Report No. 118014/1

2008 GROUNDWATER REVIEW

ANVIL RANGE MINING COMPLEX, YUKON TERRITORY

Submitted to:

DELOITTE & TOUCHE INC.

On behalf of

Faro Mine Closure Planning Office

Prepared by:

Robertson GeoConsultants Inc.
Mining, Geotechnical and Environmental Engineers

Suite 640, 580 Hornby Street
Vancouver., B.C., Canada V6C 3B6
www.robertsongeoconsultants.com

February 2009

EXECUTIVE SUMMARY

Recent time trends in groundwater quality were reviewed in different reaches of the Anvil Range Mining Complex in order to identify changes in groundwater quality that have occurred since July 2007. The main conclusions of this review can be summarized as follows:

Faro Mine Site

Elevated levels of ARD products were observed in selected wells of the Emergency Tailings Area (ETA), which is consistent with the conclusion that this area remains a major source of contaminant loading.

The groundwater quality in several wells located in the S-cluster area continued to deteriorate over the monitoring period, supporting earlier recommendations that seepage interception in this area should be prioritized;

Groundwater quality down-gradient of the Northeastern Dump at BH14A/B deteriorated over the monitoring period, probably due to seepage from the sulphide-rich waste rock that has been identified in the area. This observation raises concerns that contaminant loading from the Northeastern Dump to the NFRC may increase over time and thus could also require seepage interception.

Rose Creek Tailings Facility

Groundwater quality in the northern portion of the Rose Creek aquifer deteriorated significantly during the 2008 monitoring period. Of particular concern are recent increases in SO_4, Mg, and metal concentrations (including Fe, Zn, and Mn) observed at P03-06, located near the Faro Creek Canyon and immediately downgradient of the Original Impoundment. The recent time trends in this and other wells further downgradient confirm that the entire depth of the aquifer is affected by seepage. The most probable sources of ARD seepage in this area include the coarse tailings beaches located in the northern portion of the Second or Original Impoundments and/or seepage from the Faro Creek canyon/diversion channel.

Impacted groundwater continues to move downgradient in the northern portion of the Rose Creek aquifer, as evidenced by a gradual breakthrough of SO_4, Mg, alkalinity and selected metals (Fe, Mn) in monitoring wells at the Intermediate dam (X24), Cross Valley Dam (P01-11, P05-01) and further downstream (X18, P01-01). The transport of Zn is still significantly delayed due to chemical attenuation in the aquifer.

The groundwater in the southern portion of the aquifer did not experience the same deterioration in groundwater quality in recent years as observed in the northern portion. Several of the highly impacted wells screened beneath the Second impoundment either stabilized in recent years (e.g. P03-03) or even showed a notable improvement in groundwater quality (e.g. P03-04). Decommissioning of several “leaky wells” may have contributed to the recent improvement in groundwater quality in the southern portion of the aquifer.

Grum/Vangorda Mine Site

Groundwater quality for most of the wells located downgradient of Grum Rock Dump and screened in shallow overburden soils continued to show some impact of neutralized mine drainage but did not deteriorate further during 2008. However, recent monitoring in two shallow bedrock wells (SRK05-07 and SRK05-08) showed a continued increase in oxidation products (SO_4, Mg and alkalinity) suggesting that a gradual breakthrough of seepage from Grum Dump is also occurring in the weathered bedrock.

Groundwater quality in monitoring wells located downgradient of the Vangorda Rock Dump (and screened in till) continued to show limited impact of neutralized mine drainage. No significant changes in groundwater quality were observed for the wells in this area.

Report No. 118014/1

2008 GROUNDWATER REVIEW

ANVIL RANGE MINING COMPLEX, YUKON TERRITORY

Table of Contents

LIST OF TABLES

LIST OF FIGURES

2008 GROUNDWATER REVIEW
ANVIL RANGE MINING COMPLEX, YUKON TERRITORY

1 INTRODUCTION

1.1 Terms of Reference

Groundwater monitoring wells at the Anvil Range Mine Complex (ARMC) are sampled at least twice per year as part of a routine monitoring program carried out by Gartner Lee Limited (GLL). In 2004, Robertson GeoConsultants Inc. (RGC) completed an initial review of the groundwater quality monitoring data collected near the Faro and Grum/Vangorda rock dumps in order to assist in the deign of additional field programs (RGC, 2004) and develop water and contaminant load balances for the Rose Creek Tailings area (RGC, 2006a). In 2007, RGC was commissioned to carry out a comprehensive review of the recent groundwater monitoring data collected across the ARMC from 2005 to mid-2007 (RGC, 2008).

1.2 Study Objectives

The main objective of this report was to review groundwater monitoring data collected since the completion of the last comprehensive review of groundwater monitoring and identify any changes in groundwater quality that have occurred since mid-2007. A corollary objective was to provide recommendations with respect to the routine groundwater monitoring program.

1.3 Scope of Work

This review covers the following geographic areas of the Anvil Range Mining Complex:

- Faro Mine Site (Faro WRDs & ETA);
- Rose Creek Valley (tailings facility); and
- Grum and Vangorda Mine Site (Grum and Vangorda WRDs);

All groundwater quality data reviewed here were downloaded from the Faro database on December 8, 2008. A QA/QC of the raw data was beyond the scope of this review. The scope of 2008 monitoring, field and laboratory methods, and QA/QC results are reported in AECOM (2009).

Note that this review does not include initial groundwater quality data obtained from new monitoring wells installed in the fall of 2008 by SRK Consultants (SRK, 2009).

This scope of work was authorized as 2008/09 Task #26-4 - Ground Water Monitoring Review and this report represents the final deliverable of this task.

2 FARO MINE SITE

2.1 Geographic Overview

The general layout of the Faro mine site and the locations of groundwater monitoring wells are illustrated in Figure 2-1. The Faro mine site comprises the Faro Pit, the surrounding Faro waste-rock dumps (WRDs), the mill area, and the Emergency Tailings Area (ETA).

Groundwater monitoring is generally focused on specific geographic areas where an impact from mine waste seepage has been identified at surface. These areas are considered “priority areas” and include:

- the Emergency Tailings Area (ETA);
- the S-cluster area; and
- the Zone 2 Outwash area.

Additional monitoring wells are situated along the toe of the WRDs in order to monitor drainage towards the North Fork of Rose Creek (NFRC) and within the main Rose Creek valley in order to enhance the spatial coverage of groundwater monitoring. In the following sub-sections, the recent time trends in groundwater water quality for these geographic areas are discussed separately.

2.2 Emergency Tailings Area (ETA)

2.2.1 Background

Figure 2-2 shows the general layout of the ETA area and the groundwater monitoring wells located in this area.

Table 2-1 summarizes pertinent information related to the groundwater monitoring wells located in the ETA area, including year of construction, installation details (total depth, screening interval), and the status of monitoring.

Table 2-1. Monitoring wells in the Emergency Tailings Area (ETA), Faro Mine Site

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
ETA Area							
P96-8A	1996	4.2	1.15	4.17	1109.39	bi-annual	Alluvium
P96-8B	1996	8.6	5.50	8.52	1109.48	bi-annual	Alluvium
SRK04-3A	2004	11.9	10.40	11.90	1104.55	bi-annual	Tailings/All
SRK04-3B	2004	7.1	5.50	7.00	1104.63	no longer sampled	All/BR
SRK04-4	2004	11.6	7.64	11.6	1104.80	not routinely monitored	Alluvium
SRK05-ETA-BR1	2005	12.4	9	12	1105.21	bi-annual	Alluvium
SRK05-ETA-BR2	2005	18.4	14.6	18.9	1103.75	bi-annual	BR (Schist)
ETA-05-1	2005	7.3	4.3	7.3	1105.13	not routinely monitored	Tailings
ETA-05-2	2005	7.5	5	7.5	1105.06	not routinely monitored	Till
ETA-05-3	2005	8.8	7	8.8	1103.98	not routinely monitored	All/Till
ETA-05-4	2005	9.0	6.7	9	1105.37	not routinely monitored	All/Till
ETA-05-5	2005	5.2	2	5.2	1105.44	not routinely monitored	Tailings

2.2.2 Review of Time Trends

Figure 2-3a/b shows selected water quality time trends for monitoring well P96-8A/B (located at the toe of the Faro Main Dump) and for seepage (X23) discharging from the toe of the Main Dump.

The concentrations of SO_4, Mg, and key metals of interest (Zn, Fe, Mn) have increased considerably in X23 over the last year. Historically, a rapid increase in the concentrations of metals in X23 is related to the 'flushing' of accumulated oxidation products from the WRD in response to the infiltration of precipitation (Figure 2-3a). In the two nested piezometers P96-8A/B, temporal variation in the concentrations of major ions and metals of interest generally mimicked the trends observed in surface seepage at X23. Historic trends suggest that it can take a year or more for dissolved metal concentrations, such as Zn, to return to 'normal' levels after a 'flushing' event, yet major ions appear to be less susceptible to short-term changes. In 2008, precipitation was well above average suggesting that recent increases in water quality parameters are related to several 'flushing' events from the Main Dump.

Note that prior to 2006, the shallow well (P96-8A) showed a greater impact from WRD seepage than the deeper well (P96-8B). Starting in 2006, the deeper well abruptly showed a higher impact than the shallow well. This abrupt change in water quality pattern is suspicious and suggests that the two nested piezometers might have been incorrectly relabelled. The depth of these two piezometers should be checked during the next monitoring campaign to confirm proper labelling of these wells.

Figure 2-4a/b illustrates the time trends for selected water quality parameters in the four monitoring wells located up-gradient of the mine access road in the ETA area. Water quality differs significantly among these wells due to differences in screened lithologies (RGC, 2008). Groundwater in wells screened in the alluvial sediments of the Faro Creek channel (SRK04-3A and SRK05-ETA-BR1) or in a mixture of tailings and alluvial sands (SRK04-3B) has a slightly acidic pH, low alkalinity, and elevated levels of SO_4, Mg, and the key metals of concern (Zn, Fe, and Mn). By contrast, groundwater that resides in bedrock underlying the alluvium is less affected by mine waste seepage than the highly-impacted alluvial channel that occurs above. Nonetheless, metal concentrations in this deeper groundwater (e.g. 10 mg/L Zn) are higher than natural background for local bedrock, which suggests some direct impact by seepage from the ETA area and/or WRD seepage from areas located up-gradient.

In contrast to trends observed for X23, groundwater quality in this area did not deteriorate further over the current monitoring period.

2.3 S-Cluster Area

2.3.1 Background

Figure 2-5 shows the general layout of the "S cluster area" and the groundwater monitoring wells located in the area.

Table 2-2 summarizes pertinent information related to the groundwater monitoring wells located in the S-cluster area, including year of construction, installation details (total depth, screening interval), and the status of monitoring.

Table 2-2 Monitoring wells in the S-cluster area, Faro Mine Site

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
S-cluster Area							
S1A	1989	12.0	9.2	12.2	1085.43	bi-annual	BR (phyllite)
S1B	1989	3.8	1.3	4.3	1085.27	bi-annual	Till
S2A	1989	11.2	9.2	12.2	1086.03	bi-annual	BR (phyllite)
S2B	1989	7.0	3.7	6.7	1086.30	bi-annual	Till
S3	1989	4.8	2.6	5.6	1085.53	bi-annual	Till
P96-7	1996	9.2	6.26	9.24	~1127	bi-annual	Overburden/BR
SRK05-SP-1A	2005	19.2	13.7	19.2	1091.99	bi-annual	Overburden/BR
SRK05-SP-1B	2005	12.3	9	12.3	1091.94	bi-annual	Overburden
SRK05-SP-2	2005	11.0	7.9	11	1086.70	bi-annual	Alluvium/BR
SRK05-SP-3A	2005	22.9	17.4	21.9	1088.50	bi-annual	Overburden
SRK05-SP-3B	2005	12.3	8.3	11.4	1088.41	bi-annual	Overburden
SRK05-SP-4A	2005	21.6	16.5	21	1087.27	bi-annual	Overburden/BR
SRK05-SP-4B	2005	4.0	0.6	3.5	1087.44	bi-annual	Overburden
SRK05-SP-5	2005	14.0	9.4	12.5	1087.53	bi-annual	Overburden/BR
SRK05-SP-6	2005	11.0	3.1	11	1097.73	bi-annual	BR(Schist)
DP1	2005	n/a	1.14	1.14	1083.97	not routinely monitored	NFRC sediments
DP2	2005	n/a	0.53	0.53	1082.55	not routinely monitored	NFRC sediments
DP3	2005	n/a	0.75	0.75	1081.89	not routinely monitored	NFRC sediments
DP4	2005	n/a	0.94	0.94	1082.19	not routinely monitored	NFRC sediments
SRK04-2B	2004					no longer sampled	Alluvium
SRK04-2A	2004					no longer sampled	Alluvium

2.3.2 Review of Time Trends

Figures 2-6a/b and 2-7a/b show the time trends for selected water quality parameters in groundwater from the historical "S" wells and well P96-7. Identical plots for the "SRK05-SP" series of wells are shown in Figure 2-7a/b. Groundwater quality in the S-cluster area can be grouped into three broad categories:

- Highly-impacted groundwater (S1A, S2A/B, S3, SRK05-SP4B and -SP5);
- Moderately-impacted groundwater (SRK05-SP1A, -SP3A, SP3B and -SP4A);
- Slightly-impacted groundwater (S1B, SRK05-SP1B and -SP2).

The contaminant concentrations in the highly-impacted groundwater have increased steadily since 2000 and this trend continued throughout the current monitoring period. Of particular concern is the rapid rise in the concentrations of Mg, SO_4, and selected metals in S2B. Specifically, the concentration of Zn in S2B has risen significantly and is now approximately equivalent to S1A, S2A, and S3.

Piezometer S2B is reportedly a shallow piezometer (screened at 4 to 7m depth; Table 2-2). The recent breakthrough of highly-impacted seepage in this piezometer suggests that the shallow (perched) seepage first identified further east at SP-4B (SRK, 2006) may be laterally more extensive than originally thought. Alternatively, the breakthrough of waste rock seepage at SP2B may be an indication of deeper seepage (e.g. observed at SRK05-SP5) upwelling further down-slope.

The other monitoring wells classified as moderately-impacted or slightly-impacted did not show the same dramatic deterioration in groundwater quality. However, several of those wells have shown a gradual increase in SO4 and Mg concentrations over time (e.g. at SRK05-SP1A, -SP3A, -SP4a) suggesting increasing impact of waste rock seepage. Thus far, a breakthrough of elevated Zn concentrations in those moderately impacted wells appears to be imminent only at SRK05-SP4A.

The continued deterioration of groundwater quality along this reach of the NFRC, including breakthrough of highly elevated Zn concentrations, represents an increasing risk of contaminant loading to the nearby North Fork of Rose Creek. As a result, a seepage interception system consisting of a shallow interception trench and several recovery wells was installed in the fall of 2008 to intercept this highly impacted groundwater in this area (SRK, 2009). Start-up of operation of this SIS is planned for early 2009. Continued monitoring of groundwater quality downstream of this SIS will be required to assess the effect of this new seepage interception system on groundwater quality in this reach of the NFRC.

2.4 Zone 2 Outwash Area

2.4.1 Background

Figure 2-8 shows the general layout of the Faro WRDs and the groundwater monitoring wells in the area. Drainage from the WRDs generally flows towards the North Fork Rose Creek (NFRC), which is located up-gradient of the rock drain. Most of the groundwater monitoring wells are located in the Zone 2 outwash area (Figure 2-9), but additional monitoring wells are located along the toes of the Northeast Rock Dump and the Intermediate Rock Dump.

Table 2-3 summarizes pertinent information related to the groundwater monitoring wells located in the Zone 2 Outwash area, including year of construction, installation details (total depth, screening interval), and the status of monitoring.

Table 2-3. Monitoring wells in the Zone 2 Outwash Area, Faro Mine Site

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Zone 2 Outwash Area							
BH1	1992	5.2				bi-annual	n/a
BH2	1992	4.8			1099.70	bi-annual	n/a
BH4	1992	2.5			1097.02	bi-annual	n/a
BH5	1994	7.6	6.01	7.62	1095.57	not routinely monitored	Alluvium
BH6	1994	6.3	4.72	6.25	1097.84	not routinely monitored	Alluvium
BH7D (A)	1994	8.8	6.71	8.84	1100.70	no longer sampled	Overburden (?)
BH7S (B)	1994	6.4	4.27	6.4	1101.16	no longer sampled	BR (phyllite?)
BH8	1994	20.6	19.05	20.57	1123.37	not routinely monitored	BR (phyllite?)
BH9	1994	54.9	53.34	54.86	1141.30	abandoned	BR (Biotite-schist)
BH10A	1994	36.6	35.05	36.58	1101.73	not routinely monitored	BR (Biotite-schist)
BH10B	1994	54.9	53.34	54.84	1101.72	not routinely monitored	BR (phyllite/schist)
BH05-01	2005	3.8	2.3	3.81	1095.57	abandoned	Outwash Sed
P05-04	2005	6.3	2.19	6.34	1097.70	bi-annual	Alluvium
RGC-PW3	2005	7.4	5.5	7	1097.92	not routinely monitored	Alluvium
DP5	2005	n/a	n/a	n/a	1095.73	not routinely monitored	NFRC sediments
DP6	2005	n/a	n/a	n/a	1094.71	not routinely monitored	NFRC sediments
Zone 2 Pumping Well (X26)	n/a						waste rock (?)

2.4.2 Review of Time Trends

Figure 2-10a/b shows selected water quality time trends for the monitoring wells located in the Zone 2 outwash area.

The Zone 2 outwash area is located immediately down-gradient of the Zone 2 pit which has been back-filled with waste rock. Pumping well X26 reflects changes in the quality of water accumulating in the Zone 2 pit and pumped out during the summer months. Water quality in the Zone 2 pit shows seasonal dilution due to recharge during spring runoff. However, average water quality in the Zone 2 pit has remained remarkably constant over the last few years.

Monitoring well BH8, located immediately downgradient of the Zone 2 pit and screened in a fault zone in weathered bedrock, was sampled in 2008 for the first time since 1997. Water quality in this deep bedrock well continues to be highly impacted with SO4 concentrations ~4,000 mg/L and Zn concentrations of about 300 mg/L. Note that groundwater in this bedrock well is acidic (pH ~4.5) and has consistently shown significantly higher concentrations of Fe and Zn and other trace metals (Cd, Cu, Pb) than the water pumped from the Zone 2 pit (X26). At present, it is unclear whether the very poor water quality in BH08 is a result of seepage from the Zone 2 Pit, overlying waste rock and/or mineralized bedrock in the area and will require further study.

Trends in groundwater quality in the Zone 2 Outwash area for the current monitoring period were generally similar to those observed in previous years. The shallow wells (BH1, 2 and 4), at least partially screened in the outwash sediments, continued to show a very similar general water quality (or “fingerprint”) to that observed in the deeper wells screened in the alluvial sediments (BH5, BH6, P05-04). The groundwater quality in this area differs from other seepage areas (e.g. ETA and S-cluster) in that elevated Zn concentrations are observed in groundwater with relatively low concentrations of SO4, Mg, iron and manganese.

Several shallow wells (e.g. BH2 and in particular BH4 located near the NFRC) showed a gradual increase in Zn, manganese and SO4 during calendar year 2008. Similar increases in contaminants had been observed in previous wet years. These increases are therefore likely temporary in nature and not related to an overall long-term increase in contaminant loading in this area.

Monitoring well BH5 is located immediately downgradient of the Zone area and is screened in the permeable alluvial sediments of the NFRC valley. Sampling in this well recommenced in 2008 for the first time since 1997. Concentrations of SO_4, Mg and Zn have either remained constant or marginally improved in BH5 over this eleven year time span. This suggests that contaminant loading to the NFRC from the Zone 2 pit and associated waste rock dumps has not increased significantly over this time period.

Pumping tests conducted in this area have demonstrated that the local NFRC sediments are very permeable, that zinc loading to the NFRC sediments is significant and seepage interception may be required in this area (SRK, 2007). In preparation of such design work, we recommend that additional geochemical characterization work be completed (including geochemical finger-printing, mixing calculations and potentially use of isotopic tracers) to determine the relative contribution of Zone 2 pit seepage, waste rock seepage and leakage from the outwash sediments in this reach of the NFRC.

2.5 Northeast and Intermediate Dumps towards NFRC

2.5.1 Background

Figure 2-8 shows the monitoring wells located along the toe of the Northeast Dumps and the Intermediate Dump. Table 2-4 lists pertinent information of all groundwater monitoring wells located down-gradient of the Northeast Rock Dump and the Intermediate Rock Dump.

2.5.2 Review of Time Trends

Figure 2-11a/b shows selected water quality time trends for the three sets of nested piezometers located along the toe of the Northeast Dumps.

BH14A/B has historically shown the greatest impact of WRD seepage in this area and groundwater quality in these wells deteriorated significantly in 2008. For example, in the latest round of sampling (August 2008) SO_4 and Zn concentrations in BH14A jumped to 3,200 mg/L SO_4 and 11.9 mg/L.Zn, respectively. Similar increases were observed in the deeper piezometer BH14B. The observed increases in major ions (SO_4 and Mg) are consistent with elevated field EC readings during this sampling date suggesting that these results are not caused by a sample handling or laboratory error.

Table 2-4. Monitoring wells at the toe of Northeast Dumps and Intermediate Dump (NFRC), Faro Mine Site

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Toe of Northeast Dumps (NFRC)							
BH12A	1994	3.1	1.53	3.05	1157.39	bi-annual	BR (weath)
BH12B	1994	8.2	6.1	8.23	1157.50	bi-annual	BR (phyllite/schist)
BH13A	1994	3.8	2.29	3.81	1187.91	bi-annual	A
BH13B	1994	8.2	6.71	8.23	1188.18	bi-annual	BR (phyllite/schist)
BH14A	1994	6.3	4.72	6.25	1157.52	bi-annual	BR (weath)
BH14B	1994	9.3	7.77	9.3	1158.16	bi-annual	BR (Qtz/diorite)
Toe of Intermediate Dump (NFRC)							
P96-6	1996	20.1	18.07	20.12	~1102	bi-annual	Alluvium

Groundwater collected from wells BH12A/B and BH13A/B has remained relatively dilute in terms of major ions and dissolved metals compared to those observed at BH14A/B. However, monitoring well BH13B has shown a recent increase in concentrations of SO_4 and Mg indicative of waste rock seepage.

Increases in the concentrations of SO_4, Mg, and Zn in these wells (in particular at BH14A/B) are cause for concern because their increase are likely indicative of seepage related to the sulphide-rich waste rock that has been identified in this portion of the Northeast Dumps (RGC, 2008). If seepage continues, it is likely that groundwater quality in this reach will deteriorate further until concentrations of SO_4, Mg, and Zn reach the levels observed in the ETA and S-cluster areas. Extrapolating historic time trends observed at the S-cluster area, zinc concentrations in BH14 may exceed 100 mg/L in groundwater within the next 2 to 5 years. Over time, such seepage could negatively impact on the water quality of the NFRC in the reach upstream of the Zone 2 area.

Figure 2-12a/b shows selected water quality time trends for P96-6. This well is located along the toe of the Intermediate Dump and monitors groundwater flowing from the Intermediate Dump towards the NFRC. Similar to selected wells in the S-cluster area (e.g. SRK05-SP1A, -SP3A, SP3B and -SP4A), groundwater quality in this monitoring well is considered “moderately-impacted” by seepage. In 2008, the concentrations of SO_4 and Mg also increased in P96-6. These increases may be indicative of increased seepage from the Intermediate Dump and could precede similar increases in the concentrations of dissolved metals.

3 ROSE CREEK VALLEY (TAILINGS FACILITY)

3.1 Geographic Overview

Figure 3-1 shows the general layout of the Rose Creek tailings facility and the groundwater monitoring wells in the area. The Rose Creek tailings facility comprises the Original Impoundment, Second Impoundment, Intermediate Impoundment (w/ Intermediate Dam), and the Polishing Pond (w/ Cross Valley Dam).

The groundwater monitoring network in the Rose Creek tailings facility is extensive and for the purpose of this report, the recent time trends of groundwater quality in the Rose Creek valley are discussed separately for the following geographic areas:

- Upstream of Rose Creek Tailings Facility;
- Original Impoundment;
- Second Impoundment;
- Intermediate Impoundment;
- Toe of Intermediate Dam;
- Toe of Cross Valley Dam; and
- Downstream of Cross Valley Dam.

Note that the majority of “P01” series of monitoring wells (installed in 2001) were decommissioned in October 2005 due to concerns about the integrity of these wells (RGC, 2006b). Historic water quality time trends of those “leaky wells” are not presented here. For a review of those historic time trends, the reader is referred to the 2007 Groundwater Monitoring Review Report (RGC, 2008).

3.2 Upstream of Rose Creek Tailings Facility

3.2.1 Background

Groundwater quality up-gradient of the Rose Creek tailings facility is routinely monitored in monitoring well TH86-17, which is located approximately 450-m southeast of the Original Impoundment (Figure 3-1).

3.2.2 Review of Time Trends

Figure 3-2a/b shows selected water quality time trends for TH86-17 and other piezometers measured once in 2008. Groundwater quality in TH86-17 reflects natural base-line conditions in the Rose Creek valley sediments. Groundwater from TH86-17 remains relatively dilute in terms of major ions and dissolved metals and there continues to be no indication of mine waste seepage impact on groundwater quality at this location.

The other piezometers sampled in 2008 generally showed similar groundwater quality. For example, SO_4 concentrations ranged from 21 to 48 mg/L (average = 31 mg/L) compared to ~15mg/L in TH-86-17 and Zn concentrations ranged from < 0.005 mg/L to 0.01 mg/L (average = 0.0075 mg/L) compared to 0.017 mg/L in TH86-17. The lower SO_4 concentrations (and higher Zn concentrations) observed at TH86-17 may be a result of recharge from the nearby NFRC to the Rose Creek sediments. We recommend that monitoring wells TH86-2 and TH86-5, screened in shallow and deep alluvial sediments, respectively, be included in future routine monitoring as additional background wells for the Rose Creek valley.

3.3 Original Impoundment

3.3.1 Background

Table 3-1 summarizes pertinent information related to the groundwater monitoring wells located in the Original Impoundment, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Table 3-1. Monitoring wells upgradient of and in the Original Impoundment, Rose Creek Tailings Facility

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Original Impoundment							
TH86-17	1986	13.9	n/a	n/a	~1070	bi-annual	n/a
P03-07-01	2003	38.4	38.10	38.40	1064.98	not routinely monitored	Alluvium
P03-07-02	2003	33.8	33.53	33.83	1064.98	not routinely monitored	Alluvium
P03-07-03	2003	29.0	28.65	28.96	1064.98	not routinely monitored	Alluvium
P03-07-04	2003	21.6	21.34	21.64	1064.98	not routinely monitored	Alluvium
P03-07-05	2003	20.1	19.81	20.12	1064.98	not routinely monitored	Alluvium
P03-07-06	2003	18.3	17.98	18.29	1064.98	not routinely monitored	Tailings
P03-07-07	2003	16.8	16.46	16.76	1064.98	not routinely monitored	Tailings
P03-07-08	2003	13.7	13.41	13.72	1064.98	not routinely monitored	Tailings
NA05-11A	2005	14.3	12.8	14.3	1068.35	not routinely monitored	Alluvium

3.3.2 Review of Time Trends

None of the existing monitoring wells in the Original Impoundment are currently monitored routinely. Hence no additional water quality data was collected during the current monitoring period.

3.4 Second Impoundment

3.4.1 Background

Table 3-2 summarizes pertinent information related to the groundwater monitoring wells located in the Second Impoundment, including year of construction, installation details (total depth, screening interval), and the status of monitoring.

3.4.2 Review of Time Trends and Depth Profiles

Six multi-level wells (P03-01 to P03-06) were installed within the footprint of the Second Impoundment in 2003. Water quality depth profiles for these wells are illustrated in Figures 3-3a/b to 3-8a/b. The general shapes of the depth profiles observed during the current monitoring period are very similar to those observed in previous monitoring campaigns. In accordance with previous findings, the highest levels of ARD products (SO_4, Mg and Zn) are still observed in tailings pore-water in the south-eastern (P03-01, P03-03) and north-western sections (P03-06) of the Second Impoundment, whereas the lowest levels of ARD products were observed in the south-western section (P03-05) (RGC, 2008).

Table 3-2. Monitoring wells in the Second Impoundment, Rose Creek Tailings Facility

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Second Impoundment							
P03-01-01	2003	46.8	46.48	46.79	1061.11	bi-annual	Alluvium
P03-01-02	2003	38.9	38.56	38.86	1061.11	bi-annual	Alluvium
P03-01-03	2003	30.6	30.33	30.63	1061.11	bi-annual	Alluvium
P03-01-04	2003	24.5	24.23	24.54	1061.11	bi-annual	Alluvium
P03-01-05	2003	18.4	18.14	18.44	1061.11	bi-annual	Alluvium
P03-01-06	2003	13.3	12.95	13.26	1061.11	bi-annual	Alluvium
P03-01-07	2003	10.8	10.52	10.82	1061.11	bi-annual	Alluvium
P03-01-08	2003	9.3	8.99	9.30	1061.11	bi-annual	Tailings
P03-01-09	2003	7.8	7.47	7.77	1061.11	bi-annual	Tailings
P03-02-01	2003	33.8	33.53	33.83	1060.60	not routinely monitored	Alluvium
P03-02-02	2003	30.5	30.18	30.48	1060.60	not routinely monitored	Alluvium
P03-02-03	2003	22.9	22.56	22.86	1060.60	not routinely monitored	Alluvium
P03-02-04	2003	16.8	16.46	16.76	1060.60	not routinely monitored	Alluvium
P03-02-05	2003	13.7	13.41	13.72	1060.60	not routinely monitored	Alluvium
P03-02-06	2003	12.8	12.50	12.80	1060.60	not routinely monitored	Alluvium
P03-02-07	2003	11.9	11.58	11.89	1060.60	not routinely monitored	Tailings
P03-02-08	2003	8.8	8.53	8.84	1060.60	not routinely monitored	Tailings
P03-02-09	2003	7.6	7.32	7.62	1060.60	not routinely monitored	Tailings
P03-03-01	2003	43.0	42.67	42.98	1061.49	bi-annual	Alluvium
P03-03-02	2003	33.2	32.92	33.22	1061.49	bi-annual	Alluvium
P03-03-03	2003	27.1	26.82	27.13	1061.49	bi-annual	Alluvium
P03-03-04	2003	22.3	21.95	22.25	1061.49	bi-annual	Alluvium
P03-03-05	2003	18.6	18.29	18.59	1061.49	bi-annual	Alluvium
P03-03-06	2003	17.1	16.76	17.07	1061.49	bi-annual	Alluvium
P03-03-07	2003	15.2	14.94	15.24	1061.49	bi-annual	Tailings
P03-03-08	2003	12.2	11.89	12.19	1061.49	bi-annual	Tailings
P03-03-09	2003	9.1	8.84	9.14	1061.49	bi-annual	Tailings
P03-04-01	2003	58.2	57.91	58.22	1061.21	bi-annual plus AMP	Alluvium
P03-04-02	2003	47.5	47.24	47.55	1061.21	bi-annual plus AMP	Alluvium
P03-04-03	2003	41.5	41.15	41.45	1061.21	bi-annual plus AMP	Alluvium
P03-04-04	2003	35.1	34.75	35.05	1061.21	bi-annual plus AMP	Alluvium
P03-04-05	2003	26.1	25.76	26.06	1061.21	bi-annual plus AMP	Alluvium
P03-04-06	2003	17.4	17.07	17.37	1061.21	bi-annual plus AMP	Alluvium
P03-04-07	2003	15.5	15.24	15.54	1061.21	bi-annual plus AMP	Alluvium
P03-04-08	2003	13.7	13.41	13.72	1061.21	bi-annual plus AMP	Tailings
P03-04-09	2003	12.8	12.50	12.80	1061.21	bi-annual plus AMP	Tailings
P03-05-01	2003	44.5	44.20	44.50	1060.43	not routinely monitored	Alluvium
P03-05-02	2003	36.9	36.58	36.88	1060.43	not routinely monitored	Alluvium
P03-05-03	2003	27.7	27.43	27.74	1060.43	not routinely monitored	Alluvium
P03-05-04	2003	23.5	23.16	23.47	1060.43	not routinely monitored	Alluvium
P03-05-05	2003	21.6	21.34	21.64	1060.43	not routinely monitored	Alluvium
P03-05-06	2003	18.6	18.29	18.59	1060.43	not routinely monitored	Tailings
P03-05-07	2003	14.0	13.72	14.02	1060.43	not routinely monitored	Tailings
P03-05-08	2003	11.0	10.67	10.97	1060.43	not routinely monitored	Tailings
P03-06-01	2003	25.9	25.60	25.91	1062.79	bi-annual	Alluvium
P03-06-02	2003	22.9	22.56	22.86	1062.79	bi-annual	Alluvium
P03-06-03	2003	19.8	19.51	19.81	1062.79	bi-annual	Alluvium
P03-06-04	2003	16.5	16.15	16.46	1062.79	bi-annual	Alluvium
P03-06-05	2003	14.3	14.02	14.33	1062.79	bi-annual	Alluvium
P03-06-06	2003	12.5	12.19	12.50	1062.79	bi-annual	Tailings
P03-06-07	2003	11.0	10.67	10.97	1062.79	bi-annual	Tailings
NA05-9D	2005	11.0	7.9	10.9	1060.81	not routinely monitored	Alluvium
NA05-9S	2005	6.1	1.4	4.4	1060.57	not routinely monitored	Tailings

Contaminant concentrations in the underlying aquifer are typically highest in the shallow piezometers screened near the interface of the sand and gravel aquifer and the overlying tailings. However, different depth profiles continue to be observed at P03-03 and P03-06. At P03-03, SO_4 concentrations are elevated throughout the entire depth of the aquifer and Zn concentrations actually increase significantly with depth. At P03-06, SO_4 concentrations continued to remain higher at greater depth and Zn concentrations also continued to increase throughout the entire depth of the aquifer. In both cases these depth profiles suggest significant contributions from an upgradient source (RGC, 2008).

In October 2005, the nested monitoring wells P01-07A/B/C/D/E and P01-09A/B/C/D were decommissioned by sealing the piezometer with a bentonite slurry. At both locations, multilevel piezometers are located within a relatively short distance (<150-m) downgradient of the decommissioned wells allowing a preliminary assessment of any potential effects of this decommissioning work on the groundwater quality in the Rose Creek sediments.

Figure 3-9a/b shows the time trends of selected water quality parameters for P03-03, located about 140-m downgradient of the decommissoned wells P01-09A/B/C/D. Previous analyses had suggested that leakage from P01-09 (in particular from P01-09E) is the most likely cause for the highly elevated SO_4 and Zn at depth at this location (RGC, 2006a; RGC, 2008). However, current time trends at this location are inconclusive. While a notable decrease in Zn concentrations since decommissioning has been observed in some piezometers (P03-03-03 and -04), other piezometers have shown an increase in Zn concentrations (P03-03-05 and -06). The most impacted piezometer (P03-03-02) initially showed a decrease in Zn (and SO_4) concentrations but those contaminant concentrations rebounded in 2008. The lack of a rapid and consistent recovery in this highly impacted, deep piezometer after well decommissioning could be due to a slower than expected flushing of the residual contaminant plume. Alternatively, tailings seepage from further upgradient (unrelated to “leaky wells”) could be the source of the highly elevated Zn concentrations observed at depth at this location.

Figure 3-10a/b shows the time trends of selected water quality parameters for P03-04, located about 140-m downgradient of the decommissioned wells P01-07A/B/C/D/E. At this location, the shallow piezometer P03-04-06 (screened near the interface with the tailings) has shown a significant decrease in Zn and other ARD products (SO_4, Mg, Mn and Fe) since decommissioning of the leaky wells. Contaminant concentrations in the deeper piezometers at this location (P03-04-01 to -05) all peaked around 2007 and started to decline in 2008. These observations would suggest that sealing of the leaky wells indeed reduced the contaminant loading and improved groundwater quality in the Rose Creek aquifer at P03-04.

Figure 3-10c/d shows the time trends of selected water quality parameters for P03-06, located in the northwestern portion of the Second Impoundment (near Faro Creek canyon). Earlier monitoring had indicated significant increases in oxidation products and metal concentrations at this location (in particular at depth) (RGC, 2008). The most recent monitoring data show a continued increase in Zn and other ARD products (SO_4, Mg, Mn and Fe) at P03-06. Of particular concern is the rapid increase in Zn concentrations which approximately doubled over the last two years and currently averages about 2 to 5 mg/L Zn. Note that only one piezometer, P03-06-05 screened just beneath the tailings, showed a decline in oxidation products (in particularly SO_4 and Mg but also Zn and other metals).

A more detailed geochemical assessment, including mixing calculations, suggested that groundwater in this area may be impacted by a combination of seepage from coarse and well-drained tailings located in the Original Impoundment and seepage from the Faro Creek channel/diversion channel (RGC, 2009). This study suggested that the recent increases in oxidation products (in particular SO_4 and Zn) in the Rose Creek aquifer at this location (and further downgradient) could be a result of the recent deterioration of water quality in the Faro Creek seepage.

It was also noted that operation of a new seepage interception system (SIS) (operating below the ETA area since the fall of 2006) may reduce contaminant concentrations in the northern portion of the Rose Creek aquifer (at P03-06) by as much as 50% (RGC, 2009). Conservative transport calculations suggested that an improvement in groundwater quality at P03-06 due to operation of the Faro Creek SIS could be expected to occur after 1 to 5 years. The sharp decrease in SO_4 and, to a lesser extent Zn, at P03-06-05 observed in 2008 could potentially be a result of operation of the SIS. However, other factors such as ‘flushing’ during a very wet spring runoff could also explain this decrease. Longer-term monitoring will be required to determine the source(s) of contaminants and the effect of intercepting Faro Creek seepage on groundwater quality at this location.

In summary, groundwater quality data collected from the Rose Creek aquifer beneath the Second Impoundment suggests an incremental loading from east (upstream) to west (downstream). However, while some reaches of the aquifer experience continued deterioration of groundwater quality (in particular near P03-06) other reaches appear to have stabilized or even show a notable improvement in groundwater quality. These observations suggest that groundwater quality in the aquifer sediments beneath the Second Impoundment is strongly influenced by different local sources, including concentrated ARD seepage from coarse, fully oxidized tailings beaches, residual contamination from leaky wells (now sealed) and Faro Creek seepage.

3.5 Intermediate Impoundment

3.5.1 Background

Table 3-3 summarizes pertinent information related to the groundwater monitoring wells located in the Intermediate Impoundment, including year of construction, installation details (total depth, screening interval), and the status of monitoring.

3.5.2 Review of Time Trends

Water quality time trends for the X21 well series are shown in Figures 3-11a/b. Aside from the increase in Na concentration observed in X21A, groundwater quality in X21A and X21B did not change during the current monitoring period and no new data for X21C was available.

Note that monitoring wells X21A/B have not shown the same increase in SO_4 and Zn concentrations in the aquifer that have been observed in recent years at P03-06. Assuming a direct hydraulic connection in a contiguous aquifer, a similar breakthrough (at least of SO4) would be expected at X21A/B in about 2 to 10 years.

Water quality depth profiles for P03-08 are shown in Figure 3-12a/b. Depth profiles for the current monitoring period were similar to those defined by previously-collected data and no appreciable changes in water quality were observed.

