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Yukon Government
Faro Project Management Team
Assessment and Abandoned Mines

Att: Kaori Torigai

RE: Final Report - 2012/2013 S-Cluster SIS Performance Review, Faro Mine, Yukon

1 Introduction

1.1 Terms of Reference

In 2008/2009, a seepage interception system (SIS) was constructed near the toe of the Intermediate waste rock dump (WRD) at the Faro Mine. This system consists of a shallow interceptor trench and a series of pumping wells and is commonly referred to as the 'S-Cluster SIS'. The purpose of the S-Cluster SIS is to limit impacts by acid rock drainage (ARD) on the nearby North Fork of Rose Creek (NFRC) by intercepting highly-impacted seepage originating from the Intermediate WRD.

SRK Consulting (SRK) designed and documented the installation of the SIS in 2009 and several modifications in 2010 (see SRK, 2009; 2010). SRK also completed an initial performance review (see SRK, 2011) and Robertson GeoConsultants Inc. (RGC) has since completed annual performance reviews (see RGC, 2012; 2013a). RGC also reviews groundwater quality conditions in the vicinity of the S-Cluster SIS as part of an annual review of routine monitoring data collected across the Anvil Range Mining Complex (ARMC) (see RGC, 2013b).

1.2 Background

RGC (2013b) noted a substantial improvement in groundwater quality conditions in the S-Cluster Area as a result of seepage recovery in the S-Cluster SIS. RGC did, however, acknowledge that the effectiveness of seepage recovery may be diminishing over time. That report also noted a lack of definitive evidence that would suggest groundwater quality conditions in shallow overburden have improved as a result of operation of the S-

Cluster interceptor trench. The limited lateral extent of the trench, inadequate hydraulic control, and/or insufficient capacity during high flow periods were identified as potential explanations and a detailed performance review of the S-Cluster SIS was recommended (see RGC, 2013b). Key objectives of this performance review included identifying the cause of continued impacts downstream of the S-Cluster SIS and evaluating potential improvements to the system.

1.3 Scope of Report

In July 2013, the Faro Project Management Team of Assessment and Abandoned Mines Program ("YG") retained RGC to complete a detailed performance review of the S-Cluster SIS. This review includes the following tasks:

- Task 1: Initial Review (w/ interim report)
- Task 2: Site Visit
- Task 3: Detailed System Performance Review
- Task 4: Final Report

The results of an initial site inspection of the S-Cluster SIS on July 15, 2013 and initial review of SIS performance data (Tasks 1 and 2) were initially reported in a letter report entitled "Interim Report - 2012/2013 S-Cluster SIS Performance Review, Faro Mine, Yukon" dated August 15, 2013 (RGC, 2013a). Included in that report were recommendations for short-term improvements to the S-Cluster SIS.

The current report is the final report on the detailed system performance review. This report contains a detailed review of data collected for the monitoring period April 2012 to December 2013 and provides recommendations for system modifications and operational improvements (Tasks 3 and 4). Key findings of the site inspection and initial review are included here for ease of reference.

2 S-Cluster SIS Overview

2.1 System description

Figure 1 shows the location of the S-Cluster SIS and associated monitoring wells and surface water monitoring stations. Figure 2 shows a blow-up of the S-Cluster Area that illustrates the current (2013) layout of the SIS.

The original S-Cluster SIS consisted of two groundwater components:

- A shallow rock-filled interceptor trench that cross-cuts the Shallow Aquifer in this area and incorporates a 2.1 m diameter central sump (and pumping well SRK08-PW3); and
- Two pumping wells (SRK08-SPW1 and SRK08-SPW2) screened in the Deep Aquifer.

Water pumped from the bedrock aquifer is directed to the sump and then pumped to the Faro Pit with groundwater collected by the interceptor trench. The construction of the S-Cluster SIS was completed by January 24, 2009 and was operational on February 28, 2009. Initial as-built specifications and design parameters of the SIS are summarized in SRK (2009).

In late 2009, several modifications were made to improve the overall performance of the S-Cluster SIS (see SRK, 2010):

- The interceptor trench was extended eastward by 25 m;
- Well SRK08-SPW3 was deepened by 2.0 m (and pump lowered by 1.8 m) in order to place the base of the sump 0.6 m below the base of the Shallow Aquifer (at 1083.3 m asl);
- The discharge pipes for wells SRK08-SPW1 and -SPW2 were lowered below the working water level within the sump;
- A second, 4” diameter pipeline was installed in parallel to the (insulated) 2” diameter pipeline to accommodate higher flows during the spring freshet; and
- The pipeline discharge points were extended to a depth of 30 m in the Faro Pit Lake.

Also completed at this time was the installation of six additional monitoring wells immediately downgradient of the interceptor trench (i.e. the ‘P09-SIS’ well series) and a shallow finger drain from the toe of the Intermediate WRD to the eastern extension of the interceptor trench (Figure 2). The finger drain intercepts surface seepage that had been bypassing the SIS during the spring freshet (see SRK, 2010).

2.2 Site Inspection of Current Condition

On July 15, 2013, Dr. Christoph Wels (RGC) visited the Faro Mine to inspect the S-Cluster SIS and to collect S-Cluster SIS performance monitoring data for this review (i.e. transducer data, water quality data, etc.). At the time of the visit, the S-Cluster SIS system was not operating due to a site-wide power outage. Appendix 1 provides a photo log illustrating key aspects of the S-Cluster SIS site inspection.

During the site visit, Dr. Wels discussed operational issues with Mr. Dan Duivenvoorden, one of the TEES operators. Dr. Wels was also accompanied by Ms. Kaori Torigai (YG) during the site inspection. The following observations were made during the inspection and follow-up discussions:

- According to TEES staff, the S-Cluster SIS system (pipes and pumps) are in good operating conditions; however, this could not be directly verified as the system was shut down.

- According to TEES staff, significant iron scaling (up to 0.5” thick scaling in three pipes representing 50% loss of 2” pipe diameter) builds up over time in the two pipelines transporting the seepage from the SPW-3 manhole to the Faro Pit:
  - “Stubs” and “rings” were installed along both pipelines to allow physical cleaning of the pipelines
  - Both pipelines were cleaned in 2013 prior to the onset of spring runoff
- A small ditch (referred to as “road ditch”) had been excavated to collect shallow seepage along the northern side of the access road and divert it into the original (western) portion of the SIS trench (see Figure 2 and Photos 1 and 2); no flow was observed in this shallow ditch at the time of the site inspection.
- According to TEES staff, the current pumping capacity of SPW-3 (about 100 USGPM or ~6 L/s using a 15 HP submersible pump) was insufficient to handle peak flows into the S-Cluster SIS during the 2013 spring runoff:
  - Despite running at full pump capacity in “by-pass” mode, the water level in the SPW-3 manhole rose above the target sump water level of 0.1m above pump intake (appr. 1082.7 masl) for about three weeks in May 2013
  - On days of peak flow, the SIS trench was observed to overflow (reportedly occurring once the water level in SPW-3 rises to about 3m above pump intake) and seepage in the SIS drain was observed flooding into the road ditch and from there into the berm area (Photo 3)
- In addition, moderately-impacted groundwater (~1 to 7 mg/L Zn) was also observed emerging and pooling in a swampy area commonly referred to as “Little Pond” (or simply “Pond”) in close proximity of the NFRC located immediately downstream of the eastern extension of the SIS trench (see Figure 2 and Photos 4 and 5); according to TEES staff, this local depression usually remains flooded for about 3 weeks following local snowmelt but groundwater was still ponding in this area during the site inspection on July 15 (see Photo 5)
- During the snowmelt period 2013, water accumulating in the “Pond” was pumped into the SPW-3 manhole using a small (portable) sump pump (see Photo 4); on days when the trench was overflowing, water from the “Pond” was pumped into a vacuum truck and released into the Intermediate Pond (Dan Duivenvoorden, pers. comm.); TEES staff pointed out that this swampy area was completely flooded by the NFRC during peak runoff in June 2013
- At the time of the site inspection (July 15, 2013), two seeps were observed emerging at the toe of the waste rock dump (upstream of the SIS):
  - A larger seep located upstream of the eastern extension of the SIS trench (station number FD54, see Figure 2 and Photos 10 and 11) with an estimated flow (visual estimate) of 0.25 L/s; this seepage is collected in a

shallow trench backfilled with coarse rock ("finger drain") which discharges into the eastern SIS extension (see Figure 2 and Photo 9).

- A smaller seep located upstream of the western portion of the SIS trench (station number FD56, see Figure 2 and Photo 12) with an estimated flow (visual estimate) of about 1 L/min (infiltrating into the wet soils and presumably intercepted by the western section of the SIS.
- On the request of the writer, TEES sampled these seeps for water quality analysis after the site visit (see Section 3.3.3 for discussion of water quality results).

o Several of the monitoring wells associated with the S-Cluster SIS are not in good working conditions and require some maintenance:

- Monitoring wells SRK05-SP5 and SRK05-SP4A appear to be broken at ground level
- Selected monitoring wells (e.g. S2A/B) have no protective steel casing, possibly due to past damage and/or raise due to earthworks in the area
- Selected monitoring wells have PVC pipe extending above the steel protective casing (e.g. SBR4, SIS5, SIS6) suggesting frost heave
- Some well labels are faded or missing completely
- PVC well caps are missing in selected wells

o Down-hole data loggers ("Leveloggers") installed in several monitoring wells (SP4B, SIS3, SIS4, SIS5) do not appear to hang freely; this may be related to the relatively thick "aircraft" steel cable used for suspending loggers being entangled with Waterra tubing and/or the well is frozen.

These visual observations and anecdotal performance issues were subsequently confirmed in our review of recent performance data (see below).

3 Data Review

This section summarizes a detailed review of performance monitoring data collected from May 2012 to the end of December 2013. Separate reviews of SIS pumping data, groundwater level data, and water quality data are provided in the sub-sections below.

3.1 SIS Pumping Data

SIS pumping data compiled as part of this review included pumping rates and dynamic water levels ("pumping levels") in the two pumping wells (SPW-1, SPW-2) and the sump pumping station (SPW-3).

Table 1 summarizes the monthly 'SPW' performance data recorded by TEES in the monthly monitoring reports ("S-well reads.xls") from May 2012 to December 2013. Note that active pumping in well SPW-1 was stopped in March 2010 due to scaling from high iron concentrations. SPW-3 represents water pumped from the large diameter corrugated metal pipe (CMP) sump. This water is a mixture of deeper groundwater pumped from SPW-2 and shallow groundwater collected in the SIS trench (main trench plus east extension) (see RGC, 2012 and SRK, 2010 for more details).

Table 1. Monthly Performance Data for SPW-2 and SPW-3

Well ID	SPW2					SPW3				
Date (-)	SWL (m)	SUMP (m)	Flow (L/s)	Totalizer (m^3)	Average Flow (L/s)	SWL (m)	SUMP (m)	Flow (L/s)	Totalizer (m^3)	Average Flow (L/s)
May-12	11.205	0.42	1.07	114952	0.75	4.074	0.17	5.29	217437	2.77
Jun-12	10.536	1.09	1.08	118068	0.93	4.141	0.1	2.48	224605	2.09
Jul-12	10.437	1.09?	1.08?	118068?		1.238?	0.1?	2.48?	224605	
Aug-12	10.935	0.71	1.1	122969	1.20	N/A	0.52	6	235598	2.38
Sep-12	11.211	0.46	1.1	126183	0.95	3.423	0.1	6	241979	2.03
Oct-12	11.181	0.46	1.09	128651	0.97	4.051	0.33	N/A	247238	1.95
Nov-12	10.426	1.27	1.099	131246	1.09	3.252	1.1	2.067	252467	2.16
Dec-12	N/A	0.71	0.93	134083	0.89	4.159	0.13	2.04	258058	1.80
Jan-13	N/A	0.47	0.92	136463	0.81	4.169	0.1	1.84	262891	1.69
Feb-13	N/A	1.65	0.69	138567	0.61	3.377	0.96	1.49	267306	1.25
Mar-13	7.035	4.61	0	140167	0.65	4.18	0.1	0.85	270560	1.30
Apr-13	no read	0.88	0.8	141871	0.74	4.185	0.1	1.58	273959	1.36
May-13	no read	0.92	0.8	143810	0.75	4.182	0.1	1.51	277503	3.68
Jun-13	no read	1.73	0.89	145782	0.72	4.182	0.1	2.8	287132	2.09
Jul-13	no read	5.44	0	147650	0.49	1.585	2.76	0	292547	1.73
Aug-13	-	1.65	0.56	148974	0.60	4.28	0.1	1.75	297170	1.92
Sep-13	-	1.45	0.56	150578	0.52	4.28	0.1	1.75?	297170?	
Oct-13	N/A	1.82	0.57	151935	0.62	3.585	0.1	1.98	307270	2.16
Nov-13	-	3.72	0.34	153597	0.50	4.26	0.1	1.68	313059	1.69
Dec-13	-	1.48	0.67	154895	0.75	4.26	0.1	1.98	317448	2.13

Table 2 summarizes the average and total volumes of water collected by the S-Cluster SIS from May 2012 to December 2013. During the calendar year 2013, a total of 60,250 m^3 (or 1.91 L/s) were extracted from the S-Cluster SIS. About 66% of the total flow was captured by the seepage interceptor trench. This flow includes groundwater intercepted from the Shallow Aquifer and water pumped from ditches and the ‘Pond’ during the 2013 snowmelt period. Flows from the Deep Aquifer (via SPW-2) comprise the remaining 34% of total flow in 2013.

Table 2. Volumes of Seepage Extracted in S-Cluster SIS.

SIS Component	May - Dec 2012		Jan - Dec 2013	
	Cumulative Vol. (m^3)	Average Flow (L/s)	Cumulative Vol. (m^3)	Average Flow (L/s)
SPW1	0	0	0	0
SPW2	21511	1.02	20436	0.65
SIS Trench (SPW2 - SPW3)	23943	1.30	39820	1.26
Total (SPW3)	45454	2.16	60256	1.91

Figure 3 shows the monthly average pumping rates and observed geodetic water levels in SPW-1, SPW-2, and SPW-3 on the day that monthly readings were recorded. Well SPW-1 was not actively pumped during the monitoring period. Water levels observed on July 2, 2013, represent near-static water levels because the SIS was shut down on this day due to a regional power outage (caused by forest fires).

Figure 4 shows the daily pumping rates and daily geodetic water levels in the SPW-3 sump (extracted from the daily manual logs) for the observation period April 1 to June 8, 2013.

