 314, and 316) are 626 mg/l and 2382 mg/l, respectively. The theoretical percentage of typical finger drain water in Site 313 water is $(626-185)/(2382-185)*100$ or 20%, indicating approximately 80% groundwater dilution. This is consistent with finger drain flow measurements (approximately 7 gpm from Site 313 and less than 1 gpm from the other drains).

The TDS matrix helps to define the relative proportion of a potential source water in down-gradient waters as shown on Figure 20. The analysis led to the following observations:

- Water that exits the base of the pile is 50 to 60 percent more dilute than water held in isolated pore spaces or otherwise removed from typical fluid flow paths.
- The load from typical finger drains (e.g. a composite of Sites (312, 314, and 316) is a reasonable proxy for the contact water contribution to down-gradient waters.
- The curtain drain waters are comprised of approximately 15 percent contact water contributed from the pile and represent approximately 83 percent of the Pond D dissolved load.
- The Pond D dissolved load indicates a contribution of approximately 12% contact water. The remaining flow is derived from groundwater sources (primarily from the base of the colluvial/slide unit) beneath Site 23/D.
- A review of curtain drain and pond D flow measurements suggests that the current pond D wet well flow meter readings are low. The average flow should be on the order of approximately 100 gpm.

- Assuming a curtain drain flow of 75 gpm and the calculated 15% contact water curtain drain load, the calculated contribution of contact water flow in the curtain drains is approximately 11 gpm.
- Adjusting for the extra groundwater contribution to finger drains 311, 313 and 315, the 10.5 gpm measured total flow from all drains consists of 8.5 gpm groundwater and 2 gpm contact water.
- Summing the contact water contribution to the finger drains and curtain drain, assuming 75% efficiency yields a total contact water flow of 16.5 gpm. This is reasonably close to the theoretical value of 15 gpm discussed in Section 4.3.2.

A summary of the distribution of flows based on TDS loading and measured values is provided in Table 8.3. Runoff from Site 23 does not factor into the analysis because it is collected in the lined toe ditch below Site 23 and reports directly to Pond 23, which is pumped directly to the Pit 5 water treatment facility.