Table 3-3. Monitoring wells in the Intermediate Impoundment, Rose Creek Tailings Facility

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Intermediate							
X21A-96	1996	8.5	2.43	8.53	1052.09	bi-annual	Tailings
X21B-96	1996	14.7	11.64	14.69	1052.14	bi-annual	Alluvium
X21C-96	1996	29.4	27.86	29.37	1052.21	no longer sampled	Alluvium
P03-08-01	2003	32.6	32.31	32.61	1048.35	bi-annual plus AMP	Alluvium
P03-08-02	2003	28.3	28.04	28.35	1048.35	bi-annual plus AMP	Alluvium
P03-08-03	2003	24.7	24.38	24.69	1048.35	bi-annual plus AMP	Alluvium
P03-08-04	2003	23.2	22.86	23.16	1048.35	bi-annual plus AMP	Alluvium
P03-08-05	2003	21.6	21.34	21.64	1048.35	bi-annual plus AMP	Alluvium
P03-08-06	2003	20.1	19.81	20.12	1048.35	bi-annual plus AMP	Tailings
P03-08-07	2003	17.1	16.76	17.07	1048.35	bi-annual plus AMP	Tailings
P03-08-08	2003	14.0	13.72	14.02	1048.35	bi-annual plus AMP	Tailings
NA05-2D	2005	13.7	10.7	13.7	1052.13	not routinely monitored	Alluvium
NA05-2S	2005	8.8	4.5	7.5	1052.11	not routinely monitored	Tailings

3.6 Toe of Intermediate Dam

3.6.1 Background

Table 3-4 summarizes pertinent information related to the groundwater monitoring wells located at the toe of the Intermediate Dam, including year of construction, installation details (total depth, screening interval), and the status of monitoring.

Table 3-4. Monitoring wells at the toe of the Intermediate Dam, Rose Creek Tailings Facility

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Intermediate Dam							
X24A-96	1996	6.5	6.46	6.48	1033.10	no longer sampled	Alluvium
X24B-96	1996	11.3	9.8	11.3	1033.05	no longer sampled	Alluvium
X24C-96	1996	16.5	14.97	16.47	1033.00	no longer sampled	Alluvium
X24D-96	1996	28.3	26.84	28.34	1032.90	bi-annual	Alluvium
X25A-96	1996	8.9	7.44	8.97	1032.08	bi-annual	Alluvium
X25B-96	1996	19.1	17.7	19.17	1032.03	bi-annual	Alluvium
P01-03	2001	9.3	7.78	9.3	1032.21	bi-annual	Alluvium
P01-04A	2001	34.1	32.53	34.05	1031.90	bi-annual	Alluvium
P01-04B	2001	53.4	51.89	53.41	1031.89	bi-annual	Till

3.6.2 Review of Time Trends

Figure 3-13a/b illustrates the water quality time trends for wells located in the northern section of the Intermediate Dam (X24A/B/C/D and P01-03). Since 2001, SO4, Mg, Zn and Mn concentrations have increased in each of these wells. This trend continued throughout most of the current monitoring period. Note that the highest contaminant concentrations have been consistently observed in the deepest well (X24D).

The trend of increasing oxidation products and metal concentrations in the aquifer at X24 is indicative of mine waste seepage. The exact source cannot be deduced from the available data yet seepage from the Intermediate Pond was excluded by RGC (2008). Hence the coarse tailings beaches located in the northern portions of the Intermediate, Second or Original Impoundments and/or seepage from the Faro Creek channel/diversion channel are the probable sources.

As noted earlier, a more detailed geochemical assessment of groundwater quality at P03-06 had indicated that seepage from the Faro Creek diversion/channel is impacting the northern portion of the Rose Creek aquifer (RGC, 2009). Again, interception of Faro Creek seepage (since late 2006) may potentially improve groundwater quality at X24. However, a reduction in contaminant concentrations at X24 can be expected to be significantly delayed (by 4 to 20 years) owing to the long travel distance and potential for geochemical reactions (RGC, 2009). It is recommended that a similar geochemical assessment (including finger-printing and geochemical mixing calculations) be performed for groundwater at X24 to determine the proportion of Faro Creek seepage in groundwater in this reach of the aquifer.

Figure 3-14a/b illustrates the water quality time trends in the wells screened in the southern section of the Intermediate Dam (X25A/B, P01-04A/B). Note that there appears to be a mix-up in well ID of P01-04A and P01-04B starting in 2006. The depth of these two wells should be checked in the field and the existing groundwater quality data corrected in the field/database as required.

Groundwater quality in the aquifer beneath the southern portion of the Intermediate Dam is generally characterized by significantly lower SO_4 and Mg concentrations than observed in the northern portion. Most water quality parameters remained unchanged in the wells of the southern section of the Intermediate Dam. A notable exception was the concentration of SO_4, which increased in each of the wells except P01-04B (or P01-04A?). Note that Zn concentrations have remained at or below the detection limit for the current monitoring period in all wells located on the southern side of the Intermediate Dam.

3.7 Toe of Cross Valley Dam

3.7.1 Background

Table 3-5 summarizes pertinent information related to the groundwater monitoring wells located along the toe of the Cross Valley Dam, including year of construction, installation details (total depth, screening interval) and status of monitoring.

3.7.2 Review of Time Trends

Water quality time trends in the wells screened at the toe of the Cross Valley Dam are shown in Figures 3-15a/b to 3-17a/b. Concentrations of oxidation products (i.e. SO_4, Mg, and alkalinity) and Mn continued to increase in wells located along the northern toe of the Cross Valley Dam (P01-11, P05-01 and P05-02). This gradual increase in oxidation products (primarily SO_4 and Mg) on the north side of Cross Valley Dam mimics the breakthrough of those constituents observed further upgradient at the Intermediate Dam (at X24), except for a delay by about 3-4 years.

Table 3-5. Monitoring wells at the toe of the Cross Valley Dam, Rose Creek Tailings Facility

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Toe of Cross Valley							
P01-02A	2001	14.1	12.54	14.06	1019.73	bi-annual	Alluvium
P01-02B	2001	28.4	26.88	28.4	1019.71	bi-annual	Till
P01-11	2001	10.7	9.15	10.67	1017.83	bi-annual	Alluvium
P03-09-01	2003	35.1	34.75	35.05	1018.51	bi-annual plus AMP	Alluvium
P03-09-02	2003	32.3	32.00	32.31	1018.51	bi-annual plus AMP	Alluvium
P03-09-03	2003	27.1	26.82	27.13	1018.51	bi-annual plus AMP	Alluvium
P03-09-04	2003	23.8	23.47	23.77	1018.51	bi-annual plus AMP	Alluvium
P03-09-05	2003	21.9	21.64	21.95	1018.51	bi-annual plus AMP	Alluvium
P03-09-06	2003	18.9	18.59	18.90	1018.51	bi-annual plus AMP	Alluvium
P03-09-07	2003	13.4	13.11	13.41	1018.51	bi-annual plus AMP	Alluvium
P03-09-08	2003	9.4	9.14	9.45	1018.51	bi-annual plus AMP	Alluvium
P03-09-09	2003	7.6	7.32	7.62	1018.51	bi-annual plus AMP	Alluvium
MW1	2005	17.7	1.95/12.19	9.74/17.67	1016.97	not routinely monitored	Alluvium
MW2	2005	14.9	2.19	14.89	1018.23	not routinely monitored	Alluvium
P05-01-01	2005	25.5	25.15	25.45	1018.00	bi-annual	Till/BR
P05-01-02	2005	19.8	19.67	19.82	1018.00	bi-annual	Alluvium
P05-01-03	2005	16.8	16.62	16.77	1018.00	bi-annual	Alluvium
P05-01-04	2005	11.3	11.13	11.28	1018.00	bi-annual	Alluvium
P05-01-05	2005	5.5	5.33	5.48	1018.00	bi-annual	Alluvium
P05-01-06	2005	3.4	3.20	3.35	1018.00	bi-annual	Alluvium
P05-02	2005	5.2	1.83	4.88	1016.67	bi-annual	Alluvium
P05-03	2005	7.6	3.44	7.62	1019.79	bi-annual	Alluvium
RGC-PW1	2005	21.1	4.19/16.38	5.79/19.59	1017.31	not routinely monitored	Alluvium
RGC-PW2	2005	16.9	4.19	15.39	1018.64	not routinely monitored	Alluvium

Note that Zn (and Fe) did not increase during the current observation period and even decreased in some wells (e.g. in P01-11, P05-01)[1]. This lag in breakthrough of Zn may be a result of sorption along the flow path which results in retardation of the Zn relative to transport of SO4 and Mg. Nevertheless, it is anticipated that contaminant concentrations (including Zn) in the northern portion of the aquifer will further increase over time and will gradually approach those observed at X24.

The monitoring well located near the center of the Cross Valley Dam (P03-09 and P05-03) continue to be less impacted than the northern portion of the aquifer. However, most oxidation products (SO4,

[1] Note that the laboratory method for metals (including zinc) was changed in 2008 resulting in much lower method of detection limits for zinc. In some cases this resulted in an apparent decrease in observed zinc concentrations as the concentrations are plotted at the mdl.

Mg, alkalinity) and Mn continued to increase during the current observation period indicating a gradual breakthrough of seepage water from upgradient. As observed further north, Zn concentrations did not increase in those wells (P03-09) or actually decreased (e.g. in P05-03).

The two monitoring wells located near the southern abutment of the Cross Valley Dam (P01-11A/B) continued to show no impact of tailings seepage.

3.8 Downstream of Cross Valley Dam

3.8.1 Background

Table 3-6 lists pertinent information of all groundwater monitoring wells located down-gradient of the Cross Valley Dam, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Table 3-6. Monitoring wells downgradient of Cross Valley Dam, Rose Creek Tailings Facility

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Downgradient of							
X16A	1981	6.0	3	6	1016.41	bi-annual	Alluvium
X16B	1981	34.0	20	34	1016.01	bi-annual	Alluvium
X17A	1981	6.2	4.5	6.2	1015.45	bi-annual	Alluvium
X17B	1981	25.0	17	25	1014.89	bi-annual	Alluvium
X18A	1981	10.6	8.8	10.6	1019.59	bi-annual	Alluvium
X18B	1981	22.8	16.6	22.8	1019.65	bi-annual	Alluvium
P01-01A	2001	21.4	19.8	21.36	1015.86	bi-annual	Alluvium
P01-01B	2001	35.3	33.78	35.3	1015.86	bi-annual	Alluvium

3.8.2 Review of Time Trends

Figures 3-18a/b show the water quality time trends in wells (X16A/B, X17A/B, X18A/B and P01-01A/B) located at some distance down-gradient of the Cross Valley Dam. Monitoring wells located on the northern side of Rose Creek Valley (X18A/B, P01-01A/B) continued to show an increase in oxidation products (SO4 and Mg) during the current monitoring period. As observed near the Cross Valley Dam, Zn concentrations remained constant or actually decreased in 2008.

This gradual increase in oxidation products (primarily SO_4 and Mg) on the north side of Rose Creek aquifer is believed to represent the leading edge of the breakthrough of those constituents observed further upgradient at the Cross Valley Dam (P01-11, P05-01) and ultimately at the Intermediate Dam (at X24). It is therefore anticipated that concentrations of SO_4 and Mg, and eventually Zn and other metals (Fe, Mn) will continue to increase over time.

The monitoring wells located in the center of the Rose Creek valley (X16A/B, X17A/B) continued to show no signs of a breakthrough of tailings seepage suggesting that the impact of tailings seepage is limited to the northern portion of the aquifer at greater distance from the Cross Valley Dam.

4 GRUM & VANGORDA MINE SITE

4.1 Geographic Overview

Figure 4-1 shows the general layout of the Grum/Vangorda mine-site, including the mine waste-units and the groundwater monitoring wells in the area. The Grum site comprises the Grum Pit, Grum rock dump (with sulphide cell) and the overburden stockpile. The Vangorda site comprises the Vangorda Pit (with in-pit rock dumps) and the Vangorda rock dump. Groundwater monitoring is generally concentrated along the toes of the rock dumps.

4.2 Downstream of Grum Rock Dump

4.2.1 Background

Figure 4-2 shows the locations of the monitoring wells located down-gradient of the Grum Rock Dump and Table 4-1 lists pertinent information of those monitoring wells, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Table 4-1. Monitoring wells downgradient of Grum Rock Dump

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Grum WRD Area							
P96-9A	1996	9.5	4.96	9.45	~1098	bi-annual	Overburden
SRK04-5A	2004	23.7	22.7	23.7	1103.93	no longer sampled	BR (weathered)
SRK04-5B	2004	14.7	13.7	14.7	1103.95	no longer sampled	Overburden
BH05-9B-R	2005	18.6	15.5	18.6	1101.06	bi-annual	Overburden/BR
SRK05-05C	2005	3.2	1.5	3	1104.08	bi-annual	Overburden
SRK05-06	2005	2.7	0.7	2.7	1073.83	bi-annual	Overburden
SRK05-07	2005	5.8	0.75	5.8	1107.30	bi-annual	Overburden/BR
SRK05-08	2005	7.6	2.1	7.6	1105.25	bi-annual	Overburden
SRK05-09	2005	3.7	0.5	3.5	1072.82	no longer sampled	Overburden

4.2.2 Review of Time Trends

Figure 4-3a/b shows selected water quality time trends for the monitoring wells located near Grum Creek and down-gradient of the Moose Pond. Groundwater quality for most of the wells located down-stream of Grum Rock Dump remained unchanged during the monitoring period. An exception was SRK05-09 (a.k.a. Moose Well 2), which is located downstream of Moose Pond. In this well, the concentrations of SO_4 and Mg increased significantly throughout 2008. Groundwater quality in Moose Well #2 has been shown to be impacted by seepage from Moose Pond (station V2A), which collects seepage from the Grum Rock Dump (RGC, 2008). Note that the seepage collection system at Grum Dump was changed in 2007, resulting in direction of more contaminated water to Moose Pond (to prevent direct discharge to surface waters). This change in seepage management is likely responsible for the deterioration in groundwater quality at 'Moose Well 2'.

Note that Zn concentrations in SRK05-09 decreased during the current observation period. It is unclear whether this is a result of improved detection limits in the laboratory or reduced loading (or higher adsorption) in the field.

Water quality time trends for monitoring wells located west of Grum Creek are shown in Figure 4-4a/b. Concentrations of oxidation products (SO_4, Mg and alkalinity) in P96-9A, screened in alluvial sediments in a narrow side drainage, appeared to reach a plateau in 2007 and did not further increase in 2008. Zn concentrations in this well remained below peak concentrations observed in previous years.

The two monitoring wells located further west (SRK05-07 and SRK05-08) and screened in shallow phyllite bedrock showed a continued increase in oxidation products (SO_4, Mg and alkalinity) suggesting that a gradual breakthrough of seepage from Grum Dump is also occurring in the weathered bedrock. Zn concentrations remained elevated in SRK05-07 but decreased in SRK05-08.

These monitoring data suggest that seepage from the Grum waste rock dump affects groundwater quality not only in narrow valleys with permeable alluvial sediments (e.g. near P96-9A0 but also increasingly in the less permeable weathered bedrock along the toe of Grum Dump. Nevertheless, contaminant loads are likely to be significantly higher in the alluvial sediments due to the higher permeability and hence higher flow rates.

4.3 Vangorda WRD area

4.3.1 Background

Figure 4-5 shows the locations of the monitoring wells located down-gradient of the Vangorda Rock Dump and Table 4-2 summarizes pertinent information related to those monitoring wells, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Table 4-2. Monitoring wells downgradient of Vangorda Rock Dump

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Vangorda WRD Area							
V34	1994	12.5	n/a	n/a	1117.45	bi-annual	BR
V35	1994	15.5	n/a	n/a	1117.41	bi-annual	Alluvium
V36	1994	11.9	n/a	n/a	1118.43	bi-annual	Alluvium
V37	1994	14.1	n/a	n/a	1116.17	bi-annual	Alluvium
P2001-02A	2001	13.6	n/a	n/a	~1118	bi-annual	n/a
P2001-02B	2001	27.0	n/a	n/a	~1118	bi-annual	n/a
P2001-03	2001	n/a	n/a	n/a	~1121	bi-annual	n/a

4.3.2 Review of Time Trends

Figure 4-6a/b shows selected water quality time trends for the monitoring wells located down-gradient of the Vangorda Rock Dump. No significant changes in groundwater quality were observed for the wells in this area. Note, however, that monitoring well V34, located to the southeast of Vangorda Rock Dump, continued to show a gradual increase in concentrations of SO4, Mg and alkalinity suggesting a gradual breakthrough of neutralized waste rock seepage.

Note also that Zn concentrations were consistently lower in 2008 compared to 2007 in all wells (except V34). It is unclear whether this is a result of the change in laboratory methods (and detection limit) or dilution in the groundwater system.

5 CONCLUSIONS & RECOMMENDATIONS

Recent time trends in groundwater quality were reviewed in different reaches of the Anvil Range Mining Complex in order to identify changes in groundwater quality that have occurred since July 2007. The following sub-sections summarize the main conclusions and recommendations of this review by reach.

5.1 Conclusions

5.1.1 Faro Mine Site

The main conclusions of the groundwater quality review at the Faro Mine Site are as follows:

- Elevated levels of ARD products were observed in selected wells of the Emergency Tailings Area (ETA), which is consistent with the conclusion that this area remains a major source of contaminant loading;
- The groundwater quality in several wells located in the S-cluster area continued to deteriorate over the monitoring period, supporting earlier recommendations that seepage interception in this area should be prioritized;
- Groundwater quality in the Zone 2 Outwash Area remained relatively stable over the monitoring period;
- Groundwater quality down-gradient of the Northeastern Dump at BH14A/B deteriorated over the monitoring period, probably due to seepage from the sulphide-rich waste rock that has been identified in the area. This observation raises concerns that contaminant loading from the Northeastern Dump to the NFRC may increase over time potentially also requiring seepage interception.

5.1.2 Rose Creek Tailings Facility

The main conclusions of the groundwater quality review at the Rose Creek Tailings facility are as follows:

- Groundwater quality in the northern portion of the Rose Creek aquifer continued to deteriorate during the 2008 monitoring period. Of particular concern are recent increases in SO_4, Mg, and metal concentrations (including Fe, Zn, and Mn) observed at P03-06, located near the Faro Creek Canyon and immediately downgradient of the Original Impoundment. The recent time trends in this and other wells further downgradient confirm that the entire depth of the aquifer is affected by seepage. The most probable sources of ARD seepage in this area include the coarse tailings beaches located in the northern portion of the Second or Original Impoundments and/or seepage from the Faro Creek canyon/diversion channel (RGC, 2009).
- Impacted groundwater continues to move downgradient in the northern portion of the Rose Creek aquifer, as evidenced by a gradual breakthrough of SO_4, Mg, alkalinity and selected metals (Fe, Mn) in monitoring wells at the Intermediate dam (X24), Cross Valley Dam (P01-11, P05-01) and further downstream (X18, P01-01). The transport of Zn is still significantly

delayed due to chemical attenuation in the aquifer. In fact, Zn concentrations in many monitoring wells located at the Cross Valley Dam showed an apparent decline in Zn concentrations in 2008. This apparent decline could be, at least in part due to improved laboratory techniques implemented in 2008 resulting in a lower method of detection limit (mdl).

- The groundwater in the southern portion of the aquifer did not experience the same deterioration in groundwater quality in recent years as observed in the northern portion. Several of the highly impacted wells screened beneath the Second impoundment either stabilized in recent years (e.g. P03-03) or even showed a notable improvement in groundwater quality (e.g. P03-04). Decommissioning of several “leaky wells” may have contributed to the recent improvement in groundwater quality in the southern portion of the aquifer.

5.1.3 Grum/Vangorda Mine Site

The main conclusions of the groundwater quality review at the Grum/Vangorda mine site are as follows:

- Groundwater quality for most of the wells located downgradient of Grum Rock Dump and screened in shallow overburden soils continued to show some impact of neutralized mine drainage but did not deteriorate further during 2008. However, recent monitoring in two shallow bedrock wells (SRK05-07 and SRK05-08) showed a continued increase in oxidation products (SO4, Mg and alkalinity) suggesting that a gradual breakthrough of seepage from Grum Dump is also occurring in the weathered bedrock.
- Groundwater quality in monitoring wells located downgradient of the Vangorda Rock Dump (and screened in till) continued to show limited impact of neutralized mine drainage. No significant changes in groundwater quality were observed for the wells in this area. Zn concentrations were consistently lower in 2008 compared to 2007 in all wells possibly due to improved laboratory techniques implemented in 2008 resulting in a lower method of detection limit (mdl).

5.2 Recommendations

5.2.1 Routine Groundwater Monitoring

In general, the 2008 groundwater monitoring program at the Anvil Range Mining Complex followed the scope of monitoring proposed in the 2007 Groundwater Review Report (see tables 5.1 to 5.3 in RGC, 2008). Based on the review of the 2008 monitoring data we recommend the following changes to the groundwater monitoring program for 2009 (see tables 5-1 to 5-3):

- Increase frequency of monitoring to four times per season (May to November) for selected monitoring wells located on the northern side of Rose Creek valley (P03-06, X21, X24, P01-11, P05-01) to monitor ongoing breakthrough of contaminants and potential benefit of seepage interception of Faro Creek seepage at ETA SIS;
- Include all new monitoring wells installed in 2008 at the Faro and Grum/Vangorda mine sites (SRK, 2009) into the routine monitoring program. Those wells should be initally sampled two

additional times during the 2009 season (May and September). Those initial results should be reviewed in the 2009 groundwater review report to determine long-term monitoring requirements in those new wells.

- Monitoring wells TH86-2 and TH86-5, located upgradient of the Rose Creek Tailings facility, should be included in future routine monitoring as additional background wells for the Rose Creek valley (to be sampled annually).
- Chloride should be dropped from the “full suite” of parameters to be analysed in most wells (see RGC, 2008); a “reduced suite” of parameters (lab-EC, lab-pH, Ca, Mg, Na, K, SO4, alkalinity, Fe, Mn, and Zn) should be analyzed in selected wells to be sampled annually (see tables 5-1 to 5-3).

Table 5-1.

Recommended Scope of Groundwater Monitoring in 2009 for Faro Mine Site.

Well ID	Region	Northing UTM z8 NAD27	Easting UTM z8 NAD27	Proposed Frequency	Proposed Analysis Scheme
Faro Mine Site					
P96-8A	ETA Area	6913898	583328	Semi-annual	Full
P96-8B	ETA Area	6913898	583328	Semi-annual	Full
SRK04-3A	ETA Area	6913824	582977	Annual	Reduced
SRK05-ETA-BR1	ETA Area	6913846	582972	Annual	Reduced
SRK05-ETA-BR2	ETA Area	6913825	582987	Annual	Reduced
S1A	S-cluster Area	6912942	584539	Semi-annual	Full
S1B	S-cluster Area	6912942	584539	Semi-annual	Full
S2A	S-cluster Area	6912944	584577	Semi-annual	Full
S2B	S-cluster Area	6912944	584577	Semi-annual	Full
P96-7	S-cluster Area	6913105	584225	Semi-annual	Full
SRK05-SP-1A	S-cluster Area	6912901	584727	Annual	Reduced
SRK05-SP-1B	S-cluster Area	6912901	584726	Annual	Reduced
SRK05-SP-2	S-cluster Area	6912861	584791	Annual	Reduced
SRK05-SP-3A	S-cluster Area	6912924	584651	Annual	Reduced
SRK05-SP-3B	S-cluster Area	6912924	584652	Annual	Reduced
SRK05-SP-4A	S-cluster Area	6912939	584612	Semi-annual	Full
SRK05-SP-4B	S-cluster Area	6912939	584611	Semi-annual	Full
SRK05-SP-5	S-cluster Area	6912956	584576	Semi-annual	Full
BH1	Zone 2 Outwash	6913532	585267	Semi-annual	Full
BH2	Zone 2 Outwash	6913523	585206	Semi-annual	Full
BH4	Zone 2 Outwash	6913467	585247	Semi-annual	Full
BH5	Zone 2 Outwash	6913377	585194	Semi-annual	Full
BH6	Zone 2 Outwash	6913466	585198	Semi-annual	Full
BH8	Zone 2 Outwash	6913599	585253	Annual	Full
BH10A	Zone 2 Outwash	6913533	585190	Annual	Full
BH10B	Zone 2 Outwash	6913533	585191	Annual	Full
P05-04	Zone 2 Outwash	6913475	585224	Semi-annual	Full
Zone 2 Pumping Well (X26)	Zone 2 pit	6913770	584868	Semi-annual	Full
BH12A	NE Dumps	6914068	585871	Semi-annual	Reduced
BH12B	NE Dumps	6914068	585871	Semi-annual	Reduced
BH13A	NE Dumps	6914339	585844	Semi-annual	Reduced
BH13B	NE Dumps	6914339	585844	Semi-annual	Reduced
BH14A	NE Dumps	6913826	585676	Semi-annual	Full
BH14B	NE Dumps	6913826	585676	Semi-annual	Full
P96-6	Intermediate Dump (NFRC)	6913133	584999	Semi-annual	Full

Table 5-2

Recommended Scope of Groundwater Monitoring in 2009 for Rose Creek Tailings Facility.

Well ID	Region	Northing UTM z8 NAD27	Easting UTM z8 NAD27	Proposed Frequency	Proposed Analysis Scheme
Rose Creek Tailings Facility					
TH86-2	upgradient	?	?	Annual	Reduced
TH86-5	upgradient	?	?	Annual	Reduced
TH86-17	upgradient	6912489	583943	Annual	Reduced
P03-01 (-02,-04,-06,-08,-09)	Second Impoundment	6912580	583301	Annual	Full
P03-03 (-02,-04,-06,-08,-09)	Second Impoundment	6912698	583068	Annual	Full
P03-04 (-02,-04,-06,-08)	Second Impoundment	6913186	582085	Annual	Full
P03-05 (-02,-04,-06,-08)	Second Impoundment	6912934	582605	Annual	Full
P03-06 (all ports)	Second Impoundment	6913309	582573	4x per season	Full
X21A-96	Intermediate Impoundment	6913417	581989	4x per season	Full
X21B-96	Intermediate Impoundment	6913417	581989	4x per season	Full
P03-08 (-02,-04,-06,-07,-08)	Intermediate Impoundment	6913514	580980	Annual	Full
X24D-96	Intermediate Dam	6914124	580655	4x per season	Full
X25A-96	Intermediate Dam	6913945	580519	Semi-annual	Full
X25B-96	Intermediate Dam	6913945	580519	Semi-annual	Full
P01-03	Intermediate Dam	6914071	580639	4x per season	Full
P01-04A	Intermediate Dam	6913893	580496	Semi-annual	Full
P01-04B	Intermediate Dam	6913893	580496	Semi-annual	Full
P01-02A	Cross Valley Dam	6914044	580051	Semi-annual	Full
P01-02B	Cross Valley Dam	6914044	580051	Semi-annual	Full
P01-11	Cross Valley Dam	6914306	580214	4x per season	Full
P03-09 (-02,-04,-06,-08,-09)	Cross Valley Dam	6914229	580065	Semi-annual	Full
P05-01 (all ports)	Cross Valley Dam	6914335	580165	4x per season	Full
P05-02	Cross Valley Dam	6914265	580144	Semi-annual	Full
P05-03	Cross Valley Dam	6914171	580088	Semi-annual	Full
X16A	Downgradient of CVD	6914672	579574	Semi-annual	Full
X16B	Downgradient of CVD	6914672	579574	Semi-annual	Full
X17A	Downgradient of CVD	6914475	579874	Semi-annual	Full
X17B	Downgradient of CVD	6914475	579874	Semi-annual	Full
X18A	Downgradient of CVD	6914539	580105	Semi-annual	Full
X18B	Downgradient of CVD	6914539	580105	Semi-annual	Full
P01-01A	Downgradient of CVD	6914675	579819	Semi-annual	Full
P01-01B	Downgradient of CVD	6914675	579819	Semi-annual	Full

Table 5-3

Recommended Scope of Groundwater Monitoring in 2009 for Grum/Vangorda Mine Site

Well ID	Region	Northing UTM z8 NAD27	Easting UTM z8 NAD27	Proposed Frequency	Proposed Analysis Scheme
Grum/Vangorda Mine Site					
P96-9A	Grum Rock Dump	6903165	592753	Semi-annual	Full
BH05-9B-R	Grum Rock Dump	6903172	592747	Semi-annual	Full
SRK05-05C	Grum Rock Dump	6903208	592873	Semi-annual	Full
SRK05-07	Grum Rock Dump	6903011	592477	Semi-annual	Full
SRK05-08	Grum Rock Dump	6903063	592690	Semi-annual	Full
SRK05-09 ("Moose Well 2")	Grum Rock Dump	6902986	593058	Semi-annual	Full
V34	Vangorda Rock Dump	6902295	593553	Semi-annual	Full
V35	Vangorda Rock Dump	6902371	593293	Semi-annual	Full
V36	Vangorda Rock Dump	6902733	593243	Semi-annual	Full
V37	Vangorda Rock Dump	6902913	593420	Semi-annual	Full
P2001-02A	Vangorda Rock Dump	6902880	593098	Semi-annual	Full
P2001-02B	Vangorda Rock Dump	6902880	593098	Semi-annual	Full
P2001-03	Vangorda Rock Dump	6902865	593131	Semi-annual	Full

5.2.2 Future Assessment Work

Groundwater monitoring in the Rose Creek valley has shown a significant deterioration in groundwater quality in the last 2 - 3 years in the northern portion of the valley, from P03-06 in the Second Impoundment to the Intermediate Dam (at X24) and Cross Valley Dam (at P01-11, P05-01, P05-02). Geochemical fingerprinting and mixing calculations suggest that Faro Creek seepage could have caused, or at least contributed to, this recent deterioration in groundwater quality in the northern portion of the Rose Creek aquifer (RGC, 2009).

If this hypothesis is correct, the recent start-up of the seepage interception system in the ETA area (intercepting much of the Faro Creek seepage) may, in time, result in an improvement of groundwater quality on the north side of the Rose Creek aquifer.

We recommend that a more comprehensive geochemical assessment be completed that includes additional mixing calculations for other wells located downgradient of the Intermediate Dam (X21, X24) and the Cross Valley Dam (P01-11, P05-01, P05-02) which have shown recent increases in contaminant concentrations. In addition, consideration should be given to collecting stable isotope data in order to further constrain the sources of contaminants to the Rose Creek aquifer.

We also recommend that the performance of the ETA seepage interception system be reviewed to assess the extent of contaminant load reduction from Faro Creek seepage to the Rose Creek aquifer.

Groundwater monitoring in the North Fork Rose Creek area, upgradient of the rock drain, has shown consistently elevated zinc concentrations. Owing to the high permeability of the NFRC sediments the zinc load in this aquifer is significant. We recommend that additional geochemical characterization work be completed (including geochemical finger-printing, mixing calculations and potentially use of isotopic tracers) to determine the relative contribution of Zone 2 pit seepage, waste rock seepage and leakage from the outwash sediments in this reach of the NFRC. Such an analysis would provide guidance in the design of a seepage interception system along the NFRC reach.

6 CLOSURE

This report was prepared by Robertson GeoConsultants Inc., for Deloitte & Touche Inc. in its capacity as Interim Receiver of Anvil Range Mining Corporation. No third-party engineer or consultant shall rely on any of the information, conclusions, opinions, or any other material contained in this report without the express written consent of Deloitte & Touche Inc. and RGC.

We trust that the information provided in this report meets your requirements at this time. Should you have any questions or if we can be of further assistance, please do not hesitate to contact the undersigned.

ROBERTSON GEOCONSULTANTS INC.

Prepared by	**Reviewed by:**
Dr. Paul R. Ferguson	Dr. Christoph Wels, M.Sc., P.Geo.
Hydrogeochemist	Principal and Senior Hydrogeologist

7 REFERENCES

AECOM, 2009. Anvil Range Mine 2008 Groundwater Monitoring Report. Draft Report submitted to deloitte & Touche Inc., January 2009

Robertson GeoConsultants, 2004. Water & Load Balance Study for Rose Creek Tailings Storage Facility, Faro Mine, Yukon Territory. Report prepared for Deloitte&Touche, March 2006.

Robertson GeoConsultants, 2006a. Water & Load Balance Study for Rose Creek Tailings Storage Facility, Faro Mine, Yukon Territory. Report prepared for Deloitte&Touche, March 2006.

Robertson GeoConsultants, 2006b. Decommissioning of “Leaky Wells” Rose Creek Tailings Storage Facility, Faro Mine, Yukon Territory. Report prepared for Deloitte&Touche, April 2006.

Robertson GeoConsultants, 2006c. Design of Groundwater Interception System for Rose Creek Tailings Storage Facility, Faro Mine, Yukon Territory. Report prepared for Deloitte&Touche, October 2006.

Robertson GeoConsultants, 2008. 2007 Groundwater Review: Anvil Range Mining Complex, Report No. 118012/1, May 2008.

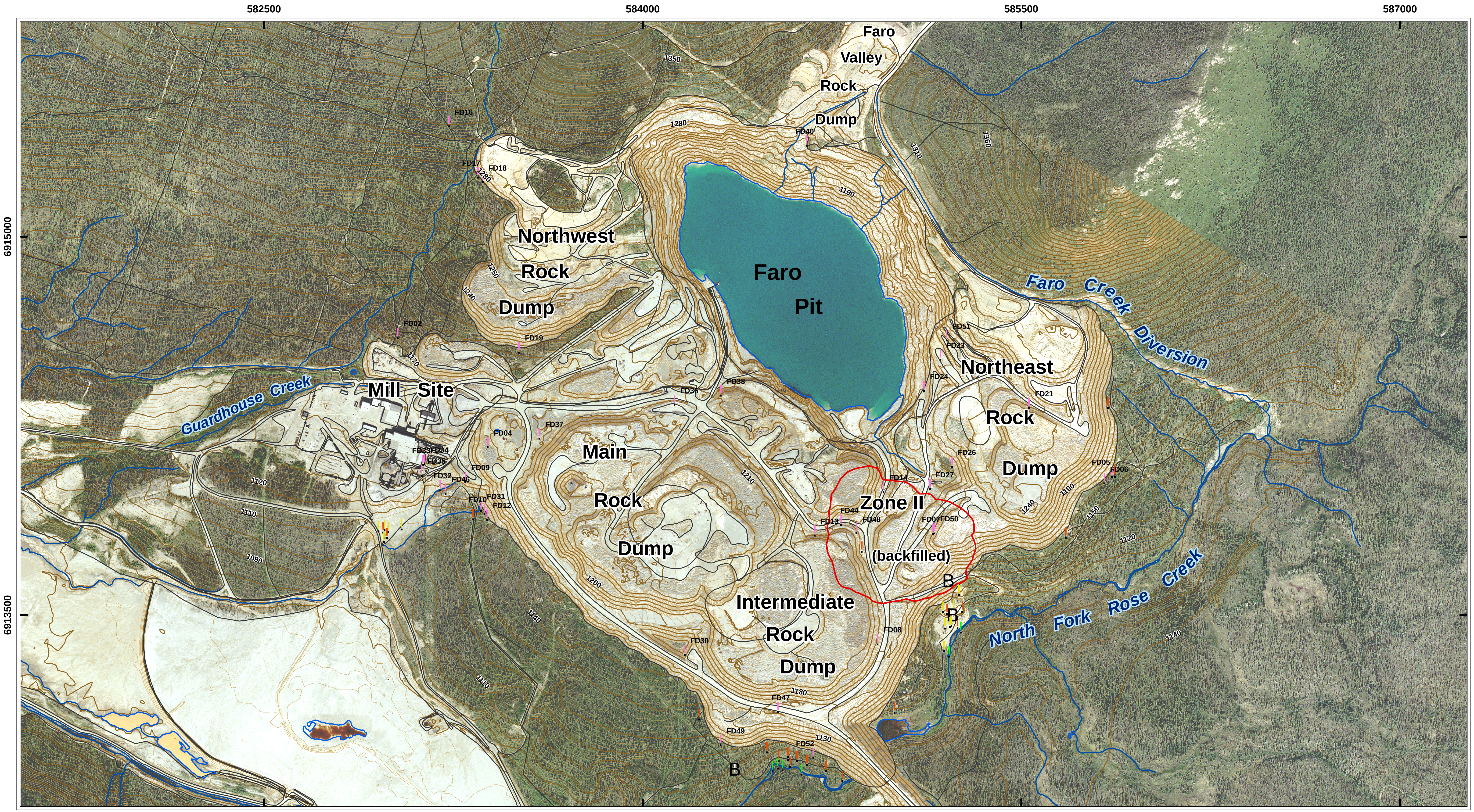
Robertson GeoConsultants, 2009. DRAFT V1 – Geochemical Assessment of Groundwater Quality in Rose Creek aquifer, Anvil Range Mine, Yukon Territory. Report No. 118013/1, January 2009.

SRK Consulting 2006. Anvil Range Mining Complex, 2005 Seepage Investigation at the S-cluster area below the Faro Waste Rock Dumps – 2005/06 Task 20e, Report prepared for Deloitte & Touche Inc., November 2006.

SRK Consulting 2007. Anvil Range Mining Complex, Continued Seepage Investigation Zone 2 Pit Outwash Area – 2005/06 Task 20e, Report prepared for Deloitte & Touche Inc., January 2007.

SRK Consulting 2009. Faro Mine Complex - 2008 S-Cluster Groundwater Investigation and Option Assessment. 2008/09 Task 24 - Report prepared for Deloitte & Touche Inc., January 2009.

