



STRATUS CONSULTING

**Analysis of Water Quality Impacts at
the Buckhorn Mountain Mine and
Recommendations for Improvement**
Final Report

Prepared for:
Okanogan Highlands Alliance

**Analysis of Water Quality Impacts at
the Buckhorn Mountain Mine and
Recommendations for Improvement
Final Report**

Prepared for:

David Kliegman, Executive Director
Okanogan Highlands Alliance
Tonasket, Washington

Prepared by:

Stratus Consulting Inc.
PO Box 4059
Boulder, CO 80306-4059
303-381-8000

1920 L St. NW, Suite 420
Washington, DC 20036

Contact:

Ann Maest, PhD

Contents

List of Figures	vii
List of Tables	ix
List of Acronyms and Abbreviations	xi
Section 1 Introduction	1
Section 2 Important Mining and Environmental Events at the Buckhorn Mountain Mine	2
Section 3 Environmental Effects, Causes, Current Status, and Predicted vs. Actual Concentrations	4
3.1 Evaluating Effects: Comparison to Permit Limits, Standards, and Baseline Conditions	4
3.2 Concentrations in Potential Contaminant Sources: Treatment Plant Effluent, Underground Mine Water, and Mine Waste Leachate	5
3.3 Effects on Surface Water	12
3.4 Effects on Groundwater, Springs, and Seeps.....	21
3.4.1 Groundwater quality	21
3.4.2 Seep and spring water quality	22
3.5 Predicted vs. Actual Water Quality in the Underground Mine and the Effectiveness of the Capture Zone.....	24
Section 4 Summary	28
Section 5 Recommendations	29
References	30

Figures

1	Monitoring location overview	6
2	Treatment plant effluent concentrations over time: (a) nitrate+nitrite and ammonia, (b) chloride and sulfate, and (c) TDS.....	7
3	Groundwater flow directions, faults, and interpreted capture zone in the Buckhorn Mountain Mine area	11
4 (a–b)	Concentrations of mine-related contaminants and pH values in South Fork Nicholson Creek (SW7) over time.....	13
4 (c–d)	Concentrations of mine-related contaminants and pH values in Gold Bowl Creek (SW9) over time	14
4 (e–f)	Concentrations of mine-related contaminants in Upper South Fork Bolster Creek (SW14) over time	15
5	Surface water, groundwater, spring, and seep monitoring points with increasing chloride concentrations.....	17
6	Surface water, groundwater, and spring/seep monitoring locations with increasing nitrate+nitrite or ammonia concentrations	18
7	Surface water, groundwater, and spring/seep concentrations with increasing sulfate concentrations	19
8	Surface water, groundwater, and spring/seep concentrations with increasing metal concentrations	20
9	Concentrations of mine-related contaminants in groundwater well MW-14, located near Gold Bowl Creek: (a) chloride and nitrate+nitrite; (b) sulfate and TDS	23
10	Concentrations of mine-related contaminants in two seeps in South Fork Nicholson Creek: (a) JJ18, chloride and sulfate; (b) JJ16, chloride and nitrate+nitrite	25

Tables

1	Summary of important mining events, NOVs, and AOs for the Buckhorn Mountain Mine	2
2	Sampling results from PAG, development rock leachate collected on June 4, 2010	10
3	Comparison between worst-case predicted and actual water quality in the Southwest Zone, and predicted Gold Bowl water quality in the Buckhorn Mountain underground mine (mg/L except as noted)	26

Acronyms and Abbreviations

AMP	adaptive management plan
ANFO	ammonium nitrate and fuel oil
AO	Administrative Order
CWA	Clean Water Act
DMR	discharge monitoring report
DRMP	development rock management plan
EPPS	environmental protection performance security
FSEIS	Final Supplemental Environmental Impact Statement
N	nitrogen
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
OHA	Okanogan Highlands Alliance
PAG	potentially acid-generating
RO	reverse osmosis
TDS	total dissolved solids
TSS	total suspended solids
UTL	upper tolerance limit