Figure 18--Conductivity vs TDS Site 23/D Data

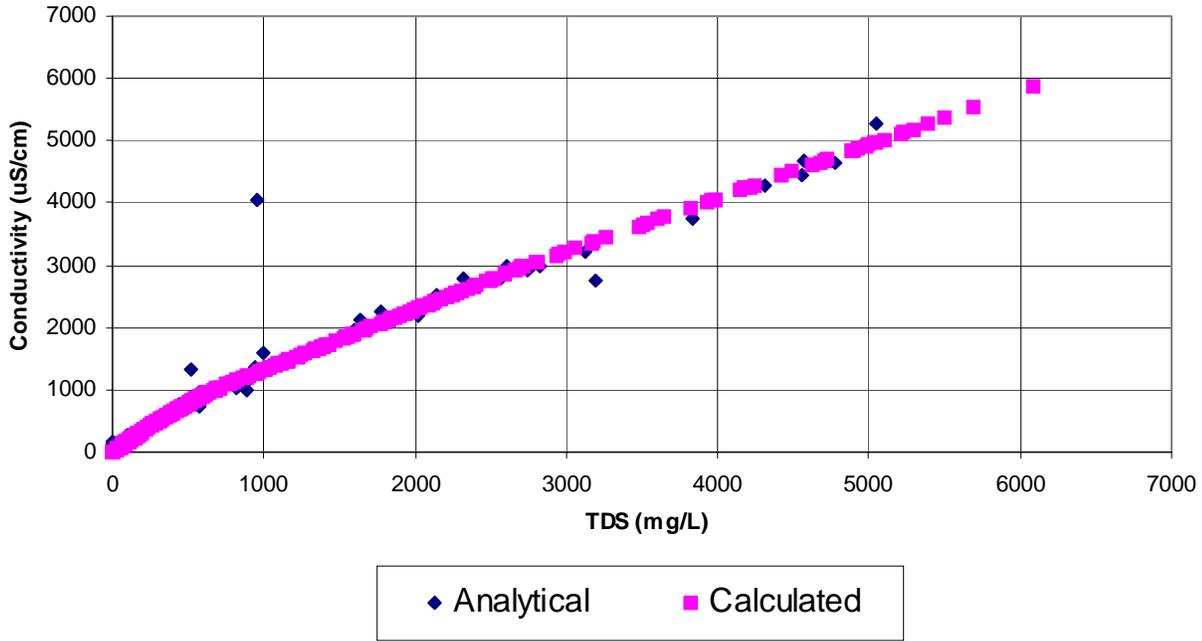


Figure 19--Site 23/D Average Calculated TDS Values

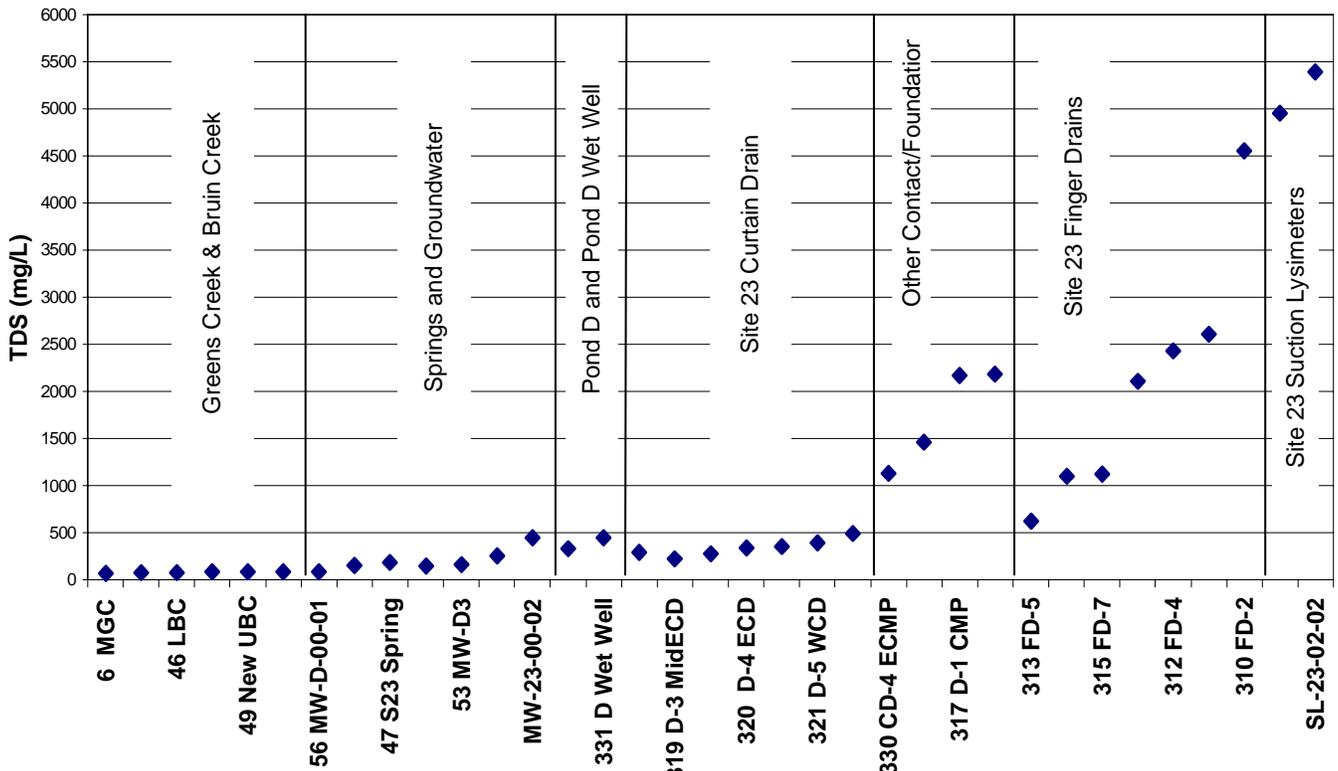


Figure 20--Site 23/D TDS versus Percent Contact Water

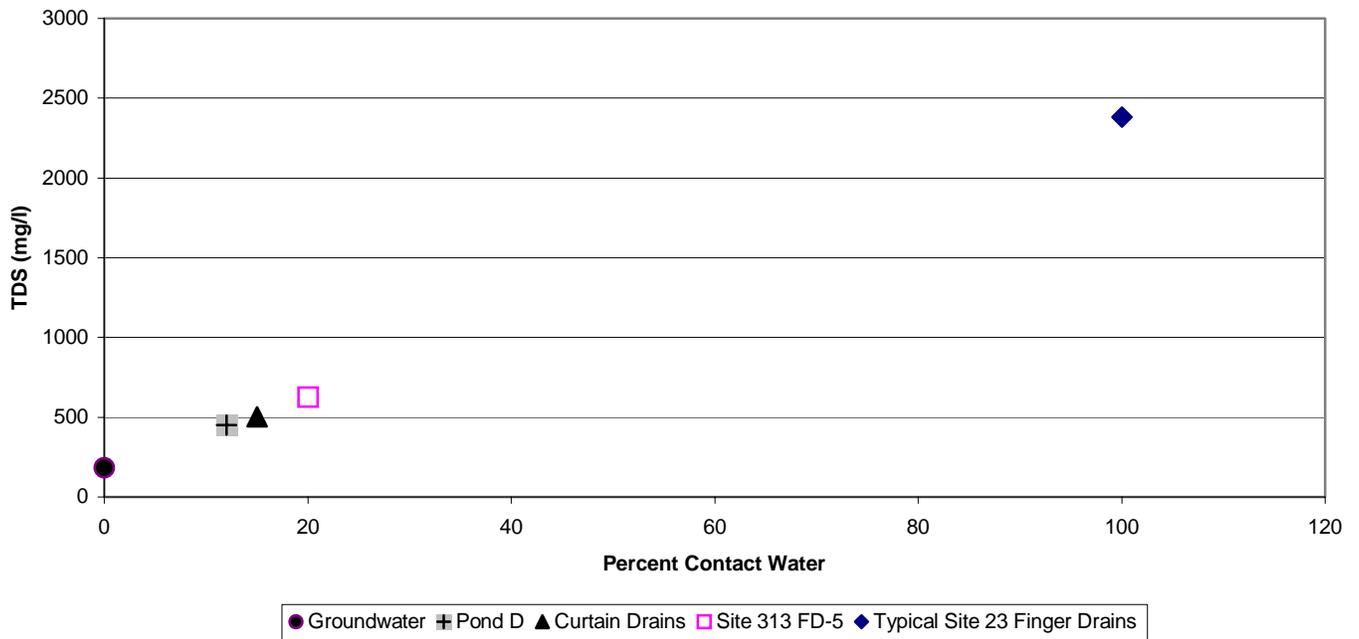


Table 8.2—Site 23/D Average TDS Values and Source Percentage Matrix

Source	TDS (mg/l) calculated	Percent of Potential Source							
		SL's	FD-2	FD typical	F-5	D2-D7 (1995)	CD+ (2003)	CD+ weighted (2003)	Pond D (1995)
Suction Lysimeters	5175	100							
FD-2	4554	88	100						
FD-4,6,8***	2382	44	50	100					
FD-5	626	9	10	20	100				
D2-D7 (1995)	279	2	2	4	21	100			
CD+ (2003)	564	8	9	17	86	403	100		
CD+ weighted (2003)	504	6	7	15**	72	339	84	100	
Pond D (1995)	334	3	3	7	34	159	39	47	100
Pond D (2003)	449	5	6	12	60	281	70	83	177
Groundwater fresh mix	185								
Surface water	80								
**Weighted CD TDS is 15% of typical FD TDS and CD flow is 75 gpm. Then 11.25 gpm if infiltration to CDs.									
***Average TDS of FD-3 and FD-7 is 1,114 mg/l, 47% of typical FDs. 53% fresh mix in addition to 80% fresh mix for FD-5. Approximately 8.5 gpm fresh mix of 10.5 gpm FD total. 2 gpm infiltration water to FDs, would be 2+11+3.5 =16.5 gpm total infiltration. This would yield a 12% FD capture efficiency.									

Table 8.3--Site 23/D Average Flow Distribution

Source	Groundwater (gpm)	Contact water (gpm)	Total (gpm)
Site 23 Pile	0	16.5	16.5
Finger Drains	8.5	2	10.5
Curtain Drains	64	11	75

8.2.6 Representative Water Quality Analyses

Table 8.4 contains analytical data from sites that are representative of the primary Site 23/D water types. The full suite of trace metals, major ions and other parameters shown in Table 8.4 augments the discussion of the relationships between various site waters described in Sections 8.2.1 to 8.2.5. For Sites 54, 46 and 50, it was necessary to draw on data from multiple sample dates to fill out the parameter list. In each case the most recent representative data set was selected. The decision to use individual sample analyses where possible instead of long-term averages is based on the following considerations:

- Changes in detection limits between sample dates cause difficulty with averaging “below detection limit” values.
- A data set based on averaged values does not represent an actual water and would be inappropriate for some forms of analysis, particularly geochemical modeling, where charge balance and an accurate representation of the distribution of aqueous species is required.
- Temporal changes in water compositions and changes in sampling frequency would skew averaged values and may not give an accurate depiction of the water compositions. Temporal changes in compositions are reflected best in time-series plots of conductivity or TDS such as those presented in Sections 8.2.1 to 8.2.5.

The pH of all water types is near neutral to alkaline. Carbonate minerals in the production rock and foundation units neutralize acids produced by pyrite oxidation and decomposition of organic matter. Alkalinity values exceed 100 mg/l CaCO₃ in all contact waters, demonstrating that carbonate dissolution continues and that acidification is not imminent. The carbonate content of Class

2 and Class 3 production rock is insufficient to neutralize all of the potential acidity in the rock. Therefore, an oxygen limiting cover will be needed to maintain long-term water quality after the site is closed.

Metal concentrations are consistent with conductivity and TDS values for each water type. Zinc, cadmium, manganese, nickel and arsenic are more mobile than other metals of interest. Iron, arsenic and manganese concentrations are generally higher in waters that are reduced (e.g. suction lysimeters). The concentrations of these metals are limited by precipitation of oxide phases under more oxidizing conditions in down-gradient waters. Zinc and cadmium concentrations are not as sensitive to redox conditions and are generally controlled by mixing and sorption mechanisms. Therefore, zinc and cadmium show less attenuation in down-gradient waters relative to the redox sensitive species.

Anomalous lead values (8 ug/l) have been recorded in up-gradient groundwater from Site 57. Sulfate concentrations (113 uS/cm) at Site 57 are also notably higher than the value from Site 50 (15 uS/cm), which is located in the same unit approximately 400 feet away. The variability in lead and sulfate values in background groundwater up-gradient of Site 23 supports the conclusion that there are multiple, perched water lenses in the slide unit. With the exception of lead, sulfate and to some degree cadmium, at up-gradient Site 57, groundwater and surface water at the perimeter of Site 23/D is relatively dilute.

Numerical calculations using The Geochemist's Workbench software indicate that gypsum is controlling calcium concentrations in Site 23/D contact water. However, mixtures of contact water and groundwater (e.g. curtain drains and finger drains with a groundwater component) are not gypsum saturated. The solubility of magnesium sulfate phases such as hexahydrate and epsomite is much higher than gypsum, and the undiluted contact waters are not saturated with respect to these minerals. Therefore, the concentration of magnesium is higher than calcium in some undiluted contact waters. The gypsum that is accumulating in the pile will control the concentration of calcium and sulfate in water exiting the pile after closure and will be removed slowly over time. Other

oxidation products such as iron oxy-hydroxides and manganese oxides will also be removed from the pile as reducing conditions expand following cover placement. Microbial and abiotic attenuation of this mobilized iron and manganese is anticipated when reduced waters mix with oxidized waters and react with the atmosphere.

Generalized mass loading calculations were used to test hypotheses about the flow regimes at Site 23/D and to predict possible post-closure water compositions. An example of the mass loading model is presented in Appendix B. The model results compare favorably with field flow and TDS measurements for past and current conditions. Measured versus modeled flows and TDS values were 90 gpm versus 96 gpm and 334 mg/l versus 374 mg/l, respectively for the pre-1995 condition. Measured and modeled flows have not changed significantly since 1995, however TDS loading has increased as Site 23 has grown. The modeled TDS values for the current conditions at Site 23 are relatively close to measured values (567 mg/l vs 552 mg/l). The modeled and measured TDS values for the current condition at D Pond are 479 mg/l and 449 mg/l respectively. Given the simplified nature of the model, discrepancies of the magnitude exhibited here. Overall the model appears relatively robust in describing the flow and TDS loading at the site.

The mass loading model discussed above was also used to predict post-closure flow and water compositions at Pond D for a variety of closure scenarios (Table 8.5). All 12 scenarios assume full build-out of Site 23 (21 acres), which maximizes the potential load from the site. Scenarios 1 and 2 assume Site D remains in place and is covered. The remaining scenarios assume Site D is removed. Cover percolation rates are varied from 2% to 20% and precipitation ranges from 40 inches to 100 inches. The resulting flows range from 70 gpm to 176 gpm, reflecting changes in precipitation. TDS varies from 171 mg/l to 478 mg/l and is predominantly controlled by percent percolation through the cover. Hardness, and sulfate values are scaled with TDS based on their relative proportions in the Site 23 contact waters. Hardness ranges from 137 mg/l to 382 mg/l. Sulfate ranges from 24 mg/l to 233 mg/l, indicating it should fall below the

Alaska water quality standard (AWQS) of 250 mg/l. Zinc and cadmium concentrations were calculated based on their measured field concentrations. For the predicted hardness values, percolation rates of 20% or less would be required to produce water at Pond D that meets the zinc standard. The model indicates that percolation rates of 2% or less would be required to meet the recently reduced cadmium standard. Percolation rates less than 5% would likely be difficult to achieve.

Despite the fact that the model used to make the predictions discussed above appears to match measured conditions relatively well, it is based on several simplifying assumptions. Refinement of the model will continue as more information about the site and its final configuration becomes available.

Table 8.4—Summary Water Quality Characteristics of Primary Site 23/D Water Types.