The pumping data may be summarized as follows:

- Monthly pumping rates in SPW-2 (deep extraction well) averaged 0.84 L/s over the monitoring period and ranged from a high of 1.2 L/s in May 2012 (spring runoff) to a low of 0.5 L/s in November 2013; pumping rates in SPW-2 were generally lower in 2013 (compared to 2012); it is unclear whether this reduction in pumping rates is caused by manual (downward) adjustment to the SPW-2 pump valve and/or due to deterioration of the well/pump efficiency.
- Monthly pumping rates in SPW-3 (deep extraction well plus shallow trench) averaged 2.04 L/s over the monitoring period and ranged from a low of 1.25 L/s in February 2013 (winter baseflow) to a high of 3.7 L/s in May 2013 (spring runoff)
- Pumping in SPW-3 was run at (or near) full capacity of ~6 L/s (100 USGPM) from May 11 to 21, 2013 (using the manual VFD bypass setting); however, even at full pumping capacity, the water level in the SPW3 sump (and presumably the SIS trench) could not be controlled (see Figure 4):
    - The water level in the sump exceeded the target level (< 0.1m above transducer or a geodetic elevation of 1082.4 m amsl) for 18 days during the 2013 spring runoff season (May 5 – 22, 2013)

- The SIS trench "overflowed" (water level >3m above transducer or ~1085.4 m amsl) for a period of 2 days during the 2013 spring runoff season (May 14 -15, 2013)

The 2013 performance data indicate that the current pumping capacity in SPW-3 is not adequate to maintain the water level in the sump/interceptor trench below the based on the Shallow Aquifer during high flow periods. As a result, highly-impacted groundwater was discharged directly into the road ditch and berm area for a period of two days during the 2013 spring freshet. To prevent this discharge, additional pumping capacity in SPW-2 and SPW-3 is required during high flow periods in order to maintain hydraulic control of water levels.

It should be acknowledged that the dynamic water level in the SIS trench is not measured directly at this time. Instead, hydraulic performance monitoring of the trench is limited to water level measurements in the main sump (at SPW-3) and in wells located immediately downgradient of the trench (see Section 3.2 below). Some head loss across the perforated sump wall may occur and hence the water level in the backfilled trench could be higher than measured in the sump. To limit this uncertainty, installation of standpipe piezometers in the backfilled SIS trench is recommended (see Section 4).

3.2 Groundwater Levels

3.2.1 SIS Performance Monitoring

Groundwater levels were recorded continuously in the SIS monitoring wells (and SP4B) during the 2012/2013 monitoring period using data loggers (i.e. Solinst Leveloggers). The water levels recorded in the "SIS" series of wells were corrected for barometric pressure and converted to geodetic groundwater levels using monthly spot measurements of groundwater levels[1]. These wells are located immediately downgradient of the SIS trench.

Figure 5 shows the computed geodetic groundwater levels in the 'SIS' wells for the last three years of record (from 2011 to 2013). Figure 6 illustrates the time trends for the high flow period of 2013 (April to July). The following observations can be made with respect to groundwater levels in the 'SIS' wells:

[1] In some instances, significant discrepancies were observed between manual and logged water levels suggesting either (i) a shift in the data logger (e.g. due to movement of the logger) and/or (ii) erroneous manual water level readings. In those cases where a sudden shift in logger position or erroneous manual reading could be identified the geodetic water level readings were adjusted to produce Figure 2.

- The groundwater hydrographs show distinct high flow periods (“peaks”) during spring runoff; in 2012, spring runoff occurred in June (with peak levels observed on June 14); in 2013,
  - In 2012, spring runoff occurred in June with groundwater levels peaking on June 14;
  - In 2013, the groundwater hydrograph showed two distinct peaks;
    - a smaller peak in early January (caused by a rainfall event associated with a warm spell)
    - a second, major peak caused by local snowmelt at the site (peaking around May 14, 2013)
  - Note that peak spring runoff in the NFRC occurred in early June, i.e. several weeks later than local snowmelt runoff in the S-Cluster area (as indicated by the renewed rise in groundwater levels in early June 2013)
- Groundwater levels in the ‘SIS’ wells increased considerably during the current monitoring period; specifically, those wells located immediately downgradient of the interceptor trench (SIS2, SIS3, SP4B, SIS4 and SIS5) have remained above the base of the shallow aquifer (i.e. elevation 1083.3m amsl) for most of the current observation period (April 2012 to December 2013); this suggests potential bypass of highly-impacted seepage in the Shallow Aquifer during these periods.
- Immediately downgradient of the eastward trench extension, groundwater levels at wells SIS5 and SIS6 remained consistently above the base of the Shallow Aquifer (even during winter baseflow conditions); this suggests that hydraulic control in this area is limited, likely due to a shallower depth of the trench extension and/or less permeable overburden soils; therefore, the bypass of seepage beneath the eastern extension towards the NFRC is likely (especially during high flow periods) (see also discussion on elevated Zn in “small pond” below).
- Monitoring well SIS1 showed different time trends than the other SIS wells; this well is located west of the interceptor trench and is screened deeper in the Shallow Aquifer than the other SIS wells; SIS1 appears to be influenced by pumping from well SPW-2; this is consistent with an increase in water level in SIS1 since the pumping rate for well SPW-2 was reduced in mid-2013 (see above).
- Besides the expected seasonal variations in groundwater levels discussed above, several short “spikes” in groundwater levels also occurred in 2013; according to TEES, these ‘spikes’ were caused by temporary shutdowns of the S-Cluster SIS (Barry Wilson, pers. comm.):
  - On January 15, the system was shut down to clean SPW-3 due to a heavy rain event that occurred on January 14;

- On June 4/5, the system was shut down to switch to standby power (due to a power outage);
- On June 17/18, the system was turned off due to a planned power outage by Yukon Energy;
- On July 1/2, the system was down due to a regional power outage caused by forest fires;
- From July 14 to 16, the system was also down due to a regional power outage caused by forest fires.

The increase in groundwater levels immediately downgradient of the interceptor trench is cause for concern because water levels are now sustained above the base of the Shallow Aquifer. This increase in water levels occurred despite the fact that the pumping level in the SPW-3 sump was maintained at the target level (0.1m above SPW-3 transducer) for most of the observation period (except for the spring high flow period and the noted short shutdown periods) (see Table 1).

The most likely reason for the reduced drawdown in the shallow aquifer is a gradual reduction in the efficiency of the drain system caused by "clogging" of the drain rock in the interceptor trench. This clogging could be caused by (i) the ingress of fines into the drain rock or the formation of iron precipitates in the drain rock and/or slots of the sump. Sources of fines potentially migrating into the trench include the surrounding formation and surface water from the road ditch and shallow finger drain that are directed into the trench (Note that a heavy precipitation event in January 2013 resulted in significant sediment entering the sump which required cleaning).

Unfortunately, the interceptor trench is not equipped with standpipe piezometers to assess drain efficiency or drain pipe/clean-out ports to clean the trench. In light of these deficiencies, we recommend that the trench be partially excavated (on both ends of the sump) to assess the conditions of the drain rock. In addition, we recommend that standpipe piezometers be installed in the interceptor trench to directly monitor the hydraulic performance of the trench (see Section 4 for more details).

3.2.2 Routine Groundwater Level Monitoring

Multi-year trends in groundwater levels in wells located in the S-Cluster Area are shown in Figures 7 and 8. Drawdown values for the Deep Aquifer in the S-Cluster area are shown in Figure 9. These values are inferred from water levels in September 2013 and reflect a cone of depression.

Key findings are summarized as follows:

- Groundwater levels in monitoring wells located outside the immediate influence of the S-Cluster SIS (e.g. SRK05-SP1A/B and SP2 upgradient and SRK08-

SP8A/B downgradient) have not changed considerably since start of monitoring in 2005 (see Figure 7);

- Commencing operation of the interceptor trench in February 2009 caused the water level at well SP4B to decrease by up to 3 m to the base of the shallow aquifer at 1083m amsl; however, throughout 2013, water levels measured in well SP4B were generally more erratic and the typical drawdown was only about 2 m or so (geodetic elevation ~1084m amsl);
- Start of pumping in well SPW-2 (and temporarily SPW-1) in 2009 caused a significant drawdown in the deeper overburden and shallow, weathered bedrock (at wells SP05, SP07A/B, S2A/B, SBR1, SBR2 and SBR4); drawdown in these deeper monitoring wells decreased in 2012/2013 due to a reduction in pumping from SPW-2; recent drawdown values are typically 1.3 to 1.5 m within about 20 to 30 m of well SRK08-SPW2 and decrease towards the NFRC (i.e. to ~1.0 m at well SP7A) (see Figure 9).

The multi-year routine groundwater monitoring data suggest diminishing hydraulic control in the perched, Shallow Aquifer and the deeper (confined) weathered bedrock over time. This is consistent with the more detailed, operational monitoring data discussed in Section 3.2.1. Both data sets indicate that pumping rates and pumping capacity (both in SPW2 and SPW3) should be increased and that further evaluation of the efficiency of the interceptor trench is required. Consideration should also be given to upgrading the SIS by cleaning/extending the interceptor trench in the Shallow Aquifer and installing additional pumping wells in the Deep Aquifer (see Section 4).

3.3 Water Quality

3.3.1 SIS Water Quality Monitoring

TEES is responsible for routine monitoring of seepage collected in the S-Cluster SIS, including monthly sampling of water pumped from:

- SPW-1 – currently inactive pumping well;
- SPW-2 – active pumping well; and
- SPW-3 – combined seepage in main sump.

Average SO_4, Fe, and Zn in seepage collected in the S-Cluster SIS from September 2012 to October 2013 are summarized in Table 3. Time trends for SO_4 and Zn in these wells are provided in Figure 10. Also shown in Figure 10 are inferred concentrations in highly-impacted seepage that reports to the SIS trench. These concentrations were approximated via conservative mixing calculation.

Table 3. Average SO_4, Fe, and Zn concentrations in seepage collected in the S-Cluster SIS, September 2012 to October 2013

Source	**SO_4, mg/L**	**Fe, mg/L**	**Zn, mg/L**
SPW-1	2,274	18.9	108.3
SPW-2	5,401	5.2	283.6
SPW-3	7,453	3.8	492.2

SO_4 and Zn concentrations in seepage from SPW-2 and SPW-3 decreased abruptly in May 2013 (see Figure 10). These decreases are related to local spring runoff and inflows of less-impacted seepage pumped from the road ditch and downstream berm area to the SIS during this period. Since May 2013, concentrations have increased significantly and reached their highest levels on record in December 2013.

Increased SO_4 and Zn concentrations at SPW-2 and SPW-3 reflect deteriorating water quality conditions in seepage from the Intermediate WRD (and presumably the Sulphide Cell). Concentrations in seepage from the inactive pumping well (SPW-1) also appeared to increase in late 2013. Note, however, that concentrations at SPW-1 are suspiciously similar to those in SPW-2 and may reflect a sampling error (SPW-1 is currently resampled to confirm those trends).

SO_4 and Zn loads recovered by well SPW-2 and the SIS trench and the total loads recovered via the main sump (at SPW-3) are summarized in Table 4. From September 2012 to August 2013 (a complete water year), a total of 27 t Zn was recovered from the S-Cluster SIS via the main sump. About 80% of this load originated from the SIS trench and the remainder was recovered via well SPW-2. During the observation period, zinc loads were lowest during the winter low-flow period 2012/2013 (~2 t Zn from January to April 2013) and highest in late 2013 (5.4 t in December 2013) (see Table 4).

Note that the zinc load recovered in the S-Cluster SIS (both in SPW2 and the interceptor trench) have increased significantly in recent months (between October and December 2013) reflecting the significant increase in zinc concentrations in seepage from the Sulphide Cell reach (see Figure 10).

Table 4. SO_4 and Zn loads recovered via the S-Cluster SIS, September 2012 to October 2013.

	SPW2		SIS Trench		SPW3 (Total)	
Date	Sulphate Load Tonnes	Zinc Load Tonnes	Sulphate Load Tonnes	Zinc Load Tonnes	Sulphate Load Tonnes	Zinc Load Tonnes
Sep-12	9.70	0.52	21.80	1.43	31.50	1.95
Oct-12	10.46	0.55	26.35	1.74	36.81	2.29
Nov-12	12.11	0.67	24.62	1.61	36.73	2.29
Dec-12	10.12	0.51	14.05	1.10	24.17	1.61
Jan-13	7.60	0.40	21.63	1.51	29.23	1.92
Feb-13	8.83	0.41	16.97	1.33	25.80	1.74
Mar-13	10.29	0.54	15.91	1.37	26.21	1.91
Apr-13	11.13	0.59	14.85	1.24	25.98	1.83
May-13	10.39	0.54	36.50	2.79	46.89	3.33
Jun-13	10.63	0.60	40.00	2.45	50.63	3.05
Jul-13	8.06	0.44	30.40	1.92	38.46	2.36
Aug-13	10.47	0.47	34.80	2.27	45.27	2.73
Sep-13	9.40	0.48	41.76	2.82	51.16	3.30
Oct-13	12.48	0.73	52.36	3.89	64.84	4.63
Nov-13	11.33	0.59	42.18	3.43	53.52	4.02
Dec-13	18.02	0.97	53.22	4.39	71.24	5.36
TOTAL Sept 2012 - Aug 2013	119.8	6.2	297.9	20.8	417.7	27

3.3.2 Ad-hoc Monitoring

In April 2012 and May 2013, TEES performed non-routine (or 'ad hoc') monitoring of additional seepage observed in the road ditch near the S-Cluster SIS and collecting in the downstream berm area and swampy 'Pond' (see Table 5). Seepage from the road ditch is currently directed (by gravity) into the interceptor trench and seepage ponding in the berm or swampy pond area is pumped back on an "as-needed" basis to the interceptor trench.

Water quality data from Table 5 indicate that the additional seepage observed in the ditches and 'Pond' under high-flow conditions was only moderately-impacted (i.e. 0.1 to 7.7 mg/L Zn).[2] Observed concentrations were typically higher than the 0.5 mg/L Zn

[2] Note that dissolved zinc concentrations are sometimes reported to be higher than total zinc concentrations which is not possible and suggests problems with the analysis/reporting.

discharge limit for the site but are 2 to 3 orders-of-magnitude lower than the highly-impacted seepage collected by the S-Cluster SIS (see Table 3).

Relatively low Zn concentrations in seepage from the ditches and ponds near S-Cluster SIS are typical of moderately-impacted groundwater observed on both sides of the main drainage channel (and throughout much of the NFRC reach, including the Zone 2 area upstream of the rock drain and the reach between the rock drain and the S-Cluster area). Therefore, the upwelling of moderately-impacted groundwater to the S-Cluster area from upstream reaches of the NFRC (during periods with high groundwater levels) cannot be ruled out as a source of this contamination at this time.

With respect to seepage potential loads to the NFRC under high-flow conditions, less than 0.1 t Zn would likely have entered the creek in May 2013 had seepage not been intercepted and directed to the SIS. This is about 3% of the total Zn load captured by the S-Cluster SIS during that month. In our opinion, seepage collected from the road ditch, berm area and 'Pond' should not be added to the S-Cluster SIS circuit unless the system has adequate pumping capacity.