1. Introduction

The Buckhorn Mountain Mine is an underground gold mine located in northeastern Washington State (the State) and is the only gold operation in the State. The mine, owned by Kinross Gold/Crown Resources (Kinross), has been operating since January 2008. Ore processing is conducted off-site at Kinross's Kettle River Mill in Republic, Washington. The mine plans to place all waste rock in the underground workings as cemented or uncemented rockfill, leaving no surface mine waste deposits following mine closure. However, even with these efforts, the mining operations have adversely affected water quality in surface water, groundwater, seeps, and springs downstream and downgradient of the mine. The Washington State Department of Ecology (Ecology) has issued numerous Notices of Violation (NOVs) and Administrative Orders (AOs) to Kinross.

In April 2008, the Okanogan Highlands Alliance (OHA) entered into a settlement agreement with Kinross that included funding for OHA to conduct independent monitoring. The mine went forward as an underground operation, and OHA continues to evaluate environmental information as it relates to the mine's performance and to participate in the annual meetings attended by Kinross, Ecology, the Washington Department of Fish and Wildlife, and the U.S. Department of Agriculture Forest Service. OHA has remained vigilant of environmental conditions at the mine through turnover of important personnel at Kinross and Ecology.

In 2010, the primary Ecology scientist overseeing the environmental performance of the mine, Bob Raforth, retired. OHA's understanding is that Ecology has received a waiver to circumvent the State's hiring freeze, and Mr. Raforth will be replaced with a qualified hydrogeologist. However, it is difficult to replace the institutional memory on such a complex project.

In the near future, Kinross plans to expand into the Gold Bowl portion of the deposit, which has a much higher potential to generate contaminants, including acidic and metal-rich drainage. Given the higher potential for impacts to the environment as mining progresses, OHA believes that Ecology must be conscientious in its oversight and that the pattern of increasing mine contaminant concentrations in area streams and groundwater decline.

This report provides a response to adaptive management plan (AMP) triggers in Gold Bowl Creek, which are more extensive than previously reported in the Crown Resources (2010) letter. More broadly, this report offers an overview of the important events at the mine, focusing on violations and orders submitted by Ecology; presents information on water quality standard exceedences that have occurred but were not noted by Kinross or Ecology; discusses other adverse environmental effects that have occurred and their current status; and proposes recommendations for actions that could be taken by Kinross to increase environmental protectiveness.

2. Important Mining and Environmental Events at the Buckhorn Mountain Mine

Table 1 lists important mining events, NOVs, and AOs at the mine. The Buckhorn Mountain Mine holds a Clean Water Act (CWA) discharge permit issued by Ecology [the National Pollutant Discharge Elimination System (NPDES) Waste Discharge Permit No. WA-005243-4] for discharge of treated mine water (Washington State Department of Ecology, 2007). The permit incorporates, by reference and permit condition, the implementation of many of the mine's environmental management plans, including the operational stormwater pollution prevention plan, the development rock management plan (DRMP), the AMP for water quality, the hydrologic monitoring plan, the environmental protection performance security (EPPS; financial assurance), the fish and wildlife mitigation agreement, and the brine management plan. Therefore, requirements in these plans and agreements are essentially regulated through the NPDES permit. In turn, certain elements of the management plans, for example, changes in concentrations that exceed baseline values, trigger requirements in Kinross's AMP (Golder Associates, 2007a).