PARAMETERS**	SURFACE WATER		GROUNDWATER		POND D	CURTAIN DRAIN	FINGER DRAINS	SUCTION LYSIMETER
	Site 54	Site 46	Site 50	Site 57	Site 331	Site 328	Site 314	SL-23-02-01
Ag (ug/l)	-0.011	-50	-0.012	-0.003	NA	-0.1	-1	NA
As (ug/l)	0.235	0.146	0.466	0.676	0.305	0.265	7.7	3.23
Ba (ug/l)	28.1	10.7	47	33.5	NA	45.8	12.1	NA
Ca (mg/l)	13.1	12	27.9	NA	93.3	113	570	520
Cd (ug/l)	0.075	0.0283	-0.034	0.209	1.8	2.61	16.1	35.3
Cl (mg/l)	NA	7.79	2.67	NA	3.15	3.56	2.21	3.21
Cr (ug/l)	-1.01	-1.01	1.16	0.0785	3.69	-0.75	2.28	-1.5
Cu (ug/l)	0.554	0.786	0.132	0.249	4.99	1.92	3.06	-1
Fe (ug/l)	13.2	6.22	-500	NA	50.7	-250	-50	3100
Hg (ug/l)	0.000854	0.00252	0.000545	0.000374	NA	-0.2	-2	NA
K (mg/l)	NA	-1	-0.5	NA	1.27	1.4	7	16
Mg (mg/l)	5.43	10.5	9.49	NA	23.6	23.7	170	700
Mn (ug/l)	8.13	0.218	17.1	NA	137	10.8	645	18800
Na (mg/l)	1.53	2.72	3.7	NA	11	8.39	8	66
Ni (ug/l)	0.967	1.12	0.703	1.28	9.79	13.4	307	1290
Pb (ug/l)	0.0638	0.0636	0.0322	8.11	1.79	0.429	2.59	1.71
Se (ug/l)	0.768	0.363	-0.474	0.36	NA	1.29	6.7	NA
Zn (ug/l)	6.36	2.72	1.86	10.7	335	503	2840	52100
Lab Conductivity (uS/cm)	128	128	240	415	624	751	2780	5120
Sulfate (mg/l)	16.2	10.5	15.2	113	189	200	1650	3790
Alkalinity (mg/l as CaCO3)	47.4	65	107	153	144	189	225	NA
Nitrate (mg/l)	NA	-0.1	NA	NA	NA	2.72	1.68	-0.1
Lab pH (std. Units)	7.79	8.17	7.76	7.54	7.96	7.15	7.46	6.73
Sample Dates	metals = 12/19/02 major ions = 9/9/96	metals = 12/19/02 major ions = 4/19/96	metals = 7/18/01 major ions = 5/8/03	10/9/2003	2/13/2003	5/28/2003	9/25/2003	10/7/2003

NOTE: Negative numbers = non-detect/detection limit values

NA = Not Analyzed.

**Trace Metals Analyses All as Dissolved

Table 8.5—Post Closure Water Quantity and Quality Scenarios.

Scenario	1	2	3	4	5	6	7	8	9	10	11	12
Site 23 Prod. Rock Area (acres)	21	21	21	21	21	21	21	21	21	21	21	21
Site D Prod. Rock Area (acres)	7.2	7.2	0	0	0	0	0	0	0	0	0	0
Cover Percolation (%)	20%	15%	15%	10%	5%	15%	10%	5%	15%	10%	5%	2%
Precipitation (in)	66	66	66	66	66	100	100	100	40	40	40	66
Site 23 Contact Flow (gpm)	14	11	11	7	4	16	11	5	6	4	2	1
Site D Contact Flow (gpm)	5	4	0	0	0	0	0	0	0	0	0	0
Pond D Flow (gpm)	116	116	116	116	116	176	176	176	70	70	70	116
Estimated Composition at Pond D												
TDS (mg/l)	478	398	345	279	213	345	279	213	345	279	213	171
Hardness (mg/l)	382	318	276	223	170	276	223	170	276	223	170	137
Sulfate (mg/l)	233	179	143	98	53	143	98	53	143	98	53	24
Zinc (ug/l)	317	238	178	119	61	178	119	61	178	119	61	25
Cadmium (ug/l)	2.24	1.71	1.29	0.89	0.49	1.29	0.89	0.49	1.29	0.89	0.49	0.25

 Above dissolved AWQS (freshwater, chronic)

Conversion factors (derived from site-specific constituent ratios)

Hardness = 0.8(TDS)

Sulfate = 0.68(TDS) - 92

9.0 Geochemistry Summary and Conclusions

Site D consists of production rock, quarry rock and excavated till. Site 23 consists of segregated, compacted production rock. Acid base accounting data indicate that portions of the production rock in both sites have the potential to generate acid. Carbonate minerals in the production rock provide substantial buffering capacity, which produces a long lag time to acid generation. The lag time is sufficiently long to allow for construction of an oxygen and water minimizing cover, which is the long-term strategy for preventing acid rock drainage. The excavated till and underlying colluvium and alluvium are not potentially acid generating.

Metal concentrations in the production rock are above crustal averages and are higher than those of the underlying till, colluvium and alluvium units. Site contact water, therefore, has a higher dissolved load than background surface water and groundwater.

Bruin Creek and Greens Creek have electrical conductivities that range seasonally from 50 to 225 uS/cm. The lack of significant differences between up-gradient and down-gradient sites on these two creeks demonstrates that effects from Site 23/D are negligible.

Groundwater up-gradient and down-gradient of Site 23/D also varies between sites and seasonally, with electrical conductivity ranging from 200 to 800 uS/cm. Compositional differences between up-gradient wells demonstrate that the slide unit hosts a series of disconnected, perched water tables.

Monitoring data from surface water and groundwater sites indicate that the combination of finger drains, curtain drain, ditches and ponds is effectively collecting contact waters and that down-gradient effects from Site 23/D are negligible.

Data collected from basal drains, the curtain drain and Pond D show a progressive, down-slope increase in the groundwater component of the flow. This is consistent with the hydrologic interpretation that water infiltrates through the slide material and daylight as springs near the toe of this unit. As Site 23

expands, the proportion of contact water in the flow increases, as demonstrated by the increase in the curtain drain dissolved load since 1995. While the amount of contact water has increased, its dissolved load has not increased over time. This is a positive result because it demonstrates that acid generation is not imminent.

A dissolved load analysis based on calculated TDS was performed to determine the relative proportions of various source waters in down-gradient waters. Based on the analysis, Pond D is comprised of approximately 12% contact water and the curtain drains contribute approximately 80% of the Pond D flow. The dissolved load analysis also helps to validate the hydrologic analysis presented in Section 4. Discrepancies between the two models are expected because several simplifying assumptions were required in both analyses. The general agreement between these two independent analyses indicates that the system is well defined.

Representative water quality analyses for the major water types are consistent with the conductivity and TDS results and help to further define the geochemical processes occurring at the site. Alkalinity and pH values from all site waters support the conclusion that carbonate minerals are effectively neutralizing acids formed by oxidation of pyrite in the production rock. Zinc, cadmium, manganese, nickel and arsenic are more mobile than other metals of interest in the drainage. Precipitation of iron oxy-hydroxides and manganese oxides controls the concentrations of iron, manganese and arsenic in the drainage. Zinc, cadmium and nickel are controlled by mixing and sorption mechanisms. Gypsum is controlling the concentration of calcium in the drainage and will slowly be removed from the system after the pile is covered.

Mass loading calculations are used to test hypotheses about flow regimes at Site 23/D and to predict possible post-closure water compositions. The results compare favorably with the TDS analysis, the hydrologic analysis and past and present flow and compositional data. The model is used to compare 12 potential post-closure scenarios, including removal of Site D, a range of cover percolation values and a range of annual precipitation rates. The resulting produced flows at

Pond D range from 70 gpm to 176 gpm while sulfate values that range from 24 to 233 mg/l. Cadmium appears to be the metal of greatest concern with respect to meeting water quality standards at Pond D after closure. Cover percolation rates of 20% or less may be required to meet dissolved freshwater chronic zinc standard and rates as low as 2% may be required to meet the recently lowered cadmium standard. These predictions do not consider natural attenuation processes, such as microbial or abiotic oxidation/reduction and sorption that could occur in the system following closure of the facility. These predictions will likely require refinement as more information about the site and its final configuration becomes available. Future updates to the model will benefit from information in the following area:

- Verification of Pond D and curtain drain flow measurement,
- Improved runoff calculations for production rock and the capture are above Site 23,
- A longer record of site specific evapo-transpiration rates,
- Ongoing monitoring of the performance of the composite cover and potential modifications,
- Continued monitoring of internal and down-gradient site water compositions and
- Quantification of potential down-gradient attenuation processes, including sorption, oxidation-reduction and precipitation.