FIGURES



LEGEND

- Monitoring Well
- Other Well (not Monitored Routinely)
- B Abandoned Well
- Drive Point
- Seep Monitoring Station
- Zone II Pit Outline

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2M

Layout of Faro Mine Site

Anvil Range Mining Complex

SCALE

0 380 760 1,140 1,520 Meters

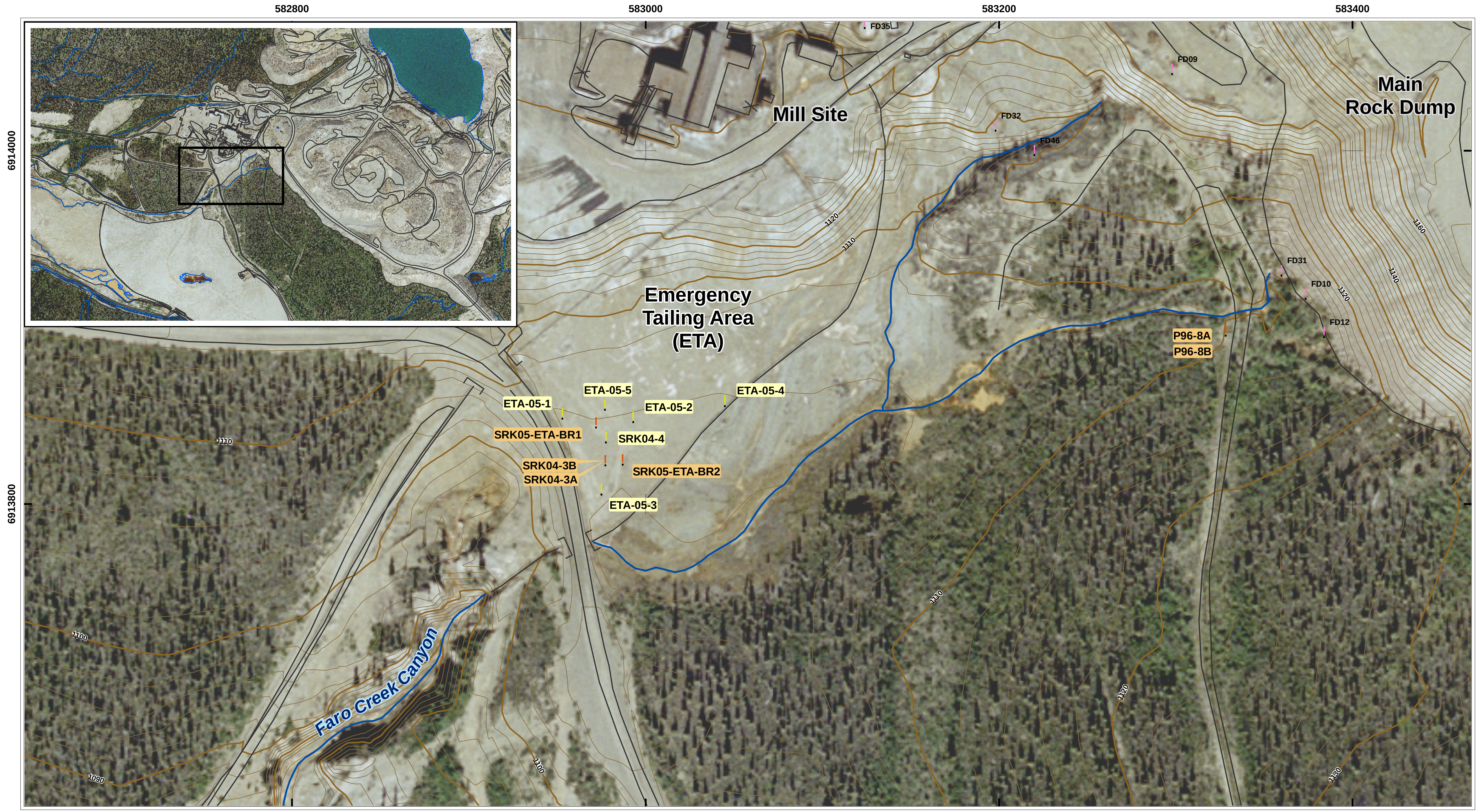
Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2008 Groundwater Review
REPORT: RGC 118014
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 2-1

DATE: 021109
DRAWN BY: OM
FILE: Faro_Site09.mxd



Groundwater Monitoring Wells
ETA Area
Faro Mine Site

LEGEND

- Monitoring Well
- Other Well (not Monitored Routinely)
- Seep Monitoring Station

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

SCALE

0 25 50 100 150 200 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2008 Goundwater Review
REPORT: RGC 118014
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 2-2

DATE: 021109
DRAWN BY: OM
FILE: Faro_ETA_area09.mxd

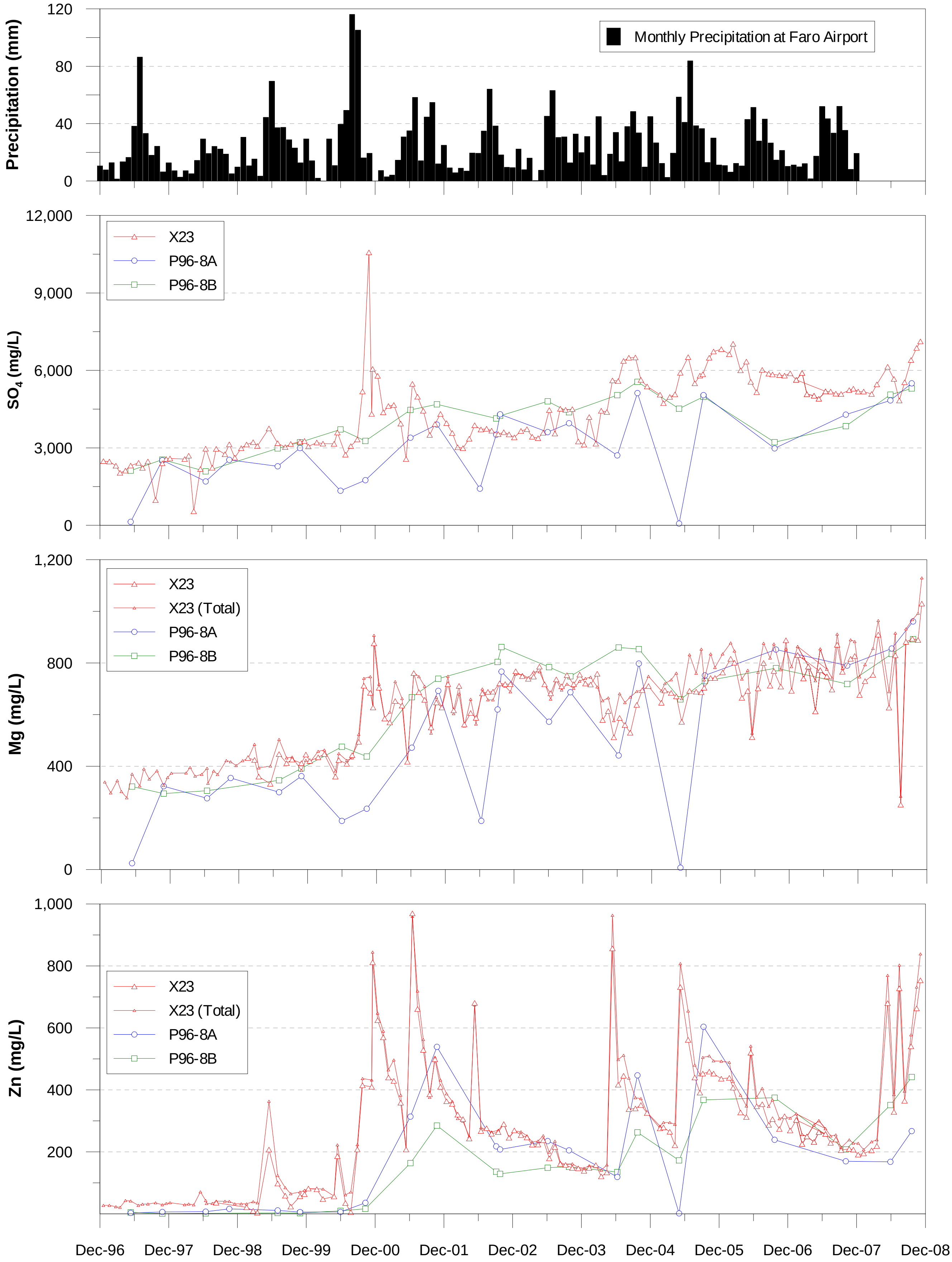


Figure 2-3a. Precipitation and water quality (SO_4, Mg and Zn) in X23 and P96-8A/B.

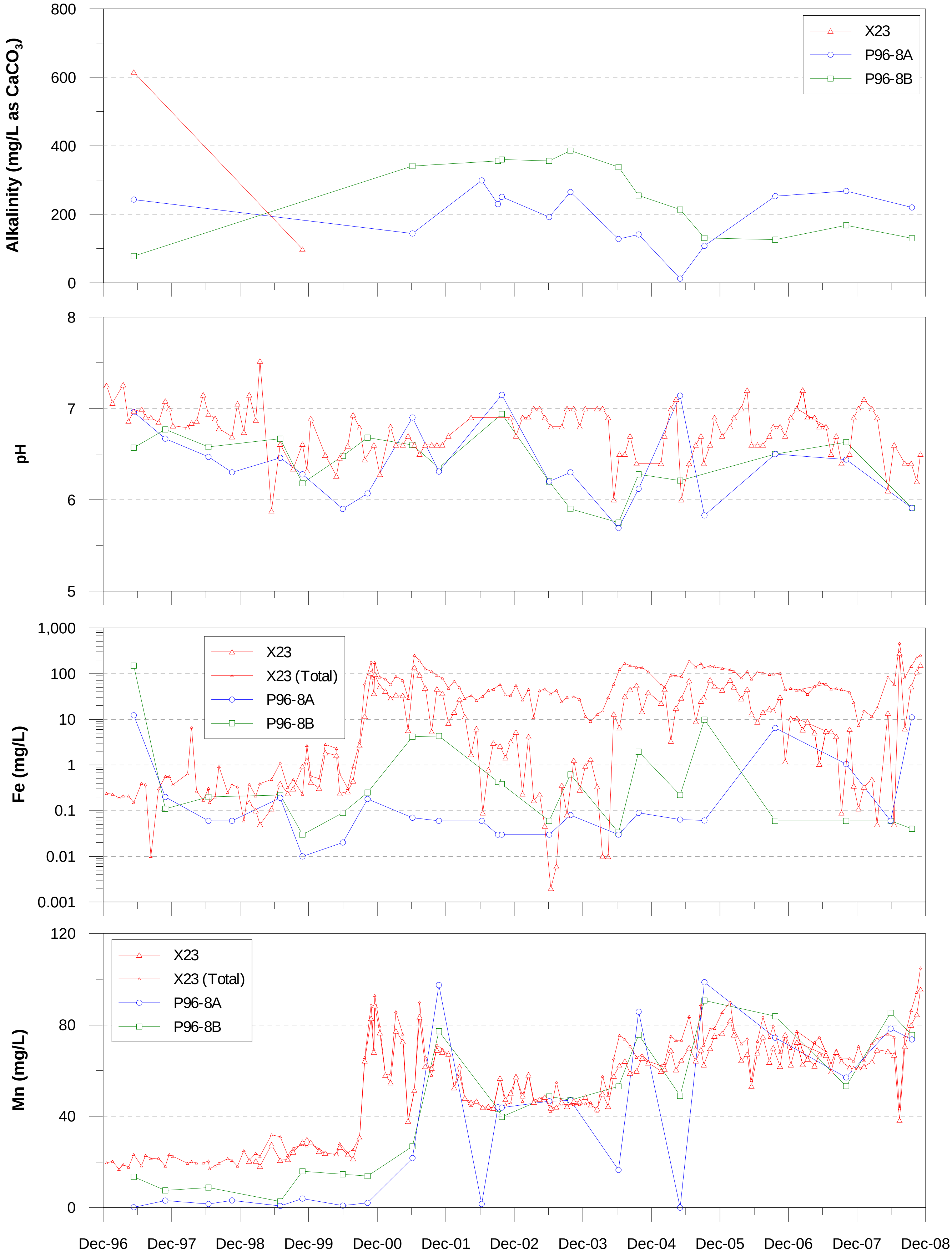


Figure 2-3b. Water quality (alkalinity, pH, Fe and Mn) in X23 and P96-8A/B.

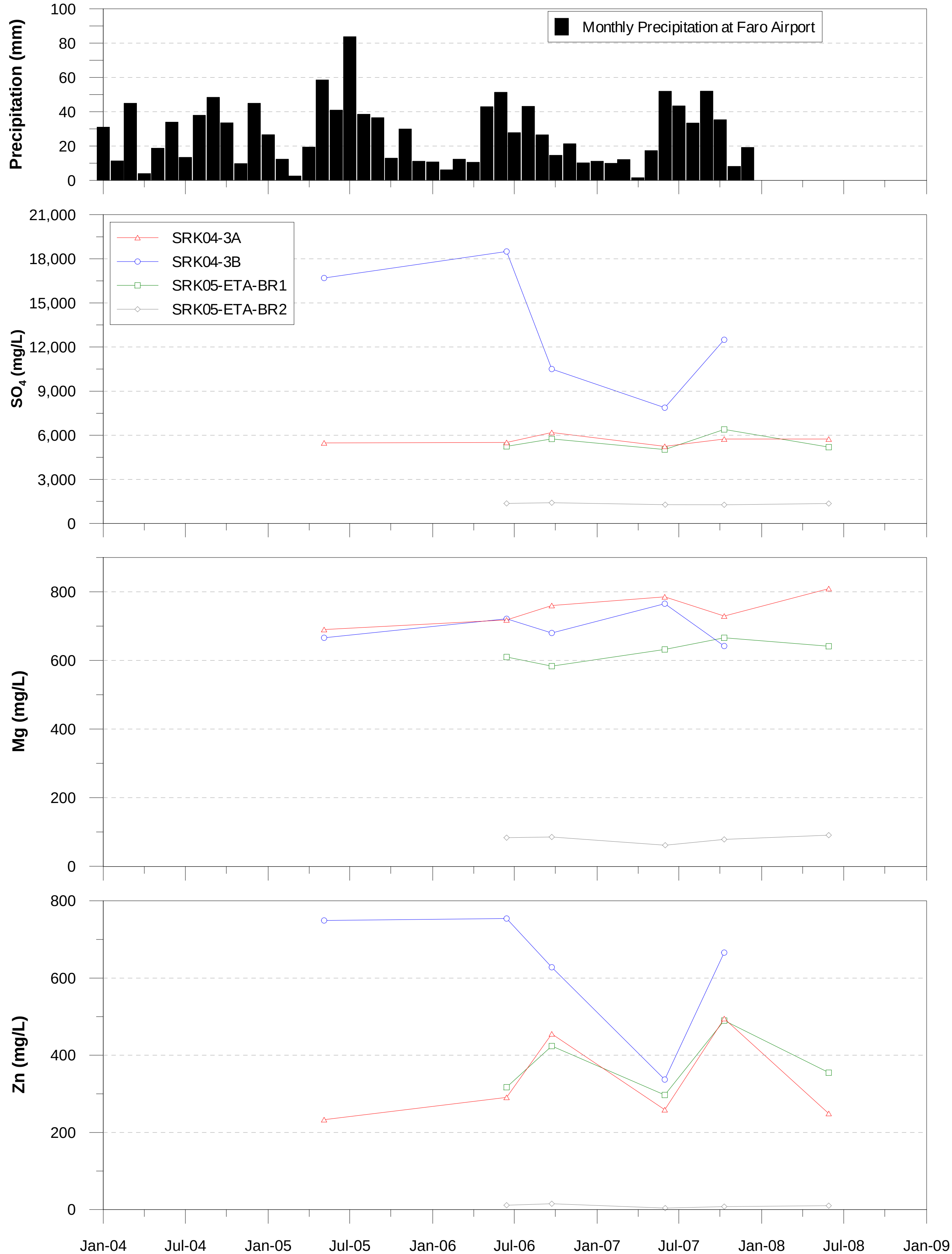


Figure 2-4a. Precipitation and water quality (SO_4, Mg and Zn) in SRK wells in ETA area.

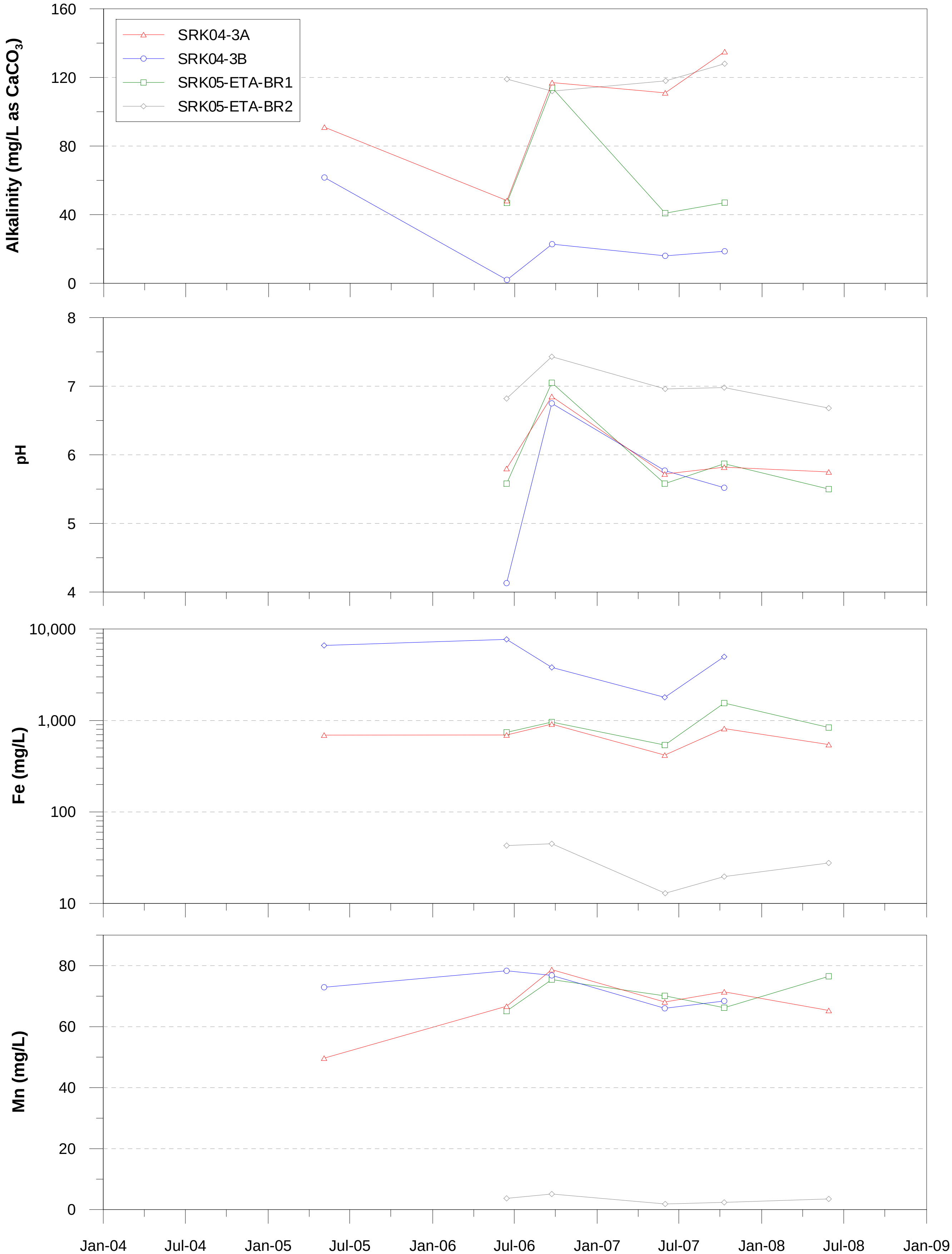
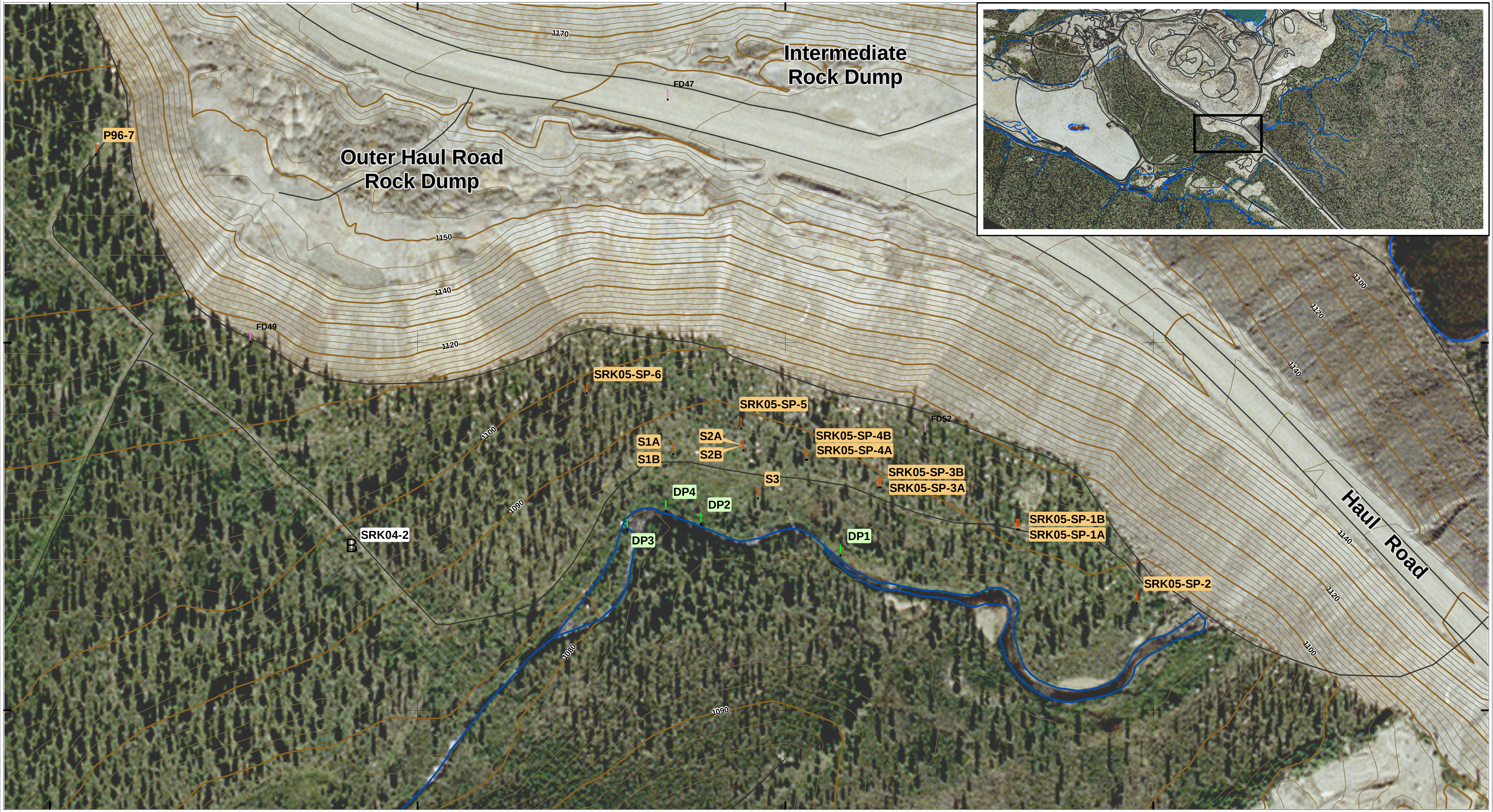


Figure 2-4b. Water quality (alkalinity, pH, Fe and Mn) in SRK wells in ETA area.



LEGEND

- Monitoring Well
- Abandoned Well
- Drive Point
- Seep Monitoring Station

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

Groundwater Monitoring Wells S - Cluster Area

Faro Mine Site

SCALE

0 25 50 100 150 200 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2008 Groundwater Review
REPORT: RGC 118014
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 2-5

DATE: 021109
DRAWN BY: OM
FILE: Faro_S_Cluster09.mxd

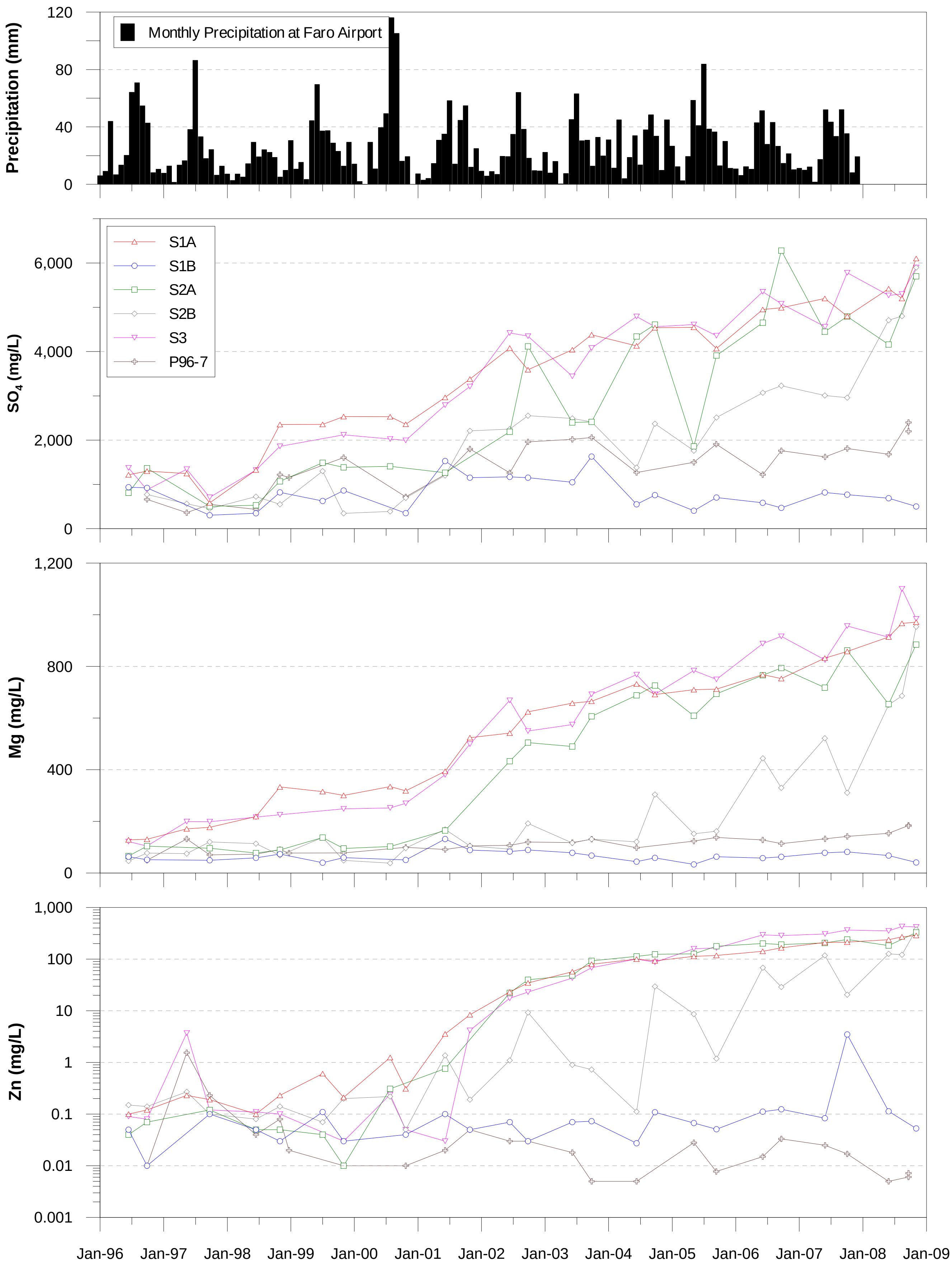


Figure 2-6a. Precipitation and water quality (SO_4, Mg and Zn) in S-Cluster Wells.

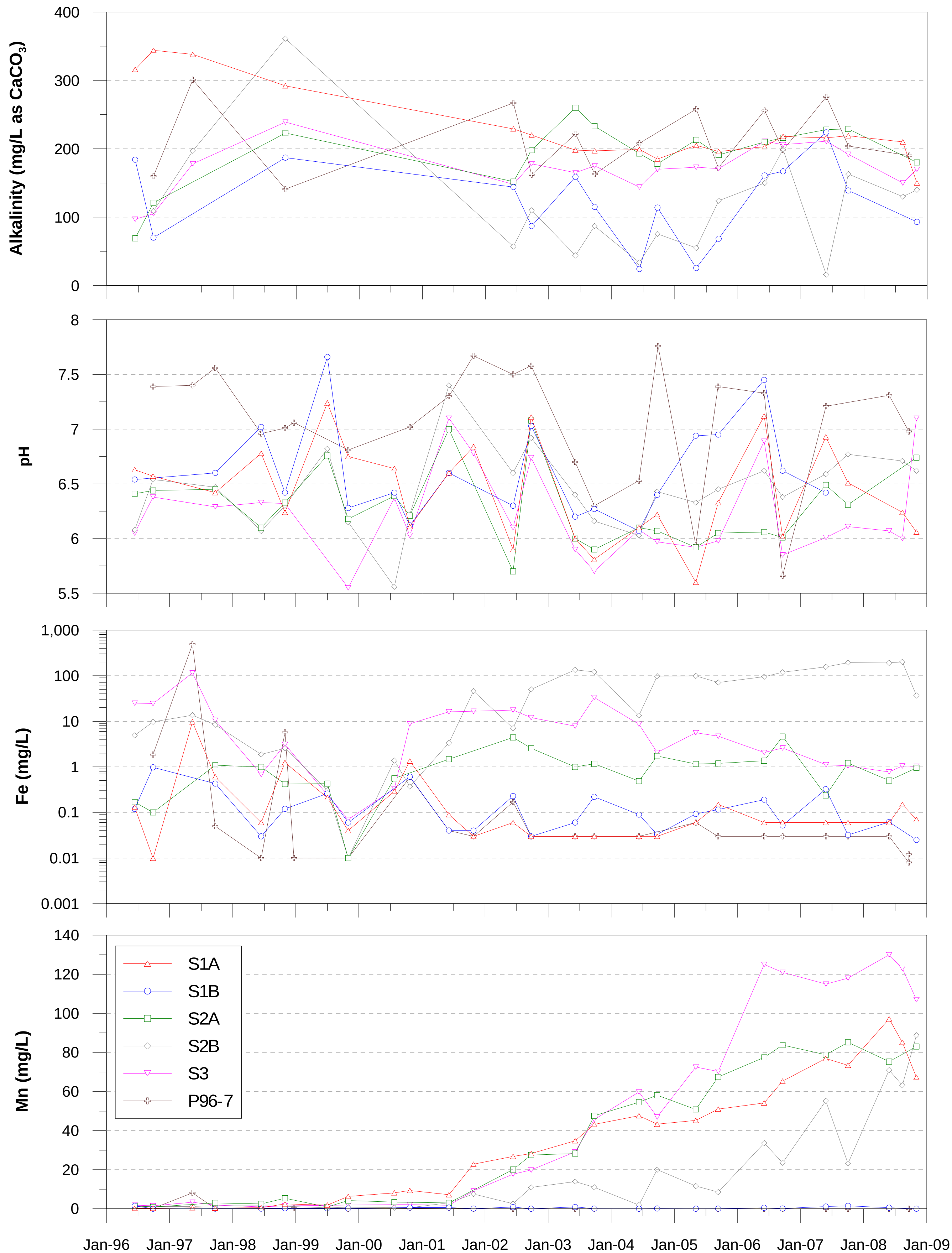


Figure 2-6b. Water quality (alkalinity, pH, Fe and Mn) in S-Cluster Wells.

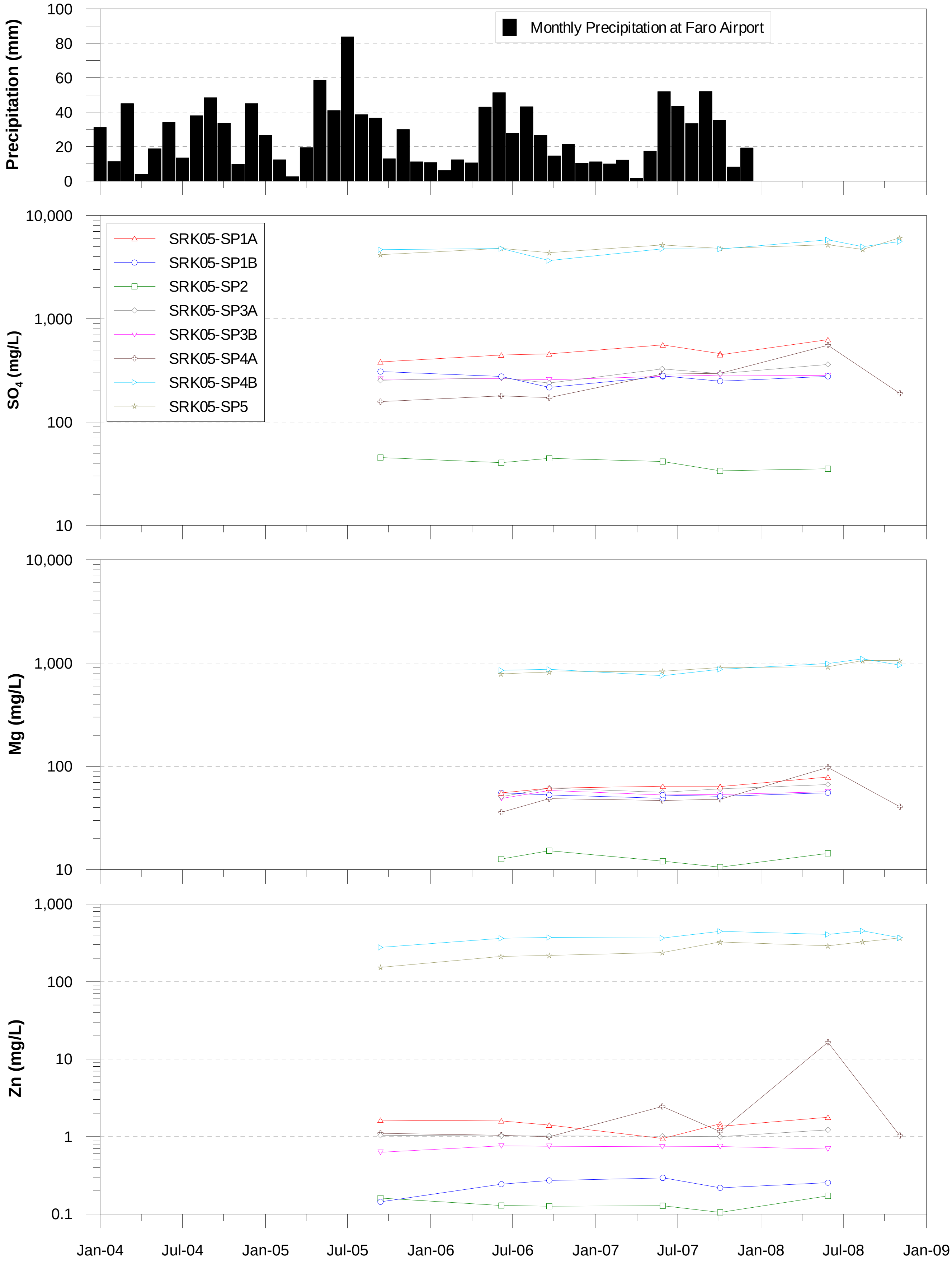


Figure 2-7a. Precipitation and water quality (SO_4, Mg and Zn) in SRK Wells in S-Cluster Area.

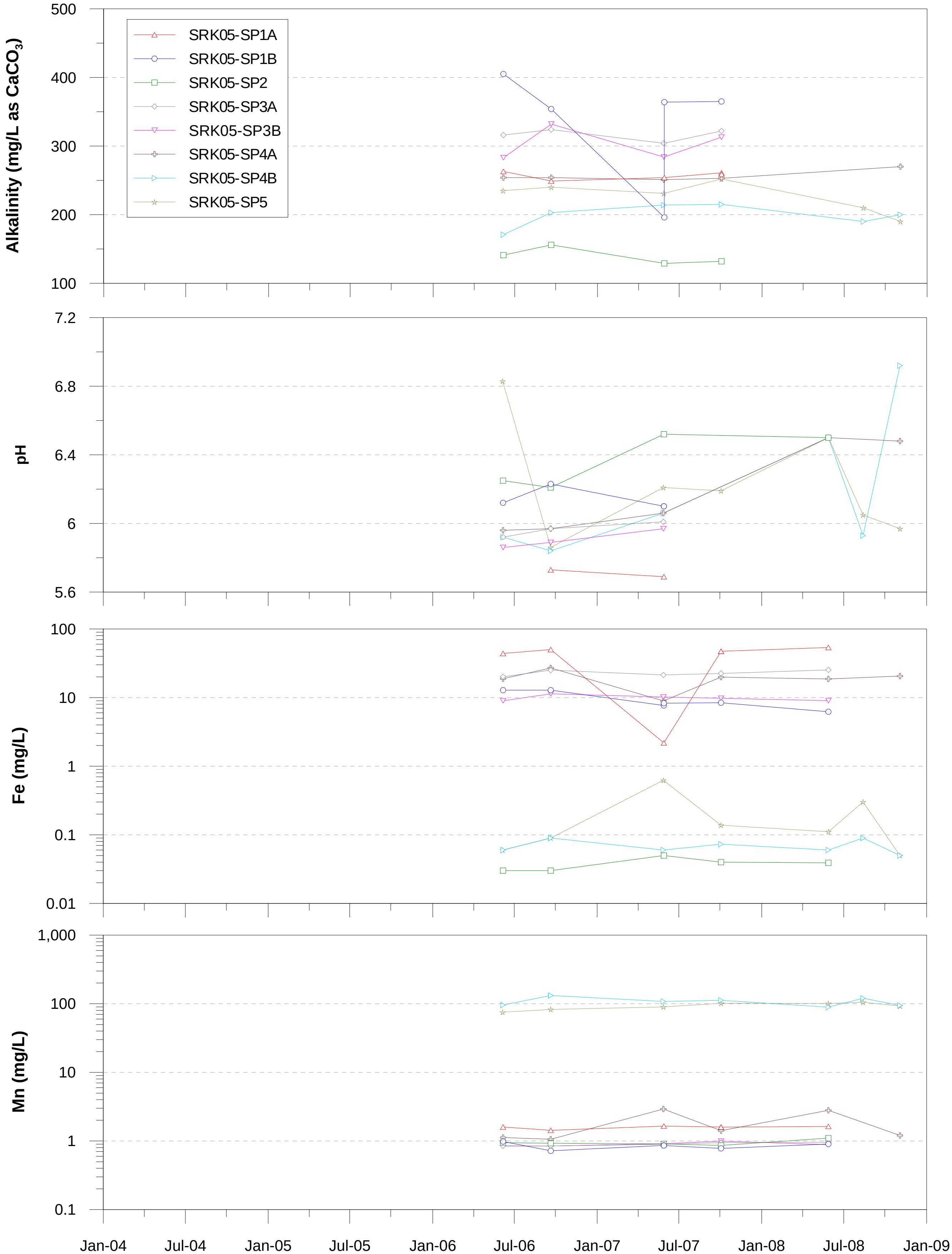
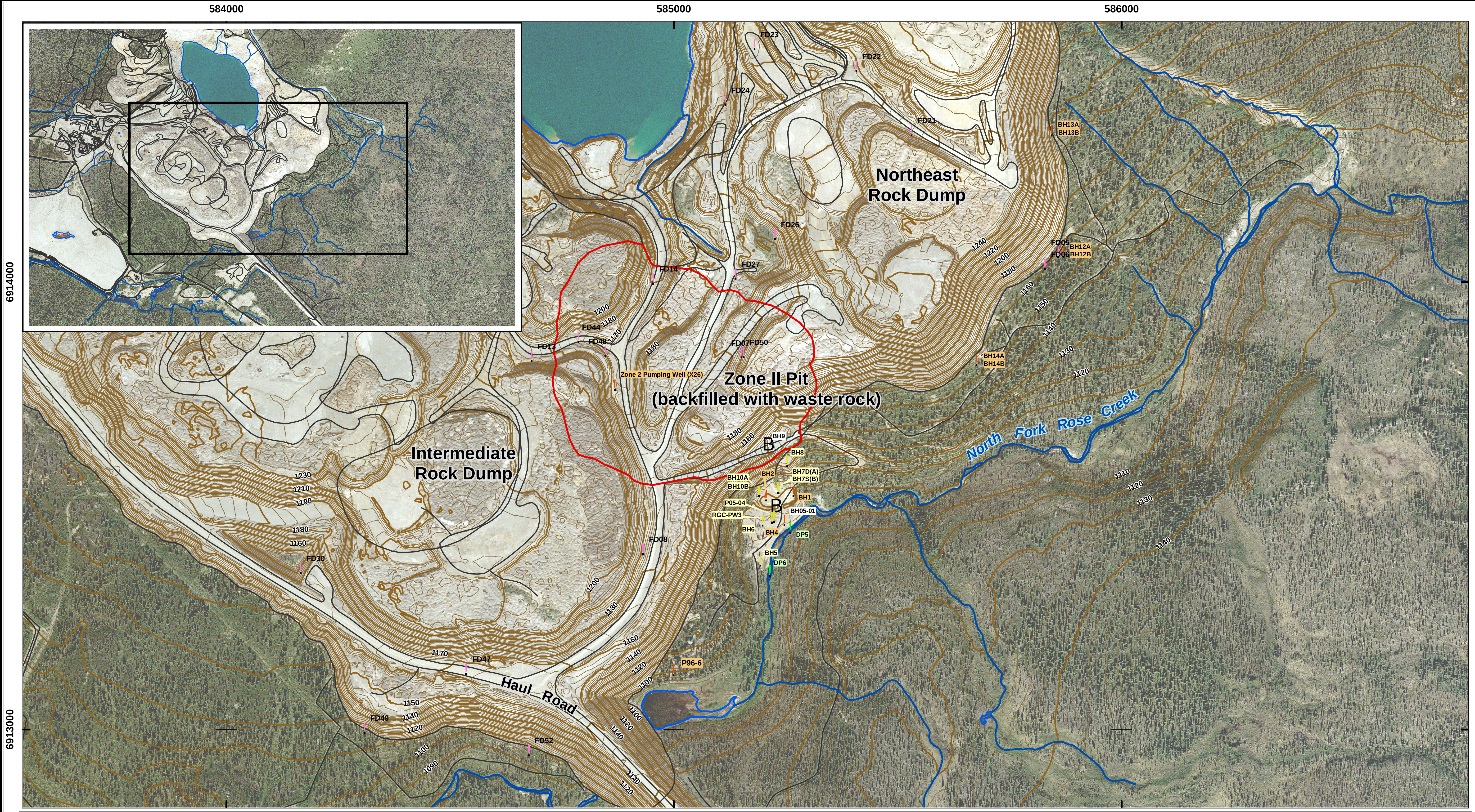


Figure 2-7b. Water quality (alkalinity, pH, Fe and Mn) in SRK Wells in S-Cluster Area.