Table 1. Summary of important mining events, NOVs, and AOs for the Buckhorn Mountain Mine

Date	Event	Explanation
9/2006	Construction began	Construction of Buckhorn Mountain Mine began.
6/26/2007	NOV 4504	Stormwater discharges occur during construction.
2007	Total violations	7 (6 permit exceedences, 1 non-reporting)
1/2008	Mining began	Start of dewatering, water treatment, development rock excavation, discharge to Outfall 002.
5 and 6/2008	Water management changes	Effluent discharge stopped due to ammonia problem. Dewatering was intermittent, excess surge pond water stored in mine sumps.
7/2008	Treatment plant discharge	Discharge to Outfalls 003 and 004 began.
7/21/2008	NOV 5760	NPDES permit violations: failure to complete sampling or report results; TDS and TSS exceedences.
9/23/2008	AO 6079	New treatment plant operational monitoring plan and comparison of operational and predicted treatment plant influent water quality required due to violations.
10/2008	Treatment plant discharge	Discharge to Outfall 001 (infiltration gallery) began.
2008	Total violations	25 (8 permit exceedences, 17 non-reporting)
4/17/2009	AO 6674	Failure to adequately capture and treat water from the mine, capture zone problem.
4/27/2009	Penalty 6675	\$40,000 for AO 6674.

Table 1. Summary of important mining events, NOVs, and AOs for the Buckhorn Mountain Mine (cont.)

Date	Event	Explanation
7/1/2009	Treatment plant modification	Kinross starts use of breakpoint chlorination to remove nitrogen compounds in effluent.
7/17/2009	Increased financial assurance	Buckhorn Letter of Credit increased by \$4.4 million to \$22.7 million for EPPS.
7/20/2009	NOV 6965	Exceeded TDS effluent and stormwater limits. Required management plans for RO; investigate/manage stormwater exceedences; stability analysis of slope above Gold Bowl Creek.
7/21/2009	Treatment plant modification	Kinross discontinued use of failed breakpoint chlorination system.
8/4/2009	NOV 7031	Violated S1 permit condition: 7 water quality exceedences in outfalls in April, May, and June 2009.
8/21/2009	NOV 7080	Violated permit and AO 6674 57 times in July; exceeded zinc, copper, lead, and TRC effluent limits.
8/31/2009	Treatment plant modification	RO treatment system operational.
10/2009	New dewatering wells operational	Response to AO 6674.
10/8/2009	AO 7151	AKART for RO or other additional treatment method: submit addendum to Engineering Report.
2009	Total violations	91 (38 permit exceedences, 53 non-reporting)
6/28/2010	NOV 7858	Violated permit condition S1 by causing slope instability near Outfall 001 (infiltration gallery).
9/7/2010	Kinross Inquiry Report	Report on misconduct related to water treatment plant operations.

See text for more detail on permit violations.

AKART: all known, available, and reasonable methods of prevention, control, and treatment.

RO: reverse osmosis.

TDS: total dissolved solids.

TSS: total suspended solids.

TRC: total residual chlorine.

The mine has received six NOVs and three AOs from Ecology since mine construction began. The first NOV was received in June 2007 before mine operations were initiated and was related to stormwater discharges during construction. All other NOVs through 2009 were related to NPDES permit limit water quality exceedences in water treatment plant effluent and the stormwater ponds. The NOV in 2010 was related to slope instability from treated water discharge at the infiltration gallery. The AOs were related to failure of the treatment plant to

properly remove contaminants and failure to adequately capture water potentially affected by the mine. In September 2010, Kinross reported that misconduct by treatment plant staff had resulted in unreported discharges that exceeded permit limits for ammonia, nitrate, TDS, arsenic, zinc, and pH between May 2009 and August 2009. To date, Ecology has not issued a violation for these exceedences.

As summarized in Table 1, the number of permit violations increased each year from 2007 through 2009. The mine violated its NPDES permit a total of 123 times from September 2006 to the end of 2009; 52 violations were for permit exceedence or violations of permit conditions and 71 were for failure to report required monitoring results. The permit water quality exceedences were for treatment plant effluent and stormwater monitoring points, which are the only locations with numeric water quality permit limits. The water quality violations were for exceedence of TDS, TSS, ammonia, arsenic, chloride, copper, lead, mercury, and zinc, as well as pH values that were higher than the permit limit of 8.5.