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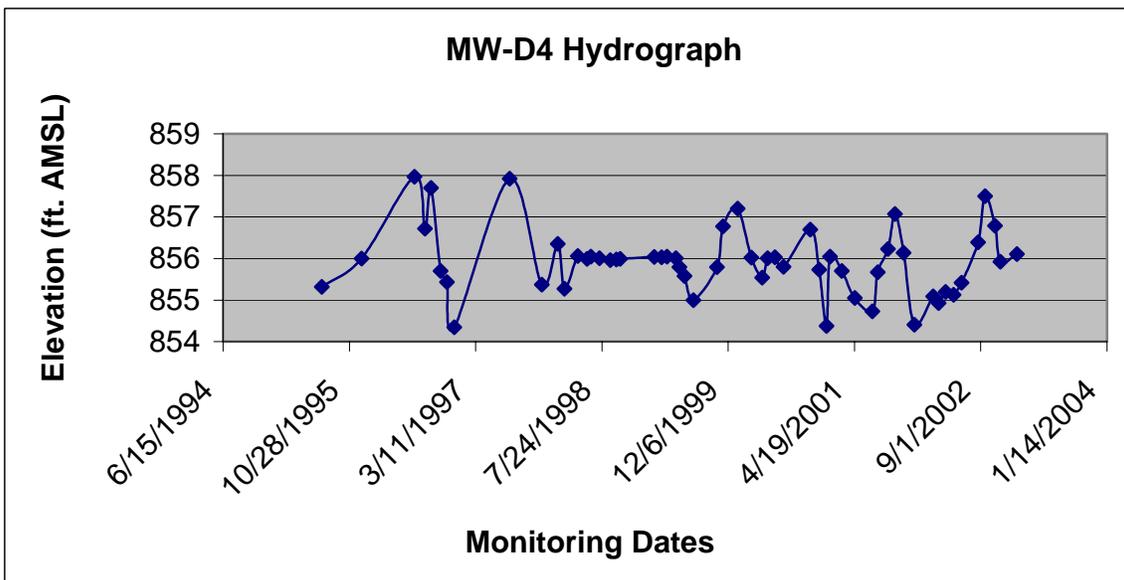
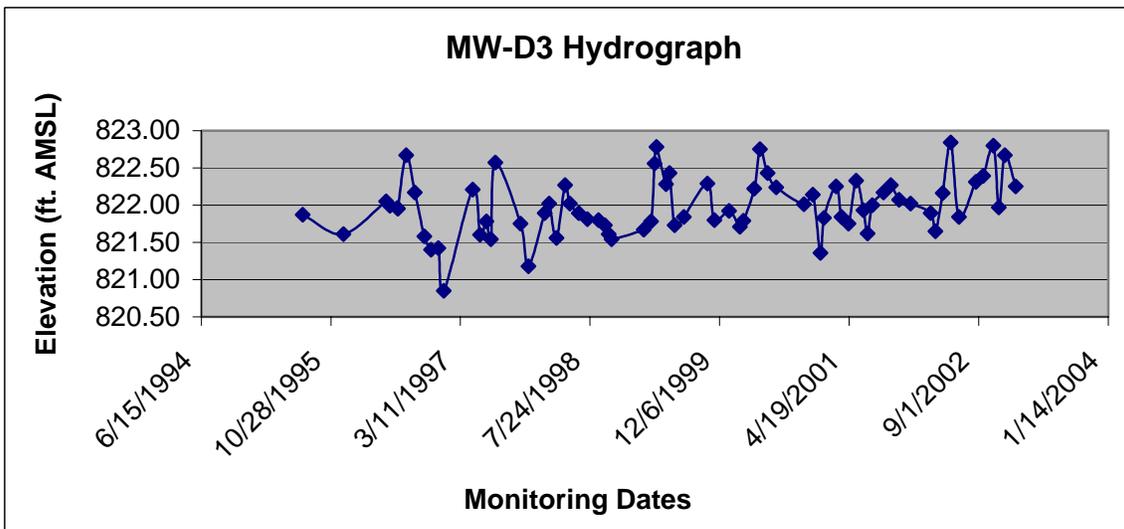
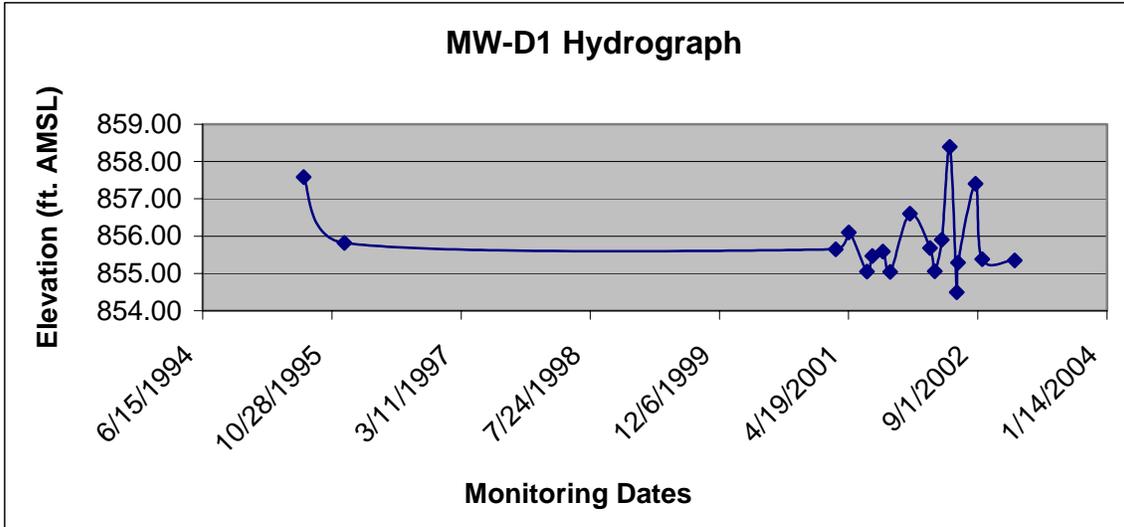
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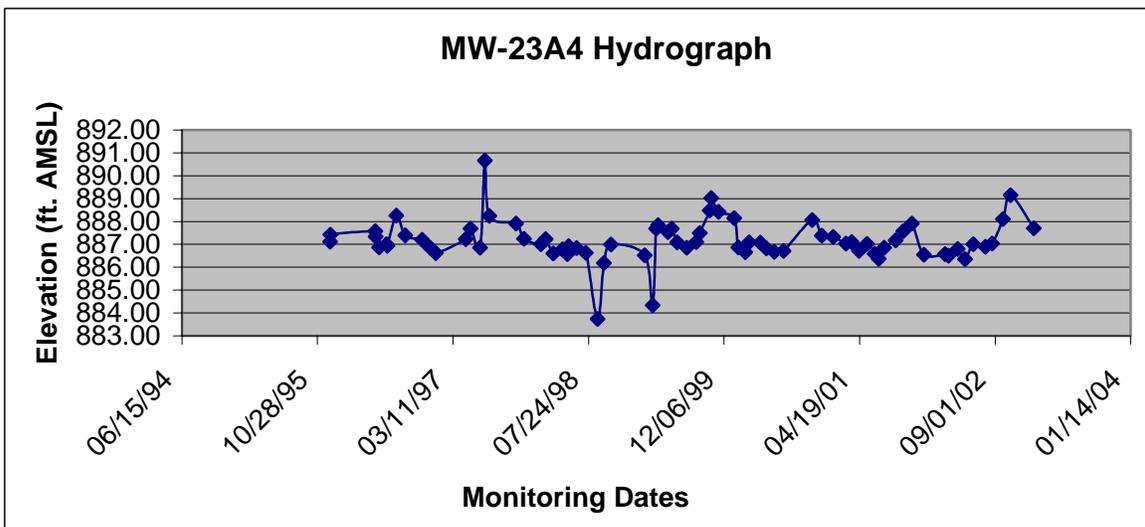
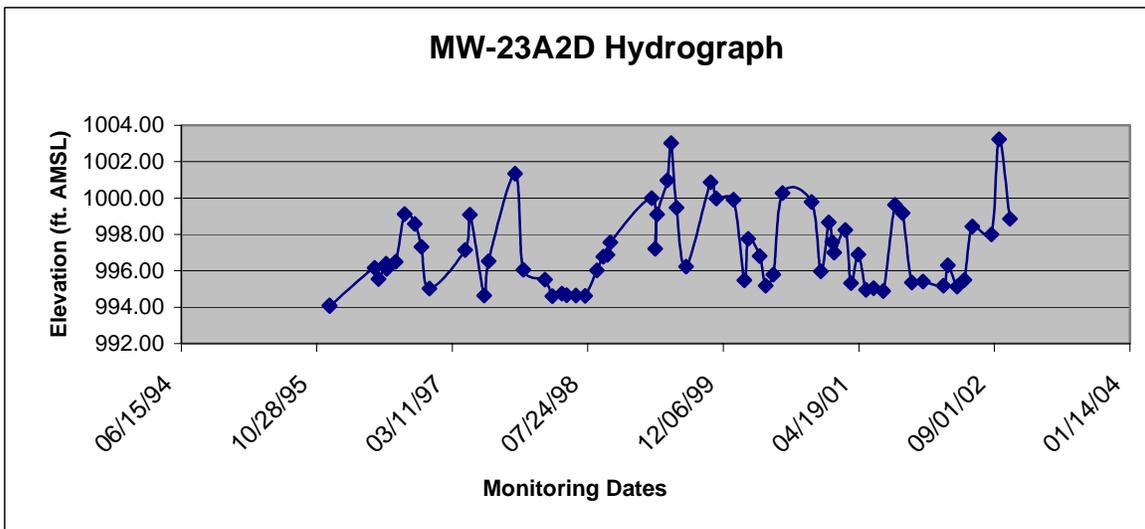
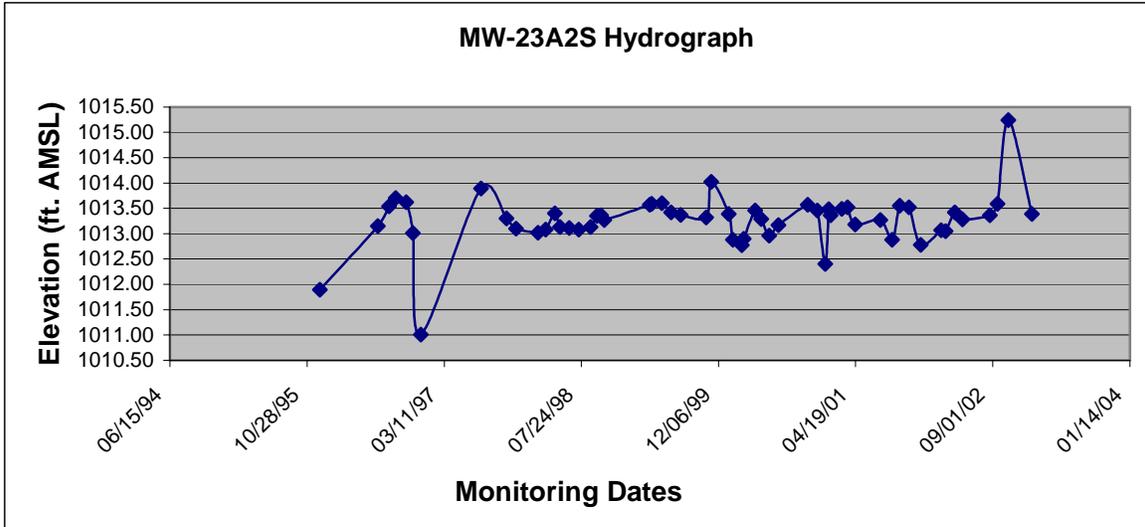