LEGEND

- Monitoring Well
- Other Well (not Monitored Routinely)
- B Abandoned Well
- Drive Point
- Seep Monitoring Station
- Zone II Pit Outline

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

Groundwater Monitoring Wells North Fork Rose Creek Area

Faro Mine Site

SCALE

0 75 150 300 450 600 Meters

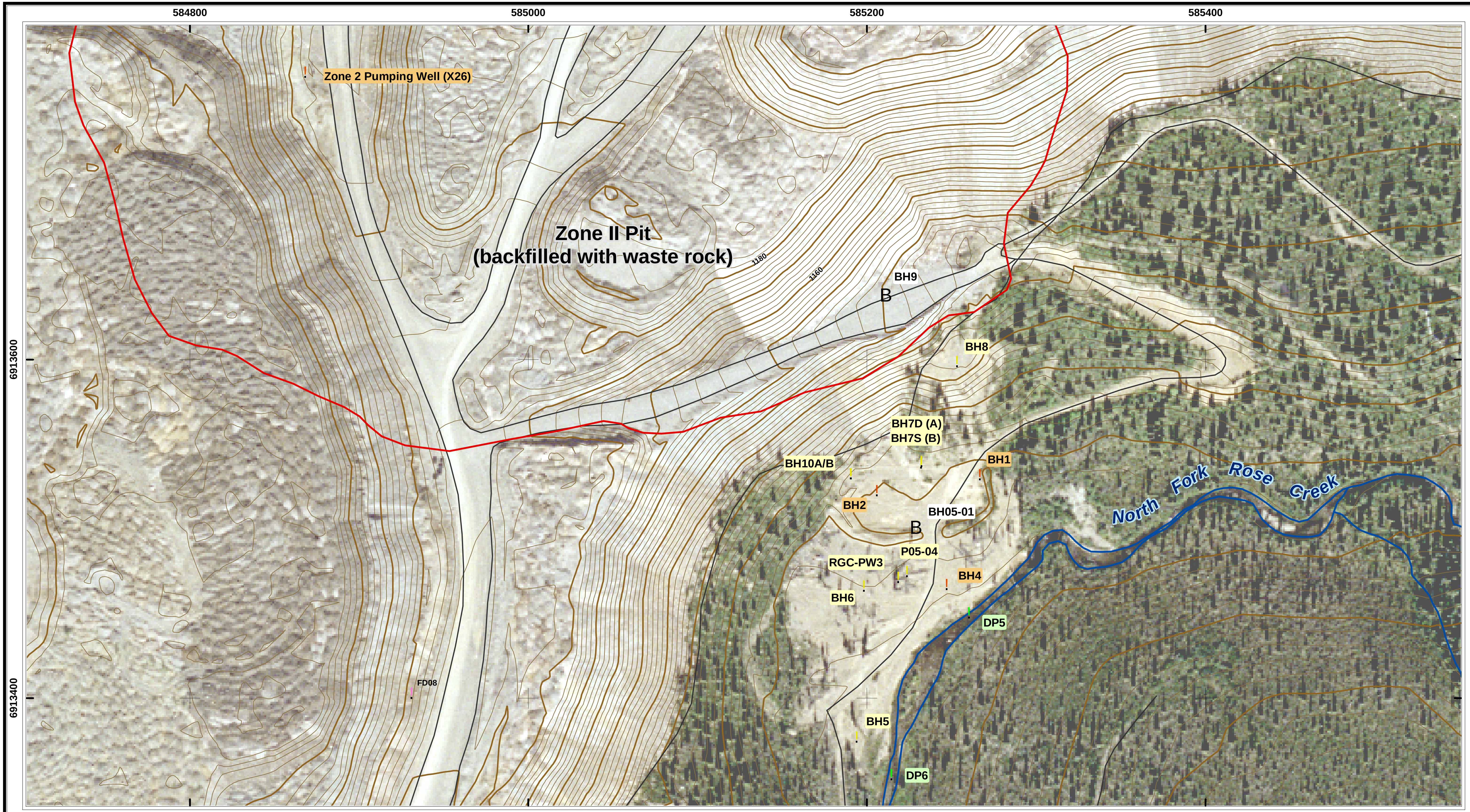
Deloitte & Touche

CLIENT: Deloitte & Touche Inc.
PROJECT: 2008 Groundwater Review
REPORT: RGC 118014
LOCATION: Anvil Range Mining Complex,YT, Canada

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

FIGURE: 2-8

DATE: 021109
DRAWN BY: OM
FILE: Faro_RoseCreek09.mxd



LEGEND

- Monitoring Well
- Other Well (not Monitored Routinely)
- B Abandoned Well
- Drive Point
- Seep Monitoring Station
- Zone II Pit Outline

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

Groundwater Monitoring Wells
Zone II Pit Outwash Area

Faro Mine Site

SCALE

0 25 50 100 150 200 Meters

Deloitte & Touche

CLIENT: Deloitte & Touche Inc.
PROJECT: 2008 Groundwater Review
REPORT: RGC 118014
LOCATION: Anvil Range Mining Complex,YT, Canada

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

FIGURE: 2-9

DATE: 021109
DRAWN BY: OM
FILE: Faro_Zone2_area09.mxd

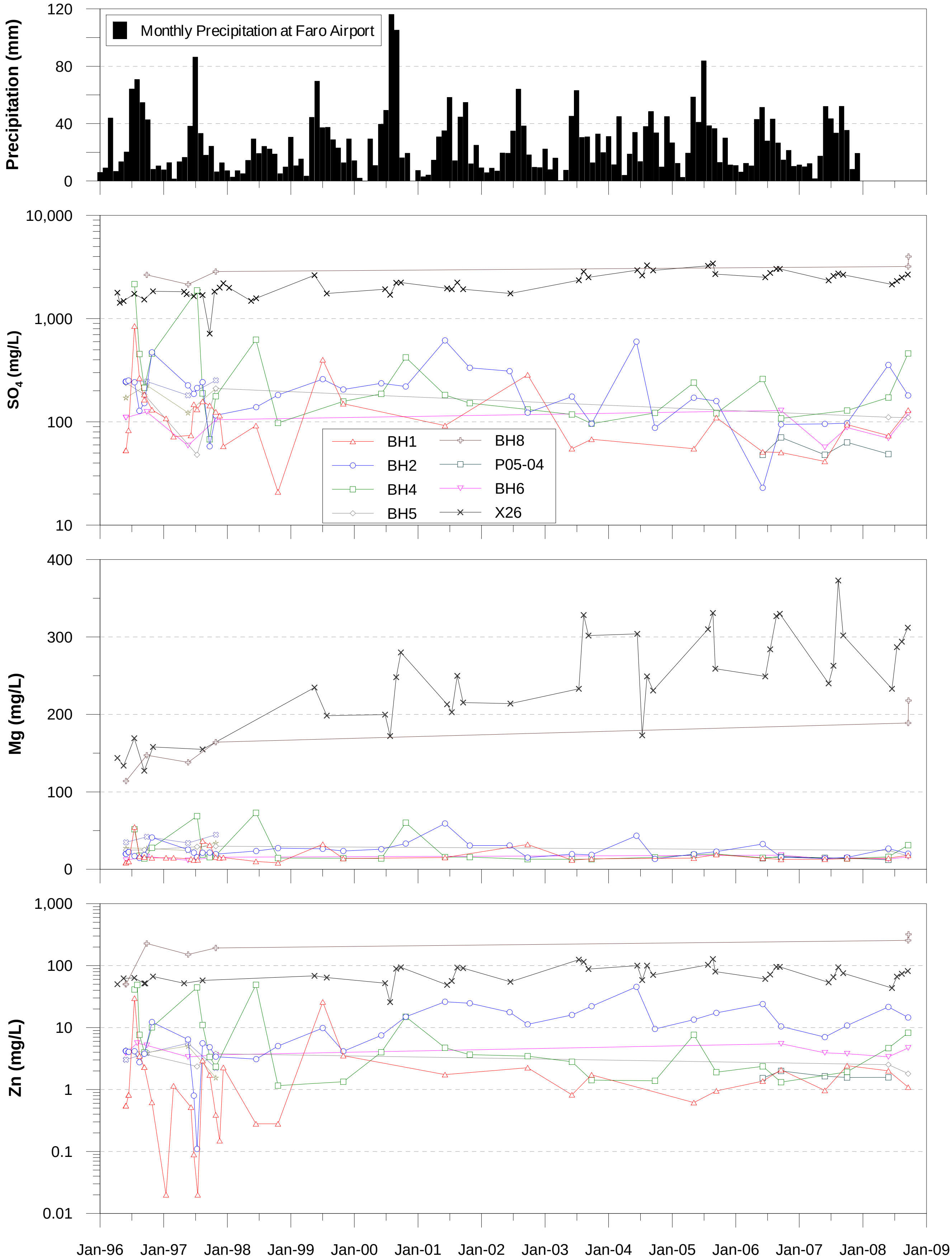


Figure 2-10a. Precipitation and water quality (SO_4, Mg and Zn) in Zone 2 Outwash Area.

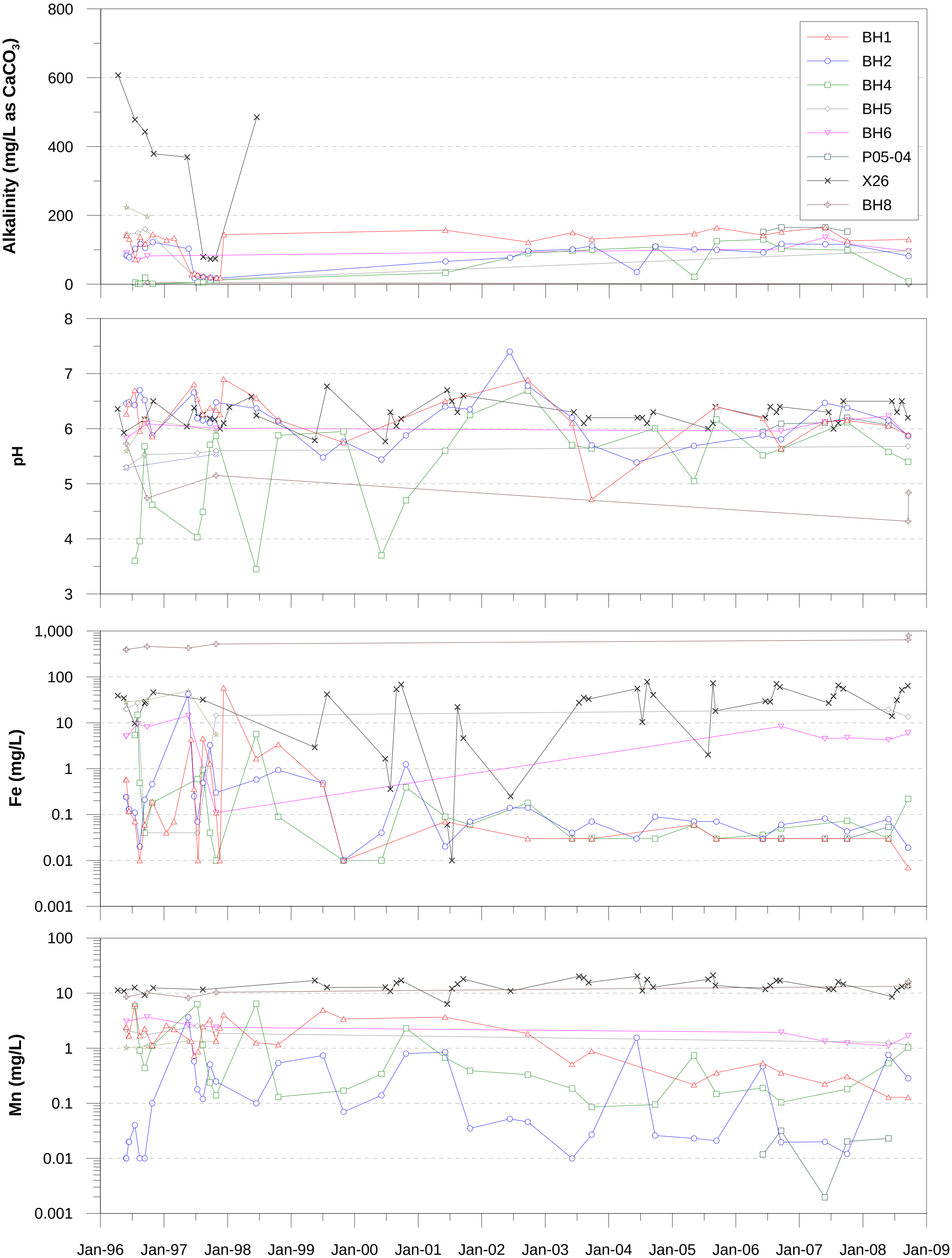


Figure 2-10b. Water quality (alkalinity, pH, Fe and Mn) in Zone 2 Outwash Area.

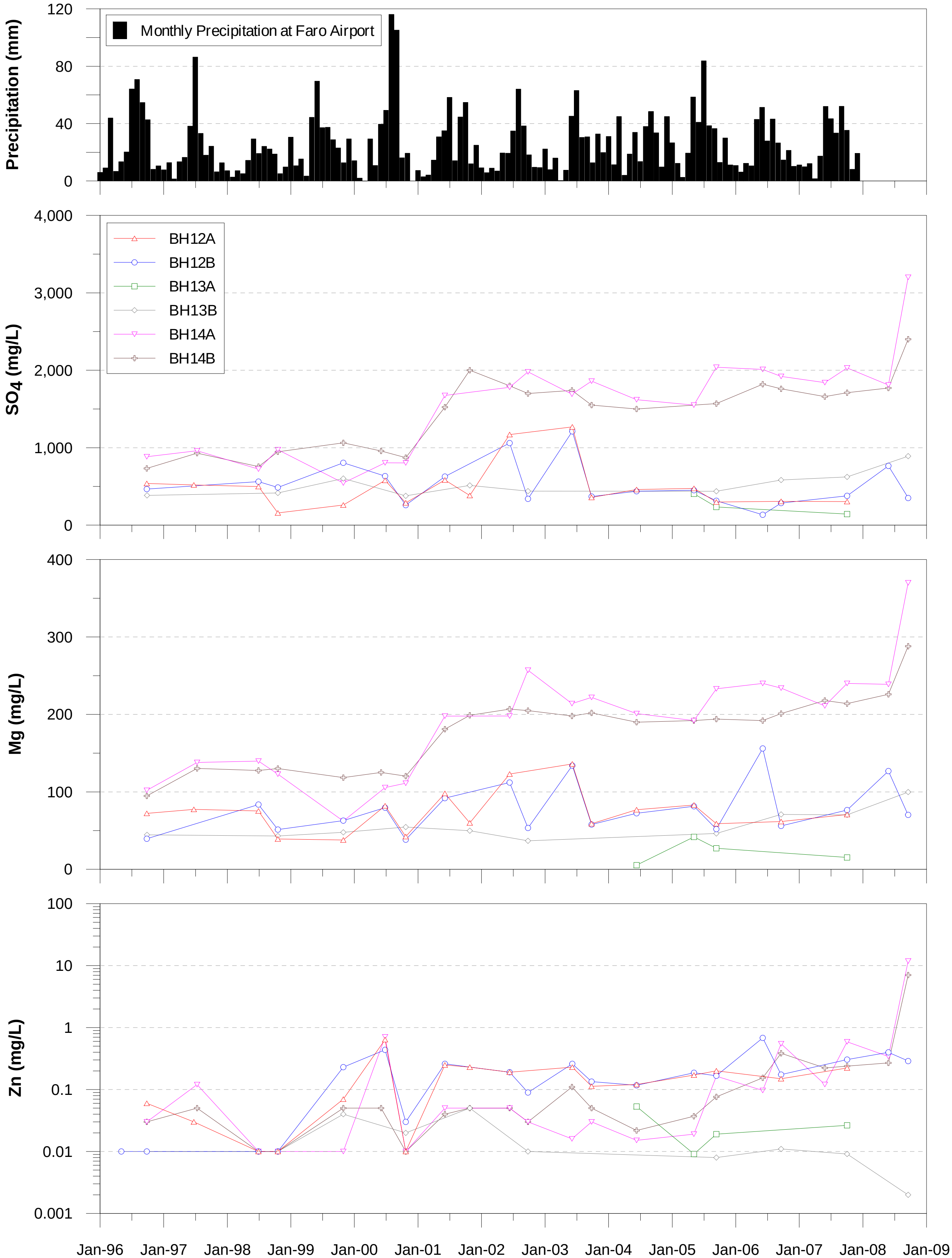


Figure 2-11a. Precipitation and water quality (SO_4, Mg and Zn) at toe of Northeast Dumps.

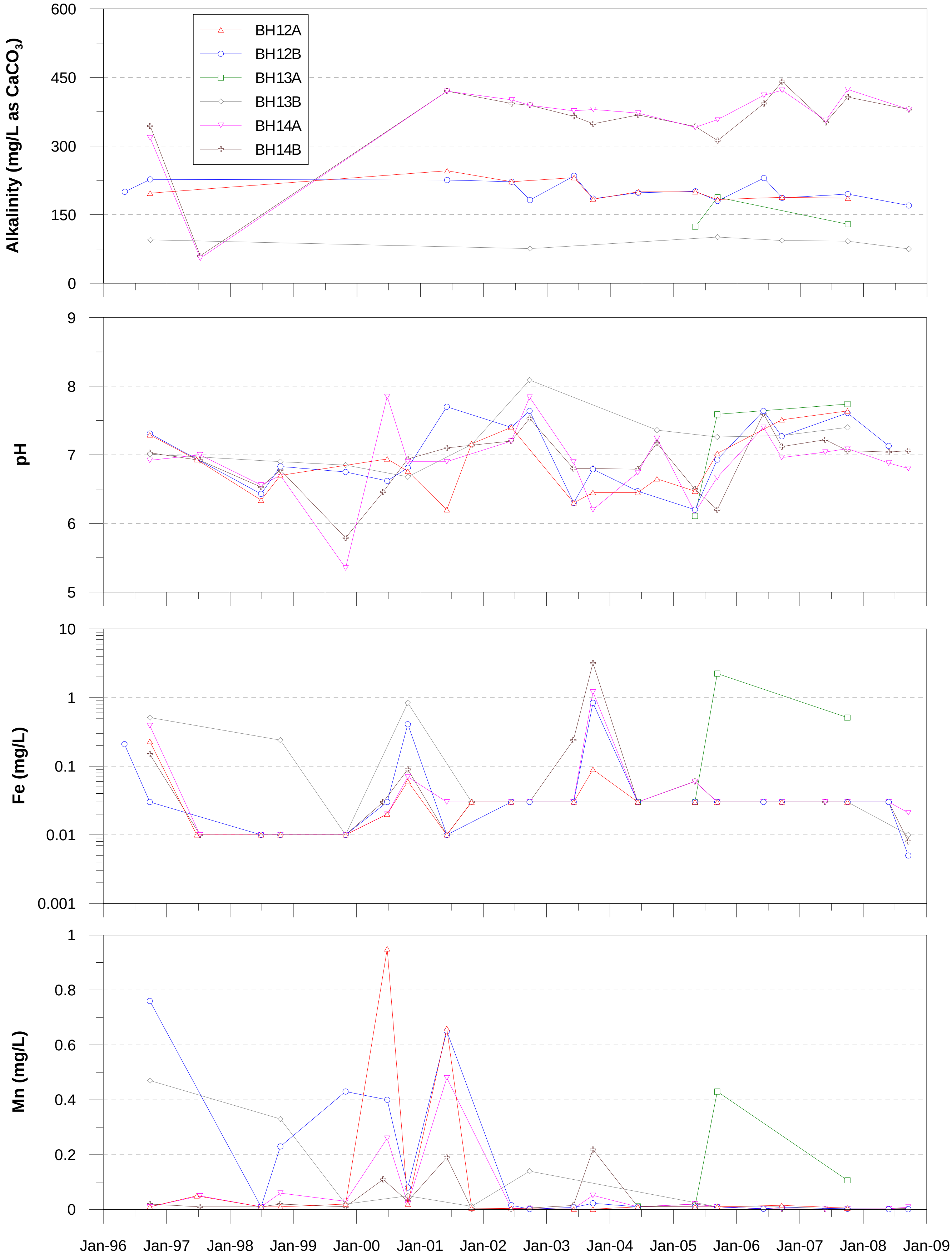


Figure 2-11b. Water quality (alkalinity, pH, Fe and Mn) at toe of Northeast Dumps.

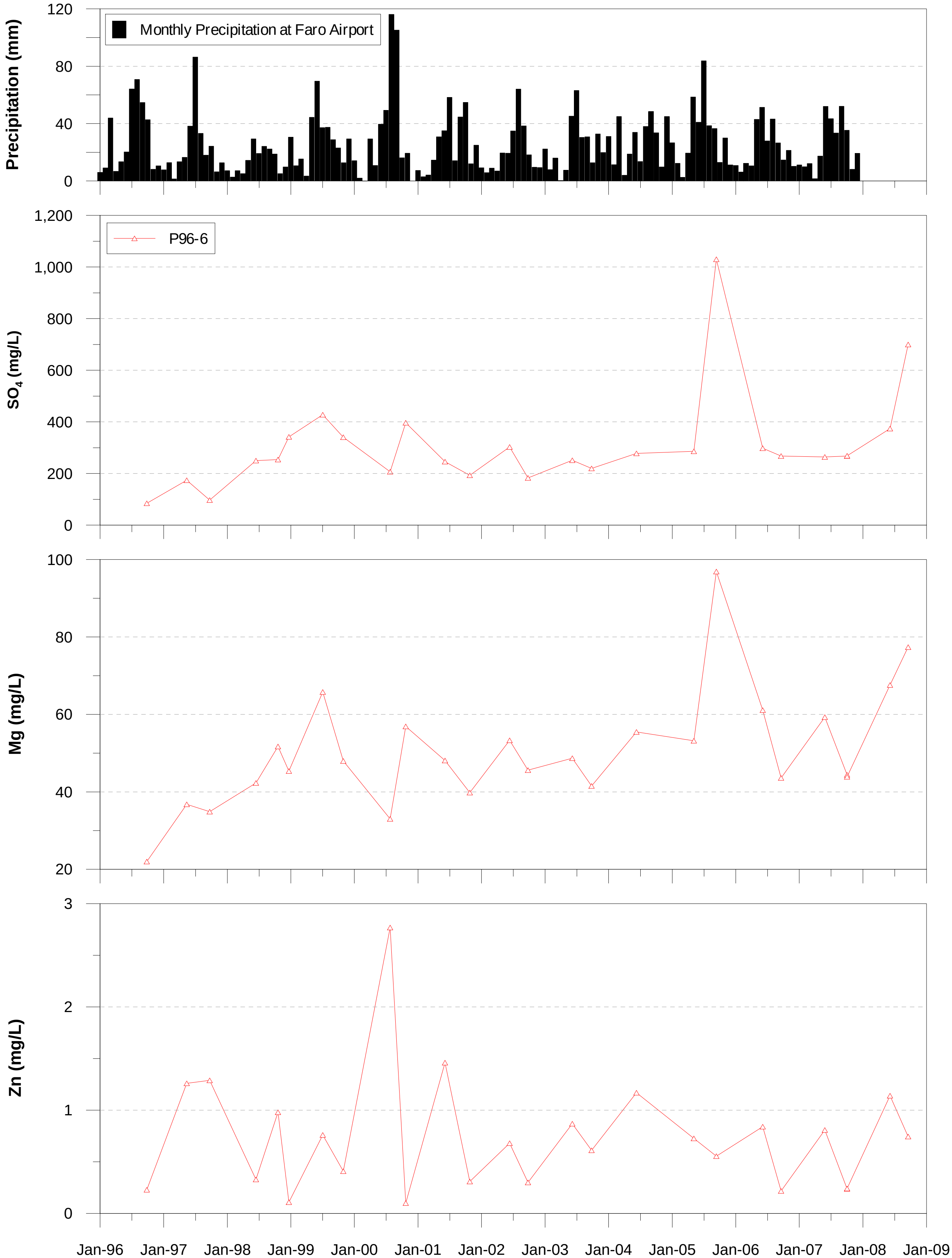


Figure 2-12a. Precipitation and water quality (SO_4, Mg and Zn) at toe of Intermediate Dump (P96-6).

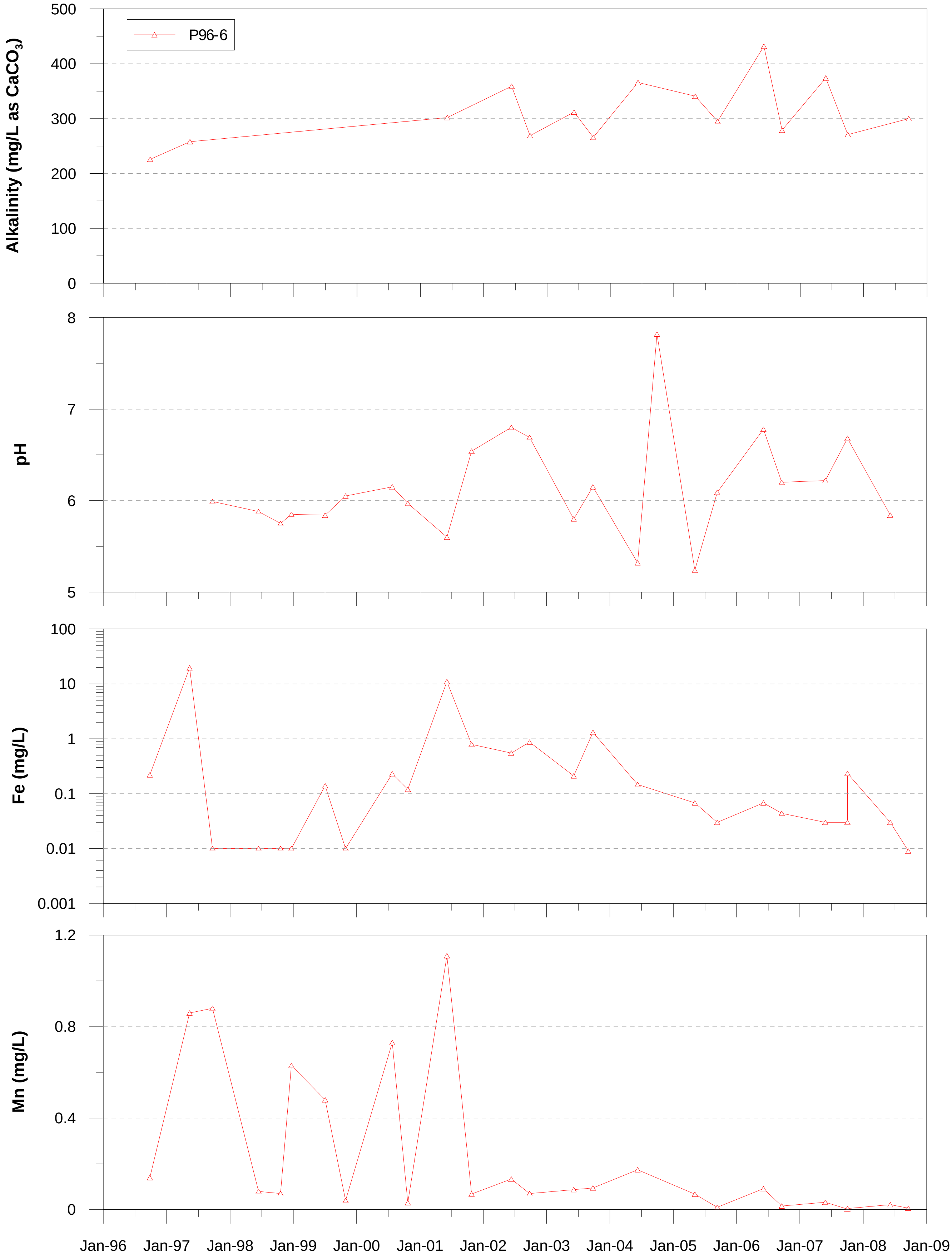


Figure 2-12b. Water quality (alkalinity, pH, Fe and Mn) at toe of Intermediate Dump (P96-6).

LEGEND

- ! Monitoring Well
- ! Multilevel Monitoring Well
- ! Other Well (not Monitored Routinely)
- B Decommissioned Well
- ! Seep Monitoring Station

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2M

Groundwater Monitoring Wells
Rose Creek Tailings Facility
Anvil Range Mining Complex

SCALE

0 210 420 840 1,260 1,680 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2008 Groundwater Review
REPORT: RGC 118014
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 3-1

DATE: 021109
DRAWN BY: OM
FILE: Faro_Tailing_area09.mxd

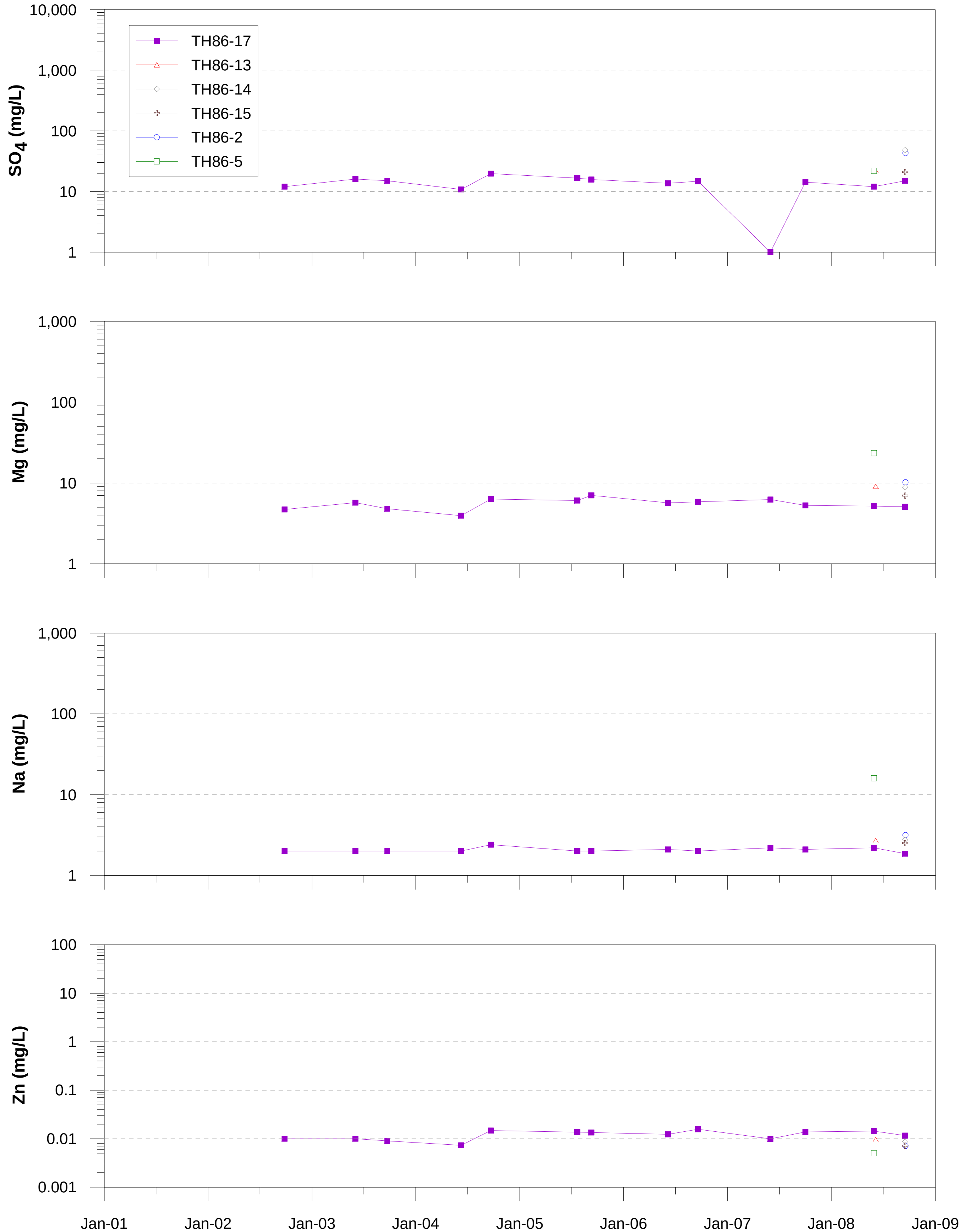


Figure 3-2a. Water quality (SO_4, Mg, Na and Zn) in TH86-17 and other upgradient wells.

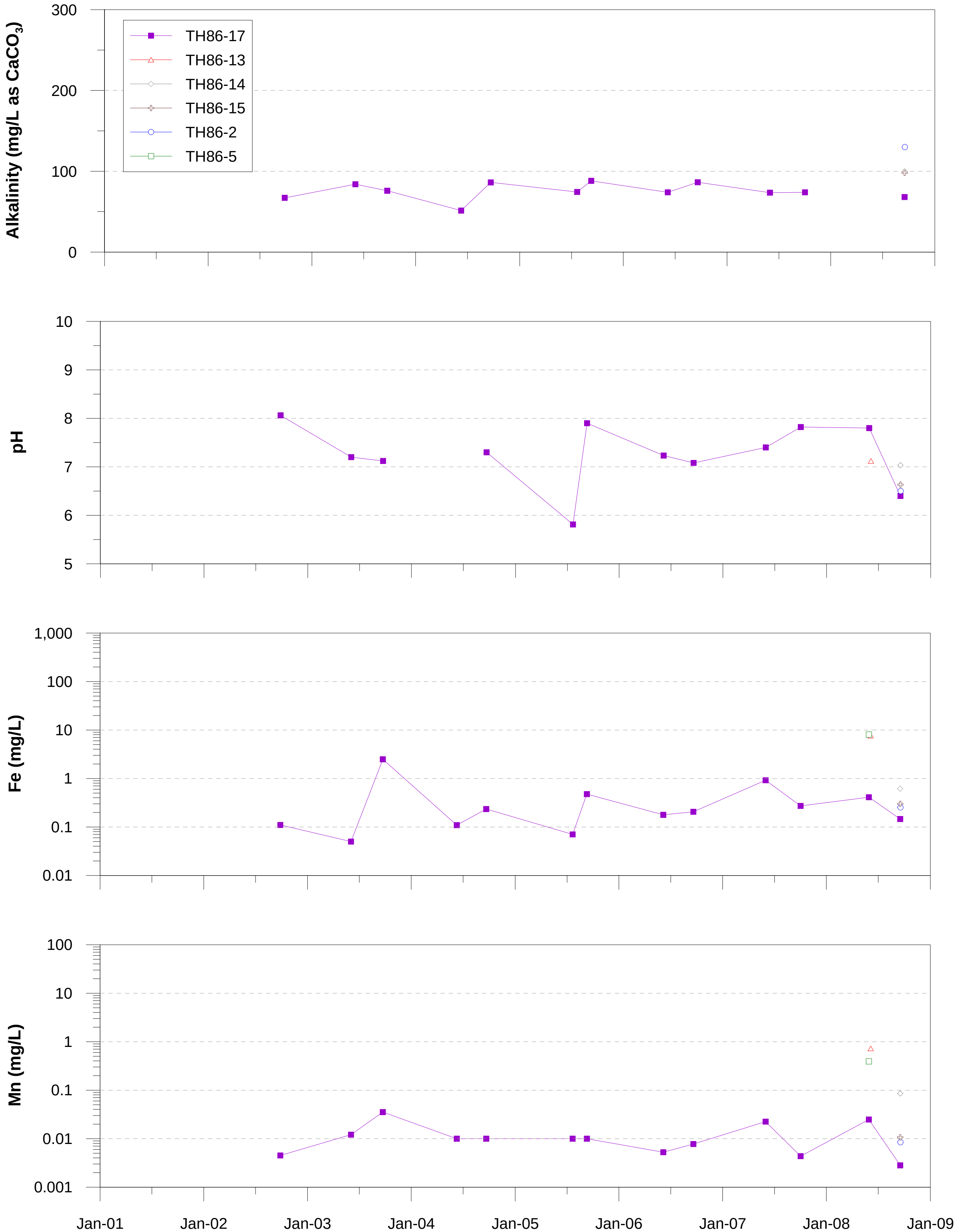


Figure 3-2b. Water quality (alkalinity, pH, Fe and Mn) in TH86-17 and other upgradient wells.

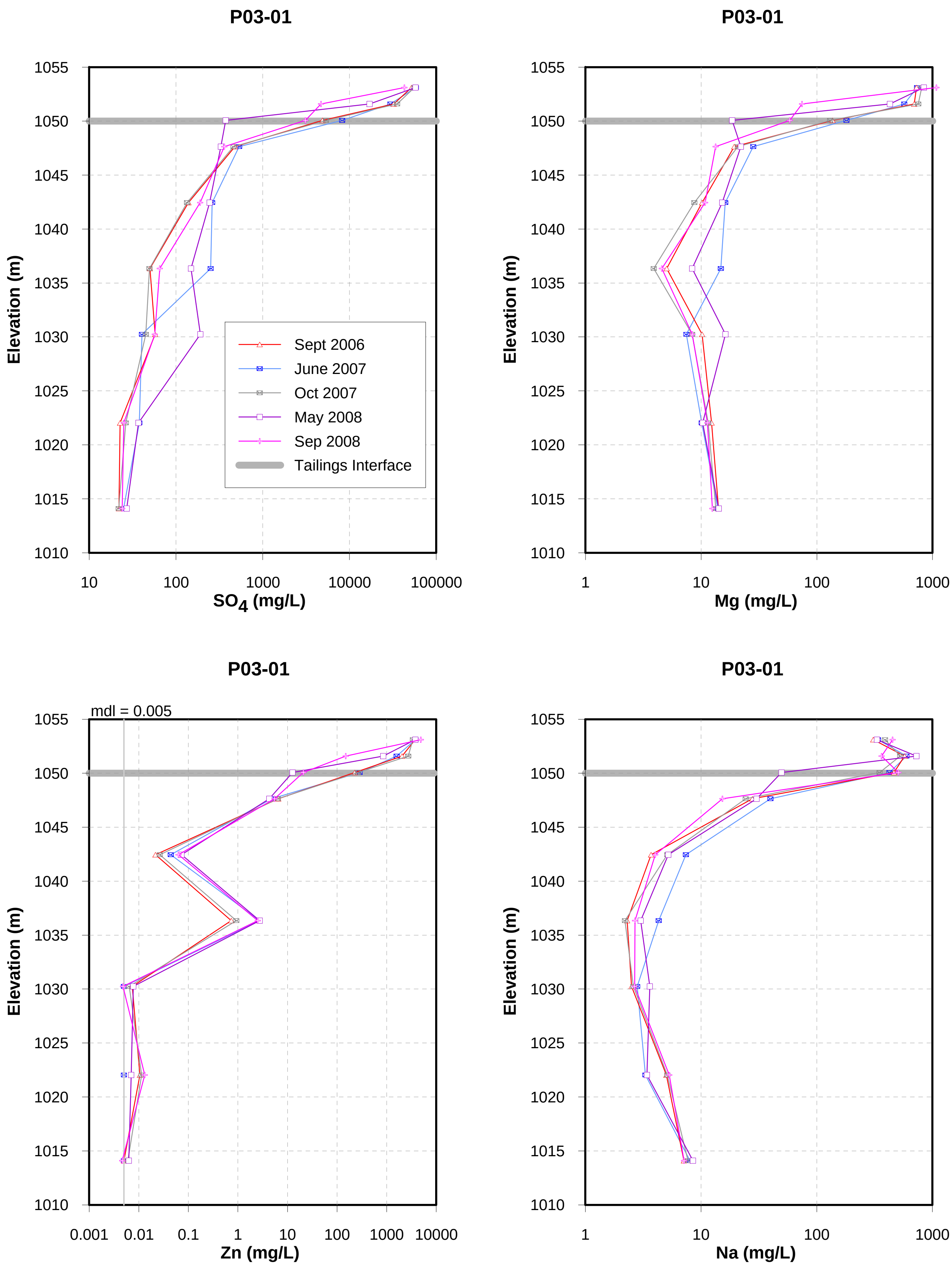


Figure 3-3a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-01 (Second Impoundment).

