TAILINGS AND PRODUCTION ROCK SITE
2009 ANNUAL REPORT

Hecla Greens Creek Mining Company

April 15, 2010

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(Data Graphs see Appendix 3; Photographs see Appendix 4)

APPENDICES

1.0 Executive Summary

This annual report has been prepared by Greens Creek Mining Company in accordance with Alaska Waste Disposal Permit 0211-BA001 and the mine's General Plan of Operations Appendices 3 and 11. The following itemized list summarizes key information and indicates where in this report the information outlined in Section 6.2 of Permit 0211-BA001 is presented:

Permit Section		Report Section
6.2.1	Closure plan summary	2.8
	Precipitation	2.4, 3.4
	Mill Site 52.3" Tailings 35.5"	
	Summary of internal monitoring and fresh water monitoring plans	2.5, 3.5
	FWMP annual report separate for water year 2009 as per the ADEC request for full data presentation.	
	Internal monitoring water compositions at both sites dominated by Ca, Mg, SO_4, neutral pH, high alkalinity, high zinc, low to moderate concentrations of other metals. Data are consistent with sulfide oxidation and carbonate mineral buffering. Sulfate reduction in saturated zone of tailings pile yields low concentrations of all metals. Concentration of As continues higher in some tailings wells due to migration of redox boundary. Seasonal compositional fluctuations continue evident in most wells/drains.	
	Stability	2.3, 3.3
	Stability monitoring at the Tailings facility and Site 23 indicate that that sites meet design specifications. Foundation heads are consistently low at both sites except for short-lived spikes in one piezometer (north end of West Buttress).	
	Cover performance	3.8
	>85% saturation maintained, barrier layer not subject to freeze/thaw cycles. Net measured "percolation" up to 19%. Oregon State University studies are ongoing to better understand cover water characteristics. Lateral flows are being analyzed within cover.	
	Pond D flow and composition	3.4, 3.5
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6.2.5	Location and volume of materials	2.2, 3.2
	Northwest Tailings area 412,736 total tons in 2009 (tailings 306,035 and other materials 106,701 tons)	
	Site 23 25,157 total tons placed in 2009	

	Compaction	2.3, 3.3
	Target compaction densities achieved in nuclear density tests.	
	Acid Base Accounting	2.5, 3.5
	Potentially acid generating Class 3 production rock	
	Neutralization potential values continue to demonstrate long lag time (buffering capacity)	
	Class 1 production rock is significantly acid neutralizing (about 36% carbonate)	
	Possible water releases	2.5
	No new signs of possible release were identified in 2009	
6.2.4	Information regarding validity, variations and trends	various
	Full FWMP data assessment in separate report	
	Internal Monitoring Plan variations are seasonal, no deleterious trends identified	

The report is separated such that all aspects of the Tailings Facility are discussed first in Section 2 followed by discussion of Site 23/D in Section 3. Information that is pertinent to both sections is generally not repeated but is discussed in the most relevant section and identified by reference in the other section.

2.0 Tailings Area

2.1 Introduction

Hecla Greens Creek Mining Company (HGCMC) has prepared this section of the Annual Report in accordance with the mine's General Plan of Operations (Appendix 3) and Alaska Waste Management Permit 0211-BA001. Permit 0211-BA001 expired in November of 2008 and is in the process of renewal. HGCMC is operating under a permit extension from ADEC (letter dated October 6, 2008) until a new permit is finalized. This report provides a summary of all operational and monitoring activities performed in 2009. Refer to GPO Appendix 3 and permit 0211-BA001 for a detailed description of the Tailings Facility and associated monitoring requirements.

HGCMC operated its Tailings Facility continuously in 2009. Primary placement of tailings was in the Northwest Excavation area (see Tailings Facility as-built in Appendix 1). HGCMC added 227,817 cubic yards of material to the Tailings Facility in 2009, bringing the total facility volume to approximately 3,078,657 cubic yards. These yardages convert to approximately 306,035 tons of tailings placed at the Tailings Facility with placement of all materials at the tailings facility totaling approximately 412,736 tons during this report period as calculated from HGCMC surveyed volumes and material densities.

2.2 Placement Records

Table 2.1 contains the monthly placement records for tailings, production rock and other materials at the Tailings Facility for 2009. Surveyed volumes (cubic yards) were converted to tons using a tonnage factor of 1.8 tons per cubic yard (134.2 pcf for tailings). Production rock from Site 23 used for road access and erosion control contributed approximately 16,117 tons to the facility. An additional 90,584 tons of other material (including production rock from Site E) were also placed at the facility in 2009. The calculated tonnage of tailings was derived by subtracting the tons of production rock and other material from the surveyed total. The full pile currently contains approximately 5.6 million tons of material. Based on the survey data presented in Table 2.1 there is a remaining capacity of approximately 4.0 million tons of the 9.6 million tons permitted for placement at the facility. Estimates of other miscellaneous materials disposed in the facility are shown in Table 2.2.

Table 2.1 Tailings Placement Area Data

2009	All Materials Monthly Total by Survey (CY)	All Materials Cumulative by Survey (CY)	All Materials Monthly Total Tonnage (Calculated tons)	All Materials Cumulative Total Tonnage (Calculated tons)	Prod Rock from Site 23 by truck count (tons)	All Other Materials (Ditch Seds and Construction) by truck count (tons)	Tailings Tonnage (Calculated tons)
1/31/2009	20,000	2,870,840	36,234	**5,201,101**	938	645	34,651
2/28/2009	15,550	2,886,390	28,172	5,229,273	1135	453	26,584
3/31/2009	14,700	2,901,090	26,632	5,255,905	4019	2794	19,819
4/30/2009	17,220	2,918,310	31,197	5,287,102	2380	3652	25,165
5/31/2009	15,929	2,934,239	28,859	5,315,961	877	210	27,772
6/30/2009	18,435	2,952,674	33,399	5,349,359	2175	170	31,054
7/30/2009	34,163	2,986,837	61,893	5,411,252	558	37125	24,210
8/31/2009	31,523	3,018,360	57,110	5,468,363	262	31738	25,110
9/30/2009	24,080	3,042,440	43,626	5,511,988	3009	9522	31,095
10/30/2009	10,495	3,052,935	19,014	5,531,002	190	2262	16,562
11/30/2009	11,507	3,064,442	20,847	5,551,849	0	1563	19,284
12/31/2009	14,215	3,078,657	25,753	5,577,603	574	450	24,729
Totals	**227,817**	**3,078,657**	**412,736**	**5,577,603**	**16,117**	**90,584**	**306,035**
Tons calculated at 134.2 pounds per cubic foot for tailings							

Table 2.2 Miscellaneous 2009 Materials Disposal Estimates

Surface Tailings	**CY**
Pressed Sewage Sludge	50
Pressed Water Treatment Plant Sludge	500
Incinerator Ash	16
Site E	40,000
Underground	**CY**
Tires	550 ea
Sump Sediments	3640
Shop Refuse	730
Mill Refuse	310
Electrical Refuse	120

2.3 Stability

Tailings placement compaction is tested to monitor the performance goal of achieving 90 percent or greater compaction relative to a standard Proctor density. HGCMC staff utilizes a Troxler Model 3430 nuclear moisture-density gauge to measure wet density and percent moisture content of placed tailings. Dry densities are calculated and compared to laboratory measured standard Proctors.

<u>Compaction</u>

Summary results for 2009 are shown in Table 2.3. Standard Proctor values were measured on samples taken from the tailings-loadout facility at the 920 and submitted to an outside materials testing lab, which performed the test within the ASTM guidelines for method #D698. The standard Proctor value was 146 pcf (pounds per cubic foot). HGCMC instituted a program at its on-site lab to determine 1-point proctors at the end of 2005. The mean dry density for 28 samples taken throughout the year in 2009 was 146 pcf, and the average percent moisture was 11.5%. Results to date confirm proctor and moisture data received from the outside materials testing lab.

Field measurement results show a high degree of achieving greater than 90% compaction (with respect to an average Standard Proctor value of 146). Testing done in prior years has confirmed that density results obtained using the Troxler procedure average approximately 2 percent higher than the densities obtained via other methods.

With the codisposal of Site E materials into the tailings facility beginning in 2009, field measurements were not as frequent. It is unlikely that the Troxler (or other methods) would provide useful information on the codisposed material. Unlike run-of-mill tailings, which have a relatively consistent standard Proctor value to compare field densities to, the mixture of rock and tailings will not. The Proctor density of the mixture would vary with the proportion of rock added and the density of the rock fraction. As with waste rock, measuring Proctor densities of materials containing a coarse fraction is not recommended. For codisposal HGCMC will use the same method of compaction necessary to achieve the target density for straight tailings. This is typically at least two back and forth passes with the dozer and at least one back and forth pass with the roller. Visual observations of the codisposed material placed to date indicate that the mixed material compacts very well. HGCMC will continue to evaluate the placement procedures and will continue to use the Troxler in areas that receive just tailings.

Table 2.3 Summary Statistics for 2009 Tailings Compaction Testing Data

Compaction Variable	Mean	Max	Min	Std. Dev.	n
Std. Proctor[ASTM #D698] (pcf)	**146**	**148**	**143**	**3**	2
Opt. Moisture (%)	11.8%	12.3%	11.2%	0.9%	
1-pt Proctor (pcf)	146	158	135	9	28
As Received Moisture (%)	11.5%	13.6%	10.0%	3.8%	
Measured Dry Density (pcf)	141	145	138	2.7	6
Measured moisture (%)	7.6%	12.4%	5.3%	2.5%	
Rel. Compaction % *	96.6%	99.5%	94.7%	1.8%	

* Percent compaction calculated with respect to corresponding monthly proctor.

Inspections

Several independent inspections are carried out at the tailings area throughout the year. Operators working at the site carry out daily visual work place inspections. The Surface Civil Engineer and/ or Surface Operations Manager carry out weekly visual inspections of the Tailings Facility area, as well as a checklist inspection of Pond 7. The environmental department carries out a monthly checklist inspection of the Tailings Facility.

ADEC representatives inspected the site five times in 2009 (May 20, June 3, August 25, September 23, and November 10). During 2009 the USFS conducted 12 routine inspections (Site inspections #298-#309) to monitor for best management practices effectiveness and compliance to the General Plan of Operations. No issues of non-compliance or poor operations practices of the surface Tailings Facility were noted during the routine inspections. The USFS typically noted that the facility is being developed and operated to required operations and maintenance specifications of GPO Appendix 3.

Well and Piezometer Water Level Data

Water level data for the Tailings Facility are presented in Figures 2.1 to 2.18. A variety of methods are used to determine water levels including:

- Measuring the depth to water by tape or sonic indicator in PVC monitoring wells (also called standpipe piezometers)
- Measuring air pressure in pneumatic piezometers where water pressure against the transducer diaphragm increases air pressure between the diaphragm and the monitoring gauge
- Measuring the frequency of vibration of a vibrating wire piezometer where water pressure creates tension on the transducer wire changing its vibration frequency

Pneumatic and vibrating wire piezometers are typically installed in locations where standpipes are impractical, such as under a liner or in active placement areas. Installation of vibrating wire piezometers allows "real time" data logging and measurement of negative pressures (matric suction). Vibrating wire piezometers can also be installed in existing PVC well casing to allow covering during liner installation and if real time data logging and water sampling is desired (e.g. MW-T-00-05A and PZ-T-00-02). A drawback of pneumatic and vibrating wire piezometers is that they do not provide a means for water sampling or aquifer testing (unless they are installed in an existing well).

Well and piezometer locations and water level cross sections are shown on the tailing facility as-built (Appendix 1). The maximum saturated thickness (approximately 35 feet) occurs near the center of the main portion of the pile. However, this elevated water table level does not extend close to the down-slope toe of the pile. The foundations of the West Buttress and southern portion of the pile are well drained, as indicated by typically consistent unsaturated conditions in the blanket drains (MW-T-00-05A, Figure 2.14) and at the base of the West Buttress (piezometers 74 and PZ-T-05-08 in Figures 2.8 and 2.9). Low head elevations near the pile toe maximize the pile's geotechnical stability. Intermittent head increases in the foundation drains are localized and of short duration and should not have an adverse effect on pile stability.

The data from standpipe and pneumatic piezometers completed above the blanket drain (Piezometer 76, PZ-T-00-01, PZ-T-00-02, PZ-T-00-03 in Figures 2.10, 2.11, 2.12, 2.13) indicate that saturated conditions can develop above the unsaturated underdrains to a thickness of approximately 12 feet. This is consistent with the low permeability of the tailings and the uncapped condition of the pile. Covering the pile will help minimize the saturated zone in the pile. This was demonstrated by the over 10 foot decrease in the water table that occurred from 1995 to 1997 when the pile was covered (see Figures 2.1 to 2.7). Water levels have rebounded to, and in some cases above, 1994 elevations in most areas. Areas where water levels exceed their 1994 values are areas where the pile is considerably thicker than it was in 1994. The increase in water levels observed in PZ-T-00-01 (and to a lesser extent in instruments nearby) from 2005 to 2008 is likely a result of new tailings placement in the area and staged decommissioning of Wet Well 2.

Periodic spikes in water levels in the wells and piezometers are due to a variety of factors including extreme weather events (e.g. Fall/Winter 2005-2006), changes to water management infrastructure (e.g. decommissioning of Wet Well 2 from 2005-2008), damage to instrumentation (Piezometer 76 in 2004), and measurement errors (e.g. MW-T-00-05A in 2002-2003 and 2007).

Water levels in four wells completed east and west of the pile are shown for comparison in Figures 2.15 to 2.18. The eastern wells, MW-T-00-03A (Figure 2.15) and MW-T-00-03B (Figure 2.16), are completed in the shallow sands 12 and 17 feet, respectively, below ground surface. The figures for these wells show that the water elevation in shallow completions in native materials can be readily influenced by abnormal weather conditions. Wells MW-T-01-03A and MW-T-01-03B are installed west of the pile. Their water levels are shown in Figures 2.17 and 2.18, respectively. MW-T-01-03A is completed in bedrock to a depth of 20 feet and MW-T-01-03B is completed in clayey silt to a depth of 12 feet. These wells show similar water level fluctuations with weather conditions as the two eastern wells. However, the water level in MW-T-01-03B shows a larger differential than MW-T-01-03A because silts and clays hold more water in tension, so a small increase in water content causes a large change in head. The ground surface elevation is 134 feet in the proximity of these two wells. Both MW-T-01-03A and MW-T-01-03B were damaged by bears in 2006 and attempts to recover them have not been successful. Therefore, no data were obtained from those wells in 2007-2009. HGCMC will consider replacing them during a future drilling program.

2.4 Hydrology

A detailed review of the hydrology of the Tailings Facility was performed by Environmental Design Engineering (EDE) in 2001 (EDE 2002a) with an update in 2006 (EDE 2007). Those reports describe the hydrogeology of the site and present calculations of anticipated post-closure hydrologic conditions. Water management at the facility consists of a complex network of drains under the pile, bentonite slurry walls around the perimeter of the site, and ditches to divert up-slope water and collect surface runoff. See the Tailings Facility as-built for locations of the site's water management components. The site is underlain by a low permeability silt/clay till and other glacial/marine deposits or an engineered HDPE liner. These features minimize the potential for the downward migration of contact waters. An upward hydrologic gradient under the site further improves contact water collection. EDE initiated work on the update to the hydrology analysis in 2006, and the final report was completed in 2007 (EDE 2007). That update made the following conclusions and recommendations:

- Bedrock exposures protruding under the northwest corner of the tailing pile may be a pathway for contact water to mix with groundwater. It is therefore practical to have the liner for the new Northwest Expansion also extend over bedrock that currently protrudes beneath the existing pile. Excavation of the northwest corner of the tailings pile will be required to expose the bedrock and tie the liner into the low permeability silt/clay glacio-marine sedimentary unit that surrounds the bedrock.

- Excavation of the northwest corner of the tailing pile will also allow installation of an underdrain to convey surface water and contact water from the northern part of the facility to the southwest. This will facilitate post-closure gravity drainage to the west.
- Excavation and lining of the northwest area is expected to lower bedrock heads, but bedrock groundwater levels may equilibrate to a level close to or slightly below the top of the fractured bedrock.
- Available data indicate that the existing placement areas are underlain either by synthetic liners or by glacio-marine sediments which act as a competent natural liner.
- Historical piezometric data were used to determine a conservative maximum tailings phreatic surface for stability analyses. Two dimensional, cross sectional flow modeling is recommended.

The 2003 Environmental Impact Statement (USFS 2003) process analyzed the incremental expansion of the Tailings Facility storage capacity, a continuation of which is in progress to accommodate the projected tailings storage requirements for the mine. As part of the expansion work, Pond 6 and Pit 5 areas are being constructed for tailings disposal. To accommodate these expansion plans and a change in the regulatory requirements for storm water retention, HGCMC constructed a new 30 acre-foot storm water pond (Pond 7) in 2005, and rerouted collection and distribution facilities to include the new Pond 7. For background and design information for Pond 7, see Klohn Crippen's 2005 report, and EDE's 2005 Pond 7 Hydrology Report.

Precipitation and temperature data are presented in Table 2.4. July was the driest month with 0.8 inches of precipitation. July and August were the warmest months while January exhibited the coolest temperatures. It was an unusually dry, cool spring and dry, warm summer, with the Juneau annual climate summary stating for 2009:

> "Total precipitation....came out more than three quarters of an inch below normal in the spring. The dry trend continued and by mid August Juneau precipitation was 2 inches below normal for the year to date."

Flow data from Wet Wells 2 and 3 are presented with the precipitation data for 2005 – 2009 in Figure 2.19. The wet well flows respond relatively quickly to precipitation events, demonstrating a significant contribution of surface water. The use of the wet well flow meters has been discontinued since 2005 as part of the tailings expansion activities.

Table 2.4 Monthly Summaries of Tailings Area Climate Data

Month	Avg Temp (°C)	Precipitation (in)
January	-3.1	4.5
February	-1.3	2.2
March	-0.6	1.9
April	3.6	1.0
May	8.0	1.4
June	11.4	1.7
July	14.6	0.8
August	12.8	5.5
September	10.1	5.9
October	6.4	4.5
November	2.2	3.5
December	-0.8	2.4
2009	5.3	35.5

2.5 Water Quality

Compliance Monitoring

Sites around the surface tailings storage facility have been monitored continuously since 1988. This sampling pre-dates the placement of tailings at this facility. The FWMP Annual Report for water year 2009 is being prepared separately and will be submitted to the Forest Service and ADEC upon completion.

Internal Monitoring

As described in Waste Management Permit Number 0211-BA001 Section 2.8.3.1, the internal plan addressed monitoring at both the surface Tailings Facility and the surface production rock storage areas covered by the permit. The Internal Monitoring Plan describes monitoring within the pile areas, in contrast to the compliance monitoring (under the Fresh Water Monitoring Plan) at peripheral facility boundary sites. As such, data generated by the Internal Monitoring Plan effort are "… not for compliance purposes…" as noted in the above referenced permit Section 2.8.3.1, but provide a continuing perspective on in-pile geochemical processes.

The analytical results of HGCMC's internal site monitoring plan are summarized in Figures 2.20 to 2.31. Sites were distinguished between foundation wet wells (Wet Well 2 and Wet Well 3), wells completed in tailings (PZ-T-00-01, PZ-T-00-02, PZ-T-00-03, MW-T-02-5 and MW-T-02-6) and suction lysimeters (SL-T-02-4, SL-T-02-5, SL-T-02-6, and SL-T-02-7). These lysimeters are installed at various depths within the pile's vadose zone. These groups are separated on Figures 2.20 through 2.31 with the suffix a, b or c, respectively. For example, a figure number such as 2.20a would show the data for the wet wells group, 2.20b would show the data for the tailings completion wells, and 2.20c would show the data for the suction lysimeters.

An in-depth evaluation of the hydrology and geochemistry of the Tailings Facility was performed by Environmental Design Engineering (EDE) and KGCMC in late 2001 (EDE 2002a, EDE 2002b, EDE 2007, KGCMC 2002a) and the Tailings Expansion EIS (USFS 2003). The observations made under the 2009 internal monitoring plan are consistent with the findings of the EDE, KGCMC/HGCMC and USFS reports.

All internal monitoring waters are captured and treated prior to discharge to the ocean floor under HGCMC's National Pollutant Discharge Elimination System Permit (AK 004320-6) from EPA.

Most values of pH remained between 6 and 8.5 for all internal monitoring site samples in 2009 (Figures 2.20a, b and c). PZ-T-00-01, PZ-T-00-2 and PZ-T-00-3, which screen the lower ten feet of the tailings pile, have the highest pH on average of the internal monitoring sites. This is likely a result of microbial sulfate reduction and equilibration with carbonate in the saturated zone of the pile. The wet wells produce water with slightly lower pH (generally between 6.5 and 7), reflecting minor influences from groundwater (organic acids) and oxidized surface waters (acidity from thiosalt, sulfide and iron oxidation). The suction lysimeters all have pH values between 6.87 and 8.03 with the exception of SL-T-02-06 which has shown pHs above 8.5 since 2006, likely a result of sulfate reduction.

Alkalinity data are presented in Figures 2.21a, b and c. Alkalinity generally ranges between 150 and 600 mg/l $CaCO_3$ within the tailings pile waters, consistent with buffering from carbonate minerals and the products of microbial sulfate reduction. The fact that these internal waters are near-neutral to alkaline and continue to show substantial alkalinity indicates that the buffering capacity of the tailings is sufficient to prevent acidification of site drainage in the near-term (at least tens of years) even though portions of this material have now been in place at this site for approximately 20 years.

The conductivity results from internal monitoring site waters are presented in Figures 2.22a, b, and c. Conductivity measurements in 2009 ranged between 2,090 (wet wells), 4,070 (wells completed in tailings) and 3,840 (suction lysimeters) µS/cm. The higher conductivity of the site contact waters reflects a larger dissolved load caused by weathering of the tailings. Pyrite oxidation and carbonate dissolution contribute dissolved ions such as sulfate, bicarbonate, calcium and magnesium to the contact waters, increasing their conductivity. Wet Well 3 has a different capture area than Wet Well 2 and shows a different pattern with respect to conductivity. The changes in conductivity observed in Wet Well 3 suggest changes in the relative contributions from runoff, addition of the Northwest Diversion Ditch flow, infiltration and groundwater as the West Buttress was constructed. The increase in conductivity seen in Wet Well 2 over the past several years likely reflects an increasing contribution from contact water in the drain system and an increase in the dissolved load from migration/remobilization of oxidation products in the pile. In 2008 Wet Well 2 was routed to Wet Well A, a new wet well located in the newly modified Pond 6 area. Suction lysimeter samples are drawn from the smallest pore spaces of the unsaturated zone. Water held in these pores is often isolated from flow paths and thus usually has higher dissolved constituent concentrations than water from the saturated zone and foundation drains.

Hardness and sulfate concentrations remain consistent with the conductivity results. Calcium and magnesium are the primary contributors to hardness (Figures 2.23a and b) and reflect dissolution of carbonate minerals, such as calcite and dolomite. Carbonate dissolution neutralizes acidity formed by sulfide oxidation, which is also the source of sulfate shown in Figures 2.24a, b, and c. Sulfate concentrations typically range between 500 and 5,120 mg/l in the tailings pile waters. The increase in sulfate and other constituents seen in PZ-T-00-03 likely reflects the replacement of interstitial process water with infiltrating surface water, which carries a higher dissolved load.

Arsenic data are presented in Figures 2.25a, b and c. The variability in arsenic concentrations observed in Wet Well 2, MW-T-02-06, and some suction lysimeters is related to evolving redox conditions in the pile. As arsenic-bearing minerals such as tetrahedrite/tennantite (and to a lesser extent pyrite) weather, the arsenic that is released is typically co-precipitated with iron oxy-hydroxides. As the pile grows, reducing conditions overtake areas that were once oxidizing. This was particularly true as the water table rose following removal of the temporary PVC cover that was placed on the pile in 1995 (removal began in 1997). Dissolution of oxyhydroxides (and possibly sulfates) is expected as the waters respond to the changing redox conditions. This will contribute arsenic and iron (Figures 2.30a, b and c) to the drainage water. Arsenic concentrations in the pile drainage will therefore decrease when redox conditions in the pile stabilize (e.g. with closure and capping of the pile). Sulfate reduction may also lower arsenic concentrations. This is apparent in the composition of waters from the saturated zone and in some of the SRMP test cells, which are discussed in more detail below.

Figures 2.26a, b and c show the concentration of zinc from the monitoring sites. Zinc levels from the saturated zone of the pile continue to remain low (Figure 2.26b), a result of sulfate reduction, which promotes zinc sulfide precipitation An increase in zinc (to 328 ppb) in PZ-T-00-02 in 2009 was observed in one sample from 2009. The cause for the increase in not immediately apparent and HGCMC will continue to monitor this well for additional changes. The zinc concentration in MW-T-02-06 in 2003 and 2004, along with the lower alkalinity, suggest that sulfate reduction may not yet have been occurring in this portion of the West Buttress. However, the April 2005 data showed a significant decrease in the concentration of zinc (from an average of 1,000 µg/l to less than 10 µg/l), and the zinc has continued to remain below 50 µg/l. Placement of argillite on the outer slopes of the West Buttress has also led to higher zinc concentrations in Wet Well 3 from surface runoff flushing of this material when it was initially placed. In 2003, the zinc concentration in this wet well returned to within historical limits, and has remained between 500 – 3,500 µg/l from 2004 – 2009, except for a result of 6030 µg/l in the first sample of 2009. The second sample in 2009 was 1830 µg/l. The two 20 foot suction lysimeters showed zinc concentrations between 730 – 2,410 µg/l (SL-02-05, SL-02-07), and the two 40 foot lysimeters (SL-02-04, SL-02-06) had zinc concentrations less that 150 µg/l (Figure 2.26c).

The concentrations of copper and lead are considerably lower than that of zinc. Both of these metals' concentrations are generally less than 5 µg/l in water from each site (Figures 2.27a, b and c and 2.28a, b and c). Previous observations have shown that copper and lead mobility are greatest when the tailings are first placed, then decrease with time.

Cadmium data are shown in Figures 2.29a, b and c. With the exception of Wet Well 2 and 3, cadmium concentrations are very low (less than 2 µg/l). Cadmium in Wet Well 3 had a maximum value of 27 µg/l in 2002 and showed seasonal fluctuation similar that of zinc, albeit at significantly lower concentrations. In the first 2007 sample, Wet Well 2 showed an elevated cadmium level, but the second sample was less than the detection limit, and has remained below the detection limit in 2009. Well MW-T-02-06 showed a cadmium concentration of 4.5 µg/l in June 2003; however, samples since then have all been 0.6 µg/l or less.

Iron and manganese data are presented in Figures 2.30 a, b and c and 2.31 a, b and c, respectively. Concentrations of iron and manganese are high in the wet wells, groundwater and most of the suction lysimeters due to oxidation/reduction and buffering reactions. Lower concentrations of iron and other metals in PZ-T-00-01, PZ-T-00-02 and PZ-T-00-03 likely indicate sulfide precipitation resulting from sulfate reduction in these waters.

In previous years, Wet Well 3 reflected surface effects while Wet Well 2 was influenced more by internal-pile contact water and foundation groundwater. However, in recent years, the compositions of Wet Well 2 and Wet Well 3 waters have become similar, reflecting a decrease in surface effects. Before it was decommissioned in 2007, MW-T-02-06 water had evolved toward compositions indicative of sulfate reduction, similar to those seen in PZ-T-00-01, PZ-T-00-02 and PZ-T-00-03.

Acid Base Accounting Analyses

ABA analyses of monthly composite samples were taken of tailings at the Mill filter press. Figure 2.32 shows the monthly composite sample ABA results for 2001 through 2009. The average net neutralization potential (NNP) results are shown in Table 2.5. The variability from year to year is primarily due to fluctuations in acid potential (AP), which is an indication of the pyrite content of the ore. Neutralization potential (NP) values, which primarily reflect carbonate content, are generally more constant.

Table 2.5 Average Tailings NNP - Mill Filter Press

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
Average NNP ($tCaCO_3$/kt)	-281	-197	-194	-200	-134	-123	-156	-237	-289

The results of ABA analyses on grid samples taken from the Tailing Facility from 2002 to 2008 are presented in Figures 2.33 and 2.34. The grid included portions of the pile that had exposures of tailings, argillite slope armoring, road rock, and ditch sediment. Figure 2.33 shows the acid generation potential (AP) versus neutralization potential (NP) of all grid samples. The pure tailings samples plot in the upper half of this figure, indicating that they are potentially acid generating. However, the high carbonate content of the tailings (NP >100 $CaCO_3$/1000t) indicates there is substantial buffering capacity remaining in the tailings. These results remain consistent with previous studies of the mine's tailings. Samples of weathered tailings (after approximately 12 years of exposure) have been shown to still retain a considerable amount of neutralization potential, equivalent to approximately 20% calcium carbonate (KGCMC 2002b). This suggests that the potential lag time to acid generation of exposed tailings is on the order of decades. This long lag time allows time for construction and adequate closure of the site (including covering the pile with a composite soil cover designed to minimize oxygen ingress).

Figure 2.34 shows the relationship of pH to net neutralization potential for the same suite of samples shown in Figure 2.33. Rinse pH is a measure of the pH of a one-to-one mixture of "as received" fines and water. The rinse pH of all of the samples of pure tailings are above 6.0, indicating that the exposed surfaces of the tailings pile remain well buffered. Grid samples with positive NNP values are not representative of tailings and may include argillite and ditch sediments. Samples containing peat can produce a lower pH because of acids formed from the natural decomposition of organic matter.

Sulfate Reduction Monitoring Program (SRMP)

Following the USFS 2003 EIS Record of Decision for expansion of the tailings pile, HGCMC began a mandated 30 month study to determine the feasibility of promoting long term sulfate reduction at the facility. HGCMC assembled a team comprised of personnel from the University of Waterloo, HGCMC and independent consultants to develop and implement the investigation. The primary objective of the sulfate reduction monitoring program (SRMP) is to determine the feasibility of meeting closure objectives related to water quality by promoting in-situ microbial processes that increase alkalinity and reduce the concentration of constituents of concern.

A summary report of the 2006 data was distributed to regulatory agencies in 2007. The report and submittal explained the need to extend the study beyond the originally envisioned 30 month time period. A summary report from University of Waterloo including data from the 2007 and 2008 field seasons is expected during the 2nd quarter of 2010. A second phase of the Waterloo investigation commenced in 2009 and will continue in 2010. Findings from this second phase will be presented in a follow-up report in 2011. HGCMC will forward both reports to the regulatory agencies for their review. By the end of 2010, HGCMC anticipates having enough information about the merits and liabilities of carbon amendment to decide if full-scale application is advisable.

Field test program

Seven field test cells were constructed and instrumented in the fall of 2004 to monitor the effects of adding different carbon sources to an unsaturated portion of the pile. Cell treatments are summarized in Table 2.6. The cells are 10 feet square and 13 feet deep. A synthetic liner was installed around the vertical sides of the excavations (Cells 2-7) to isolate the cells from lateral flow while allowing vertical flow through the cells. Pore water and core samples are taken annually from multiple depths through each cell and soil suction, moisture content and temperature profiles are also collected.

Table 2.6 SRMP Cell Treatments

	Tailings (volume %)	Peat (volume %)	Spent Brewing Grain (volume %)	Municipal Biosolids (volume %)	
Cell 1	100	0	0	0	Unexcavated
Cell 2	100	0	0	0	Excavated
Cell 3	95	5	0	0	Amended
Cell 4	95	2.5	2.5	0	Amended
Cell 5	95	2.5	0	2.5	Amended
Cell 6	95	2.5	1.25	1.25	Amended
Cell 7	90	5	2.5	2.5	Amended

The field test program results as reported in the performance report for 2006 (University of Waterloo, 2007) and follow-up communications are summarized as follows:

Addition of organic carbon has initiated microbially mediated sulfate reduction in Cells 4 through 7. Cells containing spent brewing grain (SBG) supported more diverse bacterial populations and outperformed cells that did not contain SBG. Decreases in dissolved sulfate concentrations in the SBG amended cells generally correspond to hydrogen sulfide formation, precipitation of metal-sulfide minerals, increases in alkalinity, depletion of ^{13}C in dissolved inorganic carbon, enrichment of ^{34}S in pore water sulfate, and undersaturation with respect to gypsum. Activity of sulfate reducing bacteria in mixtures containing SBG was likely sustained by fermentative bacteria producing simple forms of organic carbon.

Evidence for effective sulfate reduction was not observed in the control cells or the cell amended only with peat. This was likely a result of the inability for the peat to independently contribute dissolved organic carbon in a form usable to sulfate reducing bacteria.

Precipitation of metal-sulfide minerals is likely contributing to decreases in sulfate and metals concentrations (Fe, Zn, Pb, Ni, Mn, Sb, Tl) in cells exhibiting sulfate reduction. Mineralogical investigation determined that precipitation of Fe- and Zn-sulfide phases is occurring in cells containing SBG. Carbonate precipitation may also decrease the concentration of lead, zinc, iron and manganese in some test cells. Arsenic concentrations remained elevated in carbon amended cells, however decreases in average arsenic concentrations between 2005 and 2008 were observed for cells with SBG. Barium concentrations are controlled by barite solubility and have increased in cells exhibiting sulfate reduction.

Sulfide oxidation produced elevated sulfate concentrations in the upper 50 cm of all cells, but carbonate mineral dissolution has maintained pore water pH between 6.5 and 7.5 in this zone. Near the tailings surface gypsum is a less effective control on sulfate concentrations because of the two-to-one ratio of sulfate generated by pyrite oxidation to calcium generated by dolomite dissolution.

Carbon amendment also resulted in increased iron reducing bacteria populations. Reductive dissolution of iron oxyhydroxides and mobilization of associated oxyanions led to corresponding increases in iron, chromium, and molybdenum concentrations. Mobilization of these elements was observed in all test cells, however higher concentrations generally correspond to cells with larger iron reducing bacteria populations. Pore water concentrations of iron generally decreased in cells containing SBG in 2007 and 2008, likely a result of iron-sulfide precipitation.

Geochemical and microbial data suggest that ingress of oxygen is limited to the upper two feet of the test cells. Elevated populations of sulfate reducing bacteria (obligate anaerobes) and the presence of ferrous iron within 1.6 feet of the surface indicate that oxygen consumption is occurring. Sulfide oxidation is likely the dominant oxygen consuming mechanism.

Sulfate reduction and calcite and metal-sulfide precipitation appear to control the chemical composition of pore waters in Cells 4 through 7, while sulfide oxidation, dissolution of dolomite and gypsum precipitation/dissolution control the compositions of pore waters in Cell 1 through 3.

Data from field and laboratory batch tests indicates that the rate of sulfate reduction has declined in tailings amended with only biosolids. This suggests that organic carbon contributed by biosolids is rapidly consumed and may not sustain long-term sulfate reduction. In contrast, evidence for sulfate reduction was observed in Cell 4 in 2007 and this was not the case in 2006. The availability of reactive organic carbon may have been limited at the onset of the testing but increased over time due to fermentation. Addition of mixed sources of organic carbon (Cells 6 and 7) can rapidly promote and sustain active microbial sulfate reduction. However rapid increases in dissolved organic carbon led to increased mobility of iron and arsenic caused by iron reduction.

Evidence of methanogenesis was observed in pore water samples with low sulfate concentrations. This could indicate competition for organic carbon or other nutrients; however, methane concentrations were low and sulfate reduction appears to be the dominant of these two microbially mediated processes.

Thiosulfate was a significant component of pore water in recently placed tailings and appears to be a by-product of decomposition of the flotation reagent, sodium isopropyl xanthate. Reduction and disproportionation of thiosulfate produces hydrogen sulfide, which contributes to attenuation of metals and metalloids via sulfide mineral precipitation. Addition of organic carbon increased the rate of thiosulfate removal.

Laboratory test program

A number of laboratory batch tests have been conducted on samples of amended tailings. The most recent batch tests in 2008 included the carbon sources used in the field tests plus fish/wood compost and phosphate amended peat and brewery waste. Batch tests conducted in 2005 and 2007 suggested that municipal biosolids supported the highest sulfate reducing bacteria (SRB) populations and rates of sulfate reduction. Measurable sulfate reduction was observed with an amendment containing only peat, which contrasts somewhat with results from the field tests. A decrease in pH associated with addition of 50 wt % dried brewery waste may have limited SRB activity. The batch test dose was more than an order of magnitude higher than that applied in the field tests.

A series of supplementary laboratory batch experiments was conducted between March and August, 2008. The supplementary experiments utilized a lower amendment rate than the initial set of experiments and evaluated composted fish waste as a potential organic carbon source. These experiments utilized pore water which contained similar elevated thiosulfate and sulfate concentrations. After approximately 18 weeks, batches were spiked with metals and metalloids, including Sb, As, Fe, Ni, Se, Mo, Tl and Zn, at concentrations higher than those typically observed in tailings pore water at the Greens Creek Mine.

Organic carbon amended tailings supported pH conditions ranging from 6.2 to 7.8. Concomitant increases in alkalinity and dissolved iron and arsenic were observed in the first ten weeks of these experiments. Decreases in aqueous concentrations of thiosulfate were initially observed in mixtures containing SBG, whereas sulfate concentrations remained relatively constant. Further removal of thiosulfate occurred following spiking with elevated concentrations of metals and metalloids, and sulfate concentrations declined over this period. Greater removal of thiosulfate and sulfate following the addition of iron and zinc suggests that sulfate reduction was limited in the absence of metal-sulfide precipitation. Rapid declines in Sb, As, Cu, Mo, Se and Tl, following spiking, were also observed in SBG amended tailings. These results indicate that (co)precipitation or sorption reactions can effectively promote the removal of these trace elements under sulfate-reducing conditions. Results of these experiments demonstrate that SBG is effective in supporting sulfate reduction. Furthermore, a stoichiometric excess of sulfur relative to metals and metalloids can limit metal-sulfide precipitation and therefore sulfate removal.

Column experiments commenced in August 2007 and were monitored through 2008. These experiments focused on three mixtures of tailings and organic carbon in 30 cm long by 7.5 cm diameter acrylic columns. Simulated tailings pore water was pumped through three columns containing 0 (GC1), 2 (GC2) and 5 (GC3) vol % organic carbon. The chemical composition of the input solution was varied to simulate pore water at three distinct time periods: (1) immediately following tailings placement, (2) at the onset of sulfide oxidation and (3) following an extended period of sulfide oxidation where carbonate dissolution maintains near-neutral pH conditions. To accelerate the assessment of treatment potential, these experiments utilized a higher flow rate than that observed for the field trial experiments. Greater than 30 pore-volumes passed through each column during the test period. This higher flow rate simulates long-term treatment and places limits on kinetically controlled reaction rates.

Effluent pH remained between 6.5 and 7.5, and redox conditions were similar among columns. Alkalinity increased in GC2 and GC3, relative to the control; however, alkalinity production declined with time in both organic carbon amended cells. This suggests that carbon oxidation by SRB may be declining due to a decrease in bioavailable carbon. The data also suggest that sulfate removal is limited when pore water exhibits a stoichiometric excess of sulfur relative to metals (e.g., Fe, Zn, Ni, etc.). The lack of a sink for hydrogen sulfide may also limit the removal of thiosulfate. Reductive dissolution of iron (hydr)oxides caused an initial increase in iron in the effluent of both amended columns and the control. Subsequent removal of iron and zinc occurred in all columns, with the greatest removal occurring in GC3. Removal of arsenic occurred in all cells after an initial period of mobilization. Removal of antimony and thallium was most effective in GC3, while attenuation of molybdenum and selenium was similar among columns.

These laboratory batch tests indicated that composted fish waste supported sulfate reduction but was a less effective source of organic carbon than SBG.

Pile characterization

Five sites beyond the SRMP field test cell monitoring area were sampled to characterize the tailings pile geochemistry and microbiology in 2005. The results of the sampling indicate that the pile is generally uniform in composition and has a diverse microbial population that shows no distinct vertical or horizontal trends in distribution. Microbial enumerations give an indication of the presence of various microbial groups but do not necessarily show how active the microbes are or their influence on pore water compositions. Despite the lack of apparent zoning of microbial groups, water compositions suggest that three geochemical zones exist in the pile. Oxidizing conditions are present close to the surface and decrease rapidly with depth. A thick reduced zone that does not appear to promote robust sulfate reduction is present above the water table. The bulk of the unsaturated zone lacks oxygen but may not have redox values low enough to support a large population of sulfate reducing bacteria. Below the water table where redox conditions are even lower, hydrogen sulfide, high alkalinity and low metals concentrations are evidence of significant sulfate (and thiosulfate) reduction. The distribution of organic carbon is also relatively uniform and may not be the limiting factor for promoting sulfate reduction. Pore water compositions suggest that competition for nutrients by other microbial groups such as iron reducers may also limit the rate of sulfate reduction in unamemded tailings.

Results of acid base accounting are consistent with previous studies, indicating that the tailings are potentially acid generating. The primary mineral assemblage is quartz, dolomite and pyrite.

Hydrology

A component of the SRMP is to define how pore water passes through the tailings pile. This is necessary to determine retention times and if there is the potential for pore water to bypass zones of effective sulfate reduction.

Measurements of moisture content, pore water pressure, and soil suction indicate that a dynamic flow regime exists in the tailings pile. The main saturated zone in the pile exhibits a mounded shape that is thickest (about 35 feet) in the north/central part of the pile, where foundation drains do not appear to effectively dissipate buildup of pore pressures between the foundation and the pile. The mound thins to 15 feet or less toward the edges of the pile and over areas with more robust foundation drains. Tensiometer and vibrating wire piezometer data show that suction gradients fluctuate between upward during dry periods and downward during wet periods in the top 15 feet of the pile and that saturation fronts appear to migrate through the pile profile. The data suggest that though the bulk of the tailings are not 100% saturated, they are nearly so, due to their fine grain size and their relatively high moisture content.

The calculated residence time in the field column experiments was four to five years.

Technical considerations for full-scale application

Despite limitations highlighted by the field and laboratory experiments, addition of a small amount of dispersed organic carbon containing spent brewing grain (SBG) shows promise for improving pore water in the tailings pile. The following list of technical aspects should be considered if full-scale application of organic carbon is employed.

- Adding organic carbon at a rate of 5% by volume should support sulfate reduction and improvement of water quality. Higher application rates are not recommended because of the potential for iron and arsenic mobilization.
- Organic materials that produce concentrated, highly available dissolved organic carbon (DOC), e.g. municipal biosolids, and ones that produce very little DOC (peat) should not be applied alone. They may be used sparingly in conjunction with sources that produce moderate amounts of bio-available DOC (e.g. SPG).
- Organic carbon sources should be well mixed with tailings. Layers and large zones of organic carbon should be avoided because they can produce high concentrations of DOC which can lead to iron and arsenic mobilization and may compromise geotechnical stability.
- Addition of organic carbon to (or above) weathered tailings should be avoided because of the potential for iron reduction with increased iron and arsenic mobility. Areas receiving co-disposal of waste rock (e.g. Site E material) and tailings may not be suitable for application of organic carbon.
- Indefinite support of sulfate reduction cannot be achieved without an infinite supply of organic carbon. However, a one-time application of organic carbon during tailings placement followed by reclamation of the site with an oxygen limiting cover is a promising approach to minimizing post-closure metal loading from the site.

Ongoing work

- Finalize data interpretation from field and laboratory studies and finalize report on Waterloo study.
- Determine logistics of adding organic carbon to the tailings at production-scale and develop a standard operating procedure.
- Refine the hydrologic model for the site, including analysis of current conditions and predicted post-closure behavior.
- Analyses to determine the geotechnical effects of carbon amendment on the tailings are planned for 2010, pending successful field and laboratory geochemical testing of the various amendments.
- Continue second phase of field data collection and perform laboratory study on enzymes related to cellulose degradation.

2.6 General Site Management

Tailings Operation and Management

The General Plan of Operations (GPO) Appendix 3 includes the general operating and management goals to achieve site stability and satisfy regulatory requirements for the HGCMC tailings facility. In Appendix 3, Section 2.1.4, HGCMC operations place tailings in the impoundment using specific criteria established by Klohn Crippen Engineering in 1999 for the placement of tailings in cellular configurations with compaction standards. HGCMC continued to place tailings in this manner through 2009.

HGCMC continues the use of off-highway lidded trailered trucks to transport the tailings to the surface placement area. The material is end dumped, spread and compacted using a bulldozer, followed by a smooth-drum vibratory compactor. Compaction checks using a Troxler density and moisture gauge confirm the resultant performance in the placement area, as per the GPO Appendix 3. See Section 2.3 for a discussion of compaction results.

HGCMC does not expect any changes to the placement methodology in 2010 and will continue placement according to the established criteria in GPO Appendix 3. Continued development of placement areas for the remaining mine life are a part of the Stage 2 Expansion Project, approved in January 2004. The 2003 Stage II Tailings Expansion Environmental Impact Statement (EIS) is summarized in HGCMC Tailing and Production Rock Site 2004 Annual Report (KGCMC 2005). In 2009 the majority of tailings were placed in the Northwest Expansion area. 2009 construction activities included:

- Commissioned the use of Pond 6 for tailings placement. Tailing were placed in Pond 6 to a specific level to ensure geotechnical stability of the area.
- Lined degrit basins were constructed and commissioned at the south end of the tailings area to remove sediments prior to entering Pond 7. Geotubes were also tested as an additional sediment handling improvement.
- Dug test pits in the East Ridge area to aid in locating drill locations for 2010.

HGCMC submitted an updated West Tailings Facility Monitoring Action Plan on December 15, 2009 (HGCMC 2009). The plan described processes affecting water quality in the area and presented an updated monitoring plan. Key aspects of the plan include:

- A complex history of disturbance in the area poses challenges to identifying potential leakage from the facility; however, leakage would likely produce a chemical signature similar to Wet Well 3.
- Zinc in the drainage was an order of magnitude or more lower than contact water suggesting that effects from seepage, if any, from the tailings pile are minimal.
- Further Seep zinc concentrations remained relatively unchanged since 2000.
- Zinc in the upper portion of the Further Creek drainage (Site 610) increased with construction activity in the area but decreased subsequently.
- Zinc in the southern portion of the Further Creek drainage (Site 611) has shown a consistent increase but the absence of manganese suggests that the source of the loading is not tailings leachate.
- Site 609 is an appropriate monitoring site for tracking all facility related influences to Further Creek.
- The composition of waters in the Further Creek drainage is expected to improve as effects from previous disturbance, rock fill, dust and other sources decrease. Some element concentrations may temporarily increase as the drainage pH approaches its naturally acidic, dilute condition. The expected reduction in hardness would lower the Alaska Water Quality Standard (AWQS) for hardness dependent elements and may cause exceedances despite the improvement in water quality.
- Quarrying and construction of Pond 7 in 2004/2005 caused an increase in conductivity, sulfate, pH, hardness, and trace and major elements. Following installation of a pump to collect drainage from the pond foundation the Althea Creek drainage started to return to pre-construction conditions

- The nearly two orders of magnitude difference in zinc concentration above and below the liner indicates that the liner is intact and functioning as designed.
- As efforts to reduce the sources of sulfate and metals loading to Althea Creek and Further Creek continue, HGCMC expects these drainages to approach pre-disturbance compositions. Background conditions typical of these muskeg drainages preclude compliance with AWQS for pH, alkalinity, aluminum and iron at sites 60 and 609. The concentrations of some metals and trace elements (e.g. lead, zinc, cadmium, mercury and manganese) are expected to exceed background levels and may not meet AWQS as the pH and hardness in the drainages decrease to background levels. The magnitude of the exceedance is expected to be small and temporary.

Co-Disposal Studies

HGCMC compared the relative costs of recountouring and covering the existing Site E production rock pile versus consolidating it with another surface facility, and found that relocating the material to the surface Tailings Facility is the most economical and environmentally protective solution. The geotechncial feasibility of blending production rock with tailings was studied in 2005 (Klohn Crippen, 2005). Laboratory tests conducted in a large scale permeameter cell measured the hydraulic and strength properties of tailings only, production rock only, and various blends of production rock and tailings. Based on the results, the following main conclusions were drawn:

- The difference in permeability between compacted production rock and compacted saturated tailings is at least 33 times. Blend ratios of 2:3 (production rock to tailings by volume) and 3:2 resulted in lower values of permeability as compared to the tailings-only sample. The 2:3 blend exhibited the lowest value of permeability. This behavior is mainly attributed to the elongated length of the seepage path (and reduced seepage flow area) through the tailings dominated soil matrix and around the larger rock fragments.
- Friction angle of the 2:3 blend was similar to that of the tailings-only sample showing that the tailings were dominant in the blend. As expected, the friction angle improved with the addition of more production rock in the 3:2 blend. Addition of production rock generally increased the overall strength of the compacted tailings with all blend ratios.
- Relatively uniform mixing of the tailings and production rock was very easily obtained in the laboratory in all cases.

A production rock to tailings ratio of 3:2 (60% production rock by volume) with a permeability of 5×10^{-6} cm/s and a friction angle of 43° is recommended by Klohn Crippen as the limiting blend for blended co-disposal of production rock and filter pressed tailings at Greens Creek. Field trials confirmed that the waste rock and tailings mixed well when pushed with a bulldozer. This is consistent with the findings of the laboratory mixing experiments.

In 2006 HGCMC initiated a geochemical assessment of the blend ratio recommended by Klohn Crippen. Column testing continued in 2008 and also showed positive results. Key findings of the geochemical assessment are as follows:

- Drainage quality at Site E will improve significantly following relocation of the waste rock.
- Reduced oxidation of the waste rock by blending with tailings will extend the duration over which the rock is able to neutralize acidity (extended lag period).

- The co-disposal material will have a lower acid generation potential (higher NNP) than tailings alone.
- Characterization of Site E waste rock indicated roughly equal proportions of Class 1, Class 2 and Class 3 type materials and that Class 4 type rock is only a minor component (approximately 5%). The site was constructed prior to implementation of the classification system. Since no segregation by type occurred, the four types are likely distributed relatively evenly throughout the pile. It is unlikely that large areas of oxidized/acidic rock or any one type, particularly Class 4, are present in the pile.
- Comparison of metals and trace element contents between samples of Site E and tailings show that the co-disposal blend will have a lower metal content than the tailings.
- Co-disposal of waste rock with tailings exhibited improved pore water chemistry relative to that of tailings and waste rock disposed of separately (Figure 2.36).
- Analysis of the Mill site till indicates that it is not acid generating and that metals of concern do not appear to have accumulated in this material beneath the waste rock. Infiltration water percolates through the waste rock then likely flows laterally along the till interface to the toe rather than flowing through it to the base of the pile (Figure 2.37).
- Dissolution of oxidation products, including reductive dissolution of iron and manganese oxides/oxyhydroxides will occur in response to the change in redox environment with co-disposal. Consequently, increases in iron, manganese, arsenic and co-precipitated or sorbed metals are expected. However, pore water compositions are not expected to be significantly different than those that develop when oxidized tailings surfaces are buried as the pile expands. Microbial sulfate reduction observed below the water table in the tailing pile and in carbon amended, unsaturated test cells produces alkalinity and sulfide. This has the potential to remove much of the dissolved load caused by reductive dissolution.
- Co-disposal of unammended, acidic rock with tailings significantly reduced metals leaching relative to the acidic rock control and demonstrates that the tailings are capable of neutralizing the acidity present in the acidic rock. This positive result also suggests that addition of lime, though protective, is not an essential component of the co-disposal process.

Geochemical results, as well as a geotechnical summary and a site excavation plan, are presented in the Site E Removal: Waste Rock and Tailings Co-Disposal Plan (HGCMC 2009). This plan was approved by the agencies on June 16, 2009. The plan outlined the removal activities and associated best management practices (BMPs) to be used during active removal (summer construction season) and inactive periods (fall rainy season and winter). Between June and September, HGCMC removed approximately 40,000 cubic yards of waste rock and reclamation material from Site E. Figure 2.38 is a photograph taken during the removal activities at Site E.

<u>Dust Monitoring and Abatement</u>

Monitoring performed under the Freshwater Monitoring Program has identified lead levels in three shallow peat wells south (Site 27) and west (Site 29 and Site 32) of the tailings pile that approach or exceed freshwater quality standards (KGCMC 2007). The formation water in these wells is generally very dilute (low conductivity and hardness) and acidic (due to organic acids), which is ideal for promoting lead mobility. Dust from the tailings pile may contribute to the lead levels observed in these wells.

Visual observations and operational experience indicate that dust loss from the tailings pile occurs when dry, windy conditions persist at the site. These conditions typically occur for short periods between mid December and late February when high pressure systems produce cold, dry weather and strong northerly winds. The north-south orientation of Hawk Inlet and the Tributary Creek valley exposes the tailing pile to these winds.

Warm, dry conditions occur periodically during the spring and summer months, but wind direction and velocity are not typically as favorable for dust entrainment during these periods. Salt formation on tailings surfaces and application of water to access roads further reduces the potential for dust formation during warmer months.

Snow samples were collected just prior to the loss of snow cover each spring. Sample locations are shown on Figure 2.35a. Additional sites were added in 2009 to provide data around the entire pile. The objective of the sampling was to quantify the amount of tailings dust that had accumulated on the snow pack when conditions for dust loss were greatest (typically December through February). The samples were analyzed for total lead concentrations, and a lead load per square meter was calculated (Table 2.7).

Table 2.7 Tails Snow Dust Loading Table

Sample Location		Date	Lead Load mg/m^2	Zinc Load mg/m^2	Feet from Pile Center E40180, N53229
1007	MW 3S, Site 29	4/14/07	30	30	825
		2/20/08	2	1	
		4/16/09	8	2	
1008	MW 5, Site 32	4/14/07	3	2	980
		2/20/08	1	1	
		4/16/09	2	1	
1009	Wet Well 1 75' S	4/14/07	59	79	860
		2/20/08	14	9	
		4/16/09	6	3	
1010	MW 1S, Site 25	4/14/07	23	26	1495
		2/20/08	11	6	
		4/16/09	2	1	
1011	MW 2S, Site 27	4/14/07	15	10	1695
		2/20/08	14	15	
		4/16/09	1	0	
1012	Lease Line South	4/14/07	72	87	1215
		2/20/08	26	36	
		4/16/09	1	1	
1013	Main Embkmnt Toe	4/14/07	179	584	910
		2/20/08	62	153	
		4/16/09	2	1	
1014	MW-T-02-07	4/14/07	203	396	890
		2/20/08	69	233	
		4/16/09	11	6	
1015	MW-T-00-04A	4/14/07	404	901	875
		2/20/08	42	55	
		4/16/09	4	2	
1044	MW-T-00-03B	4/16/09	7	6	545
1045	MW-T-00-02B	4/16/09	3	2	640
1046	MW-T-00-01B	4/16/09	1	1	870
1047	MW-T-95-5B	4/16/09	1	1	725
1048	MW-T-05-04	4/16/09	0	0	1075
1049	MW-T-01-03B	4/16/09	18	5	710

The data indicate that the loading is observable up to 1600 feet from the pile and that the loading has decreased each year since 2007 (Figure 2.35b). Several factors, including fewer dust-producing weather events, a shorter snow accumulation period and improved abatement measures, likely contributed to the reduction in calculated loading values.

Lead levels in water from the three wells do not correlate directly with lead loading values. In fact, the well with the highest lead concentration (Site 32, ~ 6.5µg/l) actually has one of the lowest lead loading values determined from the snow survey. Site 32 is downwind of the Wet Well 1 building, Outfall Shack and a stand of pine trees, which may collectively act as a dust trap, preventing accumulation of dust in the immediate vicinity of the Site 32 well. Tailings dust that settles on the peat up-gradient from Site 32 may be the source of the lead observed in the well. The chemical composition of the water at Site 32 suggests that its completion zone is better suited for lead mobility than the completion zones at Site 27 and Site 29. It is the most dilute of the three waters and there is very little in the water that would cause the lead to precipitate. Complexing with organic ligands may also promote lead mobility in these peat waters.

A direct link between dust accumulation and lead concentrations in the wells has not yet been established. However the lead loading determined from snow surveys suggests that the amount of lead accumulating on the peat in the vicinity of the wells is sufficient to account for the lead values observed in the wells. This is based on the simplifying assumption that all of the lead is leached from the dust and that it is distributed evenly in a two-meter column of water (saturated peat).

HGCMC is evaluating air sampling methods that may augment the lead loading analysis. This would allow year-round monitoring, which will help quantify the temporal distribution of loading at the site. Currently, data collected from newly installed air samplers are being analyzed in conjunction with wind speed, wind direction, temperature, relative humidity and precipitation to better understand the meteorological effects on tailings dust dispersion.

The following measures were taken to reduce dust loss from the tailings pile:

- Snow fence and concrete block wind breaks were installed on the crest of the tailings pile
- Snow removal was limited to only active placement areas
- Interim slopes were covered with rock
- Outer slopes were hydroseeded where appropriate

Visual observations and snow sample assays suggest that these mitigation measures have helped reduce the dispersion of dust at the Tailings Facility, however additional efforts are still warranted. Continued snow, water and air monitoring will determine the effectiveness of the control measures. Active placement in the Pit 5 area likely contributed to reduced dusting at the southern sites relative to previous years due to its topography and location.

2.7 Site as-built

As-built drawings for the Tailings Facility are presented in Appendix 1. The drawings depict the 2009 year-end topography, water management features, monitoring device locations and other significant features of the site. An additional tailings drawing includes cross sections that show the following information:

- existing topographic surface
- prepared ground upon which the pile was constructed
- water levels
- projected locations of piezometers from Figures 2.1 – 2.18

Photographs from 2009 are presented in Figures 2.39 to 2.40 (Appendix 4). Figure 2.39 shows the Northwest area of the Tailings Facility on June 1, 2009.

2.8 Reclamation/Closure Plan

Reclamation Plan

In November 2001, as part of the ADEC Waste Management Permit requirements, Greens Creek submitted a "Detail Reclamation Plan with Cost Estimates" as an attachment to the GPO Appendix 14. A Federal/State/Municipal inter-agency team approved this attachment to Appendix 14, as the basis of current site reclamation bonding levels. Bonding levels were set for $24,400,000 in conjunction with the approved site reclamation plan. The Detail Reclamation Plan includes all estimated costs (labor, materials, equipment, consumables, administration, monitoring and long term maintenance) for task specific work associated with the final closure of the property under a default scenario. HGCMC detailed a scope of work to accommodate the physical reclamation projects and the reclamation monitoring and maintenance of all site facilities by segmenting the overall reclamation closure project work at the mine into 7 elements:

- Roads
- Production Rock Sites
- Tailings Area
- Site General
- Water Systems
- Maintenance and Monitoring
- Administration

Each of the above elements of the Detail Reclamation Plan include narrative and cost estimates to define the closure of the property by discipline (type of work) and area. The elements of the plan encompass the entire mine site, and also include reclamation performance monitoring and facility maintenance after final closure according to the Waste Disposal Permit standards.

The Stage 2 Tailings Expansion process included a National Environmental Policy Act (NEPA) review through an Environmental Impact Statement (2003 EIS) to analyze the potential environmental effects of the project. As part of the tailings expansion, a reclamation review was requested to update the current General Plan of Operations (GPO) Appendix 14 – Reclamation Plan (the Plan) and the costs associated with the tailings expansion area and to revise the Plan's cost estimates to year 2003 values. The request was made in a joint letter dated October 16, 2003 from the Alaska Department of Natural Resources (ADNR), USFS, and ADEC. HGCMC submitted this cost estimate revision as Attachment A.1 to the Plan on October 22, 2003. The estimated reclamation cost detailed in this document, including the anticipated first, 5-year Tailings area expansion development phase, was approximately $26,200,000, a difference of approximately $1,800,000 from the 2001 estimate. As noted above, the regulatory agencies accepted this bond revision amount and the company deposited the necessary funds in the Forest Service administered Federal reserve account.

The value of the reclamation bonding fund was recalculated in 2005 for an internal Rio Tinto closure review. Based on this new estimate, HGCMC proposed an adjustment increase of $2,765,371 in the fund level from the then current $26,200,000 to $29,000,000 as discussed in the 2006 annual presentation meeting and then presented in a 17 August 2006 letter to the regulatory agencies. The regulatory agencies provided their review response to HGCMC on 19 January 2007, raising 21 points for consideration and further elaboration. HGCMC fully responded to these issues with a 25 February 2007 letter.

A fully updated Reclamation Plan was submitted to regulatory agencies in April 2008. The 2008 updated Reclamation Plan fulfills a portion of the ADEC requirements for the renewal of the Waste Management Permit. SRK Consultants, in their environmental audit of the mine in 2008, reviewed the updated reclamation plan and proposed bond amount, and provided comments in their audit report. The updated plan is currently pending review by the agencies. Upon approval, HGCMC will take the necessary steps to formally update the bond amount.

Reclamation Projects

HGCMC continued using past interim reclamation measures, such as hydroseeding and various erosion controls at the Tailings Facility, to improve and maintain established site controls. A growth medium (six inches to one foot) of native soils was placed on selected slopes of the tailings pile to promote the hydroseeded growth. HGCMC also continued the use of other sediment control measures including silt fencing, straw bales, rock check dams, solid and flexible runoff collection pipes, coarse-rock slope armoring and slope contouring throughout the site. HGCMC is committed to the continued use of site controls as the operation has consistently demonstrated the benefits of these interim reclamation programs to reduce impacts during the operational period.

The Waste Management Permit allows time to gather cover performance information for further analysis, prior to installing the covers en mass. Continued evaluation of the cover performance remains ongoing since its installation in 2000 to justify and improve closure cover technology. Extensive reviews in 2002 of the cap performance also took place during the HGCMC Stage 2 Tailings Expansion project work with the USFS (O'Kane 2001). HGCMC recognizes that the soil covers represent a significant part of the site reclamation plan. Therefore, HGCMC has continued to commit resources to develop and monitor the performance of the cover at Site 23. See Section 3.8 for more details on the Site 23 test cover performance.

In 2003, EDE performed mass loading calculations to test hypotheses about flow regimes at Site 23/D and to predict possible post-closure water compositions (EDE 2004). These results compare favorably with the TDS analysis, the hydrologic analysis as well as past and present flow and water compositional data. The model was 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 results showed flows at Pond D ranged from 70 gpm to 176 gpm while sulfate values ranged from 24 to 233 mg/l. Cadmium appears to be the metal of greatest concern for this site with respect to meeting water quality standards at Pond D after closure. Cover percolation rates of 20% or less may be required to meet the 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.

In 2009, improvements in the D pond area included installation of a larger pump system to increase pumping capacity. Also, approximately 4,500 cubic yards of waste rock and pyritic berm material were removed, and replaced with clean fill. The majority of the fill was sourced from the backslope of Site 23, with minor amounts of sand and gravel used for drains. See Figure 3.36 for a photograph of this work in progress.

Underground Hydrology Study Update

Environmental Design Engineering (EDE) is assisting HGCMC with a study of the hydrology and geochemistry of the underground workings. Key aspects of the study include:

- Determining the current water table and hydrologic characteristics of the bedrock and backfill
- Consolidating information on the location of drill holes, headings, stopes and related mine features
- Characterizing the geochemistry of underground waters
- Developing a water balance for the mine system
- Estimating the stored soluble load in backfill and on rock surfaces
- Modeling natural and manual flooding scenarios
- Predicting post-closure flow rates and drainage compositions
- Evaluating potential active and passive treatment options for mine waters

HGCMC anticipates receiving an interim report in 2010, which summarizes key findings and provides a status update on the ongoing work. Elements of the study will be updated as additional data becomes available.

3.0 Site 23/D

3.1 Introduction

Hecla Greens Creek Mining Company (HGCMC) has prepared this report in accordance with the mine's General Plan of Operations (Appendix 11) and Alaska Department of Environmental Conservation Waste Management Permit 0211-BA001. A summary of all operational and monitoring activities performed in 2009 is provided. Refer to GPO Appendix 11 and Permit 0211-BA001 for a detailed description of Site 23, Site D and associated monitoring requirements.

Operation of Site 23 (HGCMC's only active production rock disposal facility) continued in 2009. See the Site 23 as-built in Appendix 2 for facility layout. Approximately 14,861 cubic yards of production rock were placed at Site 23 during this report period. HGCMC estimates the projected remaining capacity at Site 23 at approximately 558,550 cubic yards, based on the current design.

3.2 Placement Records

Site 23 survey data and truck count haulage information are presented in Table 3.1. Site 23 received approximately 25,157 tons of production rock in 2009 as calculated from HGCMC surveyed volumes. A tonnage factor of 1.7 tons/yd^3 was used to convert surveyed volume to tonnage. The difference between truck count totals and calculated totals based on survey data reflects variations in tonnage factors, small differences in load capacities and double handling of materials. The surveyed volume reported in cubic yards has the least uncertainty relative to other quantities reported in Table 3.1. The acid base accounting data presented in Section 3.5 indicate that HGCMC continues to conservatively classify its production rock. Some of the phyllite that is visually classified as Class 3 is actually chemically Class 2 (i.e. laboratory testing demonstrates a NNP between 100 and –100 tons $CaCO_3$/1000t).

Table 3.1 Production Rock Placement Data

PRODUCTION ROCK PLACED AT SITE 23					ADDITIONAL PRODUCTION ROCK HAULED					
2009	Surveyed (cy)		Surveyed (tons)		Hauled To Tails from Site 23 (tons)		From UG Truck Counts (tons)			
Date	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Class 1	Class 2	Class 3	Total
*1/31/2009	0	0	0	0	938	938	2,040	0	1,200	3,240
*2/28/2009	0	0	0	0	1,135	2,073	1,740	0	1,350	3,090
3/31/2009	2,564	2,564	4,340	4,340	4,019	6,092	1,890	0	3,900	5,790
4/30/2009	1,086	3,650	1,838	6,179	2,380	8,472	990	630	330	1,950
5/31/2009	0	3,650	0	6,179	877	9,349	1,500	0	510	2,010
6/30/2009	1,834	5,484	3,105	9,283	170	9,519	1,680	0	120	1,800
7/30/2009	922	6,406	1,561	10,844	558	10,077	1,260	0	270	1,530
8/31/2009	2,830	9,236	4,791	15,635	262	10,339	1,530	0	0	1,530
9/30/2009	1,668	10,904	2,824	18,458	3,009	13,348	360	1,110	1,230	2,700
10/30/2009	2,030	12,934	3,436	21,895	190	13,538	1,470	0	1,350	2,820
11/30/2009	468	13,402	792	22,687	0	13,538	510	0	0	510
12/31/2009	1,459	14,861	2,470	25,157	574	14,112	3,060	0	270	3,330
TOTAL	14,861		25,157		14,112		18,030	1,740	10,530	30,300

* No survey taken due to equipment failure or excessive snow

3.3 Stability

Klohn Crippen conducted a stability assessment of Site 23 and Site D in 2003. The stratigraphy and geology were reassessed using the results from drilling programs by HGCMC and Klohn Crippen, historical drill hole data, seismic refraction data, geological mapping and piezometer data. This assessment enabled the previous stratigraphic interpretations to be revised as follows (from top to bottom): a layer of colluvium and blocky rubble about 80 feet thick; a layer of glacial till and sediment about 120 feet thick; a comparatively thin layer of weathered bedrock about 10 to 20 feet thick; and unweathered bedrock (Klohn Crippen, 2004). The blocky colluvium is interpreted to be historical (likely ancient) landslide debris.

Limit-equilibrium stability analyses and the liquefaction potential of the foundation materials were evaluated for Site 23 and Site D, using the reinterpreted geological model. Site 23 has calculated static Factors of Safety greater than 1.6 for the existing configuration, and 1.7 for the proposed final build-out geometry at 1,120 feet with 3H:1V exterior slopes. The static calculated Factor of Safety of the backslope above Site 23 ranges from 1.0 for shallow surficial slips to 1.3 for deeper surfaces.

The excavation of the soil from the slope behind Site 23 (temporary construction condition) reduces the calculated Factor of Safety for those sections of the backslope, but this temporary reduction is not expected to cause serious backslope instability. Placement of rock fill within the excavation and construction of the final build-out geometry for the production rock site increases the calculated Factor of Safety to slightly above those for the pre-excavation condition.

Approximately 20 feet of saturated fill material identified at the base of drill holes DH-00-03 (north-central) and DH-02-14 (east end) at Site D was found to be potentially liquefiable under design basis earthquake (DBE) and maximum design earthquake (MDE) loading. Liquefaction of this fill material will impact the stability of Site D, but will not reduce the stability of Site 23 to unacceptable levels.

Site D is projected to fail under a significant earthquake. In its current configuration, Site D is expected to fail under the 1/475-year magnitude design earthquake. This represents an approximate probability of failure of about 0.21% annually, or about 2% during the mine's current projected remaining operational period of about 10 years.

Inspections

Several independent inspections are carried out at Site 23 throughout the year. Operators working at the site carry out daily visual work place inspections. The Surface Civil Engineer and or Surface Operations Manager carry out weekly visual inspections. The environmental department carries out a monthly checklist inspection. No visible signs of physical instability were observed at Site 23 during this report period.

ADEC representatives inspected the site five times in 2009 (May 20, June 3, August 25, September 23, and November 10). During 2009 the USFS conducted 12 routine inspections (Site inspections #298-#309) to monitor for best management practices effectiveness and compliance to the General Plan of Operations. No issues of non-compliance at Site 23/D were noted during the routine inspections. The USFS typically noted that the facility is being developed and operated to required operations and maintenance specifications of GPO Appendix 11.