Table 5. Results of ad-hoc sampling in spring 2013 of impacted water observed downstream of S-Cluster SIS (TEES, unpublished data)

Date	Sample Name	Time	Temp. (°C)	pH	EC (µS/cm)	Zn-T (mg/L)	Zn-D (mg/L)	Method of Analysis	Comments
19-Apr-12	S-Wells Pond next to Rose Creek	9:11 AM	0.0	8.00	610	5.282	7.666	ICP	
19-Apr-12	S-Wells Berm Across Road from Seacan	9:31 AM	0.0	8.25	230	0.111	0.070	ICP	
14-May-13	S-Wells Berm Across Road from Seacan	10:20 AM	0.7	7.54	313	2.379	2.264	ICP	
14-May-13	S-Wells Ditch Beside Seacan	10:17 AM	1.0	7.28	943	3.883	0.384	ICP	Will reanalyze for confirmation
14-May-13	S-Wells Pond next to Rose Creek	10:24 AM	1.1	7.13	58	0.386	3.801	ICP	Will reanalyze for confirmation
15-May-13	S-Wells Berm Across Road from Seacan	10:20 AM	0.7	7.54	313	2.304	2.356	ICP	
15-May-13	S-Wells Ditch Beside Seacan	10:17 AM	1.0	7.28	943	3.713	3.356	ICP	
15-May-13	S-Wells Pond next to Rose Creek	10:24 AM	1.1	7.13	58	0.374	4.356	ICP	
30-Jul-13	S-Wells Pond next to Rose Creek	2:45 PM	20.4	6.35	2240	-	3.570	ICP	

3.3.3 Seep Water Quality Monitoring

Seepage near the toe of the Intermediate WRD is currently monitored at stations FD-54 and FD-56 (see Figure 2). Available seepage water quality data (and flows) are summarized in Table 6. The majority of seepage samples were collected by CH2M-Hill in 2012 and 2013 and additional samples were collected by TEES in July 2013 for this review. Also provided in Table 6 are water quality data from well CH12-014-MW007, which is screened in a drainage channel leading from the Sulphide Cell of the Intermediate Dump towards the S-Cluster SIS (Figure 1).

Seepage from the Intermediate WRD was not typically observed prior to 2009 and hence toe seepage in this area is considered a relatively ‘new’ feature of the S-Cluster Area. Seepage flows at FD-54 and FD-56 are characterized by higher SO_4 and dissolved metal concentrations than in water intercepted by the S-Cluster SIS. Moreover, SO_4 and Zn concentrations at these locations have increased substantially in recent months and reached their highest levels in September 2013. Water quality at CH12-014-MW007 also deteriorated in 2013 with an abrupt increase in September 2013 (see Table 6). This deterioration in seepage water quality is related to the breakthrough of very highly-impacted seepage from the Sulphide Cell of the Intermediate WRD.

Table 6. Seepage water quality data at FD-54 and FD-56 and well CH12-014-MW007

Station	Date	Flow, L/s	pH	EC, uS/cm	SO_4, mg/L	Fe, mg/L	Zn, mg/L
CH12-014-MW007	26-Sep-2012	-	6.9	-	7,630	1.9	441
CH12-014-MW007	1-Oct-2012	-	6.8	-	6,110	7.1	317
CH12-014-MW007	11-Jun-2013	-	6.1	7,416	7,190	0.34	358
CH12-014-MW007	12-Sep-2013	-	5.6	16,020	15,200	2.5	1,530
FD-56	11-Jun-2013	0.2	3.9	9,509	9,340	43	662
FD-56	30-Jul-2013	0.1	3.8	11,600	11,800	76	918
FD-56	17-Sep-2013	0.044	-	11,650	11,500	294	952
FD-54	26-Sep-2009	-	5.7	8,030	7,900	0.4	612
FD-54	29-May-2012	-	6.9	9,118	2,660	0.4	657
FD-54	22-Sep-2012	-	6.3	11,400	8,450	<0.2	672
FD-54	11-Jun-2013	5.0	6.0	10,630	-	-	-
FD-54	30-Jul-2013	0.2	7.2	11,600	12,100	0.2	971
FD-54	17-Sep-2013	0.215	5.7	12,890	13,400	<0.2	1,280

Seepage flows at FD-54 and FD-56 are generally less than 0.2 L/s (see Table 6). A notable exception was the 5 L/s observed at FD-54 in June 2013. SO_4 and dissolved metal concentrations in this seepage were not measured but field pH and EC data are available (see Table 6). Field data suggest seepage was highly-impacted in June 2013 and could have contained up to 1,000 mg/L Zn (i.e. see Zn concentrations in July 2013 for comparison). Over a 10-day period, the corresponding Zn load could have been 3 to 4 t Zn (which is comparable to the load captured by the S-Cluster SIS during that time).

The cause of additional seepage from the Intermediate WRD in recent years (and the trend towards higher concentrations) is unclear but it could reflect higher recharge combined with loss of neutralization potential (which would accelerate ARD production). Alternatively, this seepage may have occurred before 2009 but was unnoticed due to less activity in this area or better coverage by vegetation before the S-Cluster SIS was installed. Regardless, it is recommended that seepage water quality monitoring at FD54 and FD56 be continued and the increasing contaminant load be considered for performance evaluation and potential future upgrading of the S-Cluster SIS.

3.3.4 Routine Groundwater Quality Monitoring

Routine groundwater quality data were most recently reviewed in the 2012 Groundwater Monitoring Review (see RGC, 2013b). In that report, SO_4 and Zn concentrations in the Shallow Aquifer immediately downgradient of the interceptor trench (e.g. SIS2, SIS4, and SP4B) were shown to have decreased slightly since the S-Cluster SIS became operational in early 2009. Since then, concentrations have remained relatively unchanged (or slightly improved, for example at SIS4) and this trend continued in 2013 (see Figure 11).

SO_4 and Zn concentrations in wells beyond the influence of the interception trench, such as SIS1 (to the west), have improved in recent years and continued to do so during the current monitoring period (see Figure 11). SO4 and Zn concentrations at well S2B decreased abruptly in 2013 but the overall trend is towards higher concentrations. This well is screened in till to the west of the shallow interceptor trench and is seemingly unaffected by seepage recovery via well SPW-2. Deteriorating water quality suggests some bypass towards the NFRC via the Shallow Aquifer west of the interceptor trench. In light of improving conditions at SIS1, the magnitude of the load bypassing may be small but further monitoring is needed to affirm this scenario.

SO_4 and Zn concentrations in the deep sediments/weathered bedrock within the radius of influence of SPW2 (e.g. at SBR4, S1A, S2A, SP7A/B) had decreased considerably since the start-up of the S-Cluster SIS in 2009 (see Figure 12 and 13). During the current monitoring period, SO_4 and Zn concentrations in groundwater from these wells have increased again, likely due to reduced pumping from SPW-2 (i.e. 0.5 L/s instead of 1 L/s). The response to reduced pumping is particularly evident at well SBR4 (due to its proximity to SPW-2) but SO_4 and Zn concentrations also increased in wells SBR2, SBR3, S1A, and S2A. Further downgradient, small increases in SO_4 and Zn concentrations in the Deep Aquifer at well SP7A are also likely due to reduced pumping rates at SPW-2.

Groundwater quality downgradient of the S-Cluster Area at wells SP8A/B has deteriorated in recent years and this trend continued during the current monitoring period (see Figure 13). Only SO_4 concentrations have increased to date. The increase in SO_4 concentrations likely represents the first breakthrough of deep seepage from the S-Cluster Area to this area.

3.3.5 Conditions in the North Fork of Rose Creek

Surface water samples from the NFRC are collected monthly at station X2 and quarterly at stations SC-1, SC-2, SC-3 and SC-4. Additional samples were collected from the NFRC upstream of the S-Cluster Area at NF2 (see Figure 1 for sampling locations). Time trends for Zn in the NFRC at X2 from January 2006 to the end of December 2013 are shown in Figure 14a. Also shown are data collected from the 'SC' stations since the S-Cluster SIS became operational in February 2009. Data collected in 2013 from these same stations are shown separately in Figure 14b.

Historic time trends of SO_4 and Zn clearly illustrate the improvement in water quality conditions in the NFRC that have resulted from the operation of the S-Cluster SIS (see Figure 15). Only one additional sample under winter low-flow conditions was collected in 2013 and SO_4 and Zn concentrations remained low at this time. SO_4 and Zn concentrations in the NFRC were also consistent with historic time trends throughout the spring and summer of 2013.

In October 2013, water quality in the NFRC began to deteriorate as a result of additional contaminant loads from the NFRC reach along the rock drain (near NF2A). Specifically, Zn concentrations at X2 and NF2 (and the 'SC' stations) increased substantially from October to the end of December (see Figure 14b). Deteriorating water quality conditions in the NFRC are related to the breakthrough of additional seepage along the rock drain that enters NFRC upstream of the S-Cluster SIS. Therefore, this deterioration in water quality does not reflect inadequate performance of the S-Cluster SIS (as the SIS continues to intercept the majority of contaminant loads in this area).

In light of deteriorating water quality conditions in the creek, additional data from the 'SC' stations are less sensitive to evaluating S-Cluster SIS performance than they have been in the past (as the effects of loads bypassing the SIS could be more difficult to discern). However, it should be acknowledged that the loads of additional seepage to the NFRC in late 2013 are still relatively small in comparison to those intercepted by the S-Cluster SIS and further monitoring of the 'SC' stations could still be of value. Continued quarterly monitoring of the 'SC' stations is therefore recommended.

4 Recommendations

4.1 Routine Operation & Maintenance

The following recommendations are provided for YG's consideration with respect to routine operation and maintenance of the S-Cluster SIS:

- A procedure to ensure back-up power to the S-Cluster SIS is recommended; this procedure would allow continuous pumping (24/7) in the event of planned or unplanned shutdowns of the power grid provided by Yukon Energy and prevent overflow from the trench (which can occur within 24 hours of cessation of pumping); moreover, in light of very high Zn concentrations in shallow seepage intercepted by the trench, the system should also not be shut down for more than six hours at a time (for maintenance etc.);
- The pumping rate in well SPW-2 should be increased (and the set point reduced) to achieve an average pumping rate of 1.2 to 1.4 L/s during high flow periods; some manual optimization of the pumping rate would be needed to maximize drawdown in this well and the purchase of a new pump with a Variable Frequency Drive (VFD) should be considered to automate the optimization process;
- The moderately-impacted groundwater ponding in the berm area and/or pond (swampy depression) during high flow periods should only be pumped into the main sump if the SPW-3 pump and pipeline to Faro Pit can handle the additional flow (see also recommended short-term improvements in section 4.2)
- The iron scaling in the 4" pipeline should be removed by pigging (steaming with snake hose) at least once per year to prevent reduced capacity and eventual clogging of the pipeline;
- The submersible pump in the SPW-3 sump should be pulled, inspected and cleaned of precipitates when line pressure increases (currently done twice per year); also, the perforated sump walls and sump bottom should be inspected using a down-hole camera to identify any precipitates/corrosion/sedimentation; if required, the sump bottom and/or perforated walls should be cleaned;
- The submersible pump in SPW-1 should be pulled and the well screen inspected with a down-hole camera and cleaned, if necessary; a recommendation on whether to restart pumping in SPW-1 will depend on confirmation of the water quality from this well and the effectiveness of additional pumping wells proposed to be screened in weathered bedrock (see below);
- All monitoring wells in the S-Cluster area should be inspected for damage and repaired (as required); after repair, the top-of-casing elevations should be re-surveyed; necessary repairs include:

  - Monitoring wells with broken surface protective casing and/or broken PVC casing (e.g. SRK05-SP5 and SRK05-SP4A);
  - Monitoring wells without protective casing (e.g. S2A/B) should be protected with a steel casing;
  - Monitoring wells with PVC casing extending beyond the protective steel casing (e.g. SBR4, SIS5, SIS6) should be inspected for damage due to frost heave; if monitoring well is still functional, the excess PVC casing should be cut down to allow closing of the steel protective casing; the reduction in PVC pipe stickup should be recorded and the new top of PVC pipe should be re-surveyed;
  - All monitoring wells should be properly labeled on the outside steel protective casing and protected with a steel/PVC cap at surface.

4.2 Future Performance Monitoring

The following recommendations are provided for YG's consideration with respect to future SIS performance monitoring of the S-Cluster SIS:

- A maintenance log (electronic version) should be kept that documents pertinent aspects of operation and maintenance of the S-Cluster SIS system including:
  - Pump settings (VFD vs. manual by-pass) and use of discharge line (2" vs. 4" line vs. both lines in parallel)
  - Date, time and duration of system outage (e.g. due to power outage, maintenance etc.)
  - Date and time of maintenance work (line cleaning, pump service etc)
- System data recorded on HMI (Seacan panel) should be inspected upon monthly download to ensure data is recorded correctly. The HMI datalogger should be purged routinely to maintain adequate memory space for new observation period.
- Monitoring wells used for continuous logging of groundwater levels ('SIS' well series, SP4B, DBI steel point) should be inspected to ensure correct logging of groundwater levels:
  - Waterra tubing and any other down-hole obstructions should be removed to avoid entangling with leveloggers;
  - Leveloggers should be allowed to hang freely and "taut" (about 30cm above bottom of well)
  - All Leveloggers and barologgers should be synchronized (preset readings to be taken on top of hour and every half hour, i.e. 30 min intervals)
  - Manual water level readings should be taken at time of data download (monthly); in addition, weekly manual water level readings should be

taken during the 2014 spring runoff period (typically early May to mid-June)

- Monitoring wells equipped with data loggers that exhibit freezing during the winter months should be equipped with a heat trace to allow year-round water level monitoring
- All monitoring wells used for continuous water level monitoring (SPW2 and SPW3 (sump), SIS well series, SP4B, and DBI steel point) should be resurveyed (geodetic top-of-casing elevation)
- Reference points for static water level readings at SPW2 and SPW3 should be surveyed for geodetic elevation.