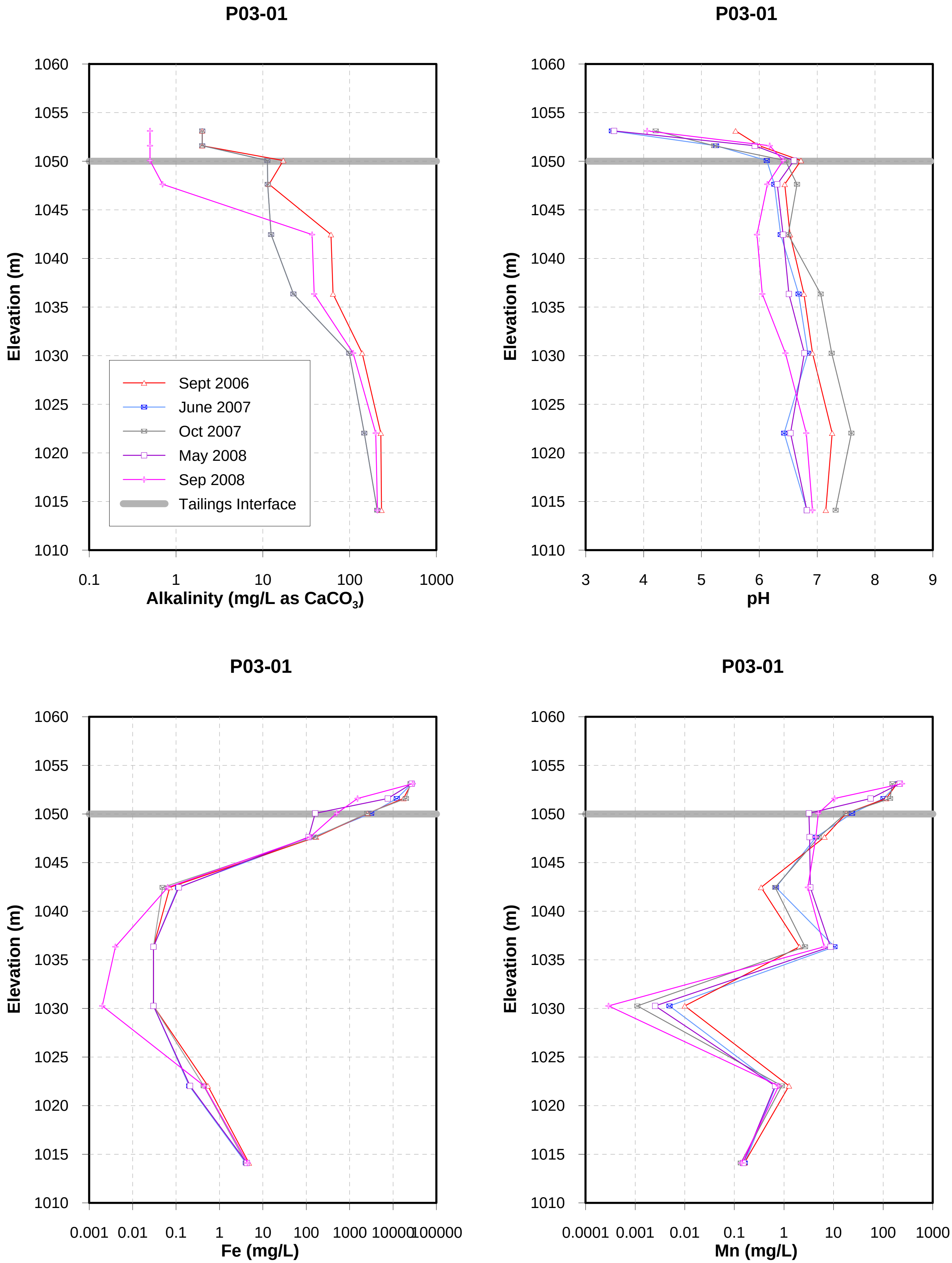


Figure 3-3b. Water quality depth profiles of Alkalintiy, pH, Fe and Mn in P03-01 (Second Impoundment).

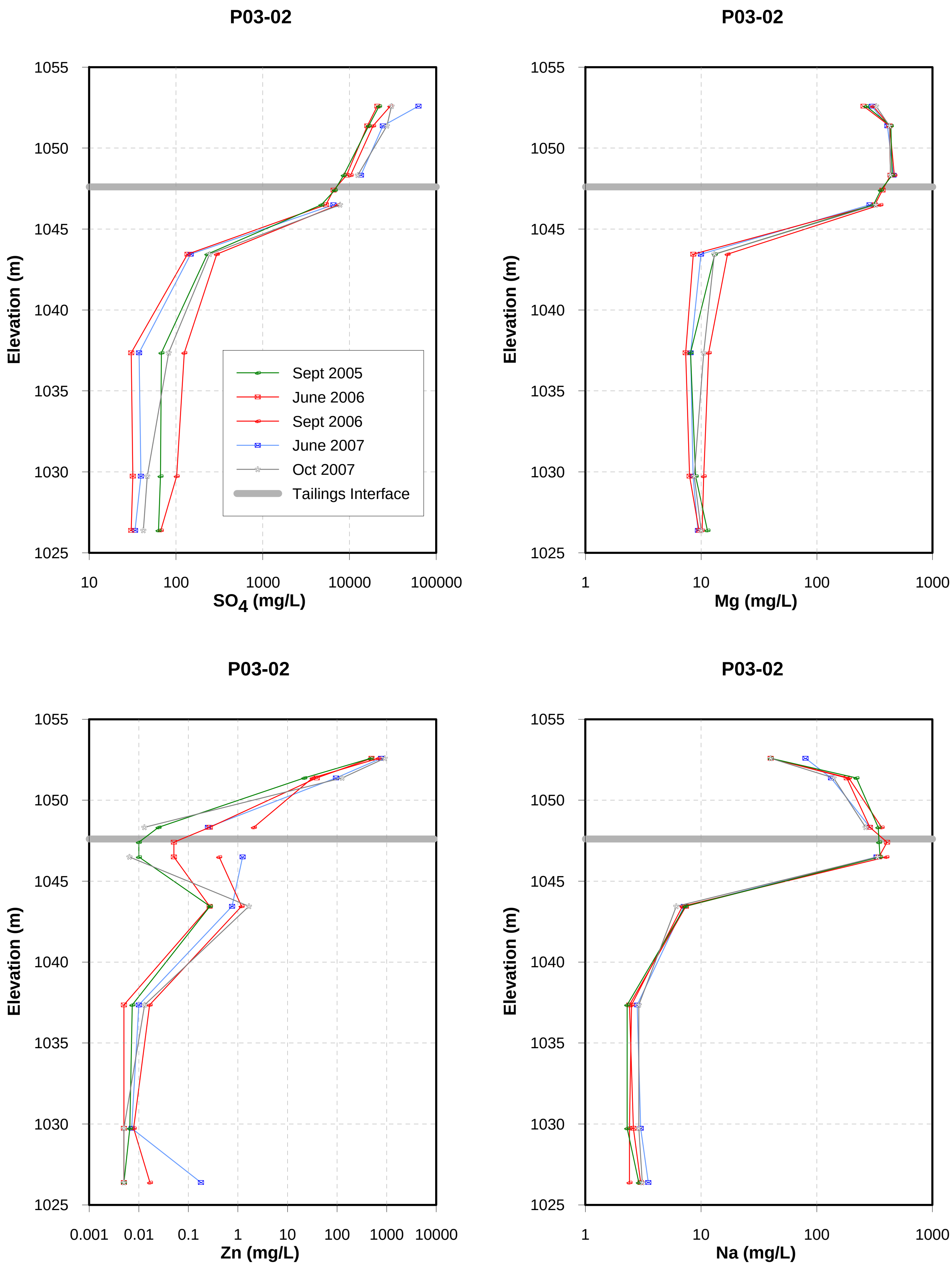


Figure 3-4a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-02 (Second Impoundment).

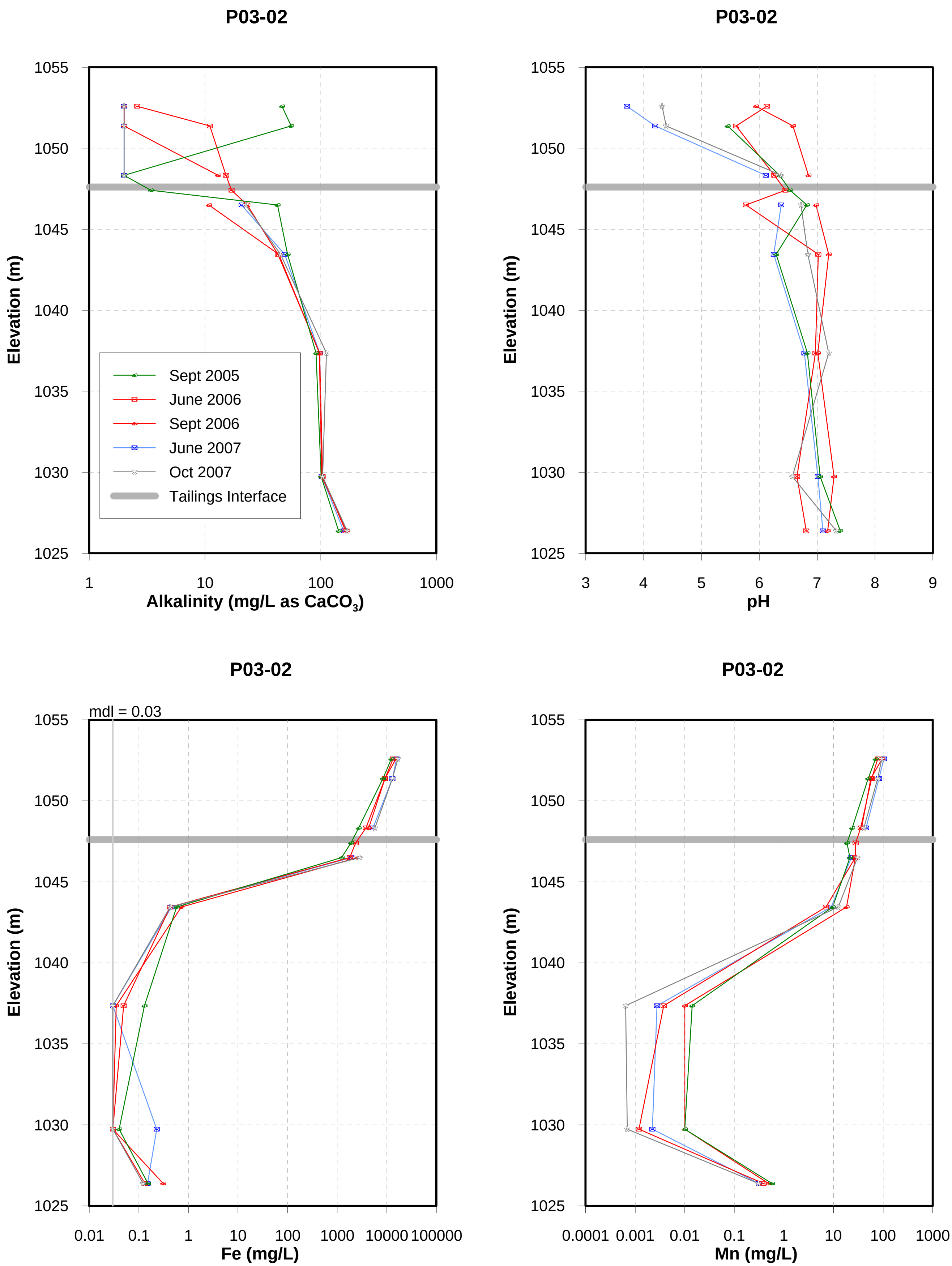


Figure 3-4b. Water quality depth profiles of Alkalinity, pH, Fe and Mn in P03-02 (Second Impoundment).

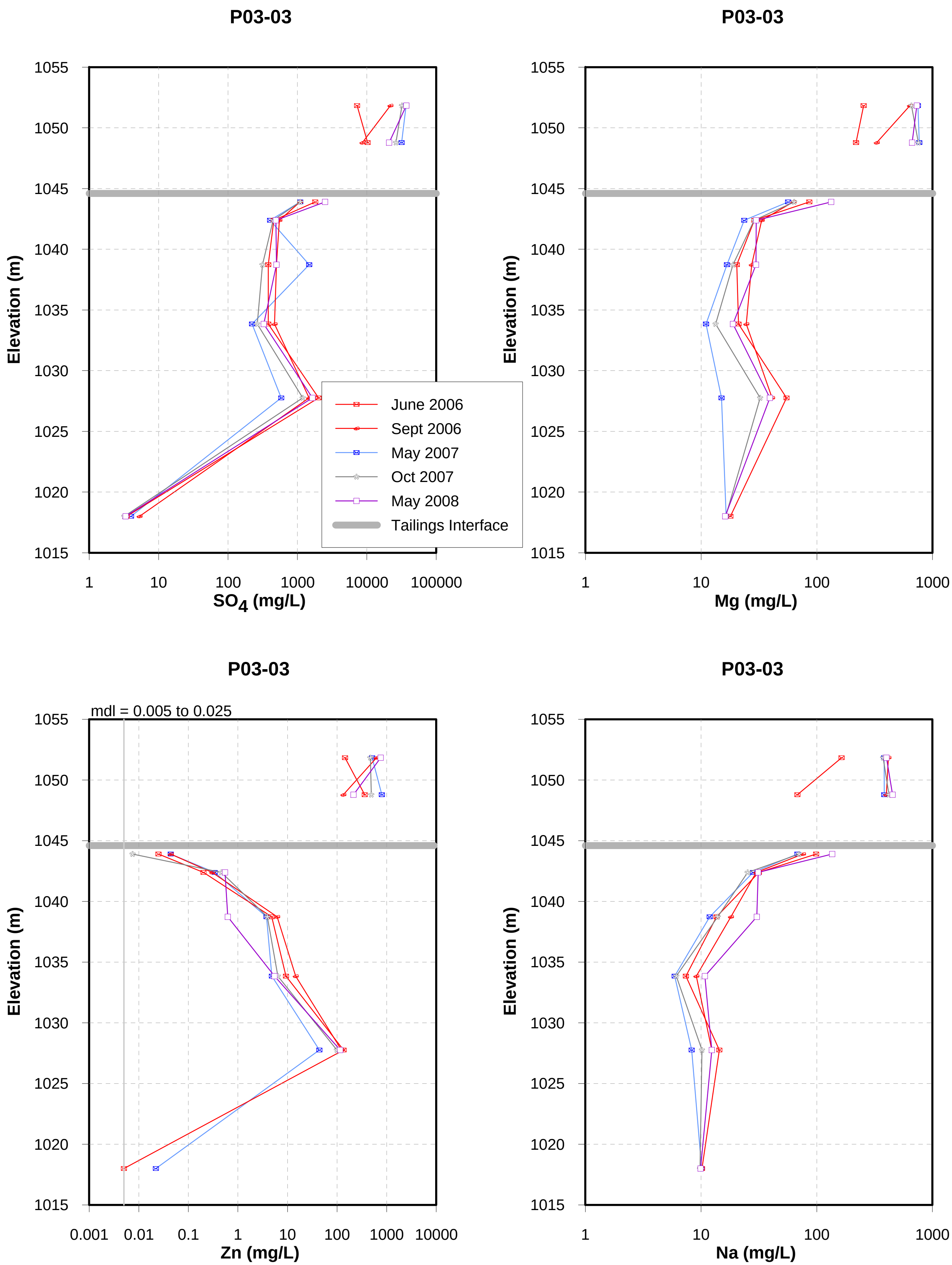


Figure 3-5a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-03 (Second Impoundment).

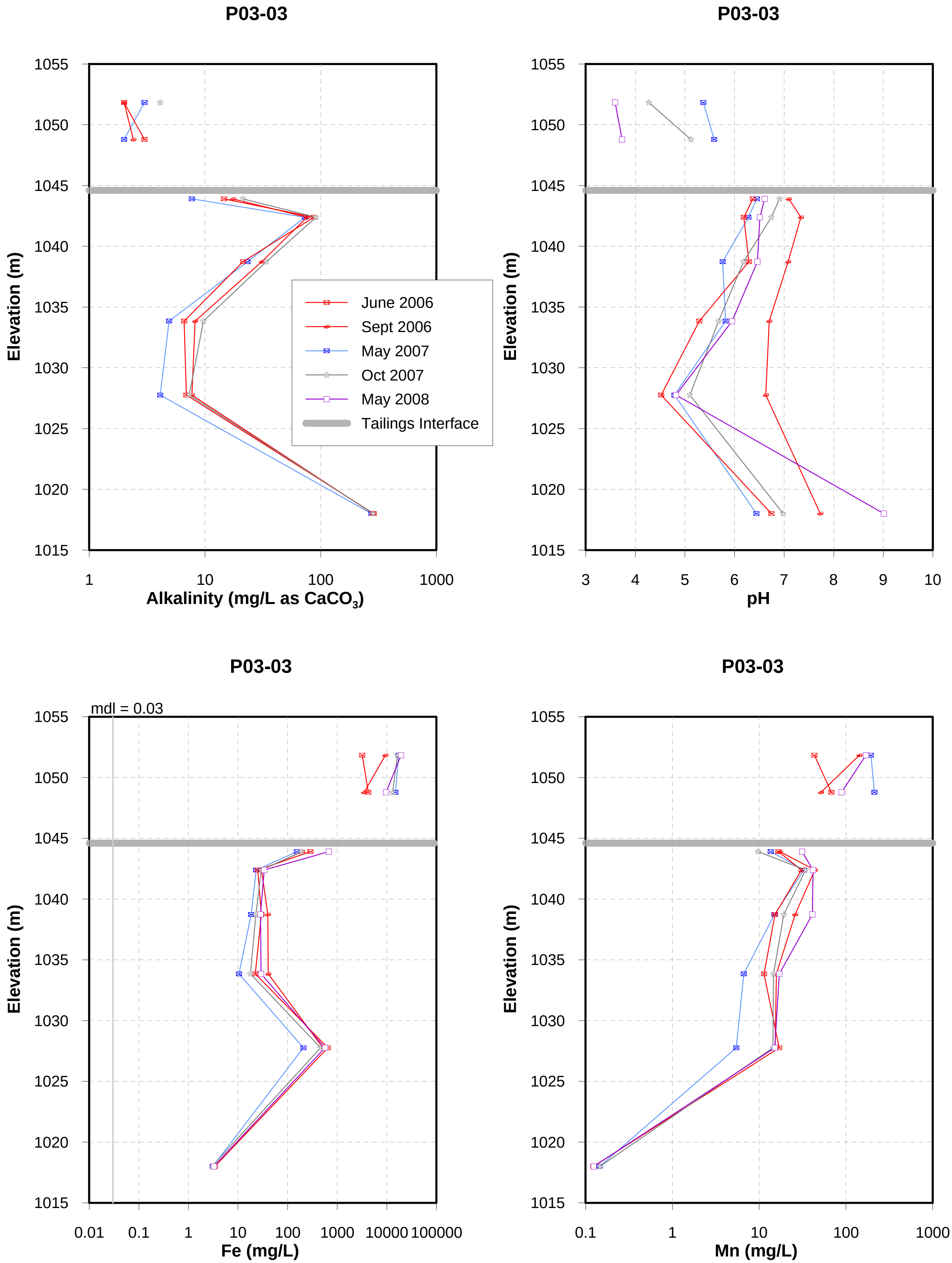


Figure 3-5b. Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-03 (Second Impoundment).

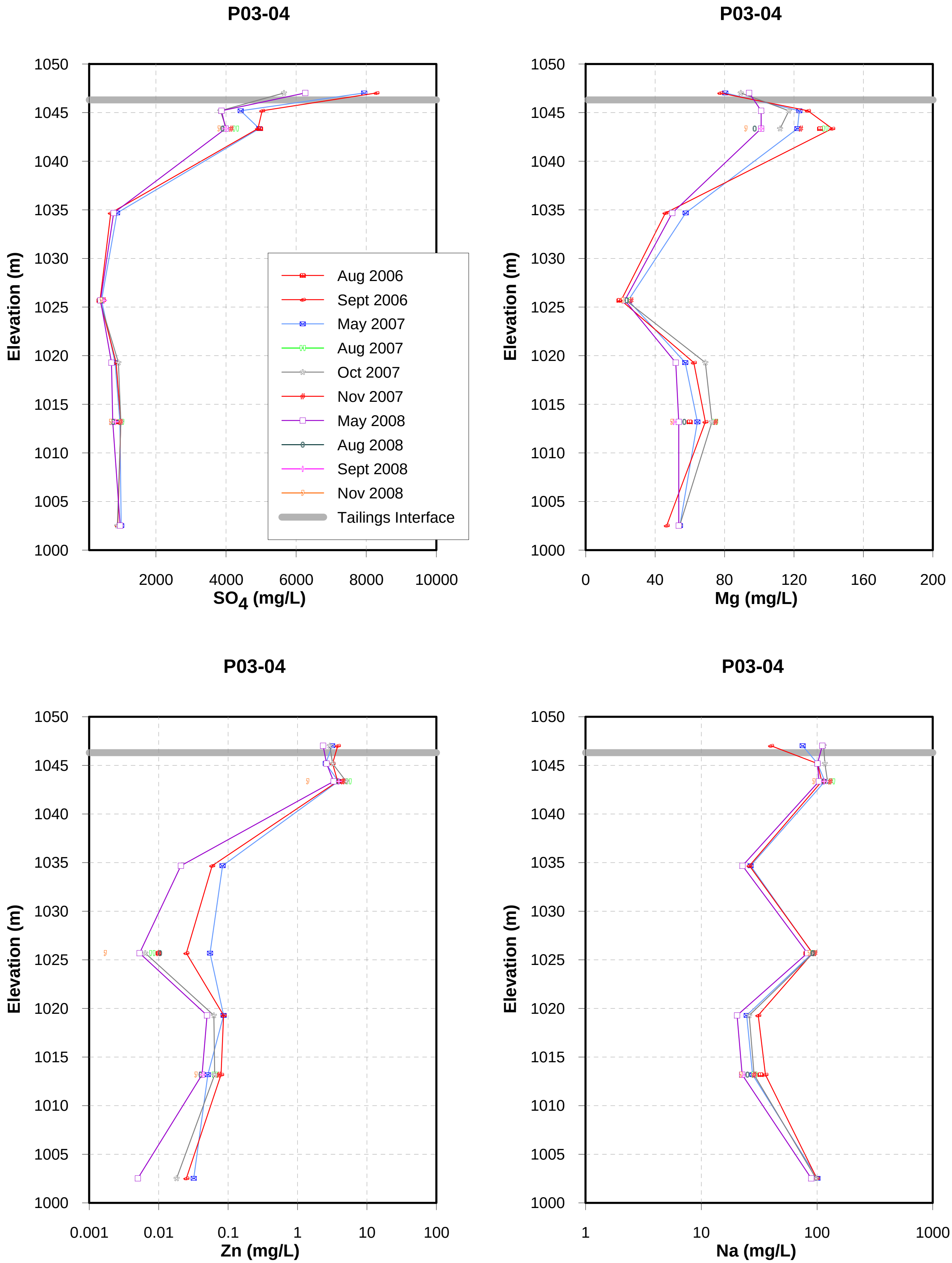


Figure 3-6a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-04 (Second Impoundment).

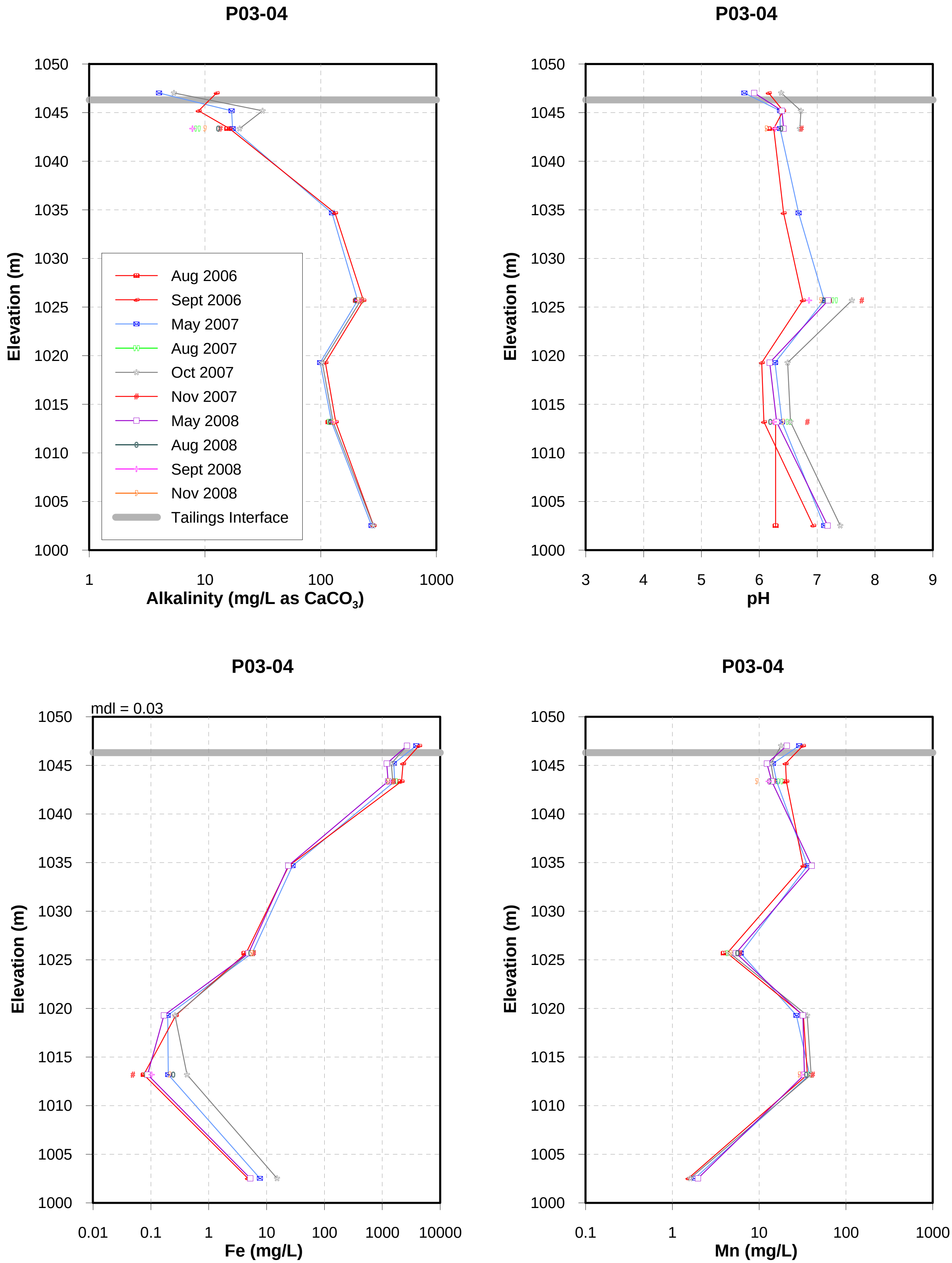


Figure 3-6b. Water quality depth profiles of Alkalinity, pH, Fe and Mn in P03-04 (Second Impoundment).

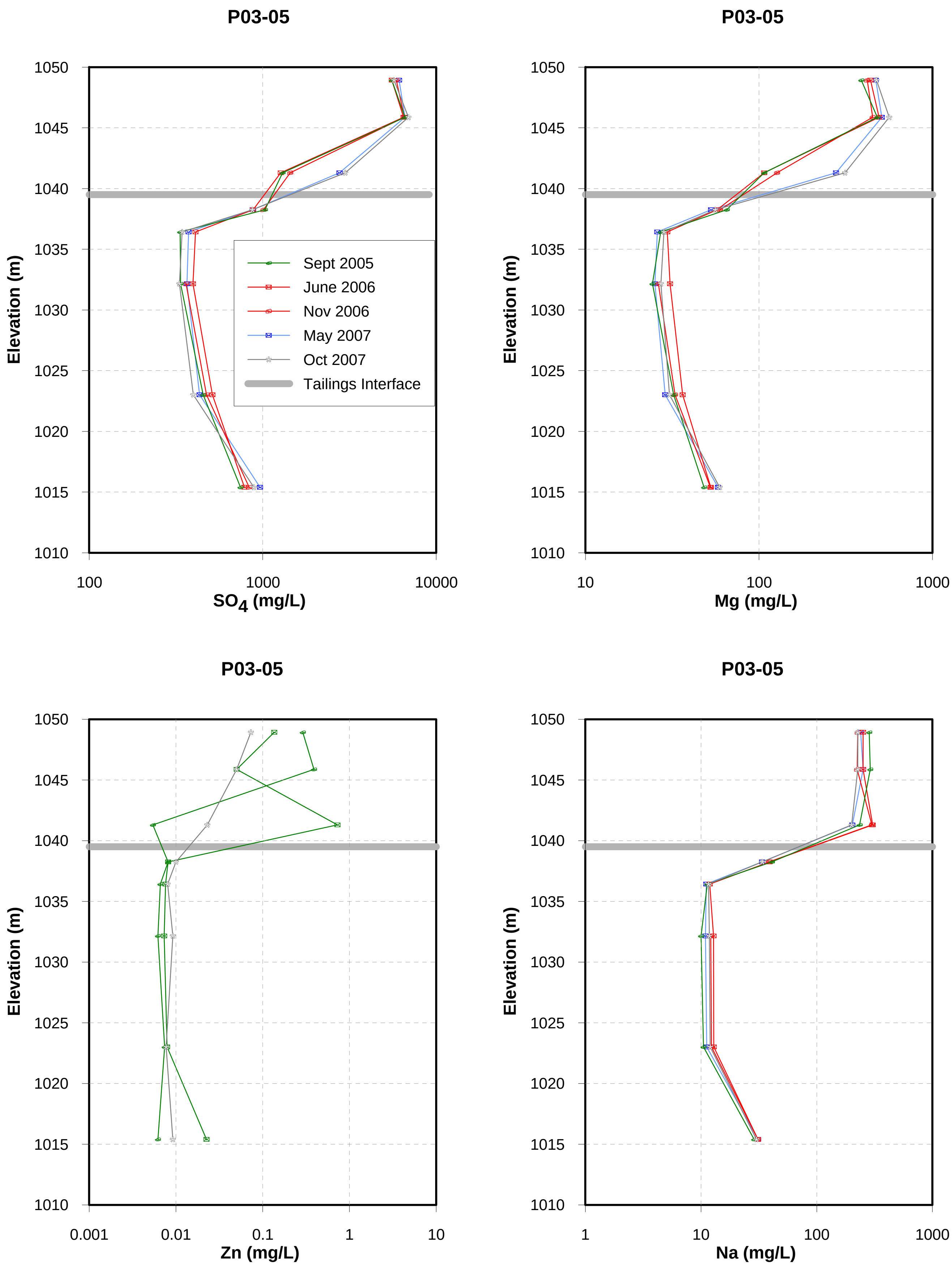


Figure 3-7a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-05 (Second Impoundment).

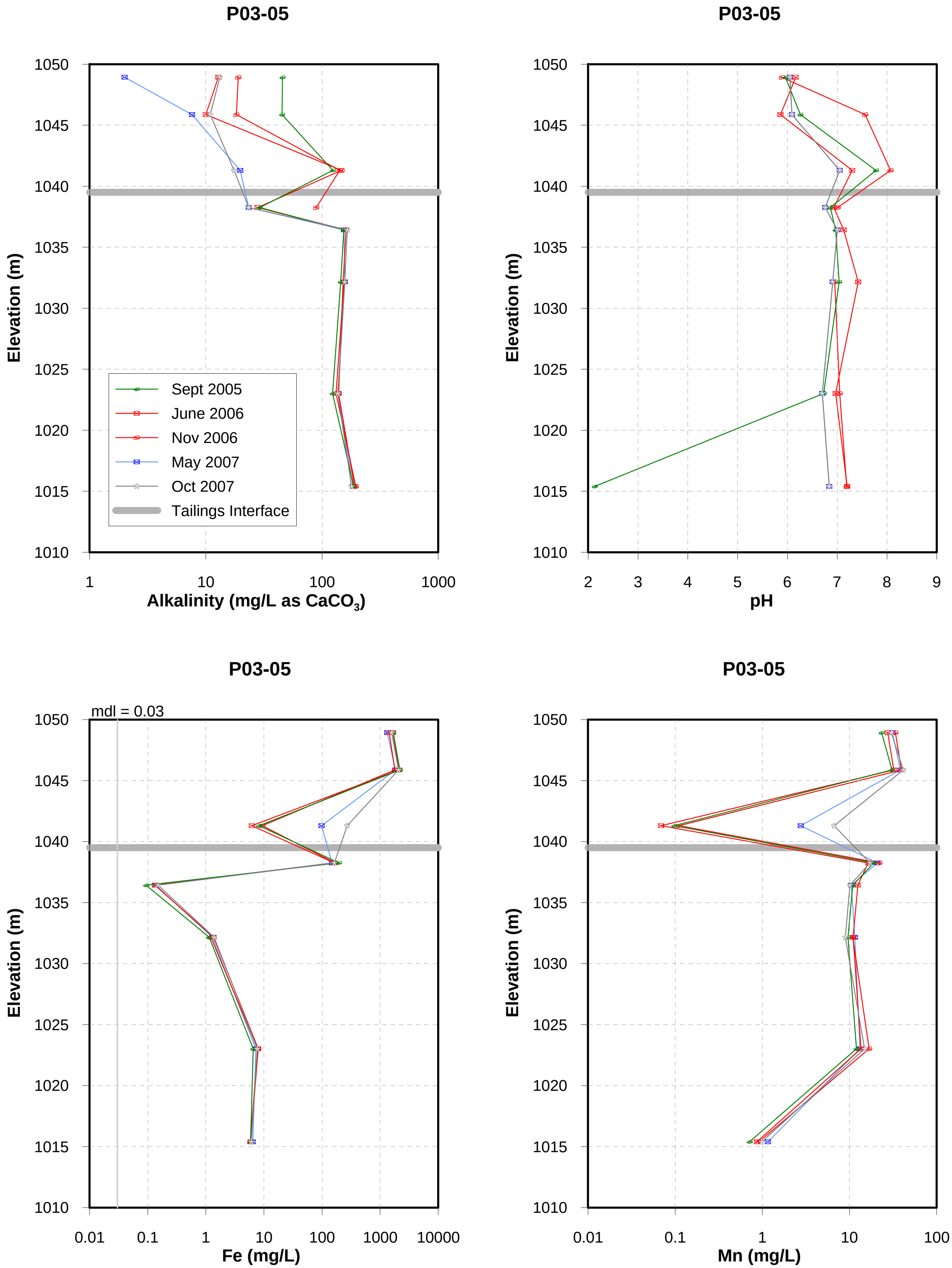


Figure 3-7b. Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-05 (Second Impoundment).

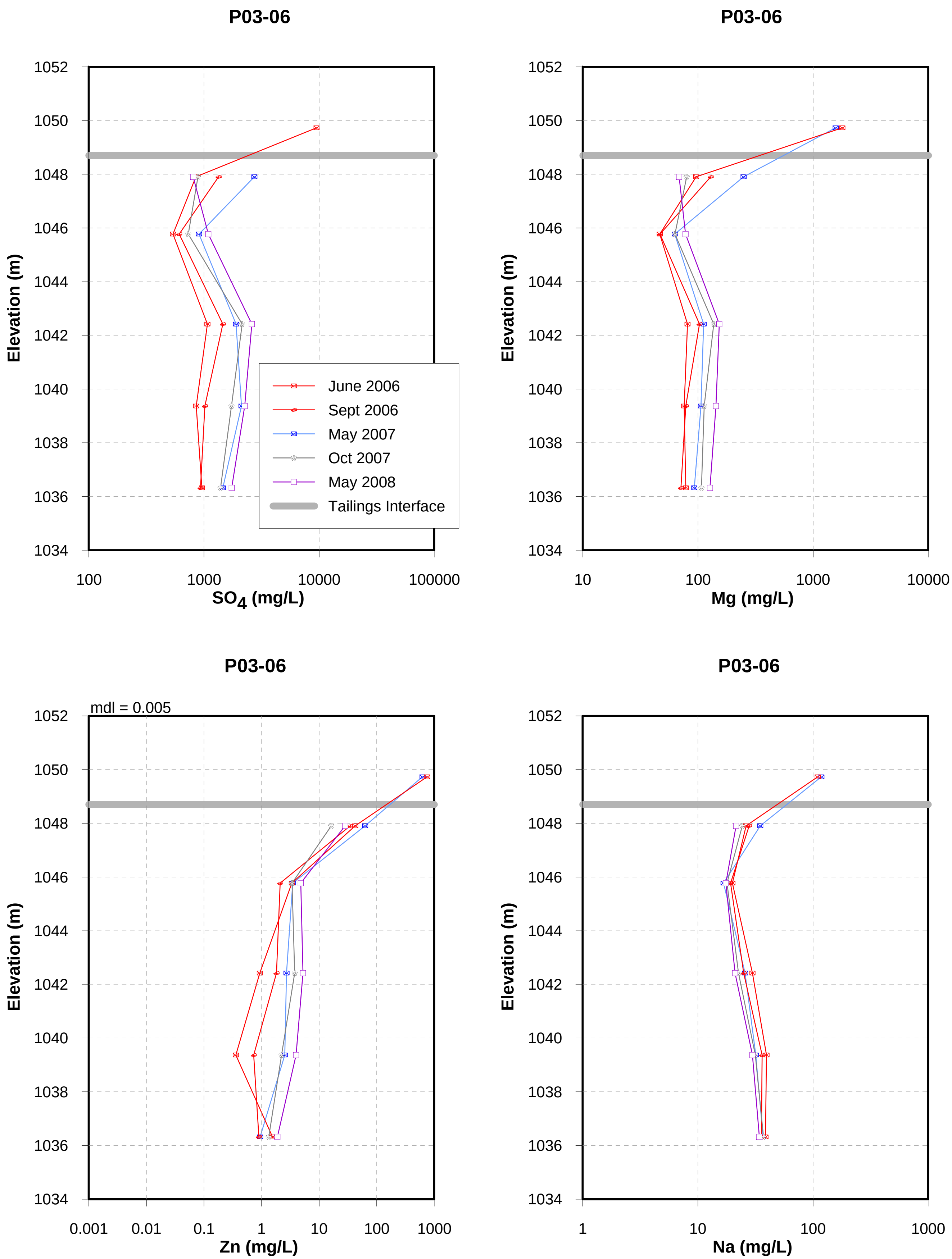


Figure 3-8a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-06 (Second Impoundment).