Slope Monitoring

Slope monitoring at Site 23/D consisted of GPS monitoring of 12 survey hubs distributed across the sites. The resolution was felt sufficient to identify large potential movement and no such movements were identified.

In addition, an inclinometer was installed at Site 23 at the end of 2005 to aid with stability monitoring. The Site 23 inclinometer has been monitored on six occasions since is installation, which included one reading in 2009. The measurements are presented in two forms, absolute position and incremental displacement. The view of absolute position (Figure 3.31) shows the orientation of the inclinometer casing. A positive deviation on the A axis and a negative deviation on the B axis indicate southerly (downslope) and easterly (up valley) deviations, respectively. The deviation from vertical in this view likely represents deflection of the bore hole that occurred during drilling. The displacements measured since the initial reading are too small to show up in this view and the curves plot on top of each other. The incremental displacement chart (Figure 3.30) shows the location and magnitude of displacement since the initial 2006 reading. Displacements at the top of the hole are attributed to frost heaving, grout settling, and damage that occurred in 2007 when a bear broke the inclinometer casing. The incremental displacement view shows the amount of movement has been 7mm (since 2006) and is confined to a surface approximately 85 feet below ground level. This surface roughly corresponds to the base of the slide/colluvium unit and the top of the dense till in the foundation HGCMC will continue to take measurements to determine if there is a seasonal influence on the movement. Given the very small rate of movement there is not an immediate cause for concern, but HGCMC will continue to monitor the situation closely.

Well and Piezometer Water Level Data

Well and piezometer water level data are provided in Figures 3.1 to 3.12. The lack of significant pressure in piezometers installed close to the base of Site 23 (piezometers 52-55, Figures 3.1 to 3.4) demonstrates that the pile remains free draining. This is consistent with the construction of a network of finger drains under the pile and a blanket drain at the pile toe. Comparison of historic versus modeled flow from the finger drains and the curtain drain indicated they are performing as designed and as necessary (EDE 2004). See Appendix 2 for piezometer and finger drain locations. The lack of pore pressure at the toe indicates that pile stability has been maximized. Water levels from several monitoring locations are shown in Appendix 2. The inferred water table is 30 to 60 feet below the base of the production rock pile material up-slope of the Site 23 active placement area and 5 to 20 feet below the base of material placed in Site D and the toe of Site 23, respectively (see also Figures 3.5 to 3.12). MW-23-00-03 data showed an atypical drop in water elevation in August 2007. However, data collected before and after that date are within the historical data range. Observations from wells completed in the colluvium below the sites indicate that perched water tables and braided flow paths exist beneath the site (e.g. compare Figure 3.6 and 3.7). This unit also shows large (up to 10 feet) fluctuations in head levels, which are consistent with perched, confined conditions and channel-like flow. There is a distinct seasonal pattern to the water level fluctuations beneath Site 23/D, particularly in the alluvial sands (Figures 3.9 and 3.11).

The silty/clay till that underlies the colluvial unit impedes downward flow and has an upward hydrologic gradient caused by its confining the more permeable bedrock below it. MW-23-98-01 (Figure 3.8) is completed in the till unit and indicates a water table near the top of the till, which is approximately 100 feet below the existing topographic surface. Alluvial sands occur between the colluvial unit and the silt/clay till near the toe of Site 23 and under Site D. Data from MW-23-A4 and MW-D-94-D3 (Figures 3.9 and 3.11) indicate that the sands are saturated. A curtain drain installed in between Site D and Site 23 in 1994 collects water that flows at the base of the colluvial unit and the top of the alluvial sands (see as-built and sections). This drain helps reduce pore pressures in the foundation of Site D, as well as capturing infiltration waters from Site 23.

3.4 Hydrology

Surface and groundwater are managed using a network of drains, ditches and sediment ponds at both Site D and Site 23. See the Site 23 as-built for locations of these features. Water that is collected in the finger drains beneath Site 23 is routed to Pond 23 along with Site 23 runoff via a lined ditch. Pond 23 also periodically receives stormwater via pipeline from the 920 area. A curtain drain below the toe of Site 23 captures groundwater from the colluvial unit beneath the site and reports to the Pond D wet well via pipelines. Pond D also captures surface water and drainage from seeps near the toe of Site D. Pond D water is returned to the Pond 23 pump station where it is either sent to the Mill or down to the Pond 7 water treatment facility. An 18” HDPE pipeline was installed in 2008 to carry stormwater from Pond 23 (which receives water from

Pond D) to the Pond 7 water treatment facility. This pipeline, along with the installation of new pumps, increased the stormwater handling capacity of Site 23/D to a 25-year 24-hour storm.

Flow data for Pond D are shown with precipitation in Figure 3.13. The Pond D flow meter was not operating from July 2008 through 2009 due to changes in pumping/piping as noted above. Once all equipment is in place and operating, flow measurements will resume.

Monthly temperature and precipitation data are provided in Table 3.2. July was the driest month with 1.3 inches. July and August were the warmest months while January exhibited the coolest temperatures.

The production rock and colluvium units respond rapidly to hydrologic events such as snowmelt and rainfall, indicating very local recharge and discharge (EDE 2004).

Table 3.2 Monthly Summaries of Mill Site Climate Data

Month	Avg Temp (°C)	Precipitation (in)
January	-4.4	6.7
February	-3.5	2.0
March	-2.6	2.2
April	2.4	1.5
May	7.2	2.1
June	11.0	3.1
July	14.7	1.3
August	12.3	6.9
September	8.9	9.1
October	4.8	6.2
November	0.0	7.7
December	-3.1	3.7
2009	4.0	52.3

3.5 Water Quality

An in-depth re-evaluation of the geochemistry and hydrology of Site 23 and Site D was performed in 2003 by Environmental Design Engineering (EDE) and HGCMC in accordance with the ADEC Waste Management Permit Section 4.1.1. In general, 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 generally higher dissolved load than background surface water and groundwater. Bruin Creek and Greens Creek have specific conductivities that range seasonally from 50 to 225 µS/cm. The lack of significant differences between upgradient and downgradient sites on these two creeks demonstrates that effects from Site 23/D are negligible.

Groundwater upgradient and downgradient of Site 23/D also varies between sites and seasonally, with specific conductivity ranging from 200 to 800 µS/cm. Compositional differences between upgradient and downgradient wells demonstrate that the slide unit hosts a series of disconnected, perched water tables of varying water qualities.

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 downgradient 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 daylights 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 volume of contact water has increased, the dissolved load of the contact water 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 downgradient waters. Based on this analysis, Pond D contains 12% contact water, and approximately 80% of the Pond D flow is contributed by the curtain drain.

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. 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.

Compliance Monitoring

Water sites around the Site 23/D production rock storage area have been monitored for various periods. Sites have been added and deleted over time as rock storage area development required. Monitoring under the revised FWMP schedule and sites began with October 2002 sampling, the first month of water year 2003. The full FWMP Annual Report for water year 2009 is being prepared separately and will be submitted to the Forest Service and ADEC upon completion.

Internal Monitoring

In May 2001 Greens Creek submitted an Internal Monitoring Plan to the Alaska Department of Environmental Conservation – Solid Waste Management Program. This submittal satisfied Section 2.8.3.1 of the HGCMC Waste Disposal Permit Number 0111-BA001. The provision was retained in Waste Management Permit 0211-BA001 with its issuance in November 2003, and reissuance in 2008.

As described in Section 2.8.3.1 of both permits, the internal plan addressed monitoring at both the surface Tailings Facility and the surface production rock storage areas covered by the permit. The Internal Monitoring Plan describes monitoring of the pile areas, in contrast to the compliance monitoring (under the Fresh Water Monitoring Plan) at peripheral facility boundary sites. As such, data generated by the Internal Monitoring Plan effort are "… not for compliance purposes…" as noted in the above referenced permit Section 2.8.3.1.

Waters represented by the internal monitoring sites are captured, routed to the Mill or Tailings Facility and treated prior to discharge to the ocean floor under HGCMC's National Pollutant Discharge Elimination System Permit (AK 004320-6) from EPA.

Operationally for HGCMC, the production rock Site 23 and the adjacent production rock Site D are treated as a single entity, primarily due to their conterminous positions making isolation from one another impractical. Consequently, they are operated and referred to as Site 23/D in this report.

The results of HGCMC's Site 23/D internal site monitoring plan are summarized in Figures 3.14 to 3.26. Sites were distinguished between finger drains and groundwater. These groups are separated on the Figures 3.14 through 3.26 with the suffix a or b, respectively. For example, a figure number such as 3.14a would show the pH data for the finger drains, and 3.14b would show the pH data for the groundwater sites. Sample collection from the Site 23 finger drains is dependent upon their flow. Flow from several of these finger drains is very irregular, responding directly to precipitation-induced infiltration and groundwater fluctuations (Figure 3.27). Monthly sampling of the flowing drains has identified the typical range of concentrations of constituents in the drain waters. HGCMC reduced the frequency of sampling to quarterly for all internal monitoring sites starting in 2003.

Figure 3.14a shows the pH of waters collected from Site 23 Finger Drains 2 through 8, and Figure 3.14b shows the pH of monitoring wells MW-23-A2D, MW-23-A4, MW-D3 and Pond D (see as-built in Appendix 2 for locations). Values of pH were between 6 and 8.5 for all internal monitoring site samples in 2009. The lower pH values (generally pH 6.0 to 7.0) were recorded in MW-23-A4 and MW-D3, both of which are completed in alluvial sands beneath Site 23 and Site D, respectively. MW-23-A2D, which screens colluvium up-gradient of Site 23 typically has the highest pH (generally pH 7.0 to 8.5). The Site 23 finger drains fluctuate at values between those of the monitoring wells. Figures 3.14a and b suggest that waters from different foundation units have different pH values and that Site 23 and Site D contact waters and the materials with which they are in contact exhibit sufficient buffering capacity to prevent acidification of site drainage in the near term. Seasonal fluctuations are apparent in the finger drains with highest pH values occurring in winter months and lower pH in mid to late summer.

As with pH, high alkalinity values (Figures 3.15a and b) indicate that the waters are well buffered. Fluctuations in alkalinity correlate with those of other parameters, such as hardness (Figures 3.16a and b) and conductivity (Figures 3.17a and b), and also appear to be seasonal. Carbonate minerals in the production rock contribute to the high alkalinity of the drainage from the finger drains. Alkalinity is lowest in samples with the highest groundwater component (e.g. the monitoring wells, Pond D, 23FD-5 and 23FD-7). Calcium and magnesium are the primary contributors to hardness (Figure 3.16a) and reflect dissolution of carbonate minerals, such as calcite and dolomite. Carbonate dissolution neutralizes acidity formed by sulfide oxidation, which is also the source of sulfate shown in Figure 3.18a.

Conductivity results from internal monitoring site waters are presented in Figures 3.17a and b. The 2009 conductivity measurements continue to range up to 4,420 µS/cm. MW-23-A2D and MW-D3 have the lowest conductivity. MW-D3 is completed in alluvial sands below the fill placed at Site D. The finger drains with the highest flow (e.g. 23FD-5, which directly drains an excavated spring) generally have lower conductivities than the drains with lower flow. This reflects a larger contribution from groundwater to the high-flow drains relative to a higher proportion of site contact water in the other finger drains. The significant decrease in conductivity in 23FD-7 that occurred in 2000 is probably the result of incorporation of groundwater collected in the upper portion of the drain above the active placement area. The presence of contact water in the alluvial sand below Site 23 (as seen in MW-23-A4) is not surprising given the permeable nature of the colluvium that lies immediately beneath the site. A clay till layer underlies the colluvium and alluvial sands beneath the site. The clay till serves as a barrier to downward flow; however, as discussed earlier, it occurs well below the base of both piles. The fact that MW-D3 does not show signs of a contribution from contact water suggests that an upward hydrologic gradient may exist beneath Site D.

Finger Drain 23FD-2 has the highest conductivity but consistently low flow, suggesting no significant influence from groundwater. This drain may also be influenced by runoff that infiltrates along the access ramp to the site. The higher conductivity of the site contact waters reflects a larger dissolved load caused by weathering of the production rock. As with tailings, pyrite oxidation and carbonate dissolution contribute dissolved ions such as sulfate, bicarbonate, calcium and magnesium to the contact waters, increasing their conductivity. Sulfate concentrations for the finger drains and groundwater wells are plotted in Figures 3.18a and 3.18b and match closely the relative value patterns of conductivity. The drier than average spring and summer in 2009 likely contributed to a greater buildup of oxidation products and reduced groundwater contribution to the water balance. This may result in higher conductivity and sulfate values for some sample sites.

Arsenic data are presented in Figures 3.19a and b and are generally quite low. All finger drains and MW-23-A4 experienced increases in their arsenic concentrations in September 2003, with subsequent decreases back down to historical levels in October. The flows in the finger drains positively correlate with these changes. Fluctuations in arsenic values in 23FD-2 can be attributed to changes in redox conditions. Low arsenic and iron (Figures 3.25 a and b) concentrations indicate that these metals are precipitating as oxyhydroxides on rock surfaces in the pile.

Figures 3.20a and b show the concentration of zinc in the internal monitoring locations at Site 23/D. Zinc levels appear to be controlled by seasonal conditions. The changes in zinc concentrations mimic those for conductivity and sulfate. 23FD-2 had a zinc concentration of approximately 70 mg/l in June 2002. Although, zinc averages have fluctuated since 2002, there has been an overall decreasing trend. In 2009 zinc levels were near 20 mg/l. Zinc concentrations in the range of 20 to 70 mg/l are consistent with laboratory kinetic weathering tests performed on samples of argillite and serpentinite (Vos, 1993). The zinc concentrations recorded for Pond D are generally below 0.9 mg/l and reflect contributions from several source waters. Pond D receives water from Site D surface runoff, seeps on the slope and at the toe of the site and the effluent from the curtain drain that HGCMC installed between Site D and Site 23. MW-D3 showed elevated zinc concentrations in both 2005 samples: zinc levels rose from an average of 10 µg/l in 1998-2004 to an average of 177 µg/l in 2005. Average sulfate also increased by approximately 30 mg/l in 2005 compared to average values from 2002-2004. The zinc and sulfate returned to within historical limits in 2006. The cause for the increases in 2005 is not immediately apparent; however, if it was the arrival of a contact water front, a significant increase in conductivity, sulfate, calcium and magnesium should have preceded an increase in metals such as lead and zinc.

Cadmium concentrations (Figures 3.21a and b) correlate well with those of zinc for the internal monitoring sites although at much lower values (0 to 35 µg/l).

The concentrations of copper and lead (Figures 3.22a and b and 3.23a and b) are considerably lower than that of zinc in the Site 23/D internal monitoring sites. Both of these metals show the same general trends as zinc with the exception of one anomalous lead result in a sample from

23FD-2 in 1999. The nickel concentrations presented in Figures 3.24a and b support the observation that the drainage from 23FD-2 is different than that of other drainages. It is possible that the material that supplies water to this drain has a greater proportion of serpentinite, which was shown to produce higher zinc and nickel concentrations than other rock types such as argillite and phyllite (Vos, 1993). What appeared to be a linear increase in nickel concentrations in 23FD-2 prior to 2002 now appears to be decreasing or at least cyclical. The December 2005 sample from MW-23-A2D was an order of magnitude higher than historical values and was likely an analytical error as it did not correspond with the conductivity and TDS of that sample. Also, the more recent metal concentrations for this site have returned within historical data values. Monitoring will continue to determine trends.

An overall increase in arsenic cadmium, copper and zinc concentrations was apparent in the majority of finger drain samples between 2005 and 2006, though the elevated levels remained within historical limits. This may be the result of capturing the flow from a spring along the site's backslope.

Manganese concentrations (Figures 3.26a and b) are generally less than 50 µg/l for MW23-A2D, MW23-A4, and three of the finger drains (23FD-3, 23FD-5 and 23FD-8). The other three finger drains (23FD-2, 23FD-6 and 23FD-7) and MW-D3 and Pond D have elevated manganese concentrations, indicative of the different redox conditions. Precipitation/dissolution of iron oxyhydroxides and manganese oxides controls the concentrations of iron and manganese in these waters.

Acid Base Accounting Data

Acid base accounting (ABA) results from 71 underground rib composites collected in 2009 are presented in Table 3.3 and Figure 3.28. Class 1 rib samples had an average neutralization potential (NP) of 349 tons $CaCO_3$/1000t, which is equivalent to about 35% carbonate. The Class 1 samples had an average acid potential (AP) of 51 tons$CaCO_3$/1000t, which produced an average net neutralization potential (NNP) of 298 tons $CaCO_3$/1000t. Class 1 production rock does not have the potential to generate acid rock drainage; however, HGCMC recognizes the potential for metal mobility (primarily zinc) from this argillite rock. HGCMC has long-recognized this characteristic of Class 1 production rock and handles the material accordingly by placing it in controlled facilities, such as Site 23 and the tailings area.

Class 2 production rock rib samples had a moderate average NP value of 133 tons $CaCO_3$/1000t and an average AP of 80 tons$CaCO_3$/1000t. The resulting average NNP for the Class 2 rib samples was 53 tons $CaCO_3$/1000t. Class 3 rib samples had an average NP, AP and NNP of 184, 409and -225 tons$CaCO_3$/1000t, respectively. Negative values for NNP indicate that the materials are potentially acid generating, thus requiring appropriate ARD control measures. Carbonate in the Class 2 and Class 3 production rock prevents ARD formation in the short term, allowing time for placement of a composite soil cover to be constructed during reclamation. The soil cover is designed to inhibit ARD formation by minimizing oxygen and water infiltration into the underlying production rock. Class 4 rib samples produced an average NNP of -757 tons$CaCO_3$/1000t. Class 4 material is retained underground.

Figure 3.28 compares actual class designation based on ABA analyses to the results of visual designation use underground to classify the production rock. Of the 71 composites, visual classification assigned 5 sample (7%) to a lower, less conservative class. Fifty-four (76%) of the composites were assigned to the appropriate class and 12 (17%) to a higher, more conservative class. These data represent a 93% success rate for the visual classification program.

Table 3.3 Acid Base Accounting Data Summary for Underground Rib Samples and Site 23

	Class 1		Class 2		Class 3		Class 4
	Site 23 #1	Rib Sample #1	Site 23 #2	Rib Sample #2	Site 23 #3	Rib Sample #3	Rib Sample #4
NP	493	349	403	133	434	184	146
AP	107	51	89	80	226	409	898
NNP	386	298	313	53	208	-225	-650

Notes: Values are averages from 71 samples for rib samples and 20 samples for Site 23
ABA units are tons $CaCO_3$/1000t
NP determined by modified Sobek method
AP determined from total sulfur assay (converted to pyrite equivalent)

2009 ABA results from the Site 23 active placement areas are shown also in Table 3.3 and Figure 3.29. Active placement area ABA results from previous years as well as the 2006-2008 grid data are also shown on Figure 3.29. The AP to NP distribution in the Site 23 samples differs from that of the underground rib samples. The Class 2 and Class 3 stockpiles areas are frequently empty except for a safety berm, which is constructed of Class 1 rock in the absence of other material. It is probable that several of the samples included this material. The grid sampling is also skewed toward higher NNP values because most of the outer surface of the pile is covered with Class 1 rock.

3.6 General Site Management

The construction method used at Site 23 (bottom-up construction) limits the site's complexity. Designated placement zones are marked on the active lift of the site and production rock is placed according to class. No activities other than routine monitoring occurred at Site 23 in 2009.

In 2005 HGCMC modified placement methods to minimize the formation of permeable areas, or chimneys, between placement zones. The homogenous, planar placement surface that resulted from the new method created surface drainage challenges. HGCMC experimented with a ridge and swale pattern that appeared to improve drainage during the rainy season but was susceptible to drifting snow in the winter months. Fine tuning of methods to improve drainage and accessibility continued in 2009.

In 2008, HGCMC received approval from ADEC to construct an interim storage area for waste rock to be backfilled underground (see photo Figure 3.35). This 25,000 cubic yard capacity area was constructed to aid in concurrent reclamation efforts and can potentially be utilized on a continual 12-month schedule. This is a large increase over the previous 920 remuck bay which had a seasonal 700 cubic yard capacity. The area is layered with 6" of sand; a 36 mil reinforced polypropylene liner, another 6" layer of sand, 3' of class 3 production rock, and finally a geofabric layer. An HDPE pipe collects water from the area which is sloped to a central collection point. The water collected in this area drains to Pond 23. Material placed in this area is treated with up to 1 wt% lime. Waste rock from the B and D Pond berms, the 1350 and segments of the pipeline excavation were placed at the Site 23 temporary storage area. These materials are backfilled underground as space and resources become available.

Approximately 5,000 cubic yards of material was excavated from the backslope of Site 23 during the 2005 construction season. The material was used as fill in the 960 road base and the Mill Backslope road. Additional material that was removed is stored at 4.9 on the B Road for future site reclamation activities. In 2007, approximately 8,000 cubic yards were removed from this area for site development and other various projects. In 2008, 360 cubic yards were excavated for the B Pond berm project. In 2009, improvements in the D pond area included installation of a larger pump system to increase pumping capacity. Also, approximately 4,500 cubic yards of waste rock and pyritic berm material were removed, and replaced with clean fill. The majority of the fill was sourced from the backslope of Site 23, with minor amounts of sand and gravel used for drains.

3.7 Site as-built

As-built drawings for Site 23/D are presented in Appendix 2. Three drawings from the Site 23/D Hydrogeology and Geochemistry Analysis Report (EDE 2004) (Site 23/D conceptual model, Site 23/D colluvium potentiometric surface and Site 23/D cross section) are also included in Appendix 2. The drawings show the year-end topography, water management features, monitoring device locations, and other significant features of the site. The as-built also includes cross sections that show the following information:

- existing topographic surface
- prepared ground upon which the pile was constructed
- original unprepared ground
- fill design level

Figure 3.34 shows an aerial photo of Site 23 in June 2008. The interim storage area at Site 23 is shown in Figure 3.35. Figure 3.36 shows the D Pond berm removal work in progress.

3.8 Reclamation

HGCMC has monitored the performance of a one-acre composite soil cover plot on Site 23 since September 2000 (see Site 23 as-built in Appendix 2 for plot location). Key performance aspects of the cover system through 2009 include:

- Damage to the Site 23 station necessitated the use of total precipitation data from the Mill site station. The 52.5 inches recorded during the 2009 monitoring period was significantly less than the 68.5 inch average for the 2000-2009 period.
- Snow depth measurements indicated that there was approximately 45 inches of snow (~9 inches of snow water equivalent) at the site just prior to snowmelt.
- Calculated potential evaporation (PE) for 2009 was 16.8 inches (long term average, 16.0 inches) and estimated actual evapotranspiration was 9.0 inches.
- Time domain resonance (TDR) probe readings collected in 2009 are consistent with neutron moisture probe measurements from previous years, showing little variation in volumetric water content at depth in the soil profiles.
- The degree of saturation in the barrier layer was greater than 85% for the entire monitoring period. In fact, saturation appears to have stabilized at about 95 percent. The very low matric suction values (<10 kPa) observed in 2009 suggest that there has been no reduction in the degree of saturation in 2009. This is a positive cover performance aspect and implies that the oxygen diffusion coefficient of the barrier material was minimized, thus minimizing the ingress of atmospheric oxygen with respect to diffusion through the pore-air space. Incomplete data capture for net percolation precluded calculating a water

balance for the cover system in 2009; however, percolation rates appear to be similar to the long term average of 15 to 20 percent of annual precipitation.
- The recorded temperatures within the growth medium layer and the compacted barrier layers have been similar for the nine years of monitoring. The data show that freezing conditions have not been encountered in the compacted barrier layer, suggesting that freeze/thaw cycling is not occurring.
- Vegetative cover continues to be dominated by the hydroseeded grass and clover plant species. However natural invasion, primarily by spruce seedlings, is evident, particularly on the western-most portion of the cover area.

In December 2006 HGCMC began collaborating with Oregon State University (OSU) and M.A. O'Kane Consultants Inc. to further characterize the hydrology of the cover plot and evaluate how evolution of native forest vegetation (spruce-hemlock forest) may affect cover system performance. Field experiments and numerical modeling will continue through 2010. Key aspects of the Oregon State University study include:

- In May 2007 a 10-meter instrumentation trench was installed at the toe of the cover system to help quantify water flows from individual layers of the cover. Standpipe piezometers and TDR moisture probes were installed on the cover up-gradient from the trench, augmenting the existing monitoring network.
- Tracer/irrigation experiments were performed in May and November 2007.
- A shelter was constructed over the instrumentation trench in November 2007 to protect the collection system during the winter months. Freezing of the trench face inside the shelter caused extensive damage to the collection system, which hampered data collection in 2008. HGCMC installed a heater and insulated the shelter prior to the onset of winter weather in 2008.
- The field data were used to calibrate and test a 2D finite element model of the cover system. OSU used the model to assess flow processes occurring in the existing cover and evaluated alternative cover designs.
- Results of dye tracer experiments indicate that the vertical flow likely predominates in the growth medium and that the flow is not particularly preferential.
- The response to irrigation events of two standpipe piezometers installed above the barrier layer were used to characterize the behavior of the growth medium and upper capillary break.
- Flow data collected from the instrumentation trench shows that the system responds rapidly to irrigation and natural rain events. Lateral flow was observed in the growth medium and upper capillary break. Greater flow rates on the western side of the trench are attributed to the southwesterly tilt of the cover. The orientation of the trench relative to the tilted strata may have allowed a substantial portion of the input water to bypass the trench. The upper capillary break contributed approximately 85% of the trench flow. The remaining 15 % of the trench flow was provided primarily by the growth medium. The barrier layer contribution was 0.2 %.
- Moisture probe measurements suggest that a greater response to irrigation events occurs near the cover surface and down-slope in the growth medium. Normal rain events had little effect on moisture contents measured using the TDR probes.
- A tracer was added to the upper capillary break approximately 9.5 meters up-slope from the trench. No tracer was observed in the discharge from the growth medium or barrier layer. The peak in tracer concentration observed in the discharge from the upper capillary break occurred approximately two hours after injection. The mean lateral subsurface velocity for transport of the tracer was calculated to be between 3.8 and 4.8

m/hr. It took two days to return to background tracer concentrations, suggesting non-ideal, dispersion-dominated transport.

- Saturated hydraulic conductivity of the growth medium was measured with a constant head permeameter. The results varied from 27 to 581 cm/day (mean 192 cm/day).
- The response in trench flow to natural rain events indicates that the lag time between peak rainfall and peak trench discharge is on the order of 6-7 hours for dry antecedent moisture conditions and 2-3 hours for wet conditions. Transient water tables perch at the interface of the upper capillary break and the barrier layer, triggering subsurface flow.
- The finite element model HYDRUS-2D/3D was used to simulate water flow in the cover system. Field and laboratory measurements of hydraulic properties of the layer materials were used in the model. Comparison of the model results with field observations indicates generally good agreement between the measured and simulated results, particularly with respect to timing and slope of rising and falling hydrograph limbs.
- The effects of evapotranspiration were later incorporated into the model, improving agreement with field results. The modeled subsurface runoff coefficient was within 1% of the measured field value for a month-scale simulation. The model predicted no surface runoff, which is consistent with field observations.
- The 2D model and 2006 meteorological data were used in a one-year water balance simulation. The modeled and measured lateral subsurface flows were 71% and 68%, respectively, and the modeled and measured vertical percolation through the base of the cover was 12% and 19%, respectively. The model also indicates that the upper capillary break layer effectively prevents buildup of excessive head pressure in the growth medium, which maximizes stability of the cover.
- A comparison between 2006 field data and the model simulation for the same time period suggests that the lysimeter at the base of the cover may be providing a reasonable estimation of the vertical percolation through the barrier layer. The model indicates that the barrier layer maintains a high degree of saturation which minimizes oxygen ingress into the waste rock but also allows a greater flow velocity relative to unsaturated conditions. Limiting the percolation rate while maintaining saturation could be achieved by lowering the hydraulic conductivity of the barrier layer.
- The model supports the field measurements, indicating that the installed cover system is very efficient at conveying infiltrating waters laterally down slope without producing surface runoff and positive pressure heads in the cover system.
- OSU used the model to evaluate eight alternative cover designs, which included changes in barrier layer conductivity, the absence of capillary breaks and the changes in growth medium thickness. Each alternative was subjected to summer and fall meteorological conditions. The results indicate that the upper capillary break is necessary to maximize lateral flow and prevent buildup of head pressures in the growth medium and barrier layer, even if a thicker growth medium is present. The lower capillary break improves performance but could potentially be eliminated if the barrier layer conductivity was reduced. Reduction of the barrier layer conductivity by an order of magnitude (to 10^{-7} cm/s) would reduce percolation from approximately 10% to about 1% of incident precipitation.
- The work plan for 2010 includes additional field data collection and assessment of the potential effects of long term vegetation changes on cover performance.

In 2008 HGCMC began monitoring oxygen and carbon dioxide concentrations in the instrumentation trench building (the “Chalet”) to determine if conditions were unsafe for human entrance. Gas levels showed a slight season fluctuation, but did not approach unsafe levels. Figures 3.32 and 3.33 show oxygen levels decreased slightly and carbon dioxide levels increased slightly in the summer months and were at atmospheric conditions in the winter months (20.9% oxygen and 0% carbon monoxide). These monitoring results are consistent with the conceptual model of pile gas transport. When the internal temperature of the pile is colder than the external air temperature, oxygen-deficient, carbon dioxide-rich air flows out the toe of the pile. When the pile temperature is warmer than external air temperature, oxygen rich air is drawn in at the base of the pile. HGCMC personnel will continue to monitor gas levels in the summer months prior to entering into the building.

Reclamation Plan

The HGCMC Reclamation Plan, as well as its implementation is discussed above in Section 2.8 Tailings of this report. Please refer to that discussion for aspects relevant to Site 23/D area reclamation.

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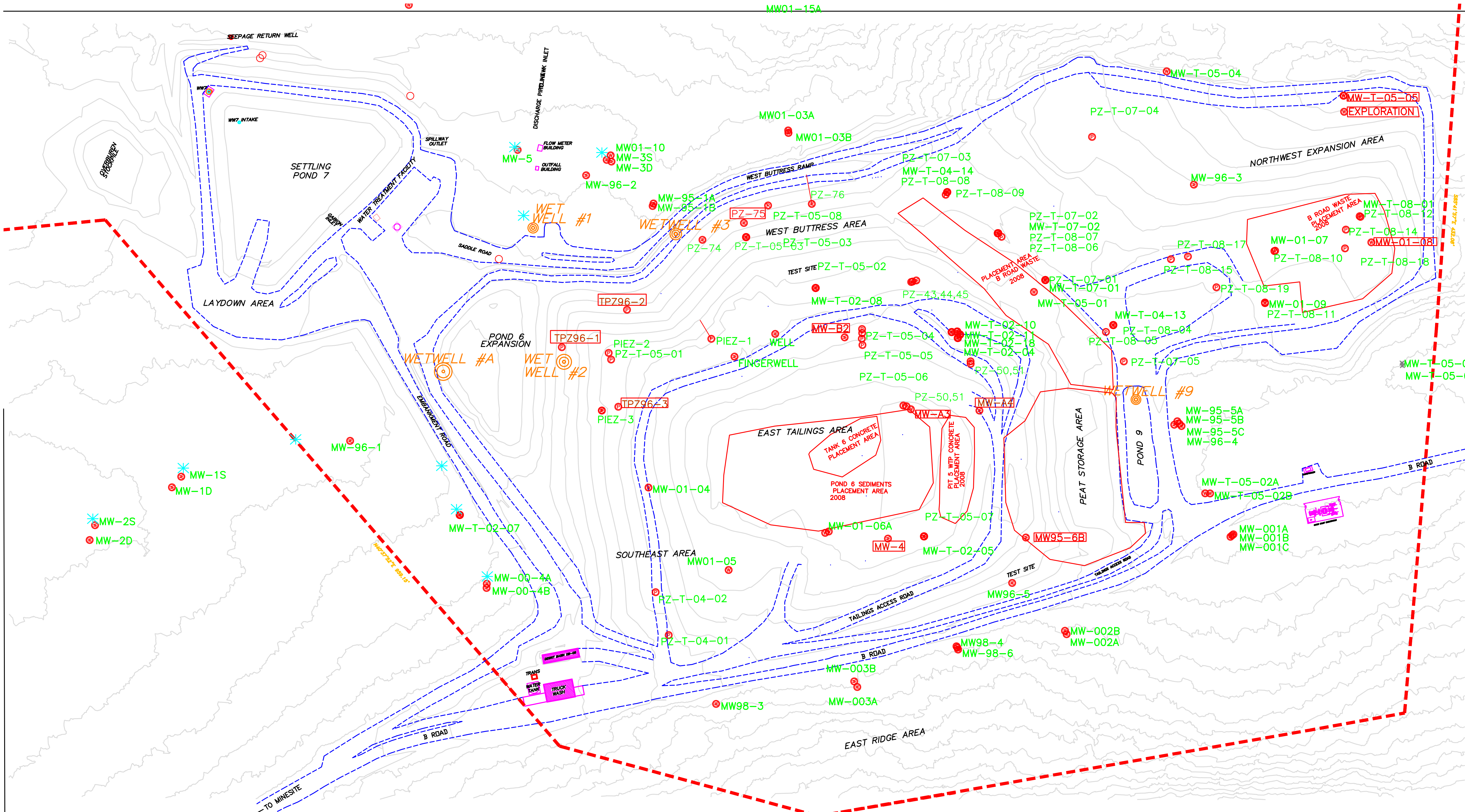
APPENDIX 1

Tailings Facility 2009 As-built and Cross Sections



LEGEND:

ROADS/DITCHES	
WATER UTILS	
BOUNDARY	
MONITORING WELL	
PIEZOMETER	
WET WELL	
DECOMISSIONED WELL	
SNOW SAMPLE LOCATION	

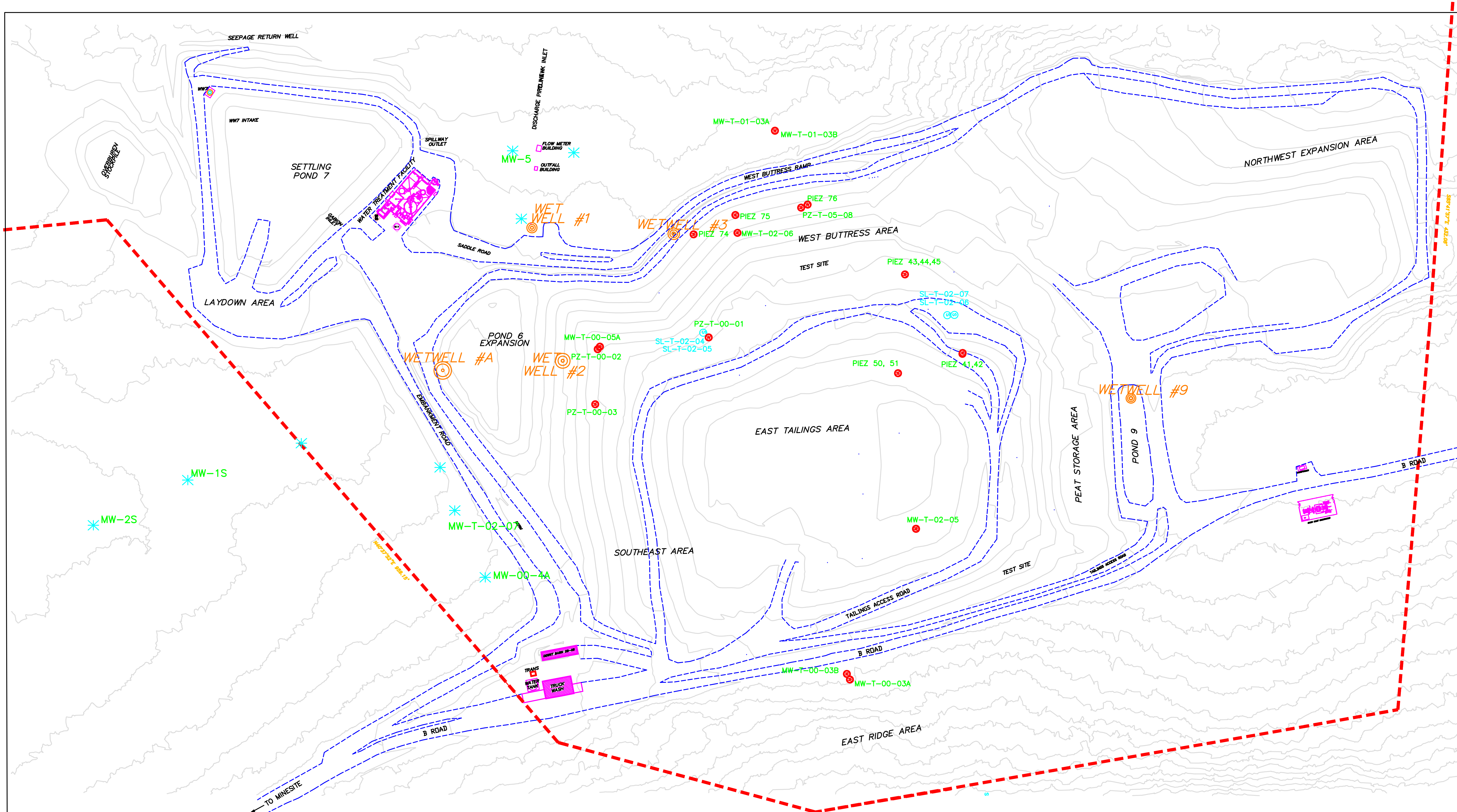
DATE: 11-31-08
DRAWING BY: Shelby Edwards
DESIGN BY: ----
REVIEWED BY: ----
PROJ OR REF. ----

HECLA GREENS CREEK MINING CO.
P.O. BOX 32199 JUNEAU, ALASKA 99803
PHONE: (907)790-8441 FAX: (907)790-8448

TITLE: Tailings Asbuilt
Wells and Piezometers

GRAPHIC SCALE

SHEET: 1 OF 1



LEGEND:

ROADS/DITCHES	——
BOUNDARY	— — — —
MONITORING WELL	
PIEZOMETER	
WET WELL	
LYSIMETER	
SNOW SAMPLE LOCATION	

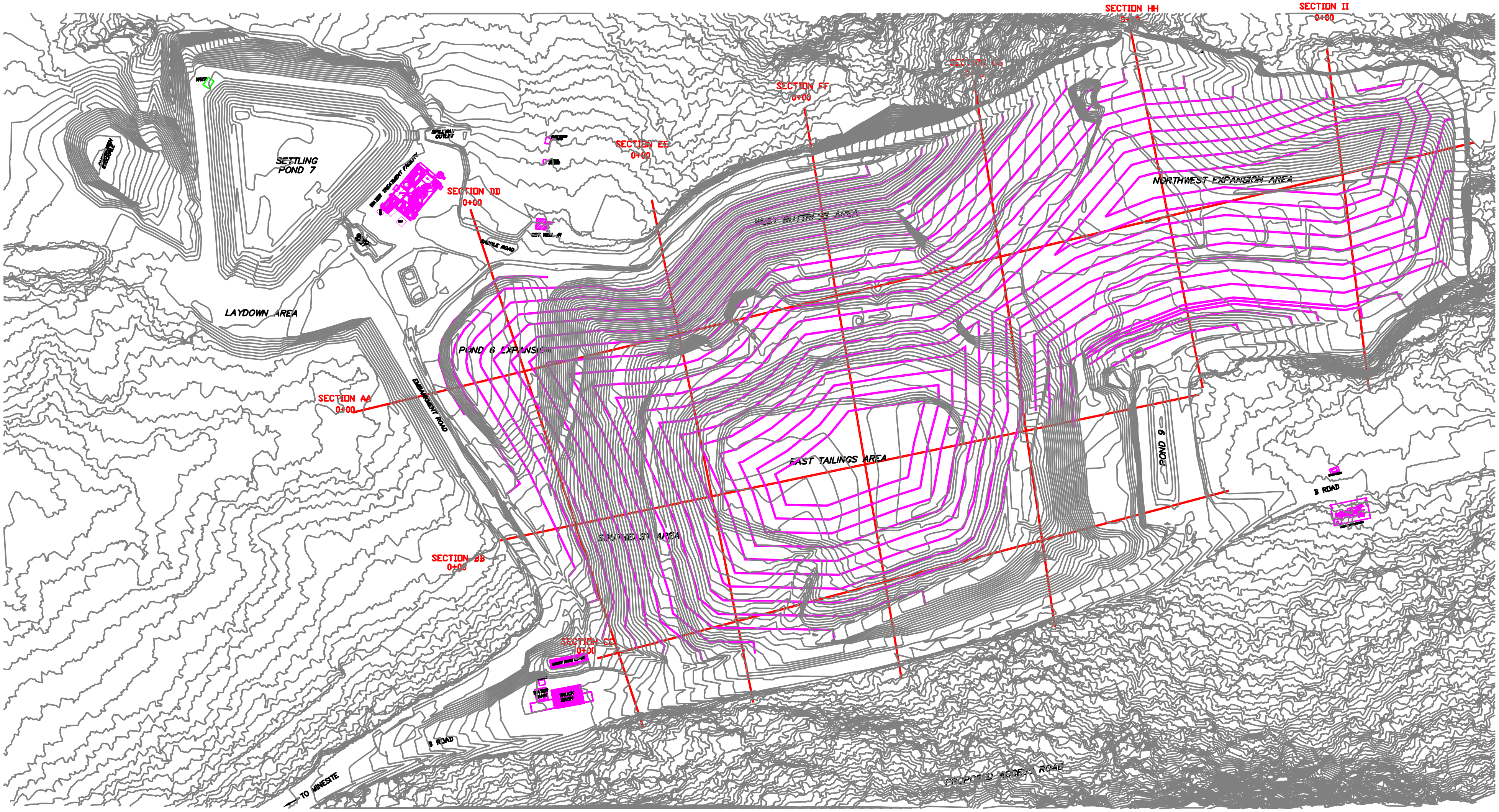
DATE: 11-31-08
DRAWING BY: Shelby Edwards
DESIGN BY: ----
REVIEWED BY: ----
PROJ OR REF. ----

HECLA GREENS CREEK MINING CO.
P.O. BOX 32199 JUNEAU, ALASKA 99803
PHONE: (907)790-8441 FAX: (907)790-8448

TITLE: Tailings Asbuilt Annual Report Instruments

GRAPHIC SCALE

SHEET: 1 OF 1



TAILINGS FACILITY 2009 AS BUILT AND CROSS SECTIONS

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LEDGEND:
DESIGN PLAN
ORIGINAL GROUND
EXISTING GROUND
EXISTING ROADS
CROSS SECTIONS

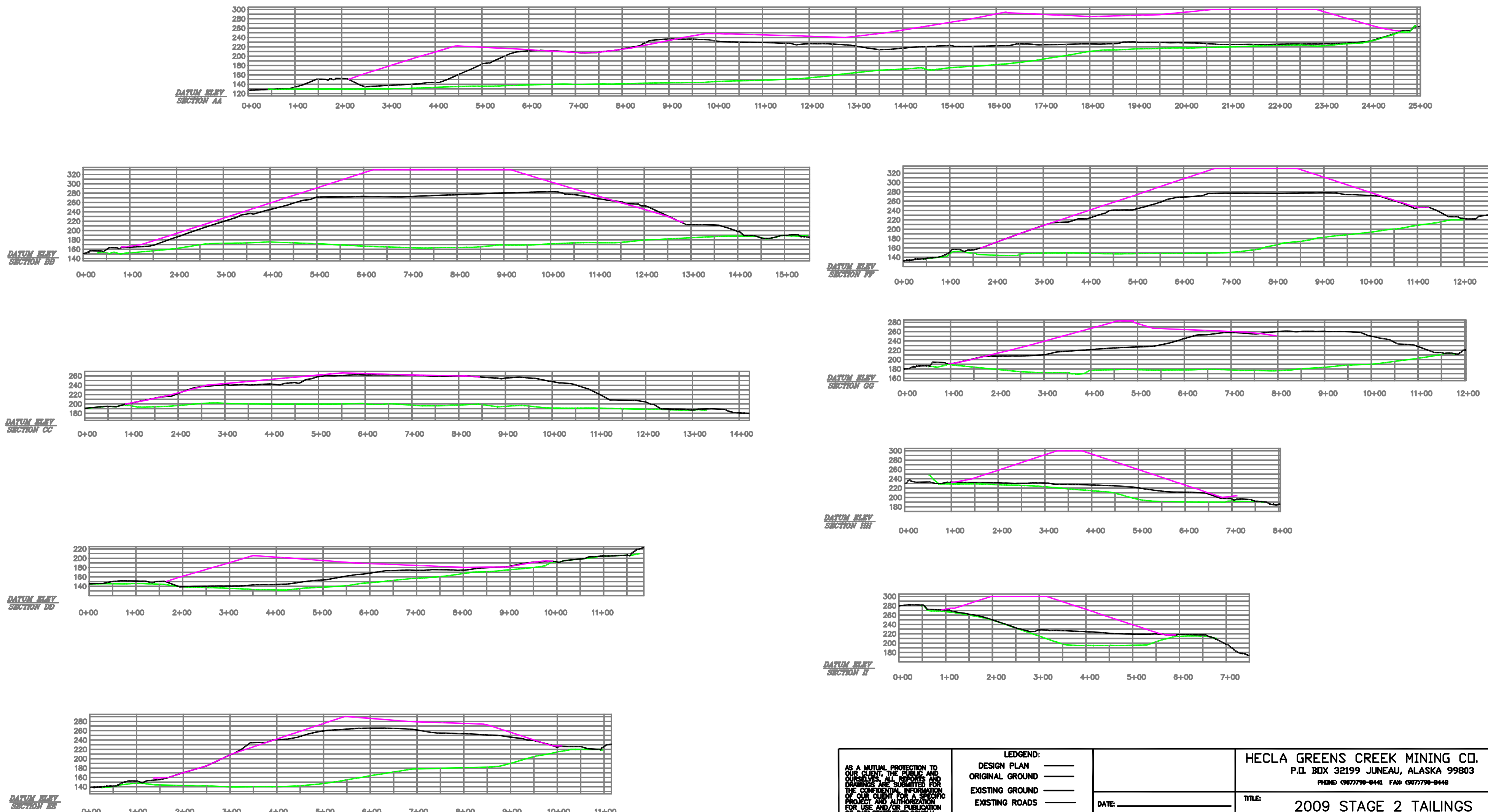
SYMBOLS:
FIRE HYDRANT
MONITORING POINT
BOLLARDS
POWER POLES
WATER VALVE
CATCH BASIN

DATE:
DRAWING BY: Shelby Edwards
DESIGN BY: ----
REVIEWED BY: ----
PROJ OR REF. ----

HECLA GREENS CREEK MINING CO.
P.O. BOX 32199 JUNEAU, ALASKA 99803
PHONE: (907)790-8441 FAX: (907)790-8448

TITLE: 2009 STAGE 2 TAILINGS EXISTING DESIGN & QUANTITIES

SHEET: 1 OF 1



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LEDGEND:
DESIGN PLAN
ORIGINAL GROUND
EXISTING GROUND
EXISTING ROADS
CROSS SECTIONS
SYMBOLS:
FIRE HYDRANT
MONITORING POINT
BOLLARDS
POWER POLES
WATER VALVE
CATCH BASIN

DATE:
DRAWING BY: Shelby Edwards
DESIGN BY: ----
REVIEWED BY: ----
PROJ OR REF. ----

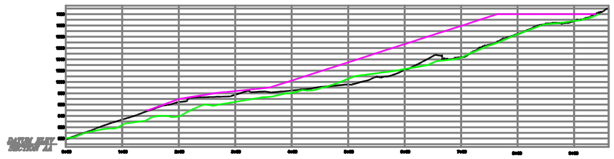
HECLA GREENS CREEK MINING CO.
P.O. BOX 32199 JUNEAU, ALASKA 99803
PHONE: (907)790-8441 FAX: (907)790-8448

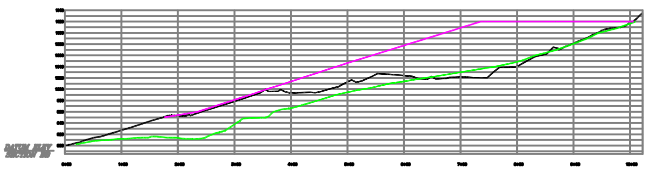
TITLE:
2009 STAGE 2 TAILINGS PROFILE VIEWS

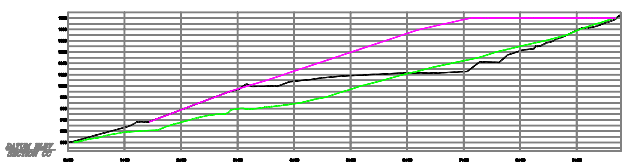
SHEET: 1 OF 1

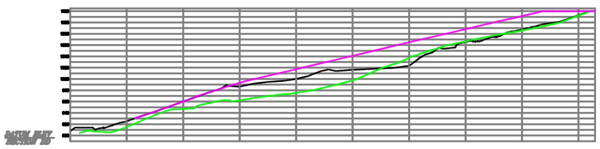
APPENDIX 2

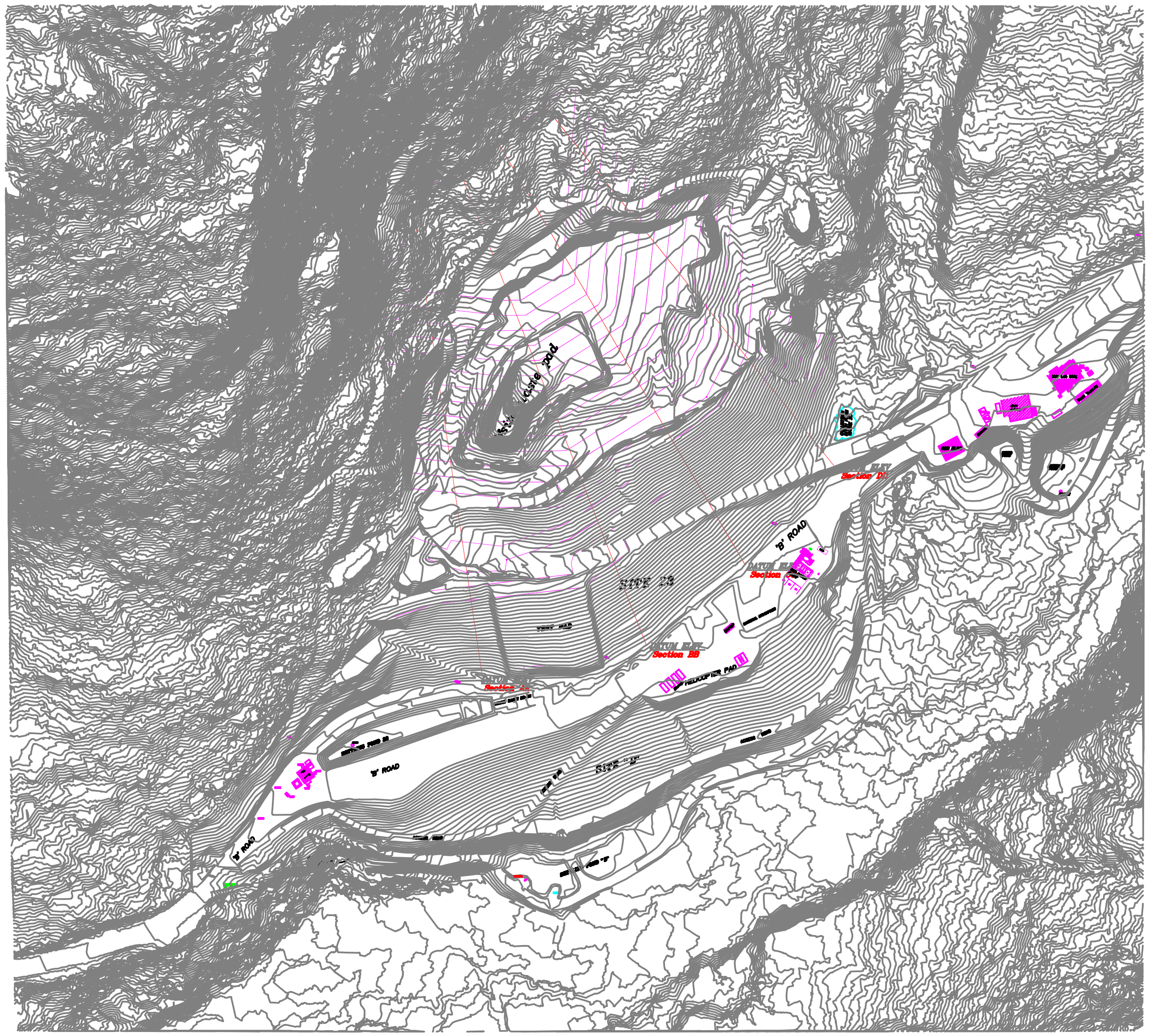
Site 23/D 2009 As-built and Cross Section











LEDGEND:

ORIGINAL GROUND TOPO

EXISTING GROUND

FINAL FILL DESIGN

WASTE SITE 23 REMAINING DESIGN CAPACITY TO ELEVATION 1120 AS OF 12-31-09

Site	Stratum	Surf1	Surf2	Cut	Fill	Net	Method
12-31	comp	n1231	2008 existing design	2515	550921	548406 (F)	Grid

HECLA GREENS CREEK MINE
ADMIRALTY ISLAND, ALASKA

WASTE SITE 23
ULTIMATE PILE DESIGN
W/ CROSS SECTIONS

PREPARED BY:
Greens Creek Mining Co.

SCALE: 1"=60'

SHEET: 1 OF 1

KENNECOTT MINERALS

KENNECOTT GREENS CREEK MINING CO.

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

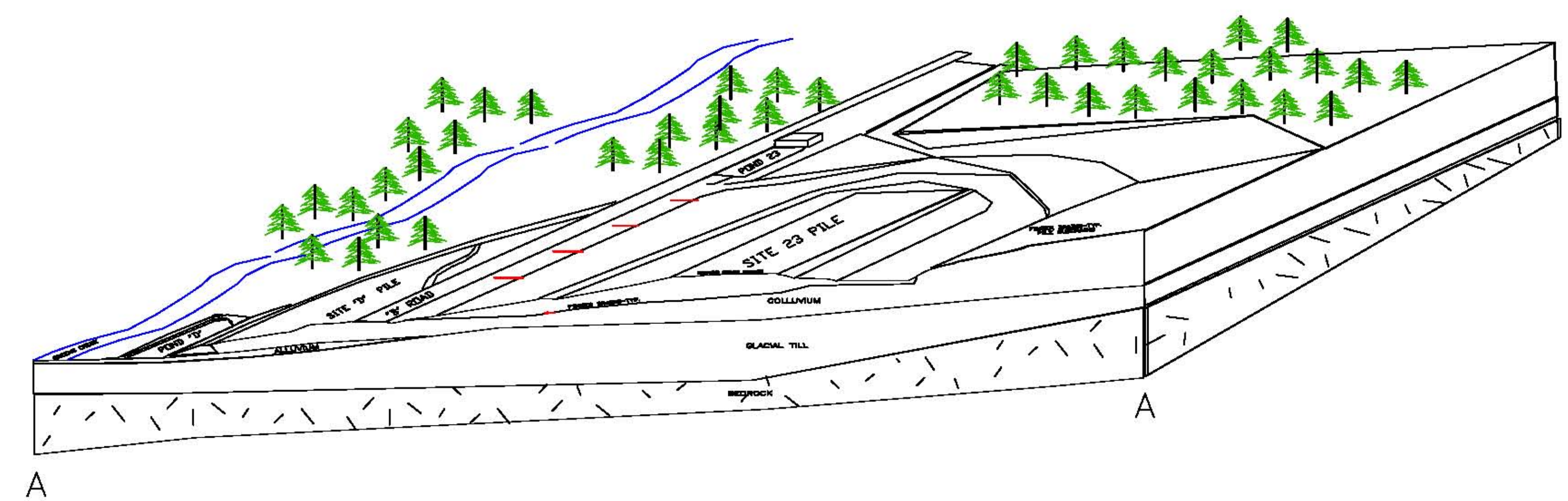
TITLE:

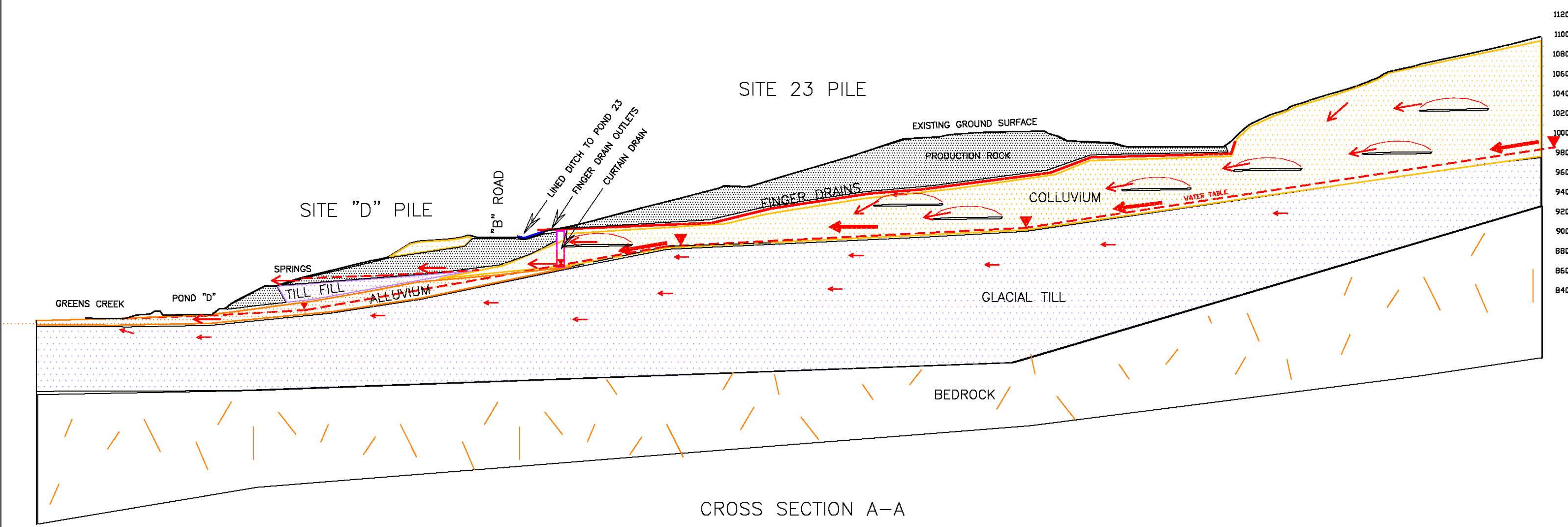
SITE 23/D CONCEPTUAL GROUNDWATER FLOW

LEGEND:

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

FIGURE 2

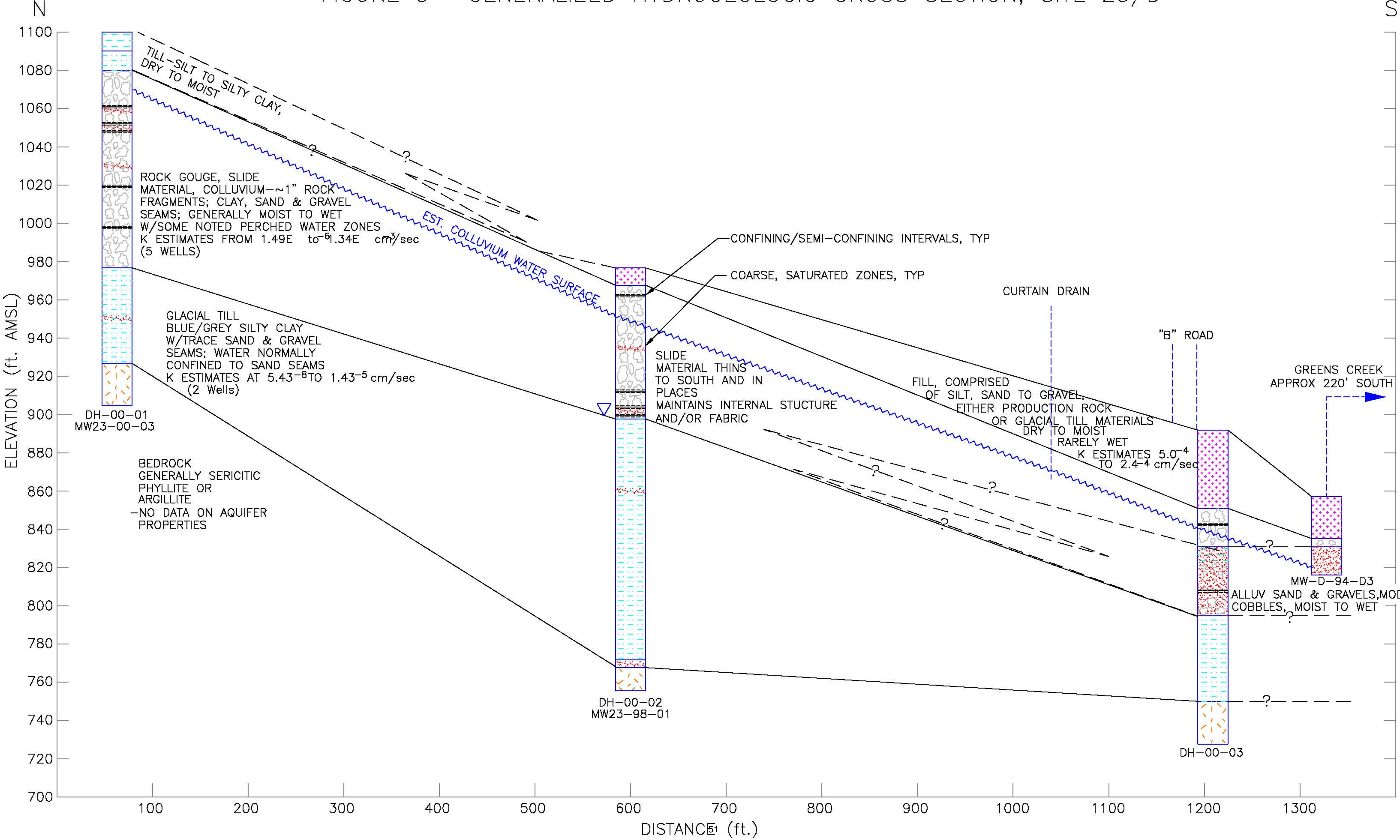


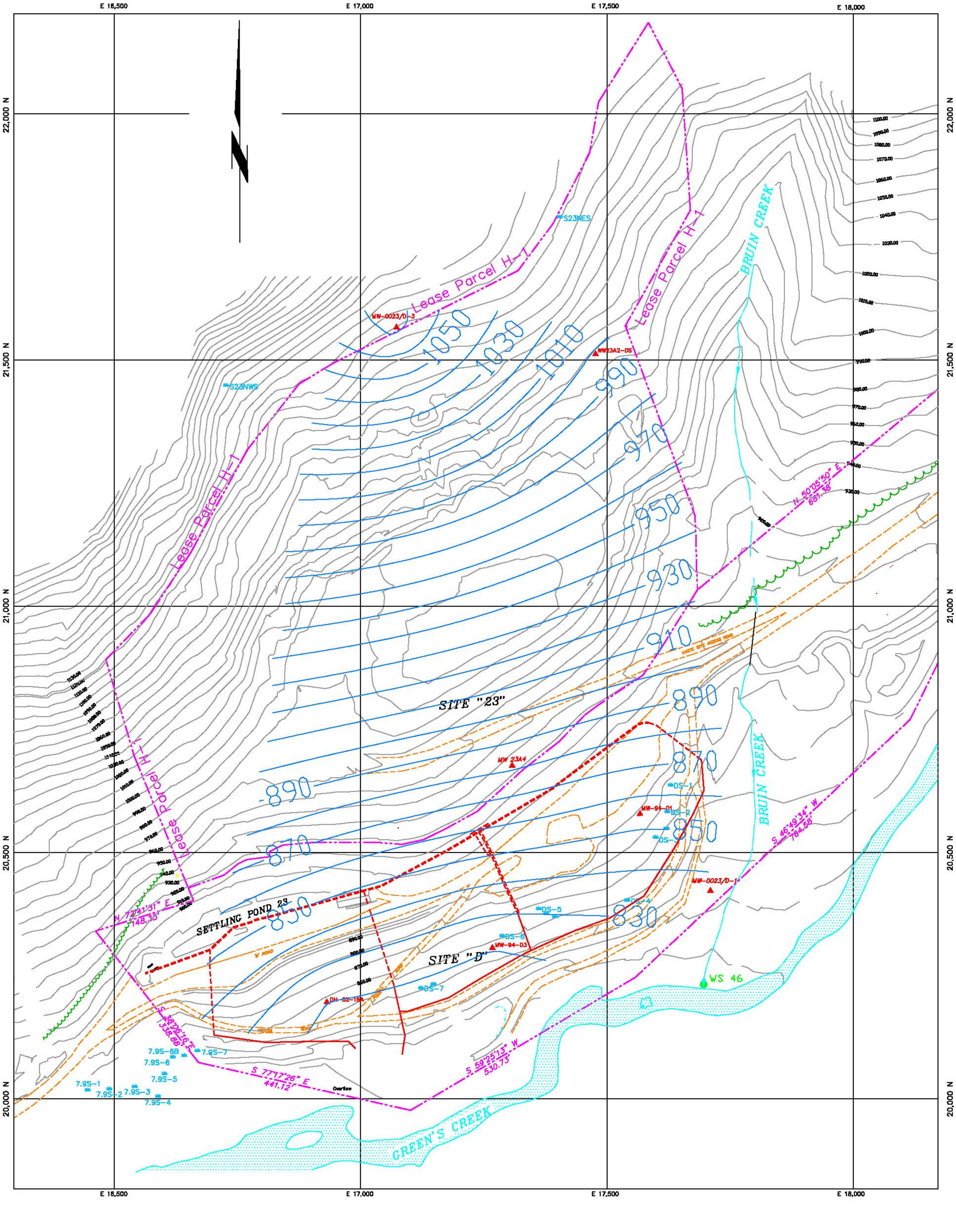


CROSS SECTION A–A

South North

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





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 MINERALS

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) 672-3763 EDE DWG site 23 base map.dwg
SCALE: 1" = 200'	SHEET: 1 OF 1