- The occurrence and water quality of impacted groundwater observed in the road ditch, berm area and pond (swamp) should be monitored routinely throughout the 2014 spring runoff period; this monitoring includes:
  - Weekly monitoring of field EC/pH and on-site lab analysis of lab-EC/pH and dissolved/total zinc (if seeps are present); during periods of system shutdown and/or overflow, monitoring of field EC/pH and on-site lab analysis of lab-EC/pH and dissolved/total zinc in berm area and pond (swamp) should be increased to 3x weekly
  - Monthly submission of split sample (including any samples obtained during time when the S-Cluster SIS was down) to a certified off-site laboratory for analysis of full suite of elements (all major anions/cations plus total/dissolved metals)
- Surface water monitoring in NFRC should be improved to determine residual impact (if any) of seepage from the S-Cluster area (SIS bypass) on surface water quality:
  - Install a winterized gauging station at NFRC monitoring station X2 that allows continuous monitoring of streamflow (using stilling well and pressure transducer) throughout the winter low flow period;
  - Continue monthly monitoring of surface water quality at stations NF2 (upgradient) and X2 (downgradient)[3]
  - Conduct monthly monitoring of surface water quality at stations SC-1, SC-2, SC-3 and SC-4 (as per original monitoring plan for the S-Cluster area)

[3] Surface water station NF2 is already monitored as part of the current investigation of elevated zinc at NF2A (near rock drain) and will provide valuable information on the contaminant load entering the S-Cluster reach from upstream sources

- During spring runoff 2014, increase frequency of surface water quality monitoring at stations NF2, X2, SC-1, SC-2, SC-3 and SC-4 to weekly sampling (to evaluate the transient effect of local snowmelt runoff near S-Cluster area on NFRC water quality); during periods of system shutdown and/or overflow, monitoring of these NFRC stations should be increased to 3x weekly

If it can be shown that the metal loading associated with discharge of impacted groundwater (e.g. overflow from interceptor trench during periods of high flow and/or downtime, groundwater discharging to berm area and/or Pond) has a notable effect on metal concentrations in the NFRC, then additional control measures could be designed. These measures include a cutoff walls and/or expansion of the interceptor trench (see recommendations for medium-term modifications below).

4.3 Recommended Improvements to the SIS

4.3.1 'Short-term' Improvements

The hydraulic performance of the S-Cluster SIS appears to be diminishing over time. The key issues are inadequate pumping during high flow conditions and a long-term reduction in hydraulic control of groundwater levels in the Shallow Aquifer by the interceptor trench. Both issues result in higher contaminant loads bypassing the SIS and potentially reaching the NFRC and necessitate some immediate improvements to the S-Cluster SIS. These are so-called 'short-term' improvements that should be undertaken as soon as practical (and completed before May 2014). In order of priority, these short-term recommendations are:

- Increase the pumping capacity of the main sump (at SPW-3) by adding a second, higher capacity pump that is capable of pumping 12 L/s or 200 USGPM; this higher capacity pump would also serve as a back-up in case the existing 15HP pump requires servicing; some details on installation are as follows:
  - The high capacity submersible pump (or 'sump pump') should be equipped with a float switch to control the pump, a gate valve to manually adjust the flow rate, and a flow meter/totalizer to record the flow rate;
  - The higher capacity pump should be connected to the 4" discharge line and the float switch should be set in such a way that the pump is activated when the existing 15HP submersible pump cannot maintain the target water level (at a constant pumping rate of ~2 L/s);
  - Additional power to the S-Cluster SIS may be required for additional pumping capacity; also likely required is additional pipeline capacity so the available capacity in the 2" and 4" pipeline should be checked to

ensure the available discharge lines can handle the larger flows during spring runoff.

- Collect the various seeps expressing along the toe of the Intermediate WRD (i.e. at stations FD-52, FD-54 FD-56, FD-72) in a shallow rockfill trench along the toe of the Intermediate Dump and direct it to the SPW-3 sump via a PVC pipe; this toe drain should be about 0.5 m deep and should consist of a perforated drain pipe and drain rock wrapped in geofabric; this drain would minimize overland flow of highly-impacted seepage and limit the amount of silt delivered to the interceptor trench;
- Intercept the highly-impacted seepage that has been identified further upgradient of the toe of the Intermediate Dump (near monitoring well CH12-014-MW007, see Figure 1); this seepage originates from the Sulphide Cell and could be intercepted to reduce loads to the S-Cluster SIS; a well is currently being installed at that location to test flow conditions; if sufficient water is identified, this well (and possibly additional) pumping wells should be operated routinely to reduce the contaminant load to the S-Cluster SIS.
- Excavate a small section of the interceptor trench near the western and eastern terminus of the trench to assess the extent of silt ingress and build-up of oxidation products into the rock; excavation should be to the bottom of the trench (into natural ground) so the elevation of the trench bottom can be surveyed; before backfilling, a perforated 4” steel standpipe piezometer should be installed to allow future monitoring of the water level in the backfilled trench (see Figure 16); this piezometer should be screened across the full depth of the trench;
- Install three additional pumping wells (minimum 5” ID) near wells SBR4, SIS3 and SIS6 and connect these wells to the S-Cluster SIS (see ‘PPW’ wells in Figure 16); these wells would be screened in any permeable sediments encountered in the Shallow Aquifer and over the full extent of weathered bedrock in the Deep Aquifer; weathered bedrock is ~ 6 m thick in this area but the top of competent bedrock should be confirmed during drilling; flow tests should be completed on each well to determine the sustainable yield and water quality;
- Install three nested monitoring wells further downgradient of the shallow interceptor trench (see ‘PMW’ wells in Figure 16); these wells would enable impacted groundwater that bypasses the SIS to be characterized; one well would be screened deep in weathered bedrock and the other screened in shallow (saturated) overburden.

After these short-term improvements are completed, the performance of the upgraded SIS should be monitored throughout 2014 to determine their adequacy. If they are not adequate, the additional ‘medium-term’ improvements outlined below in Section 4.3.2

should be undertaken. The adequacy of these improvements should be assessed by RGC in an interim report that reviews performance monitoring data collected from May 2014 to the end of October 2014.

It is recognized that it might be difficult to complete all of the above short-term recommendations prior to start of spring runoff (specifically the last two bullets). Any recommendations that cannot be implemented prior to spring runoff should still proceed as early thereafter as is possible to allow a better assessment of system performance (by October 2014).

In the event that additional pumping capacity and/or civil works to improve the S- Cluster SIS cannot be completed prior to spring runoff 2014 and significantly impacted groundwater is observed discharging and impacting the NFRC (above applicable water quality standards), then the following emergency measures should be implemented:

- The area downstream of the S-cluster SIS should be bermed off to prevent the highly impacted seepage to reach the NFRC directly via surface runoff), and
- Vacuum truck(s) should be used to augment the pump capacity of the S-cluster SIS and pump significantly impacted groundwater collecting in the SPW3 sump and/or ponding in the bermed area(s) and discharge the water in the Intermediate Pond (or directly to the Faro Pit).

4.3.2 Medium-Term Improvements

The S-Cluster SIS was constructed in 2008/2009 to protect the NFRC from highly-impacted seepage that began impacting this area around that time. It was an interim solution that has proved to be highly-effective in this regard. However, the condition of seepage from the Intermediate WRD has deteriorated since 2009 and additional seepage has developed in this area (near the toe of the WRD and near the road ditch/'Pond').

The S-Cluster SIS was not designed to handle the additional loads that are related to the current seepage conditions and its performance has begun to diminish. Deteriorating water quality conditions in the NFRC have not yet been observed as a result but adverse effects are inevitable if the trend in performance continues (and the NFRC remains in its current location). Accordingly, the following 'medium-term' improvements are recommended:

- Extend the lateral extent of the interceptor trench (to the east and west);
- Deepen the interceptor trench to at least 5 m below grade and upgrade the design of the rock drain (to enable drain pipe/clean-outs and better protection of the drain rock by filter fabric); and
- Install a cutoff wall/grout curtain downgradient of the interceptor trench.

In light of the capital expenditures, each of these upgrades would be designed for mine closure (not just interim care & maintenance). In our opinion, the current S-Cluster SIS (with short-term improvements implemented) would be adequate if (a) the NFRC were to be raised or 'lined' as part of closure and (b) the closure plan were to be implemented within 5 to 10 years. If closure takes longer than 10 years or if the NFRC were to remain in its current condition/location after closure, this system would not be adequately protective of the creek and replacement within the next 5 years would seem justified.

The new SIS would be designed to achieve closure water quality objectives for the NFRC and would likely be part of a comprehensive seepage interception strategy for the site. Accordingly, the decision on whether to upgrade the current S-Cluster SIS or replace it would have to be made in the context of the closure planning process for the Faro Mine. A review of closure options by RGC in light of current S-Cluster SIS performance would be beneficial in this regard (as would feedback from the design team responsible for closure planning).

4.4 Path Forward

In summary, the 'short-term' improvements and recommendations for future SIS performance monitoring should be undertaken as soon as practical (and completed by May 2014). Subsequently, the performance of the SIS from May 2014 to the end of October 2014 should be assessed by RGC in an interim report. In that report, additional specifications and design drawings for the 'medium-term' improvements would be provided. Assuming adequate review and/or feedback on closure objectives and timelines, a clear recommendation on how to proceed with upgrading the S-Cluster SIS would also be provided in that report.

5 Closure

We trust that the information provided in this report meets your requirements at this time.

Should you have any questions or if I can be of further assistance, please do not hesitate to contact the undersigned.

ROBERTSON GEOCONSULTANTS INC.

Paul Ferguson, Ph.D.
Senior Geochemist

Christoph Wels, Ph.D., M.Sc., P.Geo. (B.C.)
Principal and Senior Hydrogeologist

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SRK (2011), 2011 S-Wells Performance Review, August 2011. Project Number 1CY001.050

FIGURES

LEGEND

- Monitoring Well
- Pumping Well
- Seep Monitoring Well
- Surface Water Station
- Seepage Pipeline
- Seepage Interception Trench

Groundwater Monitoring Wells
S-Cluster Area, Fall 2013

Faro Mine Site

N S E W

SCALE 1: 2,500

0 50 100 150 200 Meters

NAD 83 CSRS UTM Zone 8N

Yukon Government

CLIENT: Yukon Government

PROJECT: 2012/2013 S-Cluster Review

REPORT: RGC 118025

LOCATION: Anvil Range Mining Complex,YT, Canada

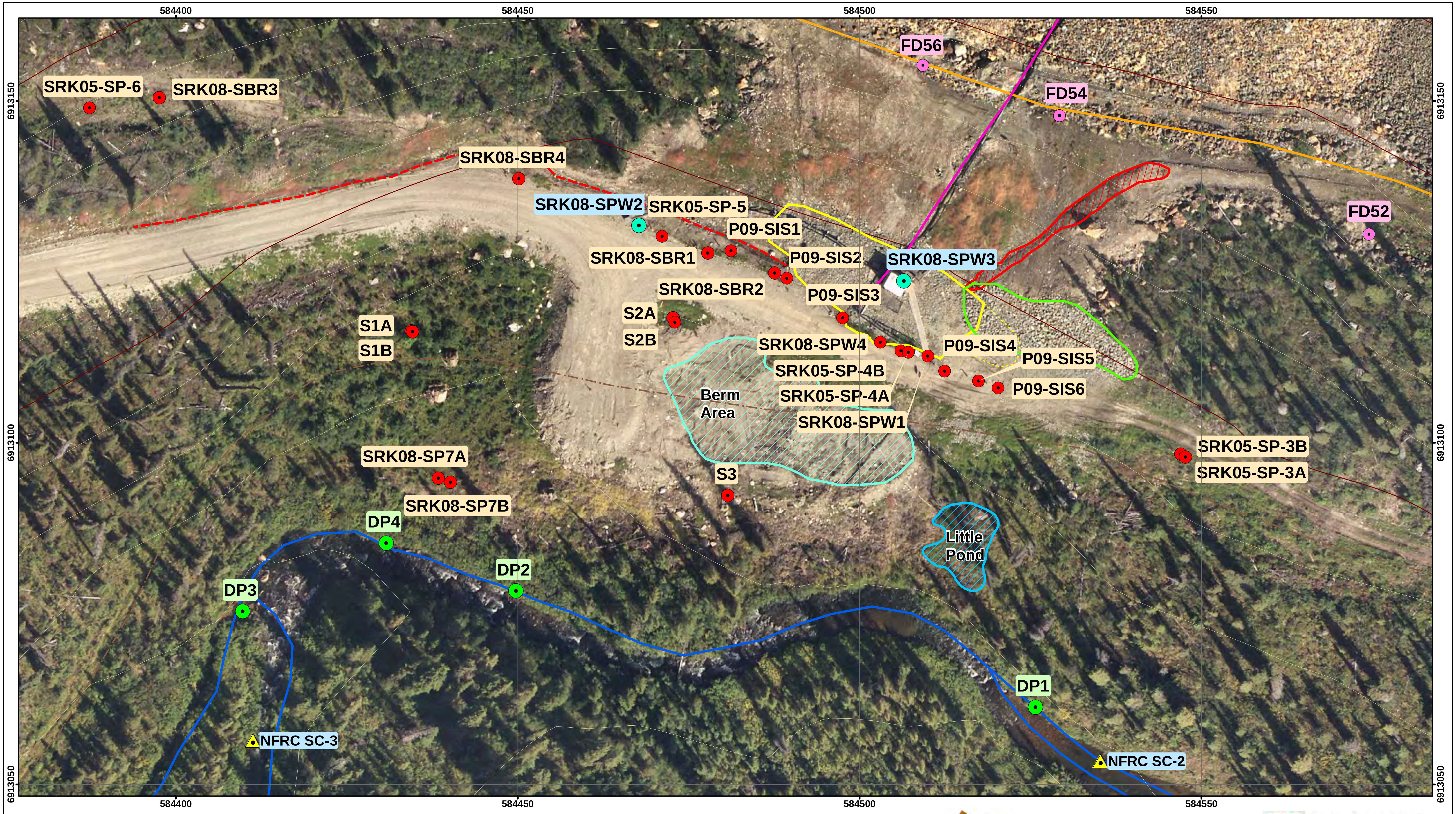
Robertson GeoConsultants Inc.
Consulting Engineers and Scientists for the Mining Industry
www.robertsongeoconsultants.com

FIGURE: 1

DATE: March 18, 2014

DRAWN BY: LR

FILE: Faro_S_Cluster_Overview_NAD83CSRS_March2014.mxd



LEGEND

- Monitoring Well
- Drive Point
- Pumping Well
- Seep Monitoring Well
- Surface Water Station
- Seepage Pipeline
- Shallow Road Ditch
- Seepage Interception Trench
- Trench East Extention
- Shallow Finger Drain
- Little Pond

S-Cluster SIS (2013 status)

Faro Mine Site

N W E S

SCALE 1: 500

0 10 20 30 40 50 Meters

NAD 83 CSRS UTM Zone 8N

Yukon Government

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Consulting Engineers and Scientists for the Mining Industry
www.robertsongeoconsultants.com

FIGURE: 2

CLIENT: Yukon Government
PROJECT: 2012/2013 S-Cluster Review
REPORT: RGC 118025
LOCATION: Anvil Range Mining Complex,YT, Canada

DATE: March 18, 2014
DRAWN BY: LR
FILE: Faro_S_Cluster_SIS_NAD83CSRS_March2014_0.5K.mxd