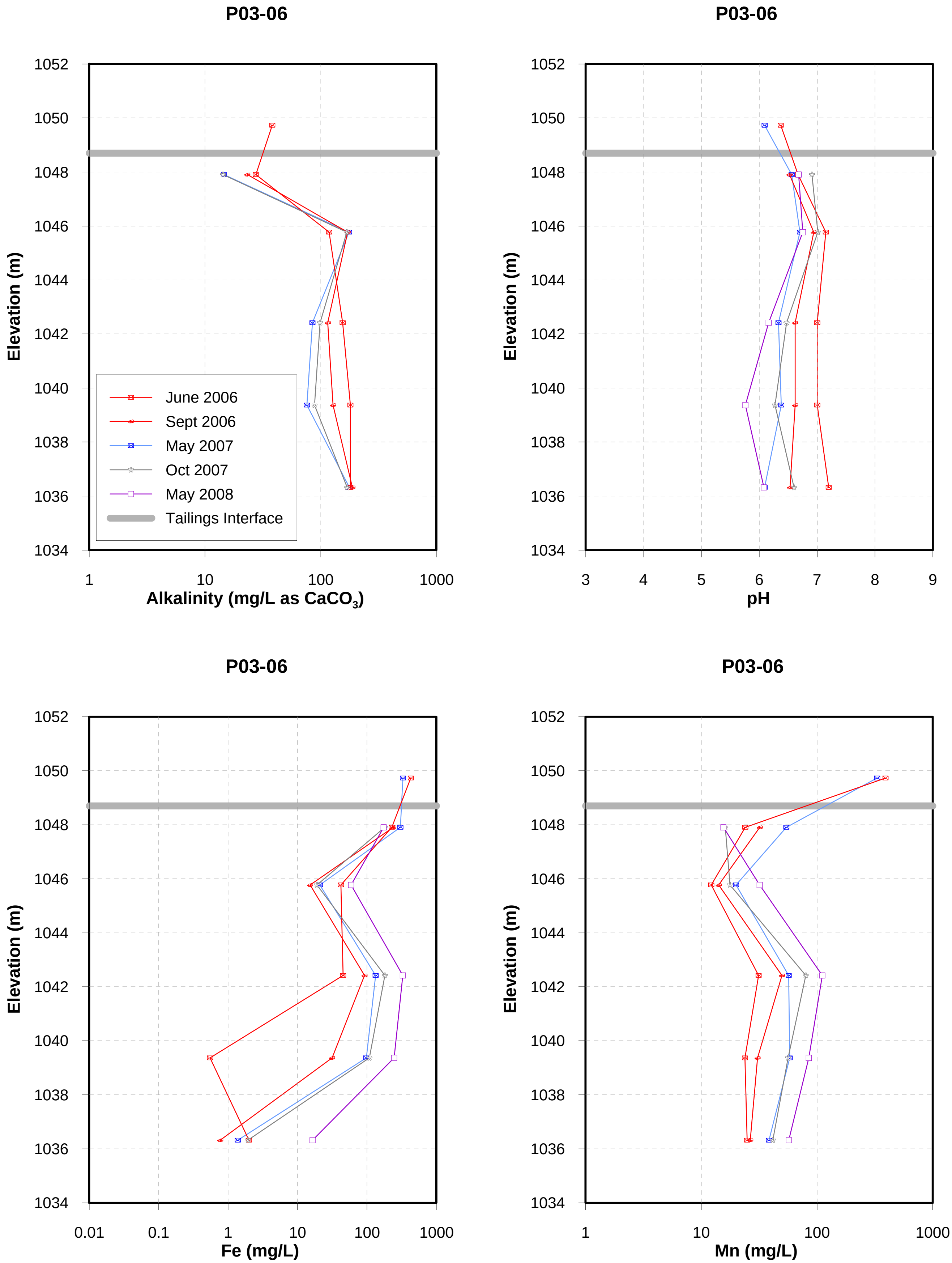


Figure 3-8b. Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-06 (Second Impoundment).

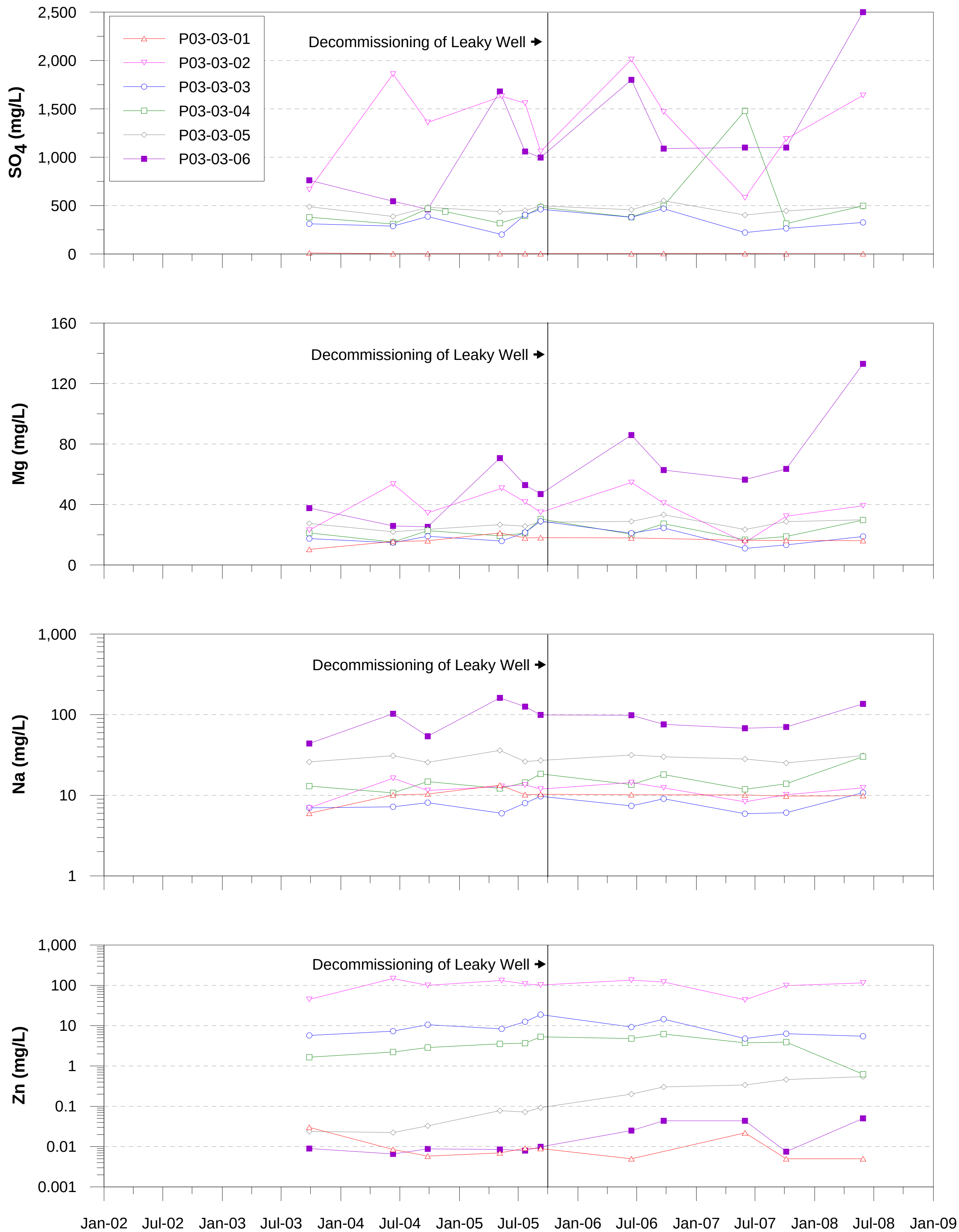


Figure 3-9a. Water quality (SO_4, Mg, Na and Zn) in P03-03 (aquifer only).

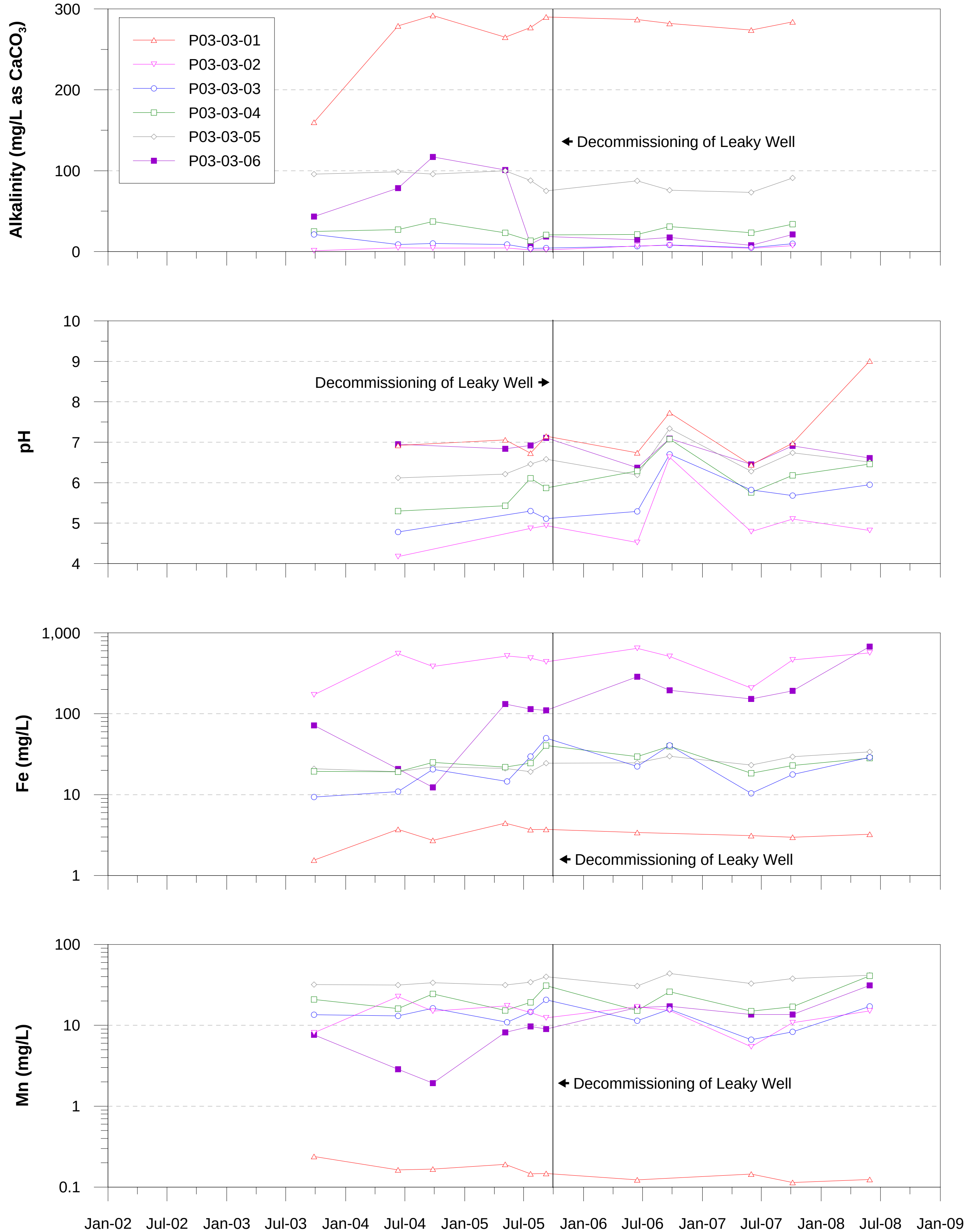


Figure 3-9b. Water quality (alkalinity, pH, Fe and Mn) in P03-03 (aquifer only).

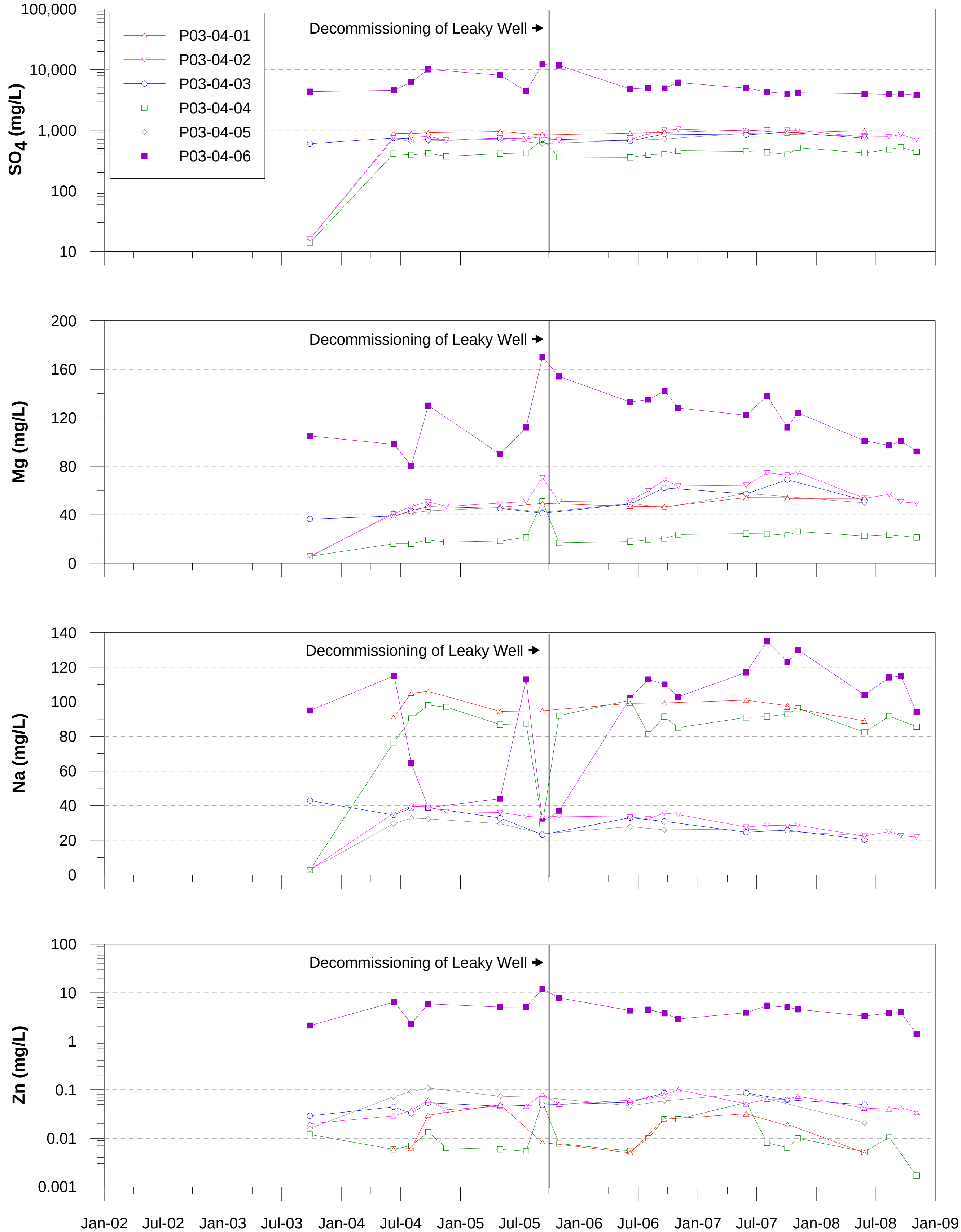


Figure 3-10a. Water quality (SO_4, Mg, Na and Zn) in P03-04 (aquifer only).

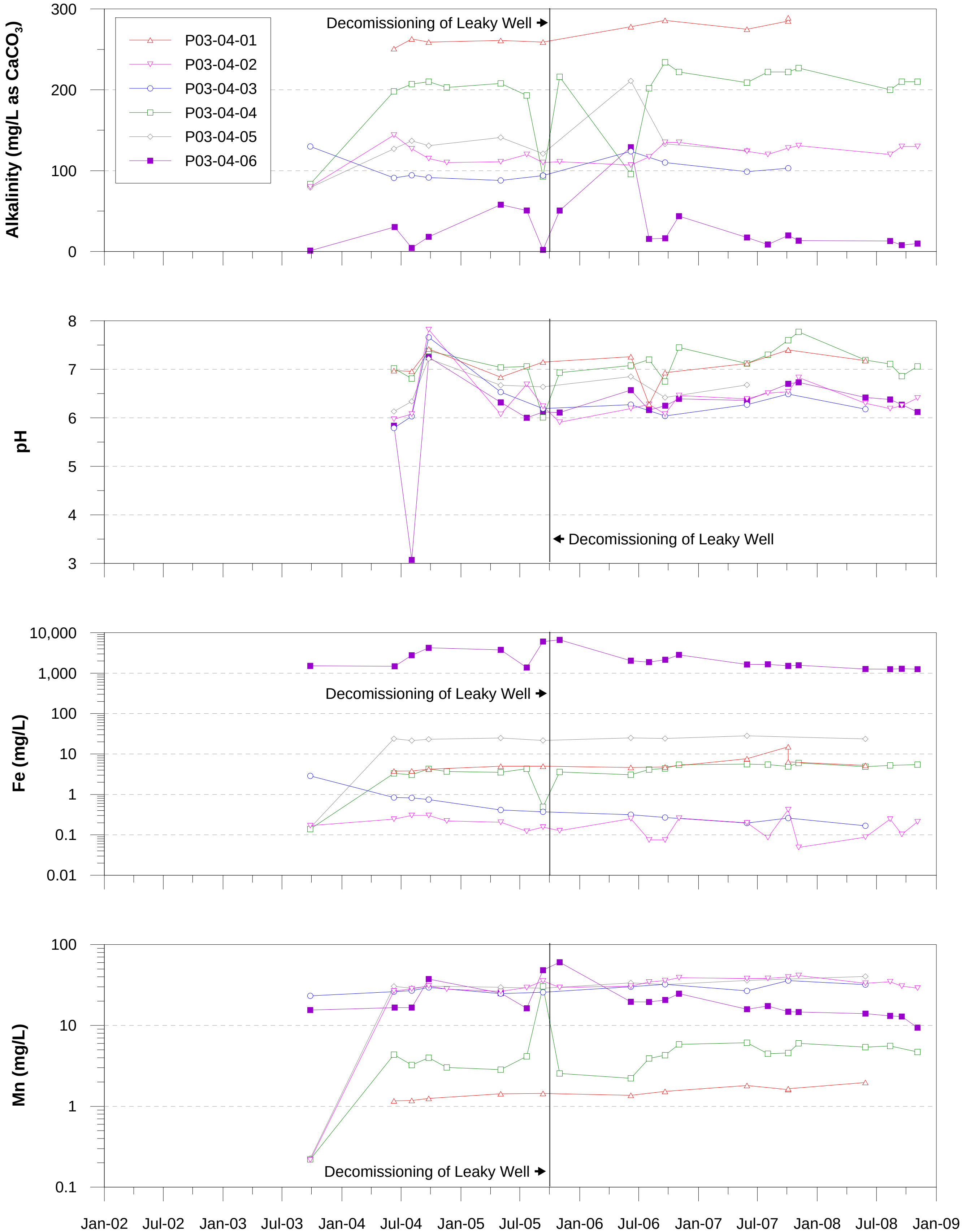


Figure 3-10b. Water quality (alkalinity, pH, Fe and Mn) in P03-04 (aquifer only).

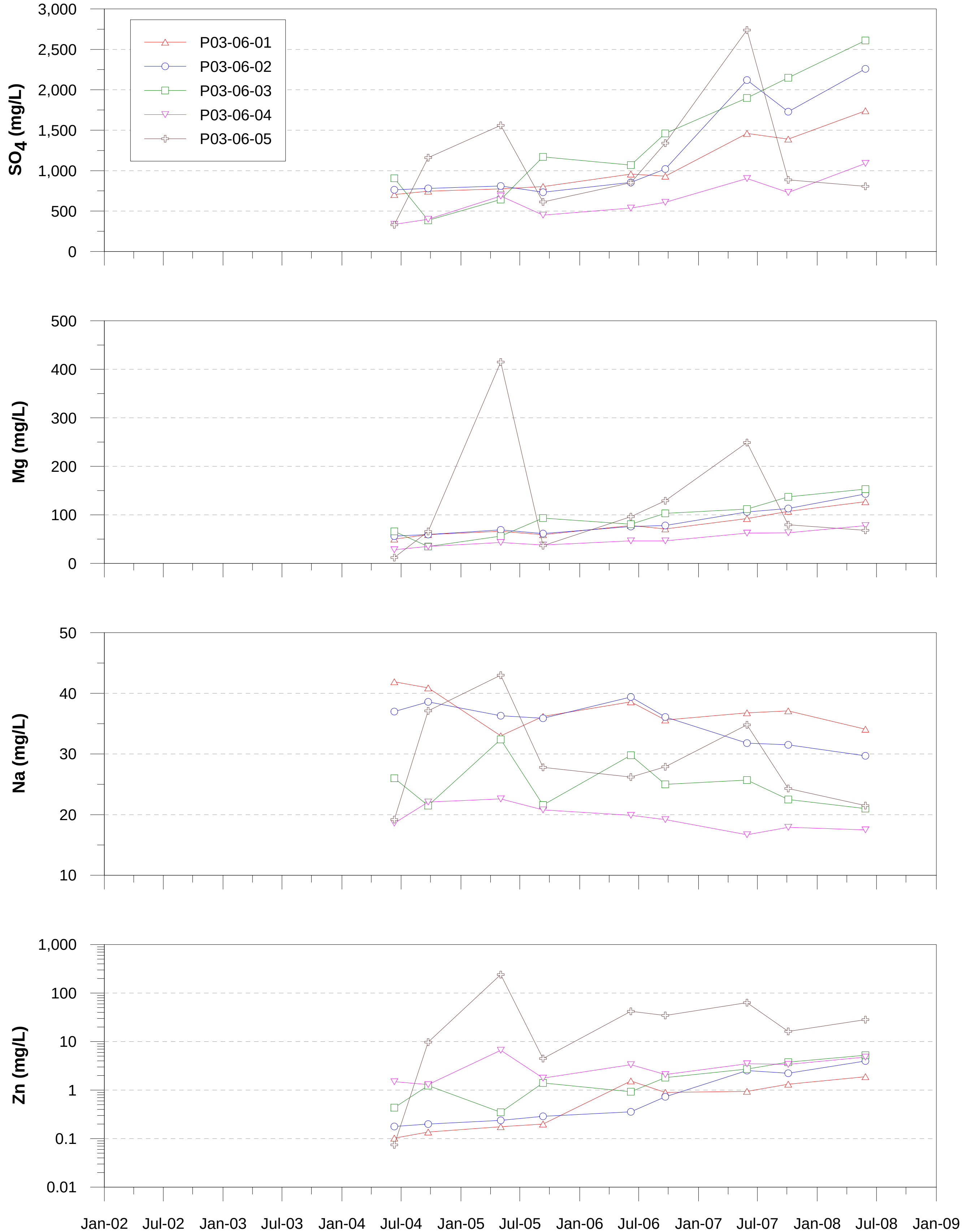


Figure 3-10c. Water quality (SO_4, Mg, Na and Zn) in P03-06 (aquifer only).

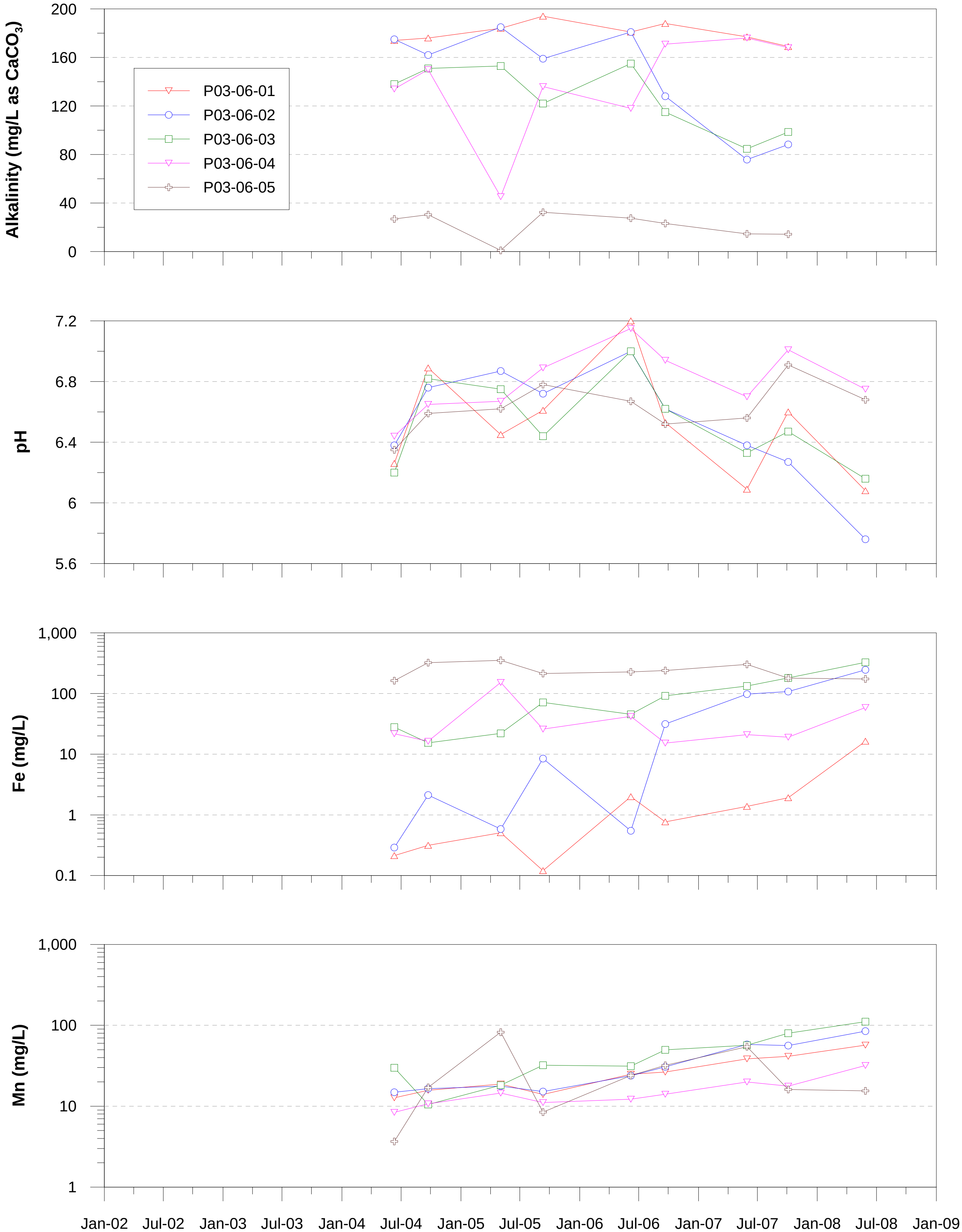


Figure 3-10d. Water quality (alkalinity, pH, Fe and Mn) in P03-06 (aquifer only).

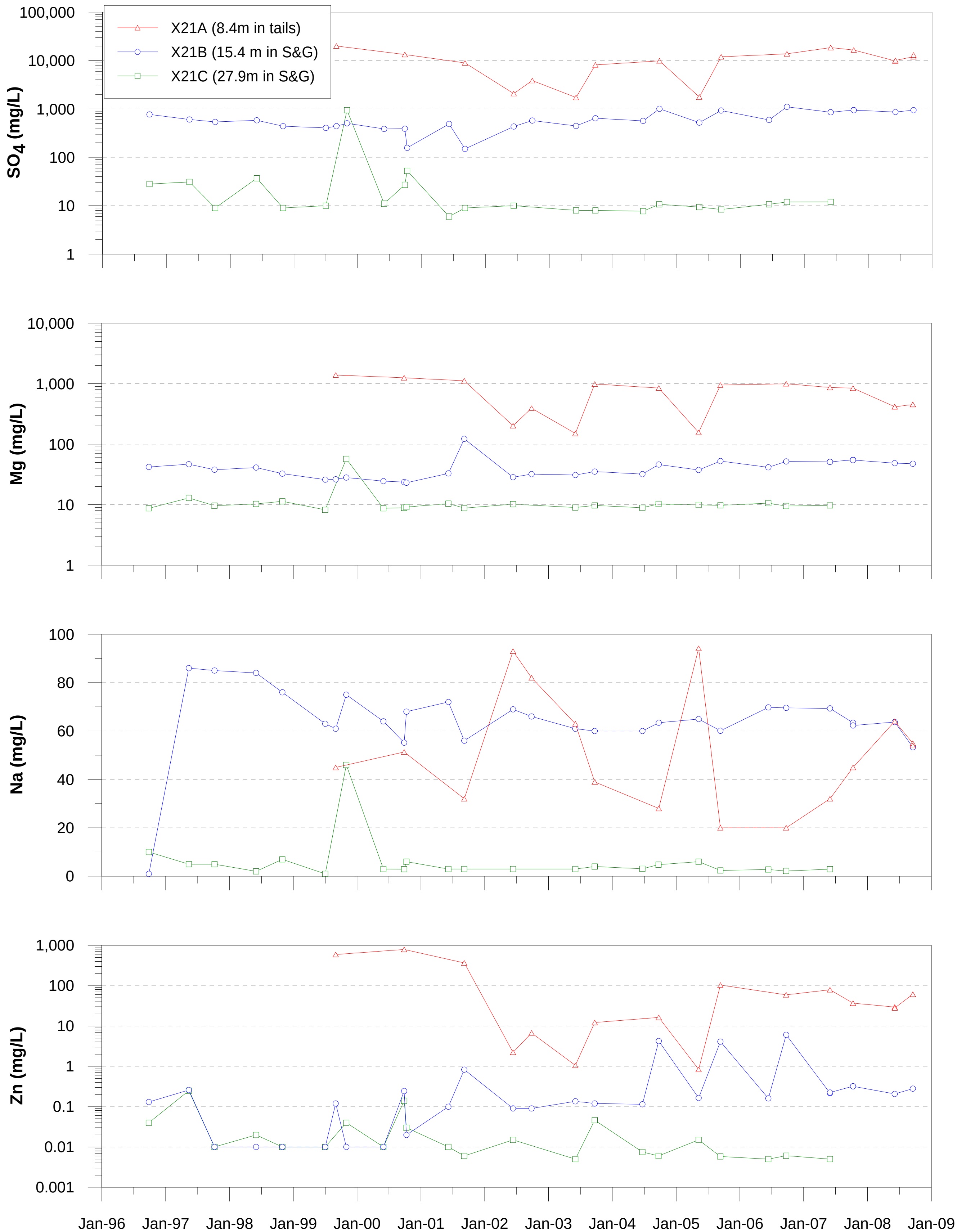


Figure 3-11a. Water quality (SO_4, Mg, Na and Zn) in X21(96) (Intermediate Impoundment).

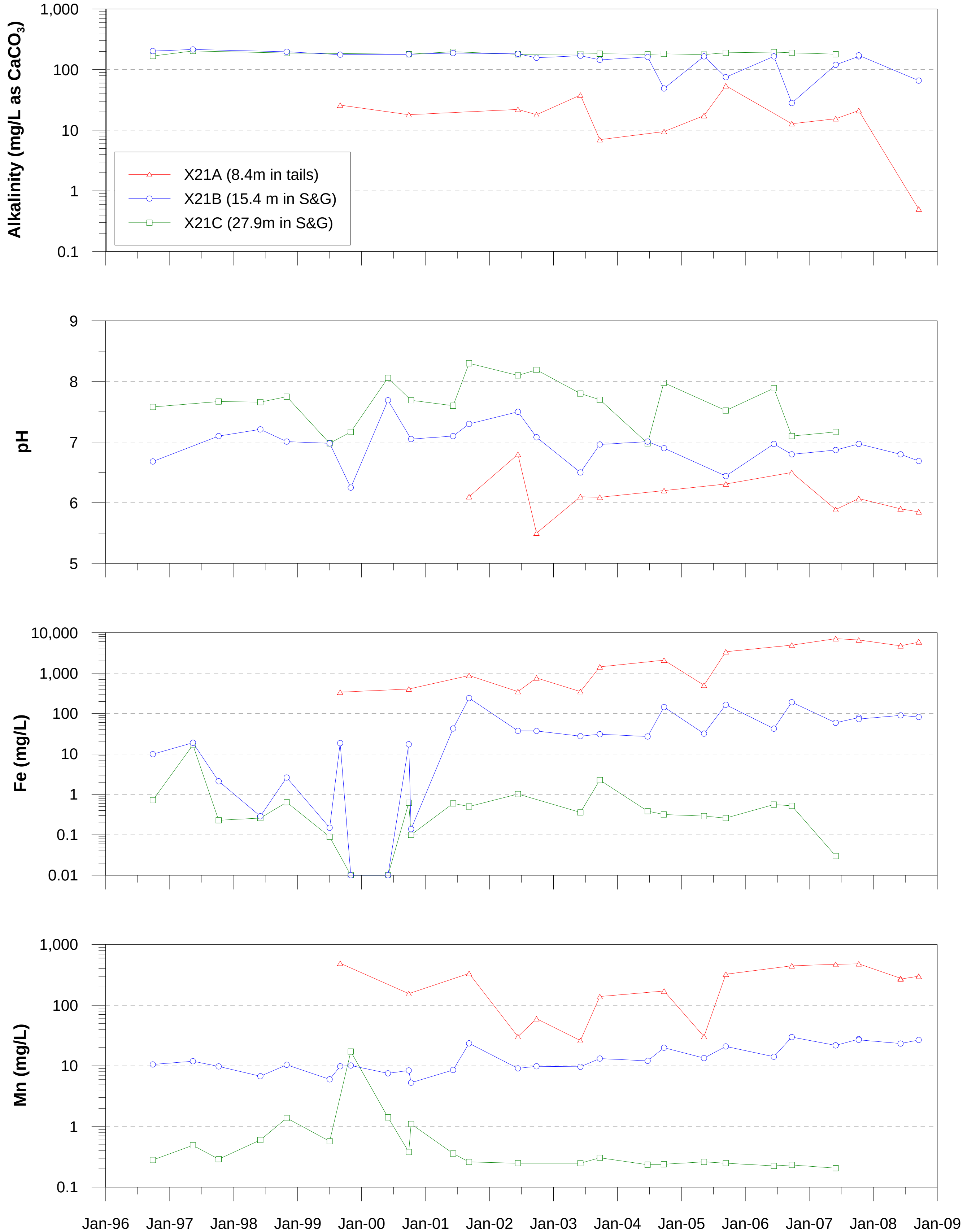


Figure 3-11b. Water quality (Alkalinity, pH, Fe and Mn) in X21(96) (Intermediate Impoundment).

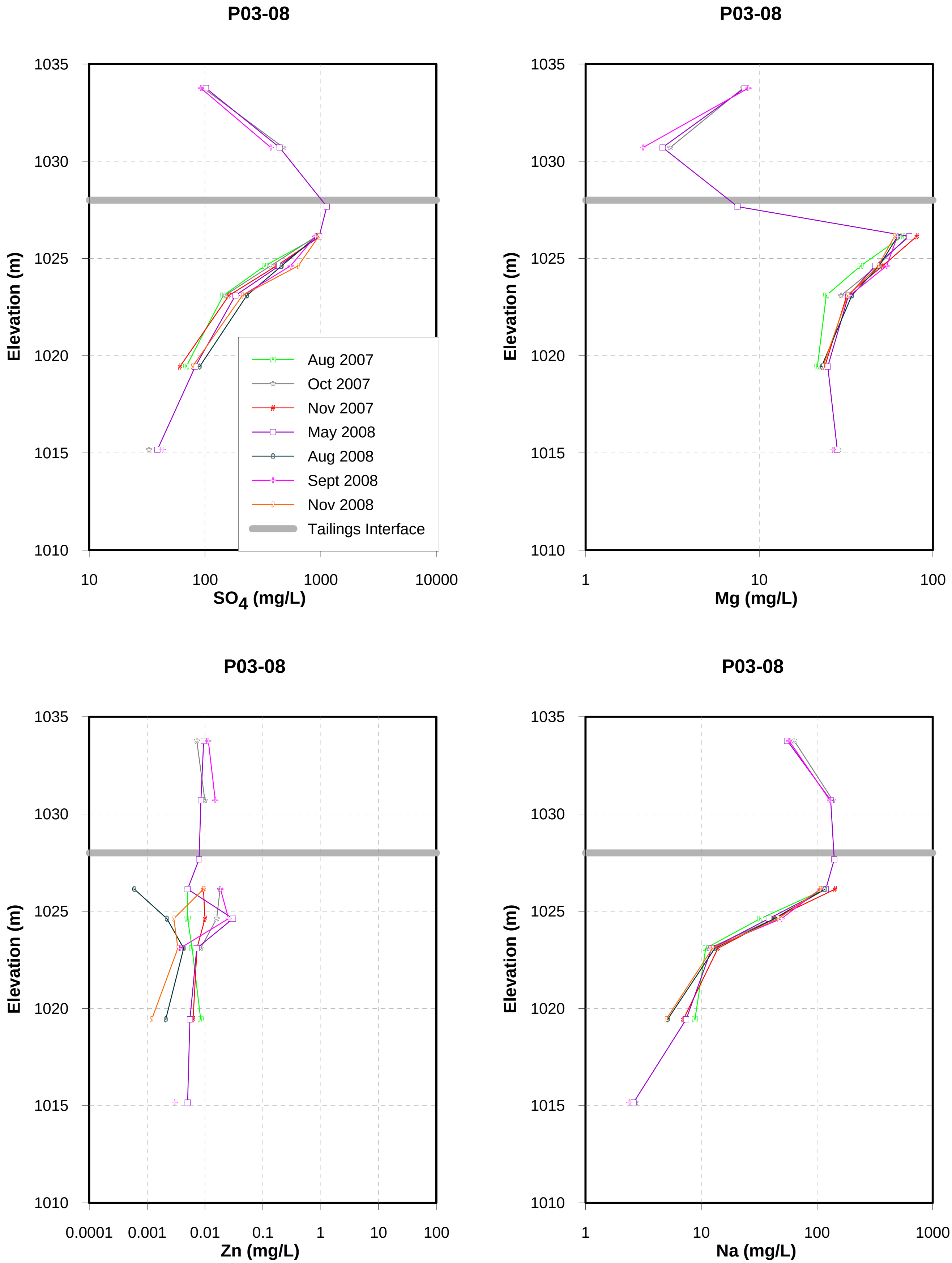


Figure 3-12a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-08 (Intermediate Impoundment).

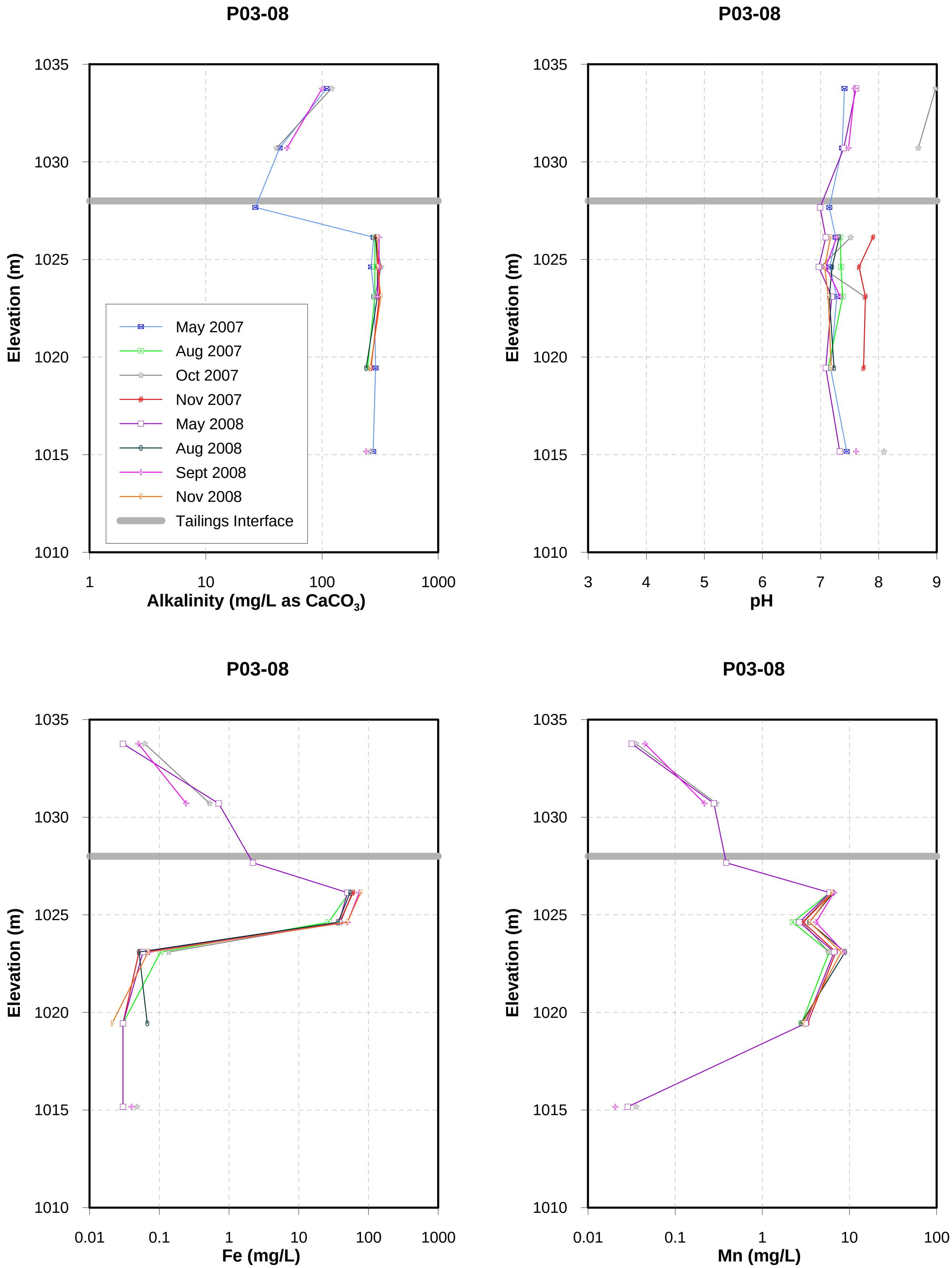


Figure 3-12b. Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-08 (Intermediate Impoundment).