APPENDIX 3

Data Figures

Figure 2.1 Water Level Data for Piezometer 41

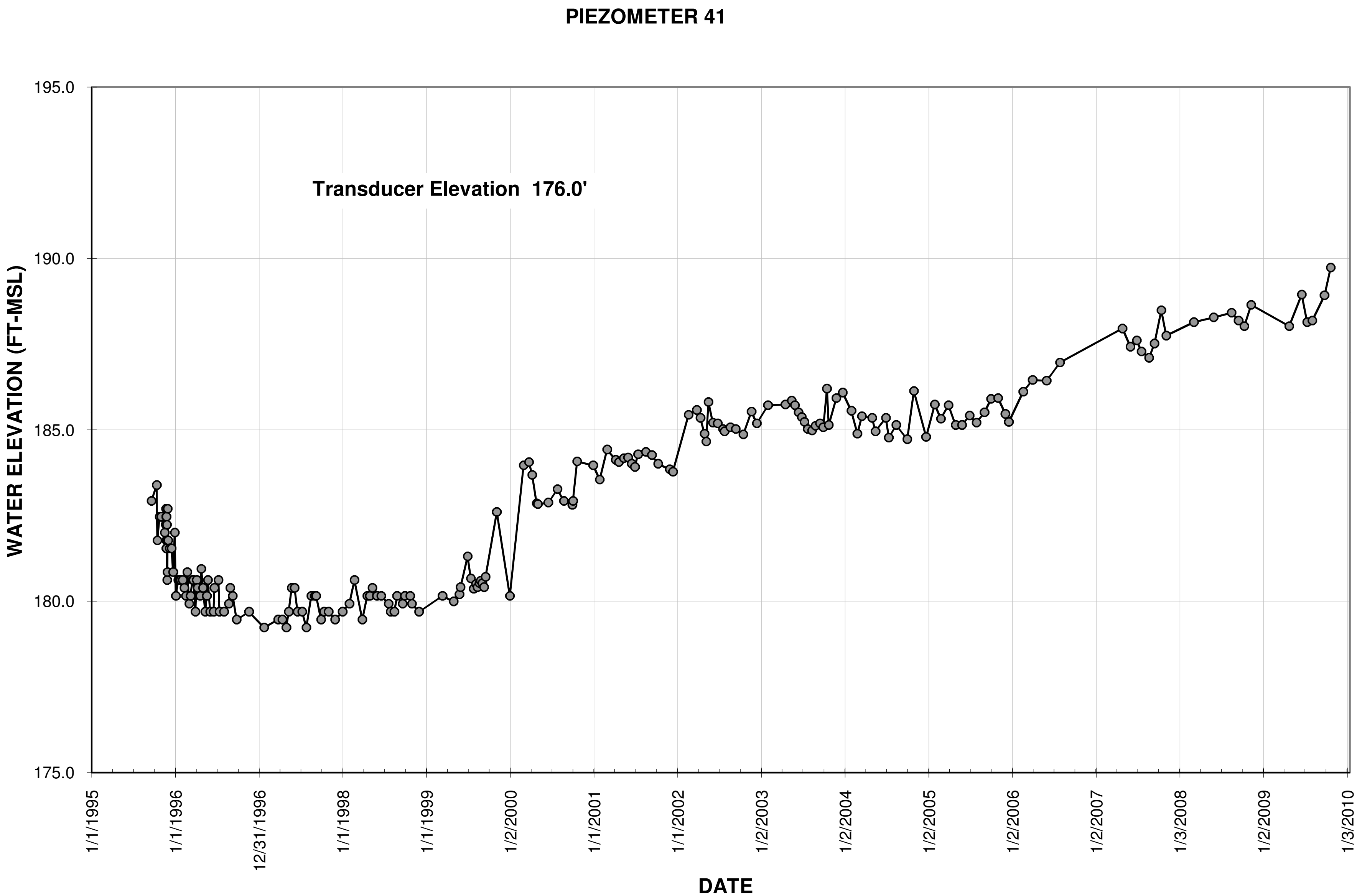


Figure 2.2 Water Level Data for Piezometer 42

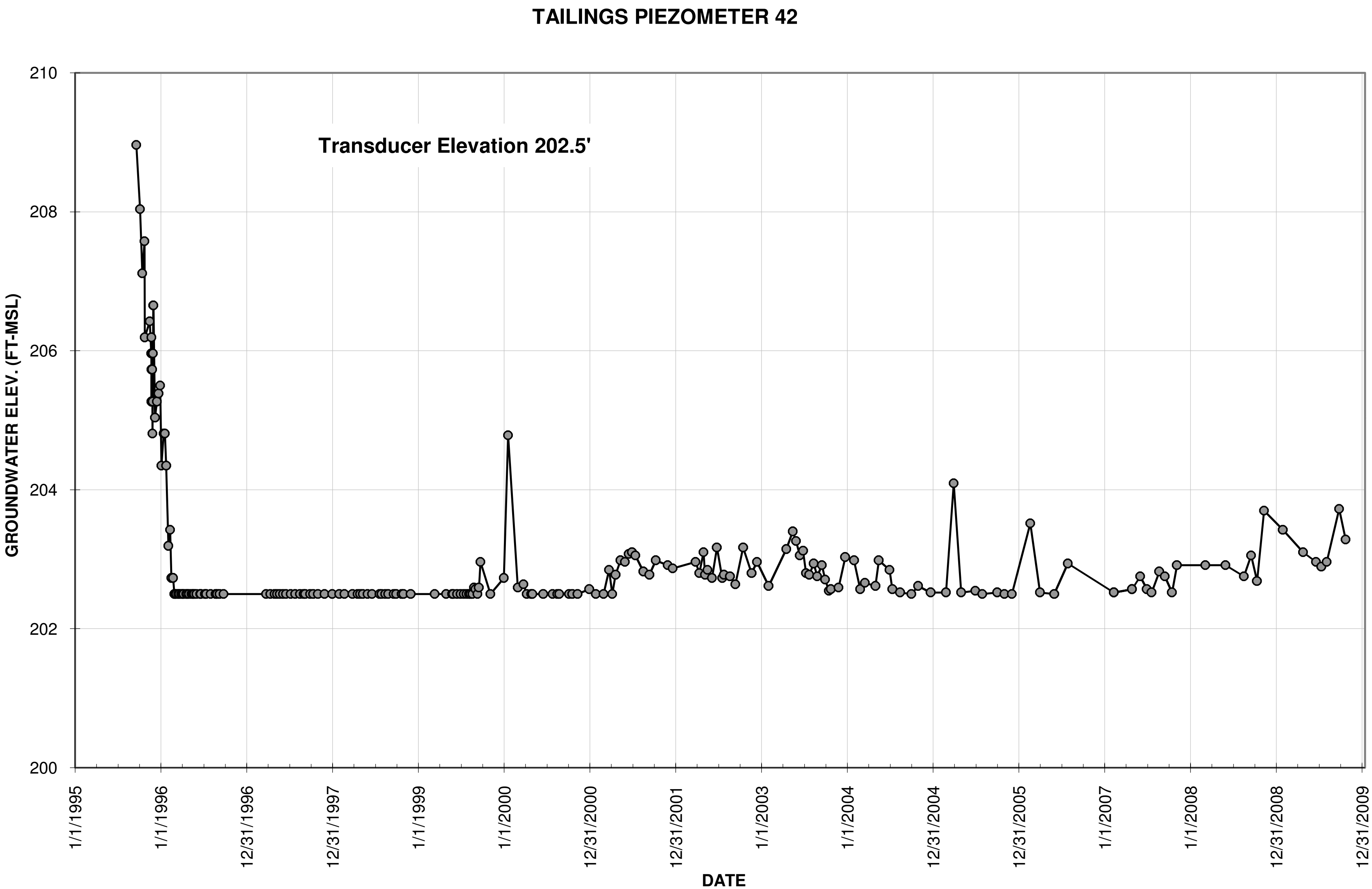


Figure 2.3 Water Level Data for Piezometer 44

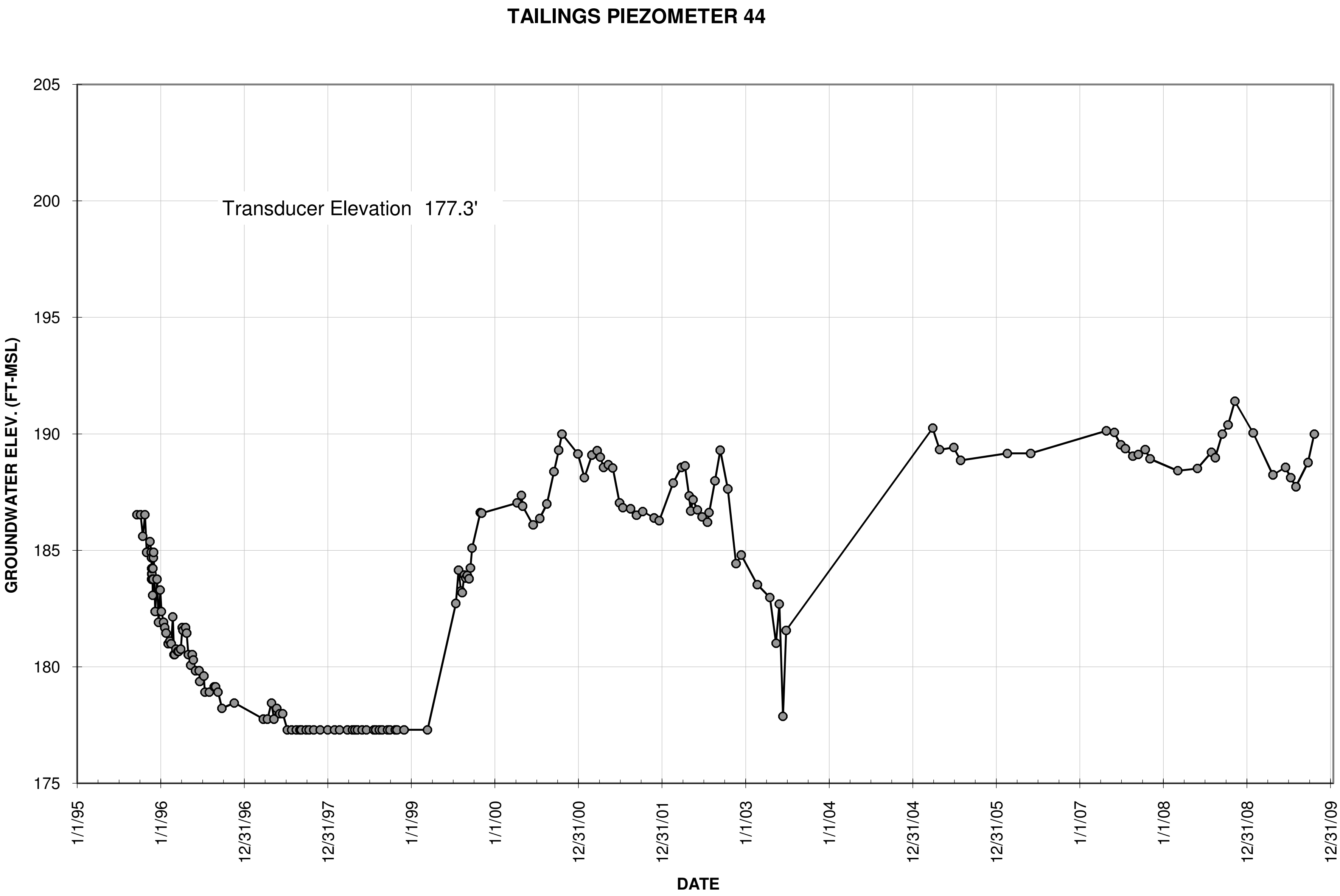


Figure 2.4 Water Level Data for Piezometer 46

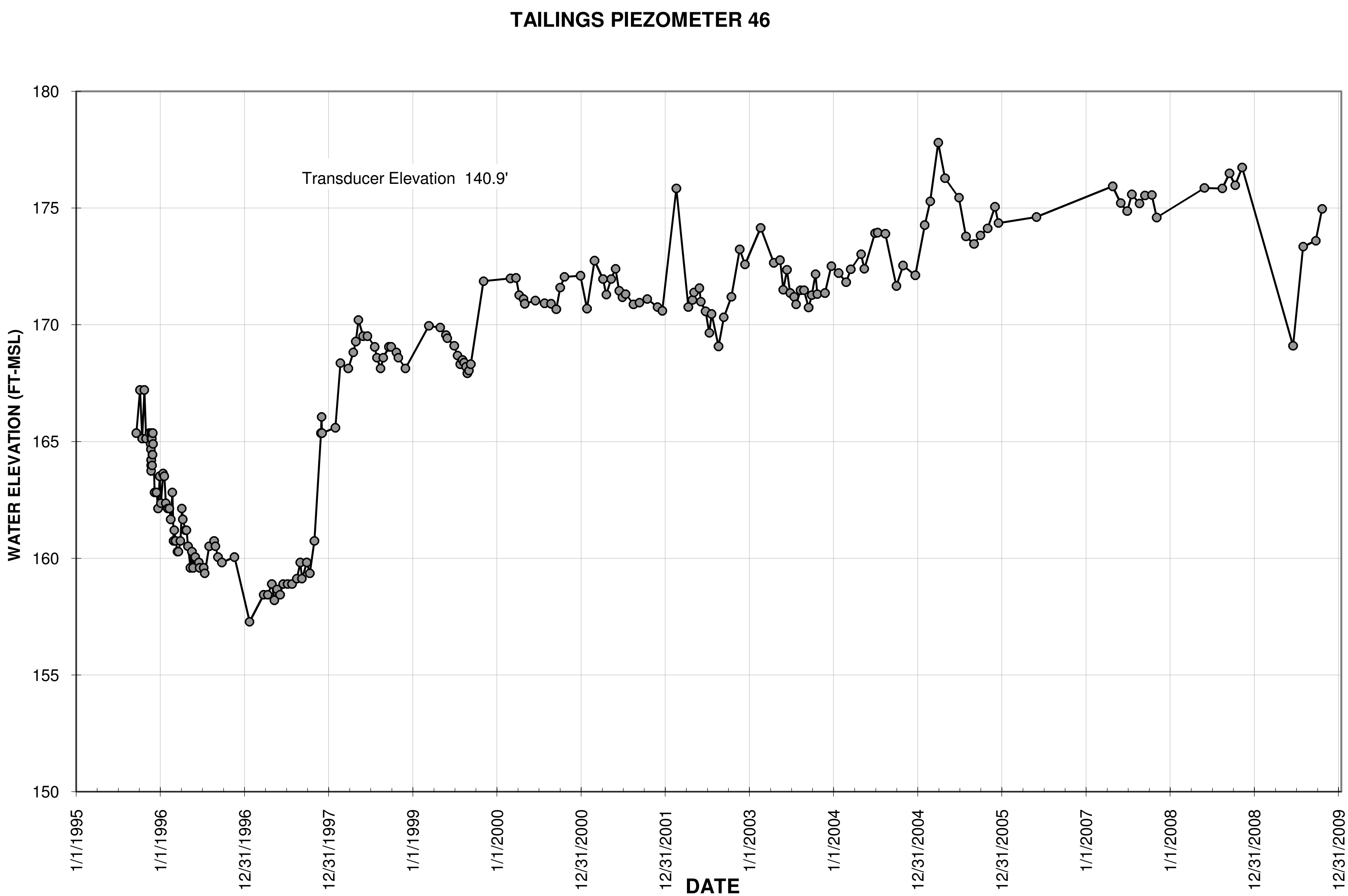


Figure 2.5 Water Level Data for Piezometer 47

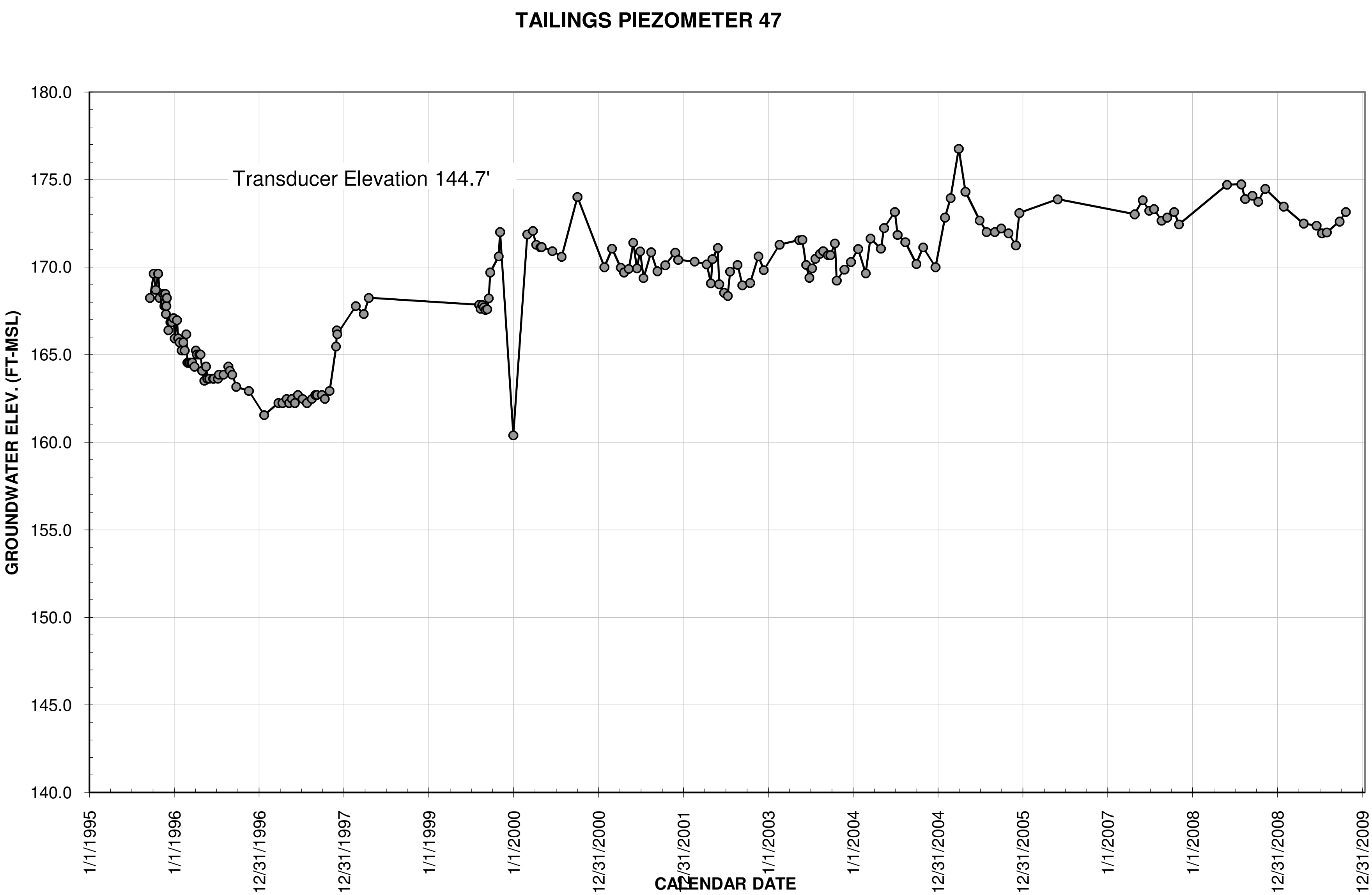


Figure 2.6 Water Level Data for Piezometer 50

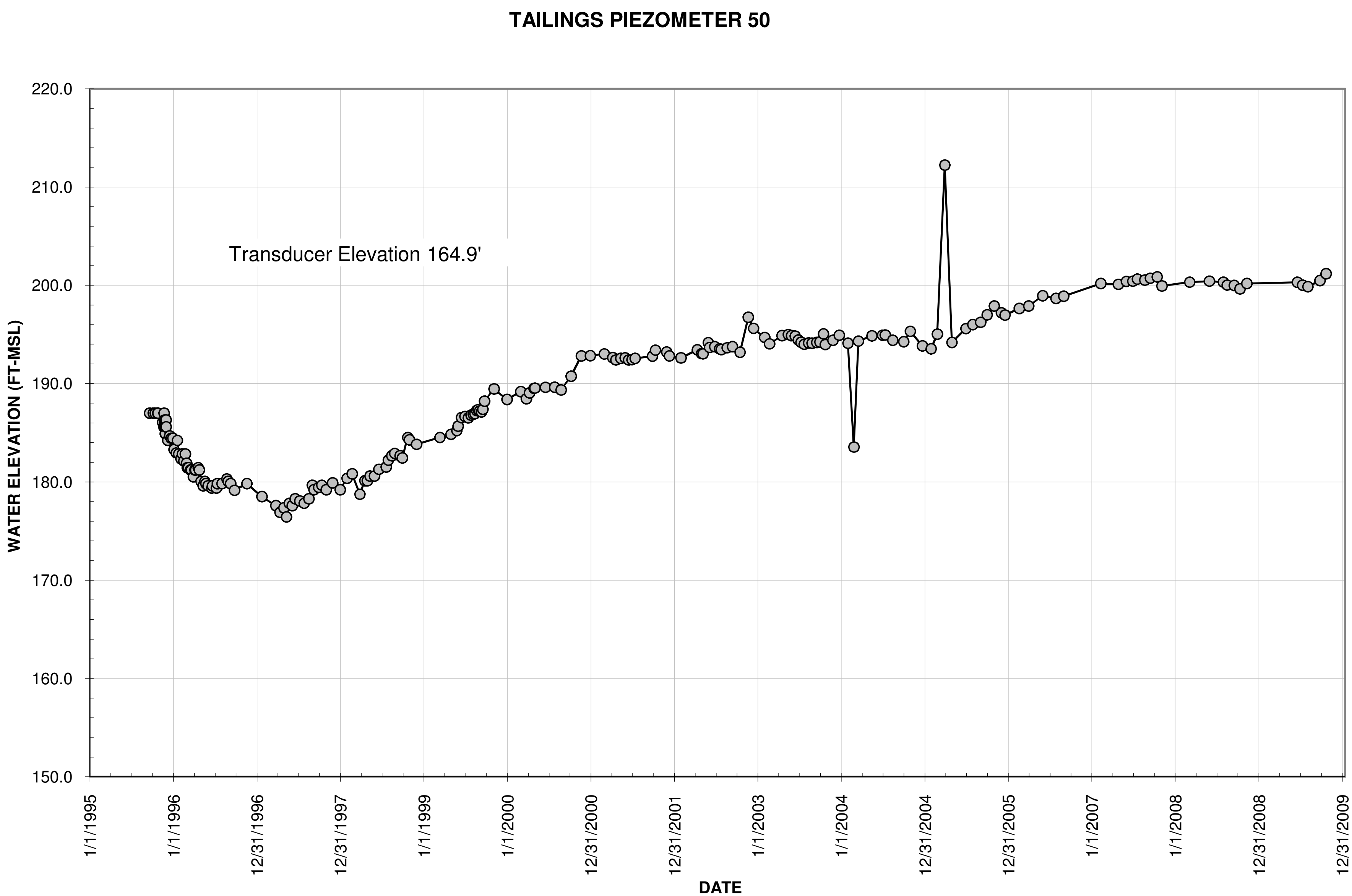


Figure 2.7 Water Level Data for Piezometer 51

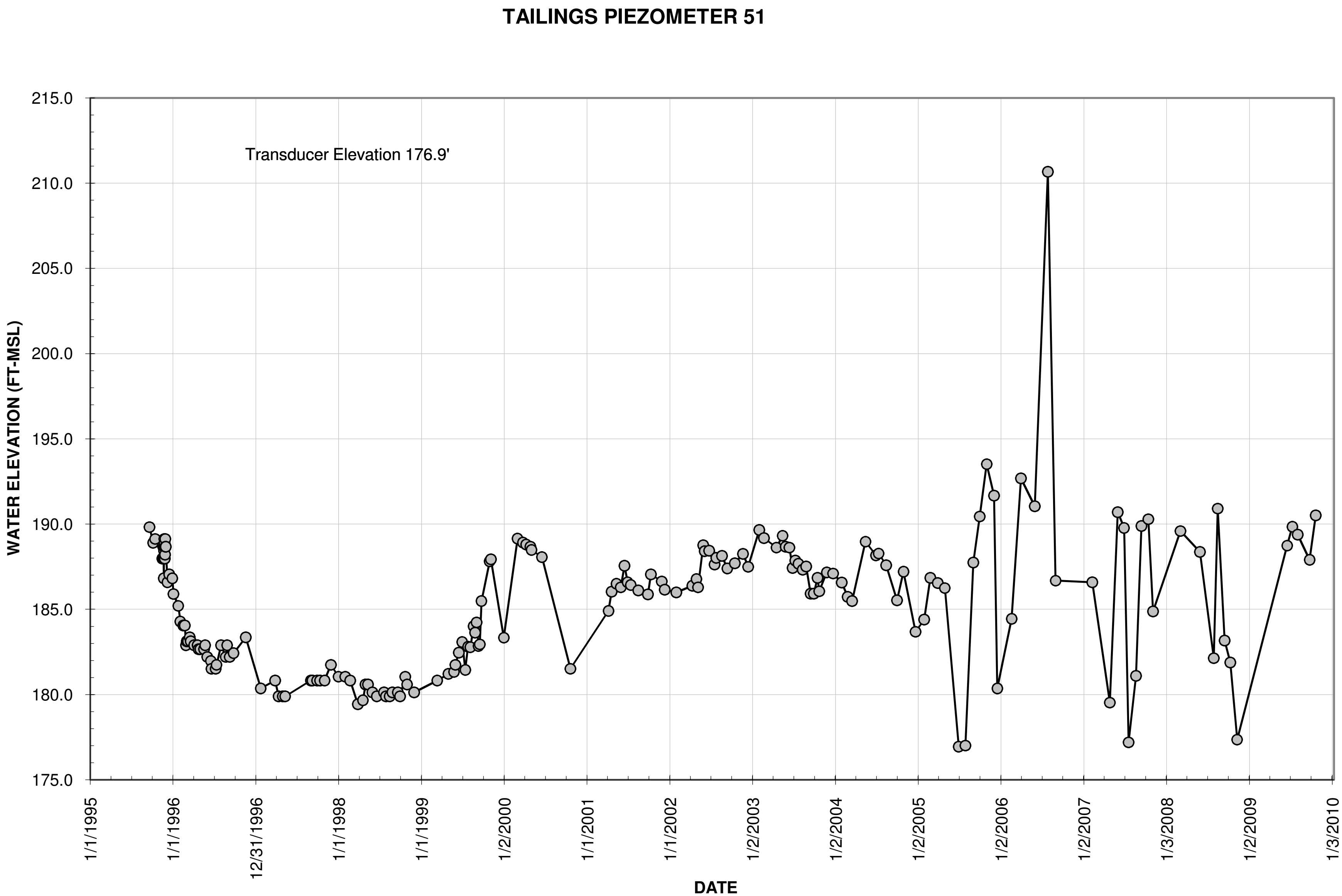


Figure 2.8 Water Level Data for Piezometer 74

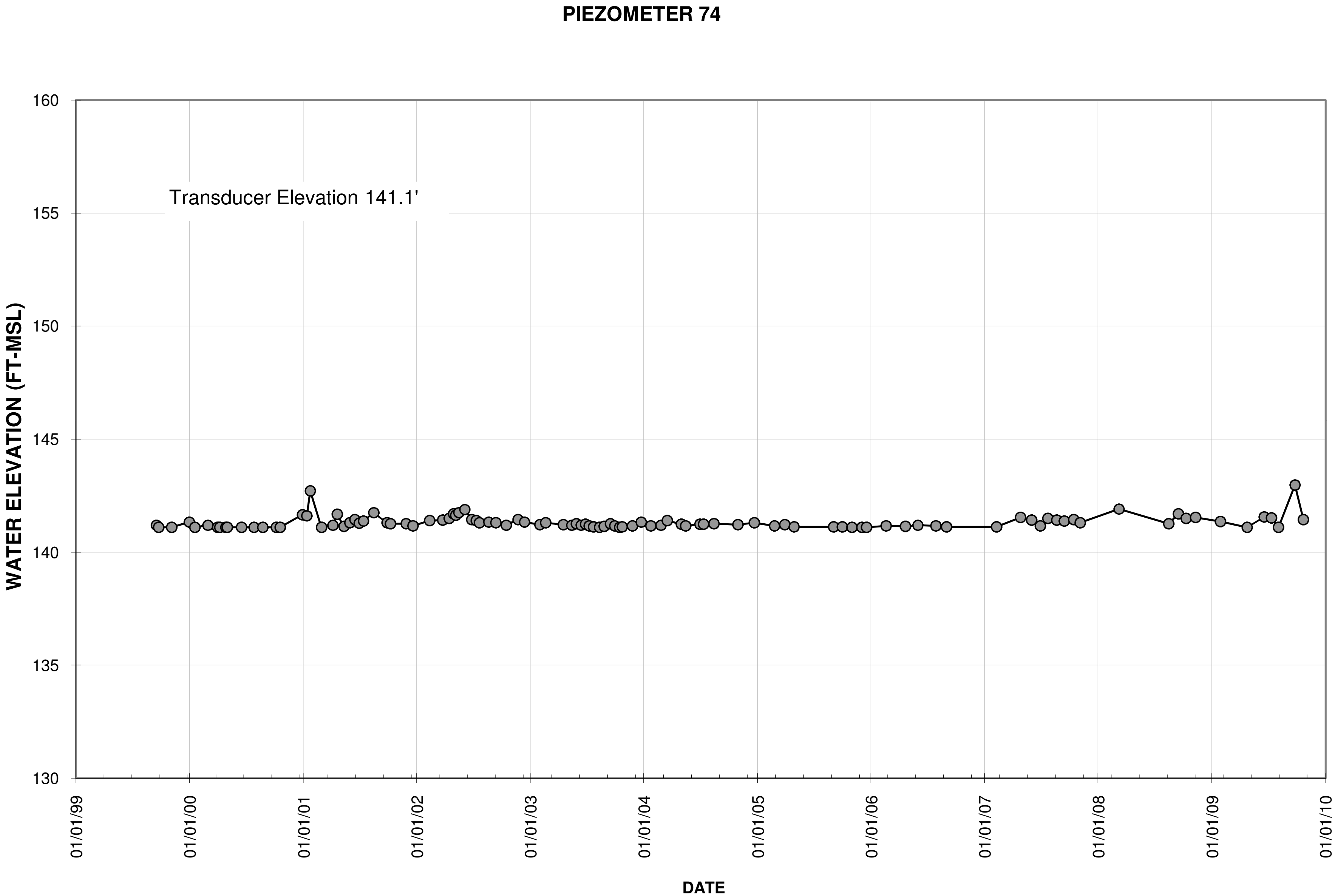


Figure 2.9 Water Level Data for Piezometer 75

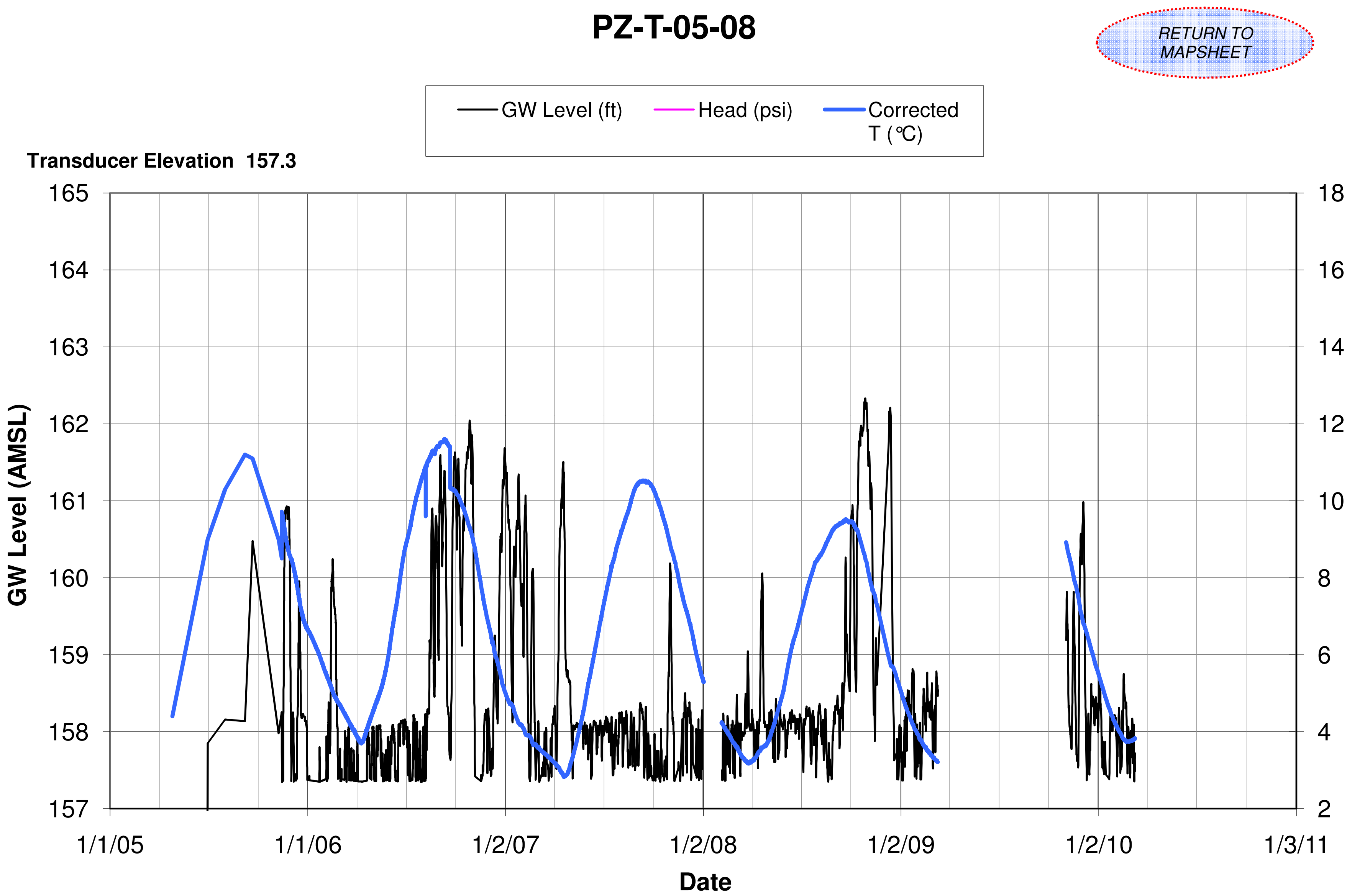


Figure 2.10 Water Level Data for Piezometer 76

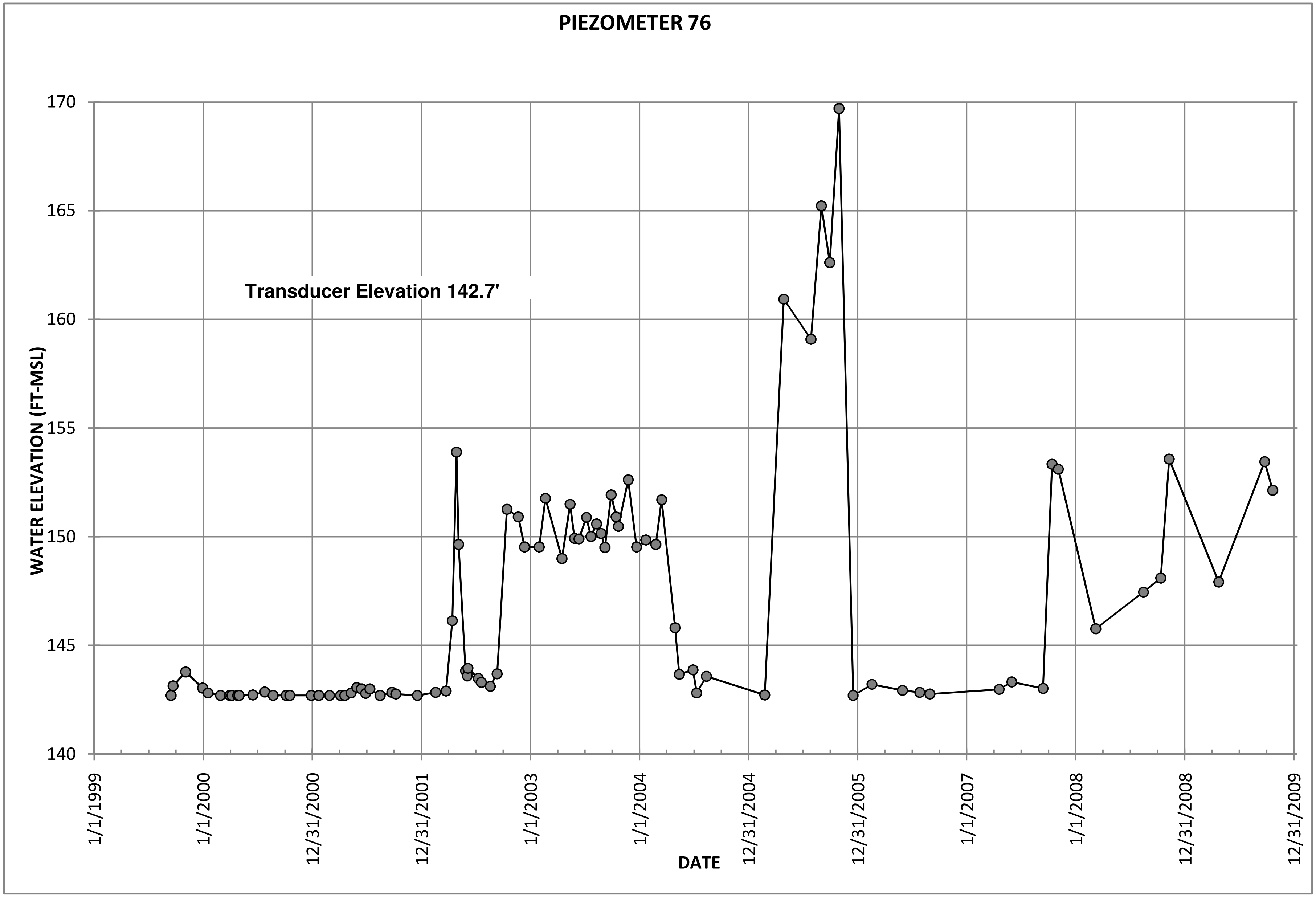


Figure 2.11 Water Level Data for Standpipe Piezometer PZ-T-00-01

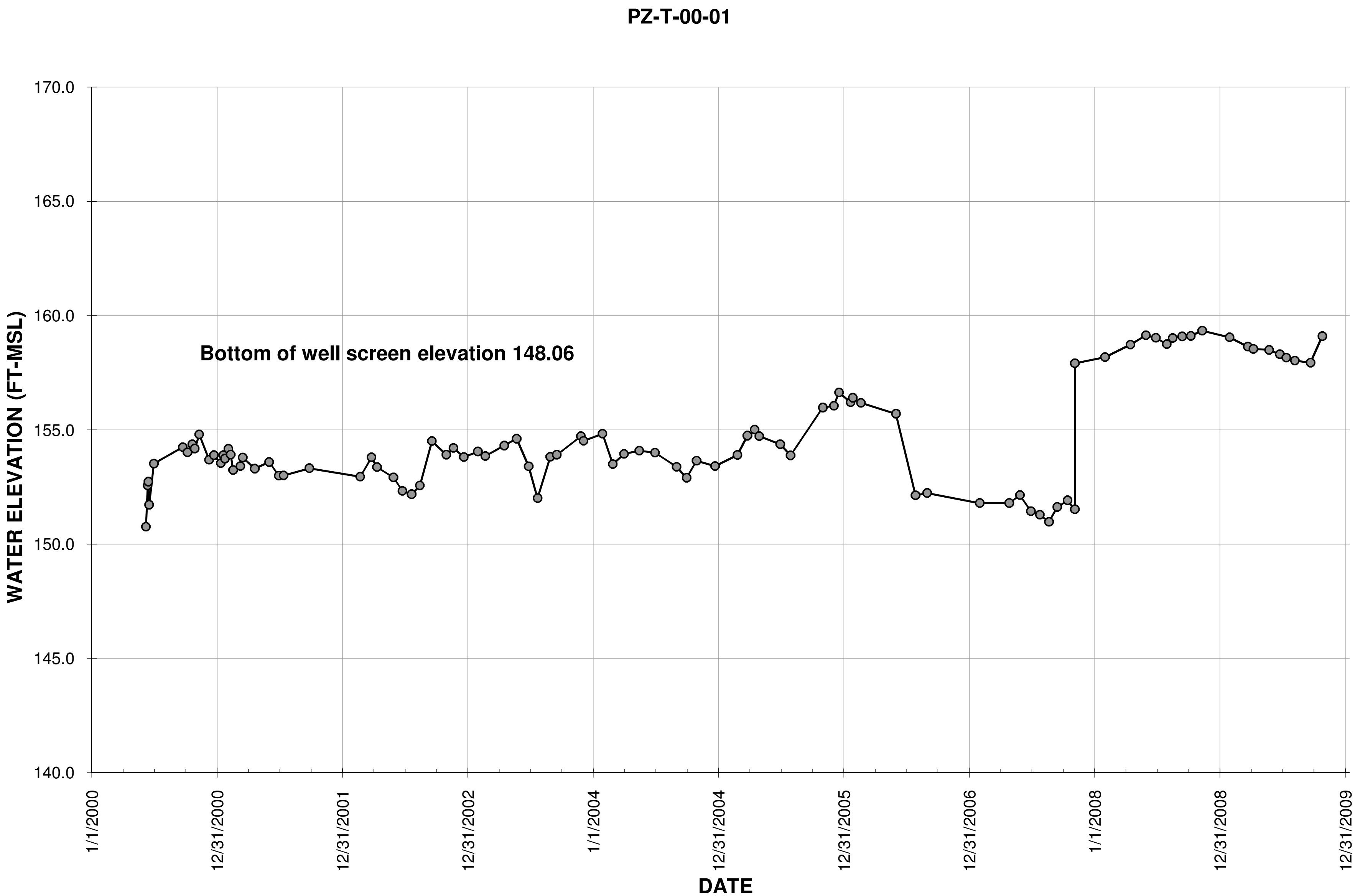


Figure 2.12 Water Level Data for Standpipe Piezometer PZ-T-00-02

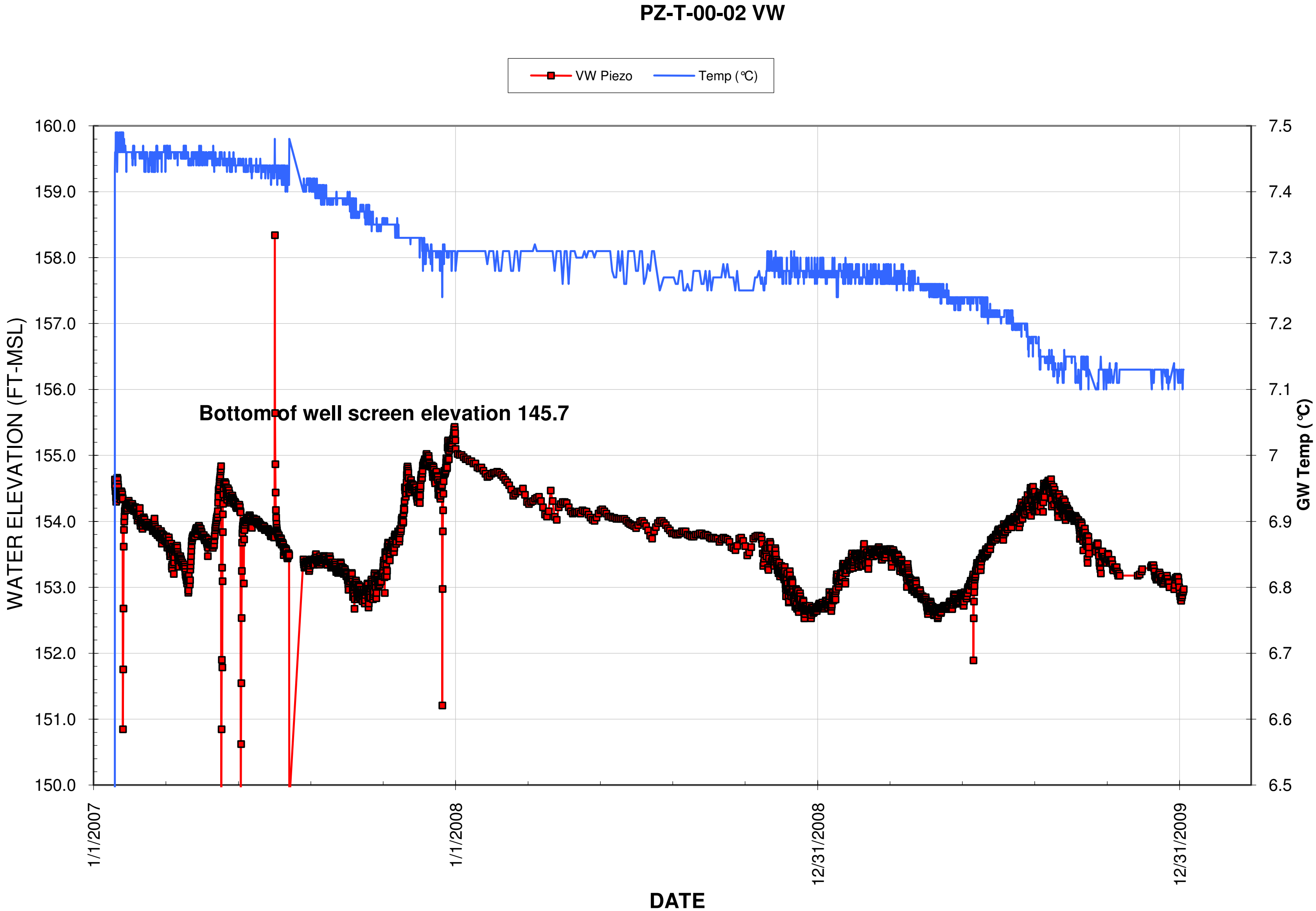


Figure 2.13 Water Level Data for Standpipe Piezometer PZ-T-00-03

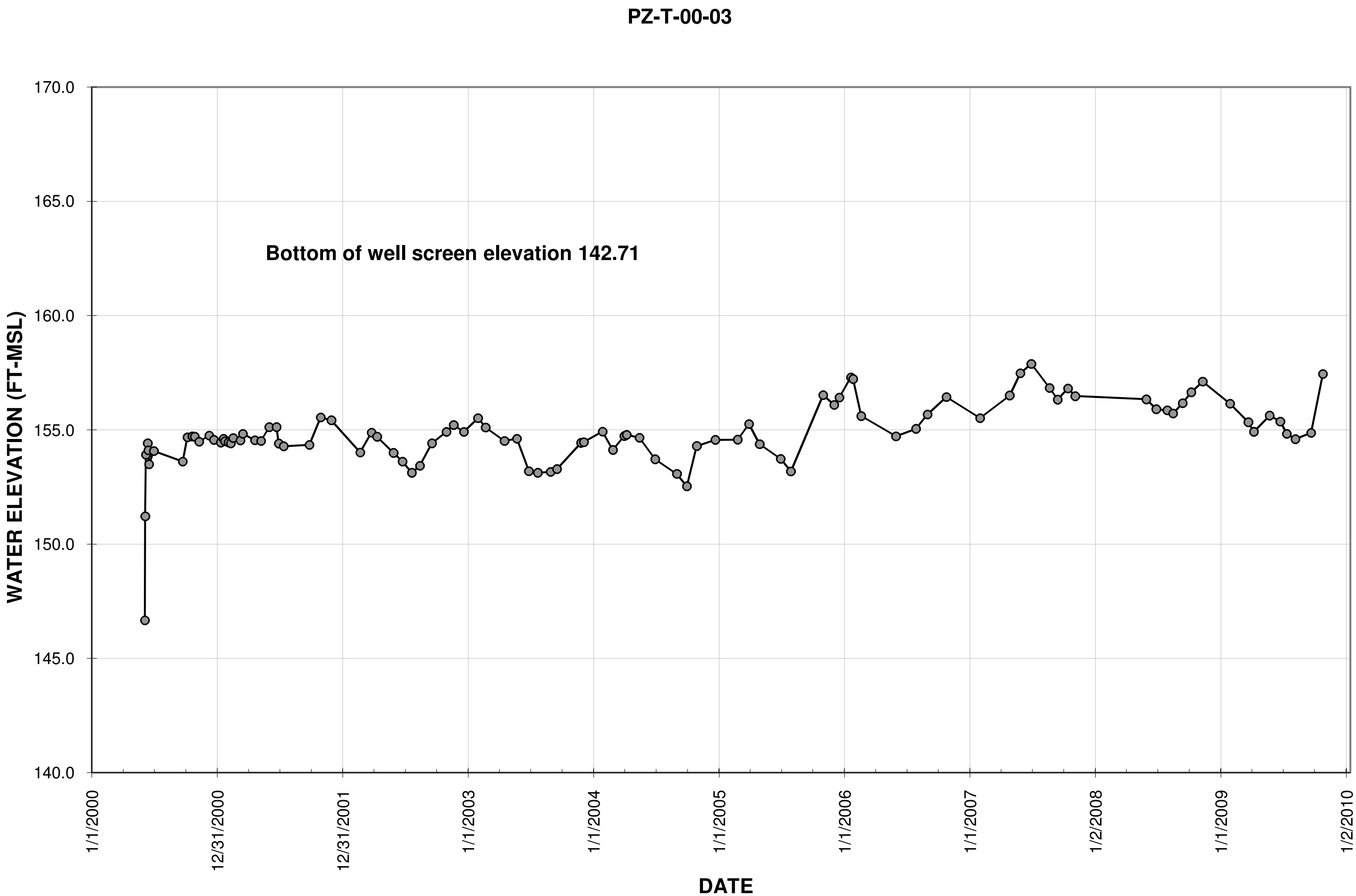


Figure 2.14 Water Level Data for Standpipe Piezometer MW-T-00-05A

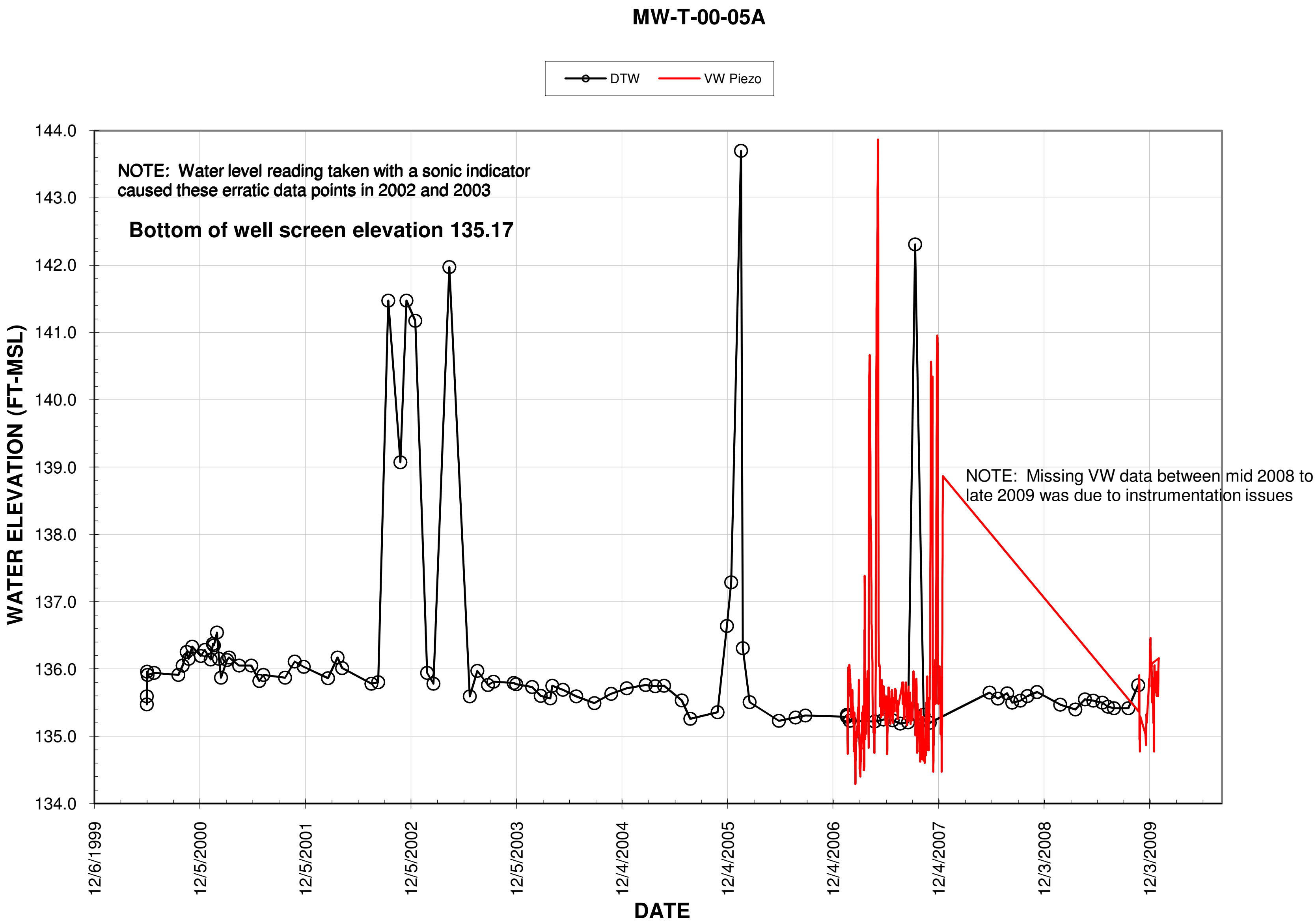


Figure 2.15 Water Level Data for Well MW-T-00-3A

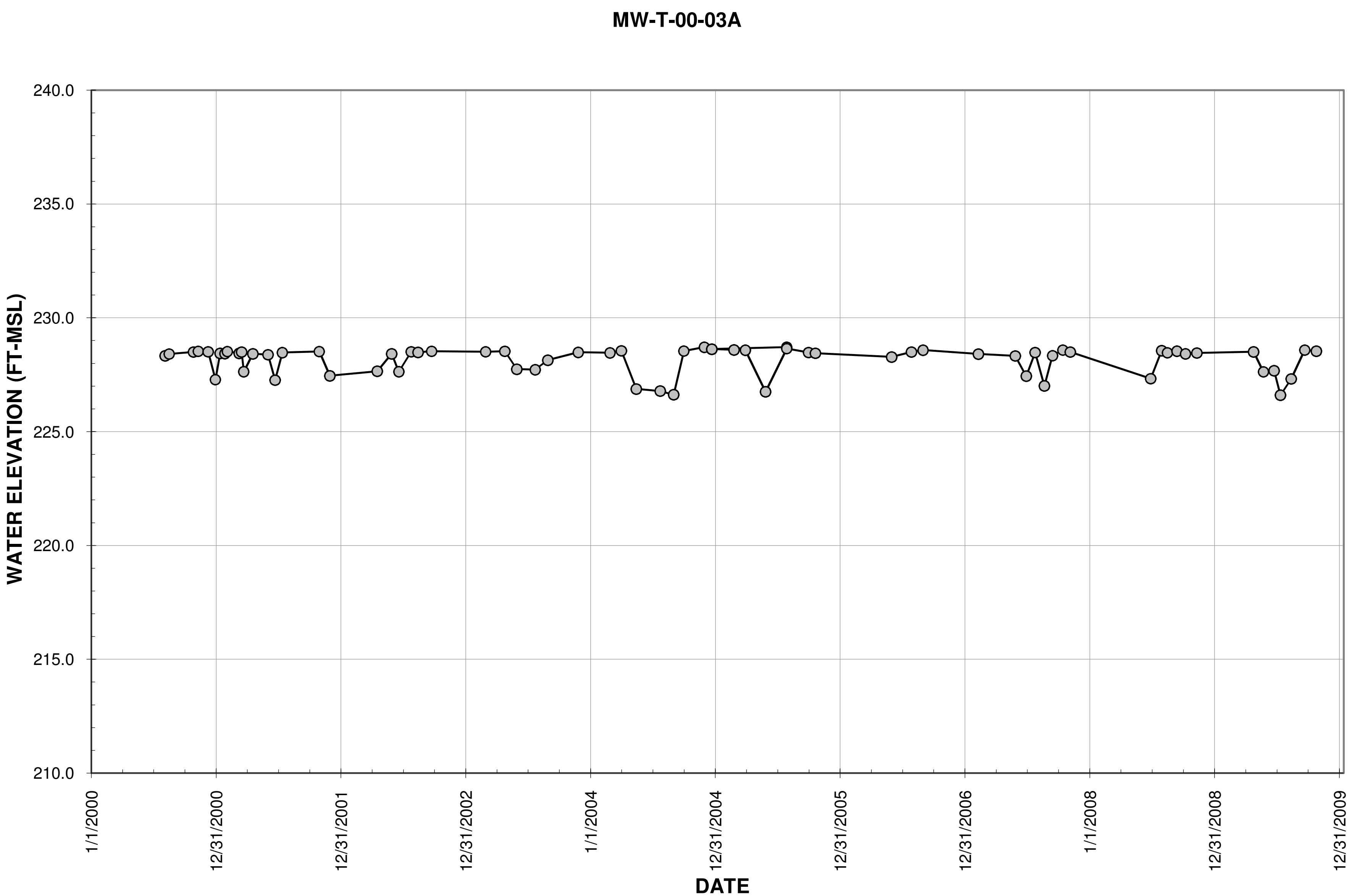


Figure 2.16 Water Level Data for Well MW-T-00-3B

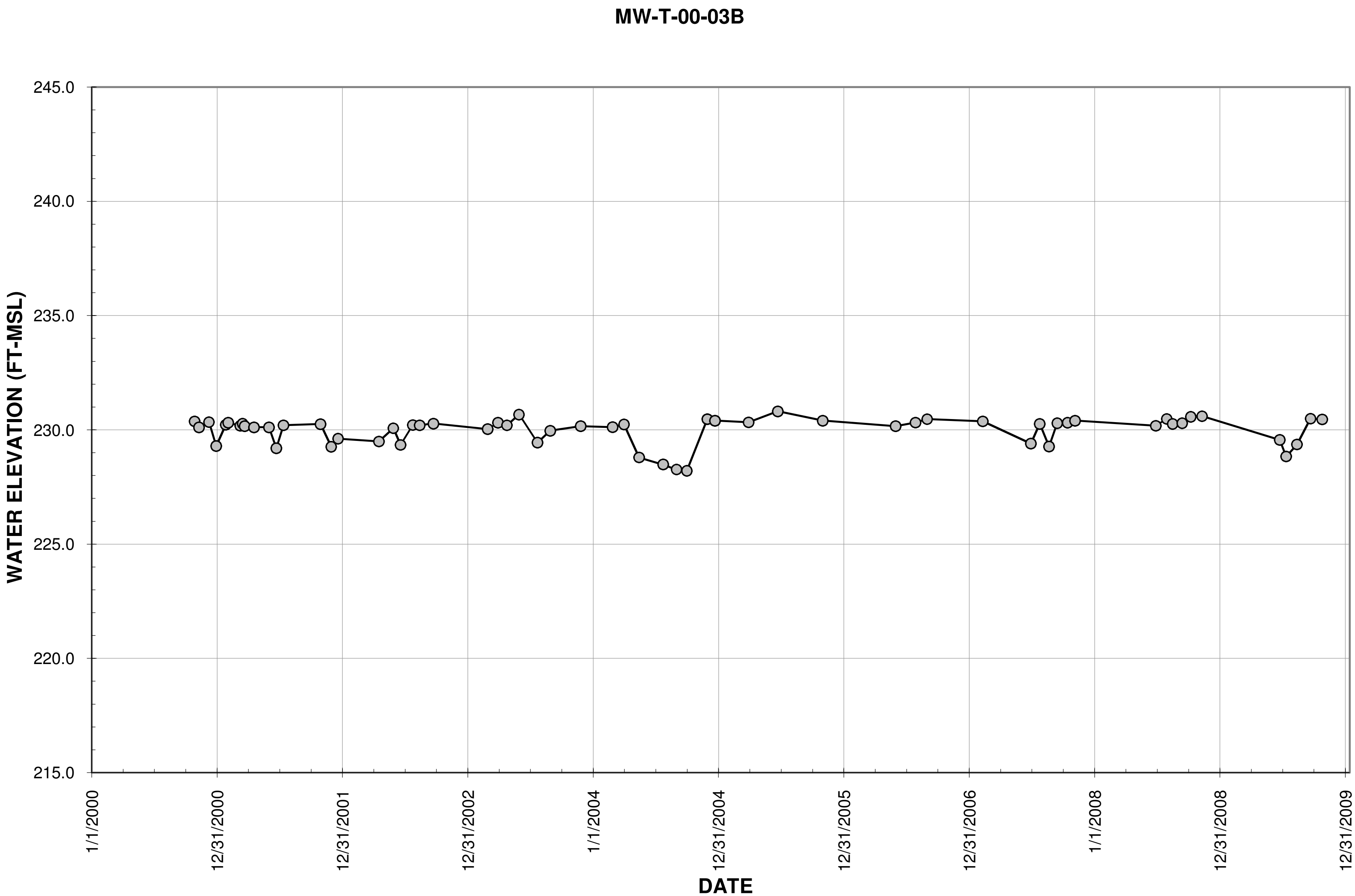


Figure 2.17 Water Level Data for Well MW-T-01-03A

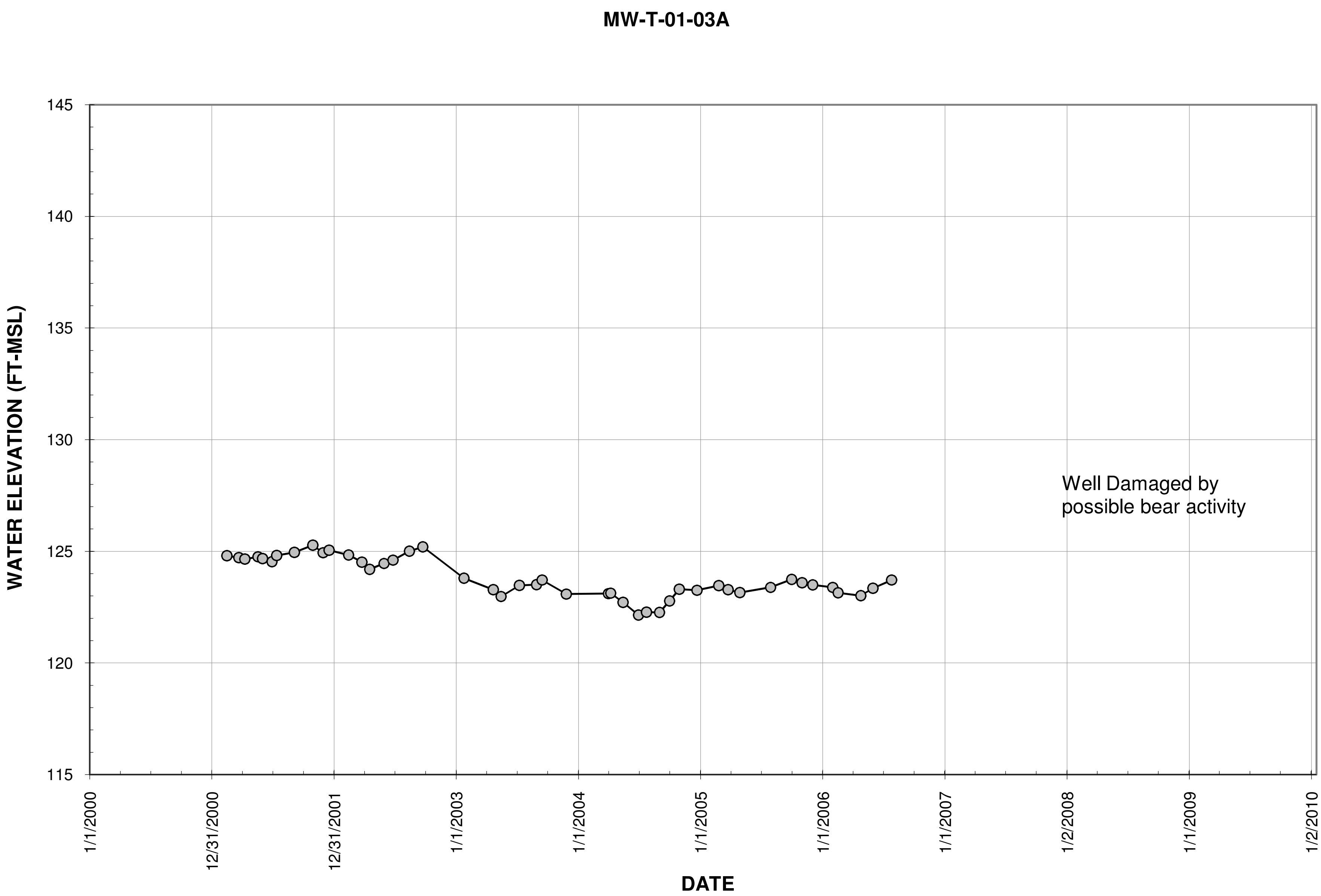


Figure 2.18 Water Level Data for Well MW-T-01-03B

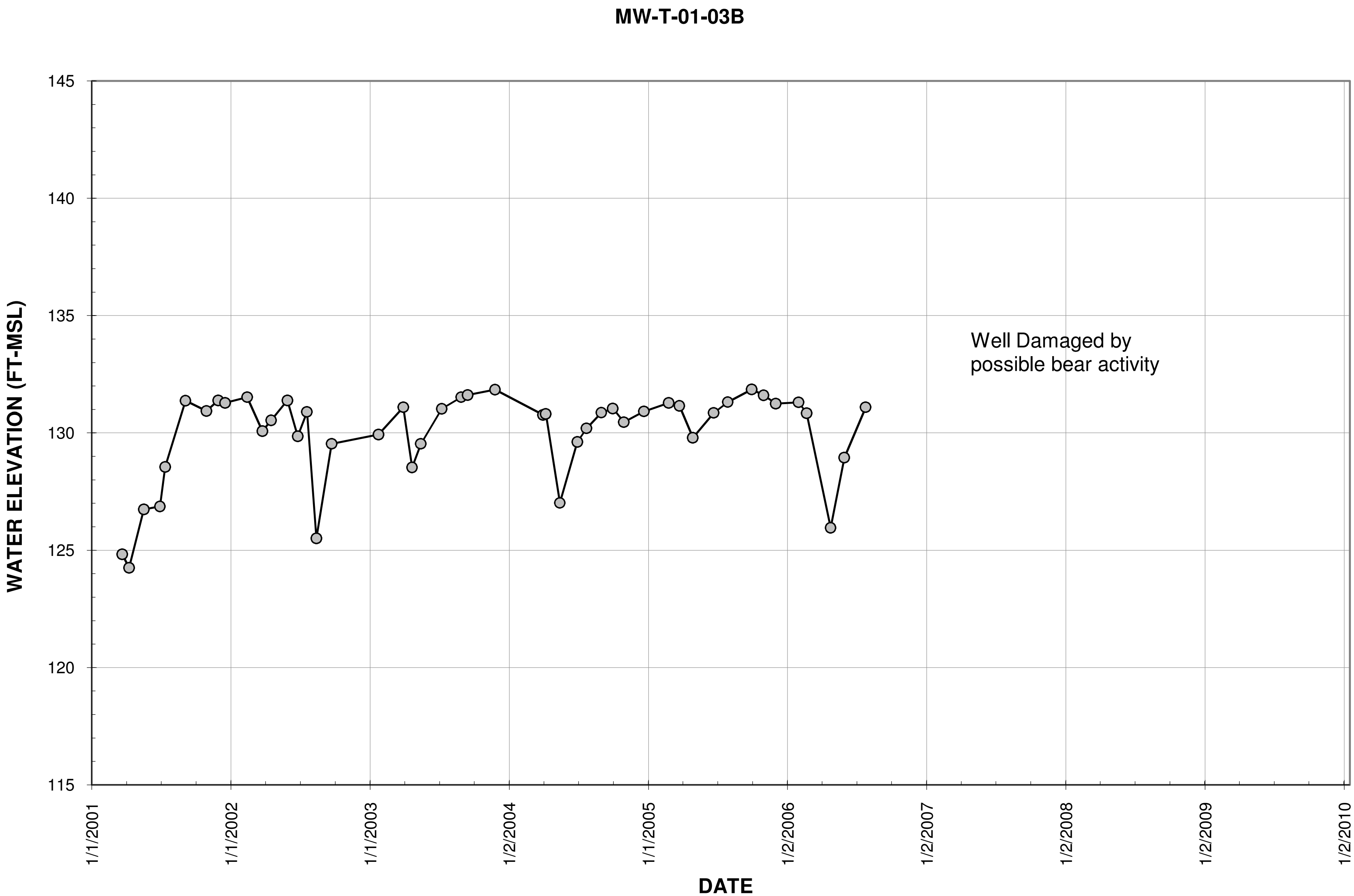


Figure 2.19 Tailings Area Wet Well Flow Data

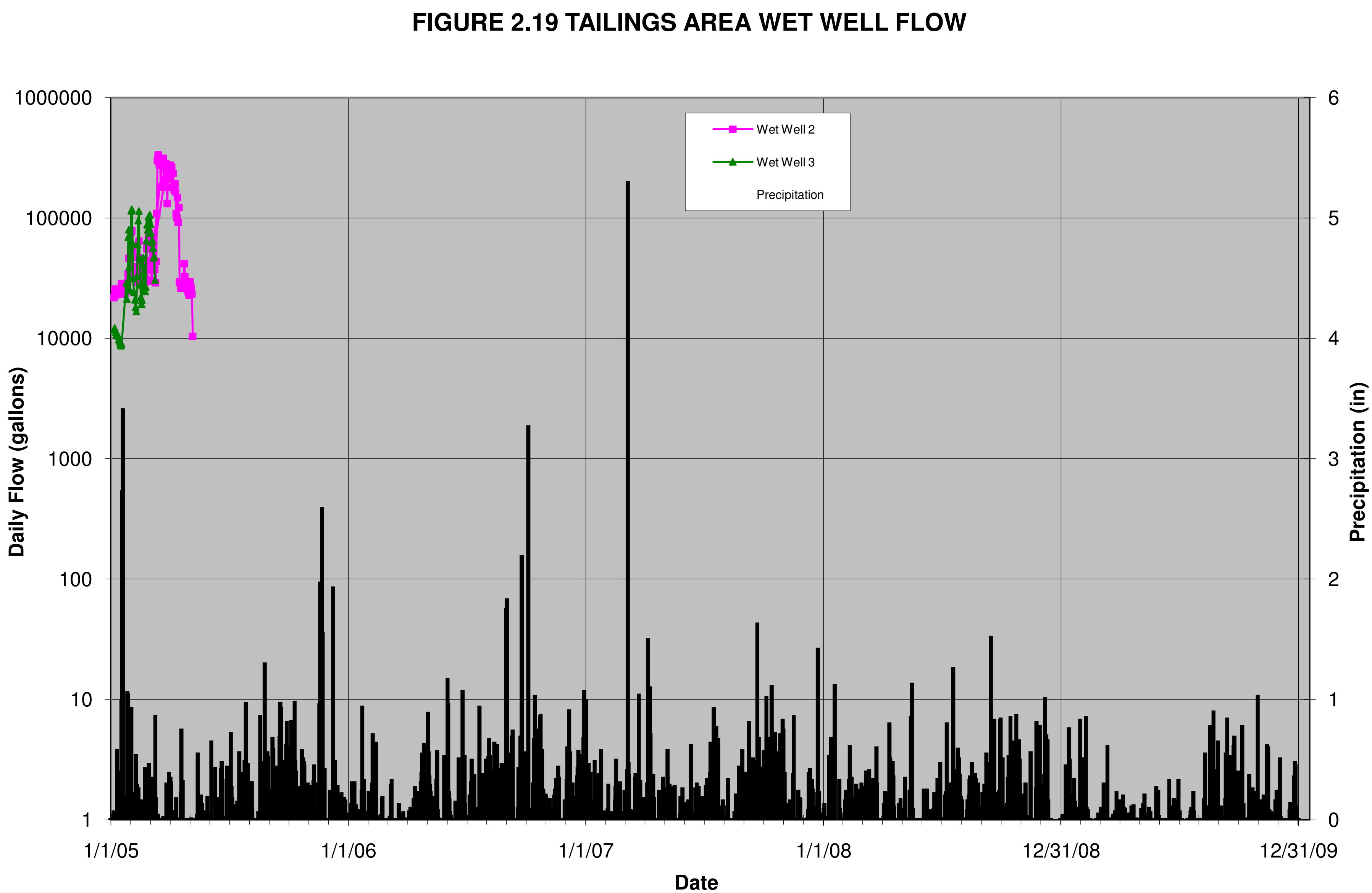


FIGURE 2.20a GREENS CREEK TAILINGS AREA INTERNAL MONITORING SITES: WET WELLS - pH DATA

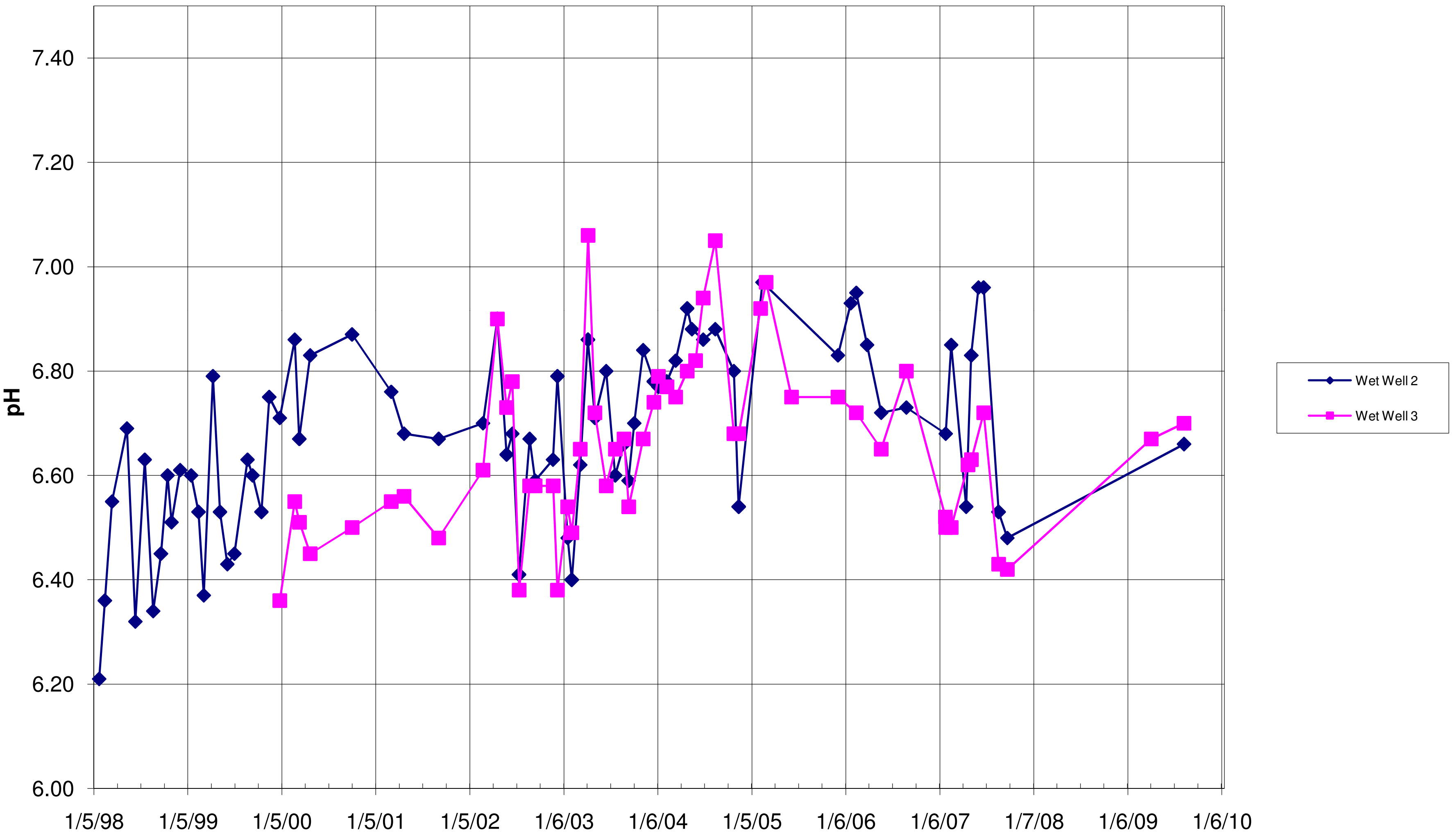


FIGURE 2.20b GREENS CREEK TAILINGS INTERNAL MONITORING SITES: TAILINGS COMPLETIONS - pH DATA

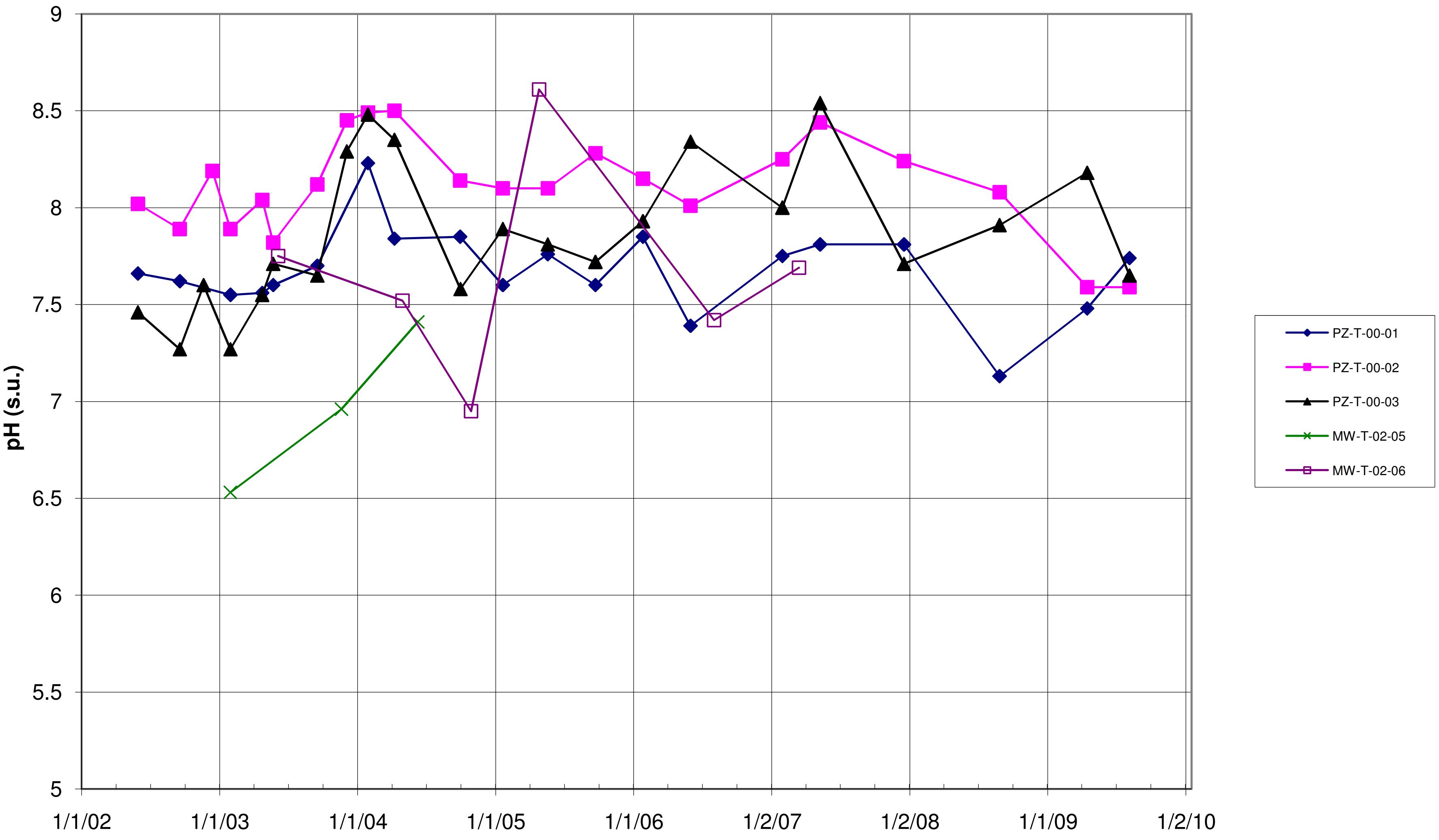


FIGURE 2.20c GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS - pH

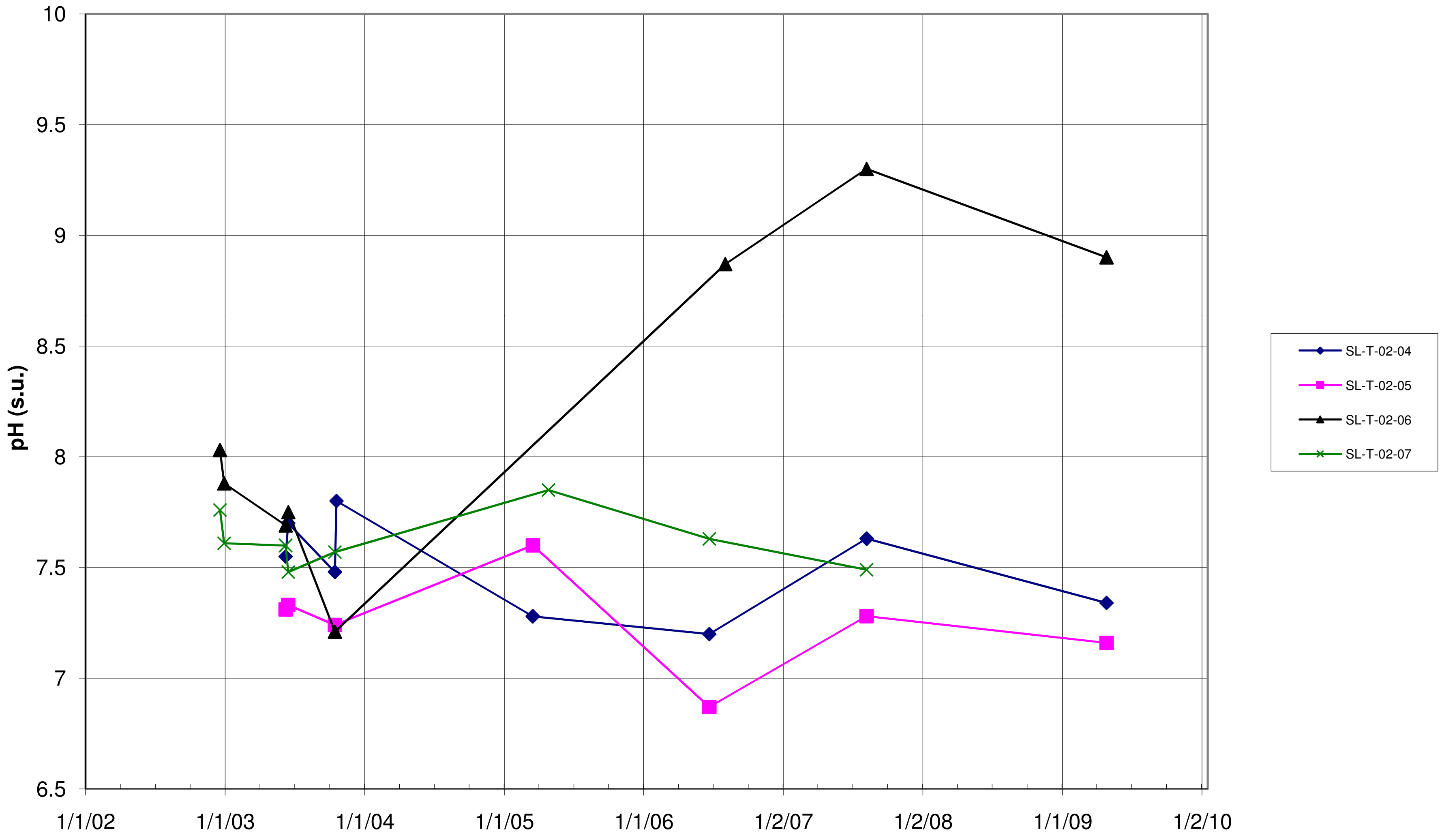


FIGURE 2.21a GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS - ALKALINITY (Non-detectable analyses plotted as zero)

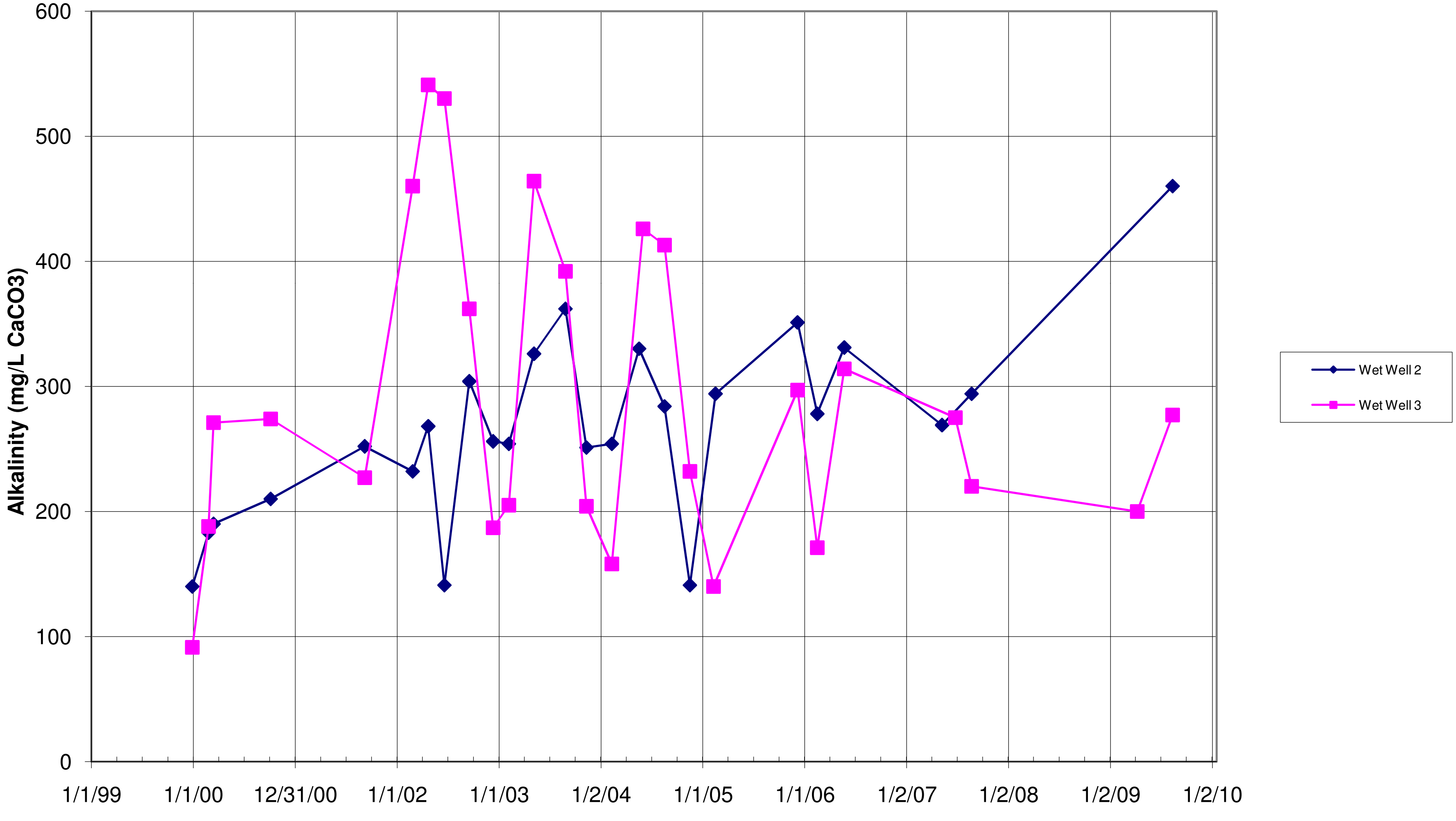