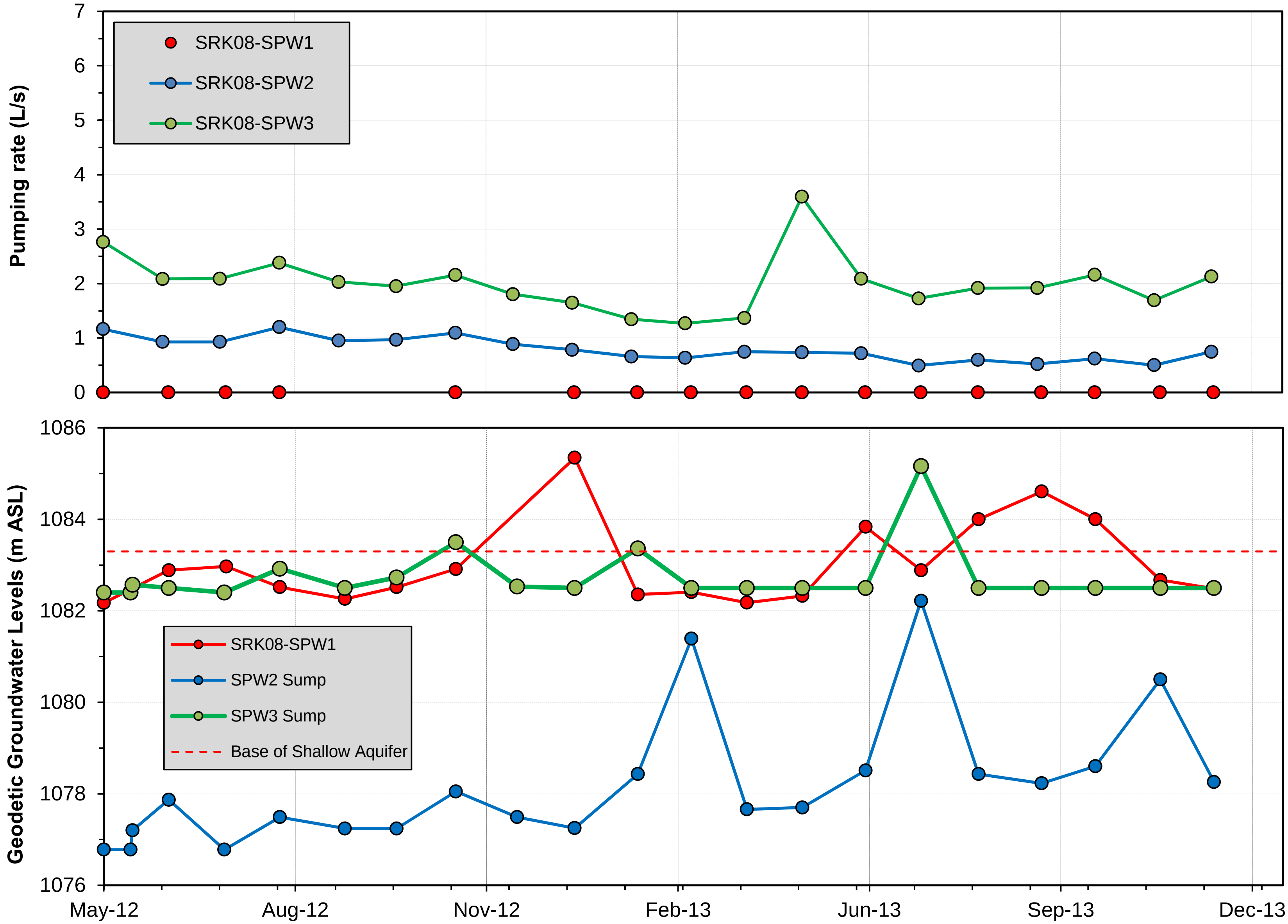


Figure 3. Monthly pumping levels and flow rates for the pumping wells in the S-Cluster area