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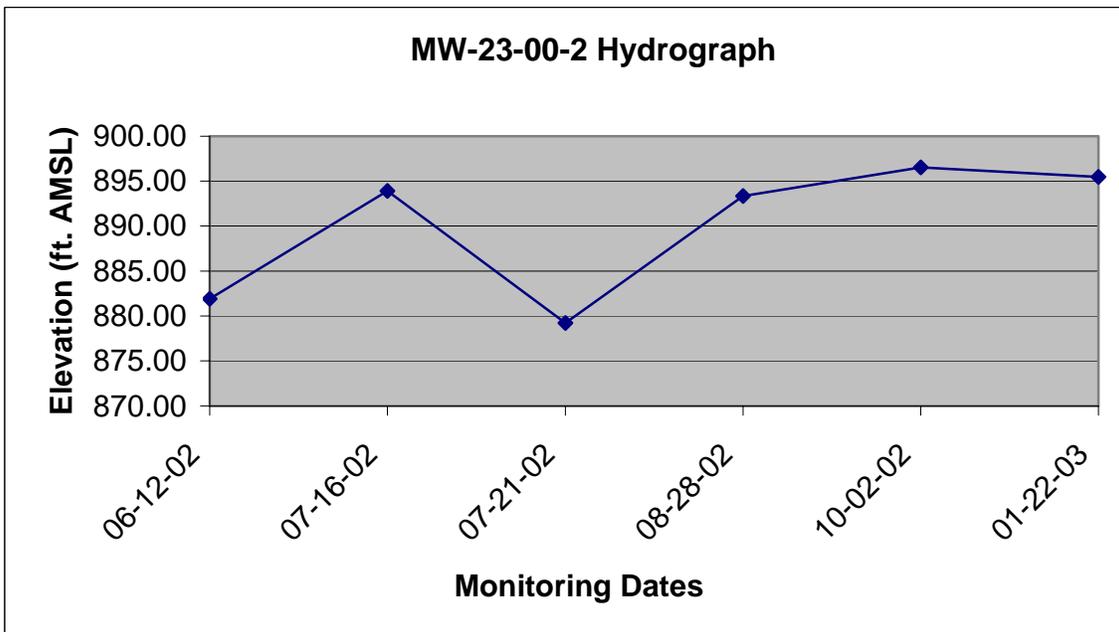
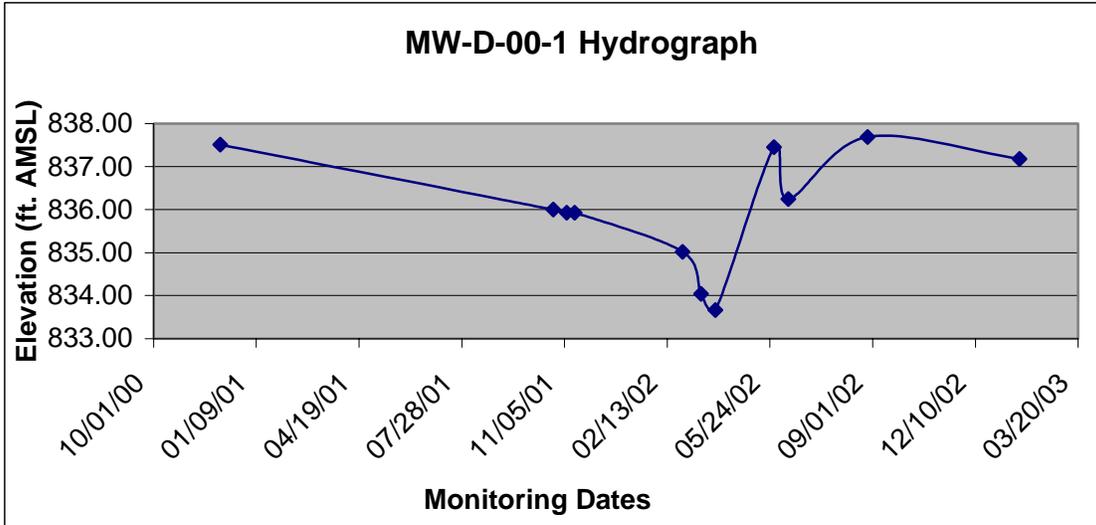
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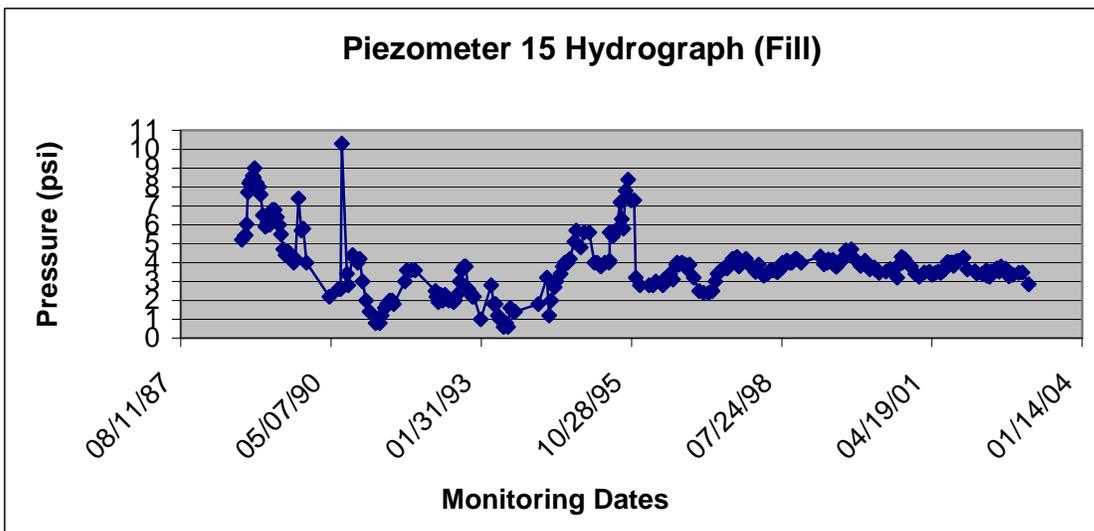
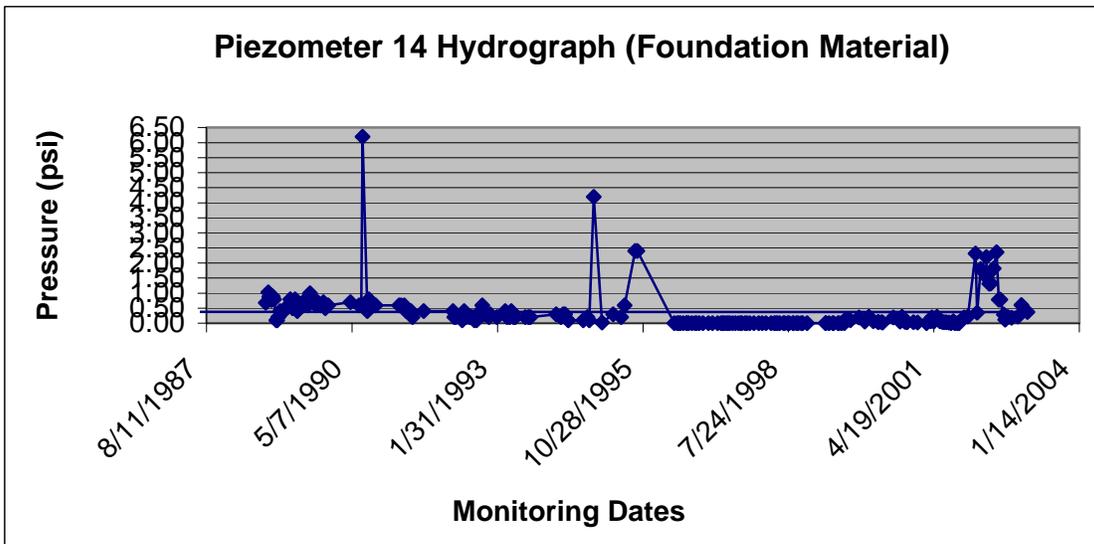
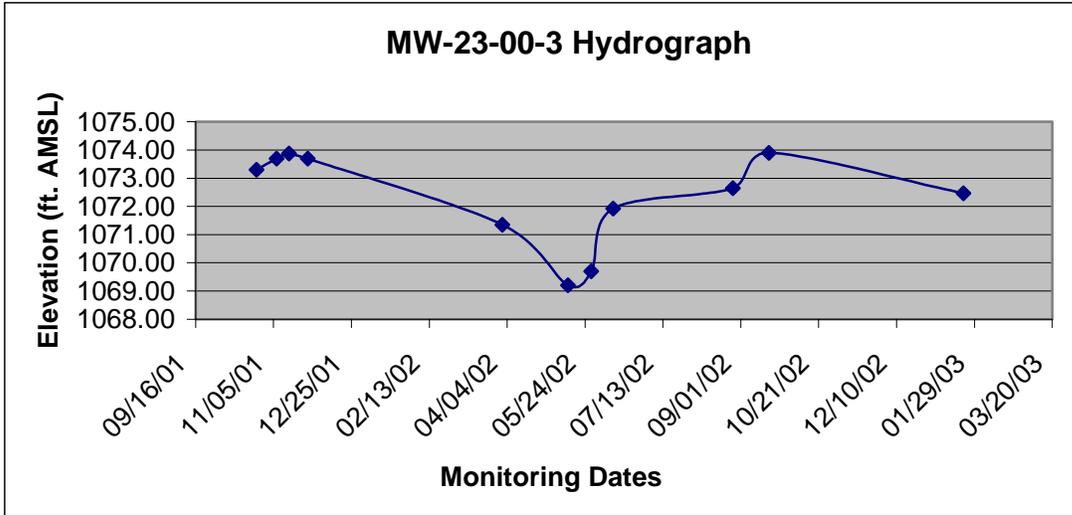
Appendix A—Life of Well Hydrographs