FIGURE 2.21b GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
TAILINGS COMPLETIONS - ALKALINITY DATA
(Non-detectable analyses plotted as zero)

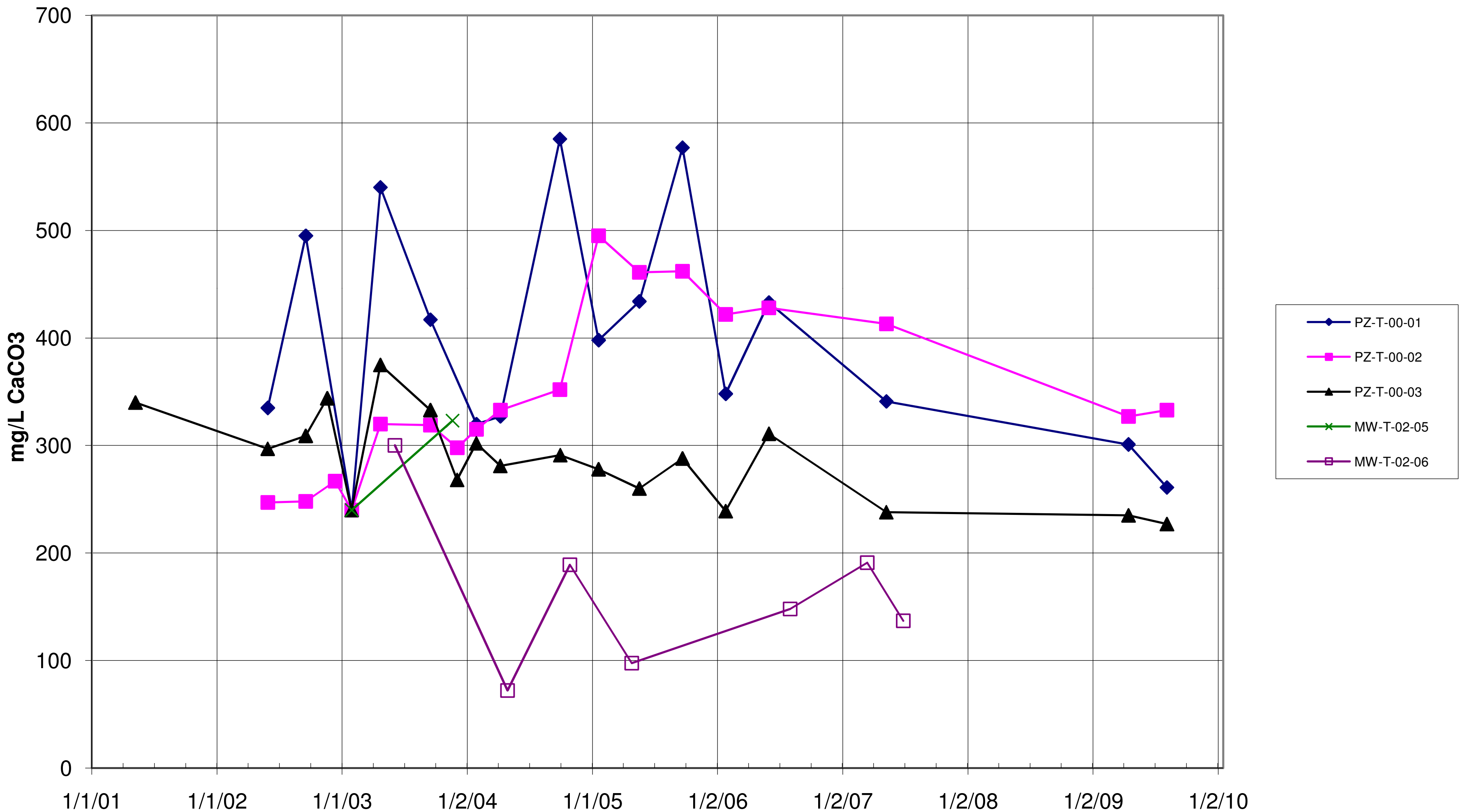


FIGURE 2.21c GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS - FIELD ALKALINITY

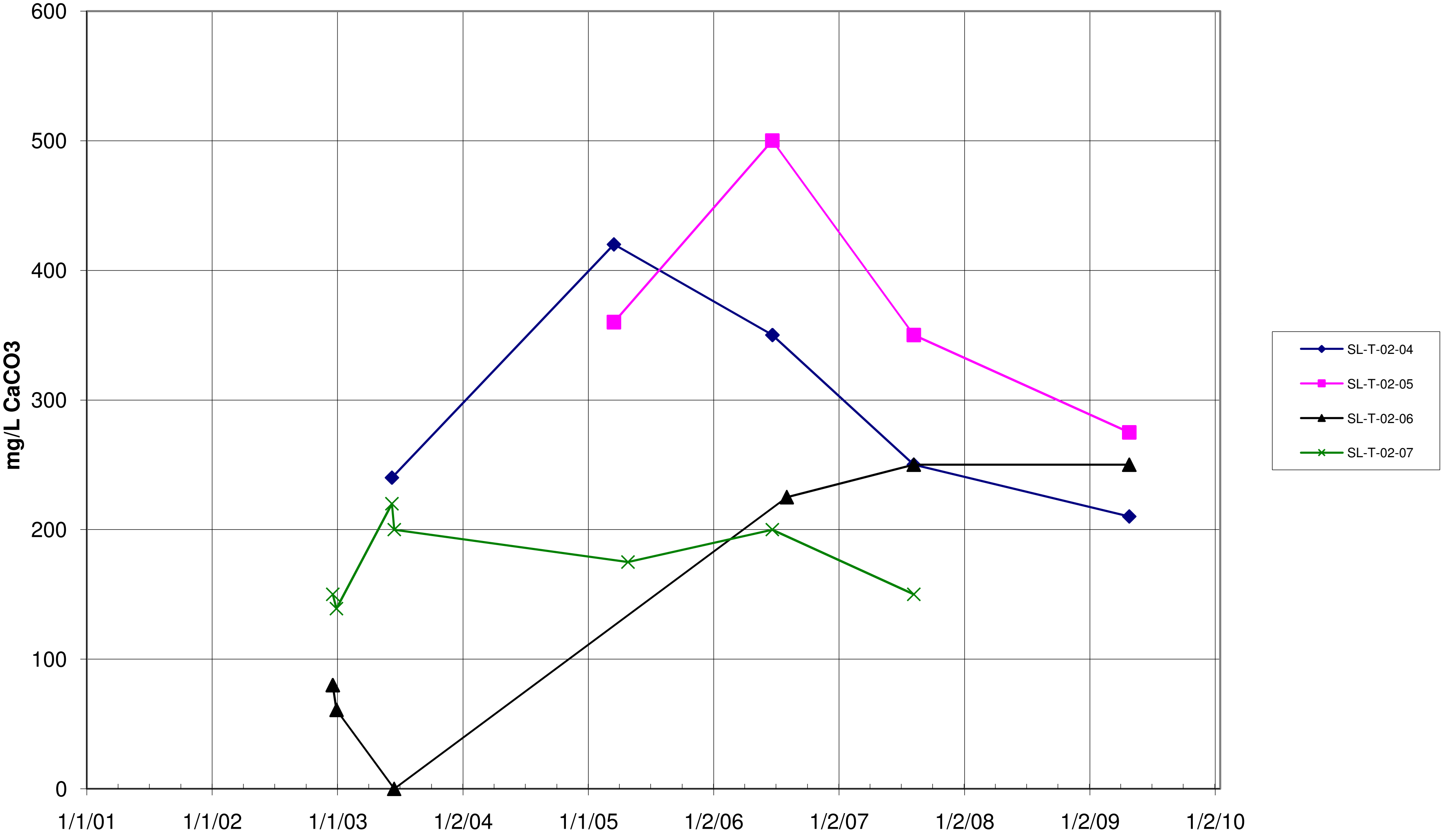


FIGURE 2.22a GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS - CONDUCTIVITY DATA

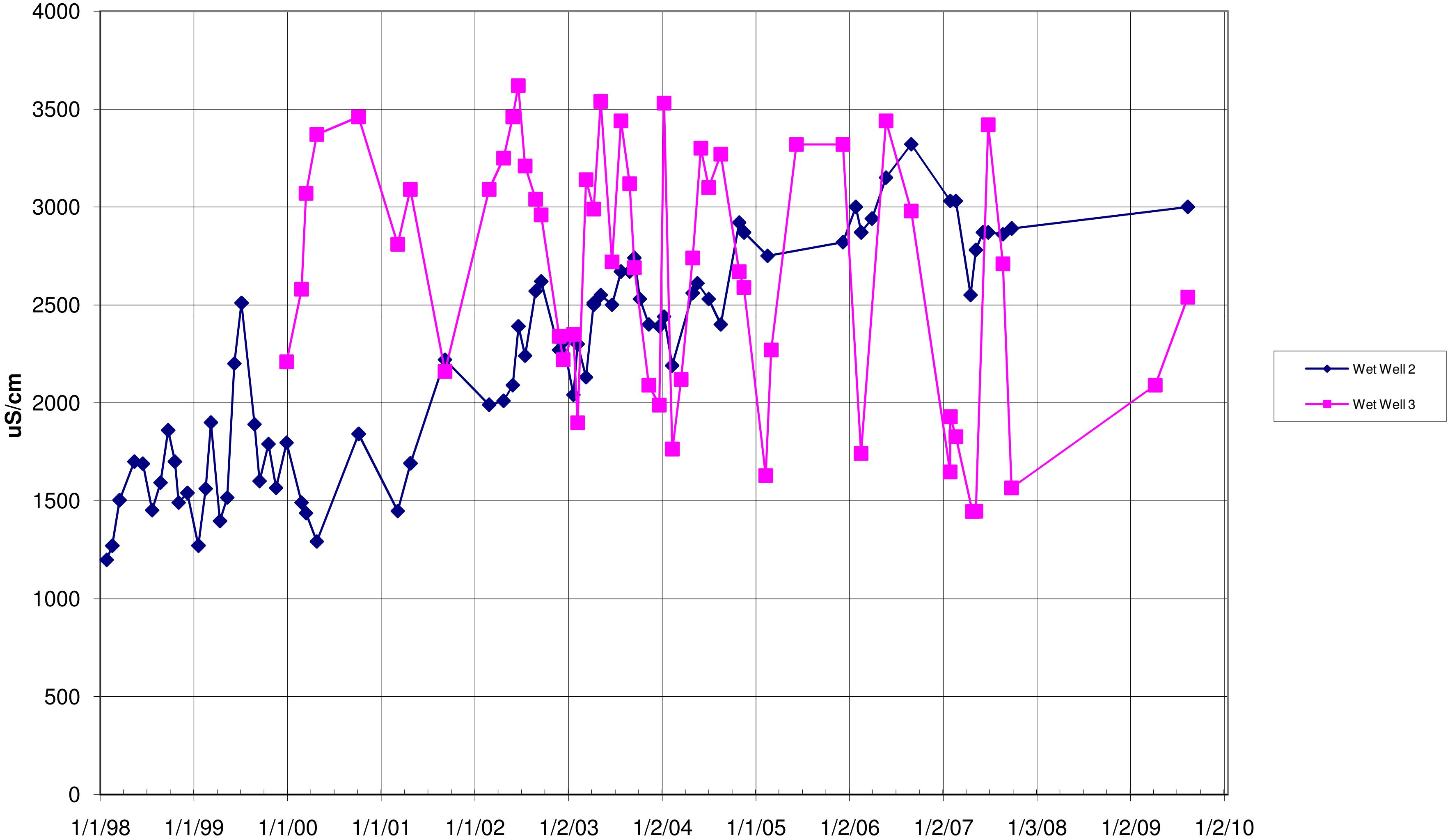


FIGURE 2.22b GREENS CREEK TAILINGS INTERNAL MONITORING SITES: TAILINGS COMPLETIONS - CONDUCTIVITY DATA

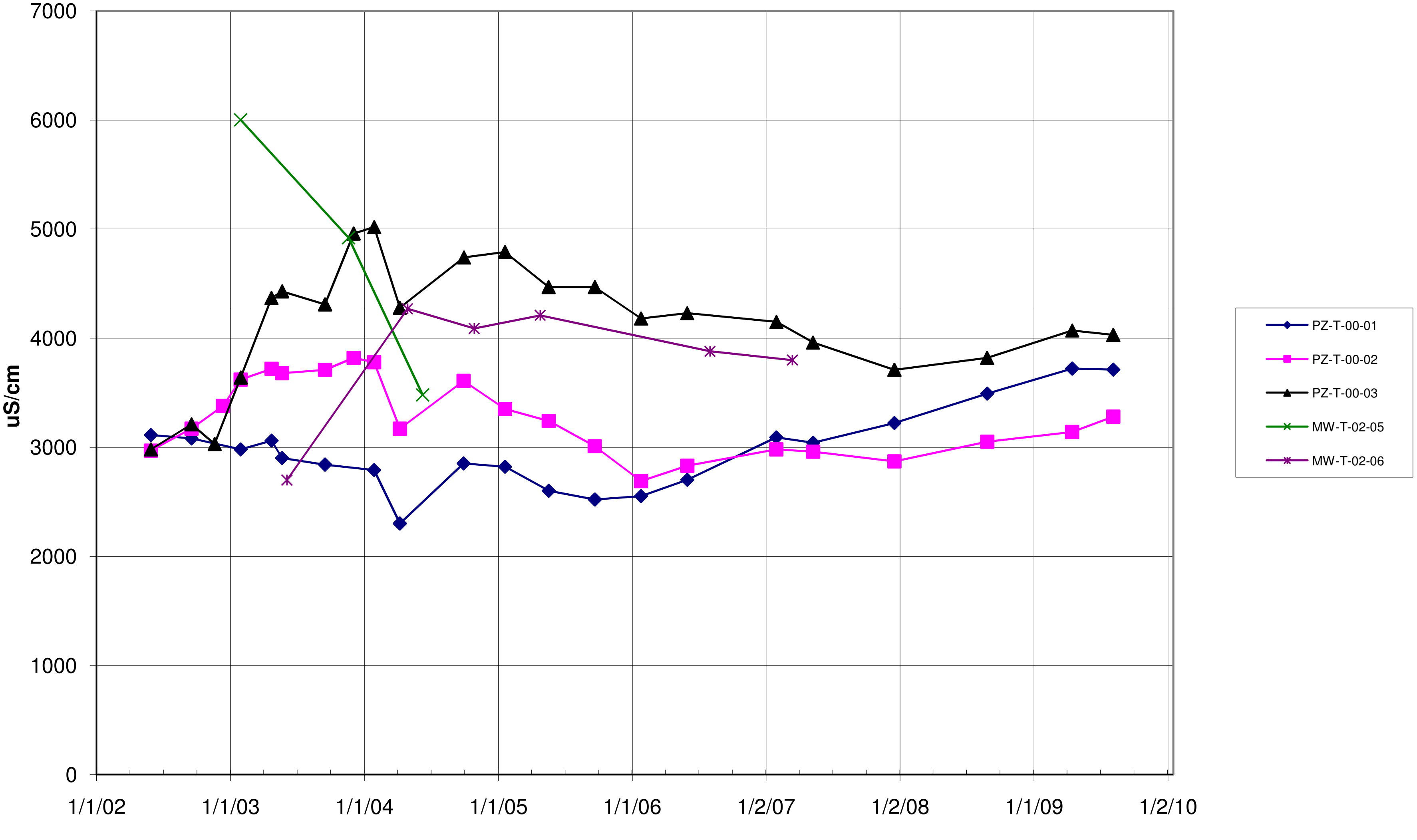


FIGURE 2.22c GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS - CONDUCTIVITY

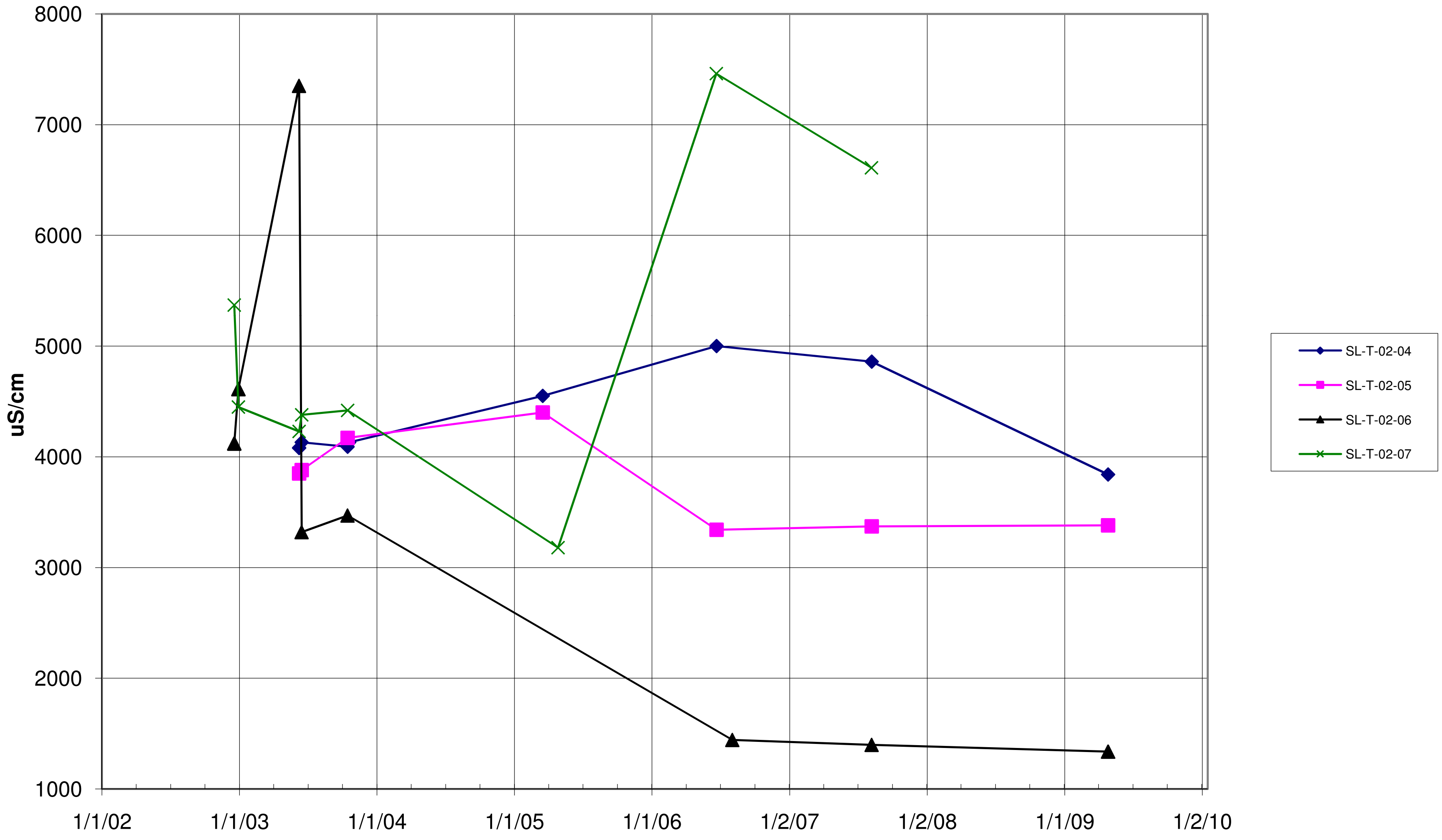


FIGURE 2.23a GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS - HARDNESS DATA (Non-detectable analyses plotted as zero)

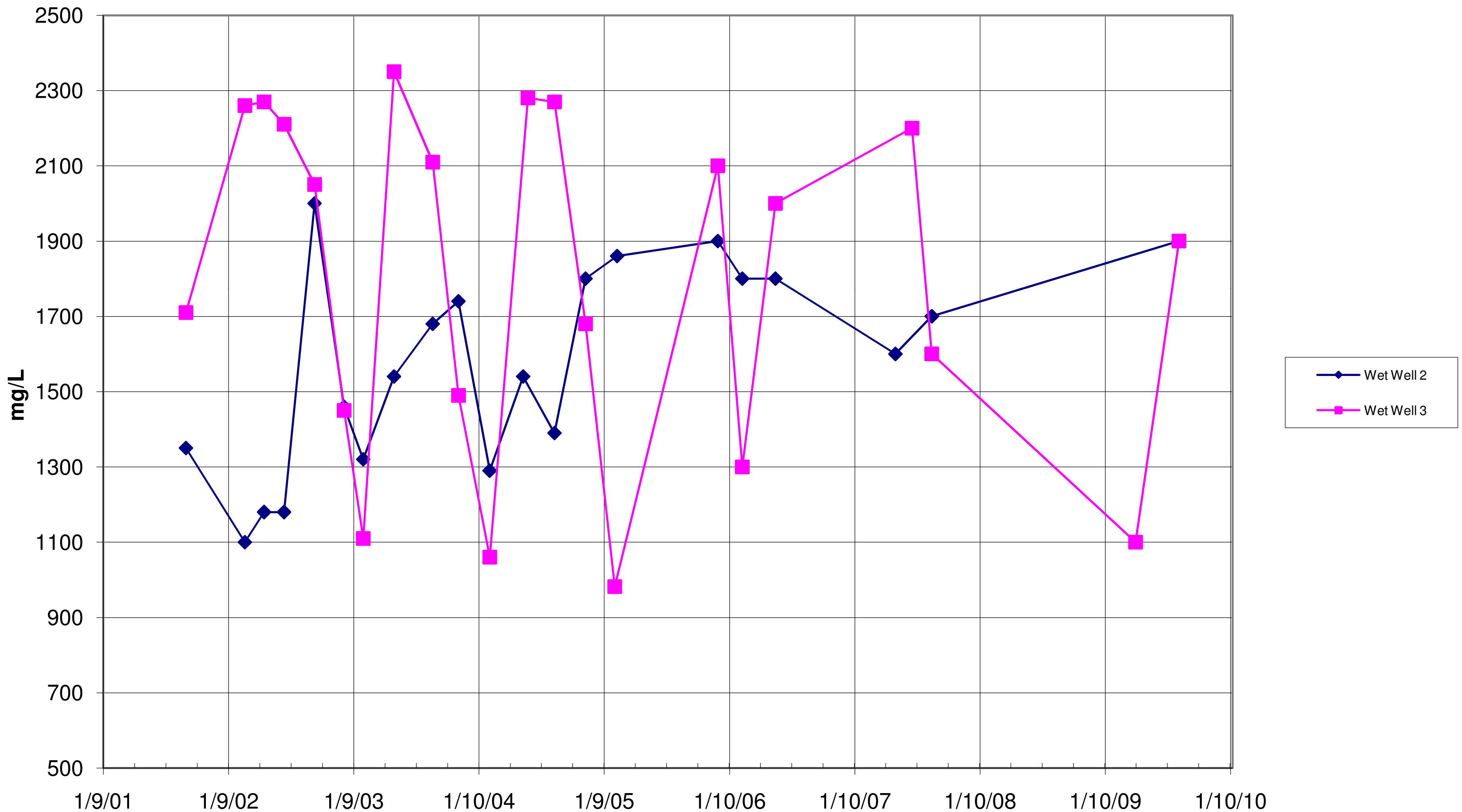


FIGURE 2.23b GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
TAILINGS COMPLETIONS - HARDNESS DATA
(Non-detectable analyses plotted as zero)

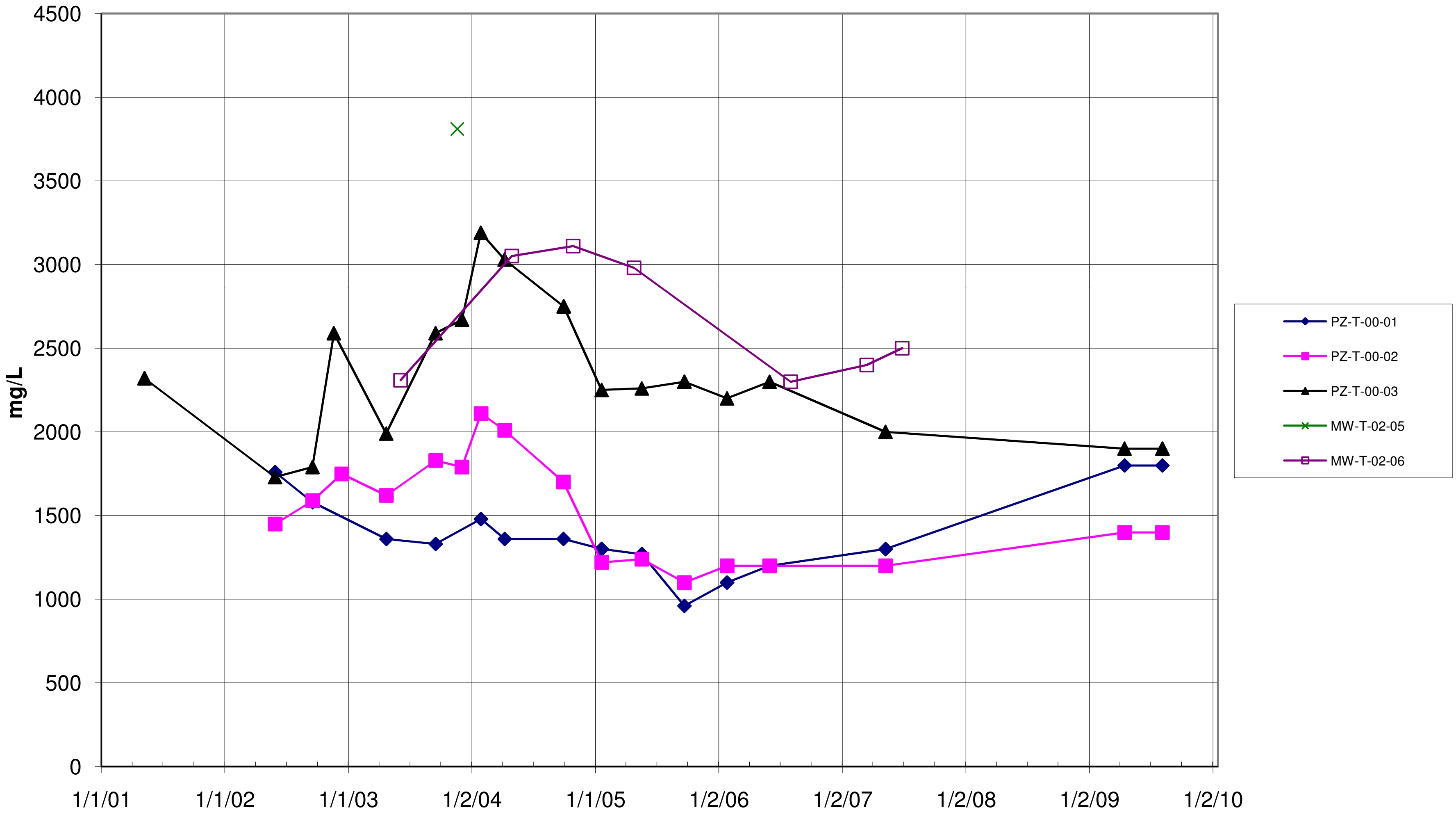


FIGURE 2.24a GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS - SULFATE DATA (Non-detectable analyses plotted as zero)

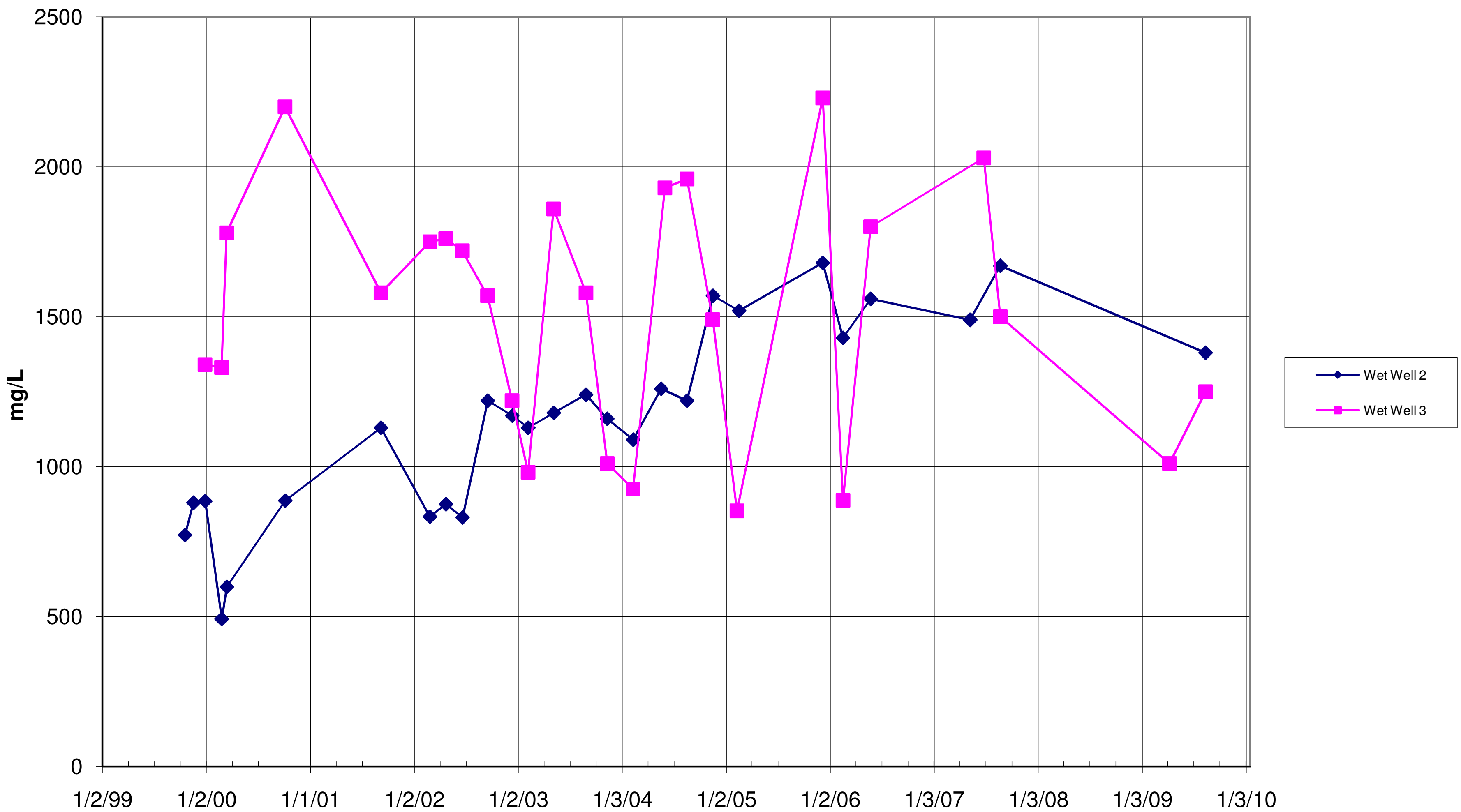


FIGURE 2.24b GREENS CREEK TAILINGS INTERNAL MONITORING SITES: TAILINGS COMPLETIONS - SULFATE DATA (Non-detectable analyses plotted as zero)

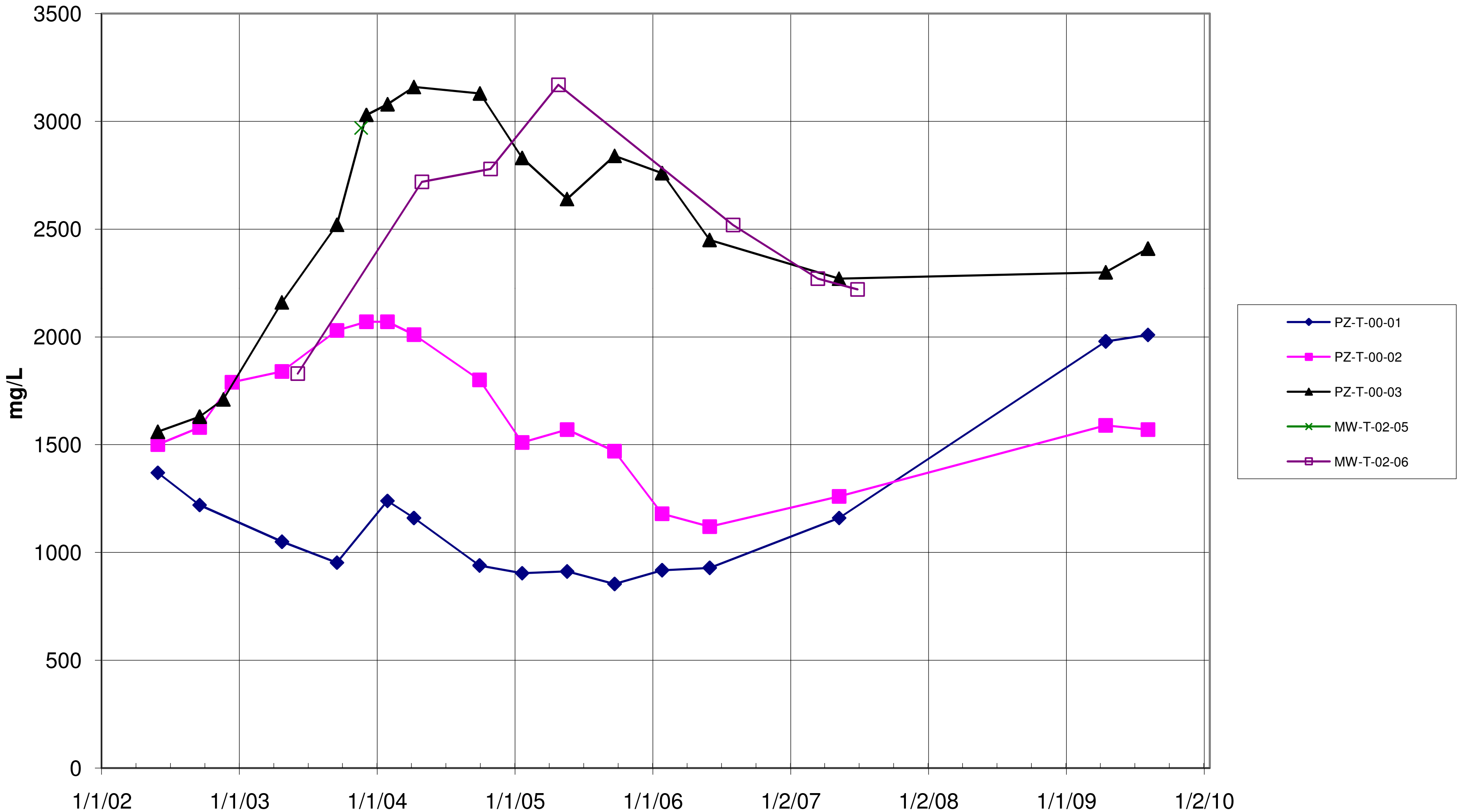


FIGURE 2.24c GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS- SULFATE DATA
(Non-detectable analyses plotted as zero)

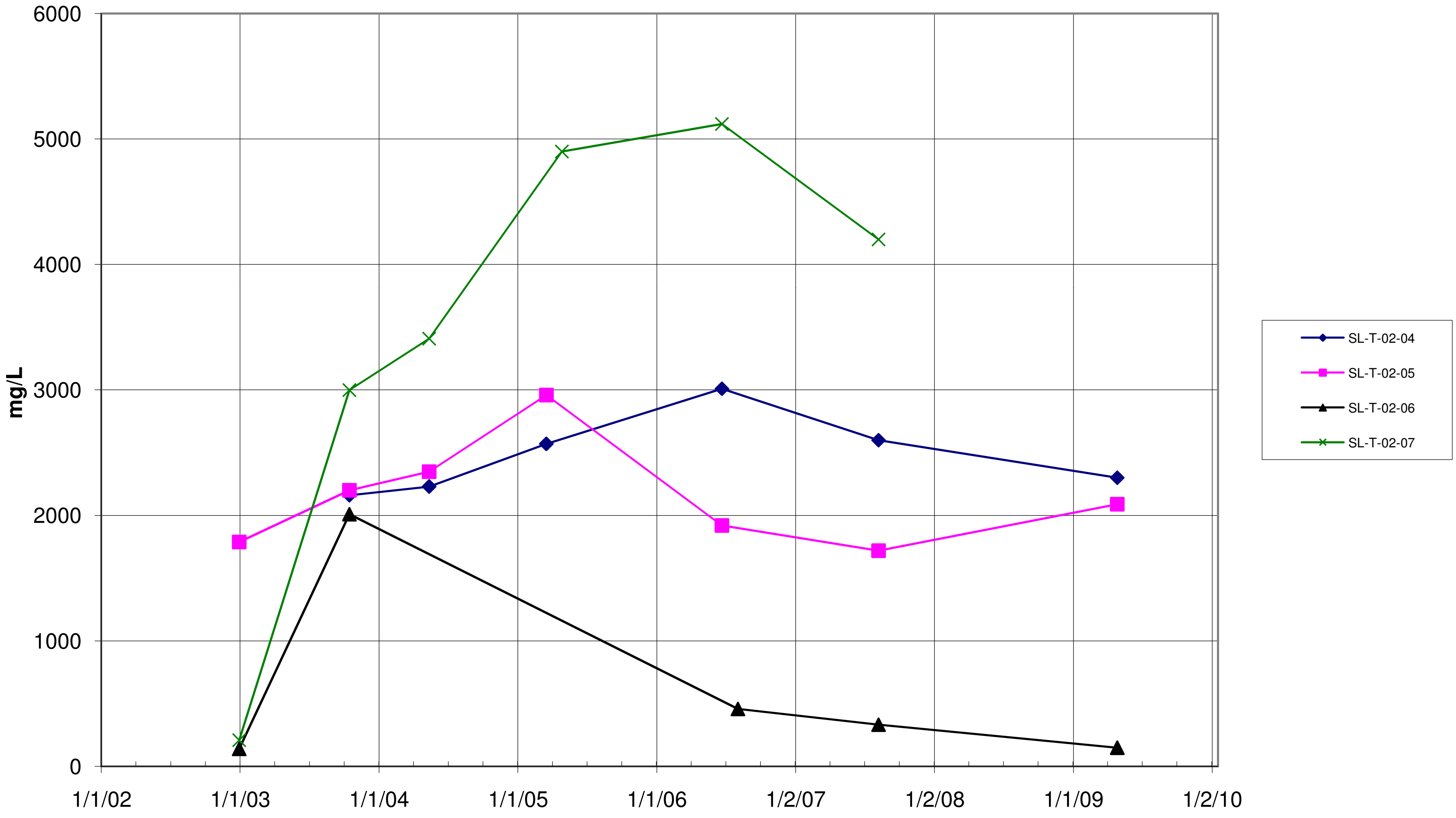


FIGURE 2.25a GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS- ARSENIC DATA (Non-detectable analyses plotted as zero)

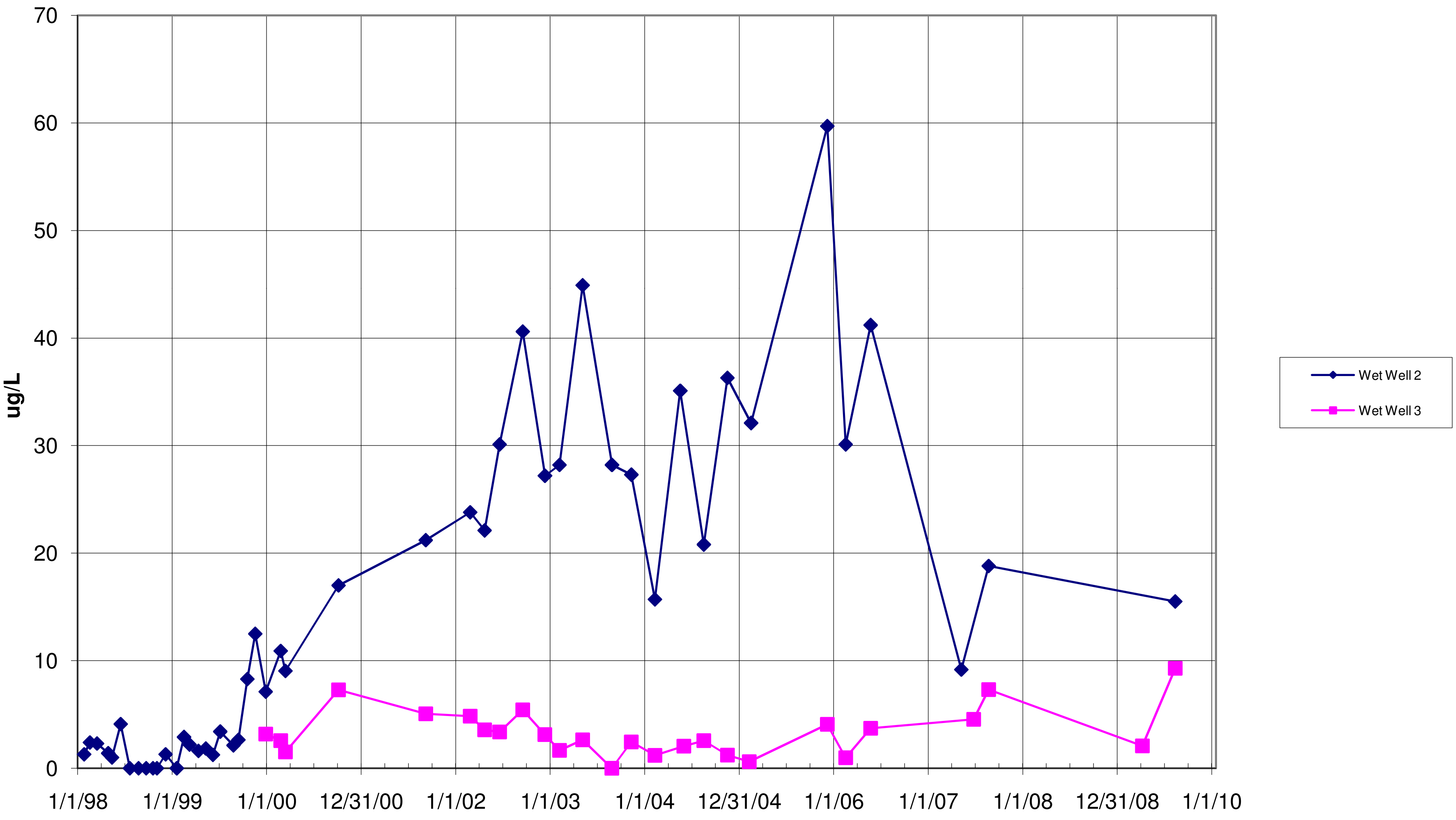


FIGURE 2.25b GREENS CREEK TAILINGS INTERNAL MONITORING SITES: TAILINGS COMPLETIONS - ARSENIC DATA (Non-detectable analyses plotted as zero)

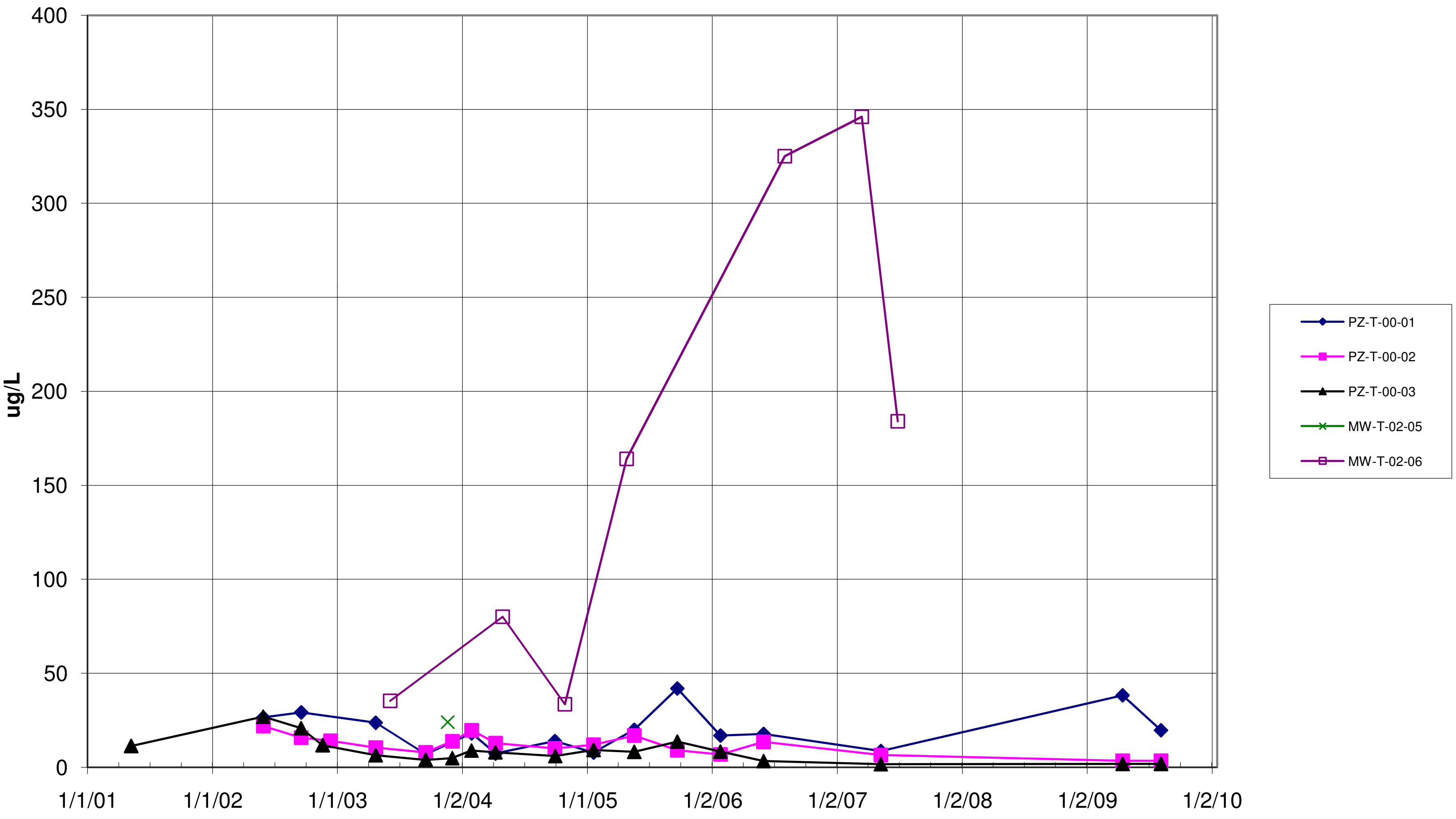


FIGURE 2.25c GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS - ARSENIC DATA (Non-detectable analyses plotted as zero)

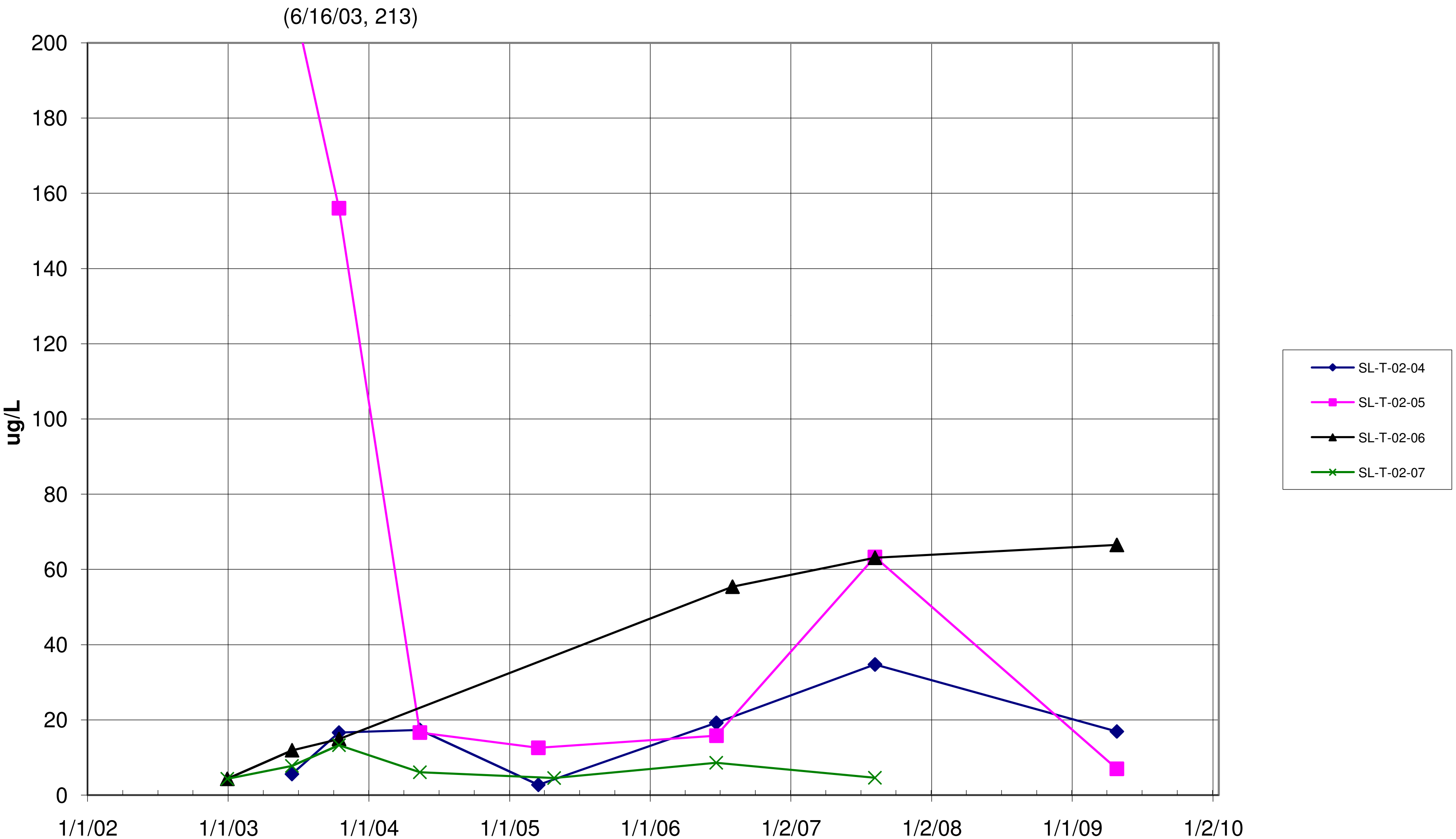


FIGURE 2.26a GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS - ZINC DATA (Non-detectable analyses plotted as zero)

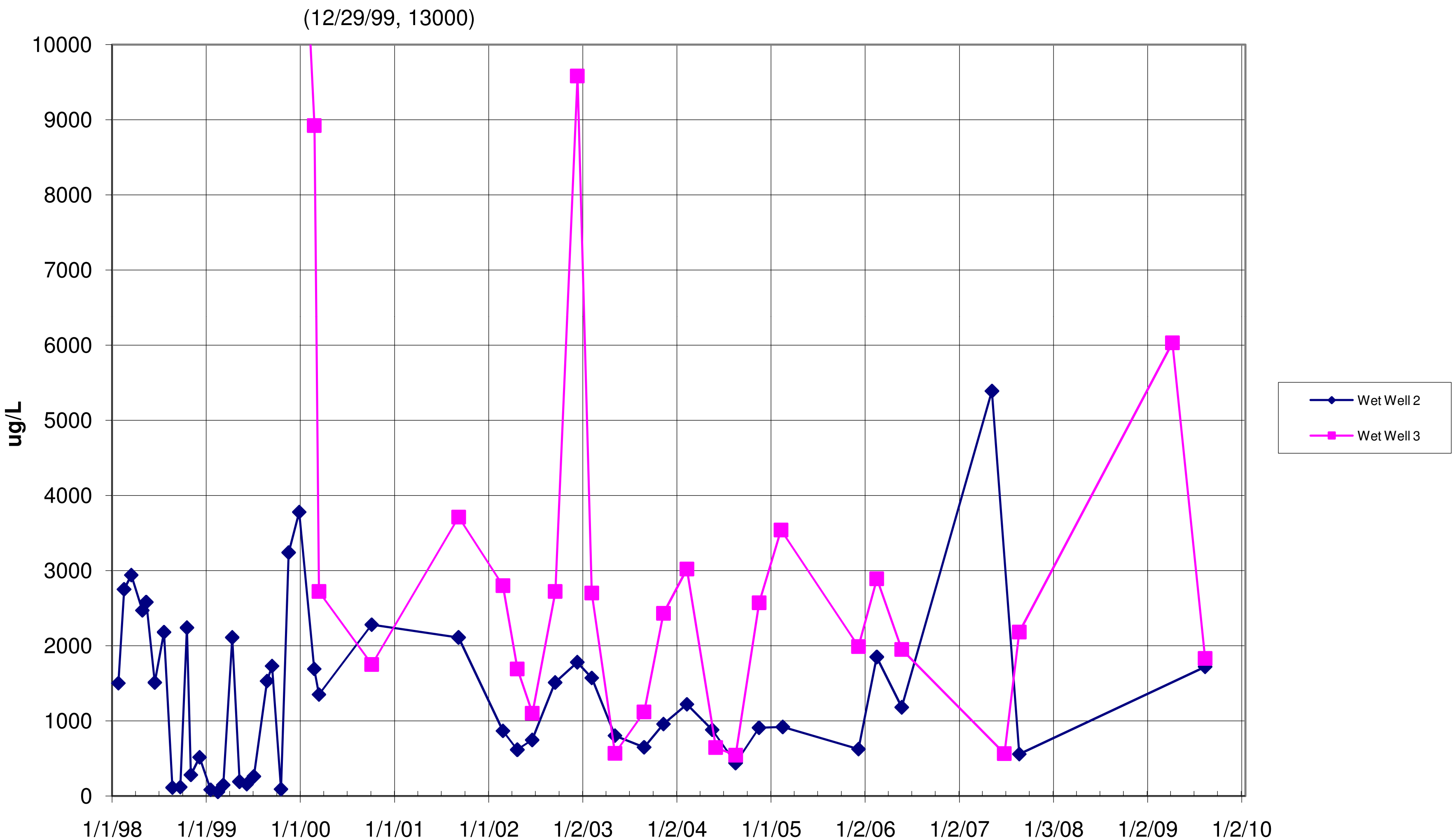


FIGURE 2.26b GREENS CREEK TAILINGS INTERNAL MONITORING SITES: TAILINGS COMPLETIONS - ZINC DATA (Non-detectable analyses plotted as zero)