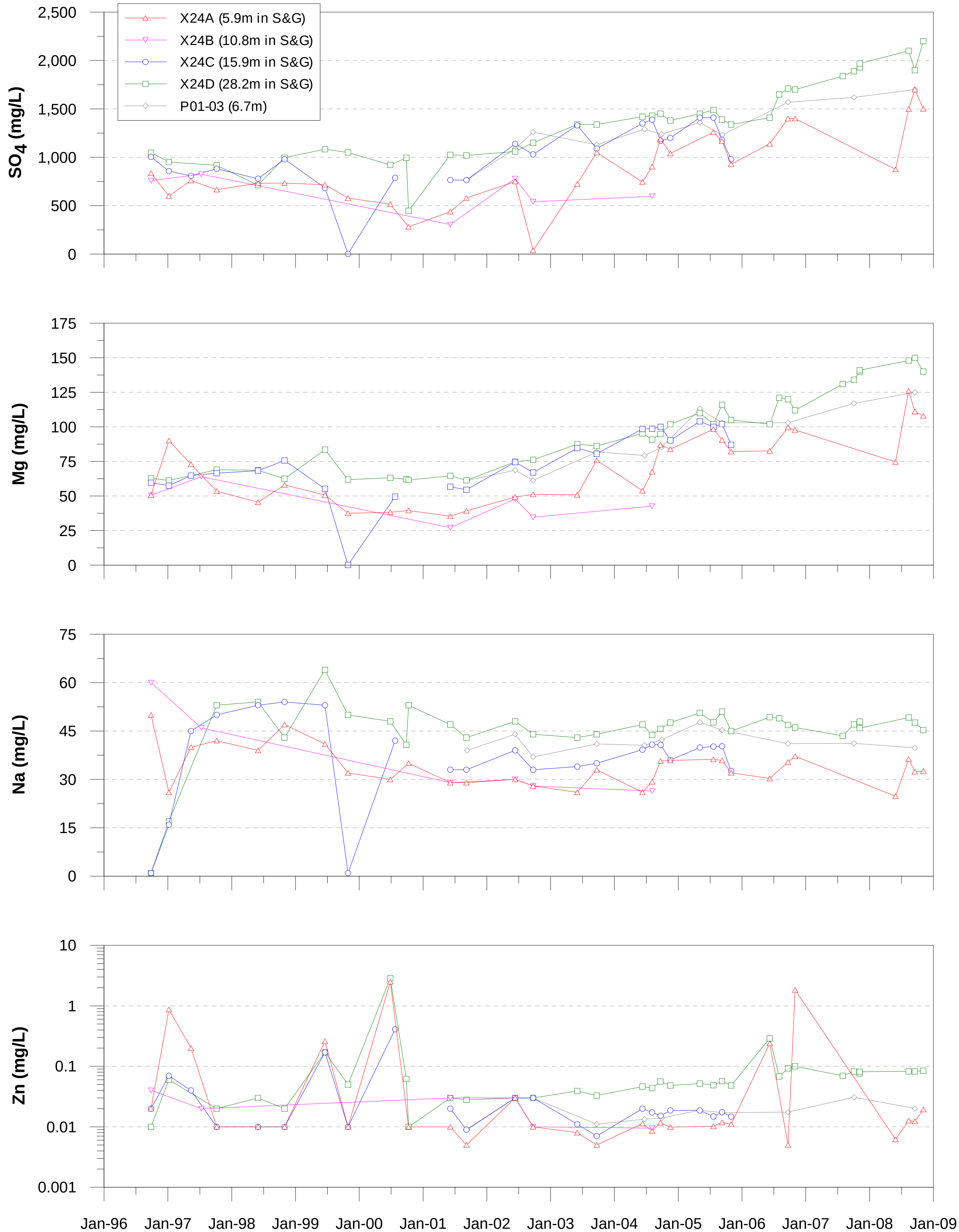


Figure 3-13a. Water quality (SO_4, Mg, Na and Zn) in X24(96) and P01-03 (north side of Intermediate Dam).

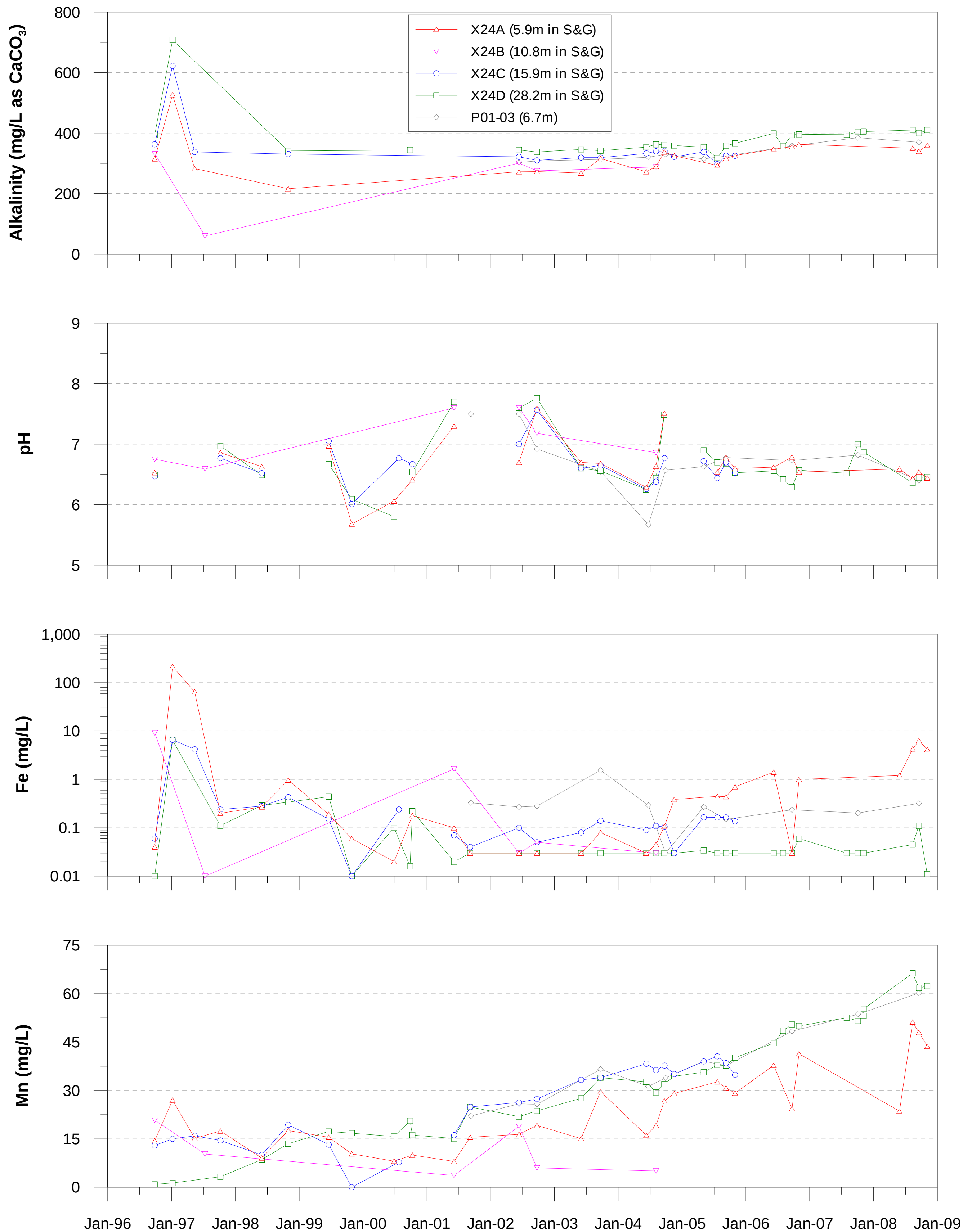


Figure 3-13b. Water quality (alkalinity, pH, Fe and Mn) in X24(96) and P01-03 (north side of Intermediate Dam).

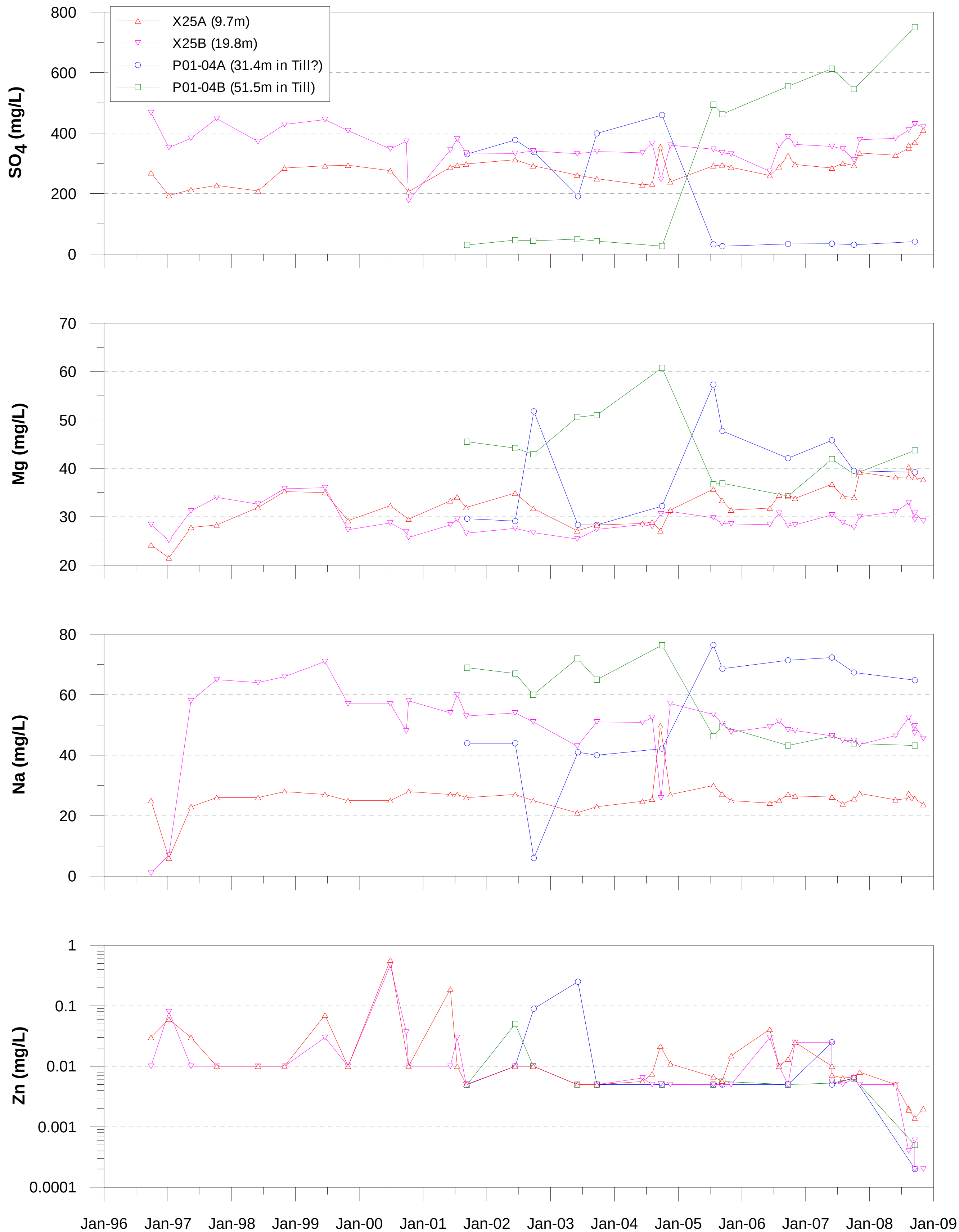


Figure 3-14a. Water quality (SO_4, Mg, Na and Zn) in X25(96) and P01-04 (south side of Intermediate Dam).

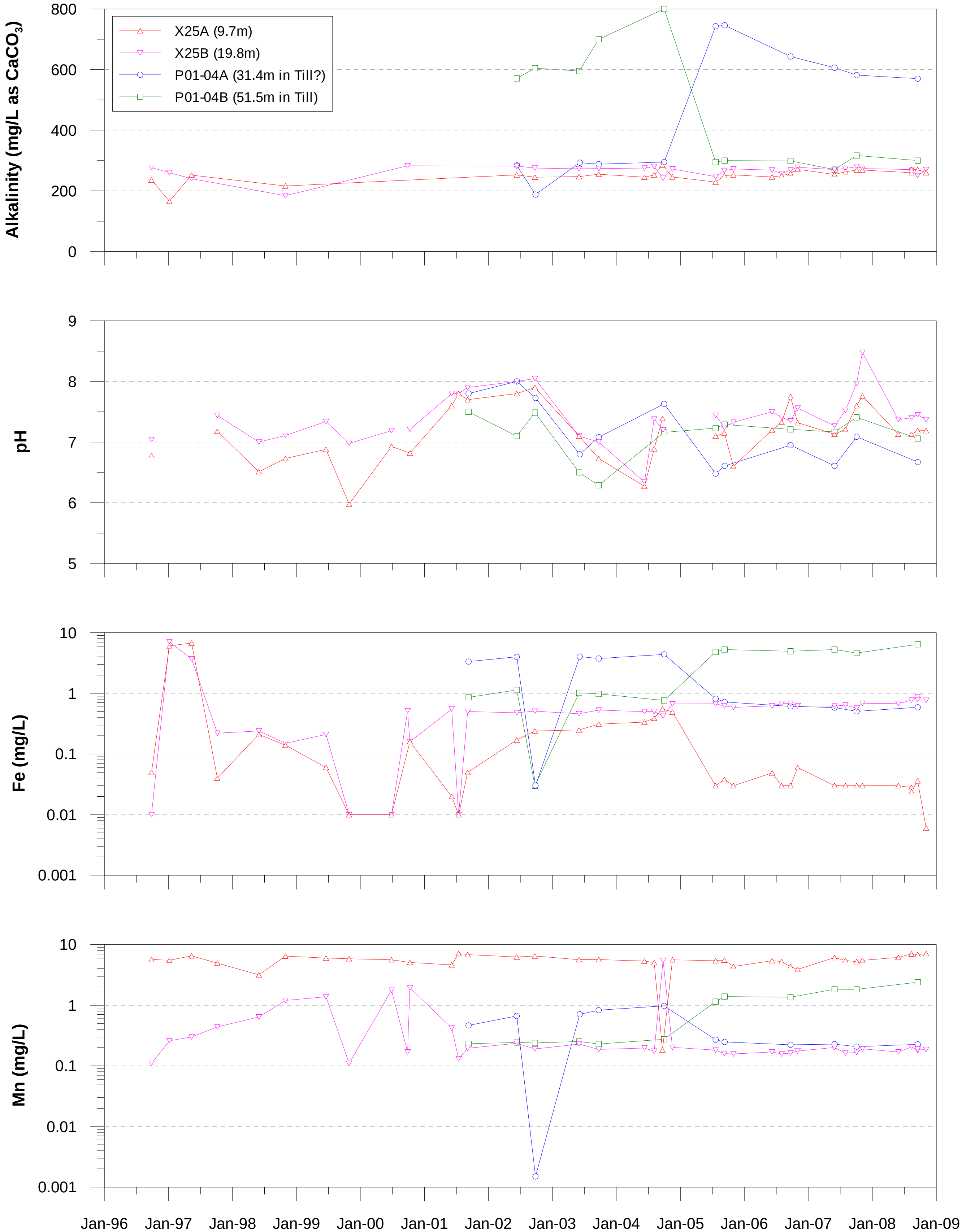


Figure 3-14b. Water quality (alkalinity, pH, Fe and Mn) in X25(96) and P01-04 (south side of Intermediate Dam).

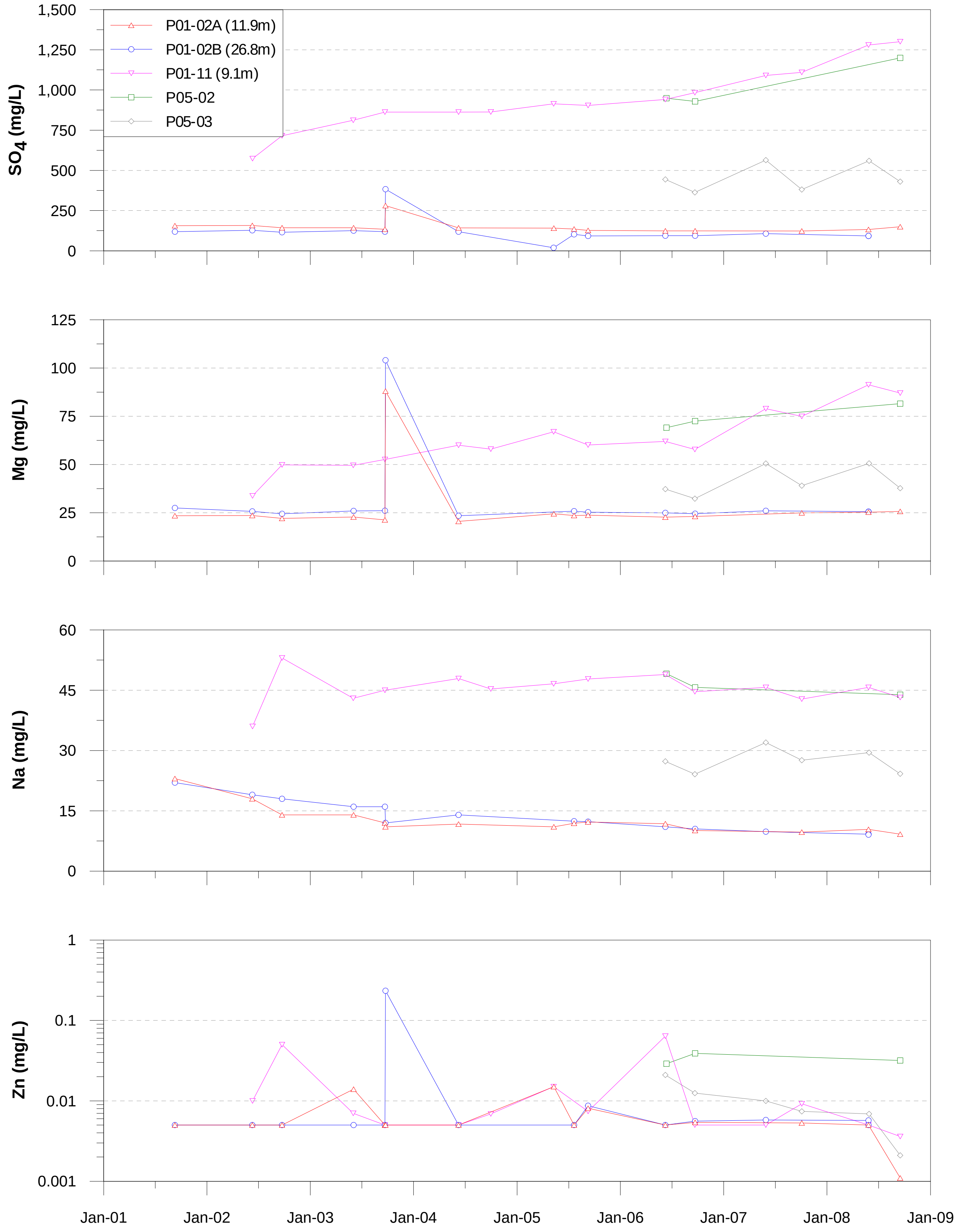


Figure 3-15a. Water quality (SO_4, Mg, Na and Zn) in wells along toe of Cross Valley Dam.

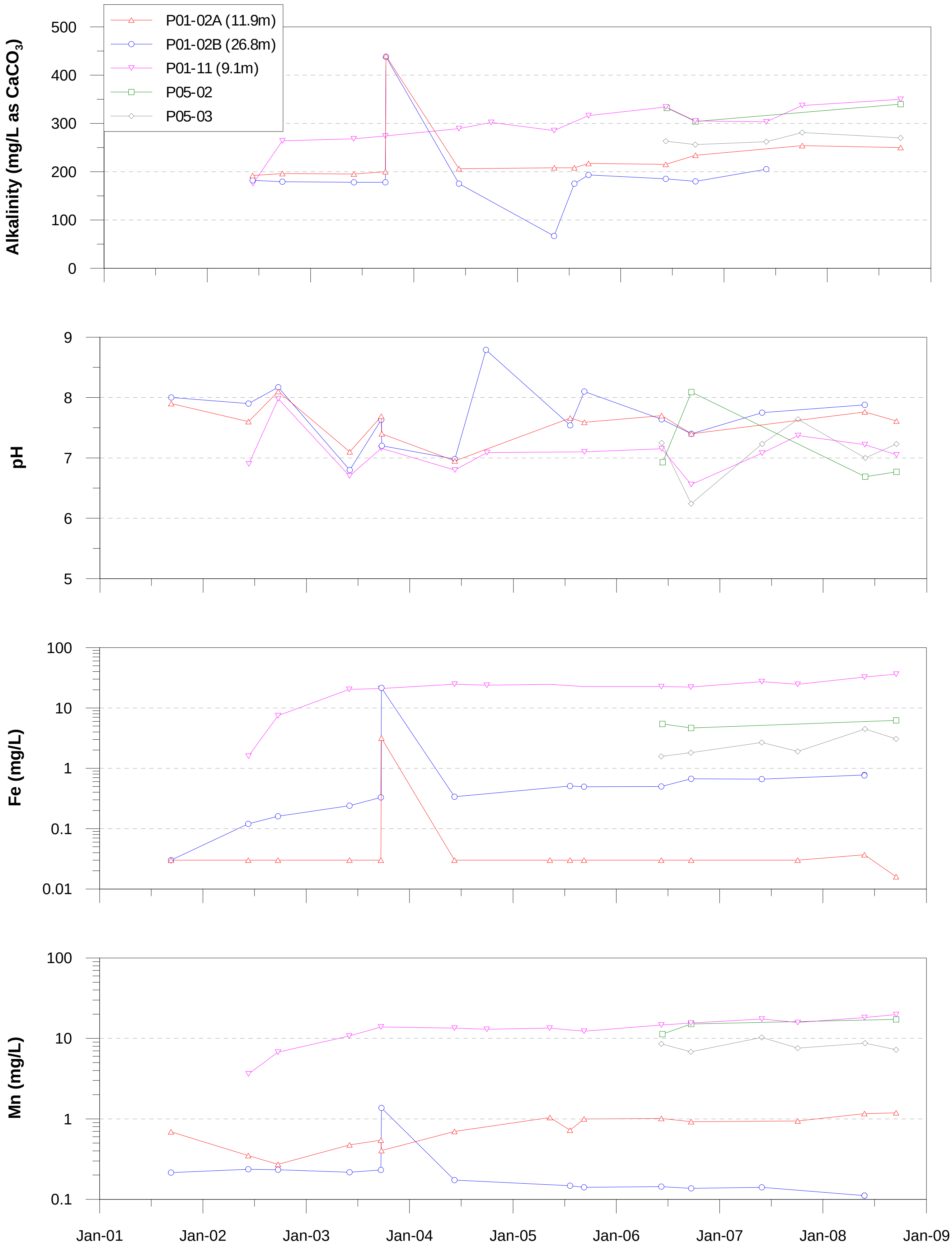


Figure 3-15b. Water quality (alkalinity, pH, Fe and Mn) in wells along toe of Cross Valley Dam.

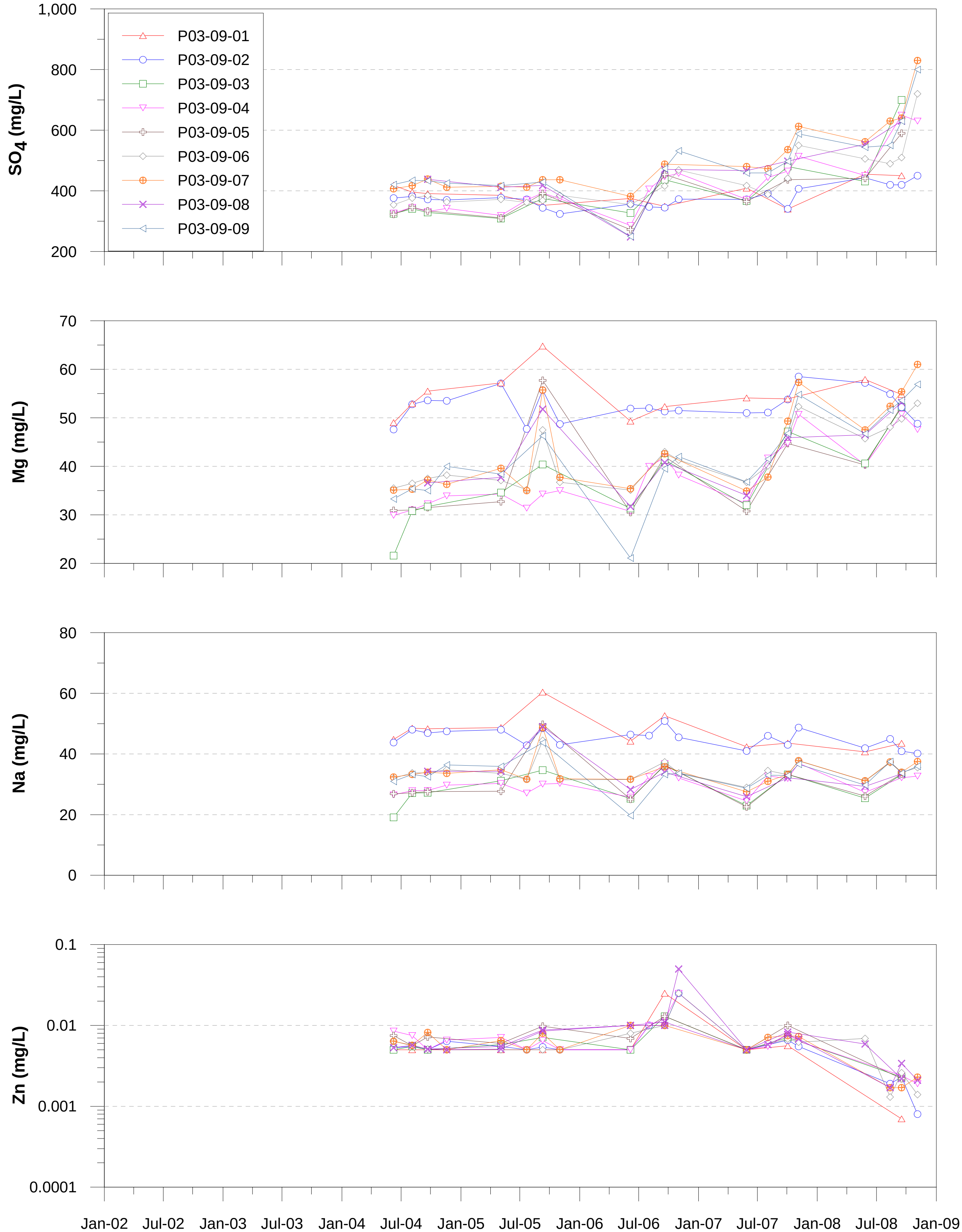


Figure 3-16a. Water quality (SO_4, Mg, Na and Zn) in P03-09 (aquifer only).

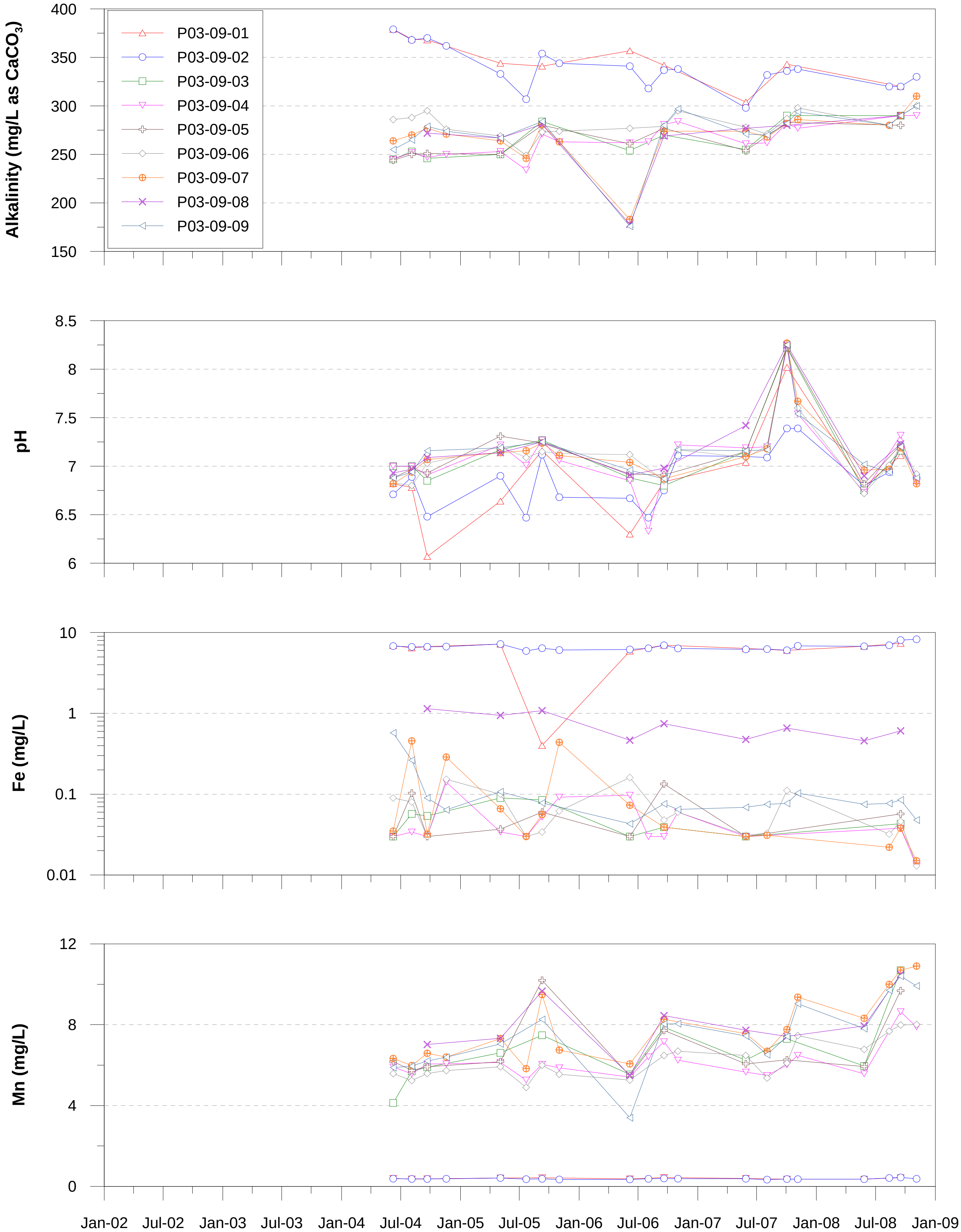


Figure 3-16b . Water quality (alkalinity, pH, Fe and Mn) in P03-09 (aquifer only).

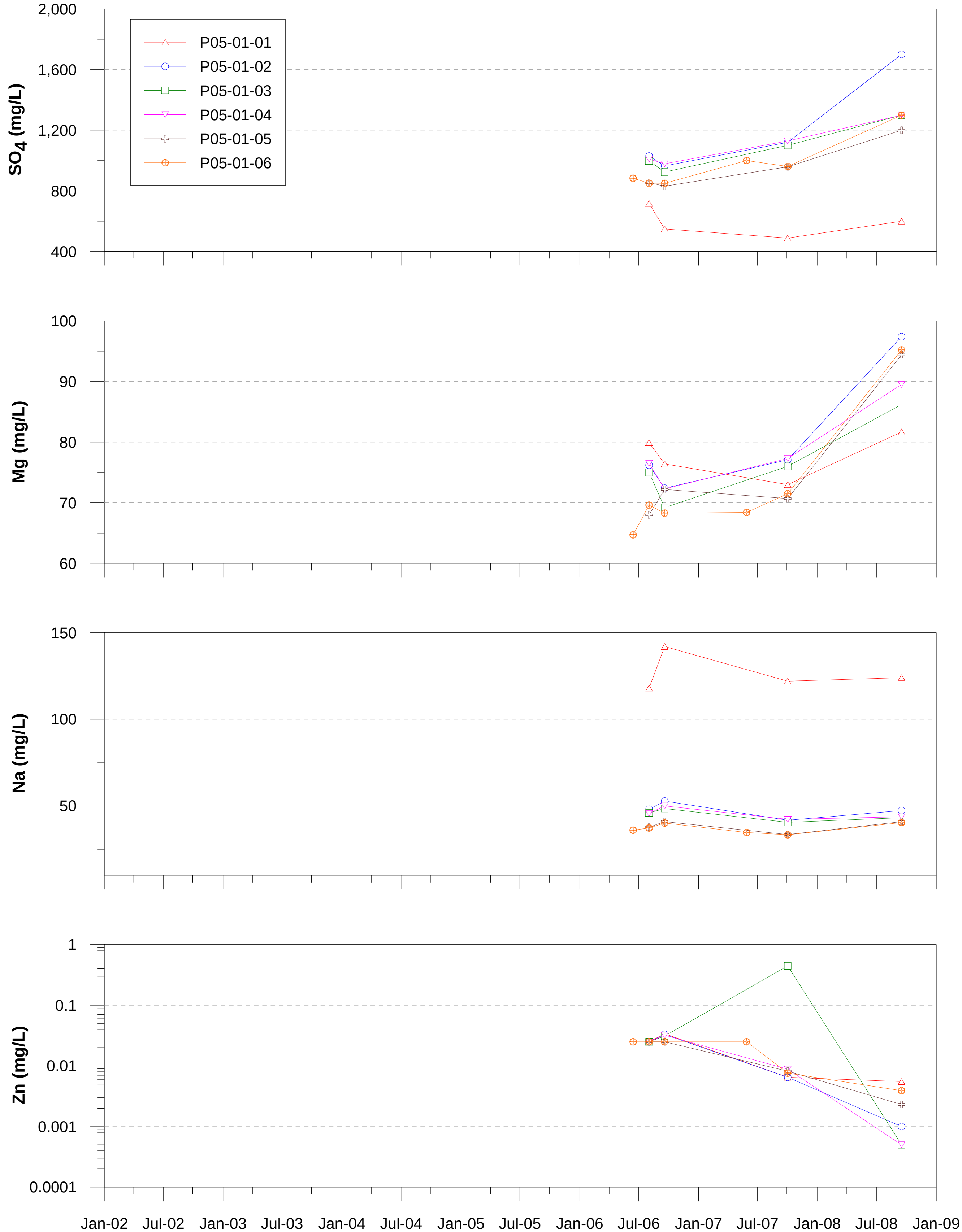


Figure3-17a . Water quality (SO_4, Mg, Na and Zn) in P05-01 (aquifer only).

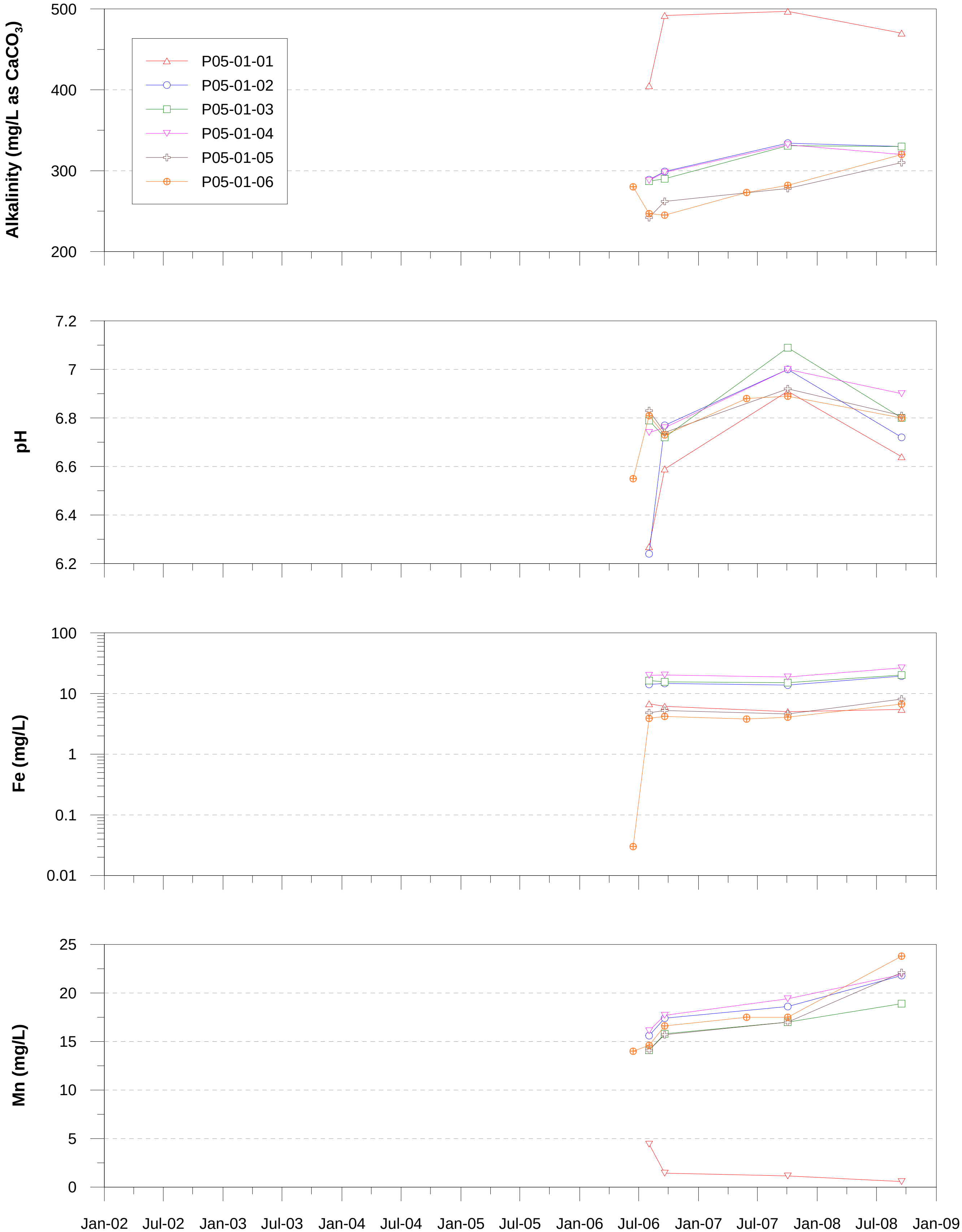


Figure 3-17b . Water quality (alkalinity, pH, Fe and Mn) in P05-01 (aquifer only).