In large part because of the discharge of inadequately treated water, concentrations of mine-related contaminants increased downstream and downgradient of the mine in local groundwater and surface water resources. The environmental effects of mine operations are discussed in Section 3.

3. Environmental Effects, Causes, Current Status, and Predicted vs. Actual Concentrations

Concentrations of mine-related contaminants have increased over time at certain surface water, groundwater, spring, and seep locations since mining was initiated. The three primary reasons for the increases are intended or unintended discharge of inadequately treated wastewater, seepage of mine water from the underground mine, and the possible onset of acid drainage from the weathering of sulfide ore and mined materials, including underground workings, development rock, and ore. This section discusses water quality trends over time and provides possible explanations for their occurrence.

3.1 Evaluating Effects: Comparison to Permit Limits, Standards, and Baseline Conditions

In order to evaluate if measured contaminant concentrations in streams, groundwater, or springs could be a result of mining activity or pose a potential threat to the environment, the measured values should be compared to NPDES permit limits, water quality standards and criteria, and/or

baseline water quality values.¹ The NPDES permit contains average monthly and maximum daily numeric limits for industrial waters on the site, including water treatment plant effluent and stormwater. The permit contains no water quality limits for surface water or groundwater monitoring locations. However, the State of Washington has water quality standards that apply to streams and groundwater (State of Washington, 2010a, 2010b).

In addition to comparing measured site concentrations to State and Federal water quality standards, values can be compared to measured baseline values. Baseline water quality conditions were monitored at stream and groundwater locations as early as 1991. Surface water and groundwater monitoring locations are shown in Figure 1. Baseline water quality data through 2004 are provided and analyzed statistically in Golder Associates (2006b), and data from June 2004 through October 2007 are presented in Golder Associates (2010b). Upper tolerance limits (UTLs) for baseline water quality were developed by Ecology and Golder Associates for a number of monitoring locations at the mine and are presented in Golder Associates (2010b).

In the following sections, concentrations of constituents in effluent, mine water, surface water, groundwater, springs, and seeps are compared to permit limits, water quality standards, and baseline water quality conditions.

3.2 Concentrations in Potential Contaminant Sources: Treatment Plant Effluent, Underground Mine Water, and Mine Waste Leachate

The most likely sources of contaminants in groundwater and surface water around the mine are the discharge of treatment plant effluent, blasting of the underground mine, and the leaching of contaminants such as sulfate and metals from ore, development rock, and underground workings.

The treatment plant started operating in late 2007, and the first discharge to the environment occurred in January 2008 when mine operations began. The treatment plant started as an ion-exchange system; at the end of August 2009, an RO circuit was added to the treatment plant, as ordered by Ecology, to decrease concentrations of TDS and other contaminants. As shown in Figure 2, concentrations of ammonia, nitrate, chloride, sulfate, and TDS increased in the treatment plant effluent shortly after mining began. Effluent concentrations also exceeded permit limits for arsenic, mercury, chlorine, TSS, and zinc.

1. Baseline conditions are defined as concentrations of constituents present in site waters before mining affects water quality. Even though mine construction began in September 2006 and mine operations began in January 2008 (see Table 1), some locations may still reflect baseline conditions if concentrations measured before and after mining began are similar, within the range of natural variability.