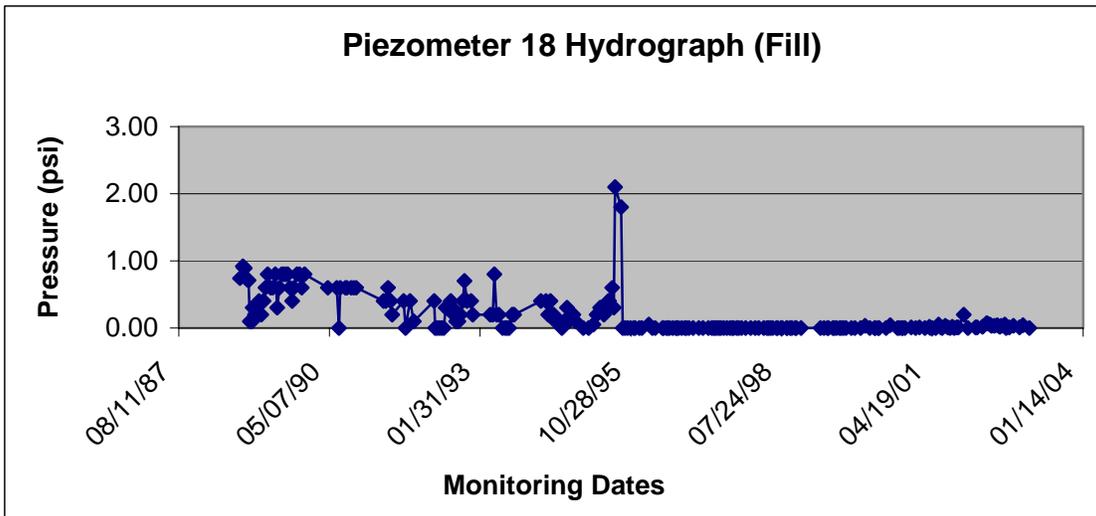
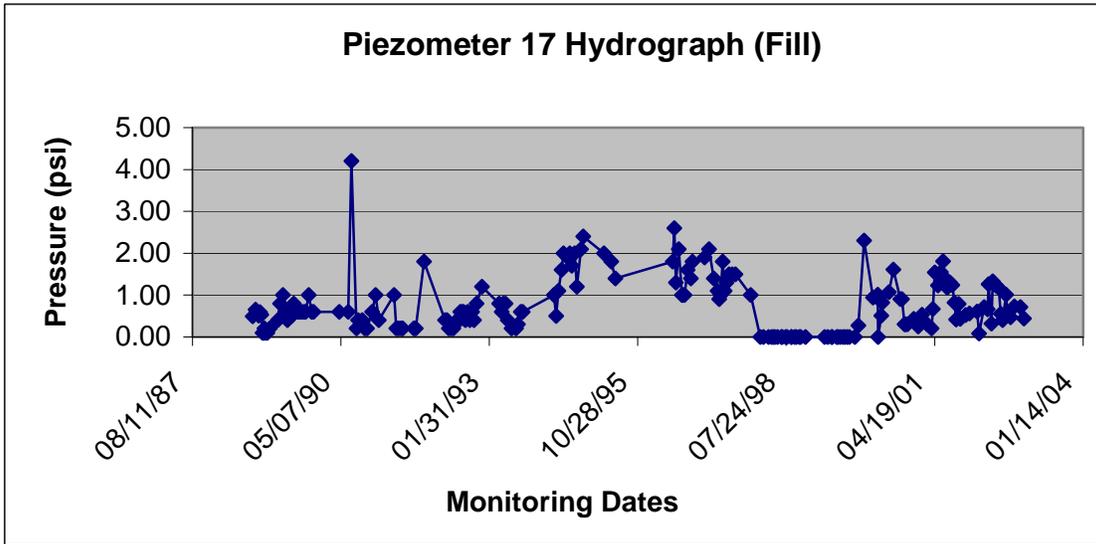
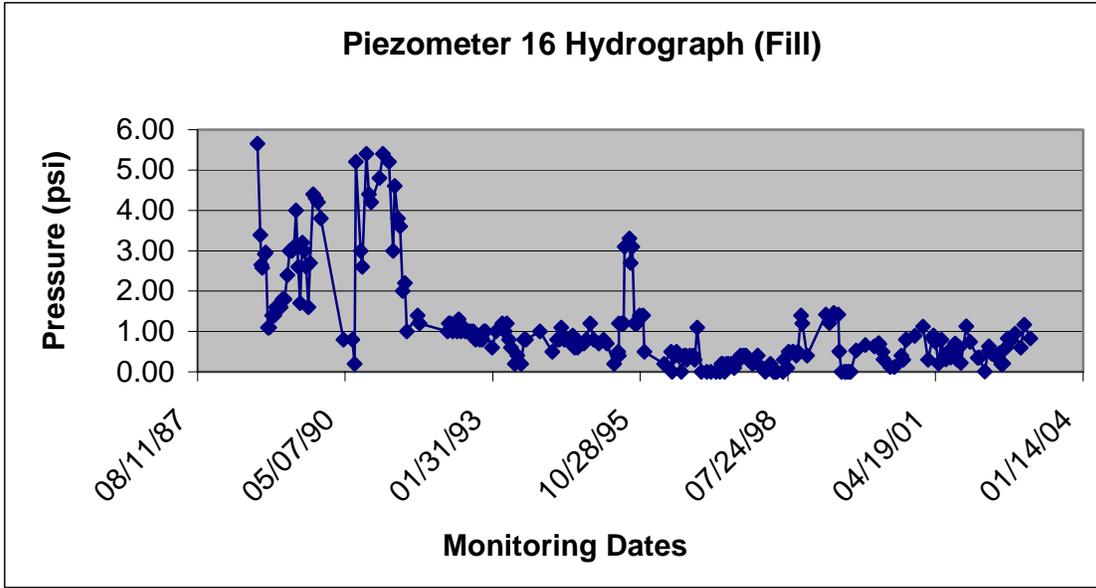
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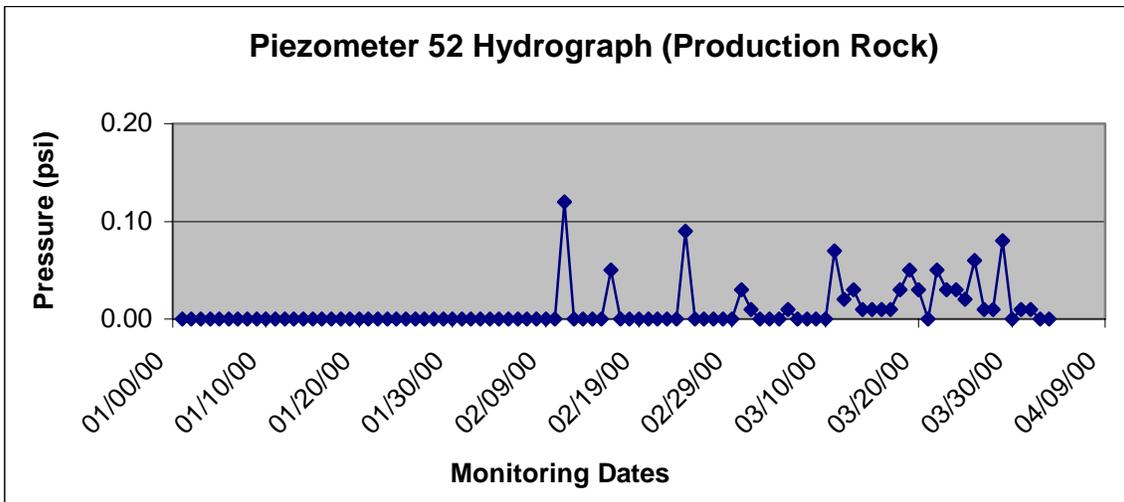
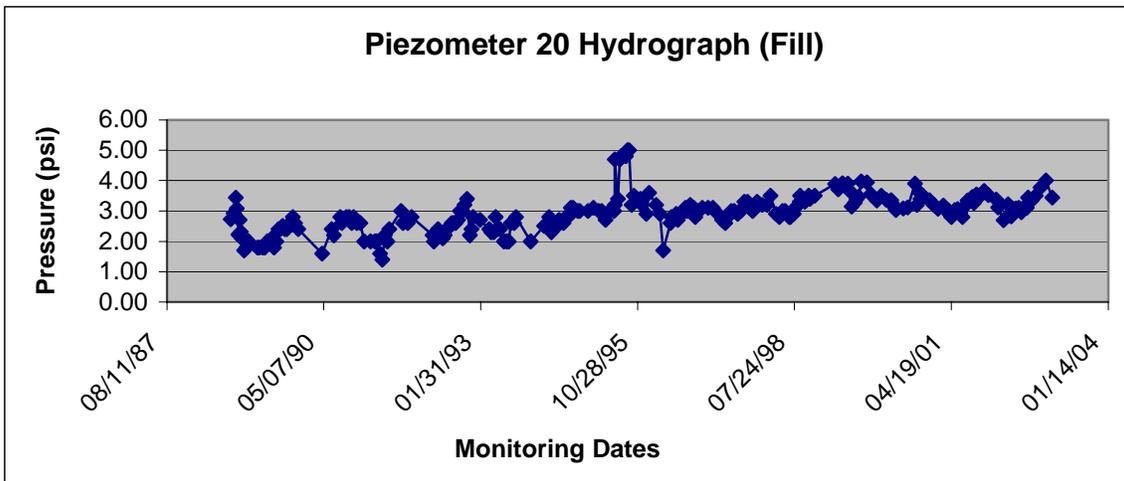
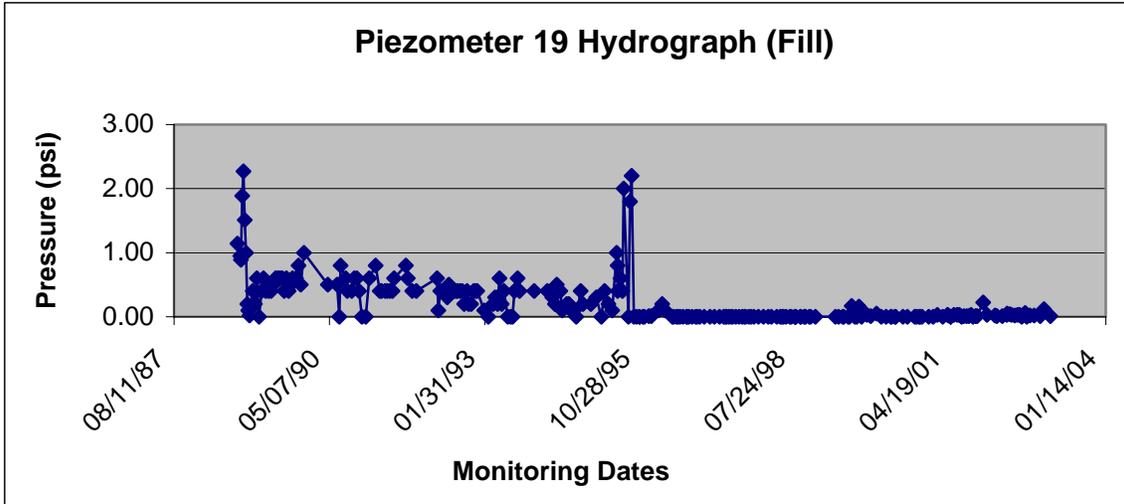