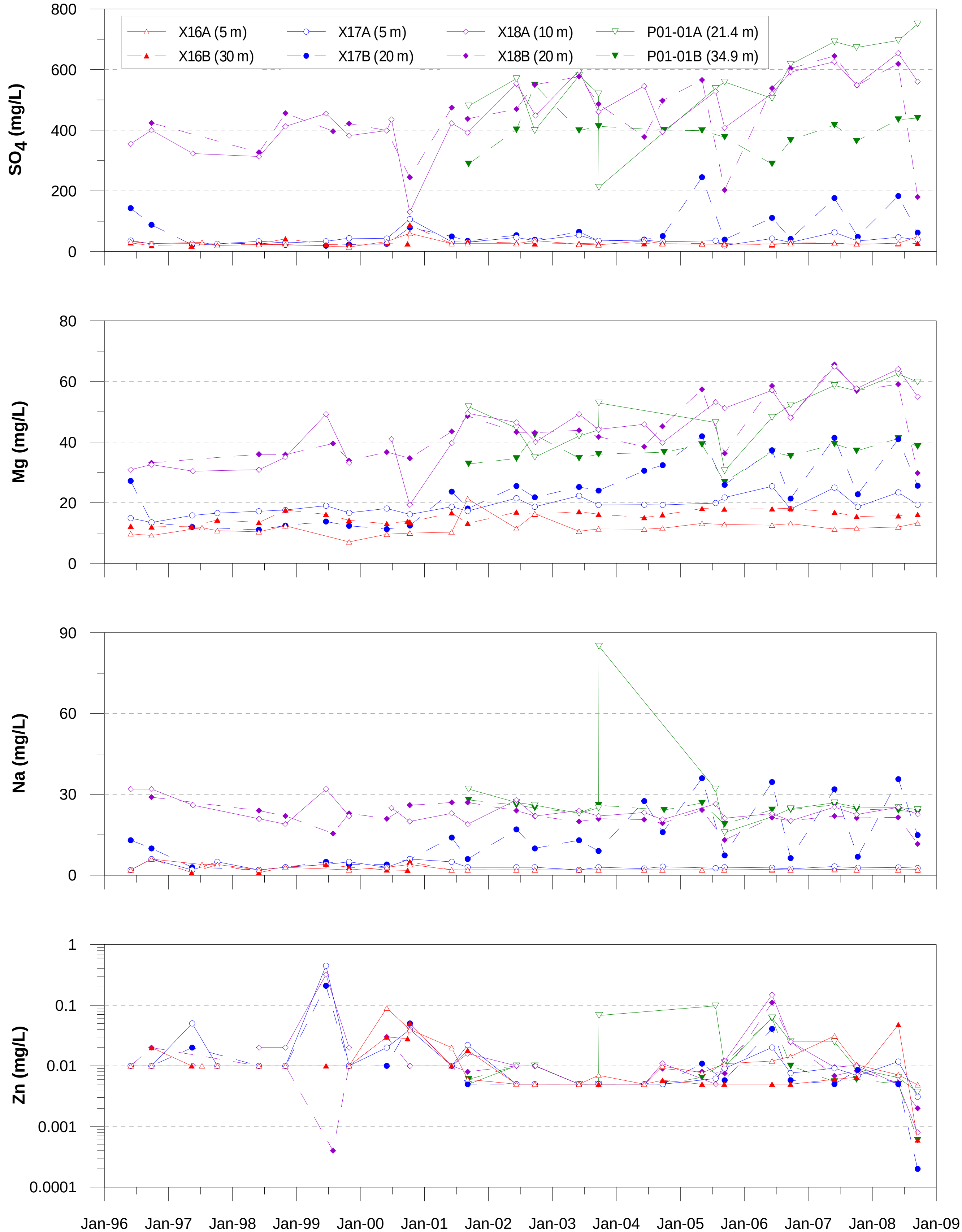


Figure 3-18a. Water quality (SO_4, Mg, Na and Zn) in wells downgradient of Cross Valley Dam.

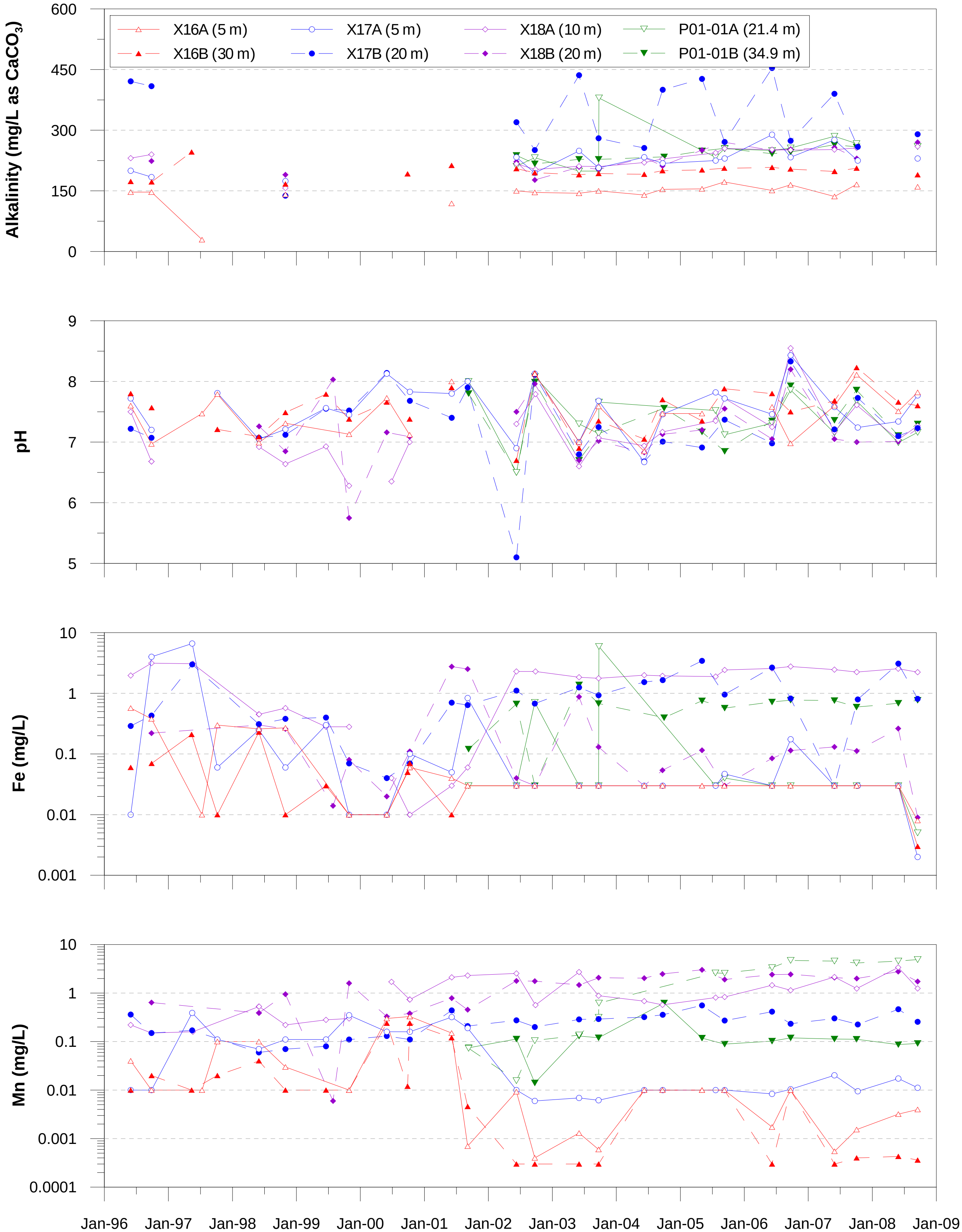
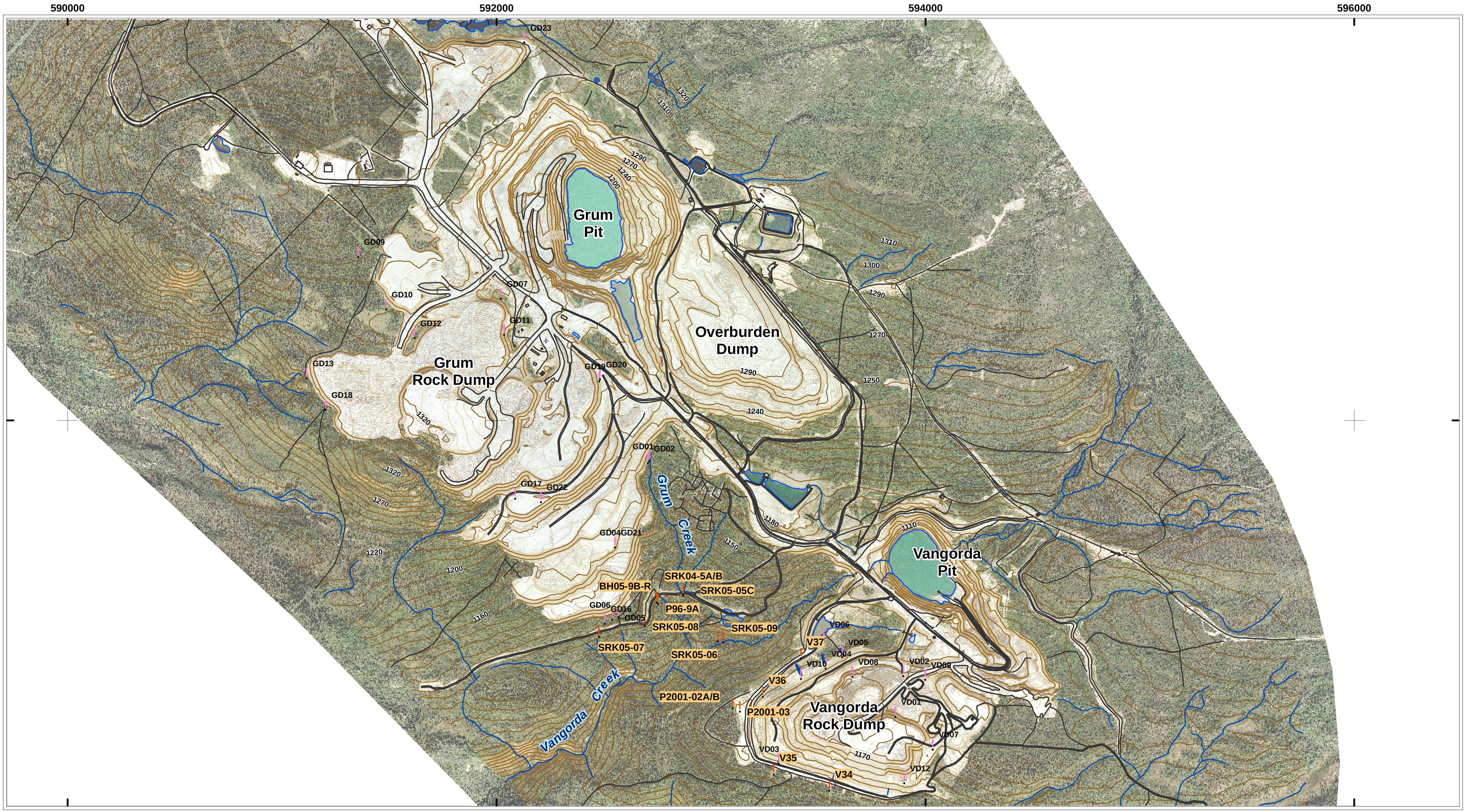


Figure 3-18b. Water quality (alkalinity, pH, Fe and Mn) in wells downgradient of Cross Valley Dam.



LEGEND

! Monitoring Well

! Seep Monitoring Station

PROJECTION: UTM

ZONE: 8

DATUM: NAD 27

UNITS: Meters

CONTOUR INTERVAL: 2m

Layout of Grum & Vangorda Mine Site

Anvil Range Mining Complex

SCALE

0 205 410 820 1,230 1,640 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.

PROJECT: 2008 Groundwater Review

REPORT: RGC 118014

LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 4-1

DATE: 021109

DRAWN BY: OM

FILE: Faro_GrumVangorda09.mxd

Groundwater Monitoring Wells
Grum Rock Dump Area
Grum & Vangorda Mine Site

LEGEND

- Monitoring Well
- Seep Monitoring Station

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

SCALE

0 25 50 100 150 200 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2008 Groundwater Review
REPORT: RGC 118014
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 4-2

DATE: 021109 DRAWN BY: OM FILE: Faro_Grum09.mxd

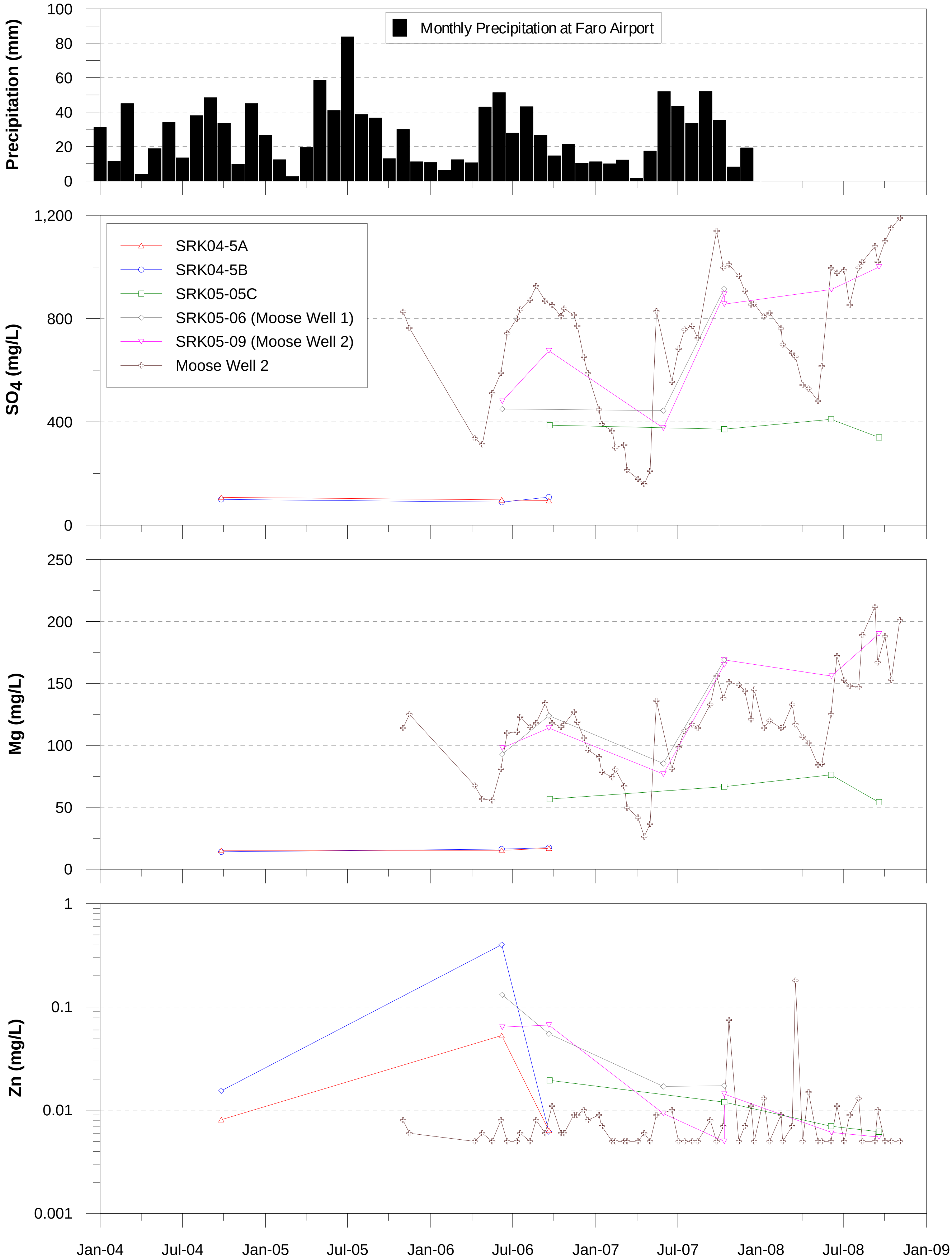


Figure 4-3a. Precipitation and water quality (SO_4, Mg and Zn) in wells in Grum Creek drainage.

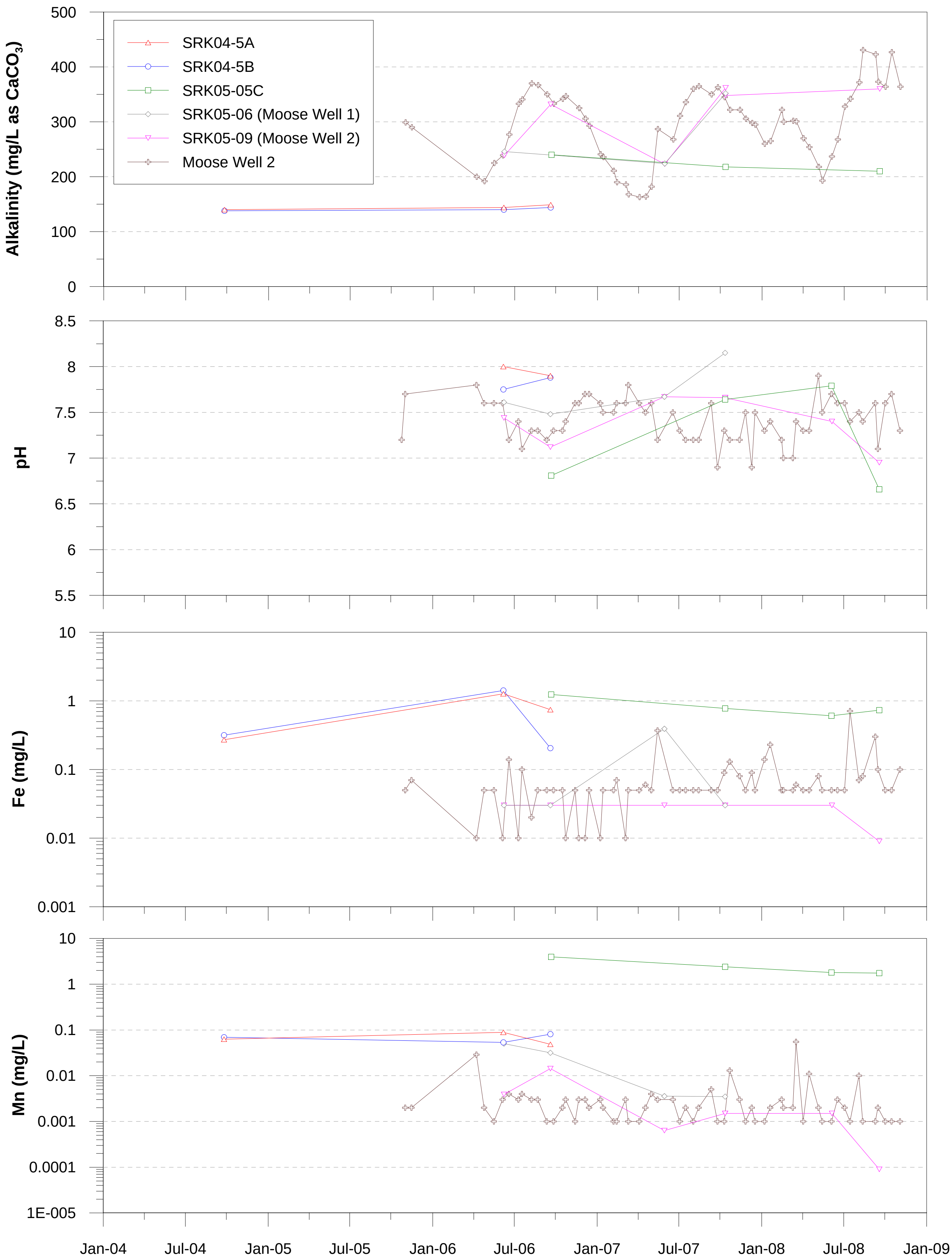


Figure 4-3b. Water quality (alkalinity, pH, Fe and Mn) in wells in Grum Creek drainage.

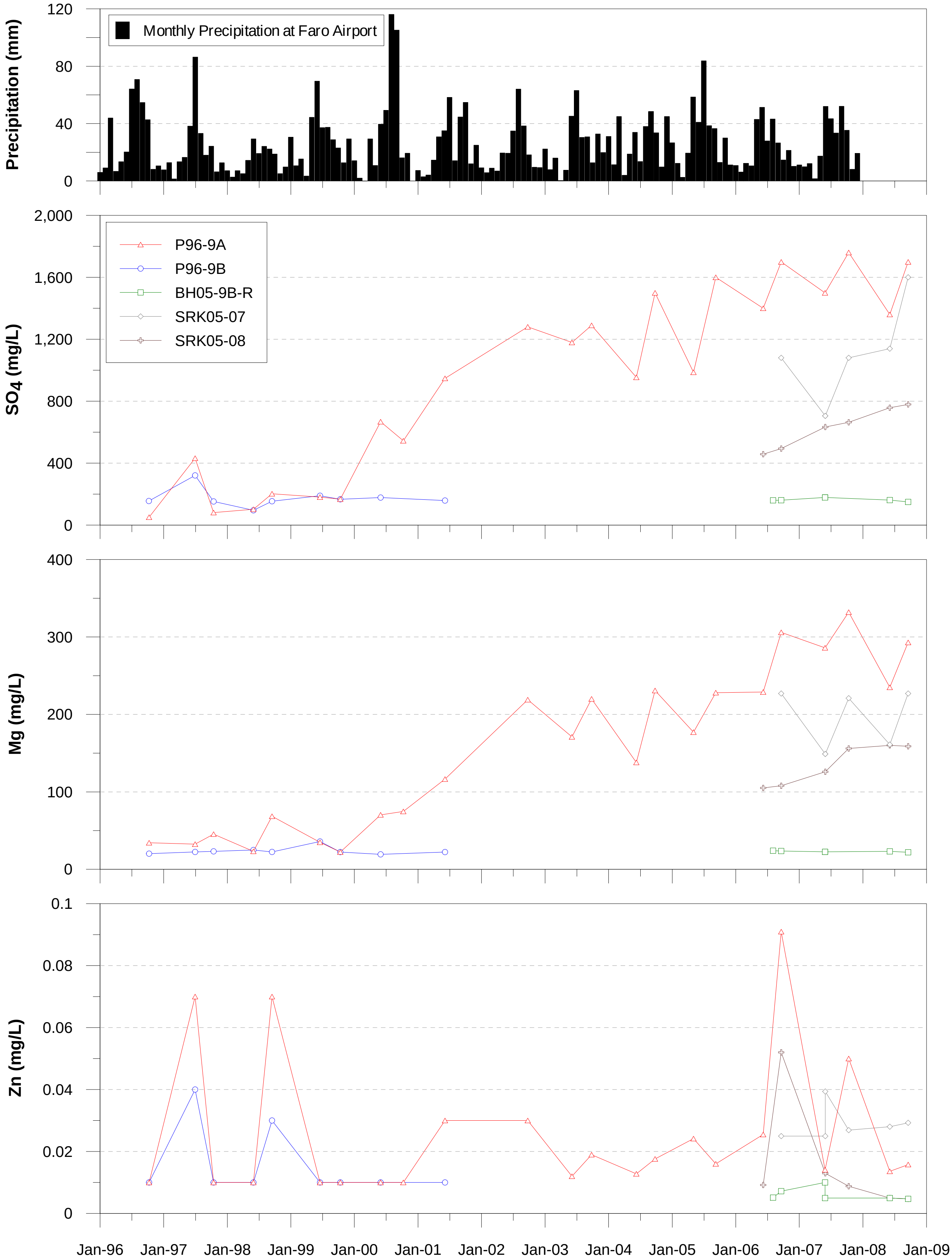


Figure 4-4a. Precipitation and water quality (SO_4, Mg and Zn) in wells located west of Grum Creek.

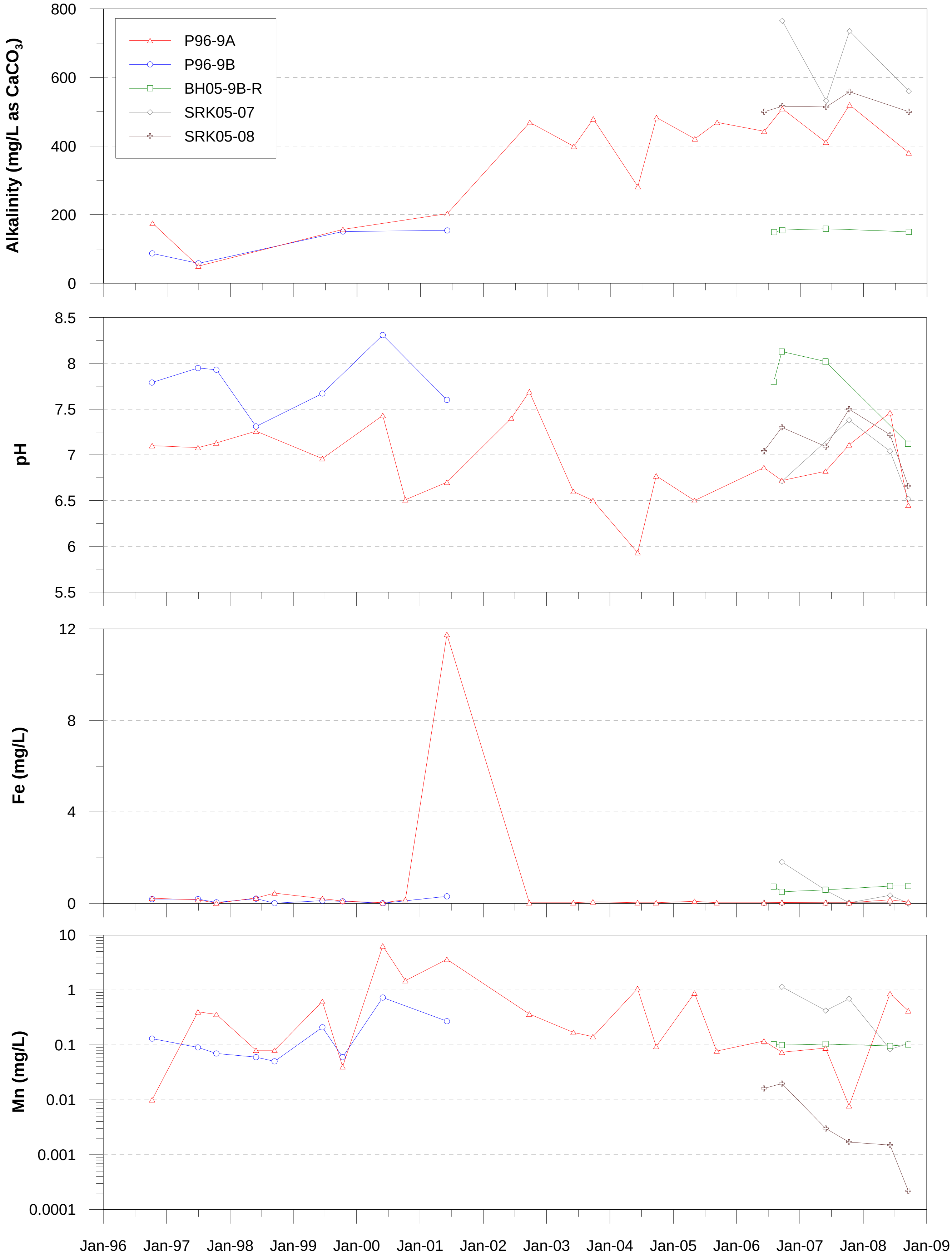
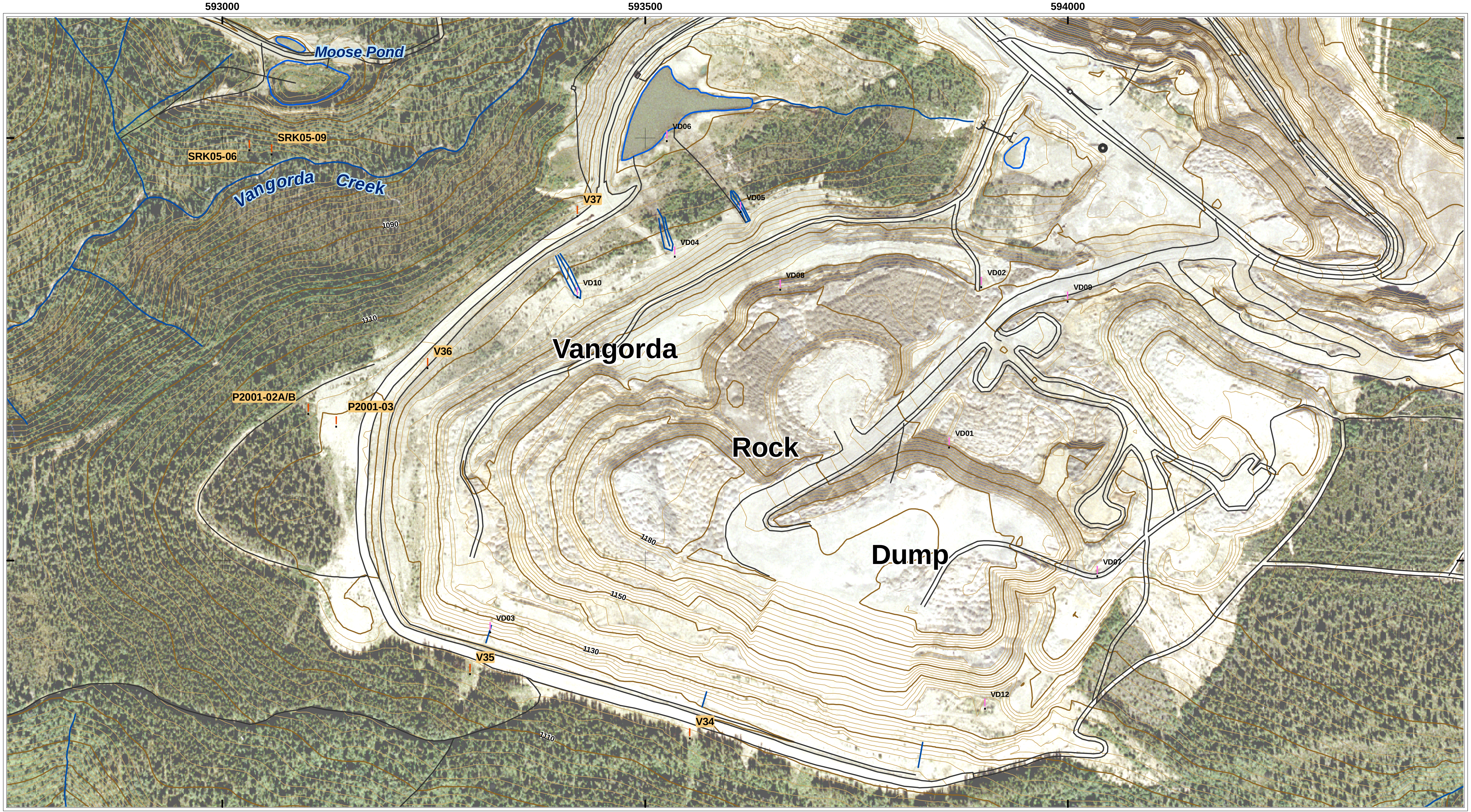


Figure 4-4b. Water quality (alkalinity, pH, Fe and Mn) in wells located west of Grum Creek.



Groundwater Monitoring Wells Vangorda Rock Dump Area

Grum & Vangorda Mine Site

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

LEGEND

- Monitoring Well
- Seep Monitoring Station

SCALE

0 50 100 200 300 400 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2008 Groundwater Review
REPORT: RGC 118014
LOCATION: Anvil Range Mining Complex, YT, Canada

FIGURE: 4-5

DATE: 021109
DRAWN BY: OM
FILE: Faro_Vangorda09.mxd

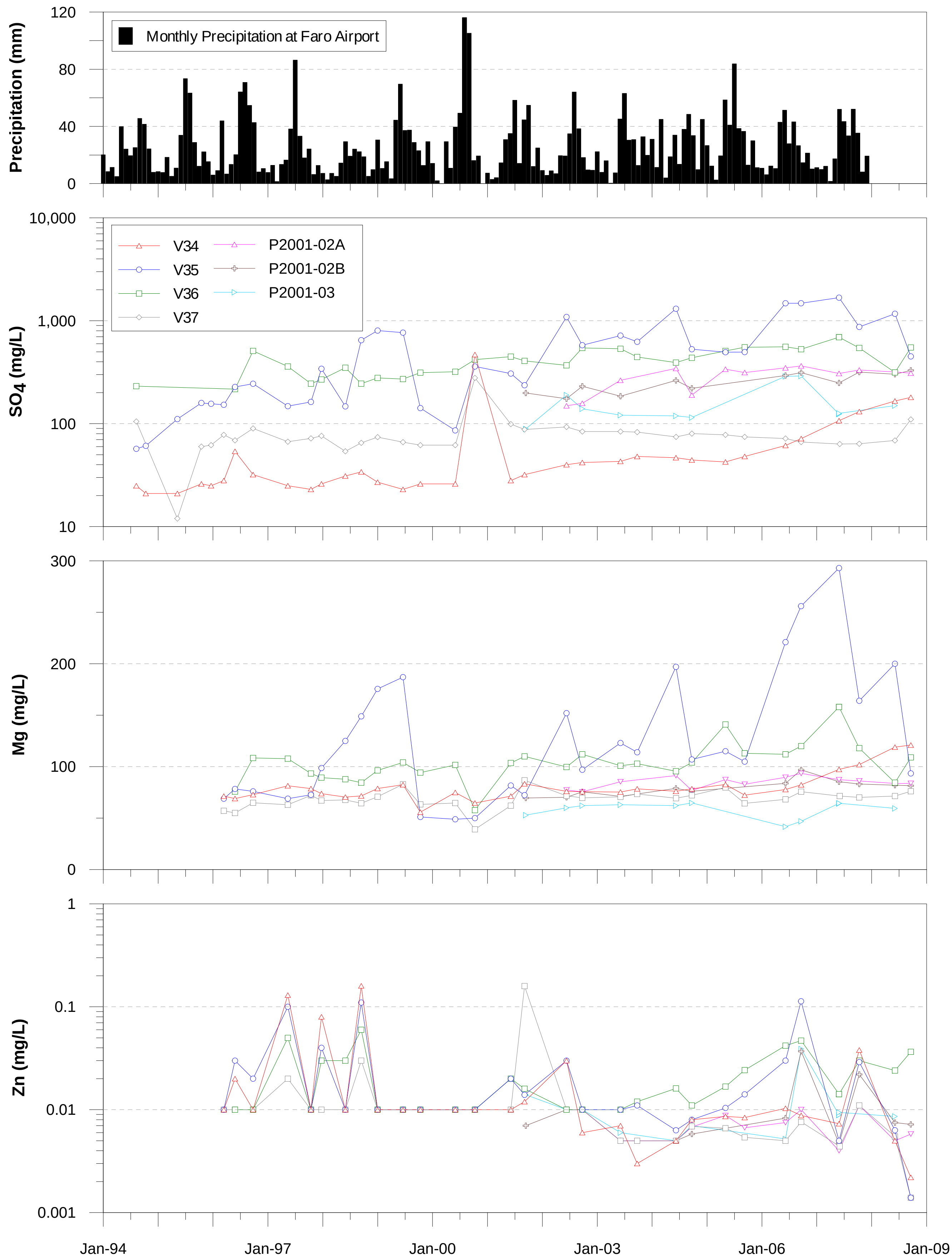


Figure 4-6a. Precipitation and water quality (SO_4, Mg and Zn) in wells downgradient of Vangorda Rock Dump.

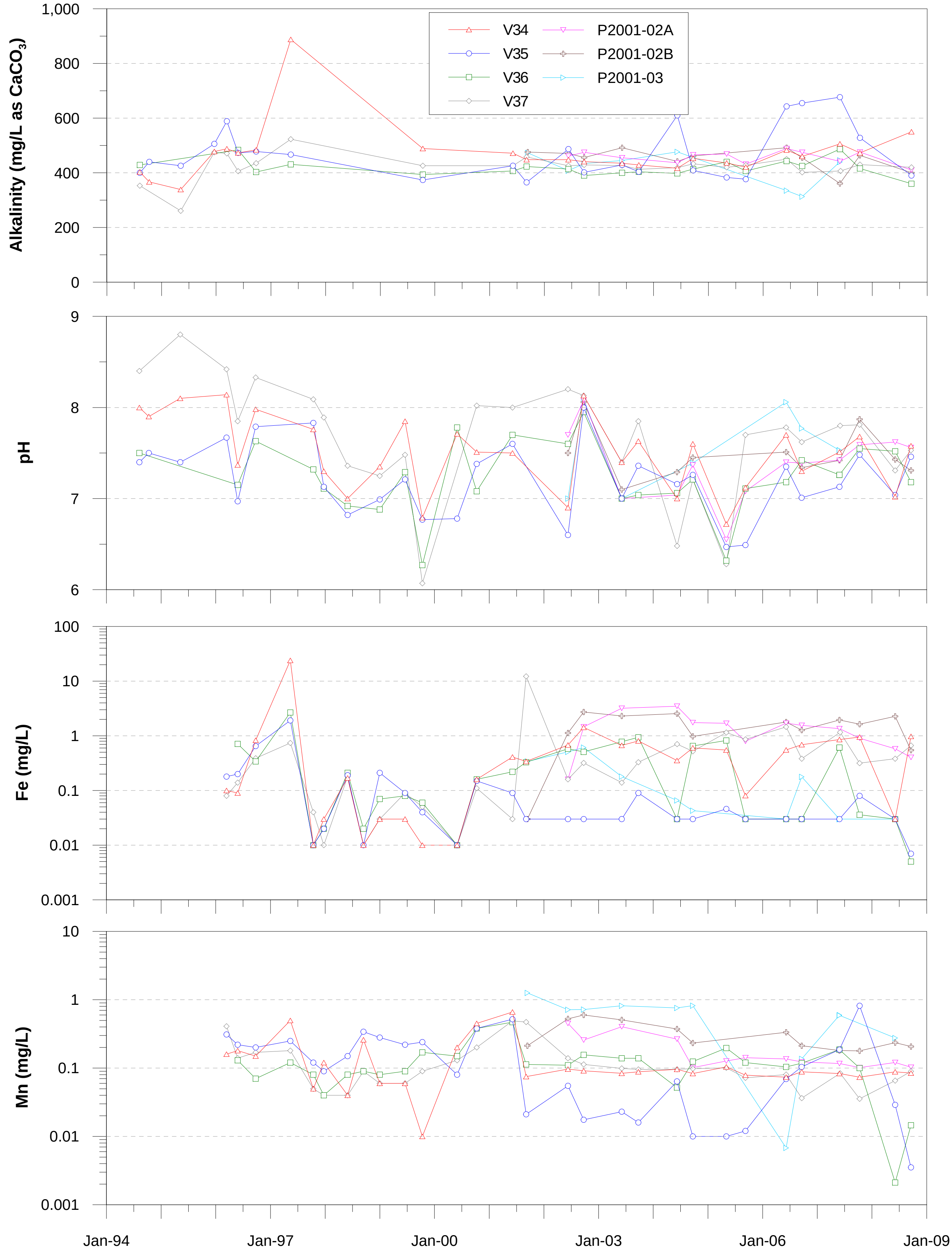


Figure 4-6b. Water quality (alkalinity, pH, Fe and Mn) in wells downgradient of Vangorda Rock Dump.