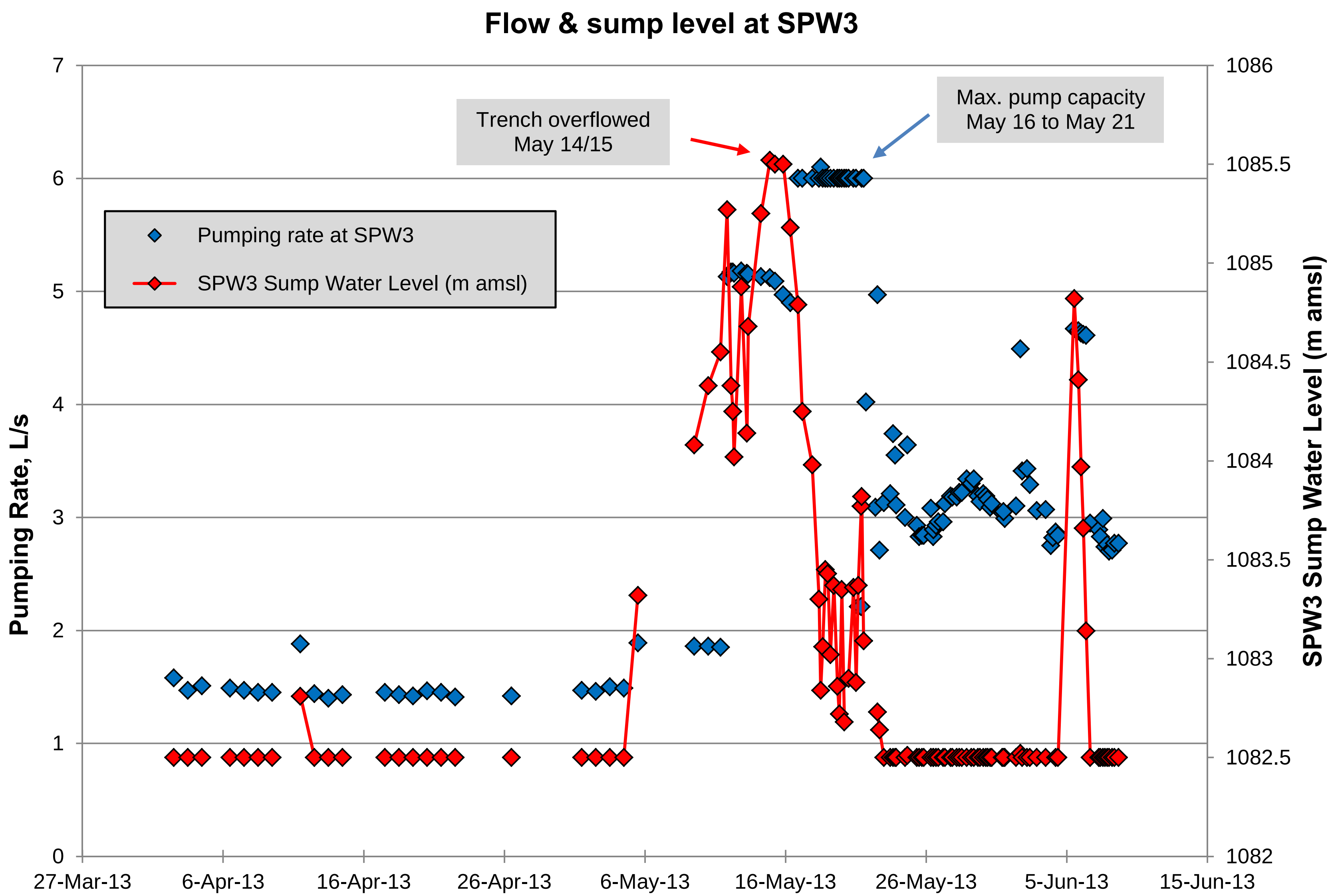


Figure 4. Daily readings of sump level and pumping rate in SPW3 Sump

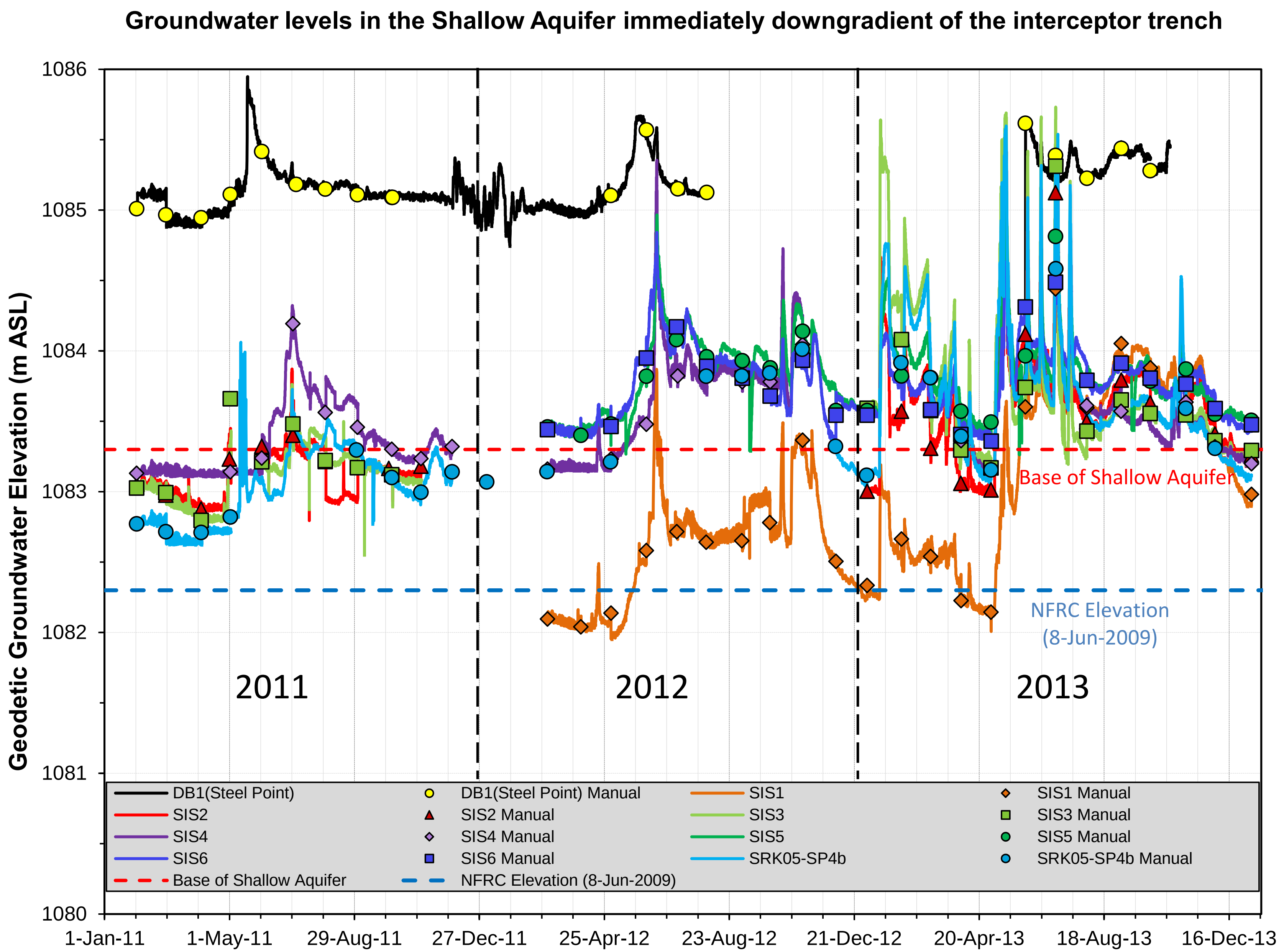


Figure 5. Continuous water level readings in 'SIS' wells, 2011 to 2013

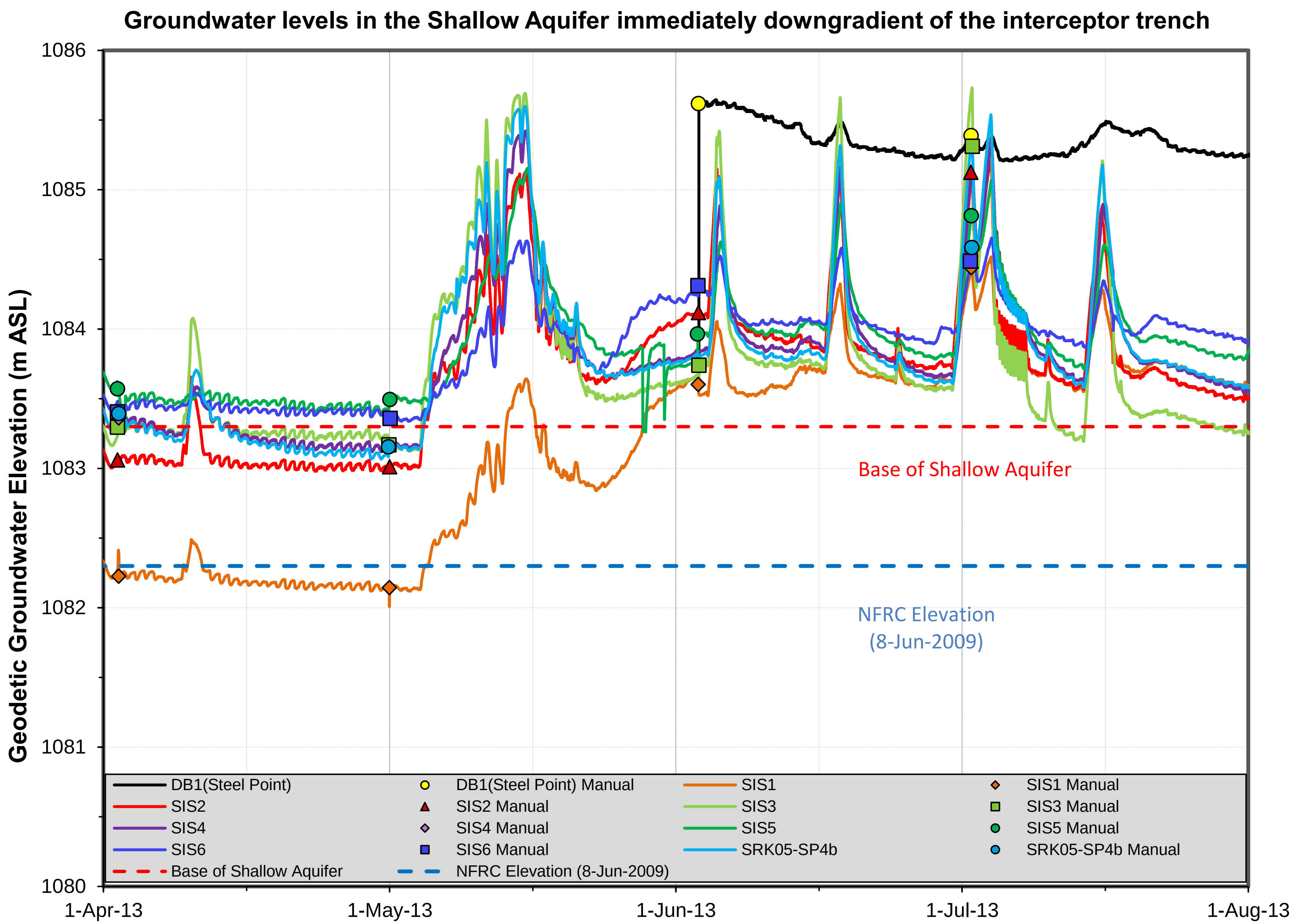


Figure 6. Continuous water level readings in SIS wells, April to July 2013

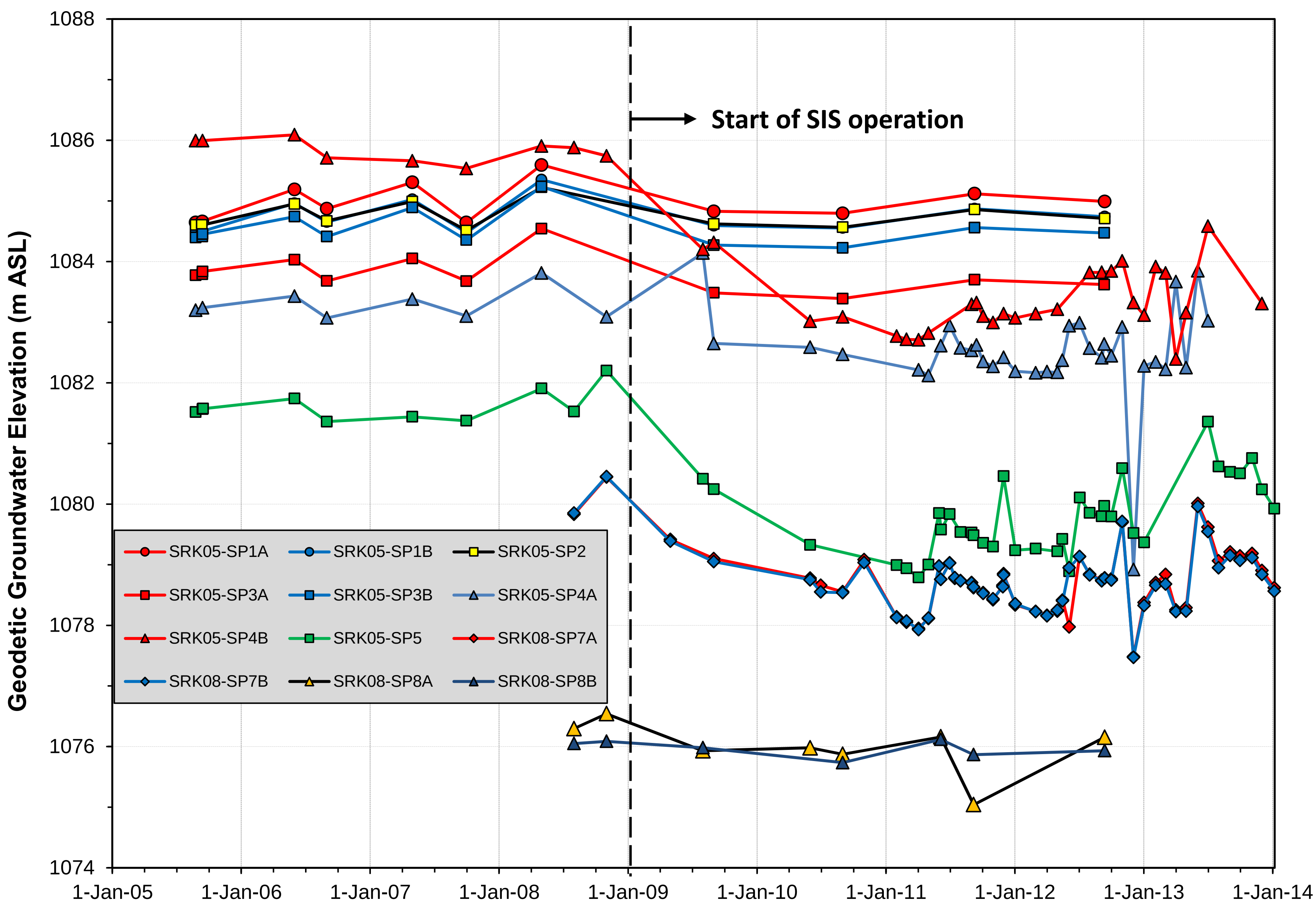


Figure 7. Longer-term groundwater levels in the ‘SP’ wells, S-Cluster area

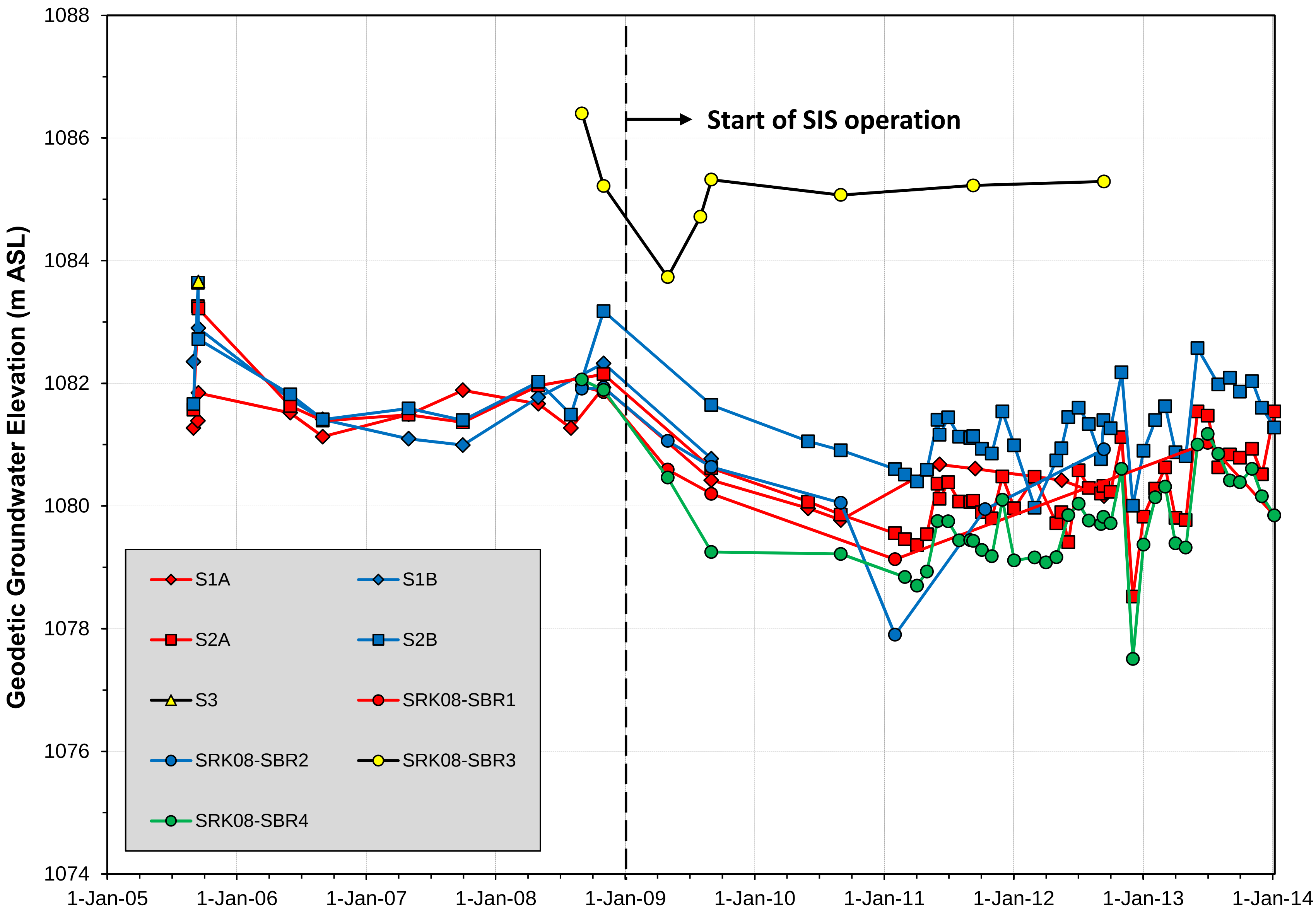
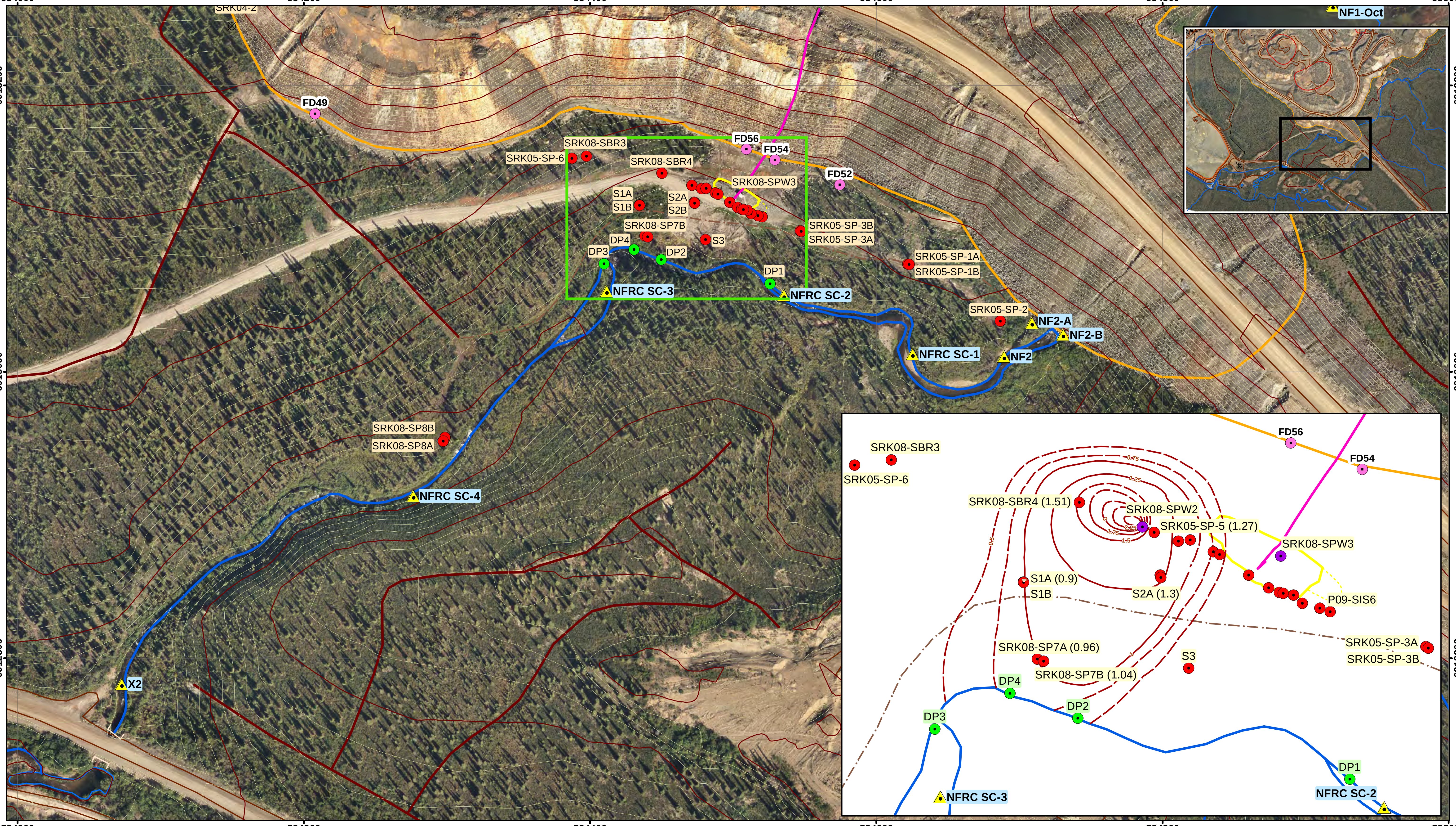


Figure 8. Longer-term groundwater levels in the 'S' and 'SBR' wells, S-Cluster area



Drawdown Map in Deep Aquifer
S-Cluster Area, Fall 2013

Faro Mine Site

LEGEND

- Monitoring Well
- Pumping Well
- Seep Monitoring Well
- Surface Water Station
- Seepage Pipeline
- Seepage Interception Trench

SCALE 1: 2,500

0 50 100 150 200 Meters

NAD 83 CSRS UTM Zone 8N

Yukon Government

Robertson GeoConsultants Inc.

CLIENT: Yukon Government

PROJECT: 2012/2013 S-Cluster Review

REPORT: RGC 118025

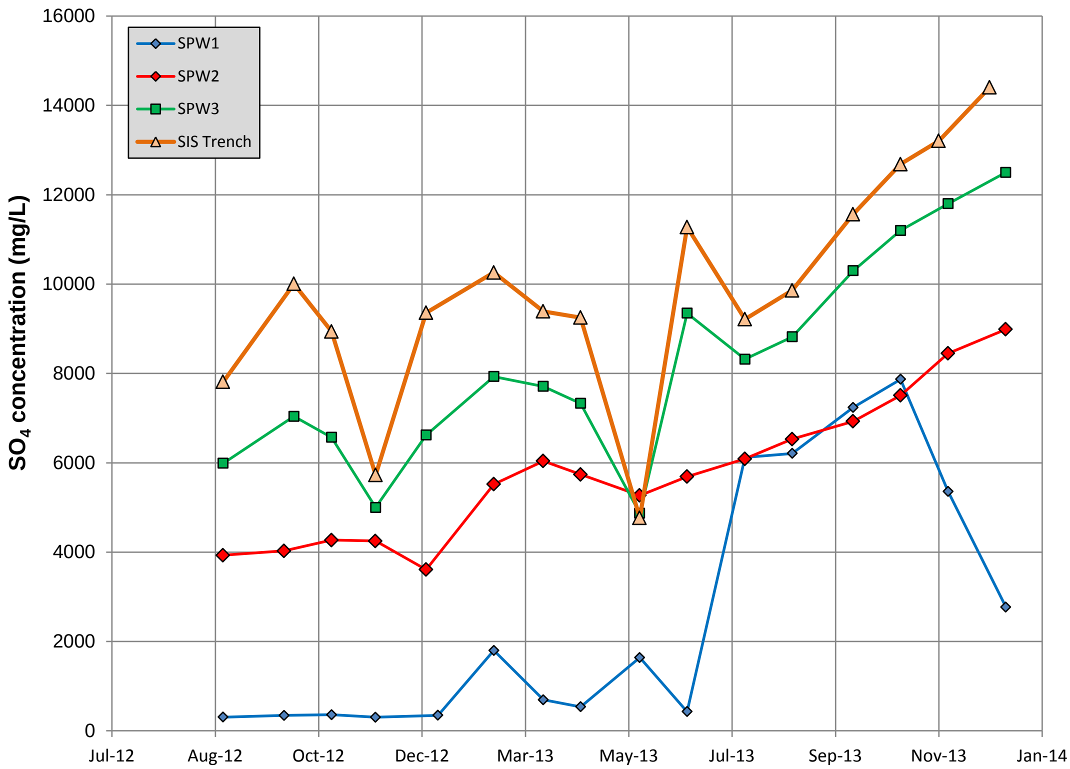
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 9