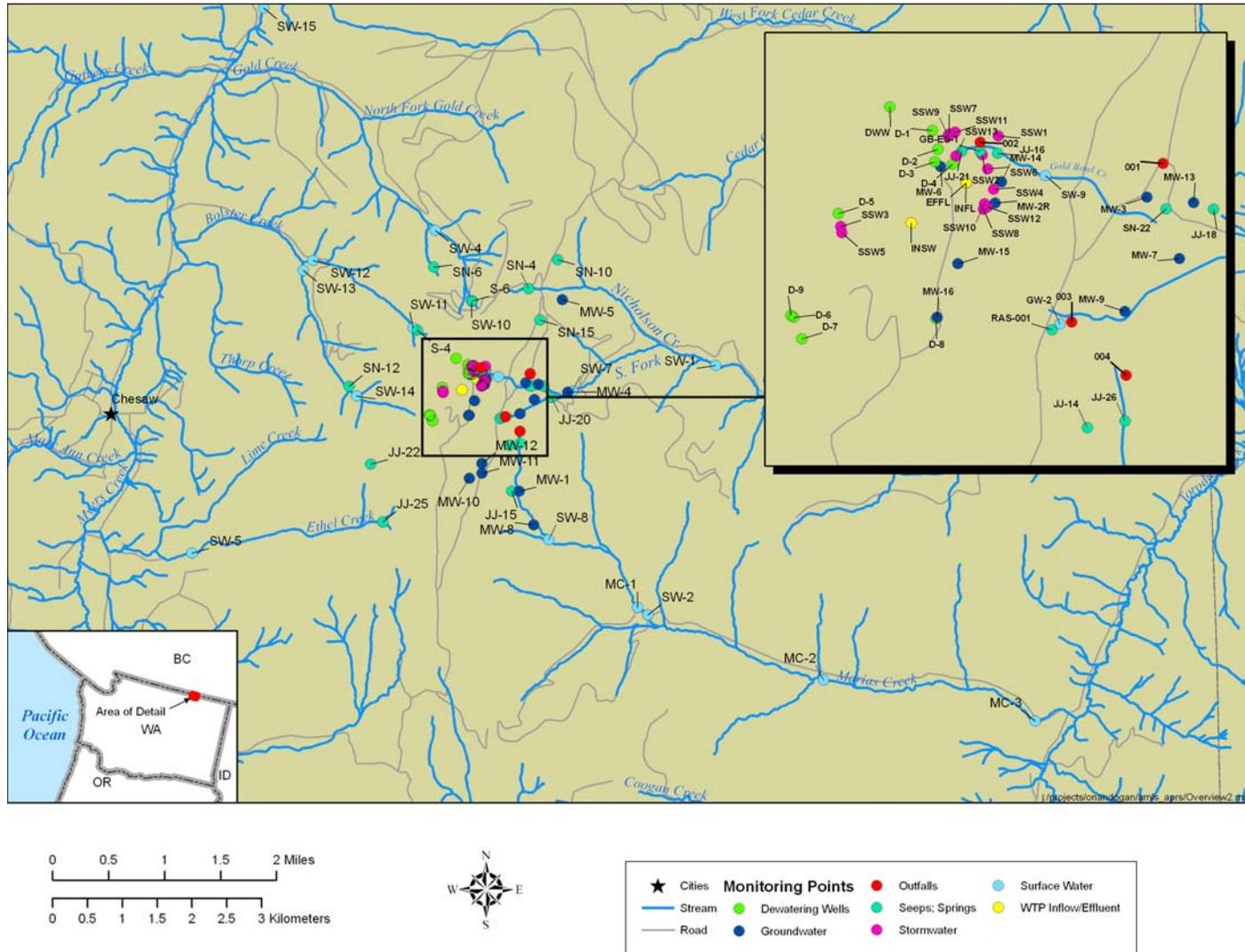


Figure 1. Monitoring location overview.