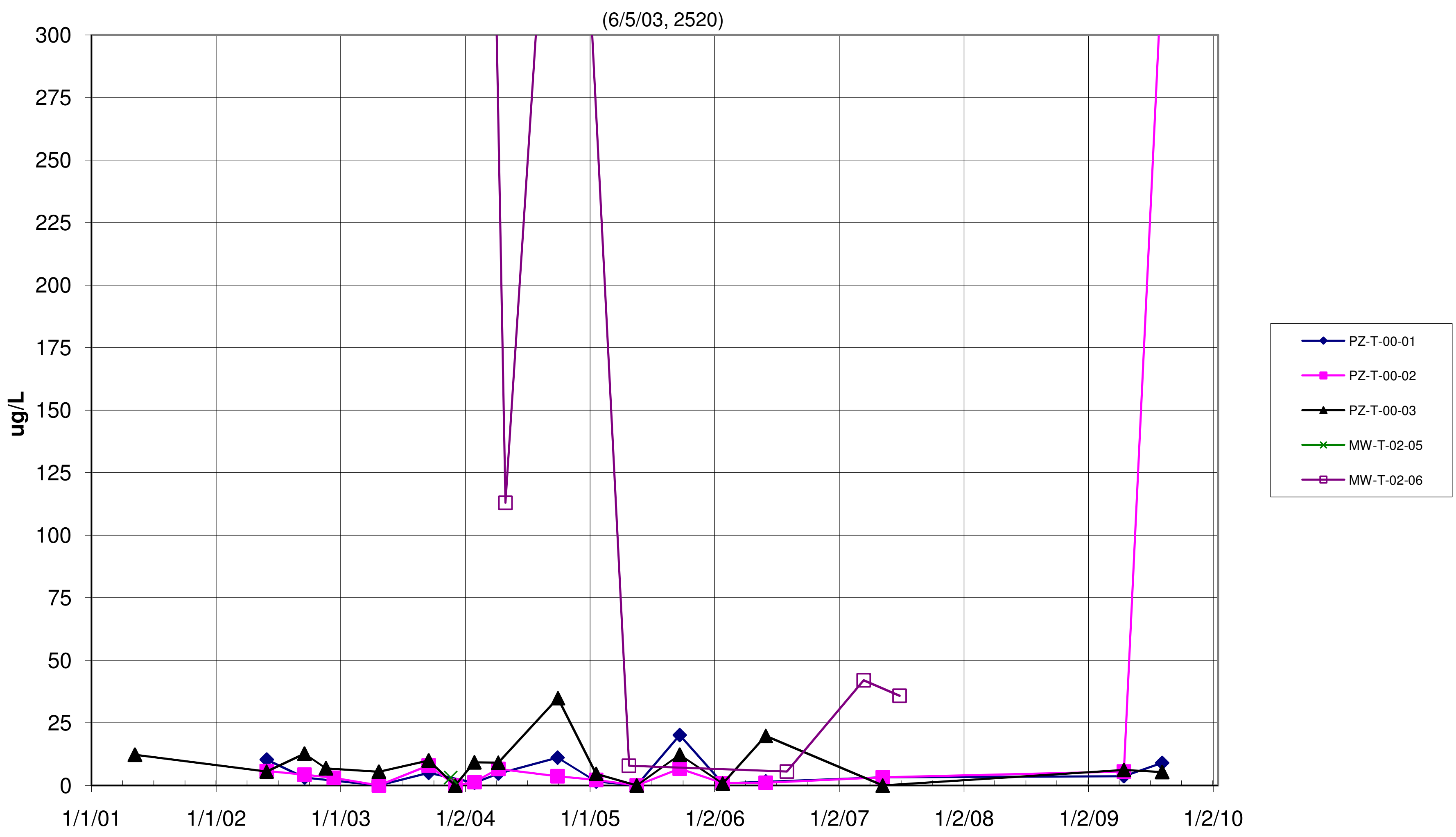


FIGURE 2.26c GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS - ZINC DATA
(Primary and secondary y axis: Non-detectable analyses plotted as zero)

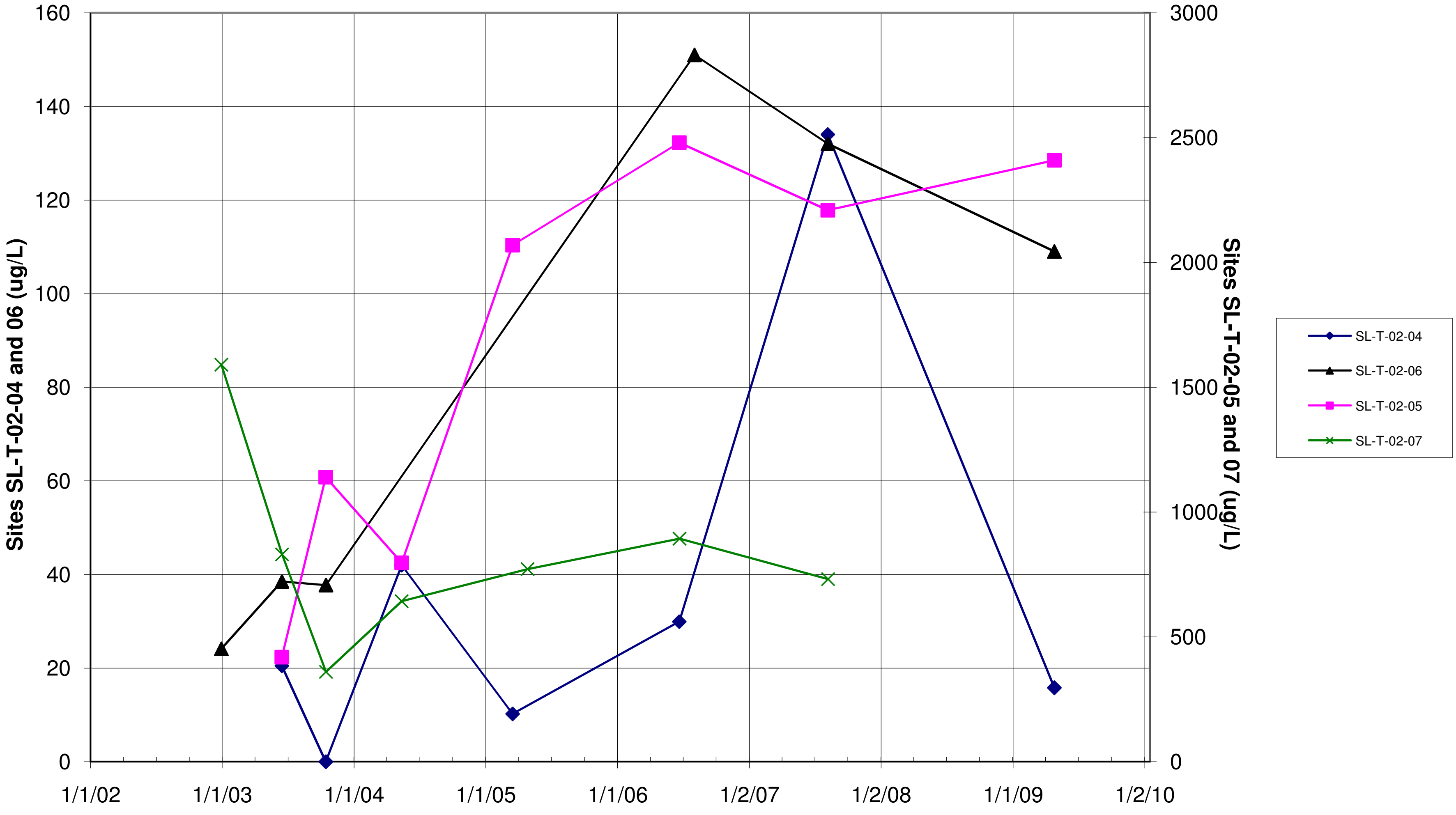


FIGURE 2.27a GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS - COPPER DATA (Non-detectable analyses plotted as zero)

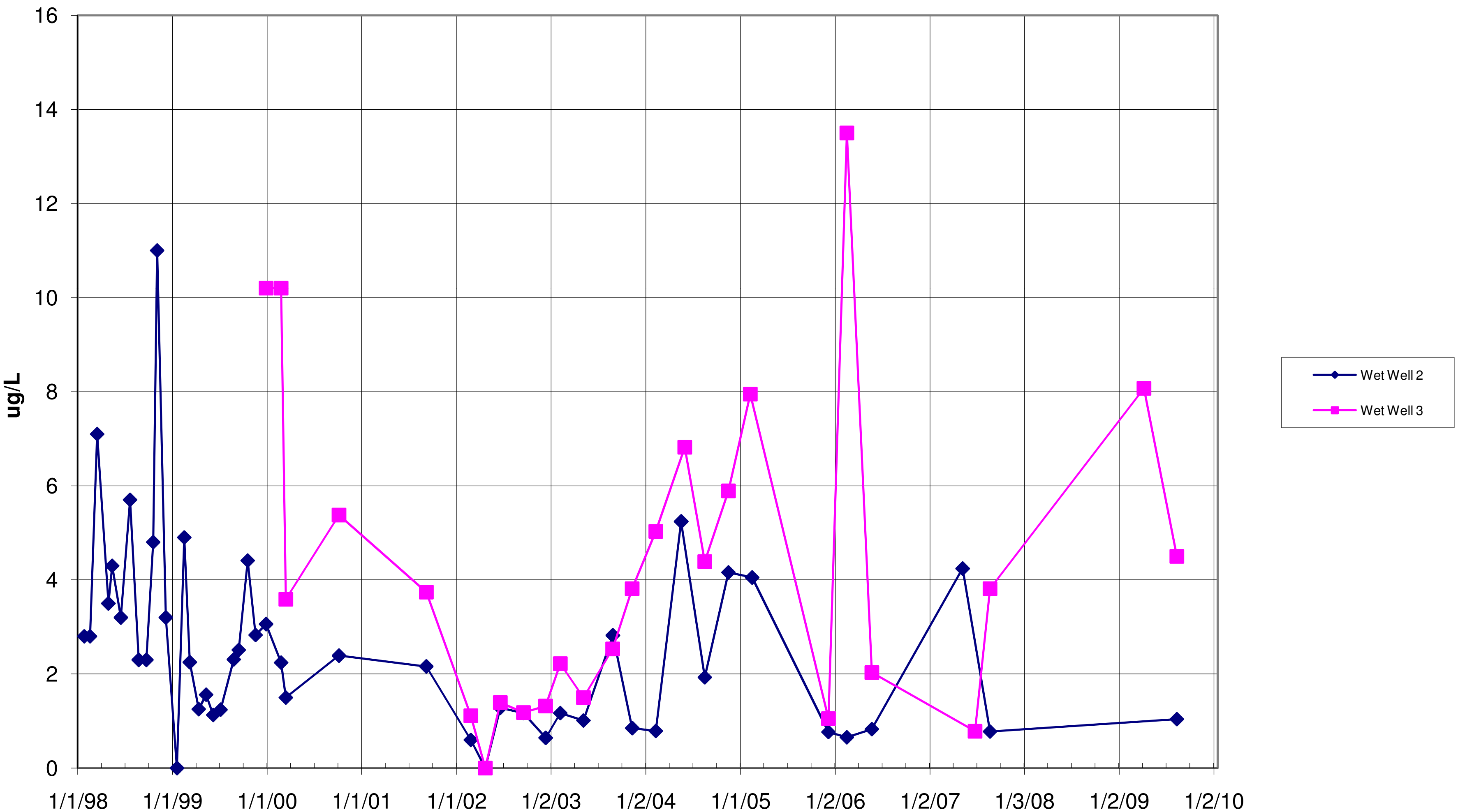


FIGURE 2.27b GREENS CREEK TAILINGS INTERNAL MONITORING SITES: TAILINGS COMPLETIONS - COPPER DATA (Non-detectable analyses plotted as zero)

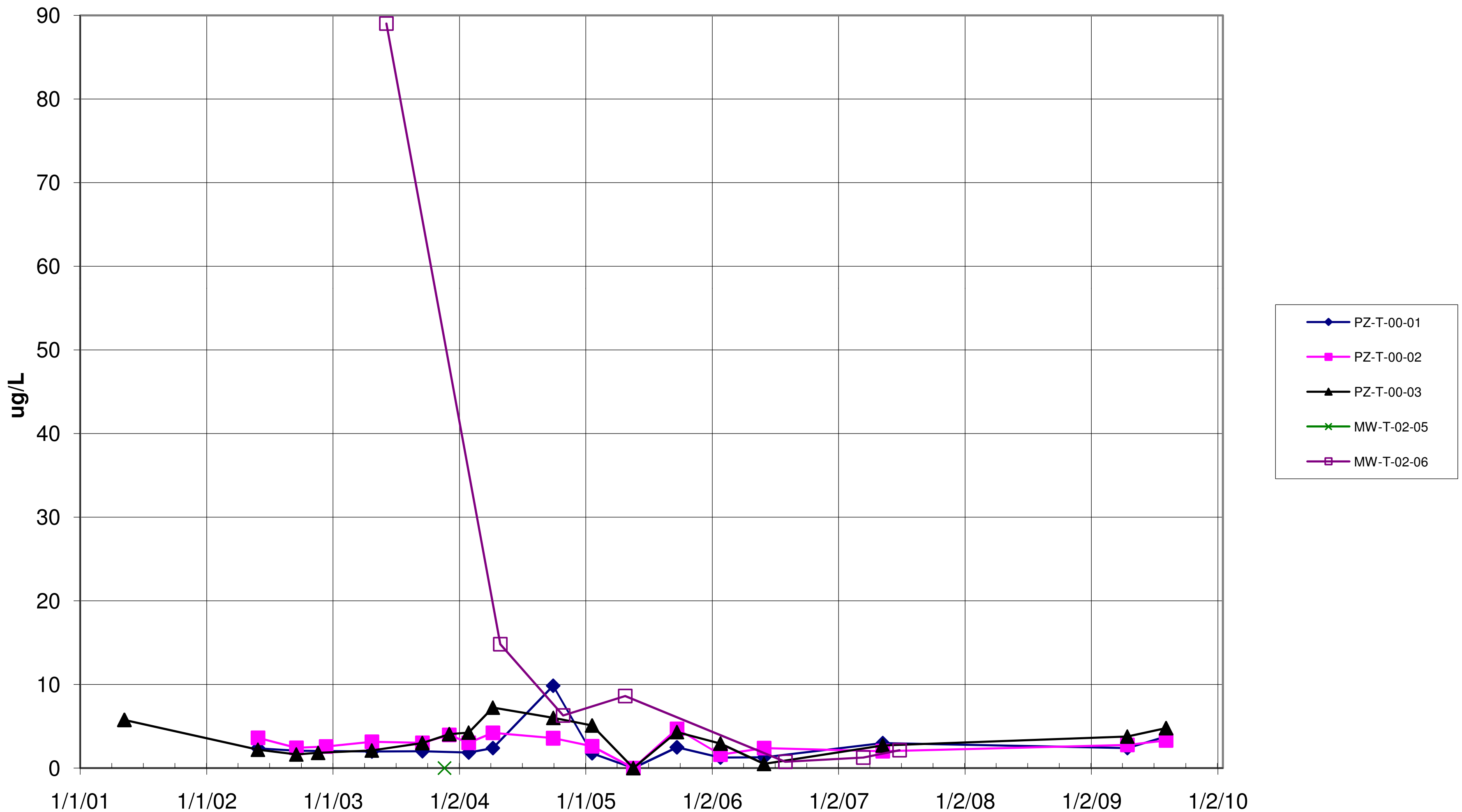


FIGURE 2.27c GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS - COPPER DATA (Non-detectable analyses plotted as zero)

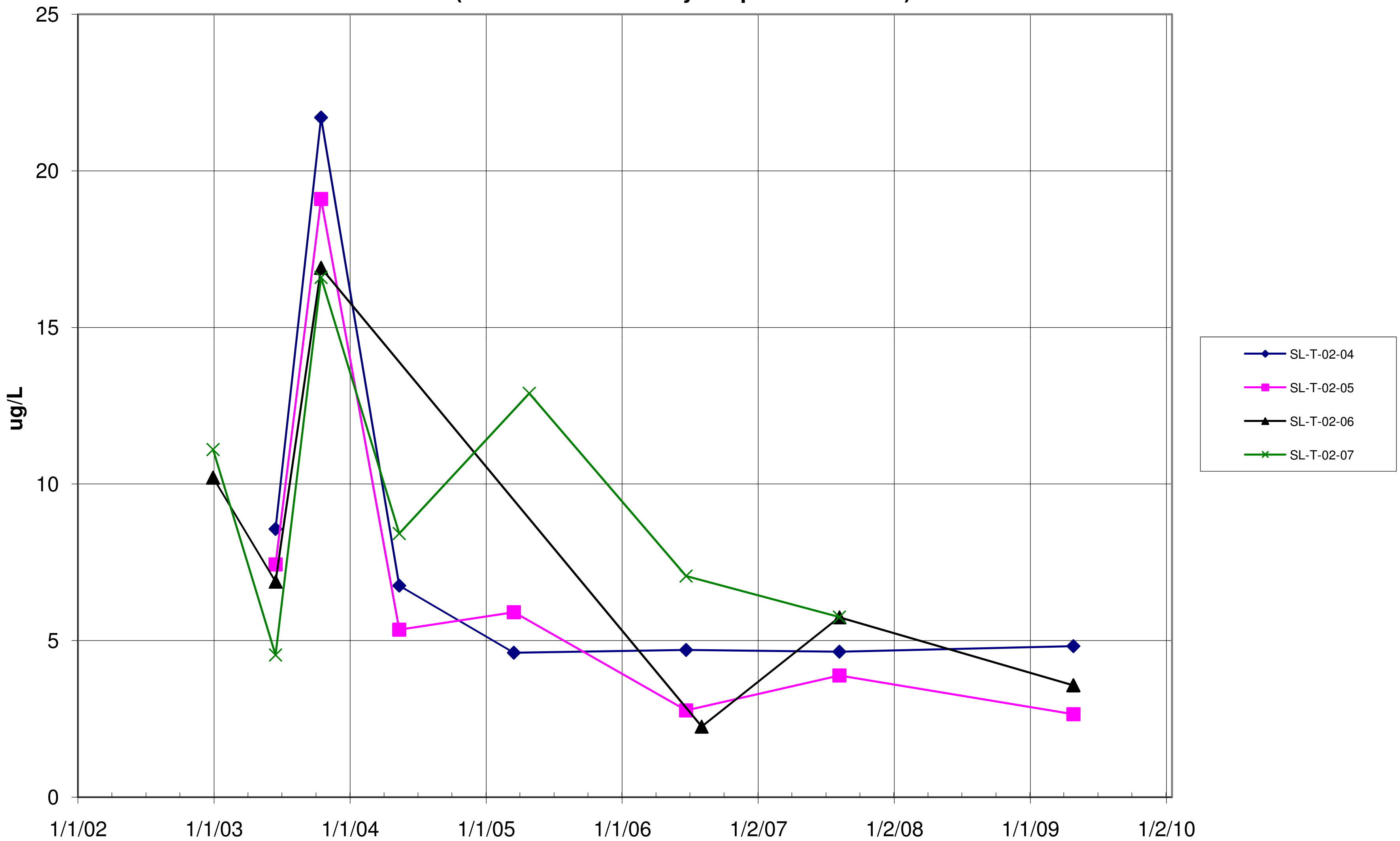


FIGURE 2.28a GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS - LEAD DATA (Non-detectable analyses plotted as zero)

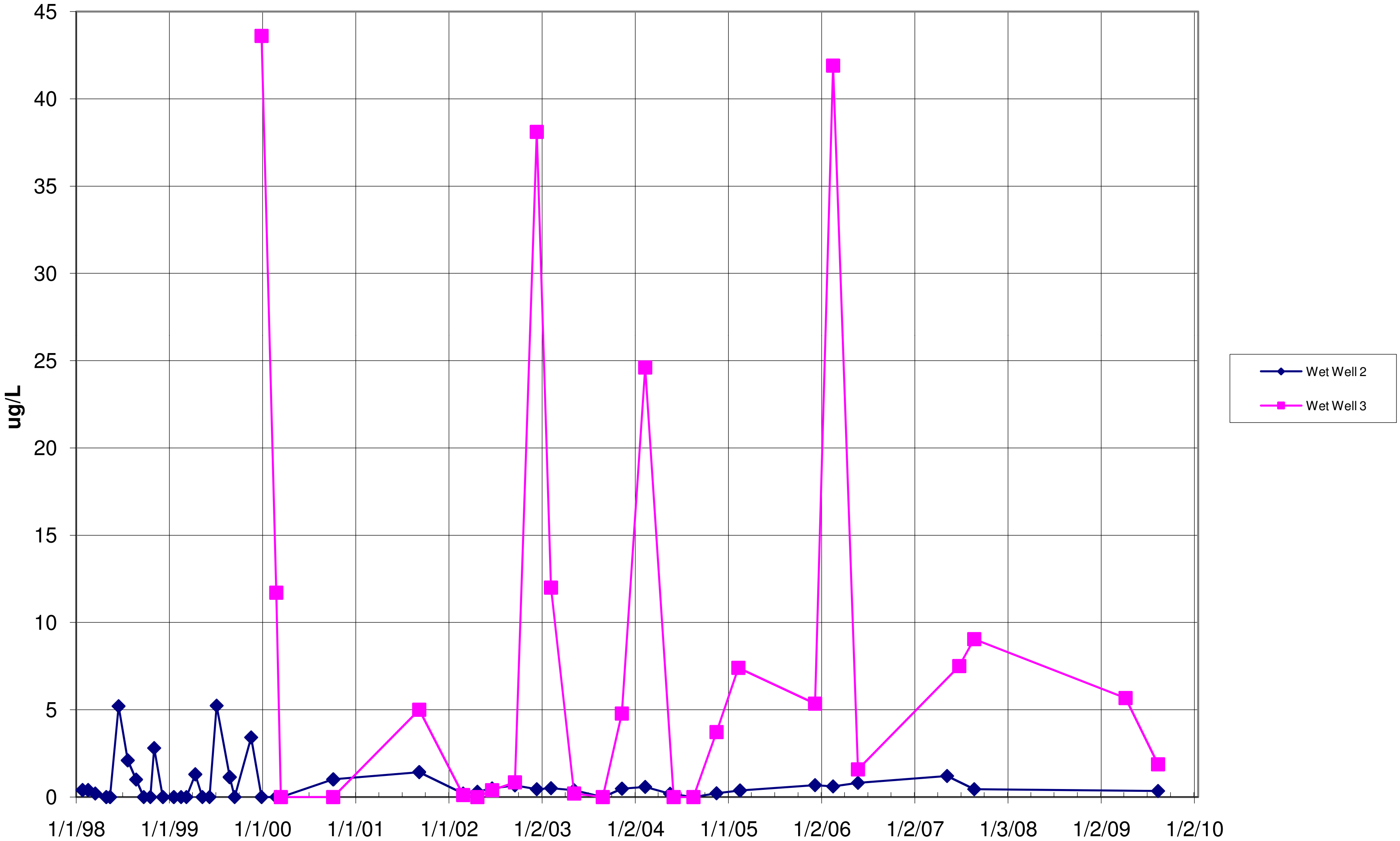


FIGURE 2.28b GREENS CREEK TAILINGS INTERNAL MONITORING SITES: TAILINGS COMPLETIONS - LEAD DATA (Non-detectable analyses plotted as zero)

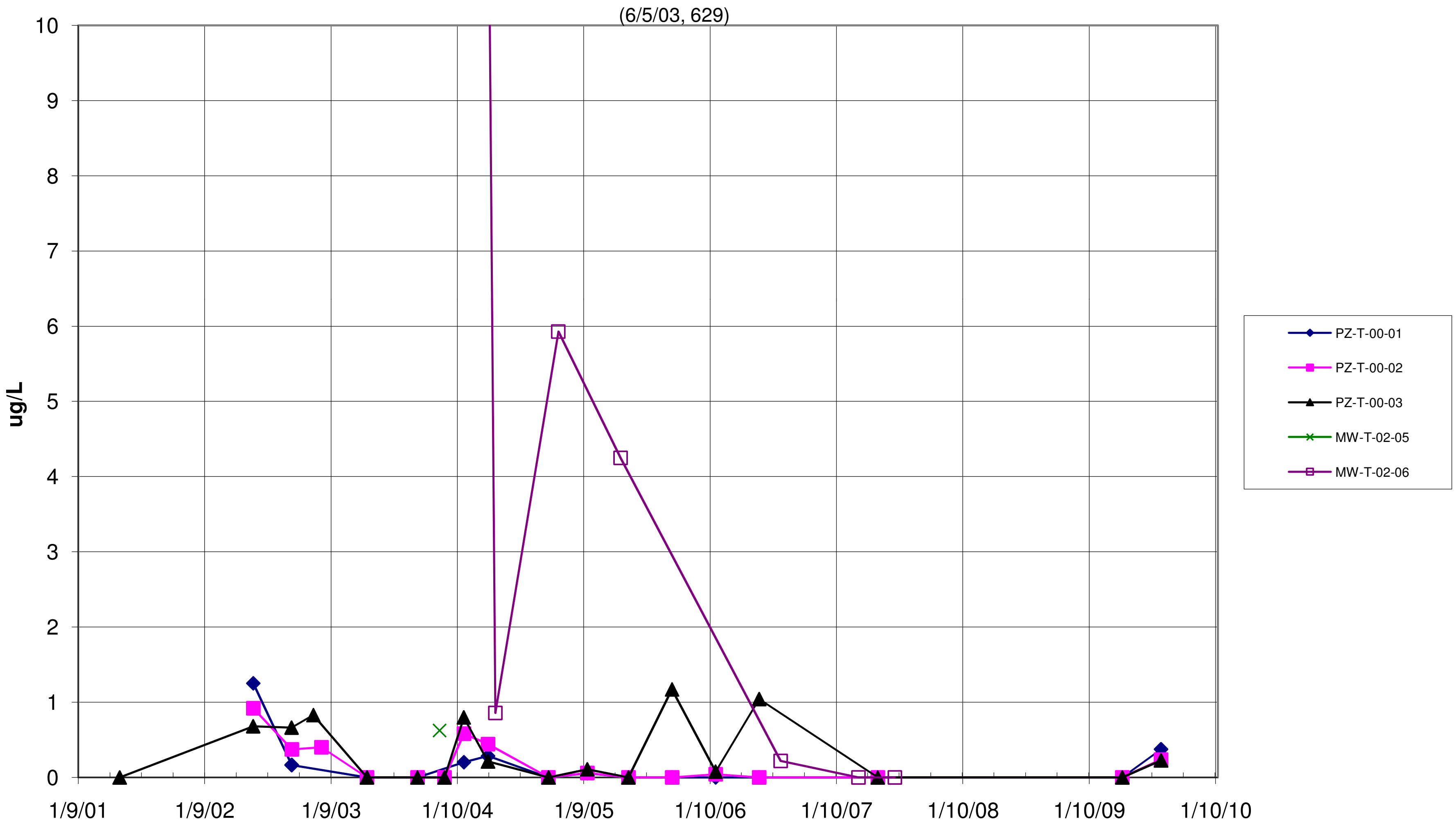


FIGURE 2.28c GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS - LEAD DATA (Non-detectable analyses plotted as zero)

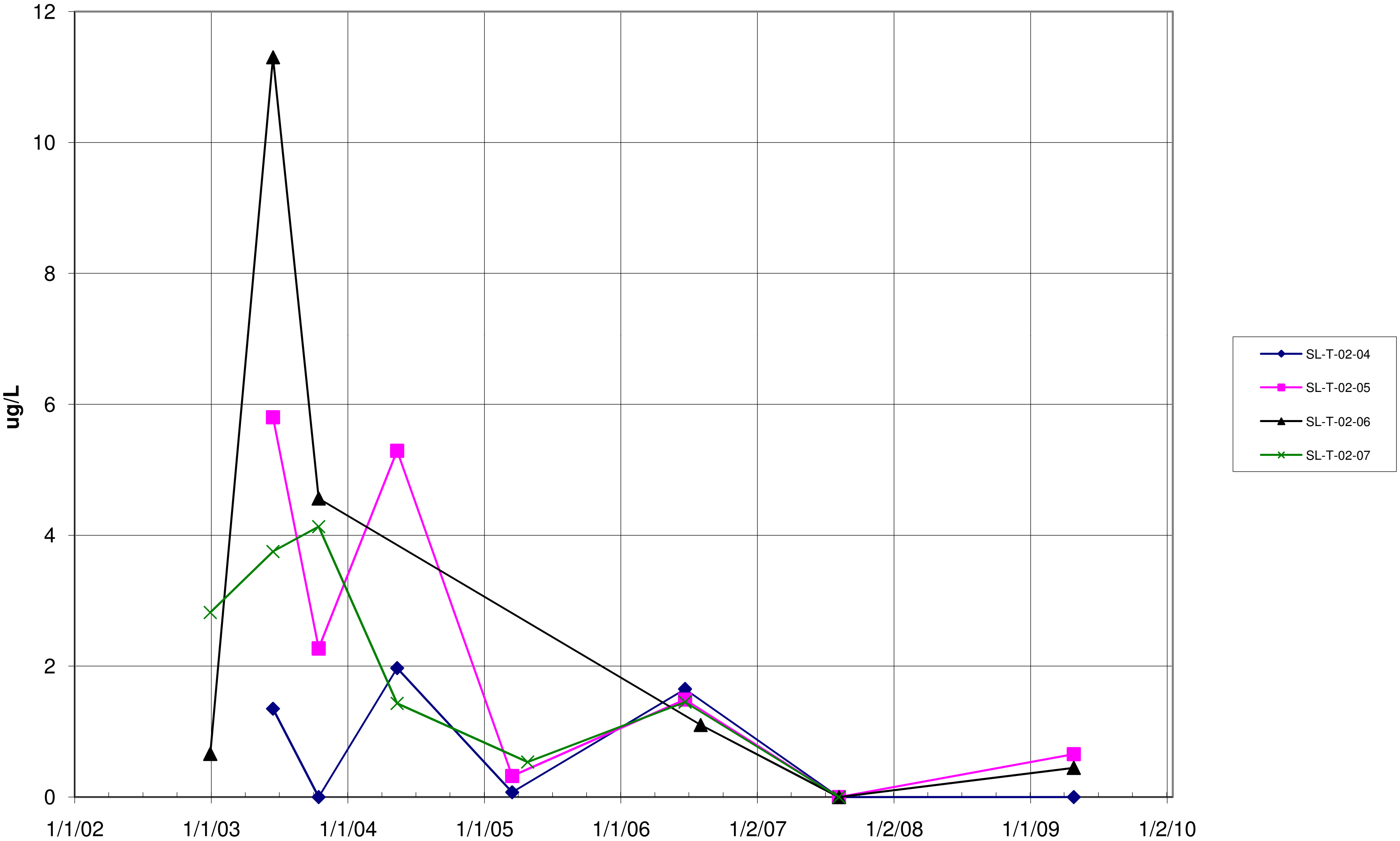


FIGURE 2.29a GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS - CADMIUM DATA (Non-detectable analyses plotted as zero)

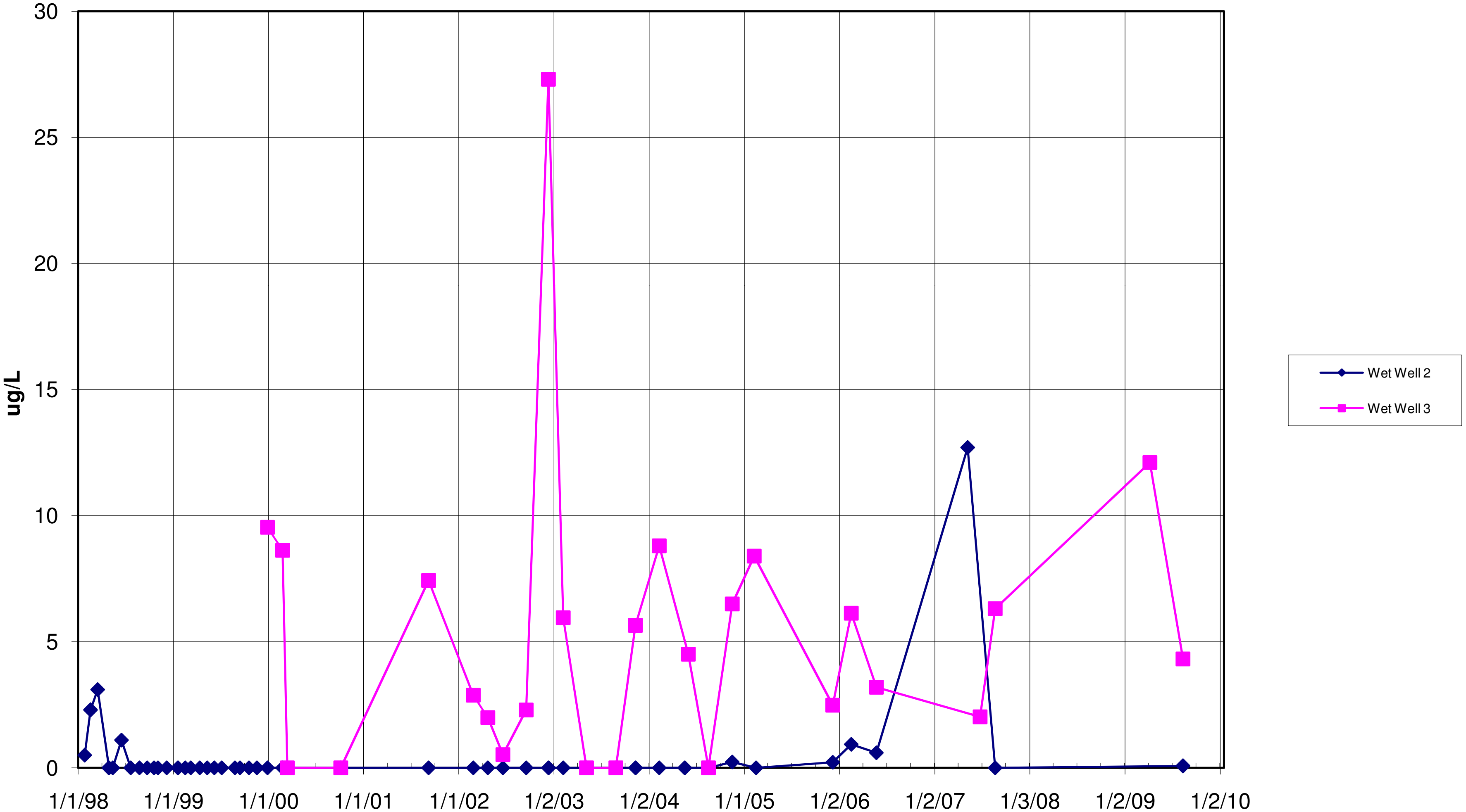


FIGURE 2.29b GREENS CREEK TAILINGS INTERNAL MONITORING SITES: TAILINGS COMPLETIONS - CADMIUM DATA (Non-detectable analyses plotted as zero)

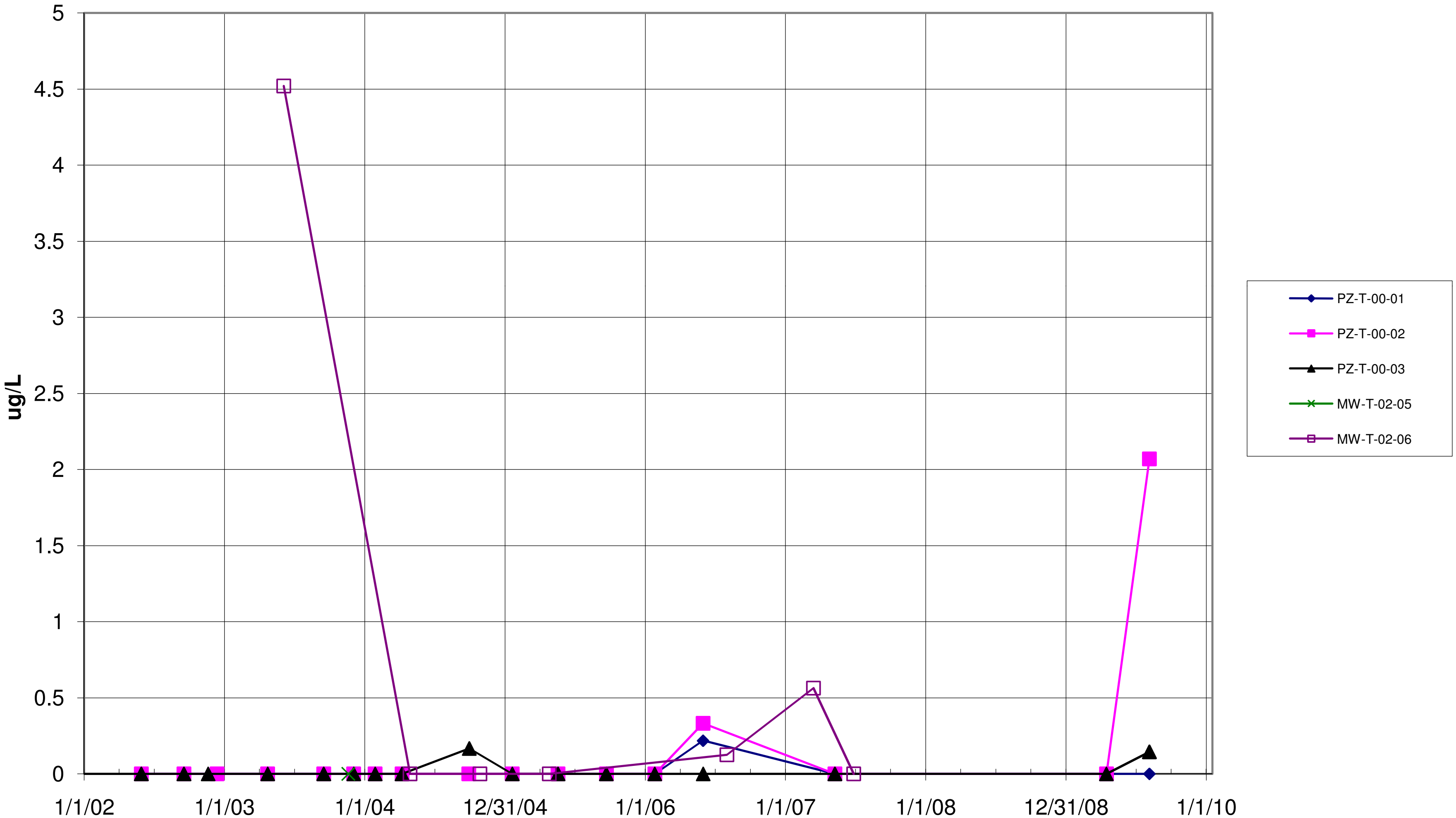


FIGURE 2.29c GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS - CADMIUM DATA (Non-detectable analyses plotted as zero)

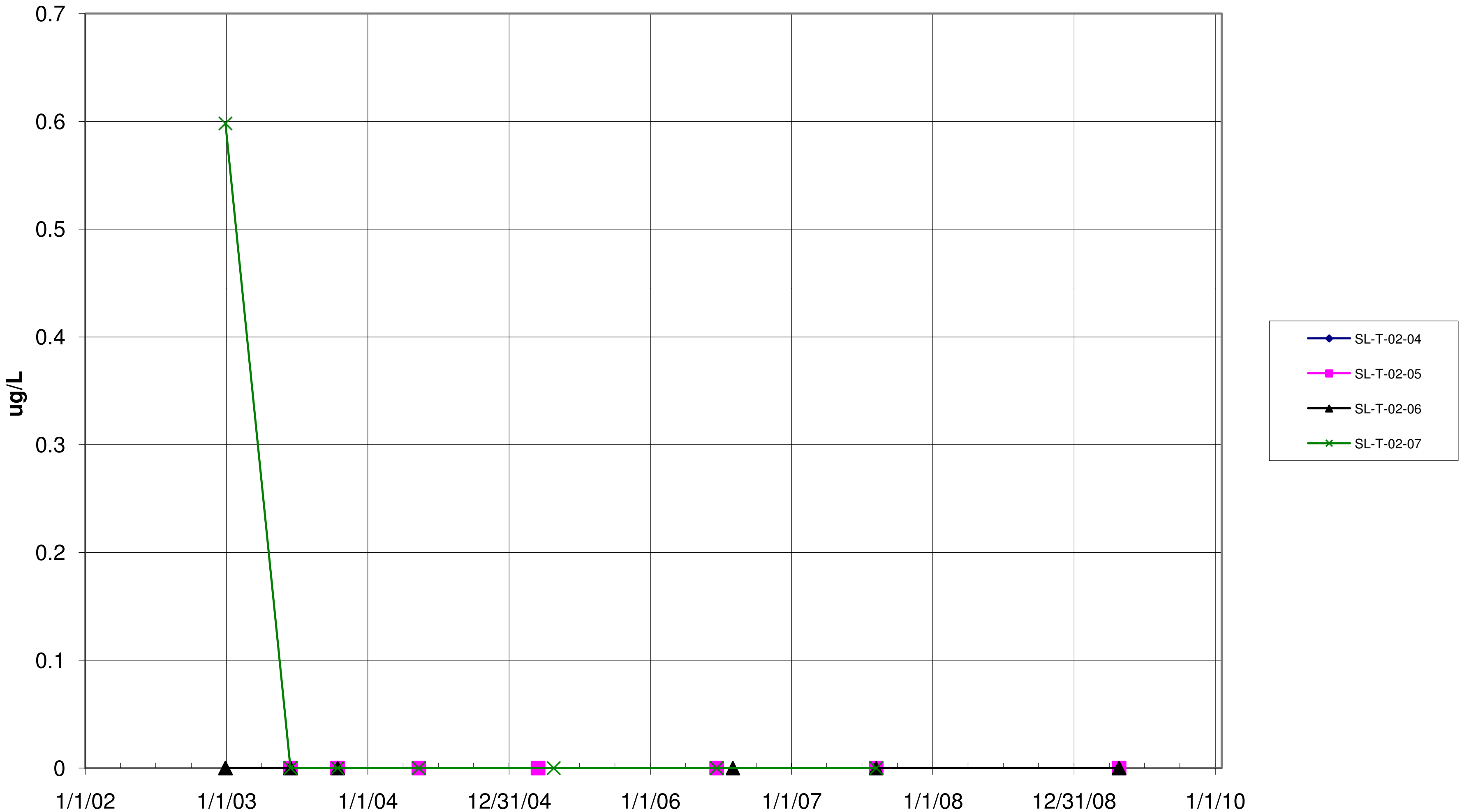


FIGURE 2.30a GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS - IRON DATA (Non-detectable analyses plotted as zero)

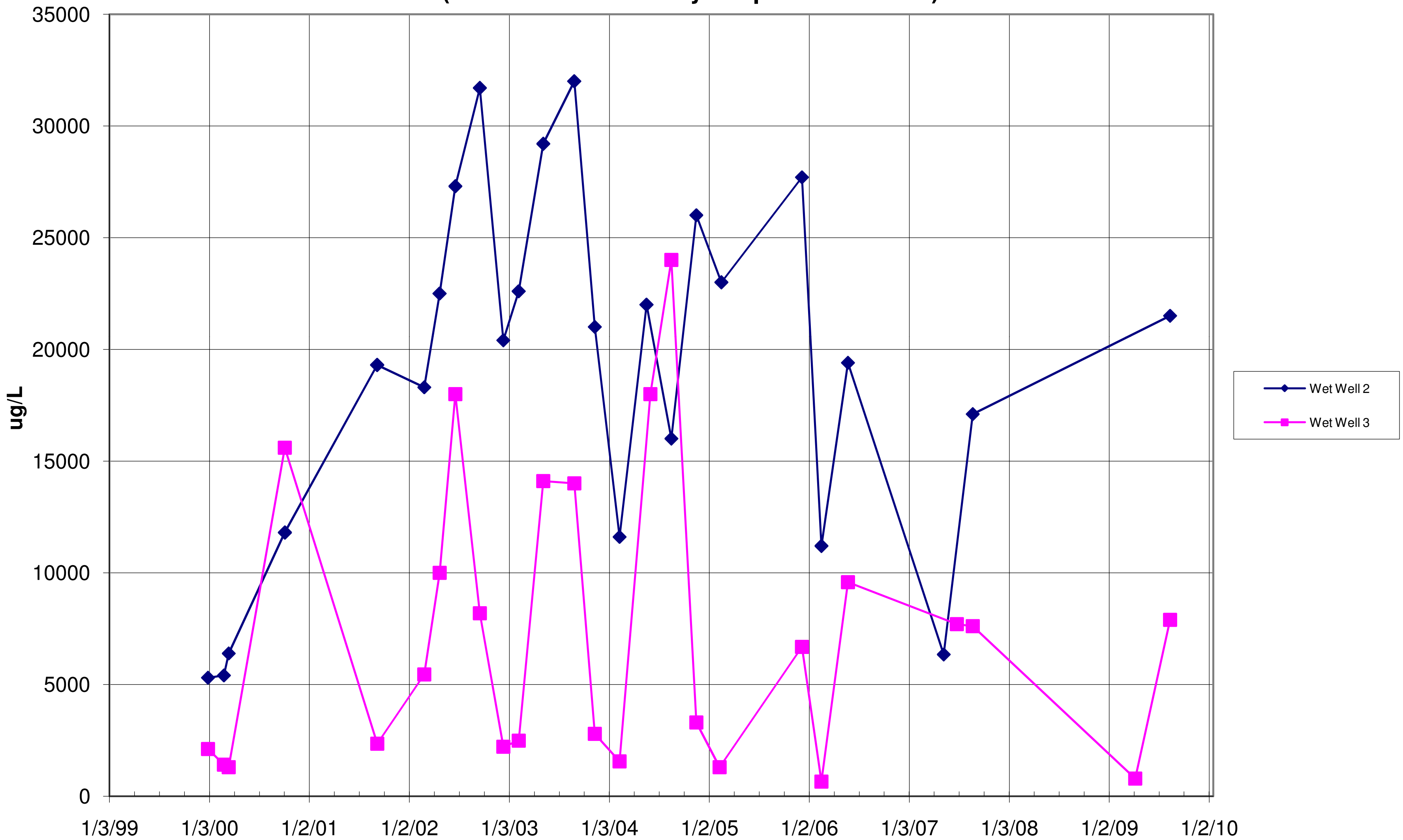


FIGURE 2.30b GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
TAILINGS COMPLETIONS - IRON DATA
(Non-detectable analyses plotted as zero)

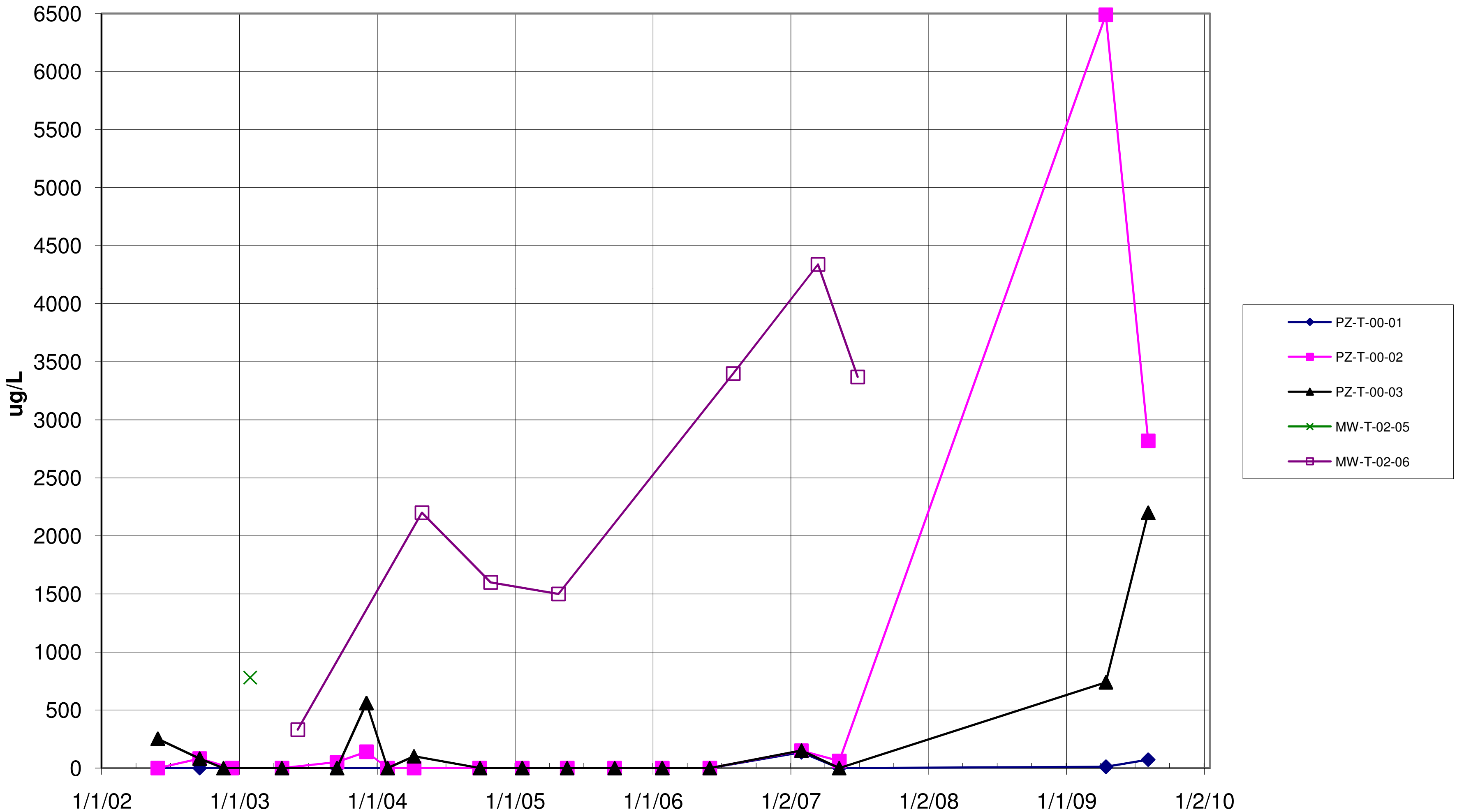


FIGURE 2.30c GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
SUCTION LYSIMETERS - IRON DATA
(Non-detectable analyses plotted as zero)

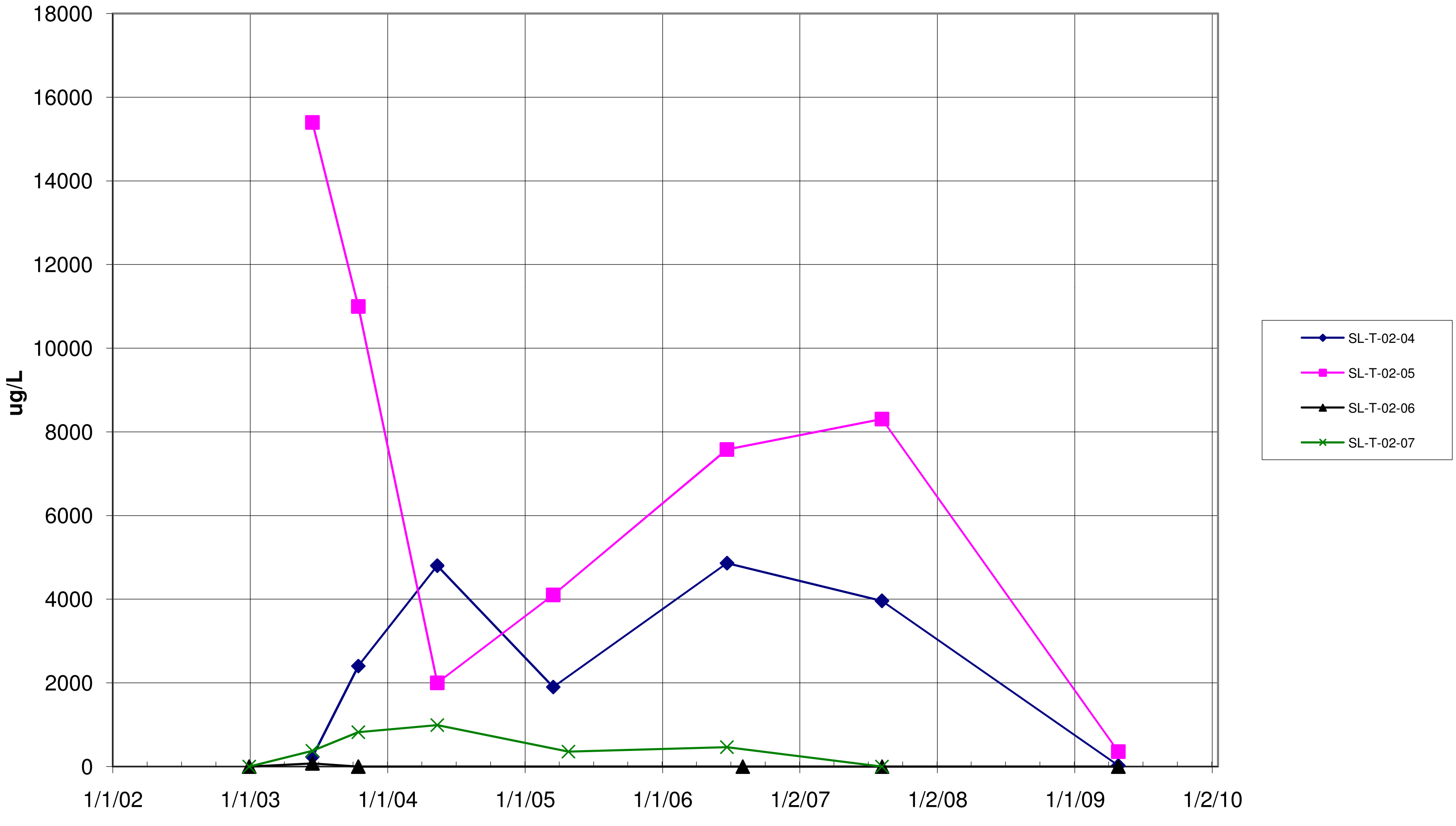


FIGURE 2.31a GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS - MANGANESE DATA (Non-detectable analyses plotted as zero)

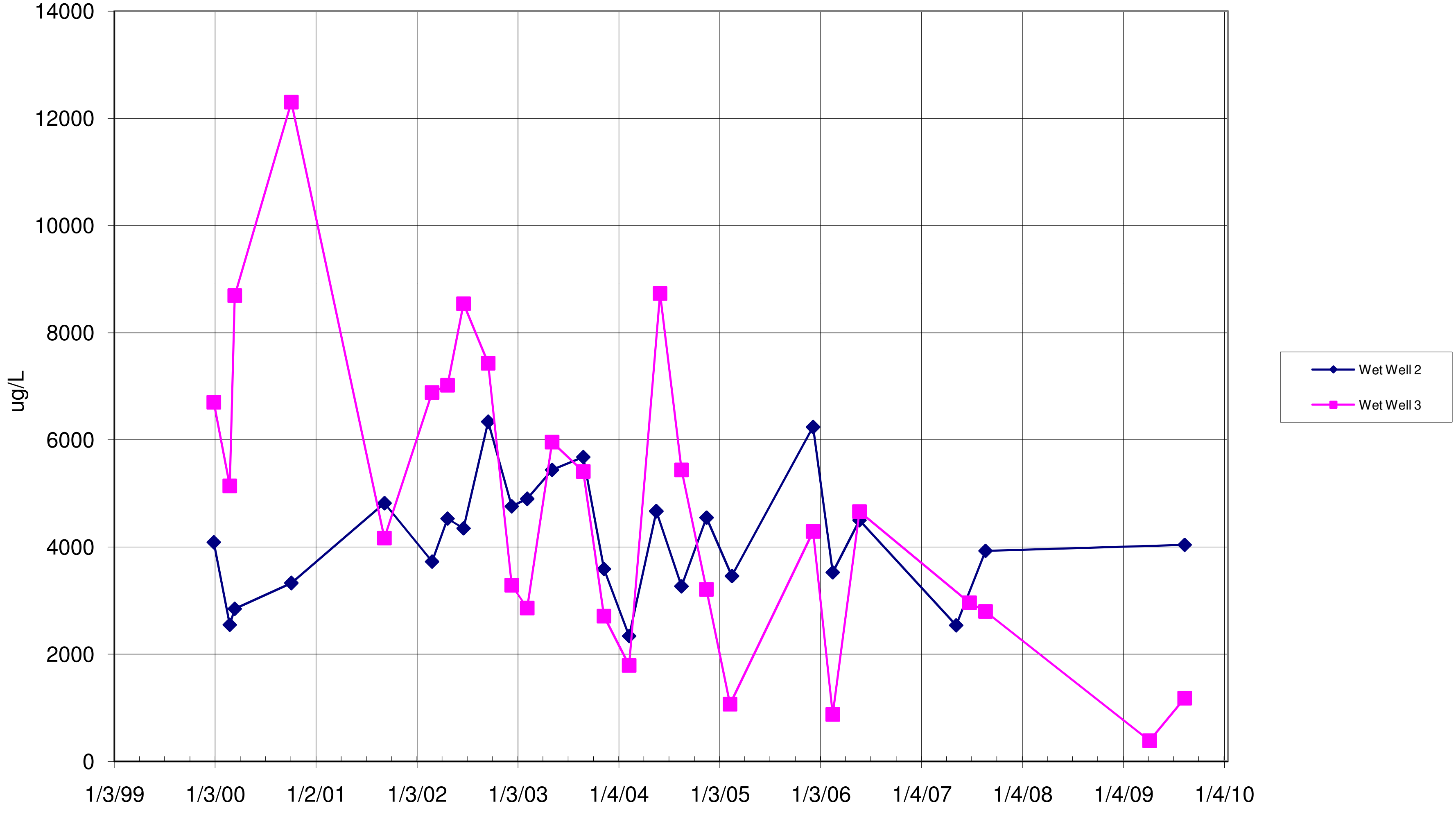


FIGURE 2.31b GREENS CREEK TAILINGS INTERNAL MONITORING SITES: TAILINGS COMPLETIONS - MANGANESE DATA (Non-detectable analyses plotted as zero)

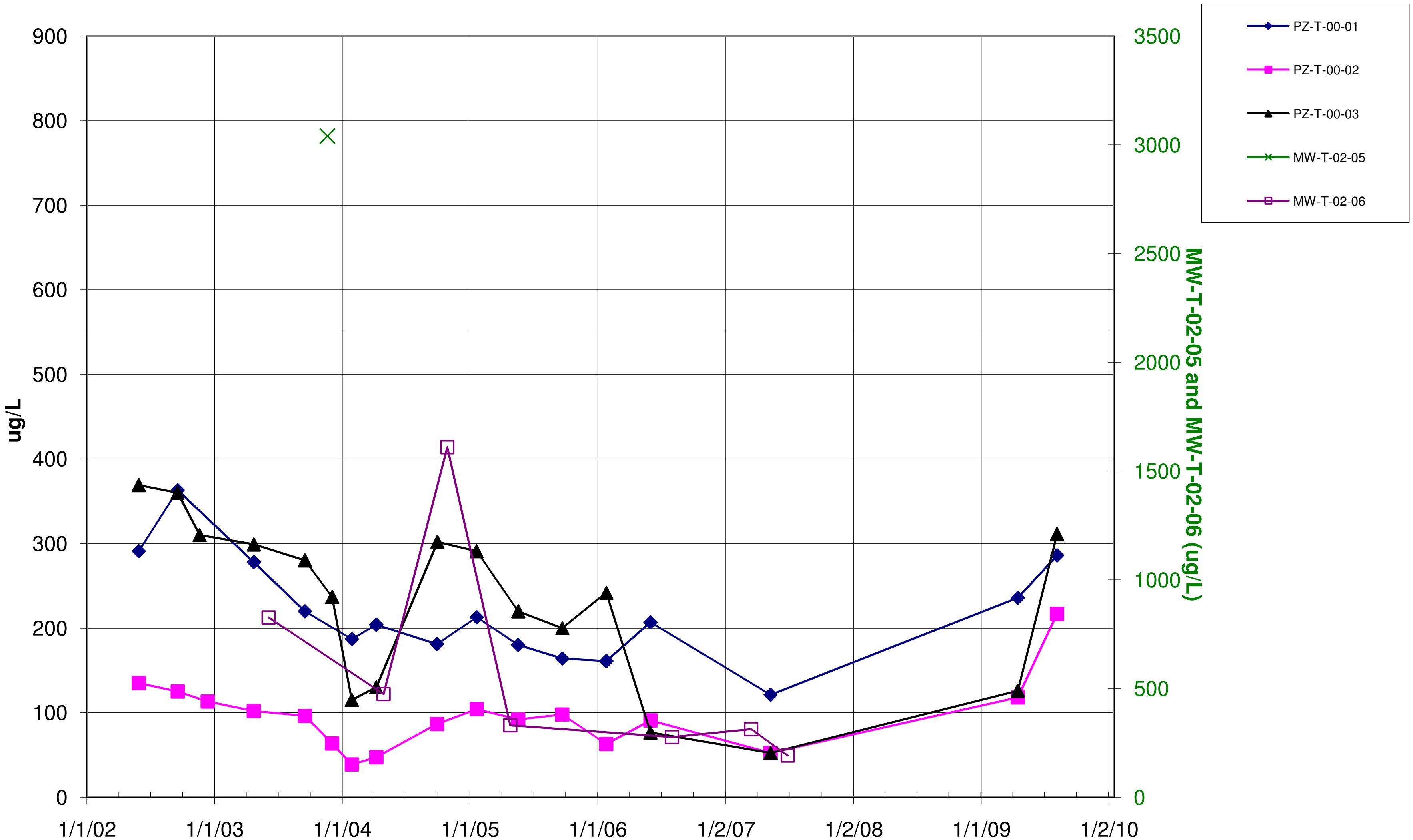


FIGURE 2.31c GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS - MANGANESE DATA (Non-detectable analyses plotted as zero)

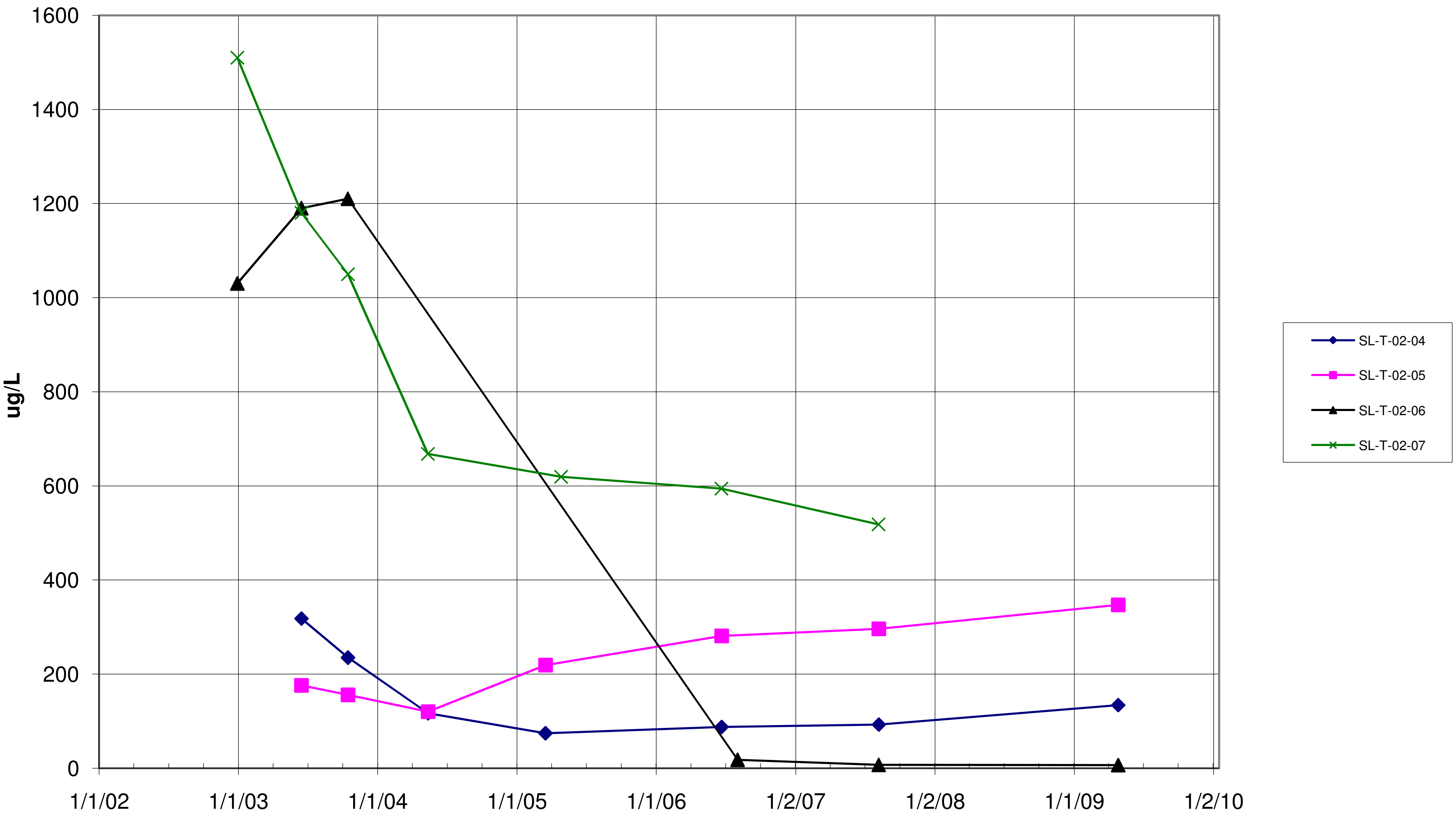
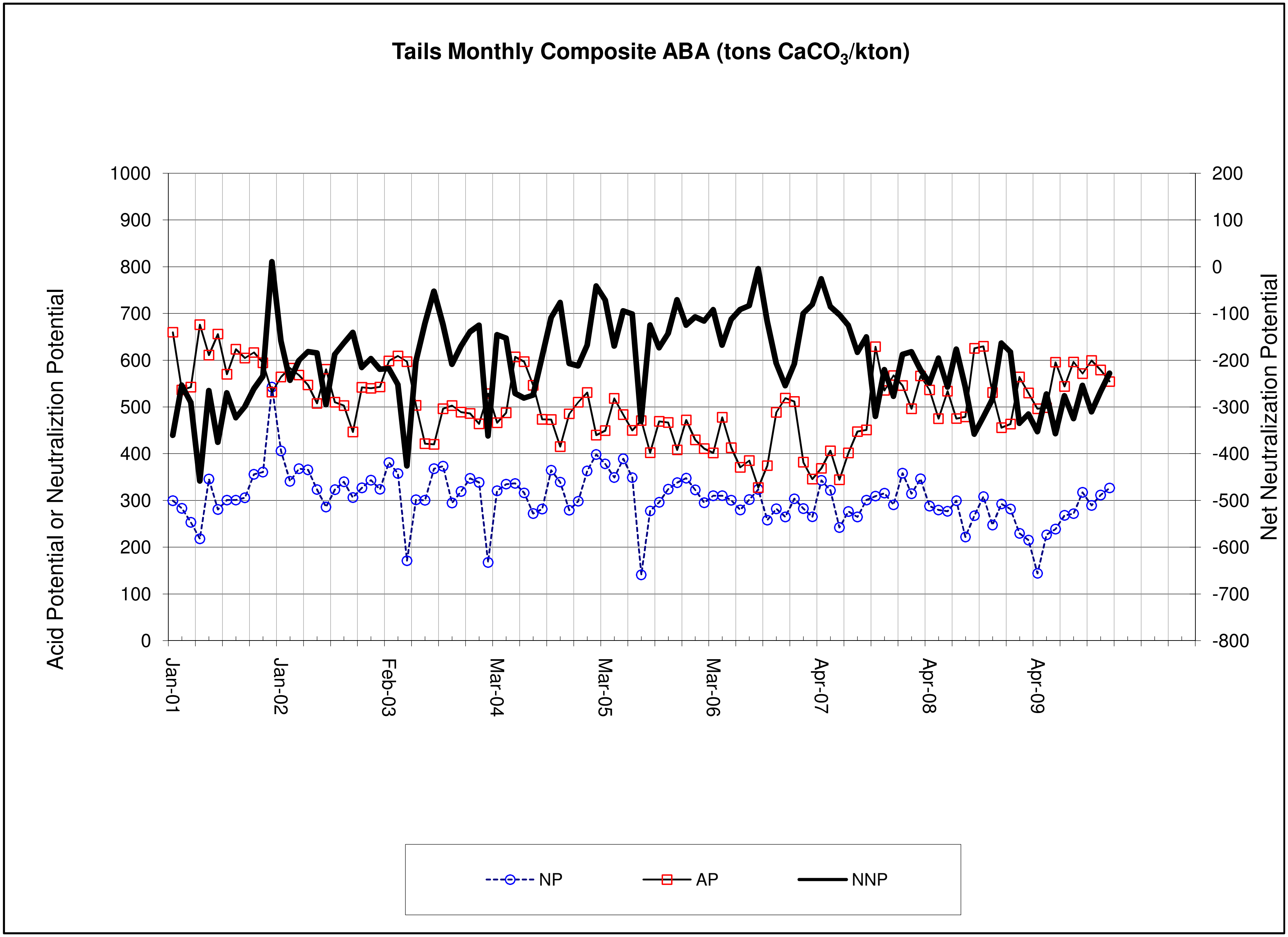