DATE: March 18, 2014

DRAWN BY: LR

FILE: Faro_S_Cluster_NAD83CSRS_March2014.mxd



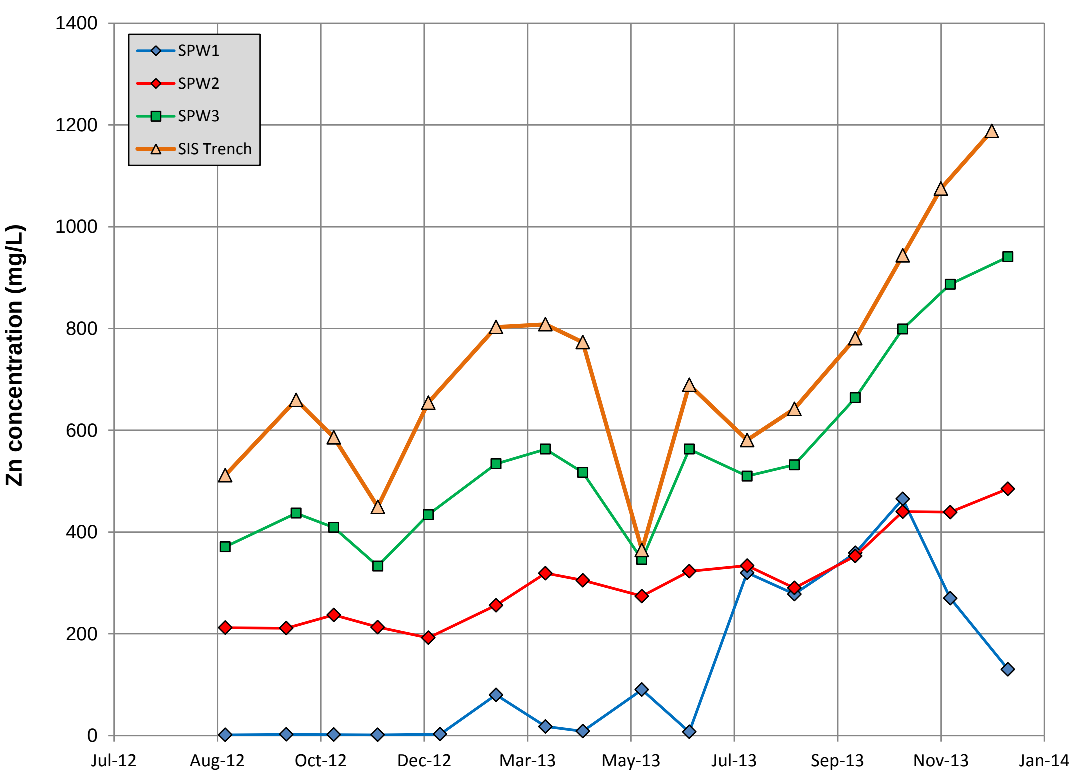


Figure 10. Sulphate and zinc concentrations in at the SIS Trench from July 2012 to December 2013

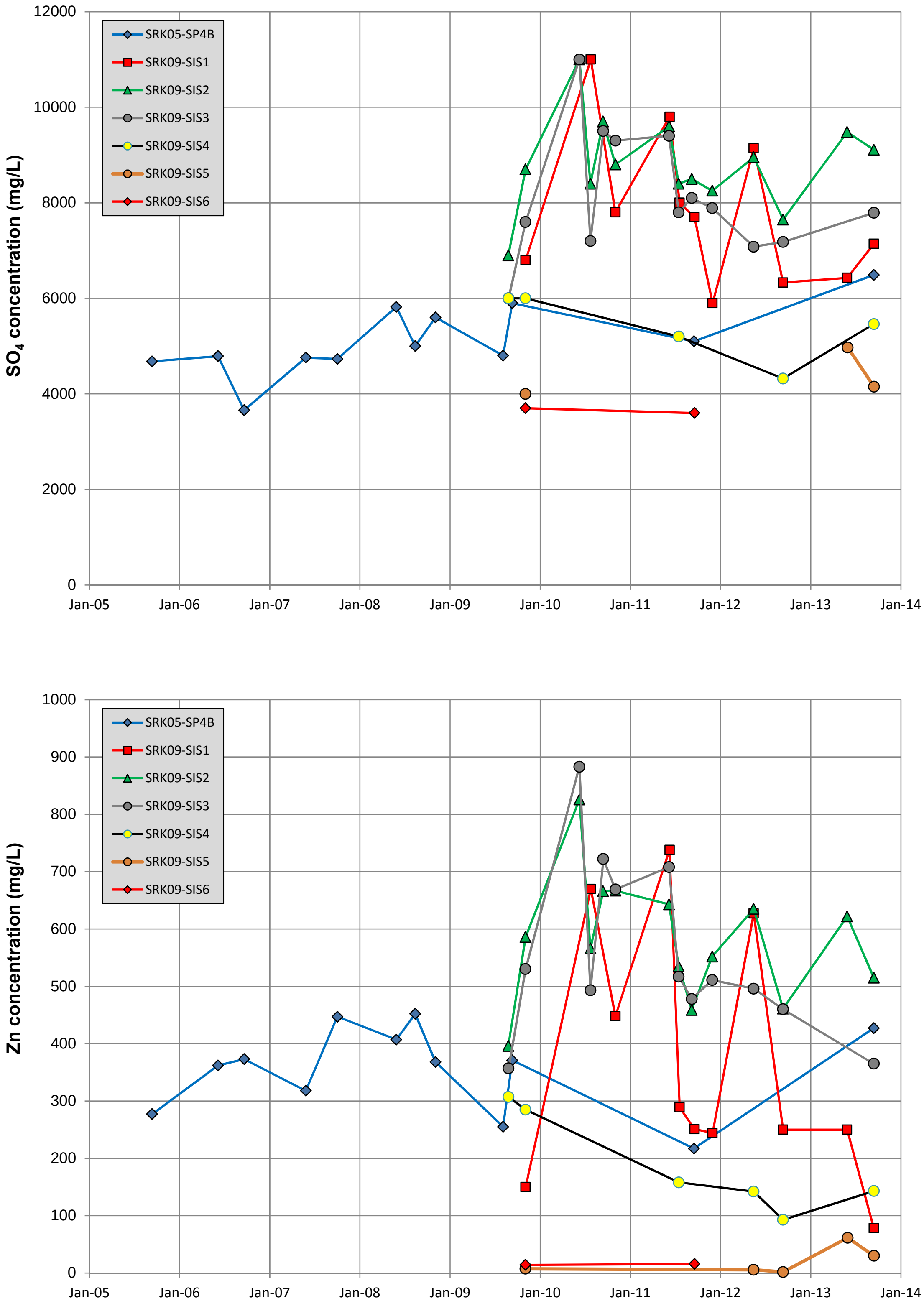
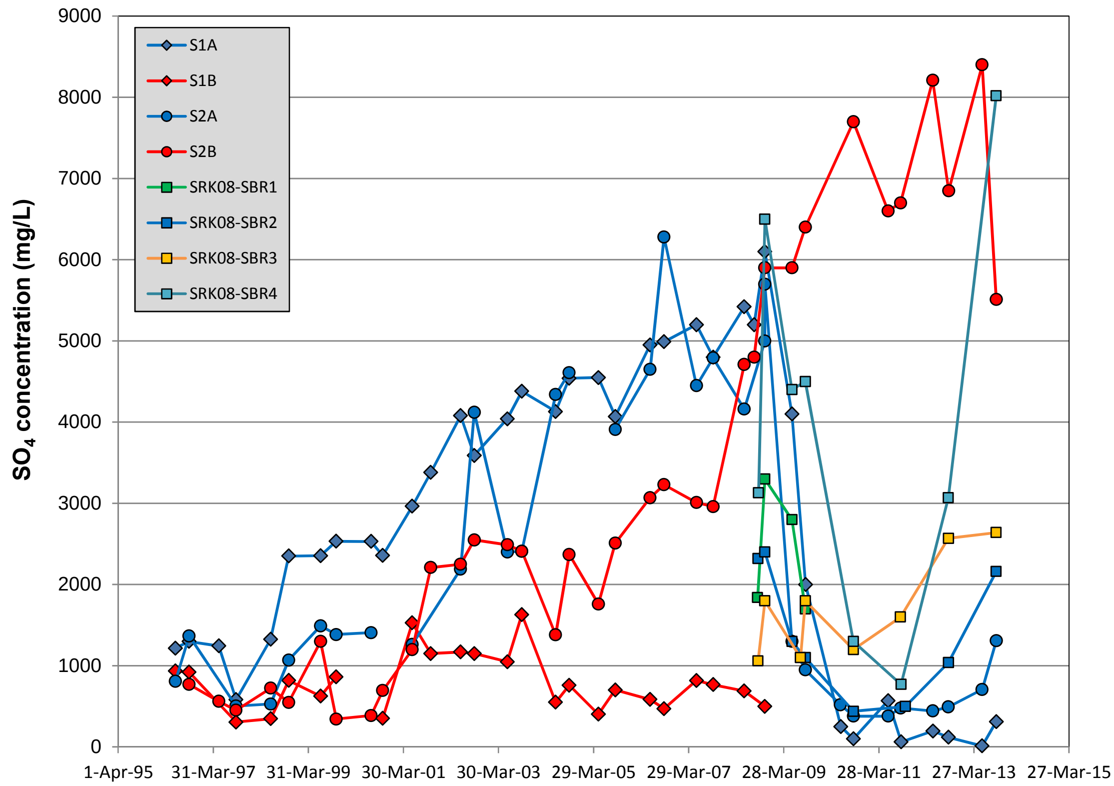


Figure 11. Sulphate and zinc concentrations in groundwater downgradient of the interceptor trench



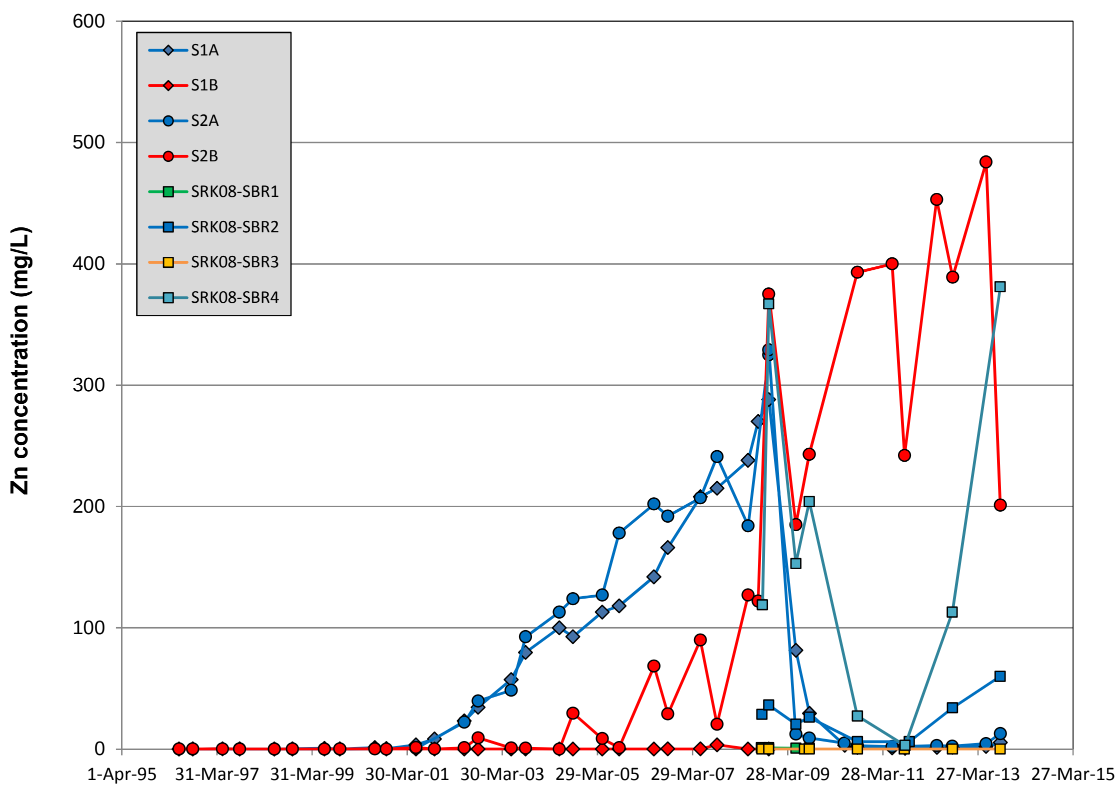


Figure 12. Sulphate and zinc concentrations in groundwater from the ‘S’ and ‘SBR’ wells