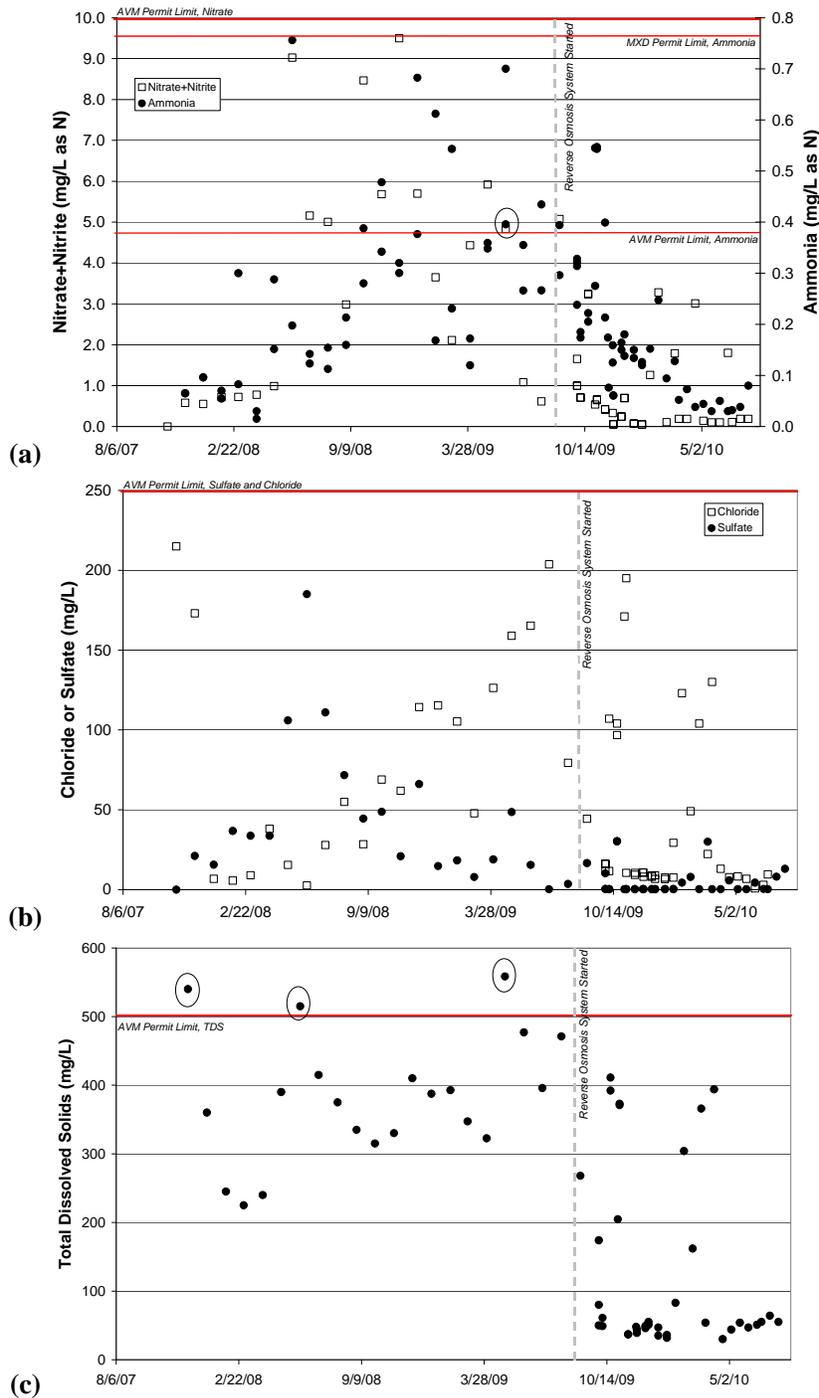


Figure 2. Treatment plant effluent concentrations over time: (a) nitrate+nitrite and ammonia, (b) chloride and sulfate, and (c) TDS. Measurements that exceeded permit limits are circled. AVM = average monthly permit limit; MXD = maximum daily permit limit.

Data source: Kinross, 2010b.

The mine has used Outfalls 1, 2, 3, and 4 for discharge of treated effluent since mining began (see Figure 1 for locations). The majority of the effluent has been discharged to Outfall 2, located in the headwaters of Gold Bowl Creek. Outfall 1 is the infiltration gallery, Outfall 3 is located at the Roosevelt Adit (Nicholson Creek drainage), and Outfall 4 is below the stock tank in the Marias Creek drainage basin. All outfalls are located on the east side of the mine.