FIGURE 2.32



Tails Monthly Composite ABA (tons CaCO3/kton)
Acid Potential or Neutraliztion Potential
Net Neutralization Potential
1000
900
800
700
600
500
400
300
200
100
0
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
Jan-01
Jan-02
Feb-03
Mar-04
Mar-05
Mar-06
Apr-07
Apr-08
Apr-09
NP
AP
NNP

Figure 2.33 Tailings ABA Data

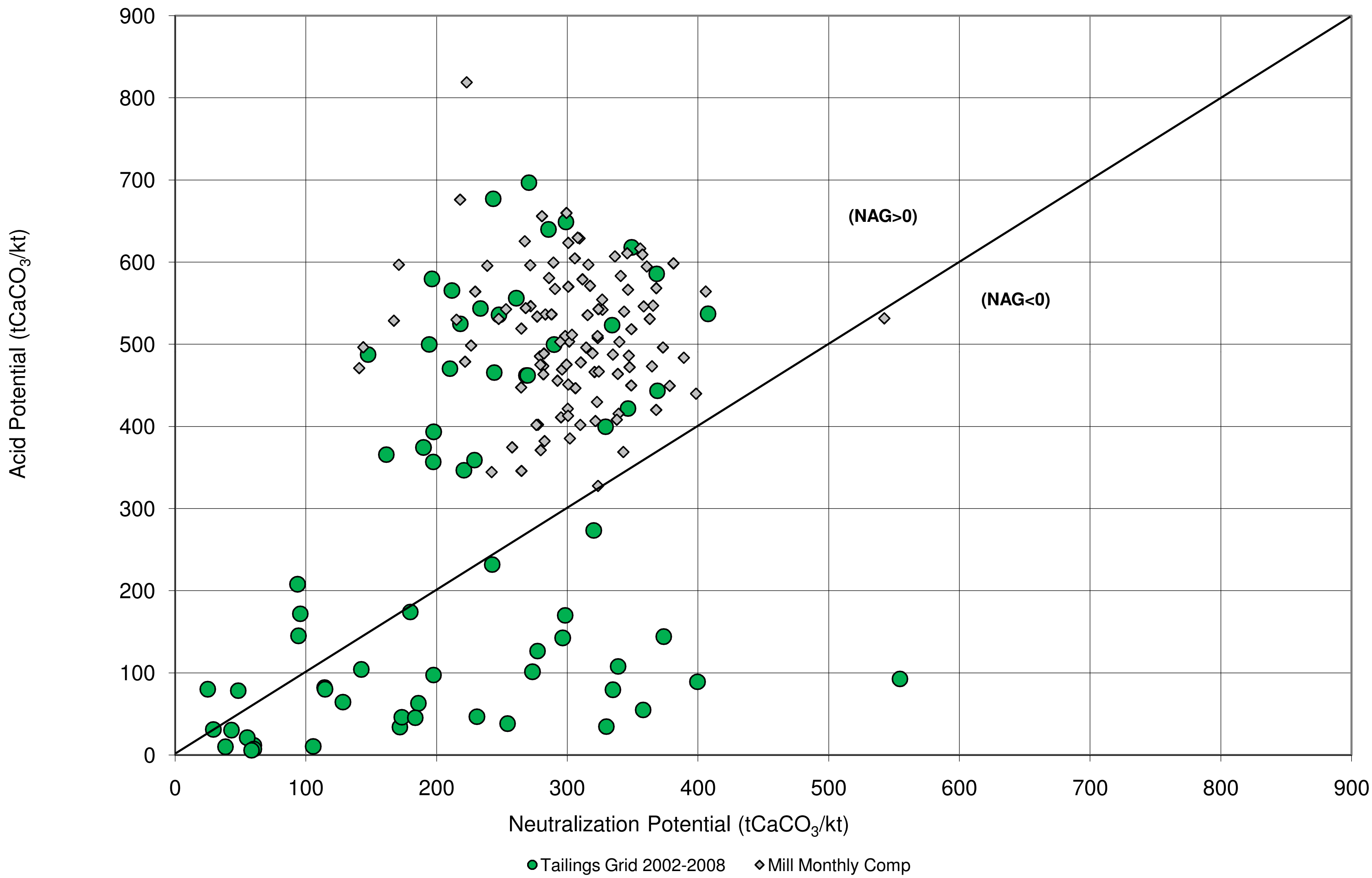


Figure 2.34 Tailings Grid ABA Data

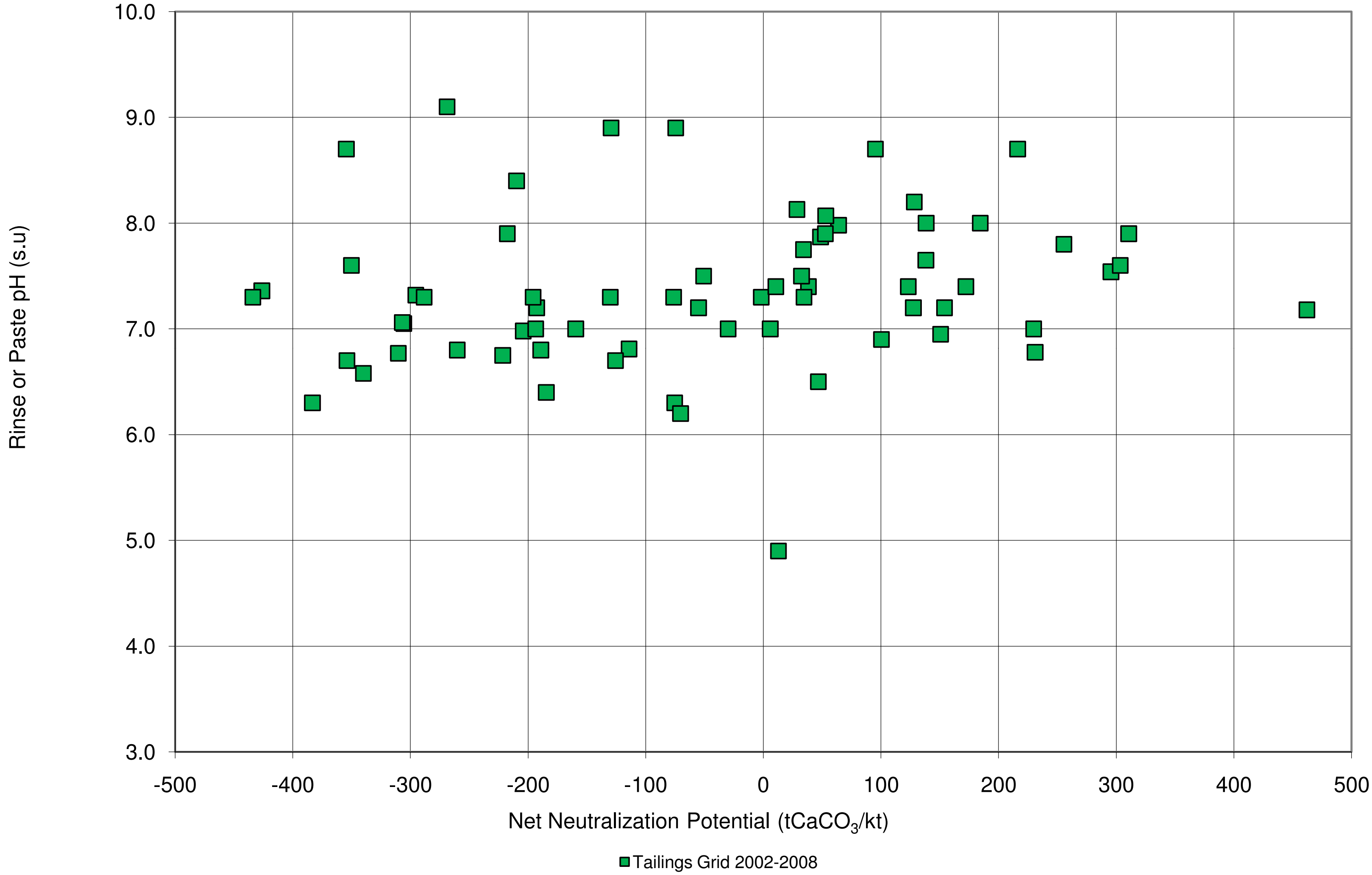


FIGURE 2.35 a Tails Snow Sample Sites

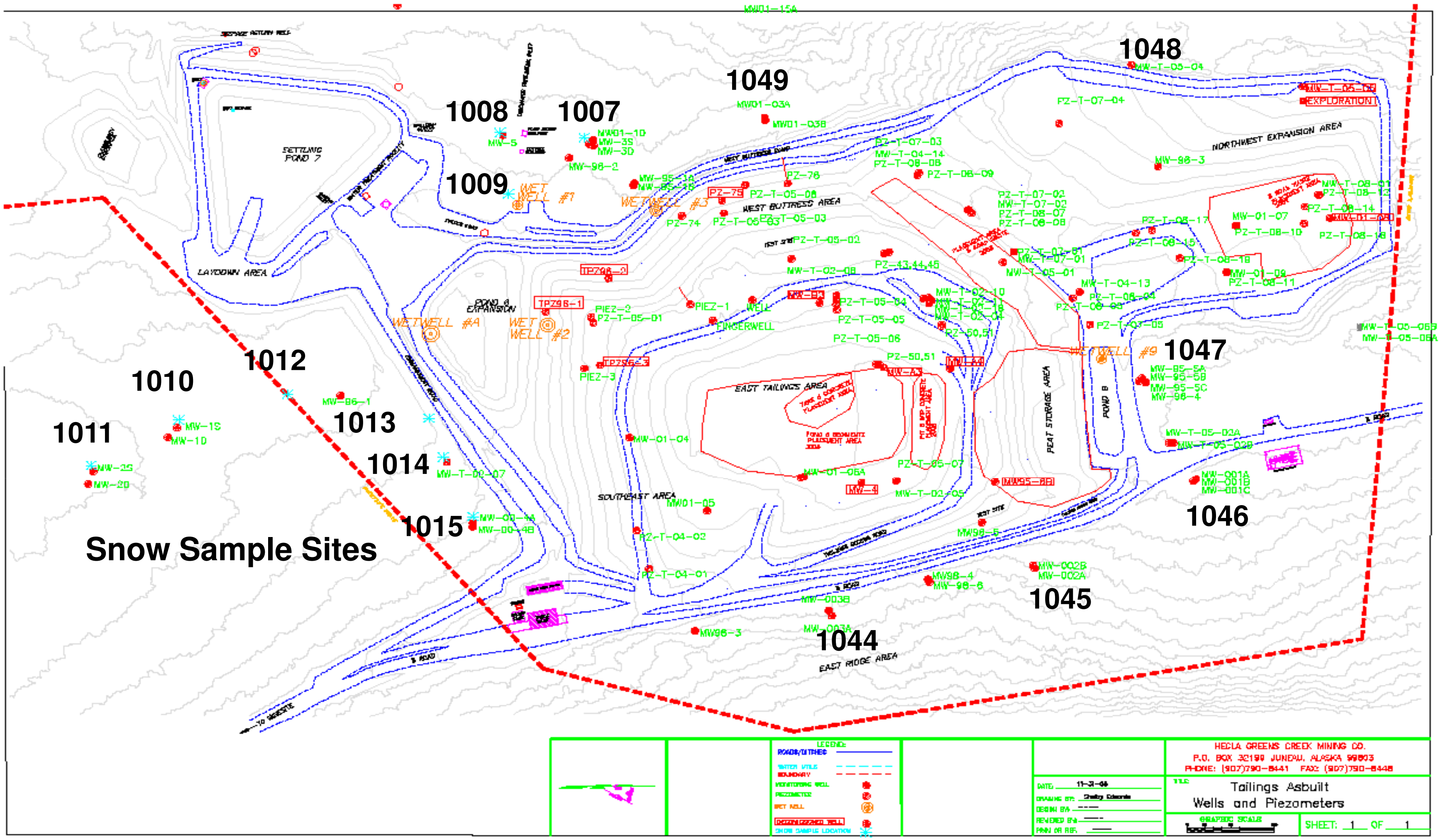


FIGURE 2.35 b Tails Snow Dust Lead Load vs Distance

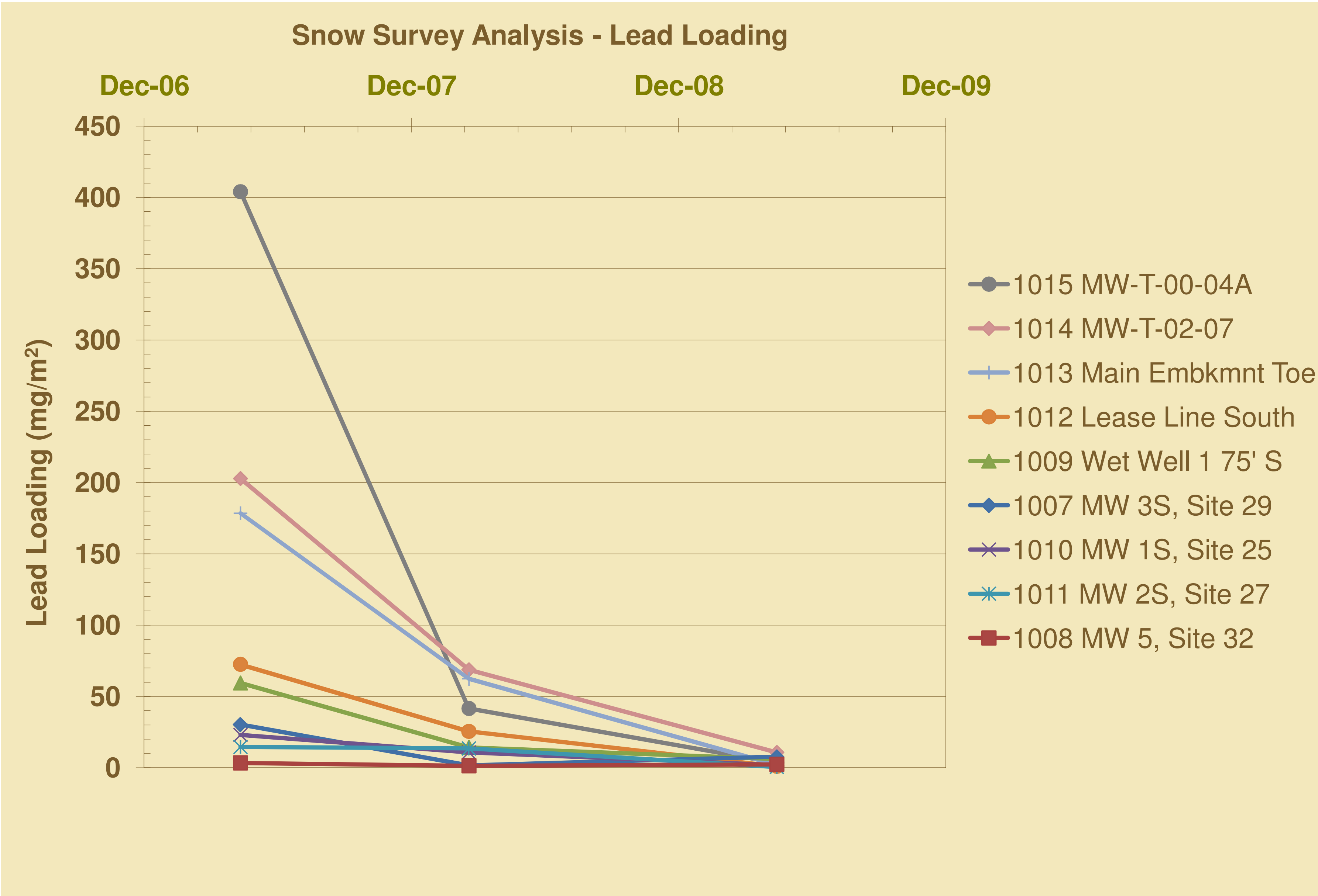


Figure 2.36 Co-disposal Test Drainage Compositions (Site E waste rock)

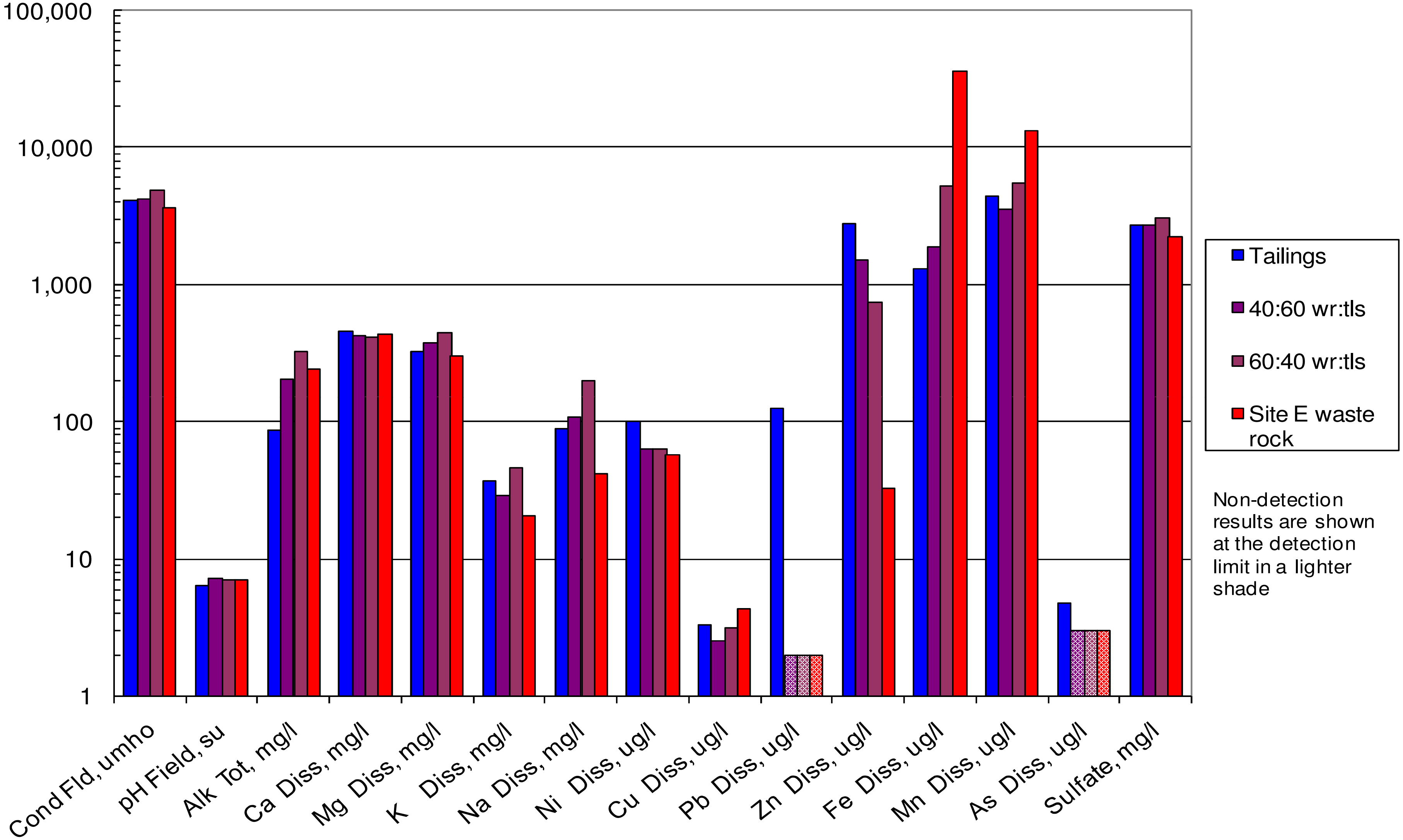


Figure 2.37 Acid Base Accounting Data (Site E Co-Disposal Study)