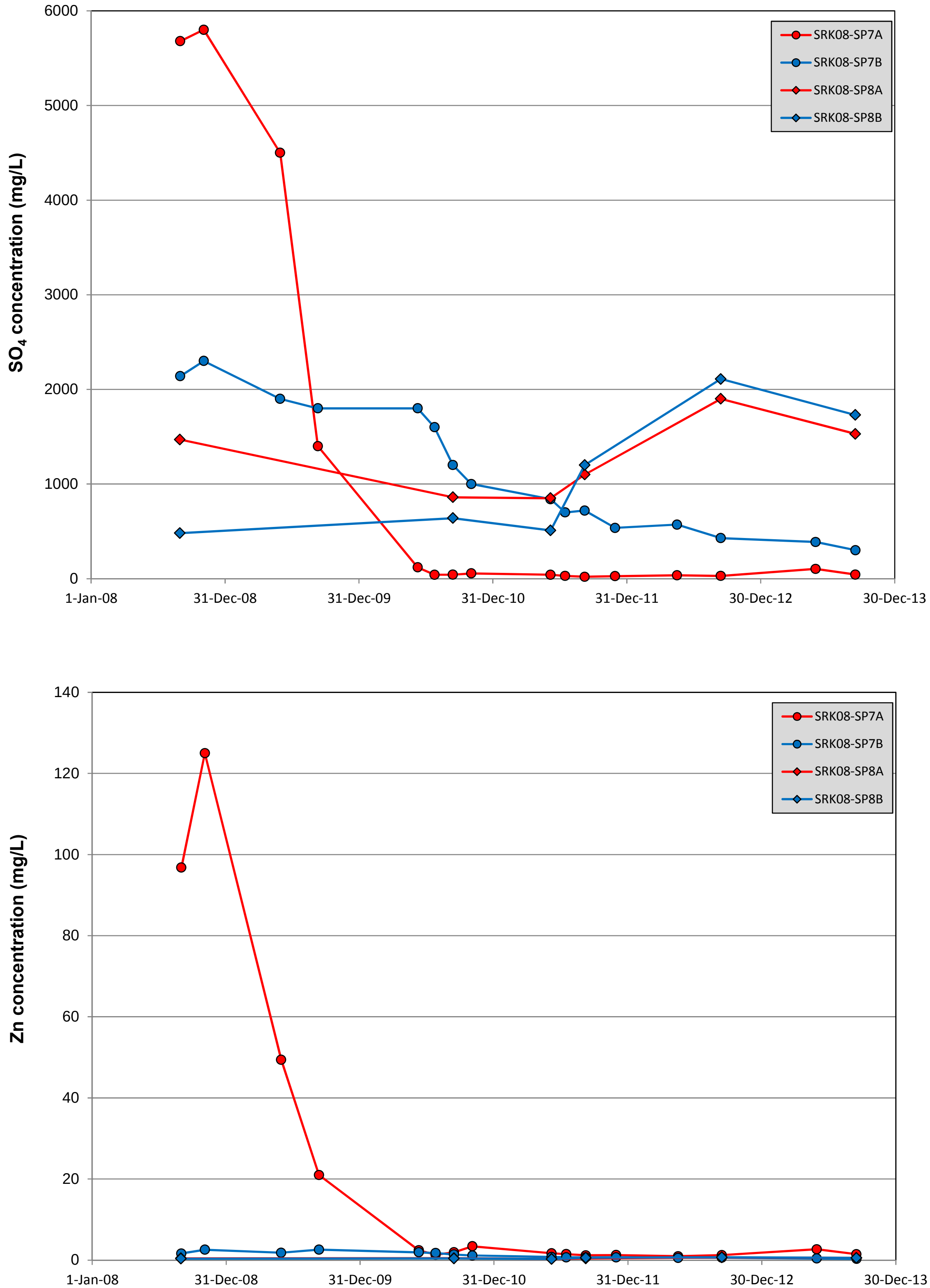


Figure 13. Sulphate and zinc concentrations in groundwater near the NFRC

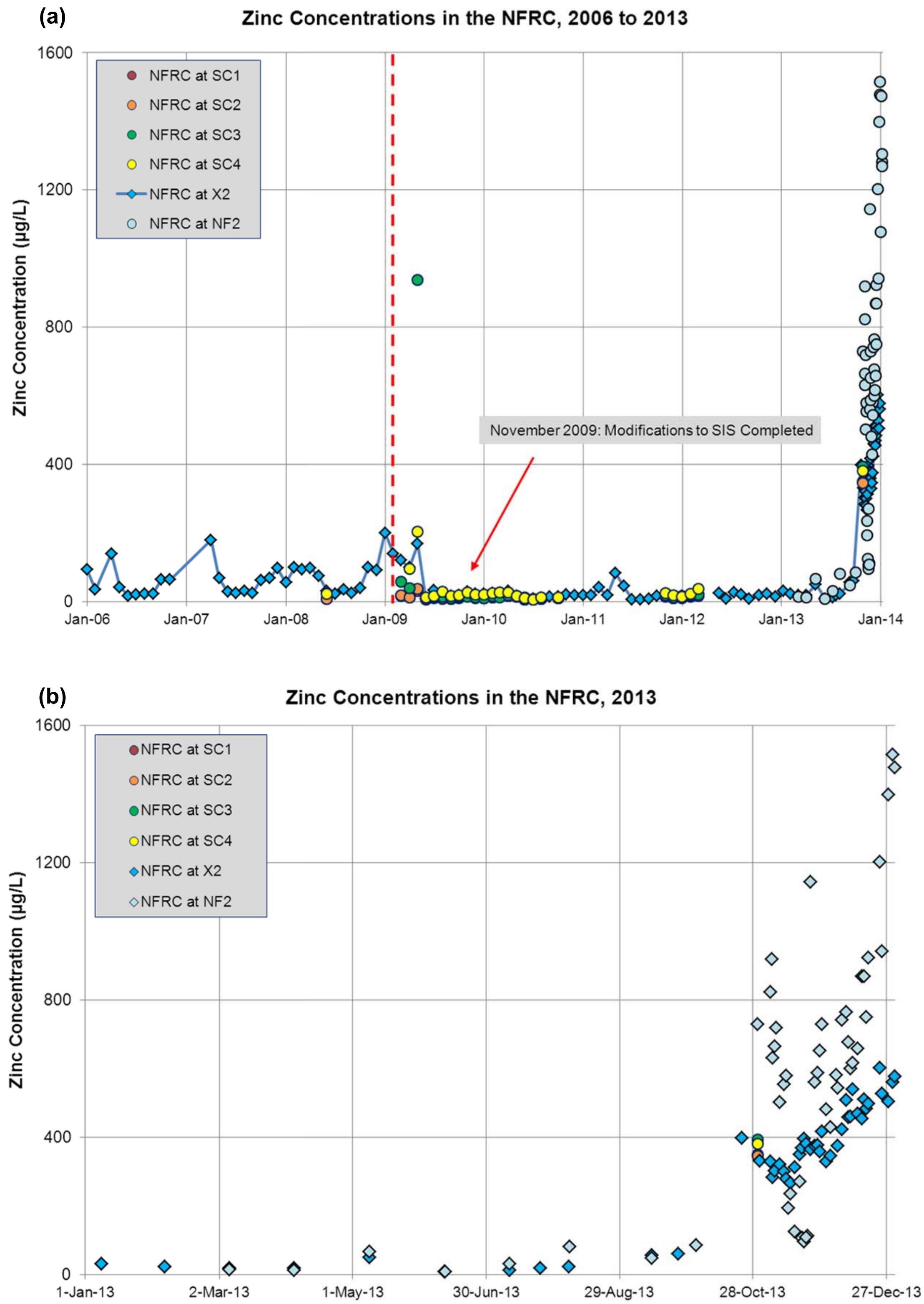


Figure 14. Zinc concentrations in the NFRC from (a) January 2006 to December 2013 (b) 2013

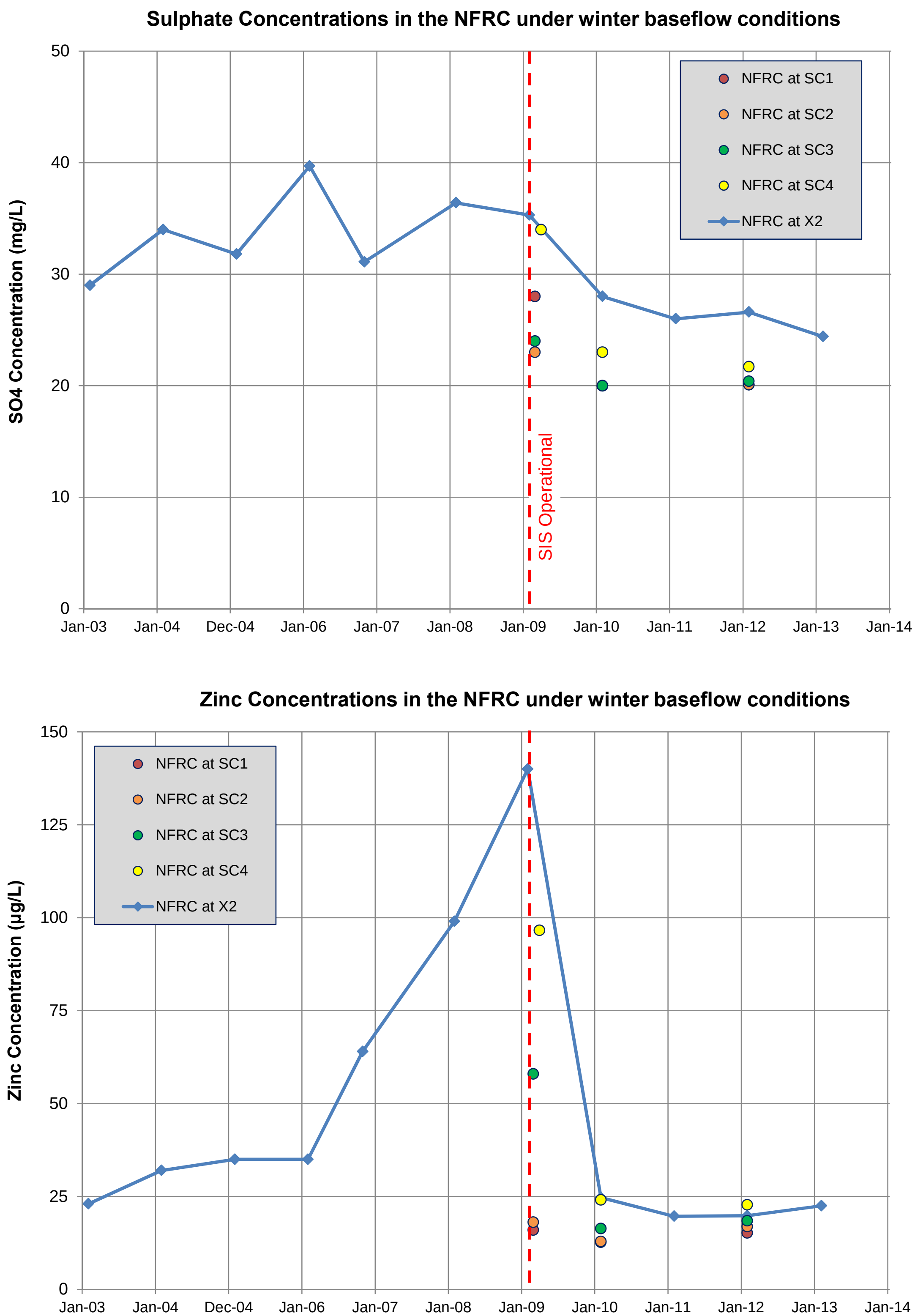
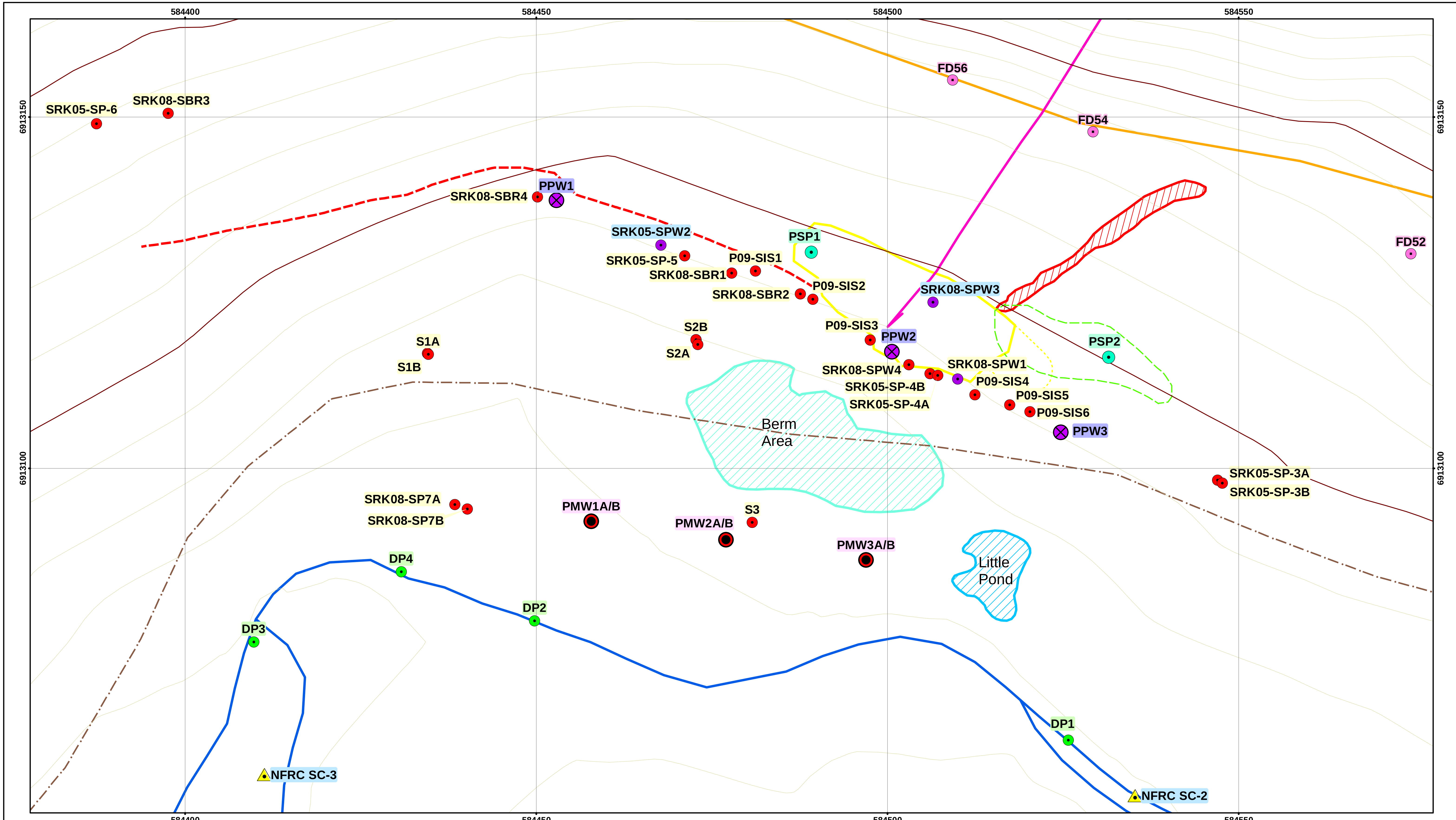


Figure 15. Sulphate and zinc concentrations in the NFRC under winter low flow conditions



LEGEND

- Proposed Monitoring Well
- Proposed Pumping Well
- Proposed Stand Pipe
- Monitoring Well
- Drive Point
- Pumping Well
- Seep Monitoring Well
- Surface Water Station
- Seepage Pipeline
- Shallow Road Ditch
- Seepage Interception Trench
- Trench East Extention
- Shallow Finger Drain
- Little Pond

Proposed Additional Groundwater Wells S-Cluster Area, Fall 2013

Faro Mine Site

SCALE 1: 500

0 10 20 30 40 50 Meters

NAD 83 CSRS UTM Zone 8N

Yukon Government

Robertson GeoConsultants Inc.
Consulting Engineers and Scientists for the Mining Industry
www.robertsongeoconsultants.com

FIGURE: 16

CLIENT: Yukon Government
PROJECT: 2012/2013 S-Cluster Review
REPORT: RGC 118025
LOCATION: Anvil Range Mining Complex,YT, Canada

DATE: March 18, 2014
DRAWN BY: LR
FILE: Faro_S_Cluster_Proposed_NAD83CSRS_March2014.mxd