The presence of nitrate and ammonia derives from the use of blasting agents (ANFO, or ammonium nitrate and fuel oil) to open up cavities in the underground mine. Nitrate concentrations in treatment plant effluent peaked in December 2008 at 9.5 mg/L as nitrogen (N), which is only 0.5 mg/L below the permit limit (Figure 2a). Only one effluent sample exceeded the average monthly permit limit for ammonia (0.384 mg/L as N) (see Figure 2a). Kinross began using breakpoint chlorination to destroy ammonia and nitrate in the effluent in mid-2009. Ecology issued NOV 6965 in July 2009, requiring Kinross to add an RO circuit to the treatment plant. The RO system became operational at the end of August 2009. Concentrations of nitrate and ammonia in the effluent have decreased since that time (see Figure 2a) to their current (2010) levels of approximately 0.1 mg/L ammonia (as N) and up to approximately 3 mg/L nitrate+nitrite (as N). However, nitrate concentrations in certain groundwater and surface water locations have remain elevated.

Chloride and sulfate effluent concentrations are displayed in Figure 2b. Chloride can derive from the ion-exchange component of the treatment plant: the anion-exchange columns take up anions such as nitrate from mine water and release chloride to maintain ion balance. However, effluent chloride concentrations are not notably higher than influent chloride concentrations. Another possible source of chloride is the sodium chloride brine used to regenerate the anionic column in the treatment plant (AMEC Geomatrix, 2010). Chloride concentrations were highest in sampling locations related to the upper or lower portals, including stormwater locations SS3, SS4, and SS8; the Lower Portal Sump Water; seep GBES1 in Gold Bowl Creek; MW14 (Gold Bowl Creek); and surface water location SW9 (Gold Bowl Creek). Chloride values at these locations were higher than those in the effluent. Sodium chloride brine may have entered the surge pond,² and water from the surge pond was stored temporarily in the Upper Portal drift in the underground mine in May 2008 (Golder Associates, 2009). However, the source of chloride needs further investigation. Leakage from the sumps along fractures could explain the elevated concentrations of chloride near the mine.

The presence of sulfate is related to the weathering of sulfides in the ore body and development rock. The most important sulfide weathering reaction at mines is the production of acid mine drainage from iron sulfide minerals, most notably pyrite. Pyrite and other metal sulfides are common in the Buckhorn ore body (Washington State Department of Ecology, 2006). The

2. Surge pond water derives from dewatering wells, mine sumps, and ore and development rock stockpiles. Treated water can be returned to the surge pond if it does not meet discharge standards. Surge pond water is sent to the treatment plant or can be temporarily stored in mine sumps (Golder Associates, 2007b).

development rock management plan requires that all exposed potentially acid-generating (PAG) rock in the underground workings above the long-term water table be lined with shotcrete to prevent the development of acid drainage. Kinross estimated that approximately 10,000 linear feet of workings will require shotcrete application (Golder Associates, 2006a). Sulfate can compromise the integrity of the shotcrete (Golder Associates, 2006a). Therefore, shotcrete should be applied shortly after the workings are drilled to prevent the production of acid drainage, which includes high concentrations of sulfate. Kinross applied shotcrete to PAG rock in 2008 but did not apply it to underground workings for PAG control after that time (Golder Associates, 2010a).

As shown in Figure 2b, concentrations of chloride and sulfate in treatment plant effluent were roughly inversely proportional before the RO system was installed. For example, low concentrations of sulfate were associated with high concentrations of chloride right after the plant began operating, and high concentrations of sulfate in mid-2008 were associated with low concentrations of chloride. Effluent sulfate concentrations have remained low since installation of the RO system; chloride effluent concentrations were elevated through early 2010 but have decreased to the 10-mg/L range recently (see Figure 2b). Sulfate and chloride concentrations have begun to decrease in some, but not all, surface water and groundwater locations downgradient or downstream of effluent discharges, as discussed in Sections 3.3 and 3.4.