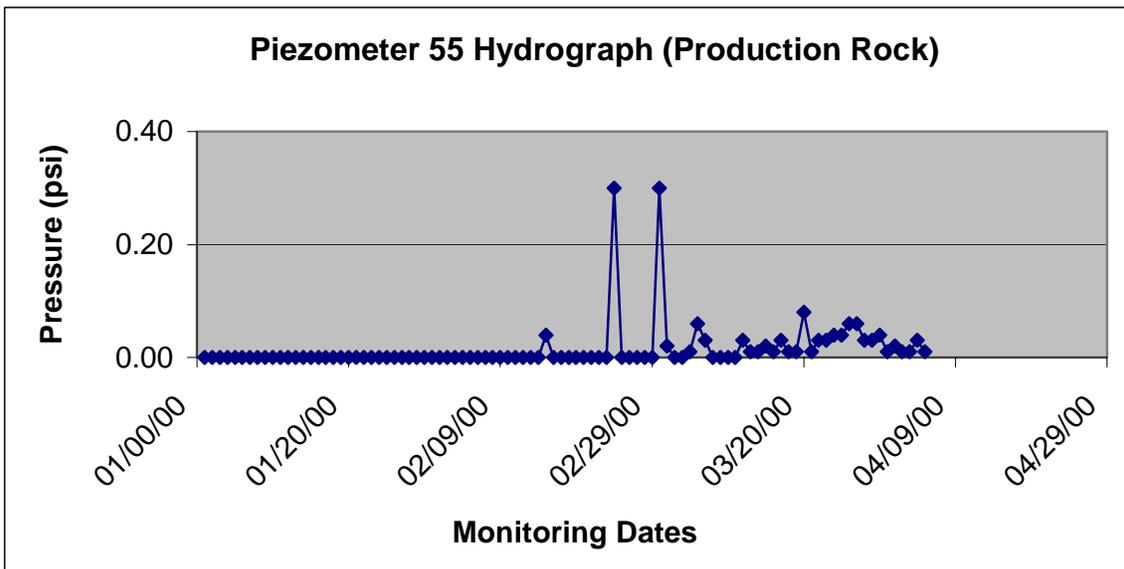
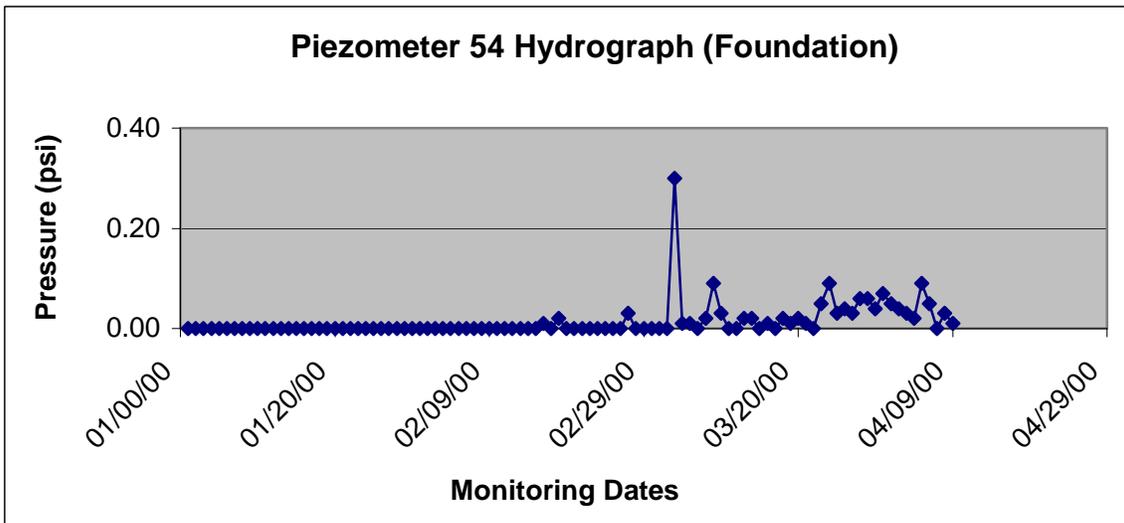
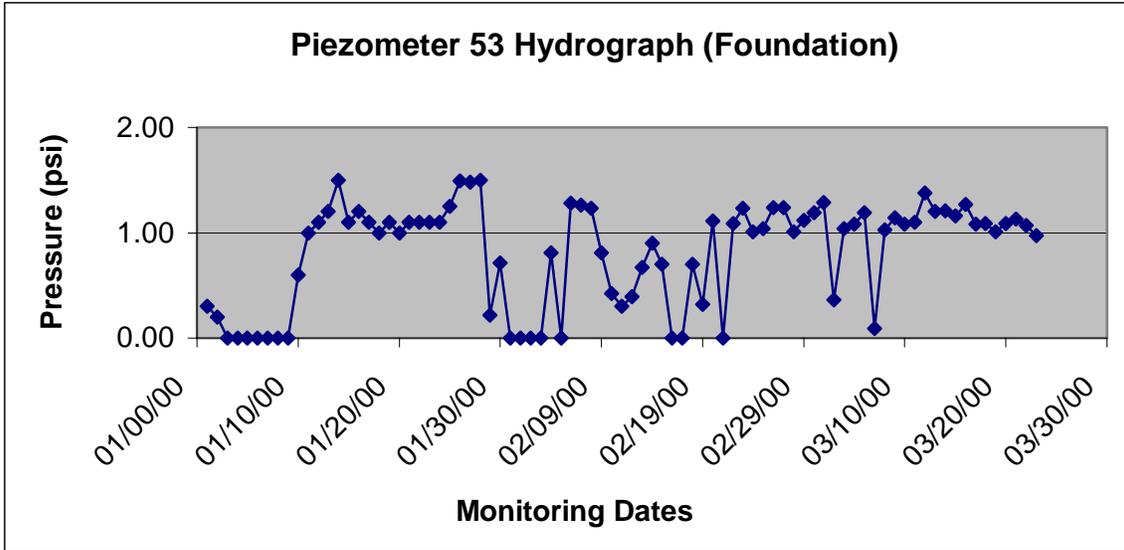