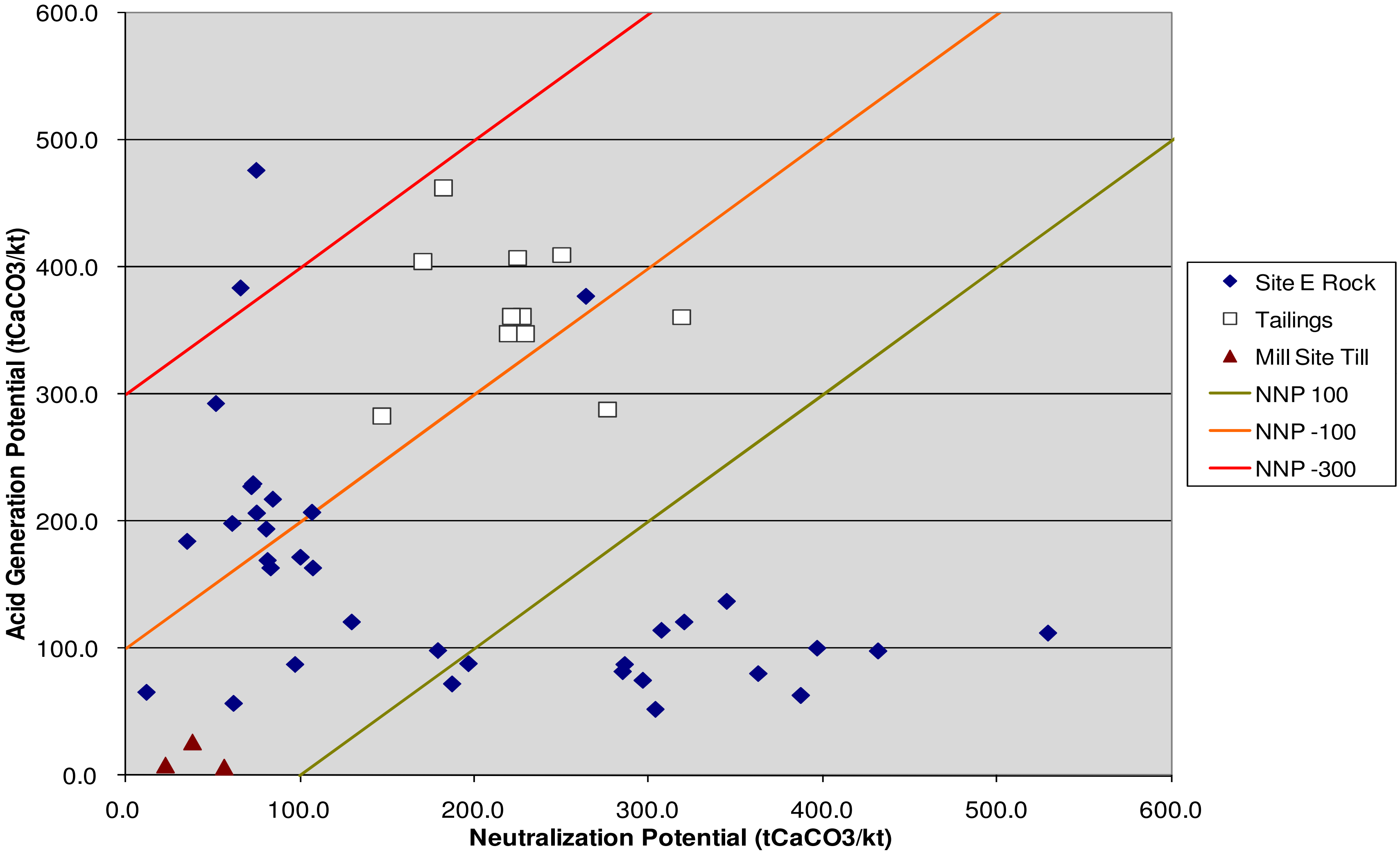


Figure 3.1 Pressure Data for Piezometer 52

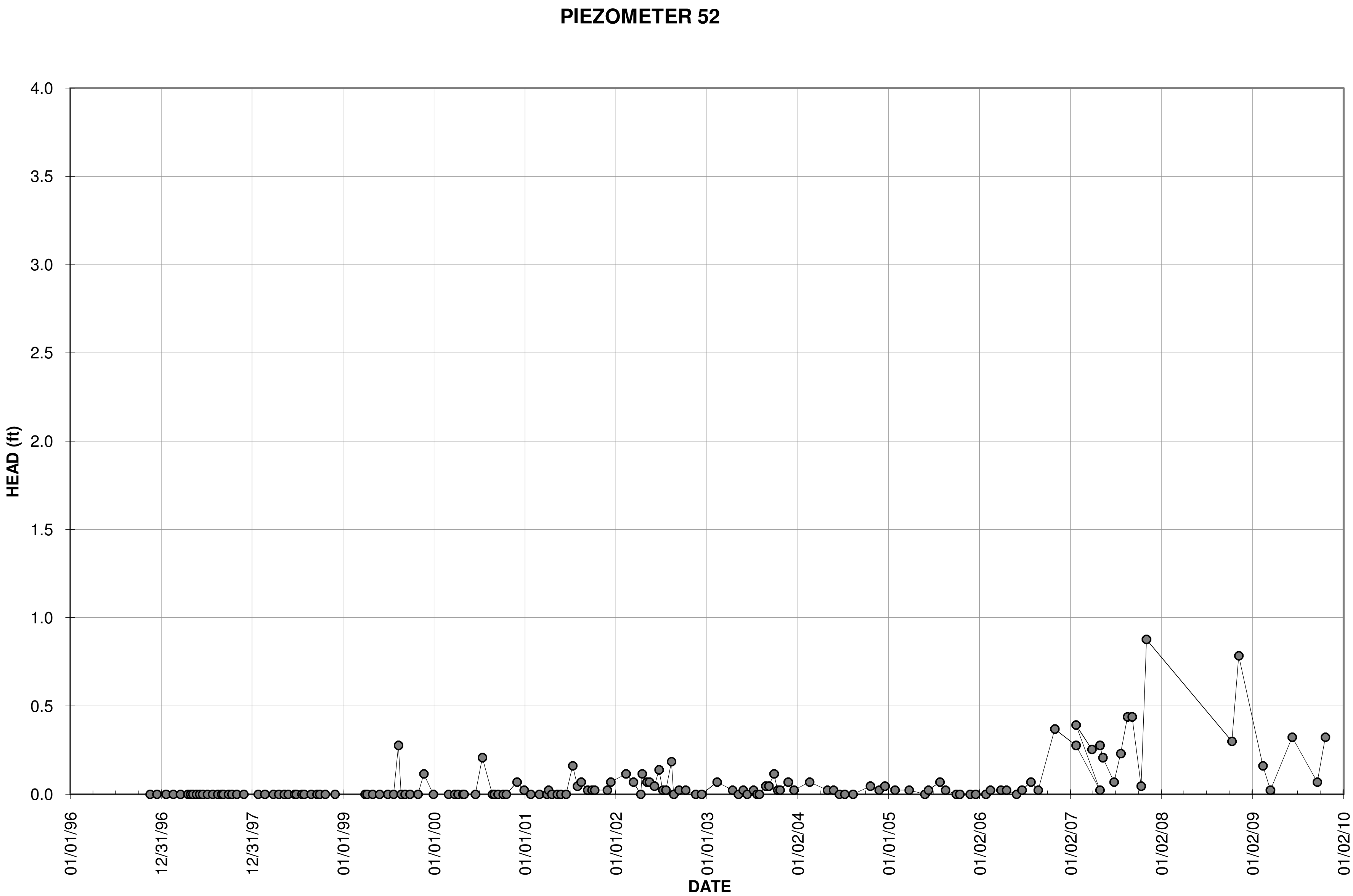


Figure 3.2 Pressure Data for Piezometer 53

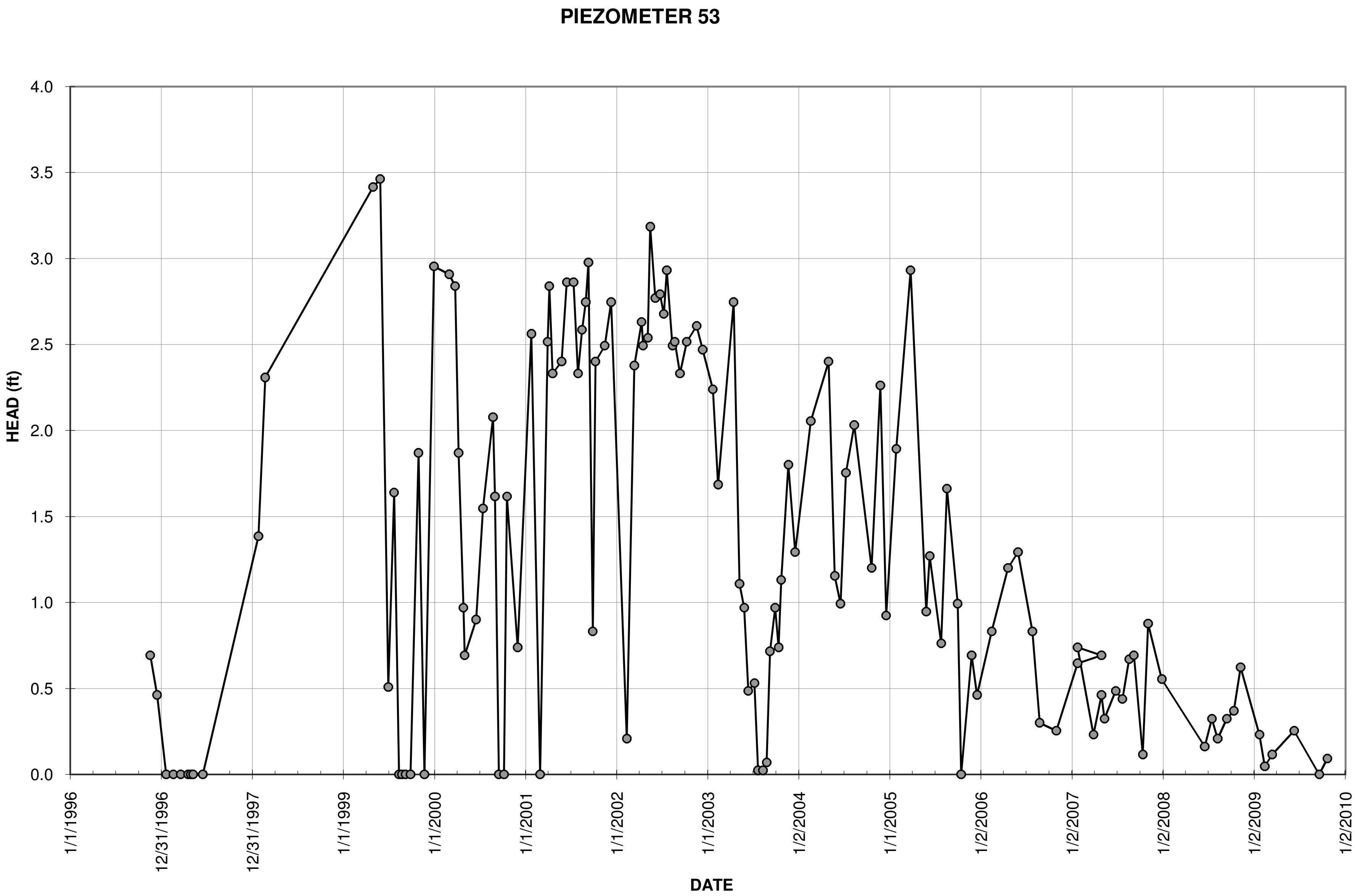


Figure 3.3 Pressure Data for Piezometer 54

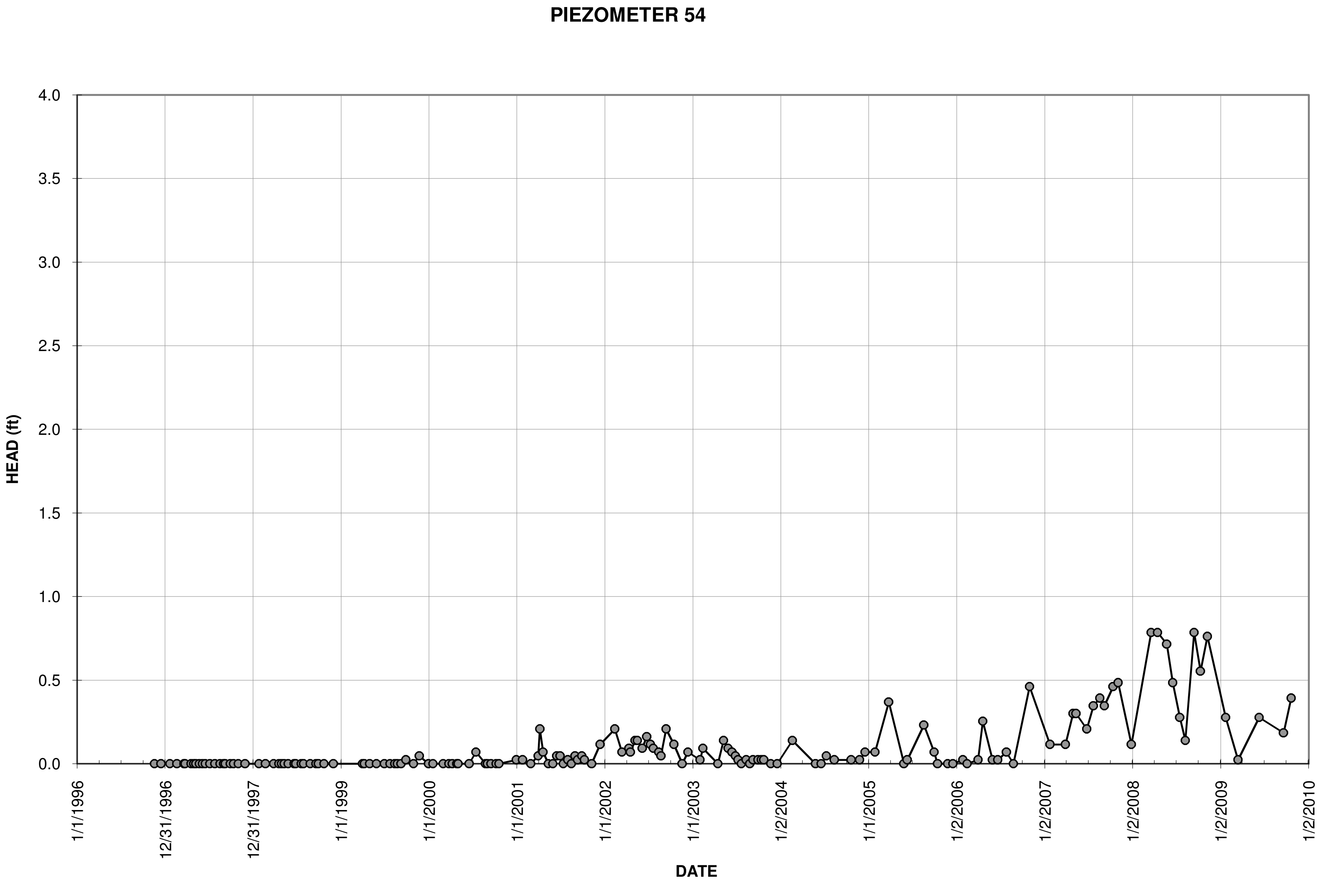


Figure 3.4 Pressure Data for Piezometer 55

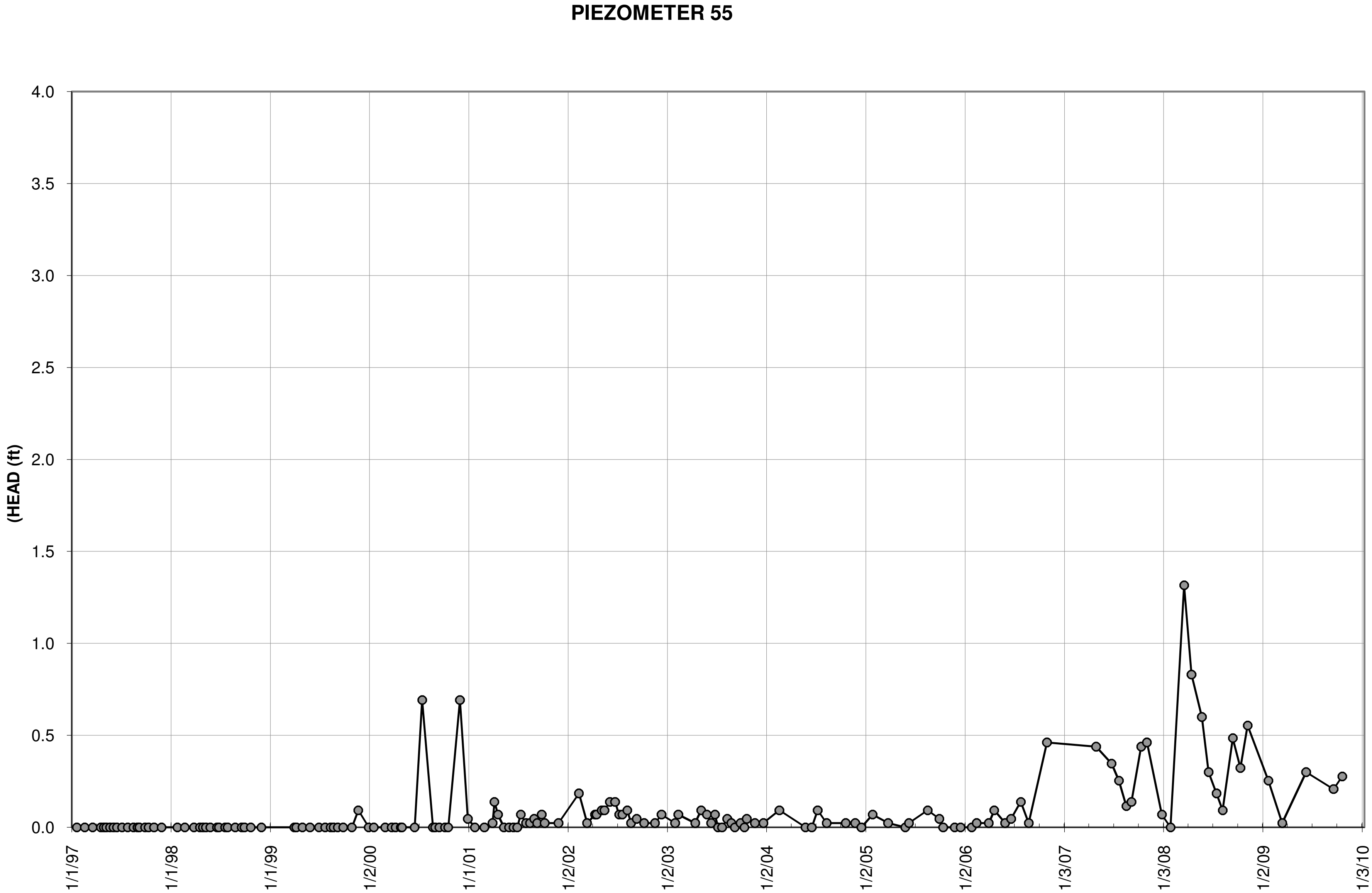


Figure 3.5 Water Level Data for Well MW-23/D-00-03

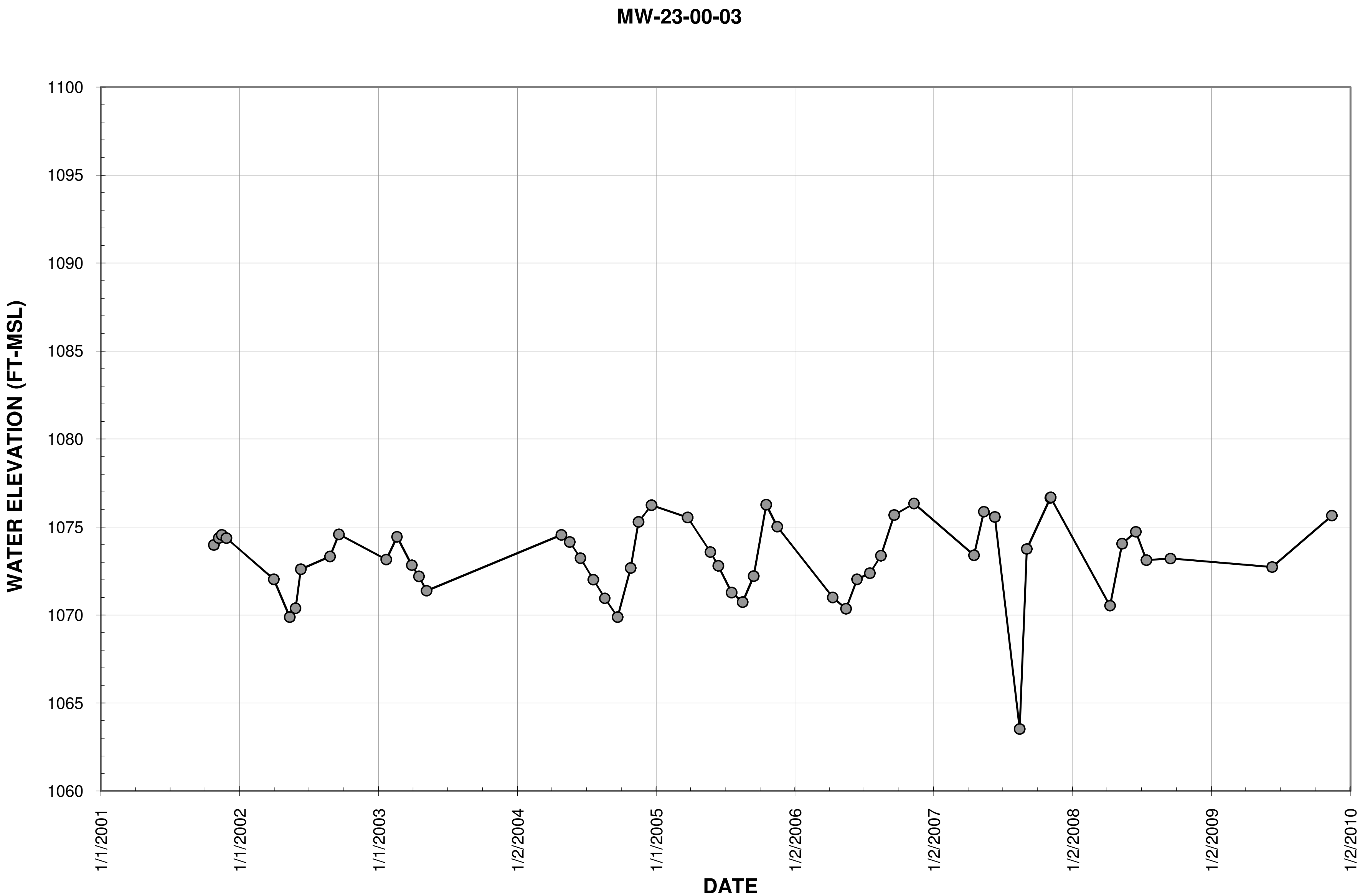


Figure 3.6 Water Level Data for Well MW-23-A2D

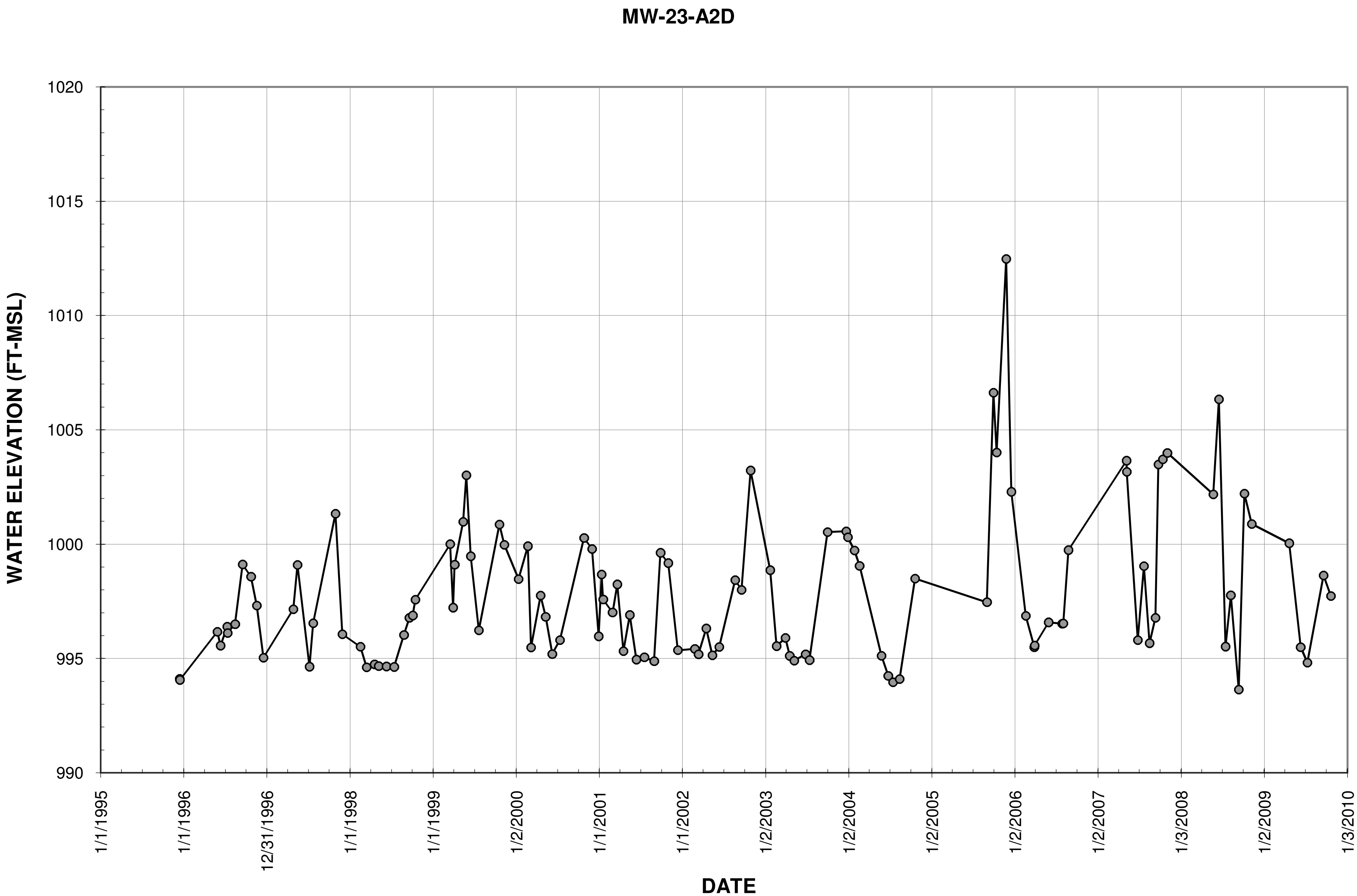


Figure 3.7 Water Level Data for Well MW-23-A2S

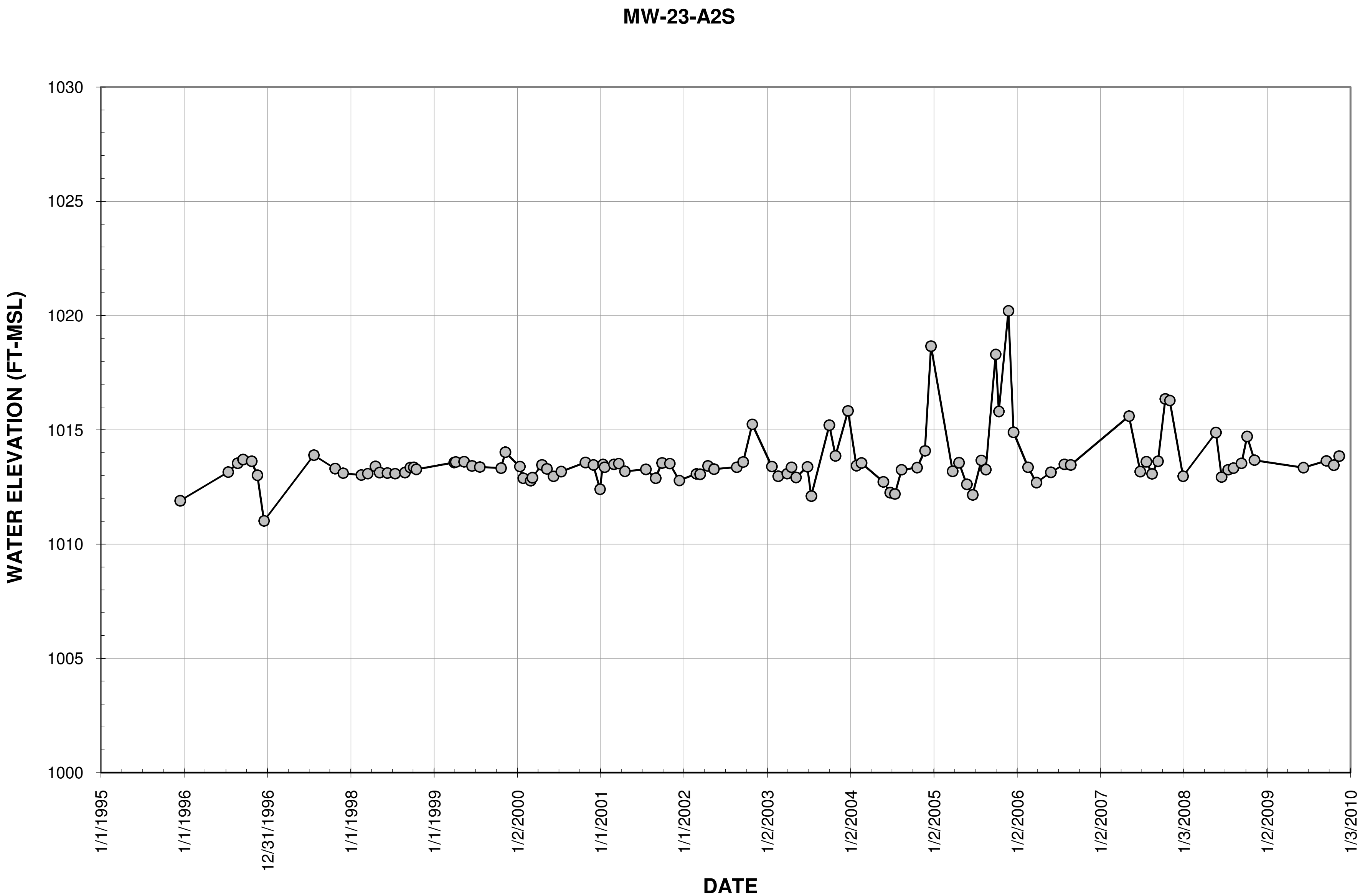


Figure 3.8 Water Level Data for Well MW-23-98-01

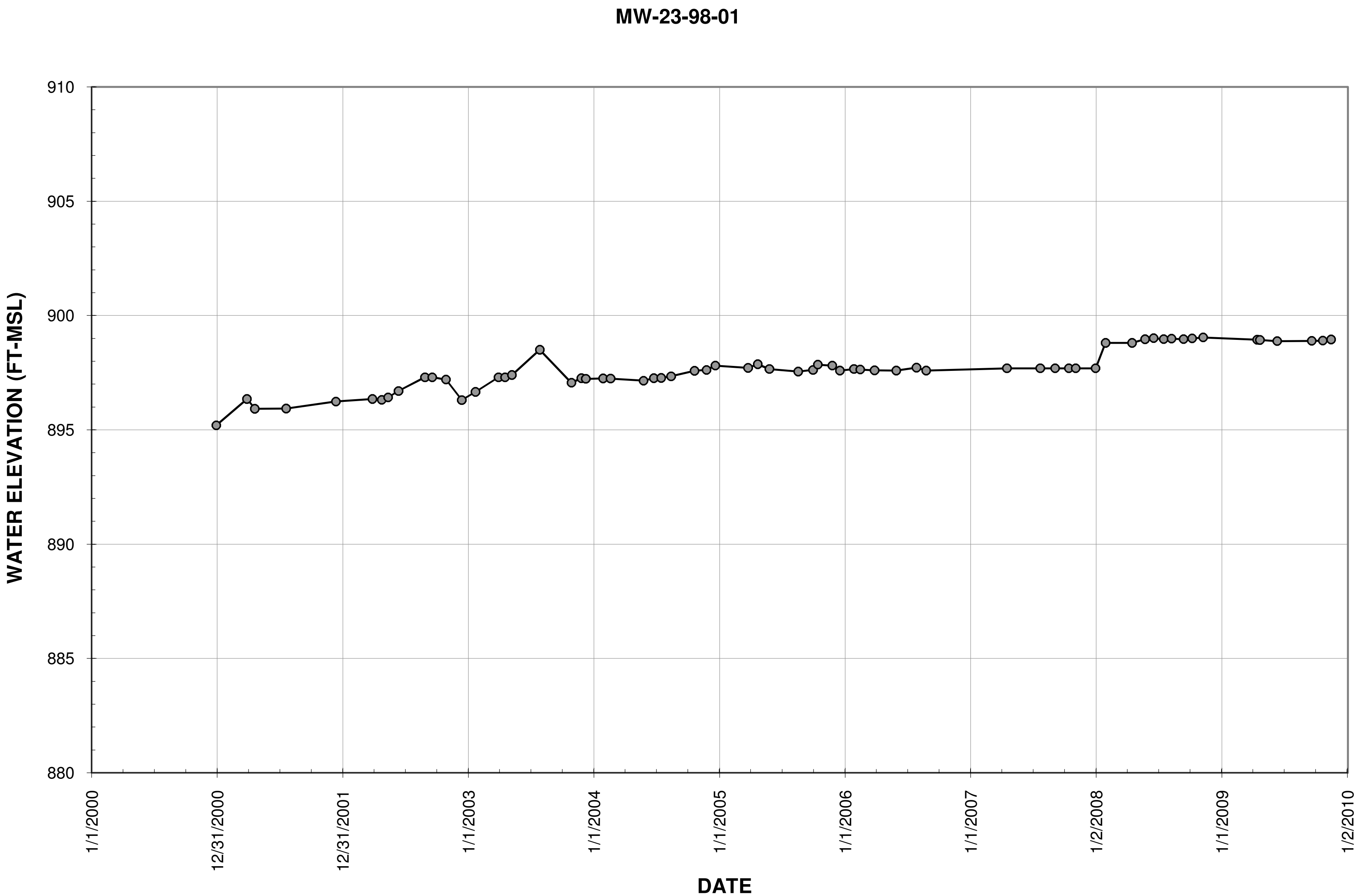


Figure 3.9 Water Level Data for Well MW-23-A4

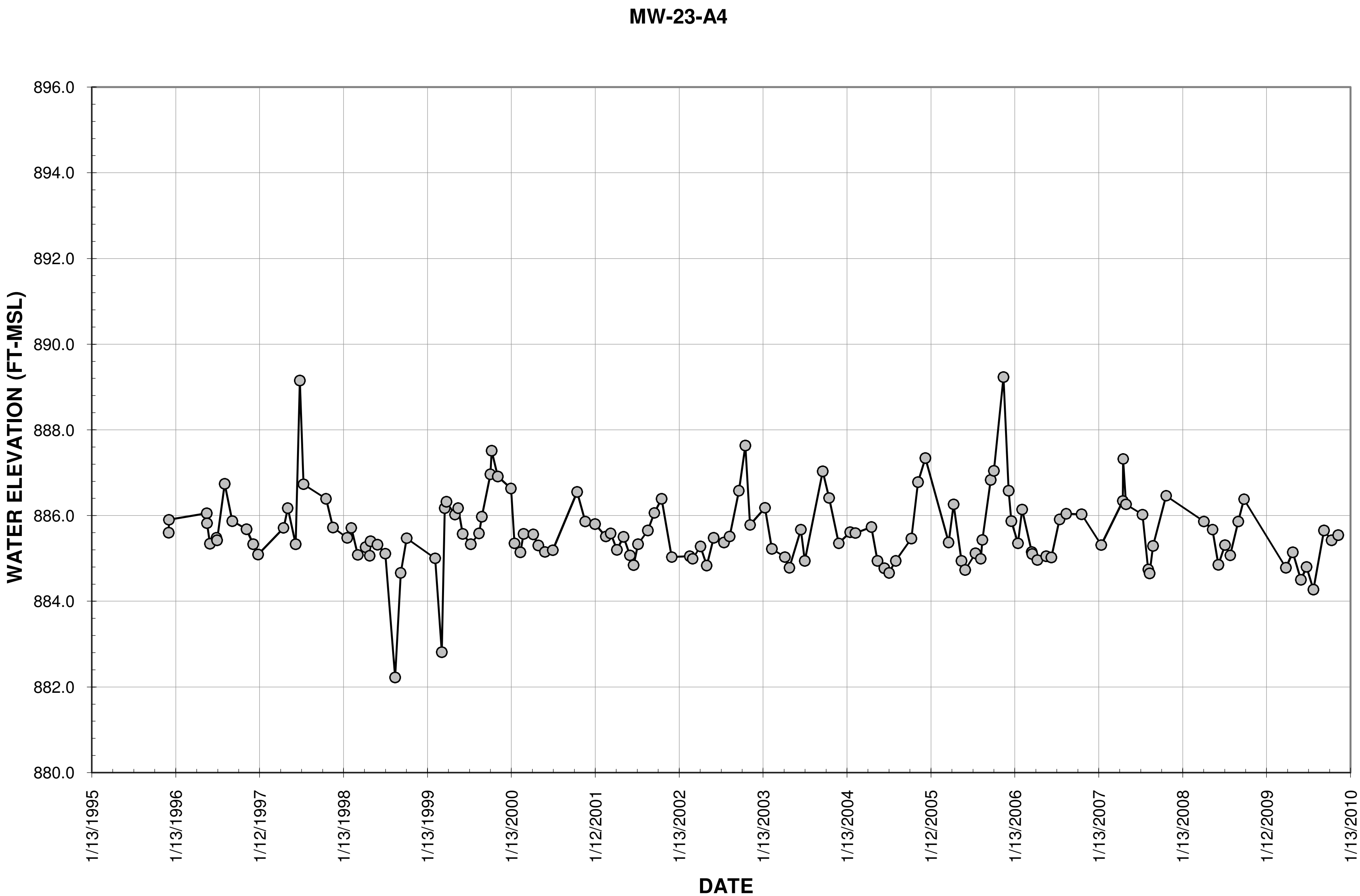


Figure 3.10 Water Level Data for Well MW-23/D-00-01

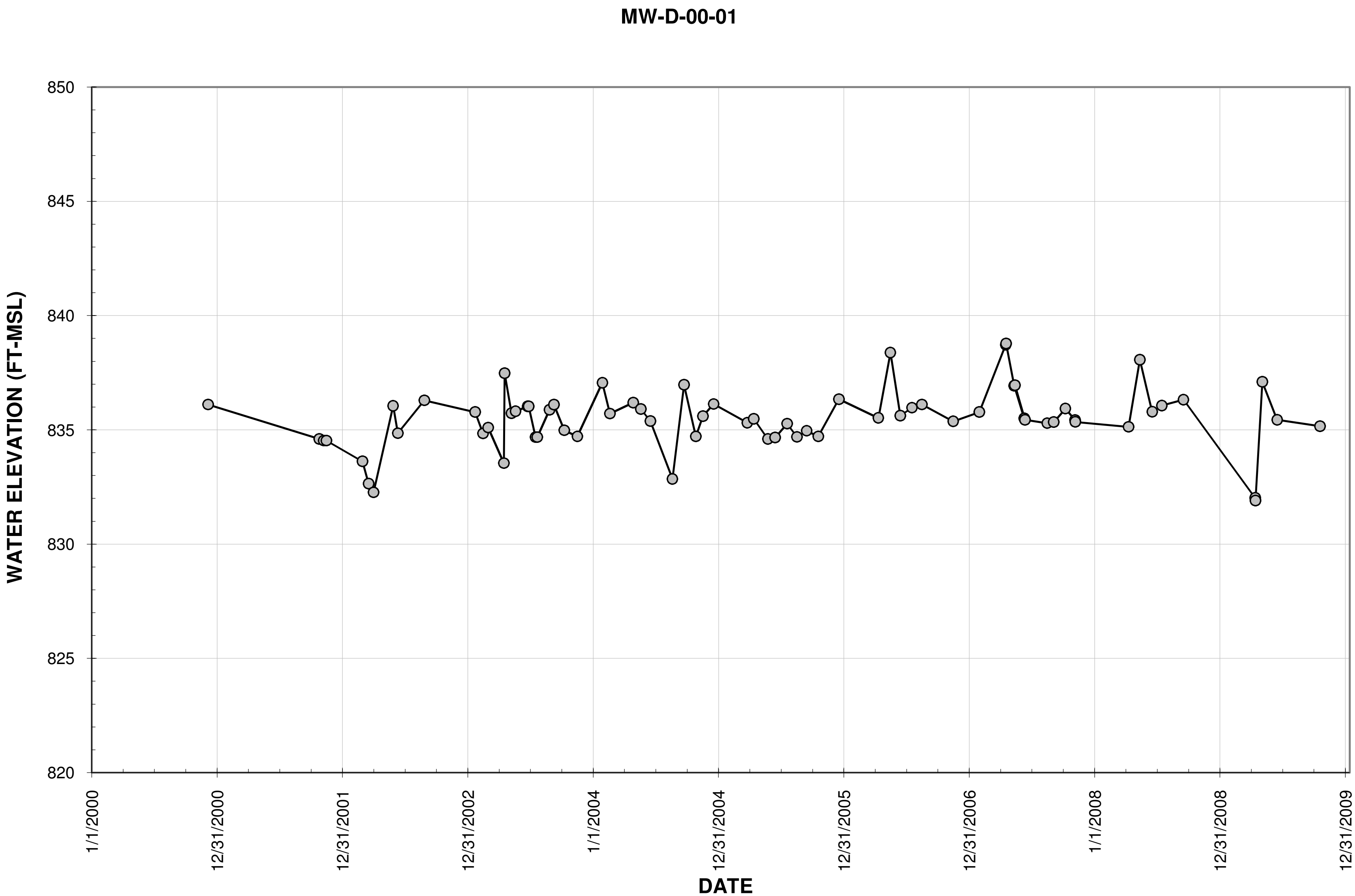


Figure 3.11 Water Level Data for Well MW-D-94-D3

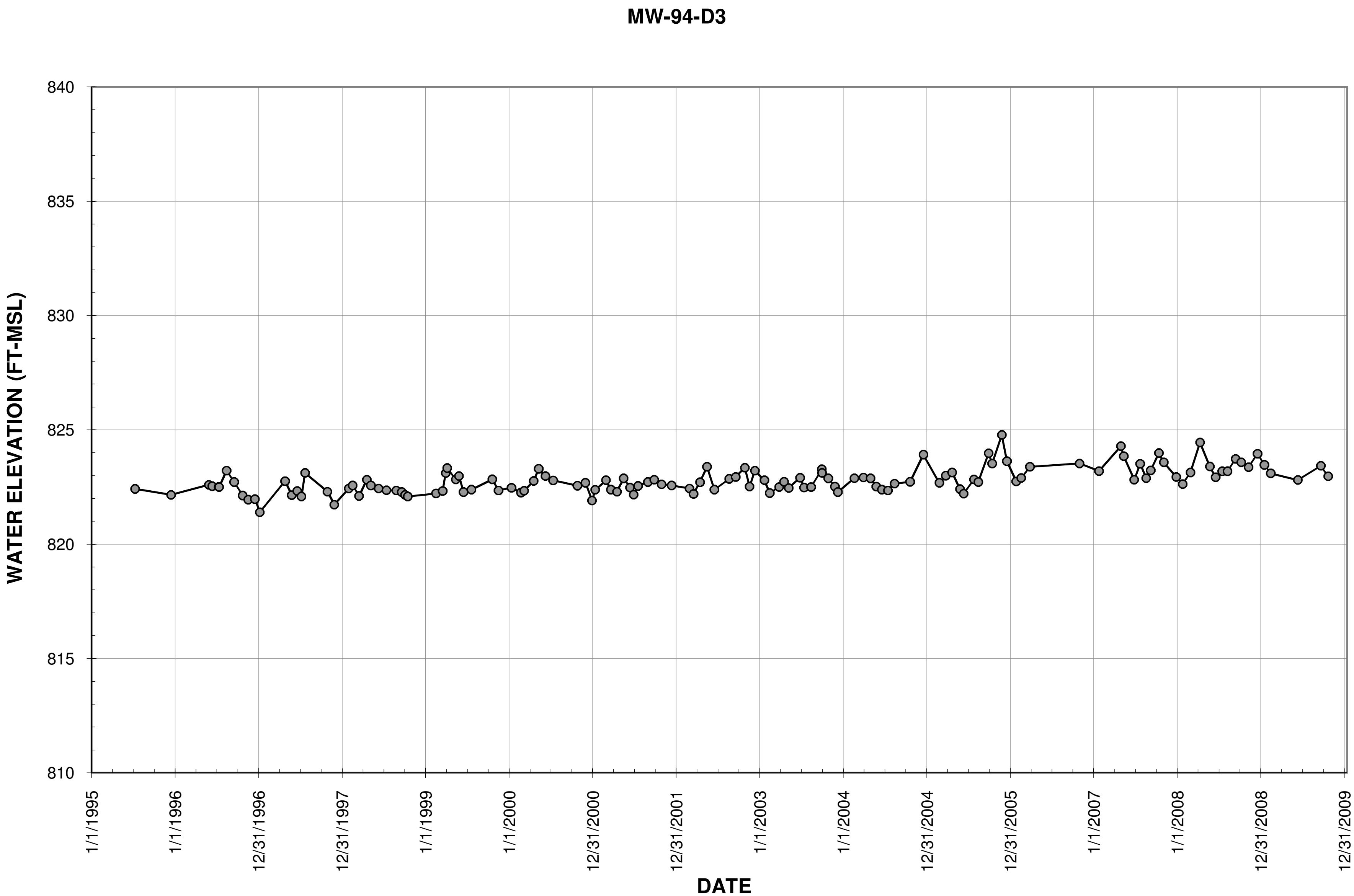


Figure 3.12 Water Level Data for Well MW-D-94-D4

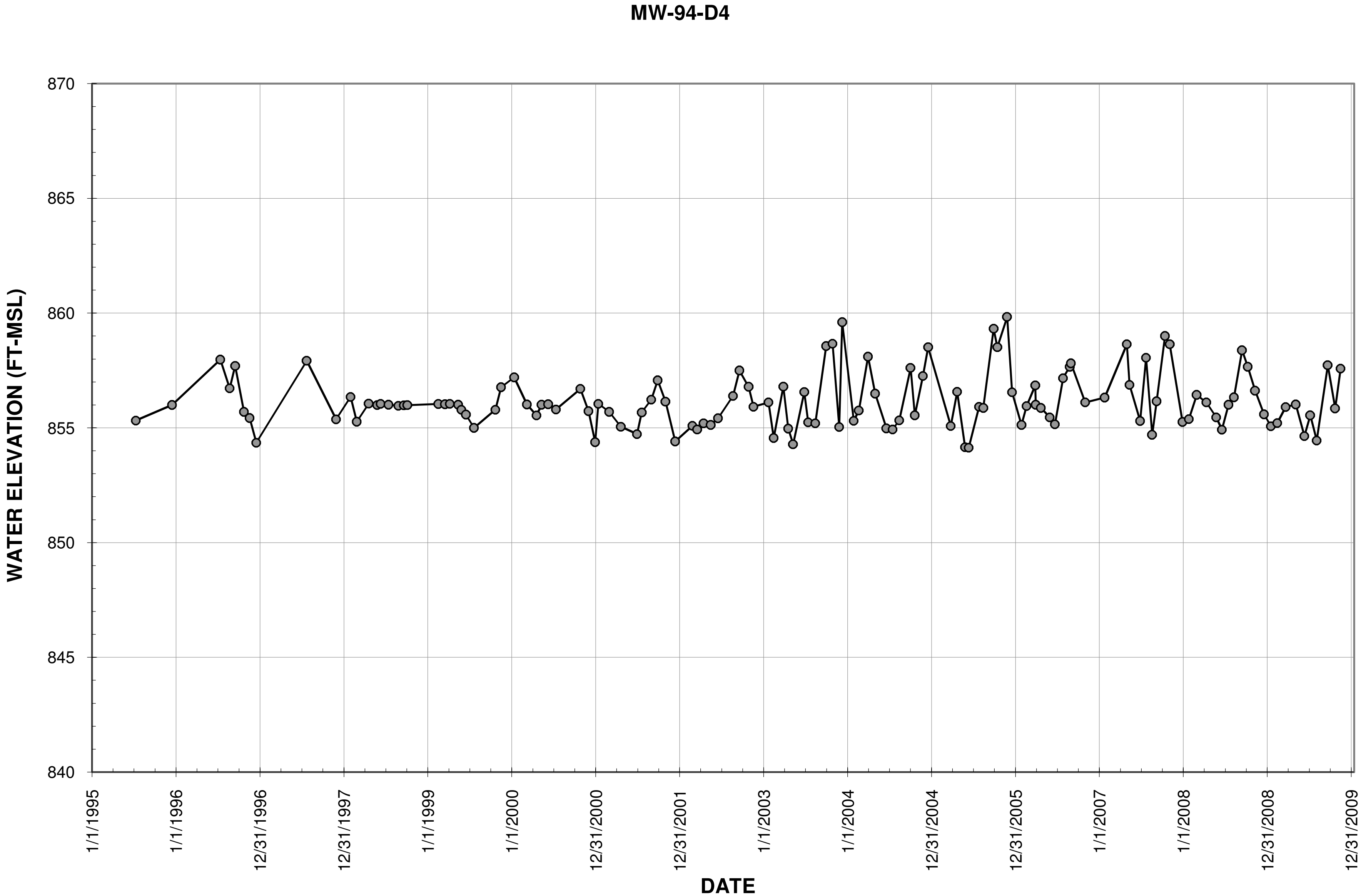


Figure 3.13 Pond D Flow Data

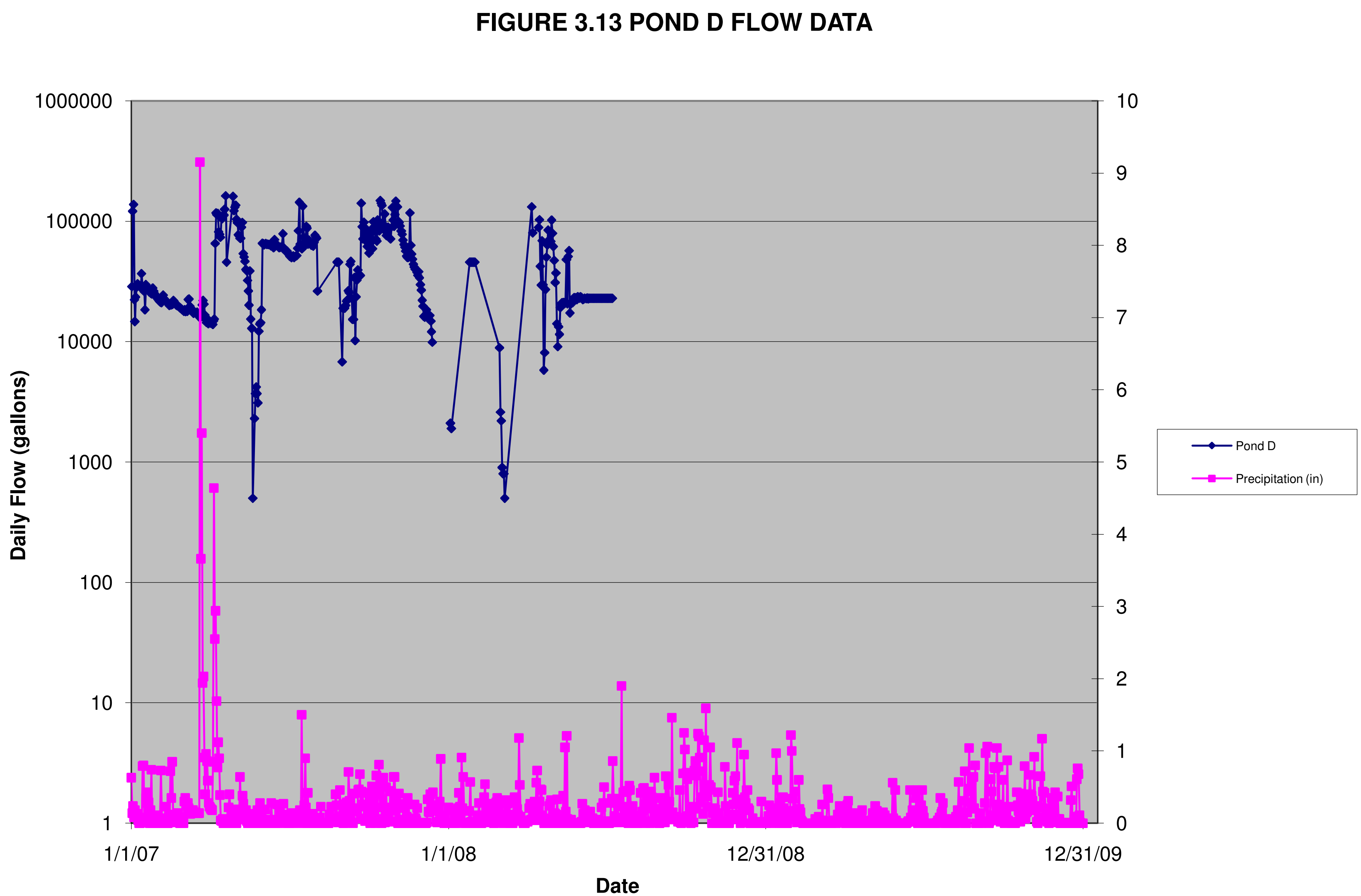


FIGURE 3.14a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - pH DATA

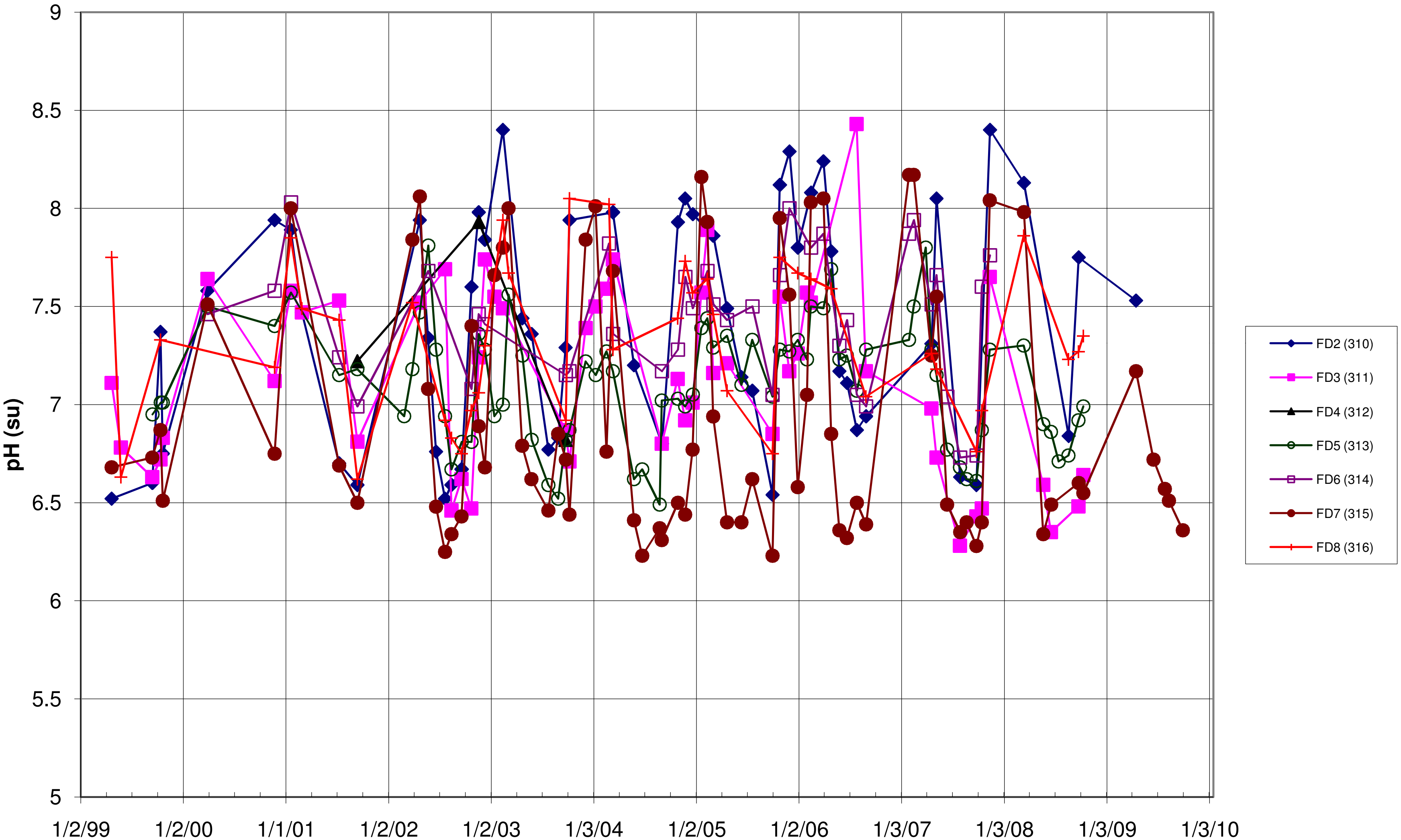


FIGURE 3.14b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - pH DATA

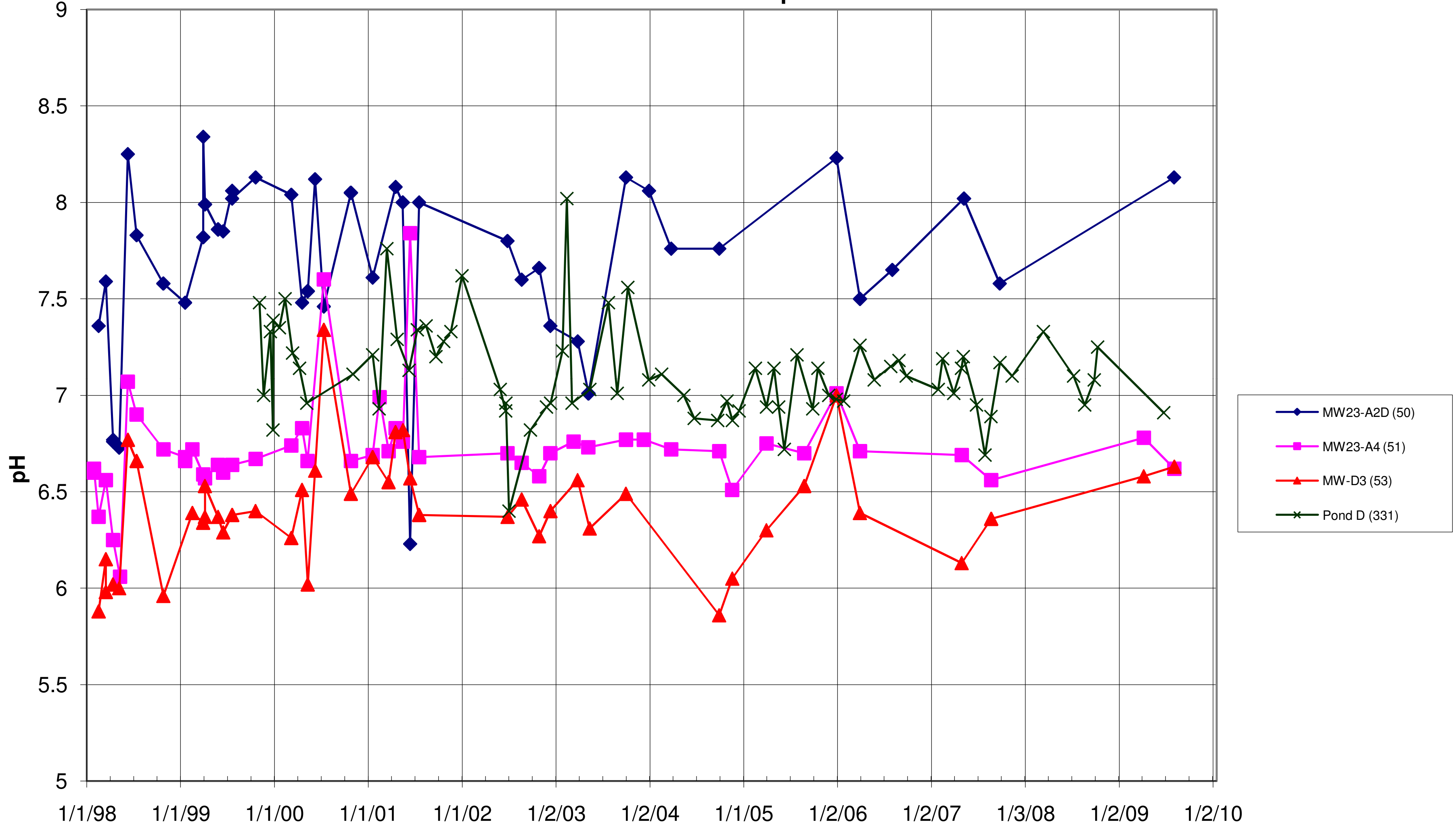


FIGURE 3.15a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - ALKALINITY DATA
(Non-detectable analyses plotted as zero)

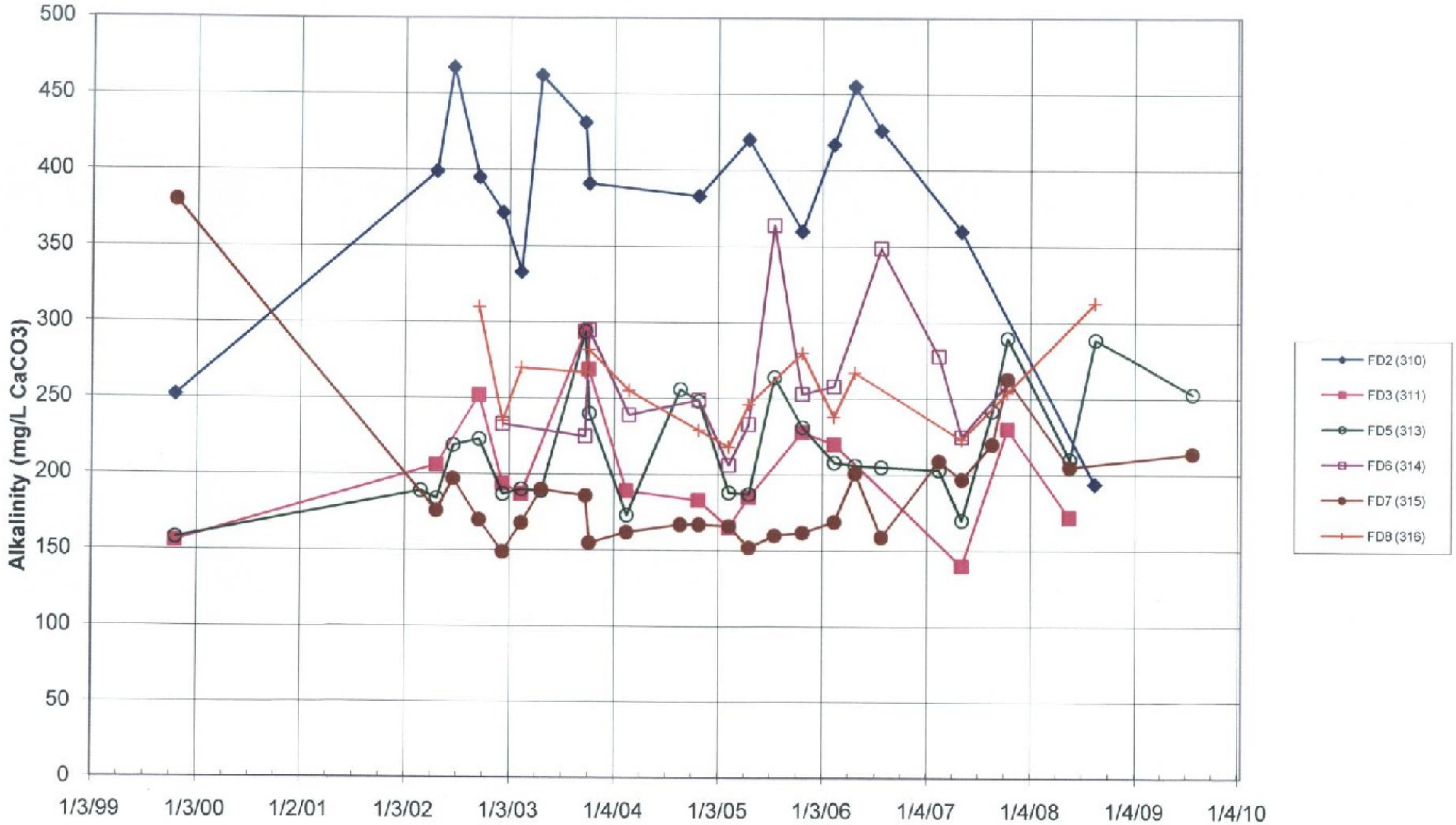


FIGURE 3.15b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: GROUND WATER - ALKALINITY DATA (Non-detectable analyses plotted as zero)

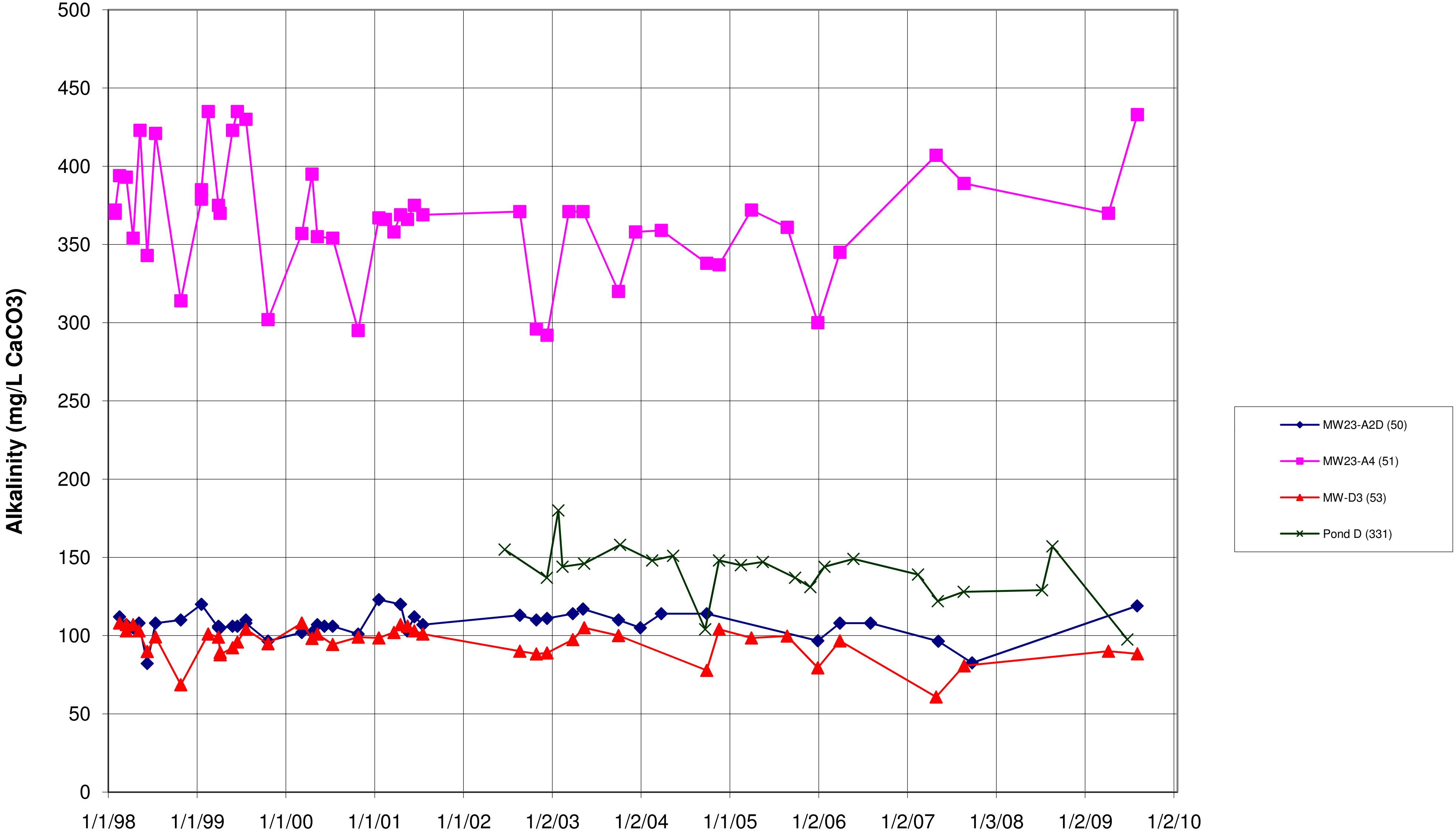


FIGURE 3.16a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: FINGER DRAINS - HARDNESS DATA
(Non-detectable analyses plotted as zero)

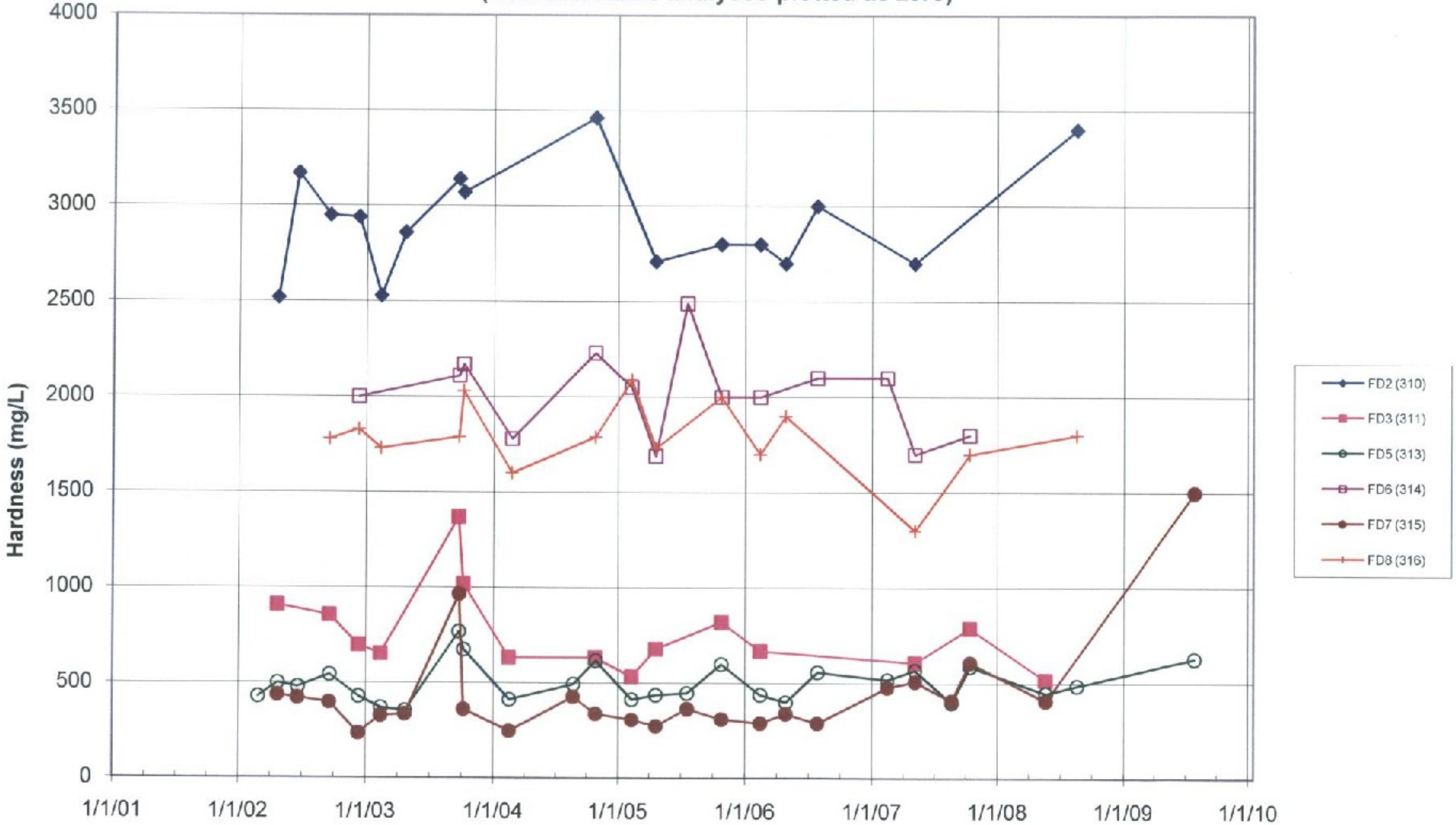


FIGURE 3.16b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: GROUND WATER - HARDNESS DATA
(Non-detectable analyses plotted as zero)

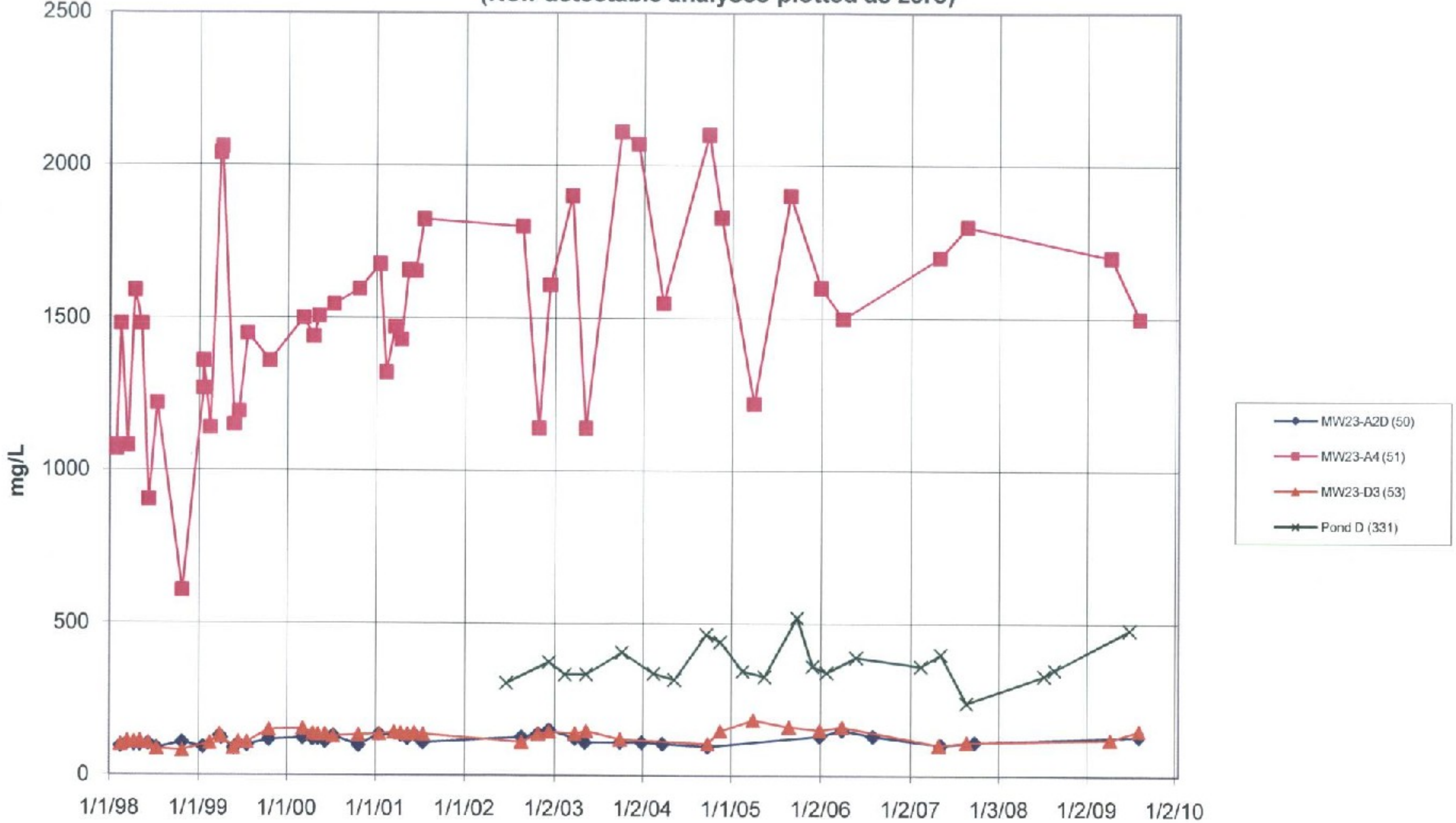
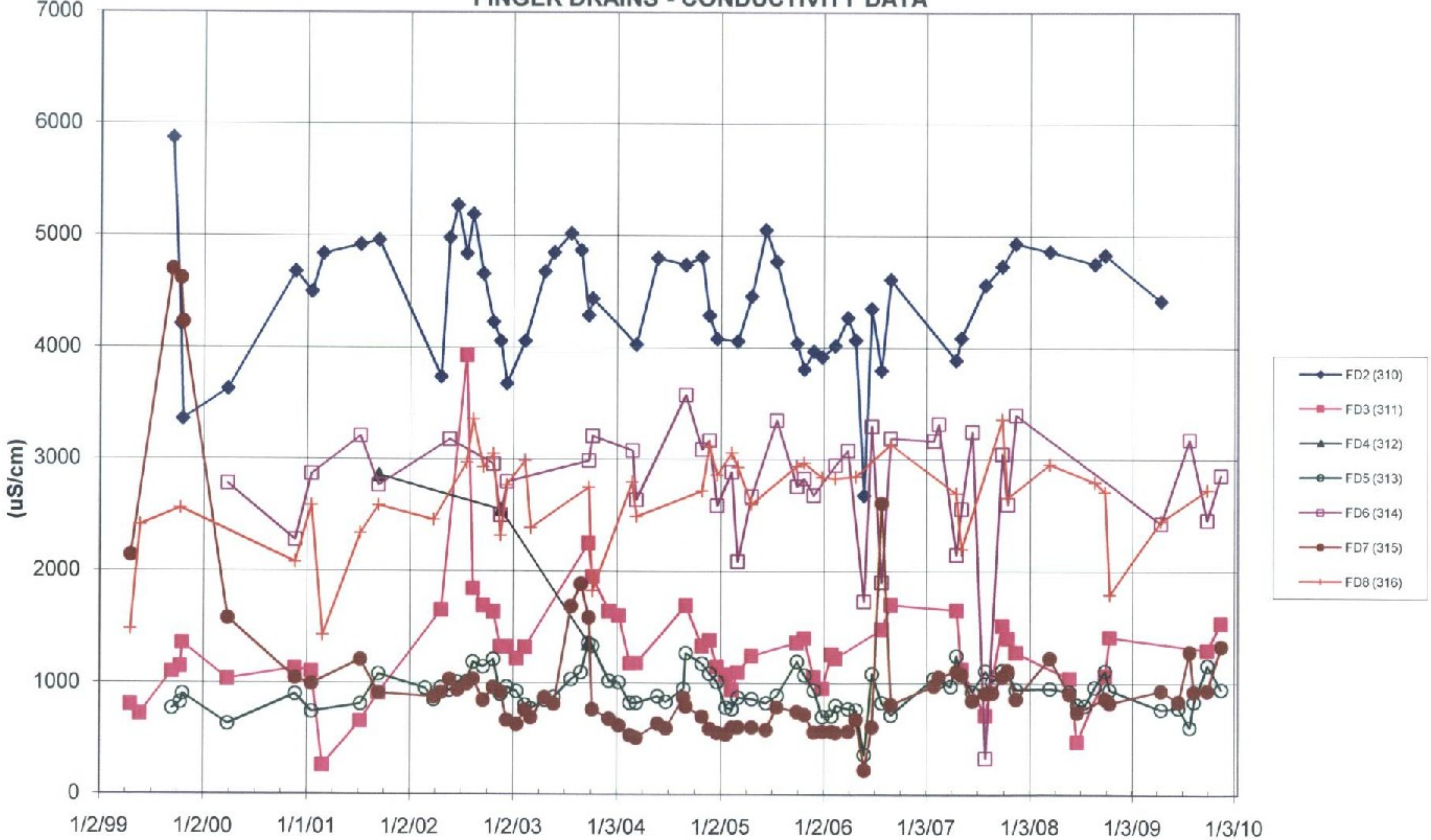


FIGURE 3.17a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: FINGER DRAINS - CONDUCTIVITY DATA



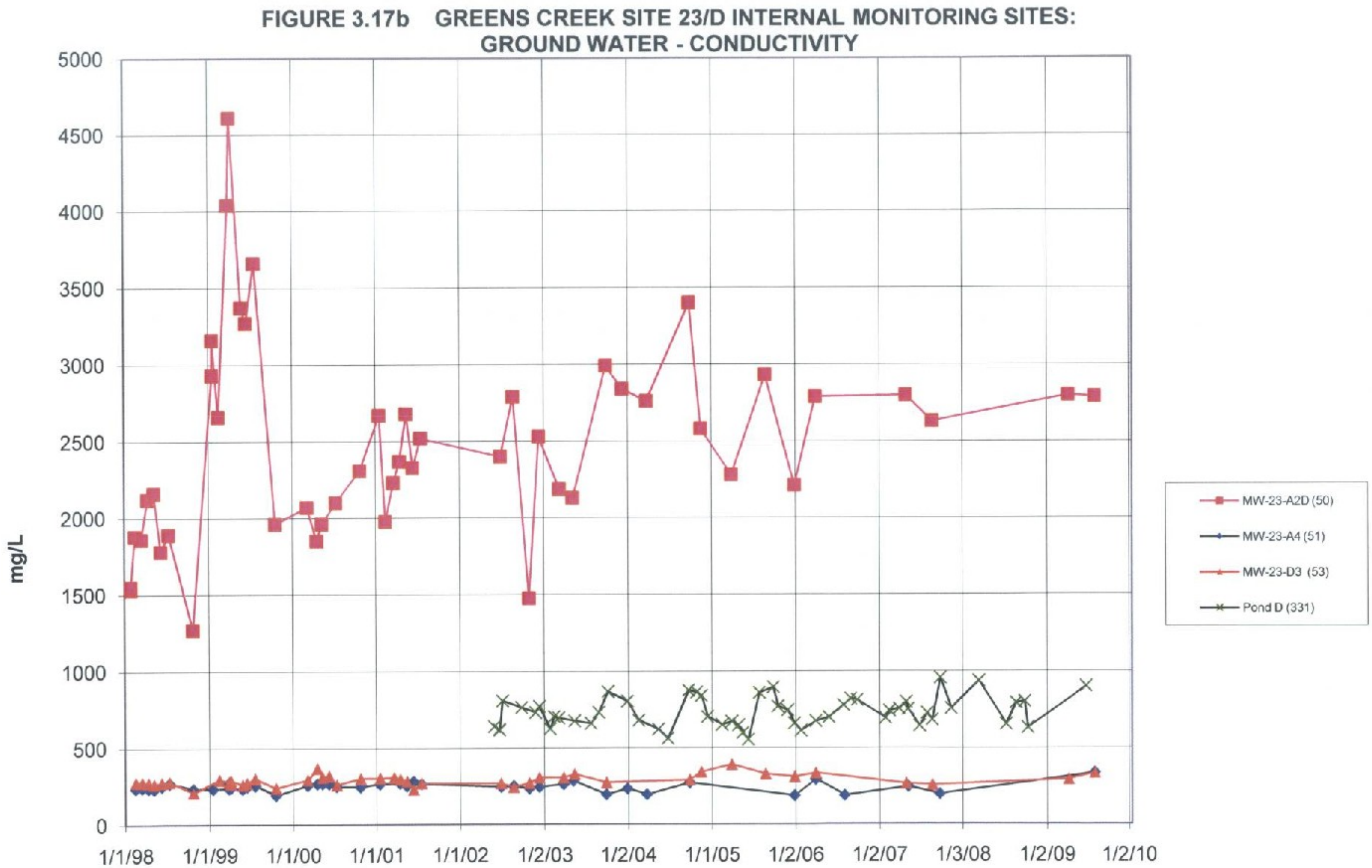


FIGURE 3.17b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - CONDUCTIVITY
mg/L
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1/1/98
1/1/99
1/1/00
1/1/01
1/1/02
1/2/03
1/2/04
1/1/05
1/2/06
1/2/07
1/3/08
1/2/09
1/2/10
MW-23-A2D (50)
MW-23-A4 (51)
MW-23-D3 (53)
Pond D (331)

FIGURE 3.18a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: FINGER DRAINS - SULFATE DATA (Non-detectable analyses plotted as zero)

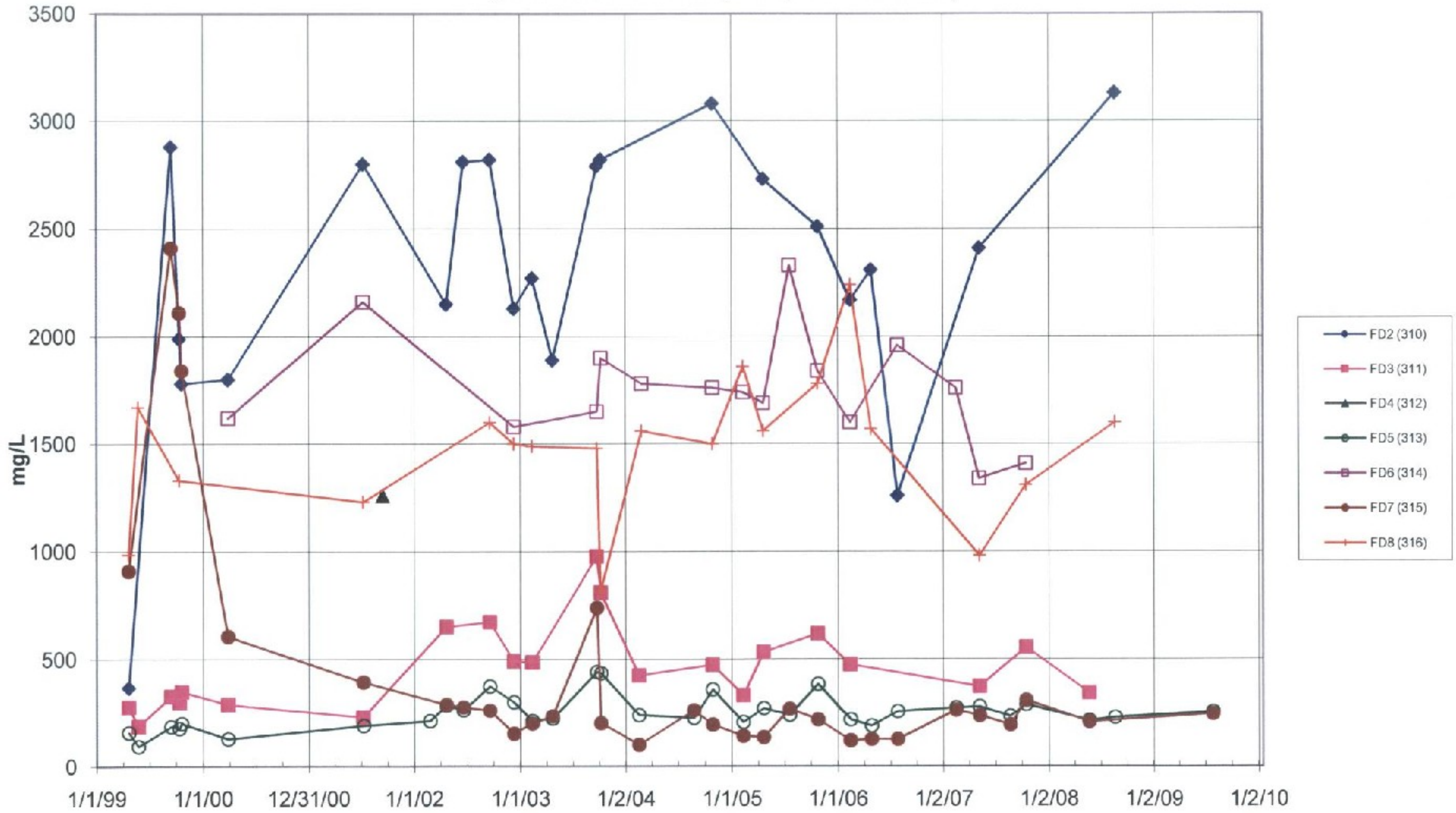


FIGURE 3.18b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - SULFATE
(Non-detectable analyses plotted as zero) (8/5/09, 3160)

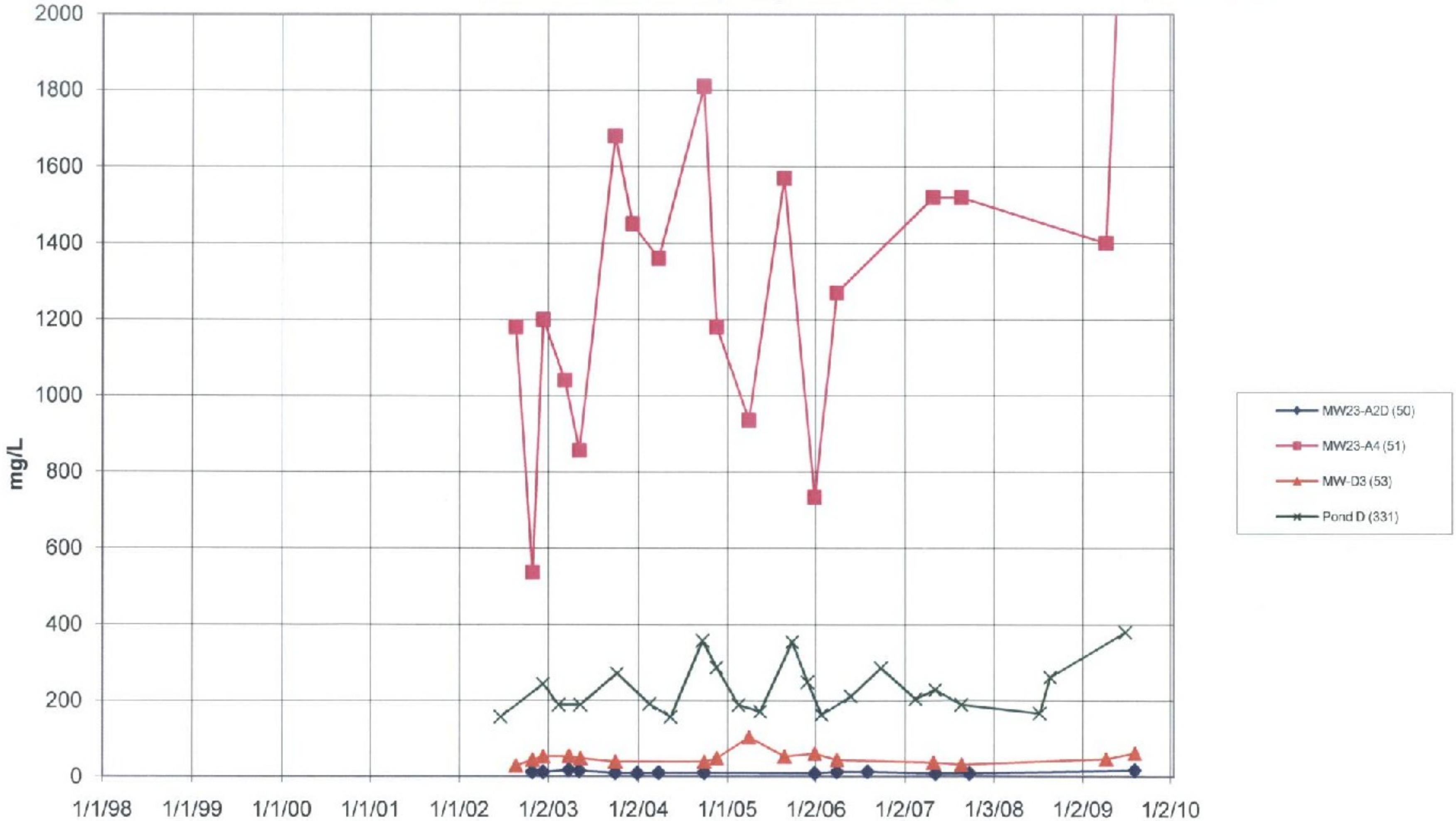


FIGURE 3.19a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: FINGER DRAINS - ARSENIC DATA
(Non-detectable analyses plotted as zero)

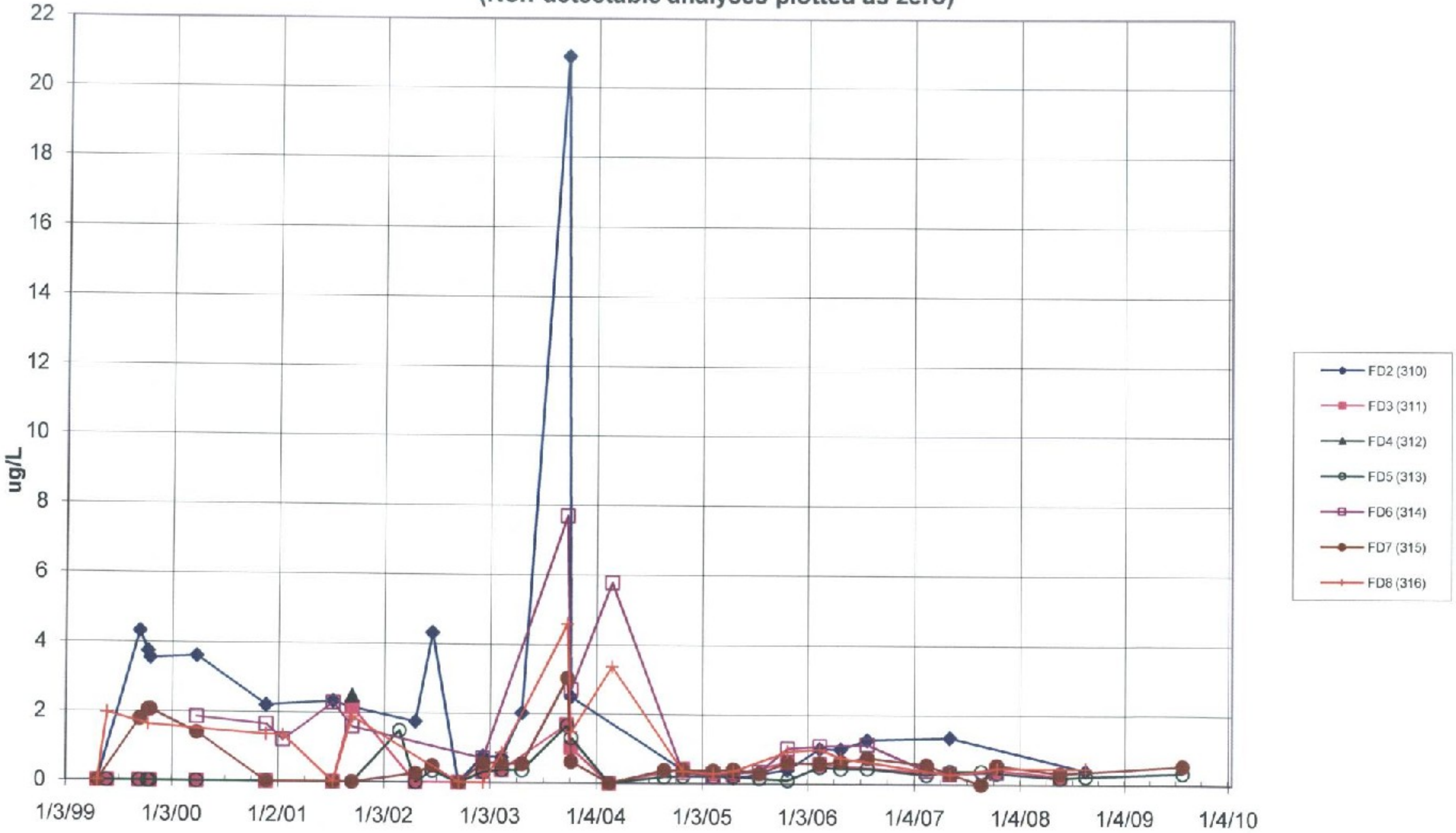
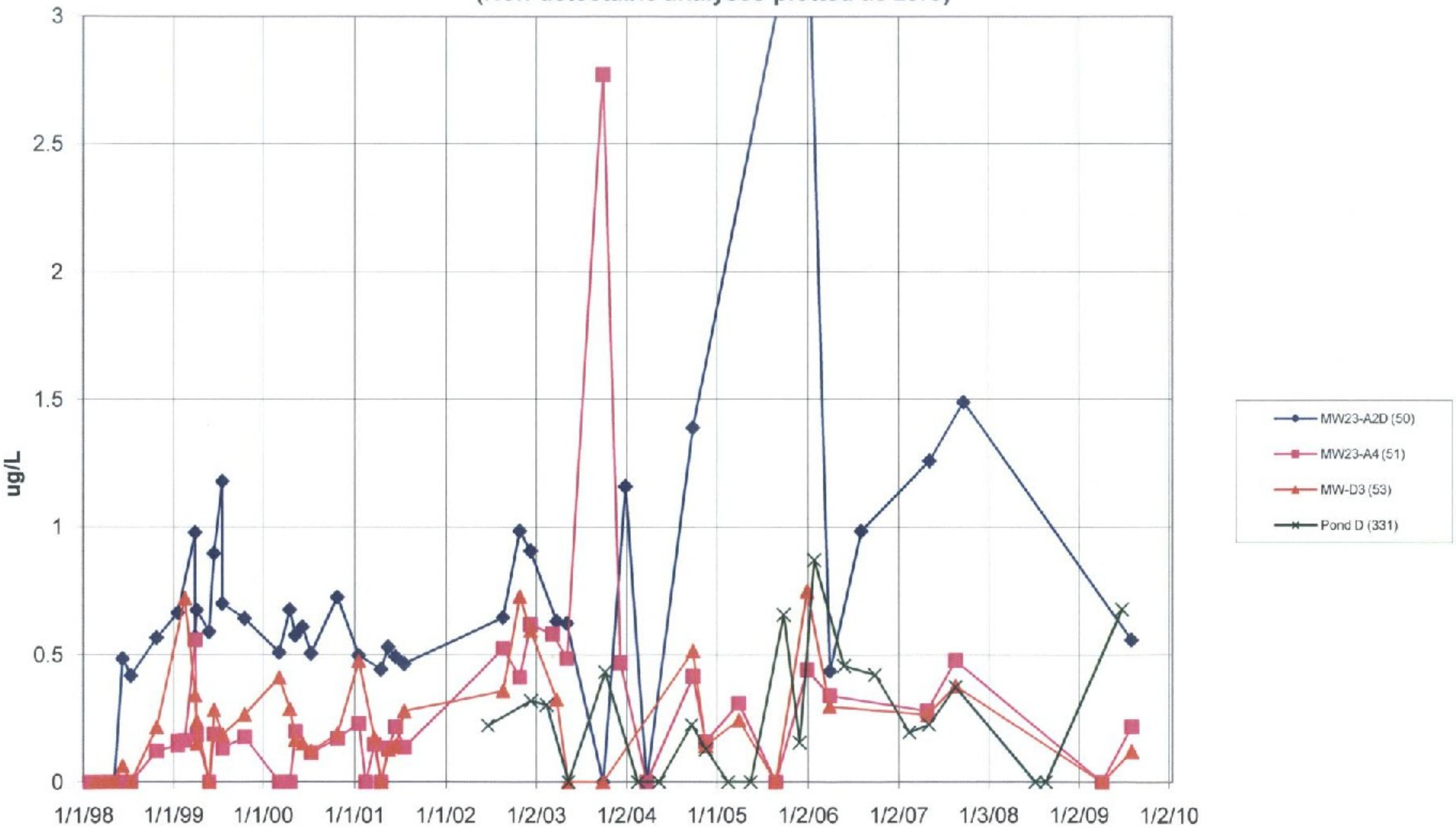


FIGURE 3.19b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: GROUND WATER - ARSENIC DATA (Non-detectable analyses plotted as zero)



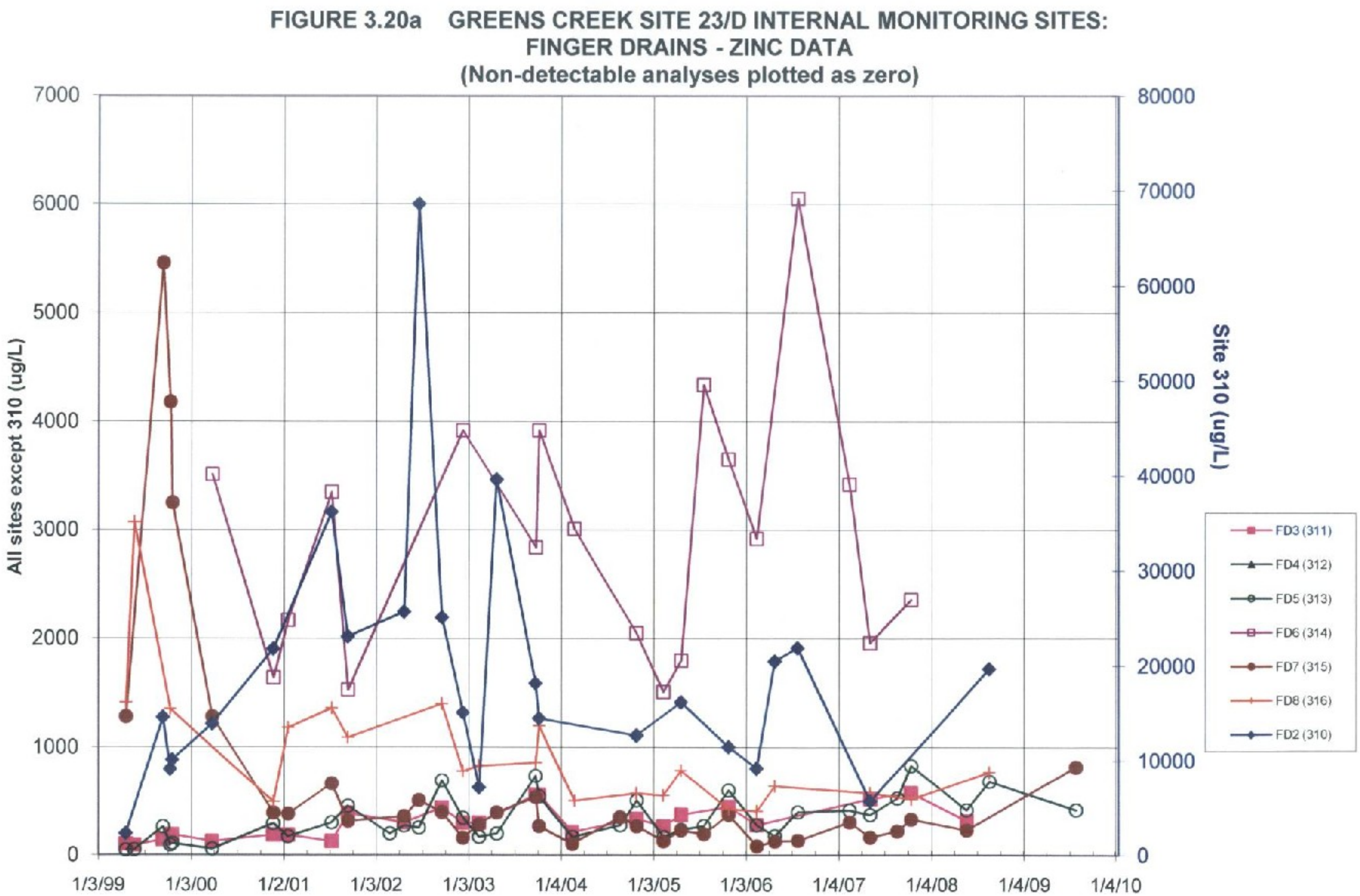


FIGURE 3.20a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - ZINC DATA
(Non-detectable analyses plotted as zero)
All sites except 310 (ug/L)
Site 310 (ug/L)
7000
6000
5000
4000
3000
2000
1000
0
80000
70000
60000
50000
40000
30000
20000
10000
0
1/3/99
1/3/00
1/2/01
1/3/02
1/3/03
1/4/04
1/3/05
1/3/06
1/4/07
1/4/08
1/4/09
1/4/10
FD3 (311)
FD4 (312)
FD5 (313)
FD6 (314)
FD7 (315)
FD8 (316)
FD2 (310)

FIGURE 3.20b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: GROUND WATER - ZINC DATA (Non-detectable analyses plotted as zero)

(6/25/09, 980)

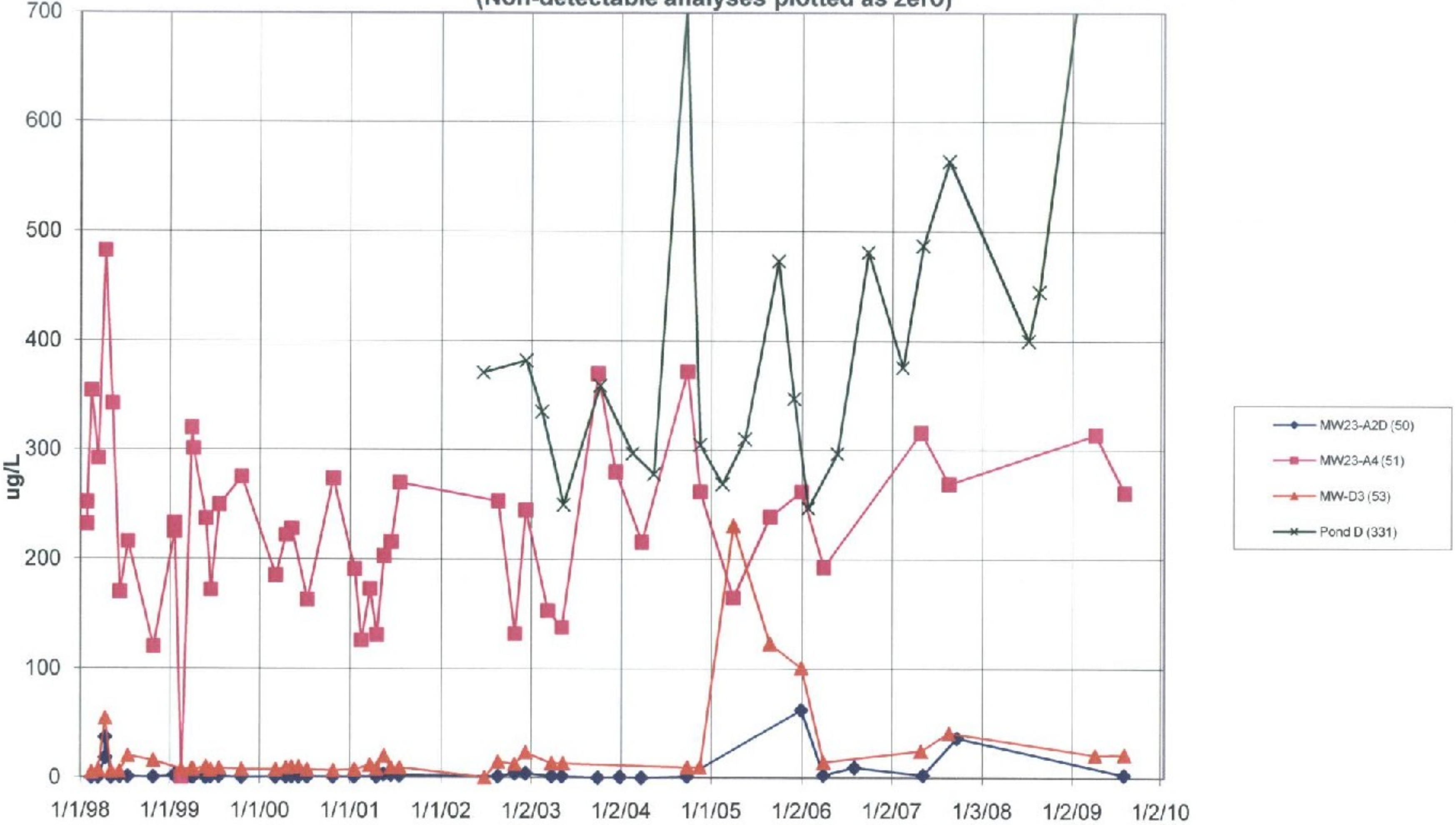


FIGURE 3.21a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: FINGER DRAINS - CADMIUM DATA
(Non-detectable analyses plotted as zero)

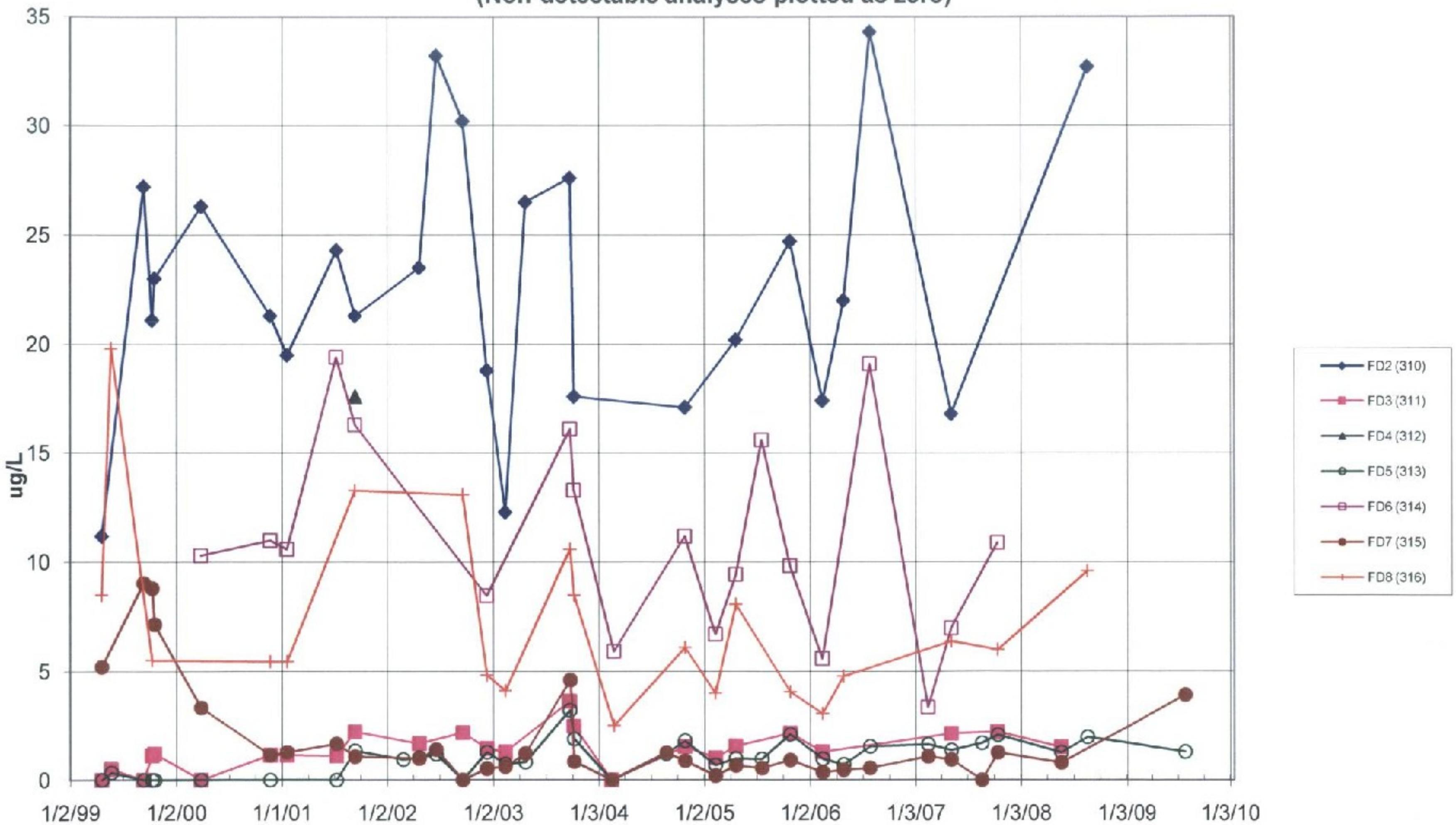


FIGURE 3.21b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: GROUND WATER - CADMIUM DATA (Non-detectable analyses plotted as zero)

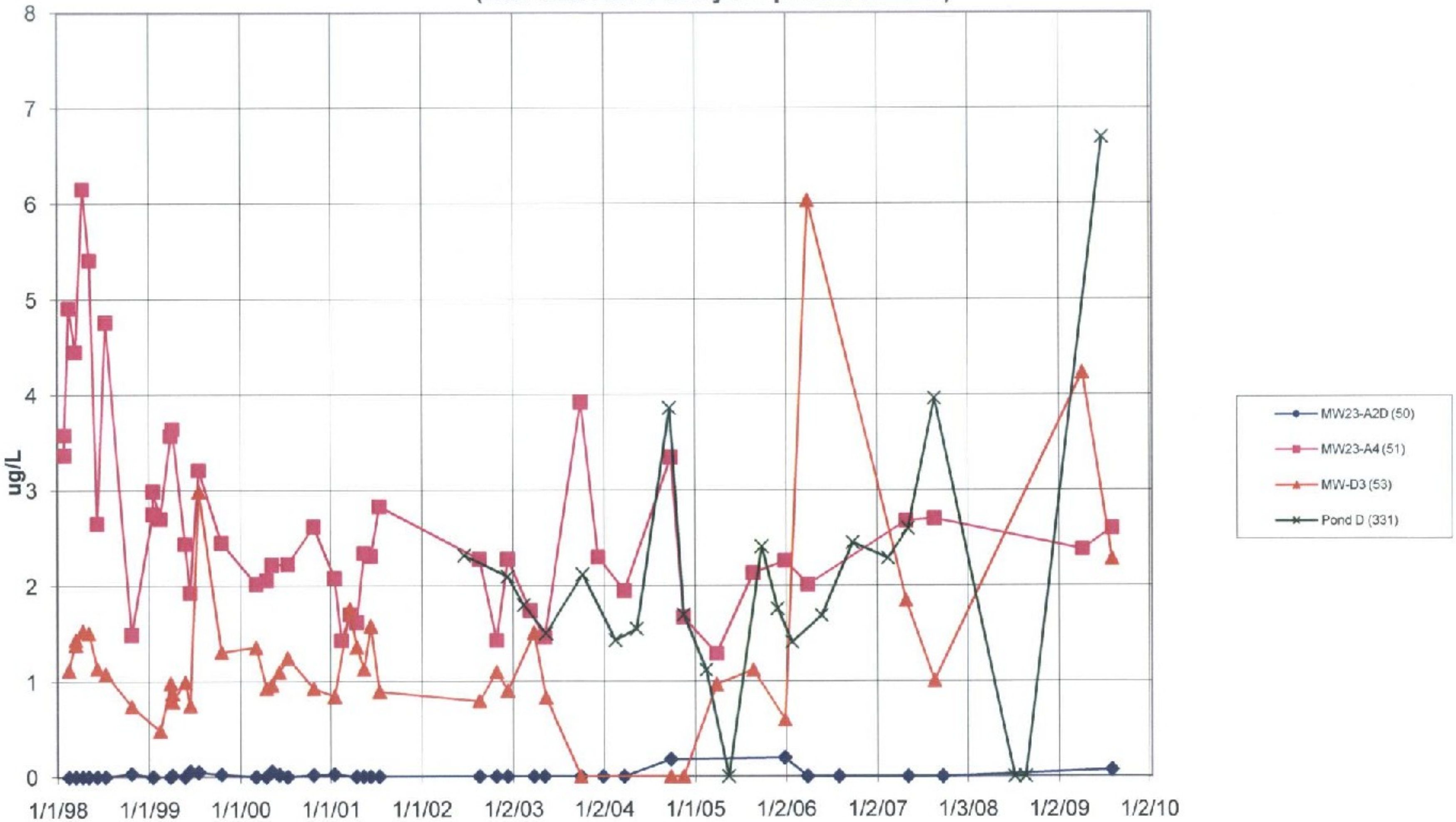


FIGURE 3.22a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: FINGER DRAINS - COPPER DATA (Non-detectable analyses plotted as zero)