Table A-1—Water elevations for wells/piezometers installed in 2002

Well/Piezometer I.D.	Water Elevation (Ft. AMSL)	Completion
DH-02-01-PZ	934.86	Site 23 Production Rock
DH-02-14	847.93	Fill Material
DH-02-16A	920.39	Fill Material
DH-02-16B	920.16	Alluvium
DH-02-17	829.44	Fill Material

Appendix B—Site 23/D Mass Loading Calculations

Site 23/D Mass Loading Calculations

			1995	2004	Closure w/ D	Closure w/o D
	Precipitation	inches	66	66	66	66
		feet	5.5	5.5	5.5	5.5
	Capture Area	acres	40	40	40	40
		sq. feet	1742400	1742400	1742400	1742400
		Site D				
		Prod. Rock Area	acres	7.2	7.2	7.2
		sq. feet	313632	313632	313632	0
		Infiltration	%	25	25	30
		feet	1.4	1.4	1.7	0.0
		inches	16.5	16.5	19.8	0.0
	Runoff	%	30	40	40	0
		feet	1.7	2.2	2.2	0.0
		inches	19.8	26.4	26.4	0.0
		ET	%	15	15	15
		feet	0.8	0.8	0.8	0.0
		inches	9.9	9.9	9.9	0.0
	Cover Perc	%	30	20	15	0
		feet	1.65	1.1	0.825	0
		inches	19.8	13.2	9.9	0.0
		Site 23				
	Prod. Rock Area	acres	0	11	21	21
		sq. feet	0	479160	914760	914760
	Infiltration	%	0	45	30	30
		feet	0.0	2.5	1.7	1.7
		inches	0.0	29.7	19.8	19.8
		Runoff	%	0	40	40
		feet	0.0	2.2	2.2	2.2
		inches	0.0	26.4	26.4	26.4
	ET	%	0	15	15	15
		feet	0.0	0.8	0.8	0.8
		inches	0.0	9.9	9.9	9.9
		Cover Perc	%	0	0	15
		feet	0	0	0.825	0.825
		inches	0.0	0.0	9.9	9.9
Non Contact	Area	acres	32.8	21.8	11.8	19
		sq. feet	1428768	949608	514008	827640
	Infiltration	%	65	65	65	65
		feet	3.6	3.6	3.6	3.6
		inches	42.9	42.9	42.9	42.9
		Runoff	%	20	20	20
		feet	1.1	1.1	1.1	1.1
		inches	13.2	13.2	13.2	13.2
	ET	%	15	15	15	15
		feet	0.8	0.8	0.8	0.8
		inches	9.9	9.9	9.9	9.9

KENNECOTT GREENS CREEK MINE,
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			TDS				
			concentration		flux		
			measured	theoretical	measured	theoretical	
			mg/l	mg/l	grams/min	grams/min	
Pre-1995 Conditions							
		gpa	gpm				
Non-contact infiltration		3.8E+07	73	175		48	
Non-contact runoff		1.5E+07	29	120		13	
Contact infiltration Site D		3.9E+06	7	2200		61	
Contact runoff Site D		3.9E+06	7	1500		42	
Total flow		6.1E+07	116	334	374	147	164
Current Conditions							
		gpa	gpm				
Non-contact infiltration		2.5E+07	48	175		32	
Non-contact runoff		7.8E+06	15	120		7	
Contact flow Site 23		8.9E+06	17	2300		147	
Runoff Site 23		7.9E+06	15	2500		142	
Contact flow Site D		2.6E+06	5	1500		28	
Site D non contact flow/runoff		8.4E+06	16	185		11	
Curtain Drain		3.3E+07	62	552	567	130	134
Total flow		6.1E+07	116				
D Pond		5.0E+07	96	449	479	163	174
Closure Conditions							
		gpa	gpm				
Non-contact infiltration		2.5E+07	48	175		32	
Non-contact runoff		4.2E+06	8	120		4	
Contact flow Site 23		5.6E+06	11	2300		94	
Runoff Site 23		1.5E+07	29	120		13	
Site D Contact flow with Site D		1.9E+06	4	1500		21	
Site D non-contact flow/ro w/ D		9.0E+06	17	185		12	
Site D non-contact flow/ro w/o D		1.1E+07	21	120		9	
Curtain Drain		2.7E+07	52		475		94
Total flow with D		6.1E+07	116		398		175
Chemistry @ D pond without D		6.1E+07	116		345		151
Field Observations							
Flow from springs (estimated)		gpm	12	Springs observed on slope west of Site D			
Slope width of spring zone		feet	150				
Flux		gpm/ft	0.08				
Curtain drain length		feet	940				
Theoretical CD flow		gpm	75	Flow calculated using spring flux and CD length			
Measured CD flow (average)		gpm	72	1995 average			

Comments

Theoretical combined and total flow concentrations were determined by summing individual fluxes.
 Measured combined and total flow concentrations are based on the range of reasonable field analogs.
 Pre-1995 Site D total flow measured concentrations are based on historic D pond effluent data.
 Contact water composition is based on data from fingerdrains that do not have groundwater component.
 Site 23 combined flow measured concentrations are based on data from curtain drains and FDs w/groundwater.
 Current total flow measured concentrations are based on recent Pond D effluent data.
 Water shed by cover in closure analysis was added to non-contact flow.

KENNECOTT GREENS CREEK MINE,
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	gpa	gpm	Zinc (ug/l)			
			concentration		flux	
			measured ug/l	theoretical ug/l	measured mg/min	theoretical mg/min
Pre-1995 Conditions						
Non-contact infiltration	3.8E+07	73			0	
Non-contact runoff	1.5E+07	29			0	
Contact infiltration Site D	3.9E+06	7			0	
Contact runoff Site D	3.9E+06	7			0	
Total flow	6.1E+07	116		0	0	0
Current Conditions						
Non-contact infiltration	2.5E+07	48	3		1	
Non-contact runoff	7.8E+06	15	1		0	
Contact flow Site 23	8.9E+06	17	1900		121	
Runoff Site 23	7.9E+06	15	1900		108	
Contact flow Site D	2.6E+06	5	1900		35	
Site D non contact flow/runoff	8.4E+06	16	1		0	
Curtain Drain	3.3E+07	62		362	0	85
Total flow	6.1E+07	116				
D Pond	5.0E+07	96	339	333	123	121
Closure Conditions						
Non-contact infiltration	2.5E+07	48	3		1	
Non-contact runoff	4.2E+06	8	1		0	
Contact flow Site 23	5.6E+06	11	1900		77	
Runoff Site 23	1.5E+07	29	1		0	
Site D Contact flow with Site D	1.9E+06	4	1900		26	
Site D non-contact flow/ro w/ D	9.0E+06	17	1		0	
Site D non-contact flow/ro w/o D	1.1E+07	21	1		0	
Curtain Drain	2.7E+07	52		277		55
Total flow with D	6.1E+07	116		238		104
Chemistry @ D pond without D	6.1E+07	116		178		78
Field Observations						
Flow from springs (estimated)	gpm	12	Springs observed on slope west of Site D			
Slope width of spring zone	feet	150				
Flux	gpm/ft	0.08				
Curtain drain length	feet	940				
Theoretical CD flow	gpm	75	Flow calculated using spring flux and CD length			
Measured CD flow (average)	gpm	72	1995 average			

Comments

Theoretical combined and total flow concentrations were determined by summing individual fluxes. Measured combined and total flow concentrations are based on the range of reasonable field analogs. Site D contact measured concentration values are based on data from Site 23 finger drains. Site 23 contact water composition is based on data from fingerdrains that do not have groundwater component. Site 23 combined flow measured concentrations are based on data from curtain drains and FDs w/groundwater. Current total flow measured concentrations are based on recent Pond D effluent data. Water shed by cover in closure analysis was added to non-contact flow.

KENNECOTT GREENS CREEK MINE,
Site 23/D Hydrogeology and Geochemistry Analysis

	gpa	gpm	Cadmium (ug/l)			
			concentration		flux	
			measured ug/l	theoretical ug/l	measured mg/min	theoretical mg/min
Pre-1995 Conditions						
Non-contact infiltration	3.8E+07	73			0	
Non-contact runoff	1.5E+07	29			0	
Contact infiltration Site D	3.9E+06	7			0	
Contact runoff Site D	3.9E+06	7			0	
Total flow	6.1E+07	116		0	0	0
Current Conditions						
Non-contact infiltration	2.5E+07	48	0.14		0	
Non-contact runoff	7.8E+06	15	0.04		0	
Contact flow Site 23	8.9E+06	17	13.1		1	
Runoff Site 23	7.9E+06	15	13.1		1	
Contact flow Site D	2.6E+06	5	13.1		0	
Site D non contact flow/runoff	8.4E+06	16	0.04		0	
Curtain Drain	3.3E+07	62		3	0	1
Total flow	6.1E+07	116				
D Pond	5.0E+07	96	2	2	1	1
Closure Conditions						
Non-contact infiltration	2.5E+07	48	0.14		0	
Non-contact runoff	4.2E+06	8	0.04		0	
Contact flow Site 23	5.6E+06	11	13.1		1	
Runoff Site 23	1.5E+07	29	0.04		0	
Site D Contact flow with Site D	1.9E+06	4	13.1		0	
Site D non-contact flow/ro w/ D	9.0E+06	17	0.04		0	
Site D non-contact flow/ro w/o D	1.1E+07	21	0.04		0	
Curtain Drain	2.7E+07	52		2.00		0
Total flow with D	6.1E+07	116		1.71		1
Chemistry @ D pond without D	6.1E+07	116		1.29		1
Field Observations						
Flow from springs (estimated)	gpm	12	Springs observed on slope west of Site D			
Slope width of spring zone	feet	150				
Flux	gpm/ft	0.08				
Curtain drain length	feet	940				
Theoretical CD flow	gpm	75	Flow calculated using spring flux and CD length			
Measured CD flow (average)	gpm	72	1995 average			

Comments

Theoretical combined and total flow concentrations were determined by summing individual fluxes.
 Measured combined and total flow concentrations are based on the range of reasonable field analogs.
 Contact water composition is based on data from fingerdrains that do not have groundwater component.
 Site 23 combined flow measured concentrations are based on data from curtain drains and FDs w/groundwater.
 Current total flow measured concentrations are based on recent Pond D effluent data.
 Water shed by cover in closure analysis was added to non-contact flow.