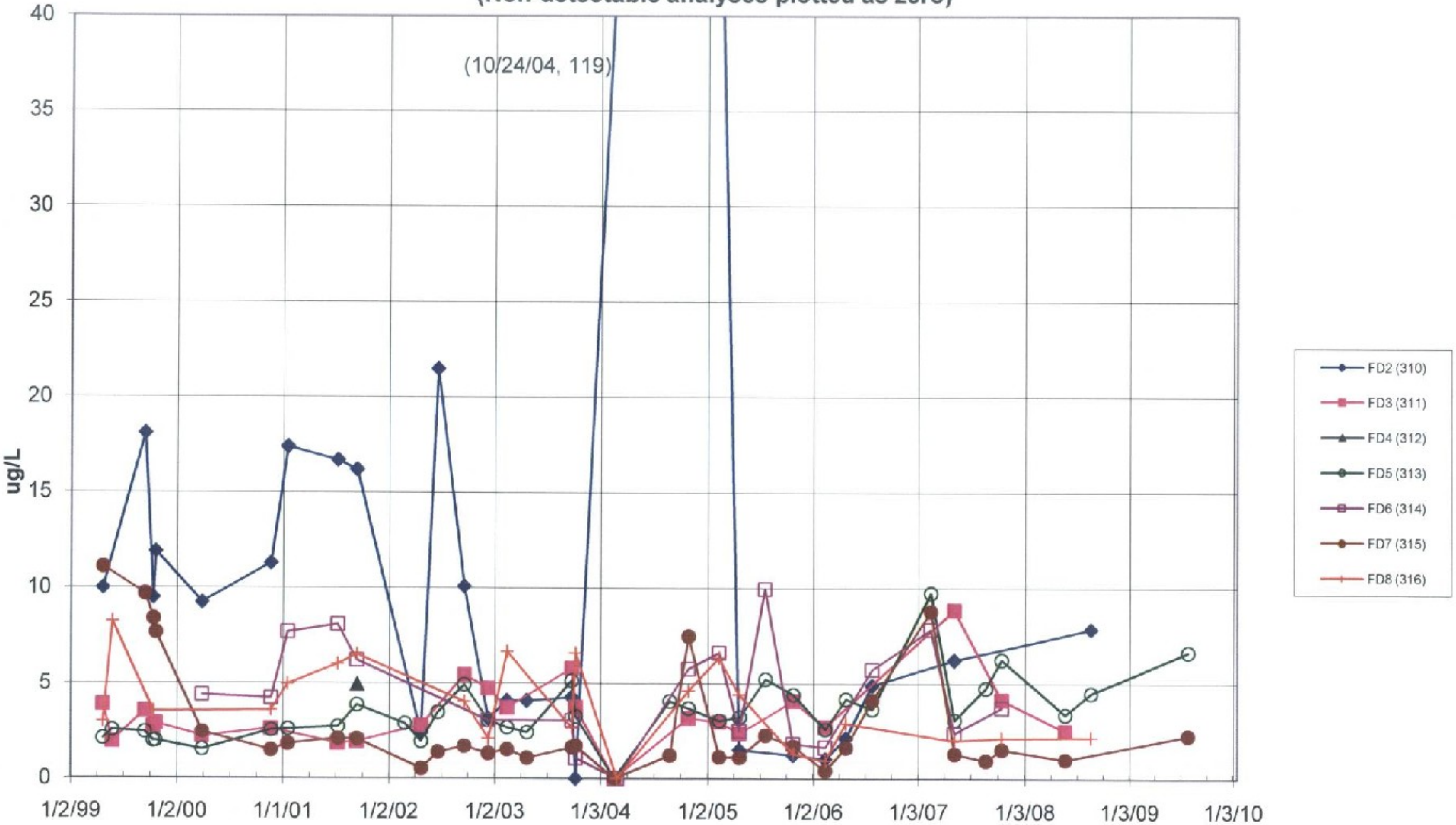


FIGURE 3.22b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: GROUND WATER - COPPER DATA
(Non-detectable analyses plotted as zero)

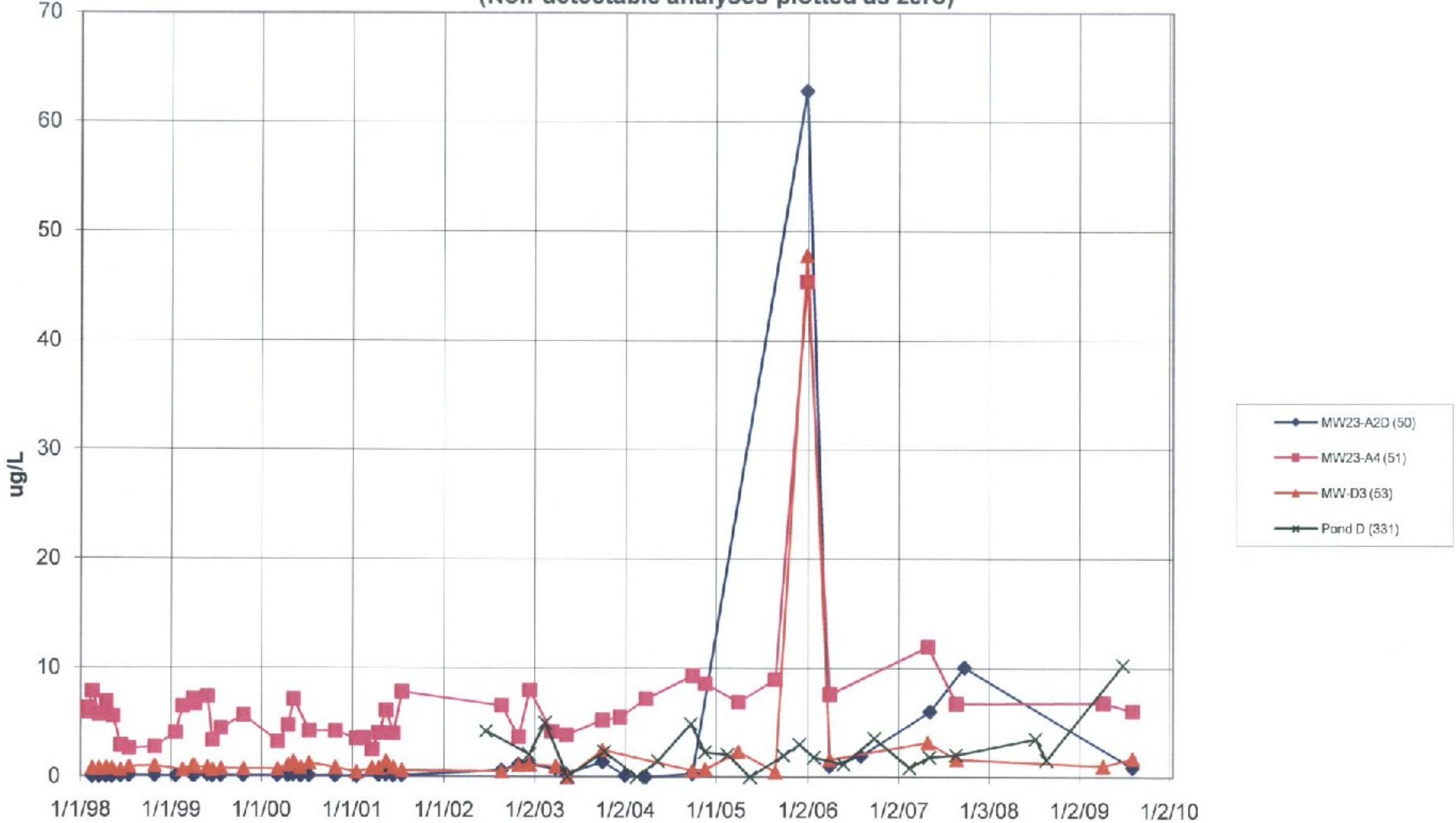


FIGURE 3.23a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - LEAD DATA
(Non-detectable analyses plotted as zero)

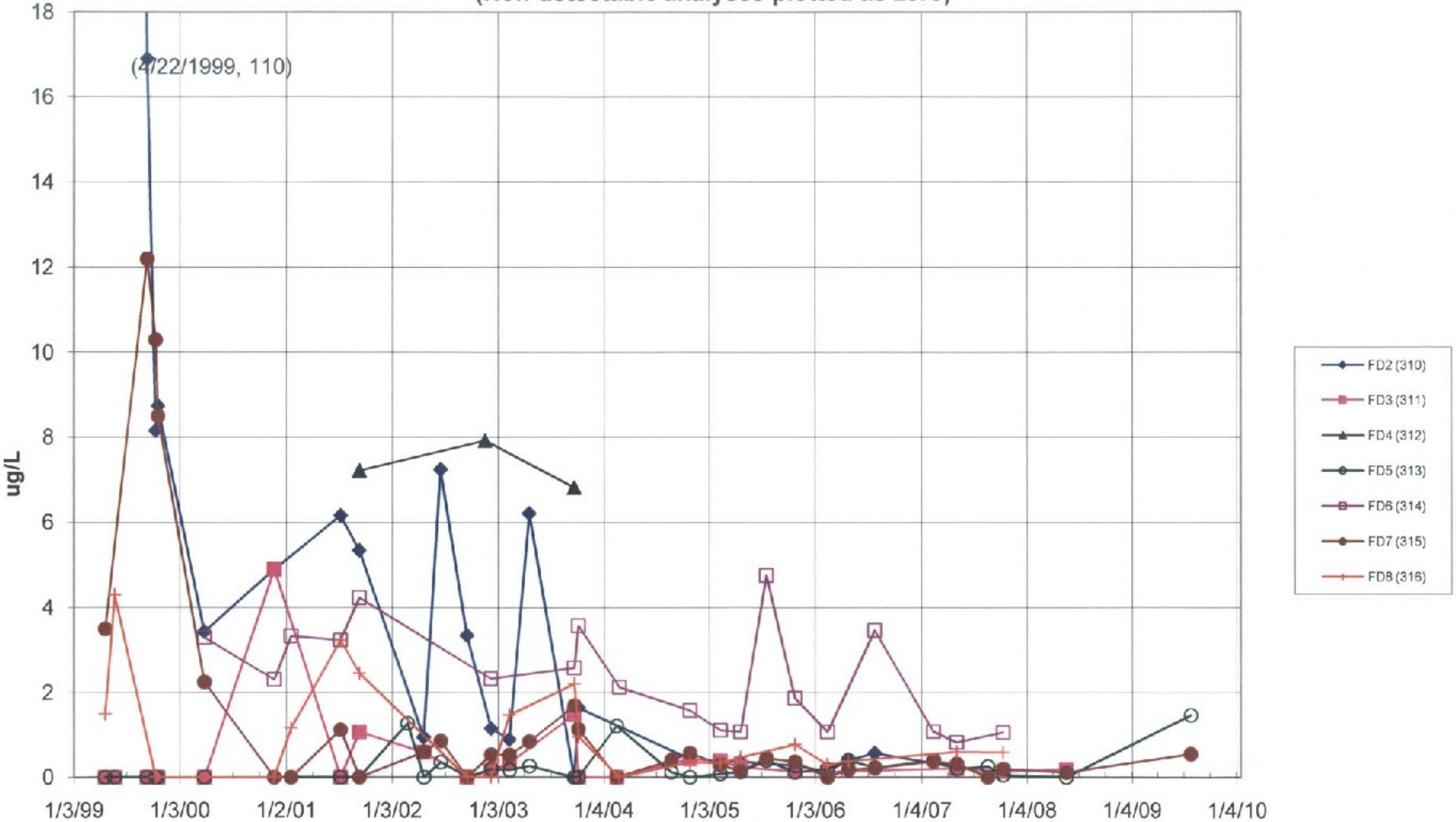


FIGURE 3.23b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: GROUND WATER - LEAD DATA
(Non-detectable analyses plotted as zero)

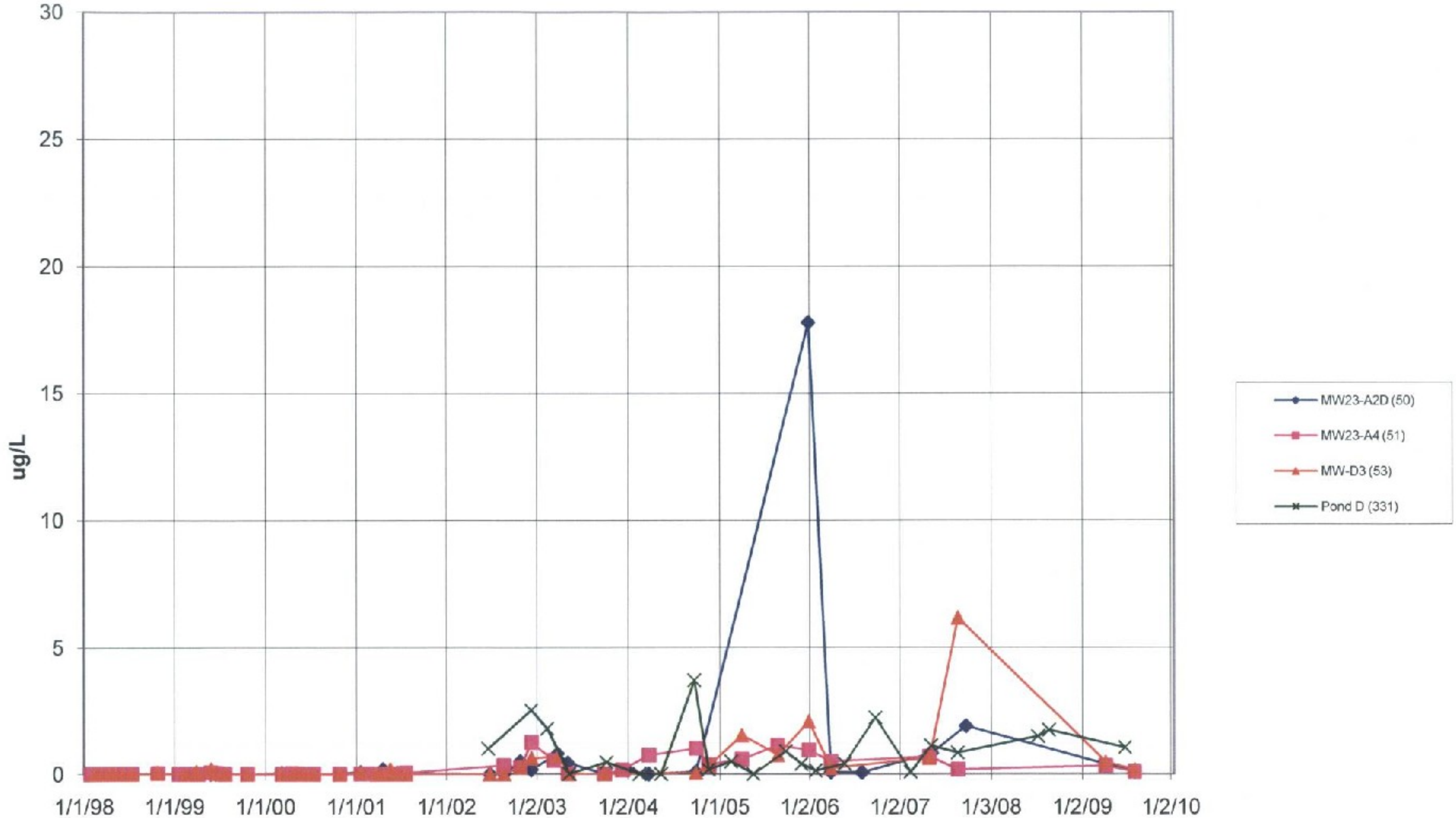


FIGURE 3.24a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - NICKEL DATA
(Non-detectable analyses plotted as zero)

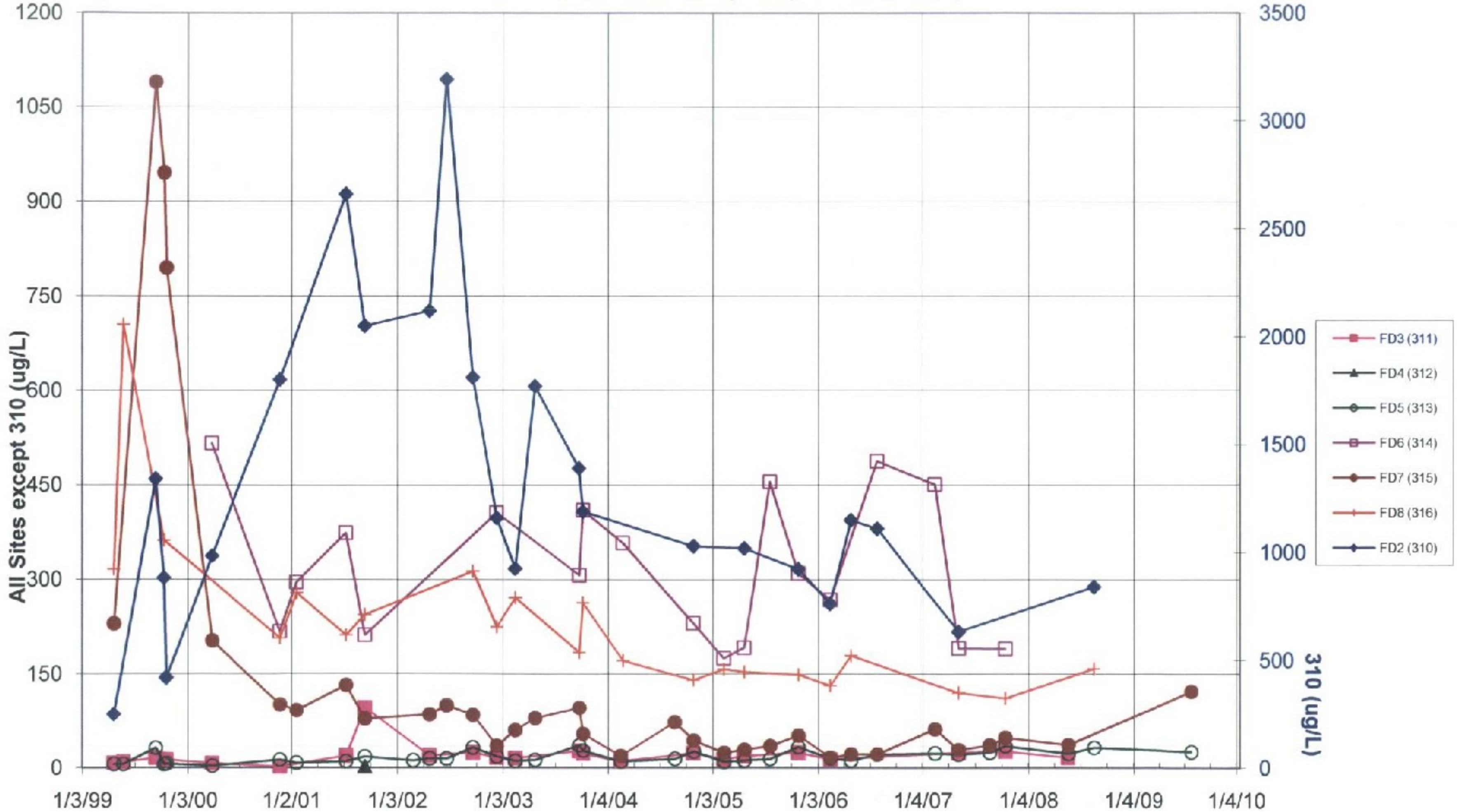


FIGURE 3.24b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: GROUND WATER - NICKEL DATA (Non-detectable analyses plotted as zero)

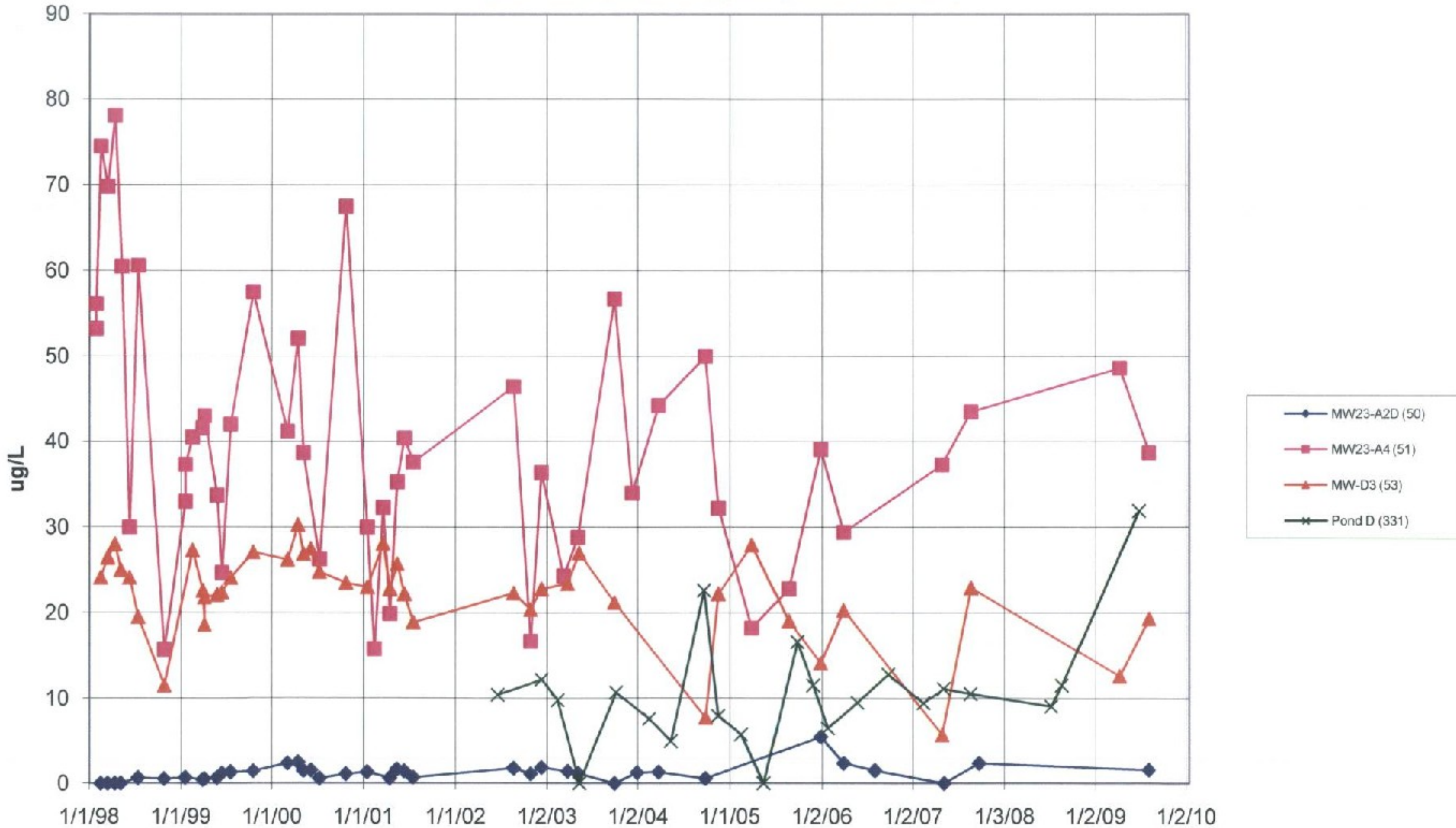


FIGURE 3.25a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: FINGER DRAINS - IRON DATA (Non-detectable analyses plotted as zero)

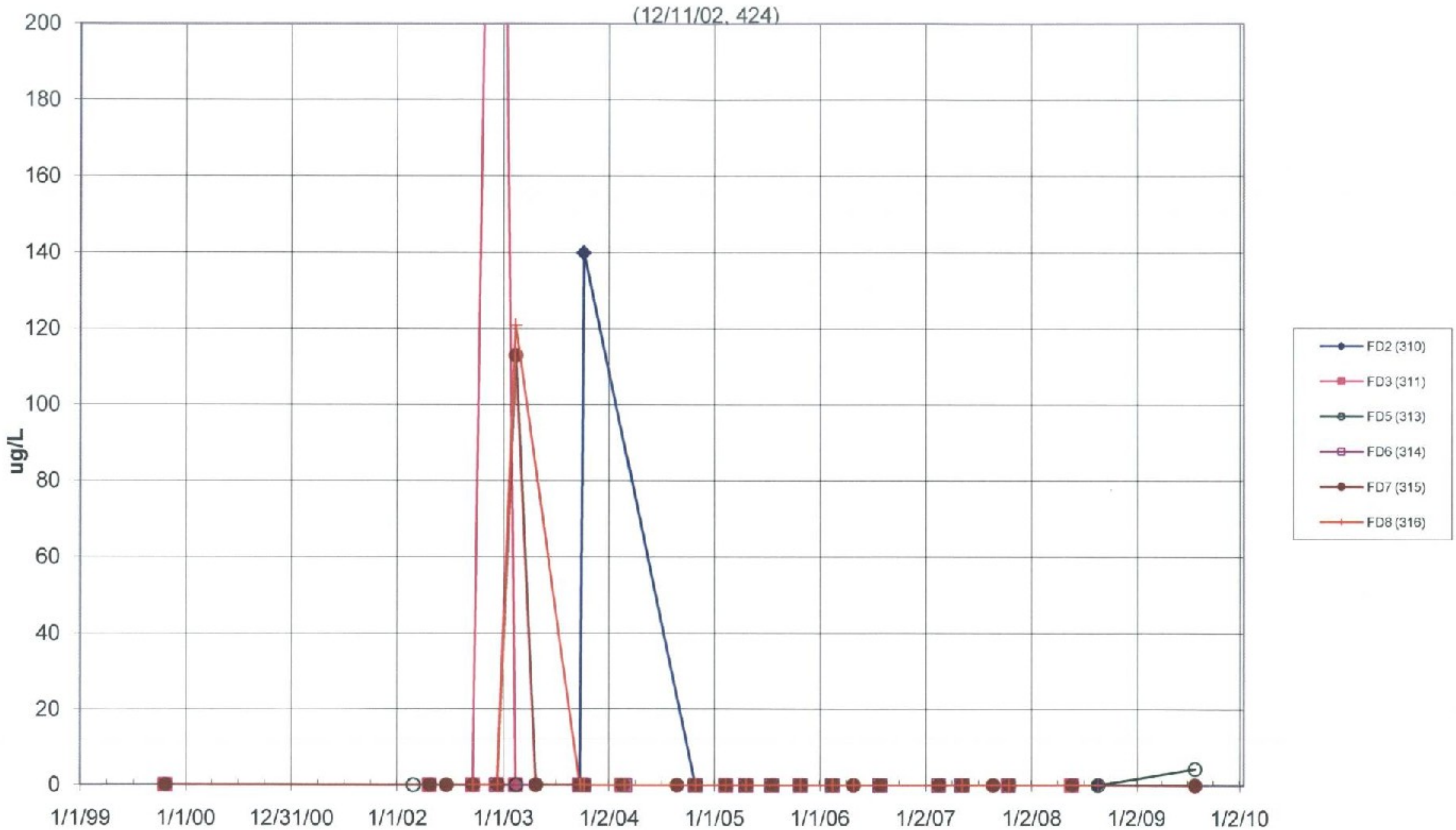


FIGURE 3.25b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: GROUND WATER - IRON DATA
(Non-detectable analyses plotted as zero)

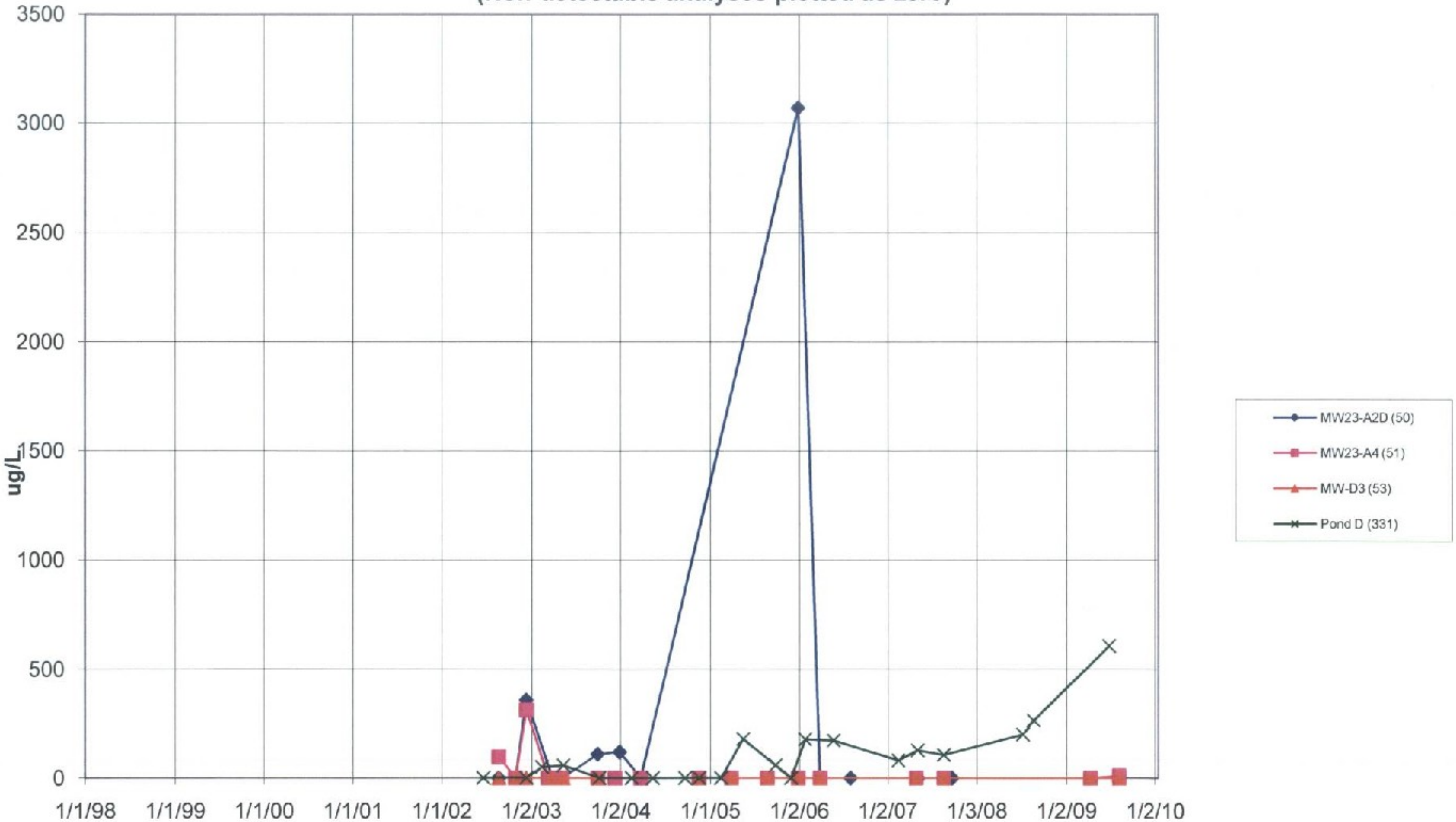


FIGURE 3.26a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: FINGER DRAINS - MANGANESE DATA (Non-detectable analyses plotted as zero)

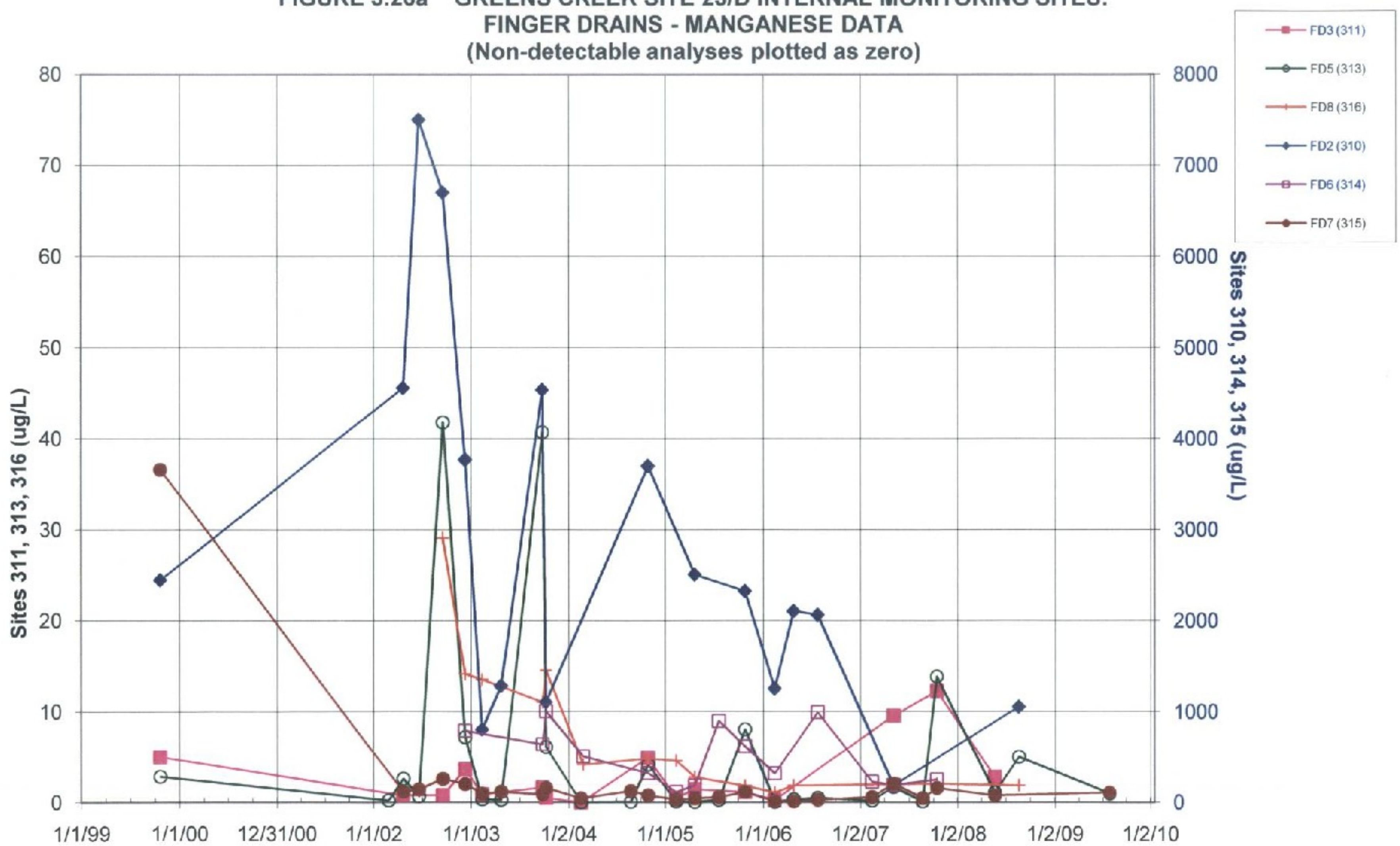


FIGURE 3.26b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: GROUND WATER - MANGANESE DATA
(Non-detectable analyses plotted as zero)

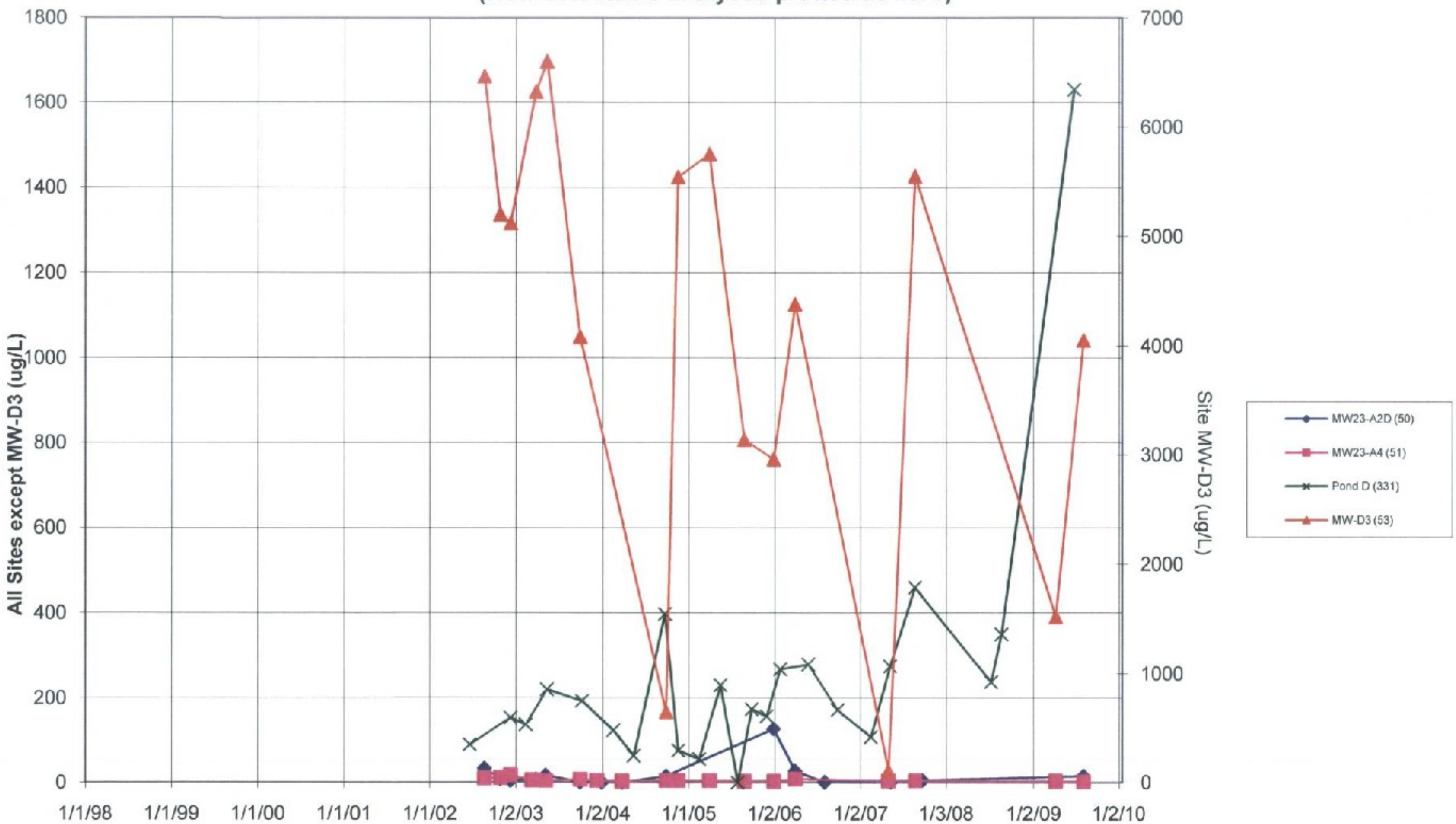


FIGURE 3.27 GREENS CREEK SITE 23/D INTERNAL MONITORING SITES: FINGER DRAINS - FLOW

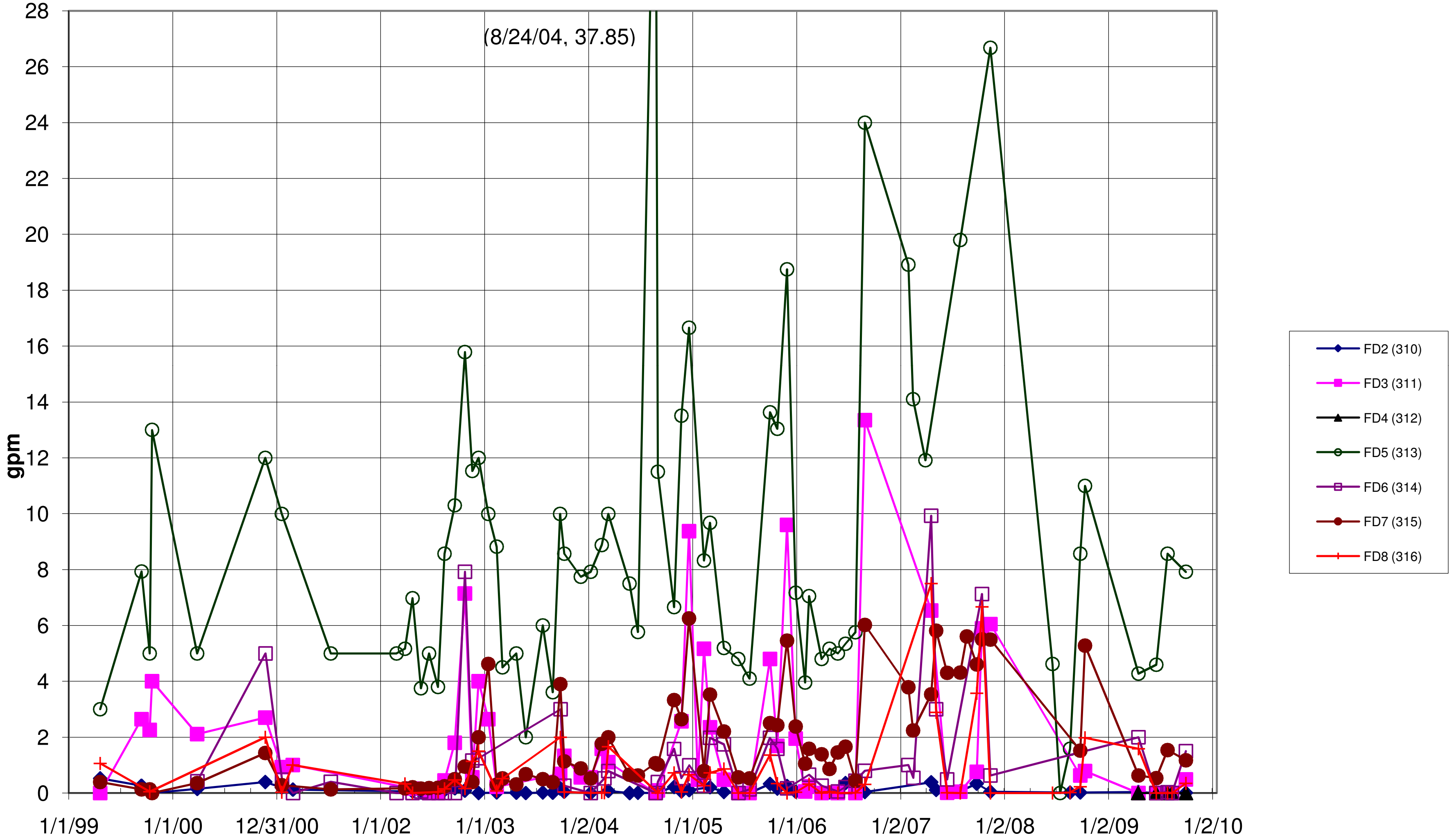


FIGURE 3.28 2009 ABA DATA FROM UNDERGROUND RIB SAMPLES

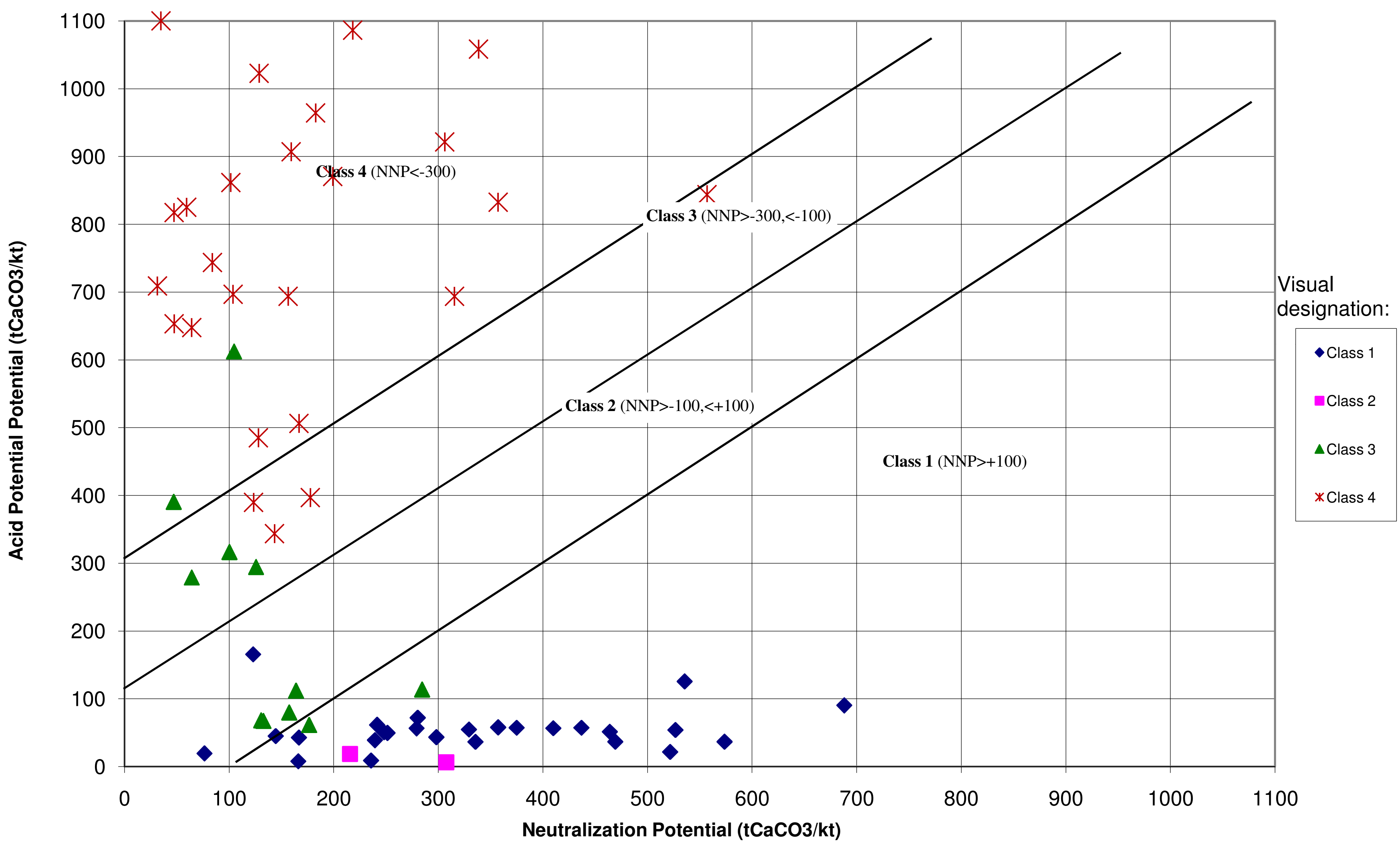


FIGURE 3.29a   SITE 23 ABA DATA

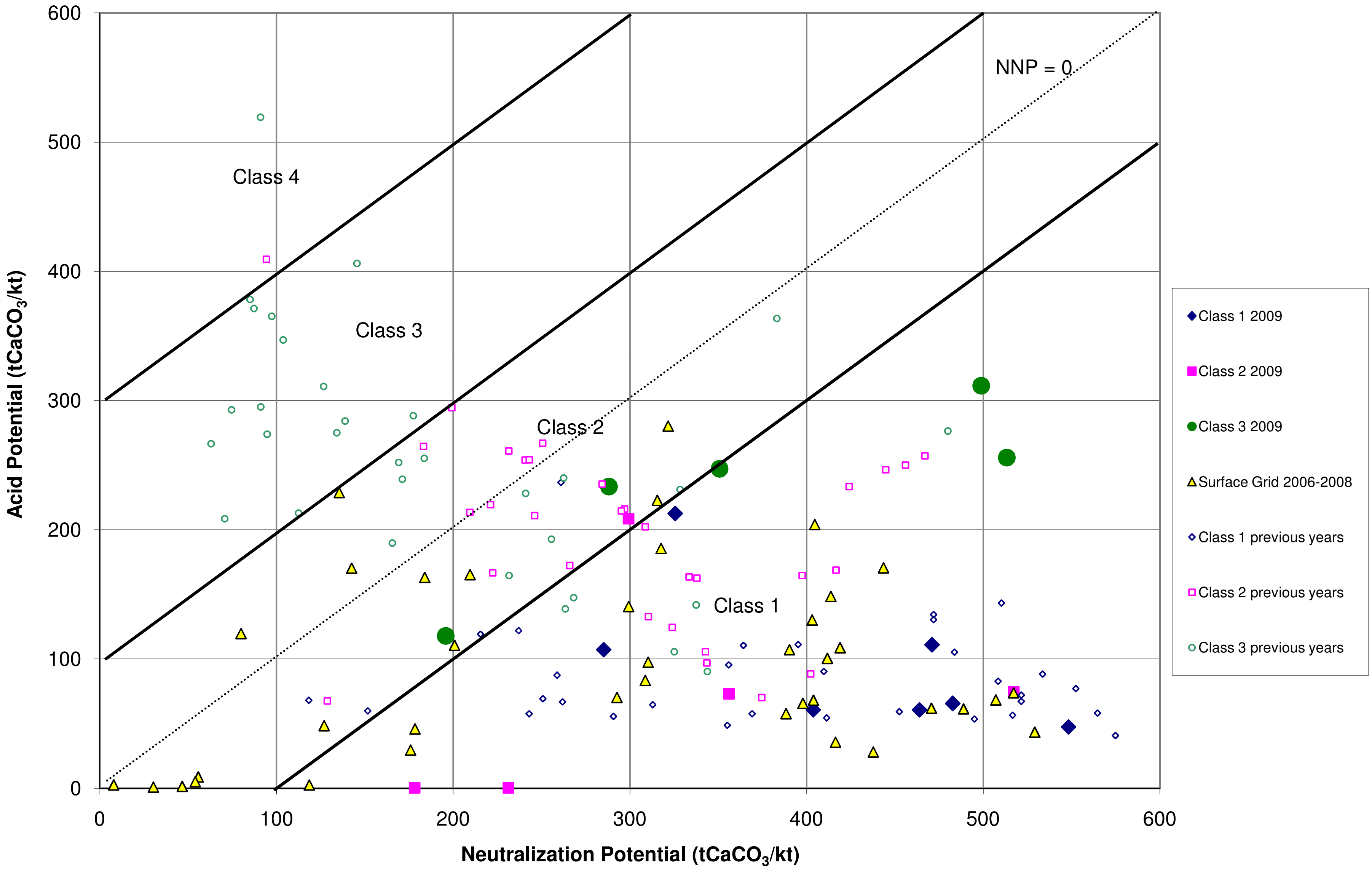
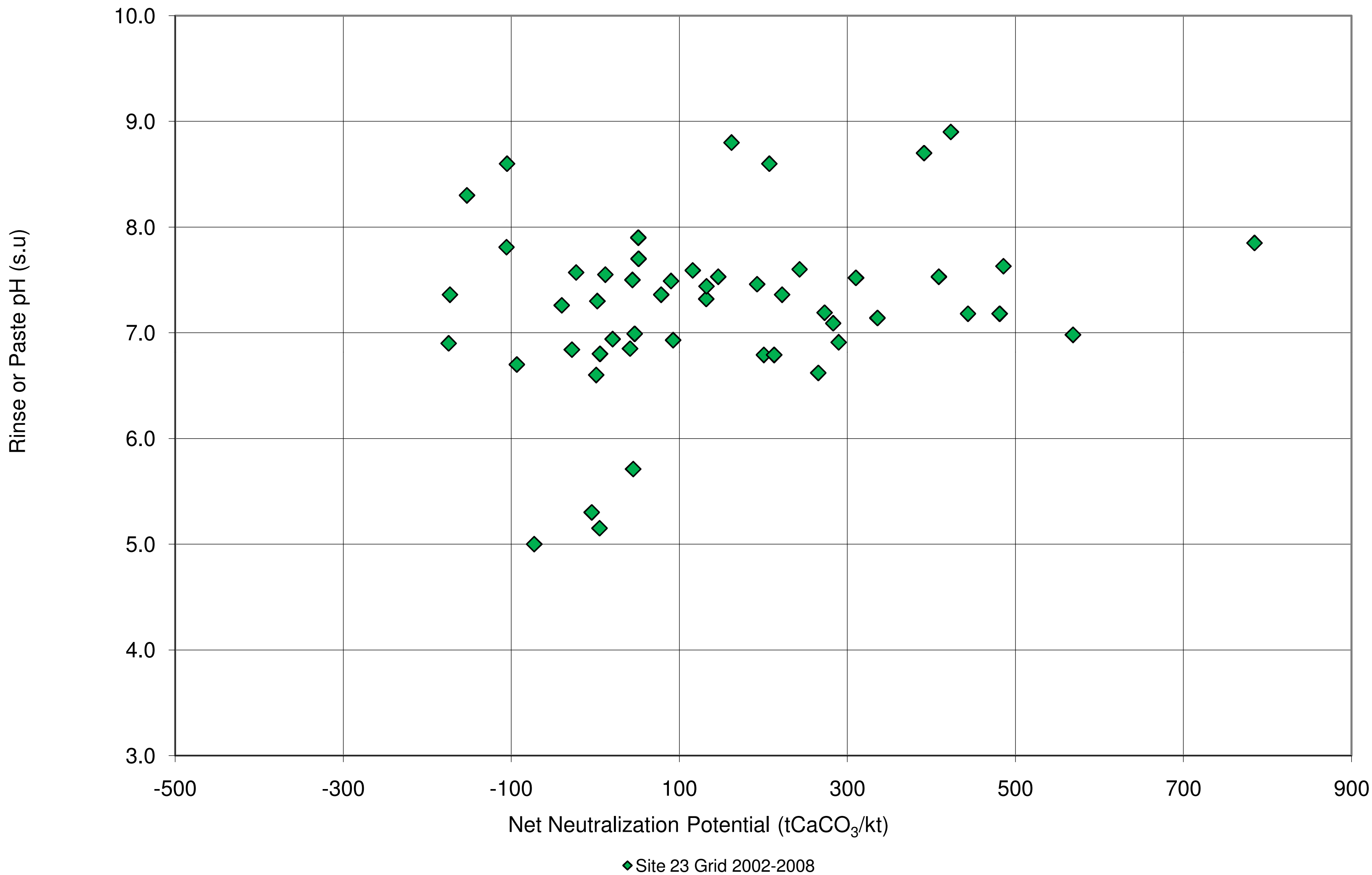


FIGURE 3.29b SITE 23 GRID ABA DATA



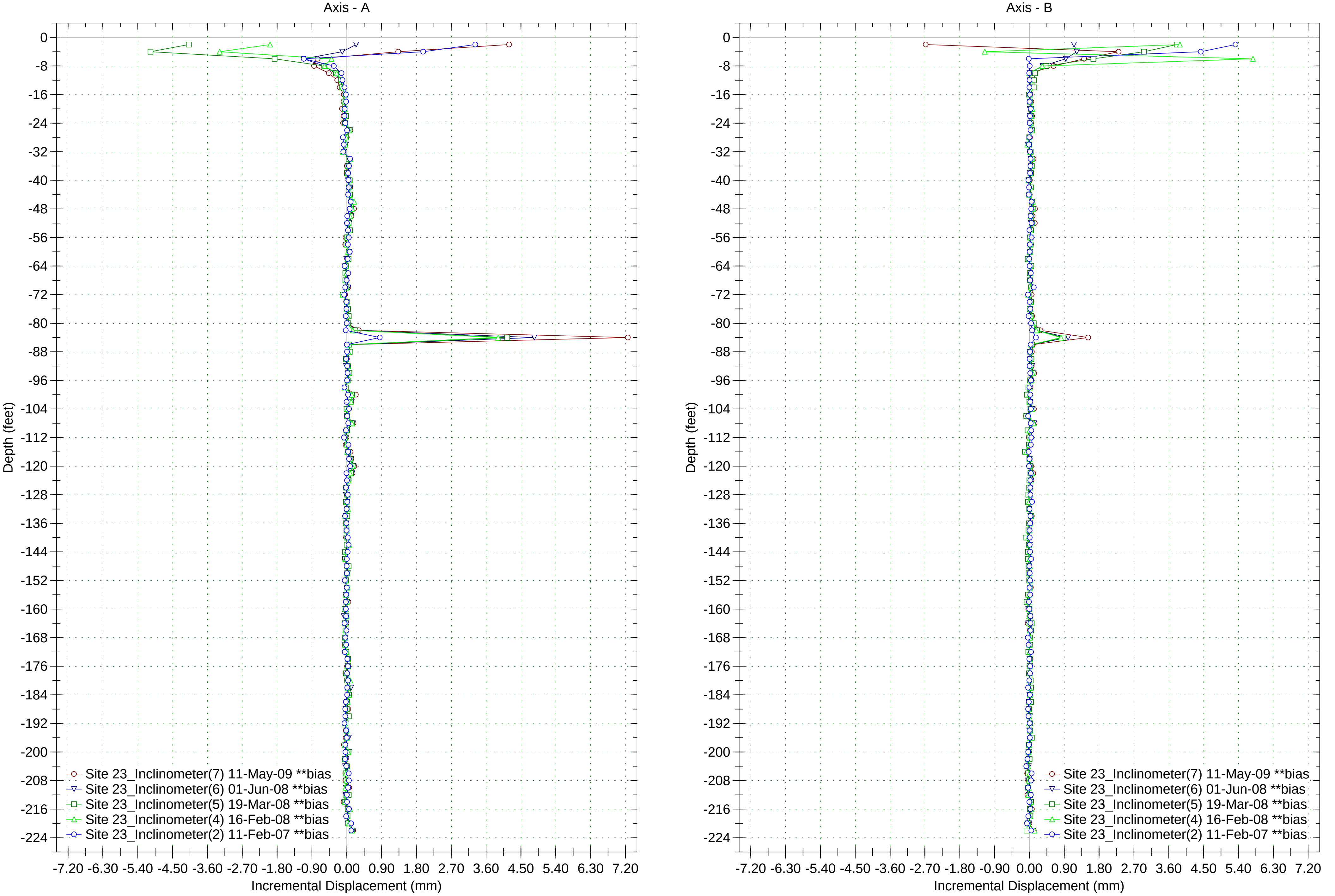
RST Instruments Ltd.

Borehole : Inclinometer
Project : Site 23
Location :
Northing :
Easting :

FIGURE 3.30 Site 23 Inclinometer Incremememental Displacement

Inclinalysis

Spiral Correction : N/A
Collar Elevation :
Borehole Total Depth : 222.0 feet
North Groove Azimuth :
Base Reading : 2006 Oct 07 10:28



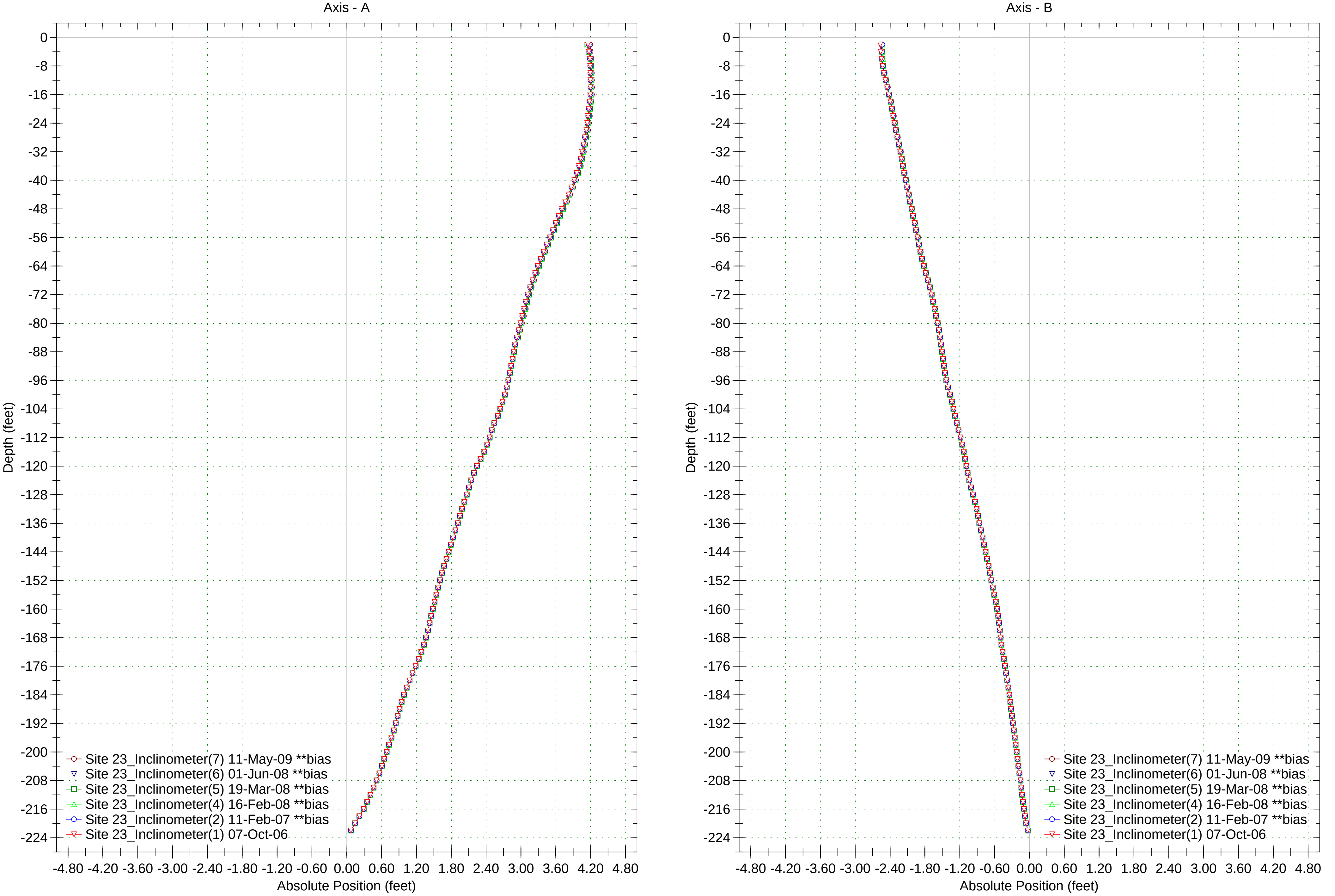
RST Instruments Ltd.

Borehole : Inclinometer
Project : Site 23
Location :
Northing :
Easting :

FIGURE 3.31 Site 23 Inclinometer Absolute Displacement

Inclinalysis

Spiral Correction : N/A
Collar Elevation :
Borehole Total Depth : 222.0 feet
North Groove Azimuth :
Base Reading : 2006 Oct 07 10:28



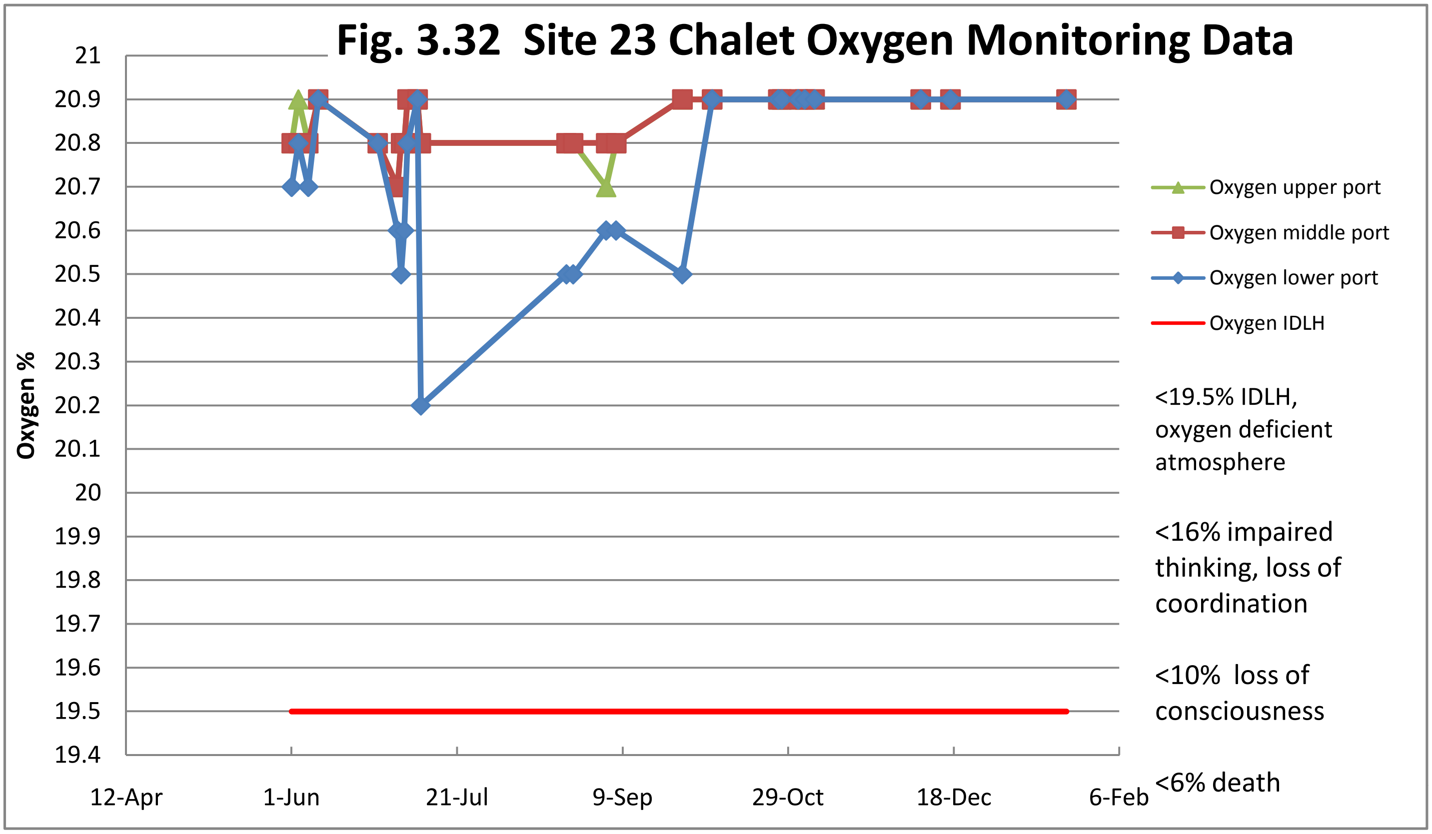


Fig. 3.32 Site 23 Chalet Oxygen Monitoring Data
Oxygen %
21
20.9
20.8
20.7
20.6
20.5
20.4
20.3
20.2
20.1
20
19.9
19.8
19.7
19.6
19.5
19.4
12-Apr
1-Jun
21-Jul
9-Sep
29-Oct
18-Dec
6-Feb
Oxygen upper port
Oxygen middle port
Oxygen lower port
Oxygen IDLH
<19.5% IDLH, oxygen deficient atmosphere
<16% impaired thinking, loss of coordination
<10% loss of consciousness
<6% death

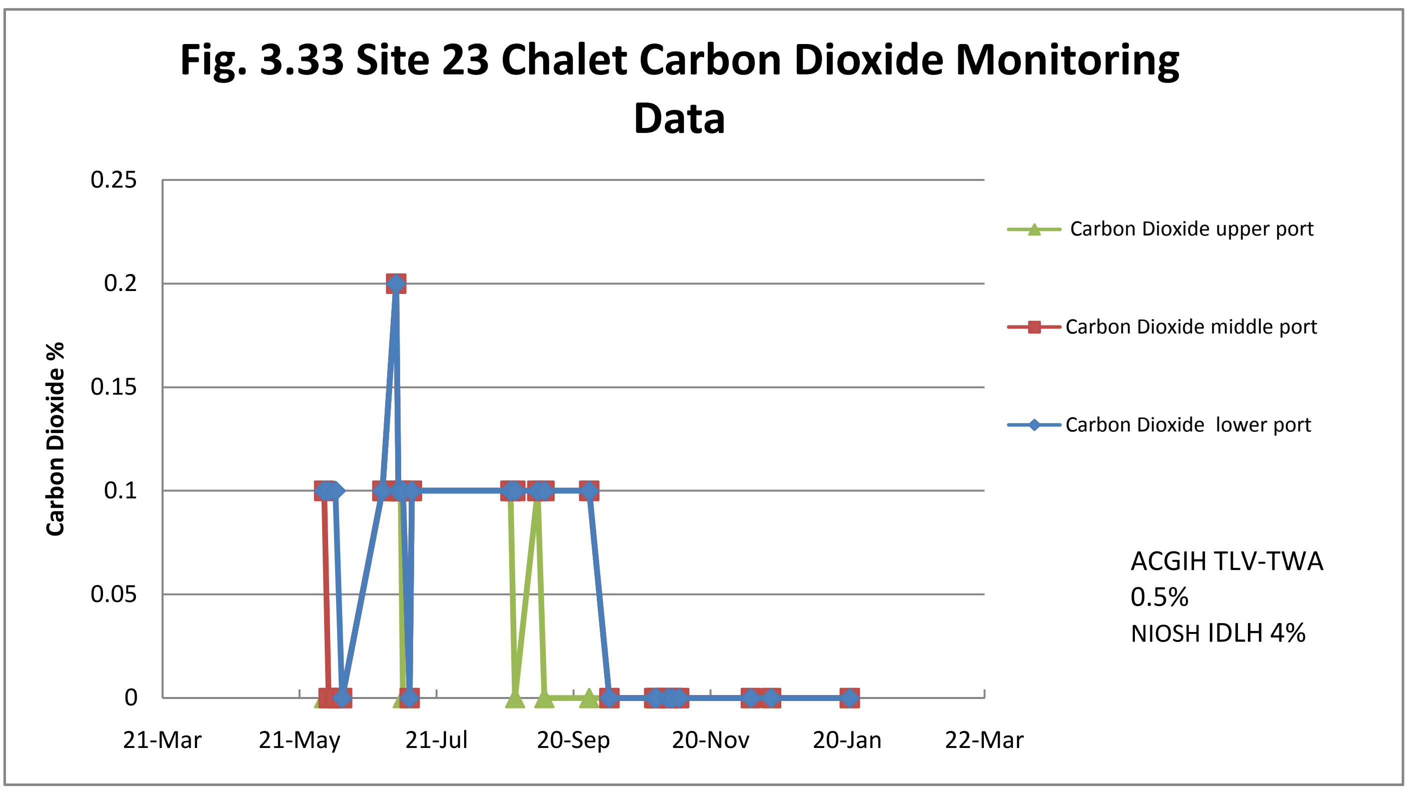


Fig. 3.33 Site 23 Chalet Carbon Dioxide Monitoring Data
Carbon Dioxide %
0.25
0.2
0.15
0.1
0.05
0
21-Mar
21-May
21-Jul
20-Sep
20-Nov
20-Jan
22-Mar
Carbon Dioxide upper port
Carbon Dioxide middle port
Carbon Dioxide lower port
ACGIH TLV-TWA 0.5%
NIOSH IDLH 4%

APPENDIX 4

Site Photographs

Figure 2.38 Site E Removal Activities August 11, 2009

Figure 2.39 Northwest Expansion Area June 2009

Figure 3.34 Site 23- July 2008

Figure 3.35 Site 23 Temporary Storage Area- June 2008

Figure 3.36 Pond D Activities August 2009, showing replacement of berm material, and new caisson