The elevated concentrations of TDS in the effluent are related to sulfate and cations such as sodium and calcium in the wastewater. As with sulfate, TDS concentrations have decreased since the RO system was installed, but values were occasionally as high as approximately 400 mg/L through April 2010. TDS values exceeded permit limits within the first month of operation (Figure 2c). More recently, effluent TDS concentrations have remained relatively stable in the 30- to 60-mg/L range (Figure 2c).

An additional issue related to the treatment plant is the low hardness values after the RO circuit was added in August 2009. Most hardness values measured in the effluent after this time were below 10 mg/L as CaCO₃, although there were occasional values above 200 mg/L. The toxicity of certain metals, including copper, cadmium, lead, and zinc, to aquatic biota increases with decreasing hardness (U.S. EPA, 1999). RO removes most solutes from the treated water, and Kinross should consider adding calcium back into the water before it is discharged to the environment. Pre-mining hardness values in SW9, the location directly downstream of Outfall 002 in Gold Bowl Creek, ranged from 188 to 266 mg/L as CaCO₃ (Kinross, 2010b, April 2004 through August 2007, n = 19). Hardness values farther downstream from Outfall 002 in South Fork Nicholson Creek (location SW7) were somewhat lower and ranged from 115 to 200 mg/L as CaCO₃ under pre-mining conditions (Kinross, 2010b; January 2004 through November 2007, n = 41).

Mine water that flows into the treatment plant is a blend of water from the underground mine, groundwater from the pumping (dewatering) wells, some drainage from the ore and development

rock stockpiles, and stormwater (Golder Associates, 2007b). Treatment plant inflow nitrate concentrations have ranged from approximately 0.5 to 50 mg/L as N. Sulfate concentrations in treatment plant influent have ranged from approximately 30 to 180 mg/L, and chloride concentrations have ranged from < 1 to 191 mg/L. Concentrations of these contaminants in mine water from the upper and lower portal were the highest measured at the mine site, reaching approximately 425 mg/L chloride, 222 mg/L ammonia (as N), almost 3,000 mg/L nitrate, and 207 mg/L sulfate (Kinross, 2010b). Although more measurements are needed to distinguish the sources of contaminants in treatment plant influent, it is clear that nitrate, ammonia, and sulfate from the underground mine are important contaminants in treatment plant effluent. The source of high concentrations of chloride in the underground mine could be from use and storage of surge pond water in the underground mine. Because the upper end of the concentration range is higher in mine water than in effluent, it seems unlikely that the source of chloride in the underground mine is the treated effluent discharged at Outfall 002 that followed the North Lookout Fault (Golder Associates, 2010b).

Samples were collected from the PAG development rock storage pile in June 2010. The sample was collected from the vertical culvert on the west side of Road 6 at the PAG pile drain upstream of the desiltation basin (Falcon Price, Kinross, personal communication, September 23, 2010). The results, shown in Table 2, demonstrate that development rock left on the surface can generate acidic leachate with high concentrations of sulfate, nitrate, and TDS. Concentrations were highest during the spring flush as snow first melted (data not available; Falcon Price, Kinross Gold, personal communication, September 2010). The pathways for migration of contaminants from the PAG pile to groundwater or surface water are unknown at this time, but the potential exists for contamination of downgradient groundwater and surface water from PAG leachate. The PAG pile, located within the capture zone, is also located directly above a number of faults, which could move contaminated water outside of the capture zone. As shown in Figure 3, groundwater flow in the mine area is directed inward by the capture zone in places but also travels parallel to fault zones. According to Golder Associates (2009), the North Lookout, Northwest, and North East Fracture fault zones are the primary groundwater flow and transport pathways at the site. Contaminants in the underground mine can be transported along fault zones to downgradient surface water locations.

Table 2. Sampling results from PAG, development rock leachate collected on June 4, 2010

Parameter	Unit	Measurement
PH	SU	4.96
Specific conductance	microSiemens/cm	3,070
Nitrate	mg/L as N	166
Sulfate	mg/L	1,110
TDS	mg/L	2,480

SU = standard pH units.

Source: Kinross e-mail, September 23, 2010.

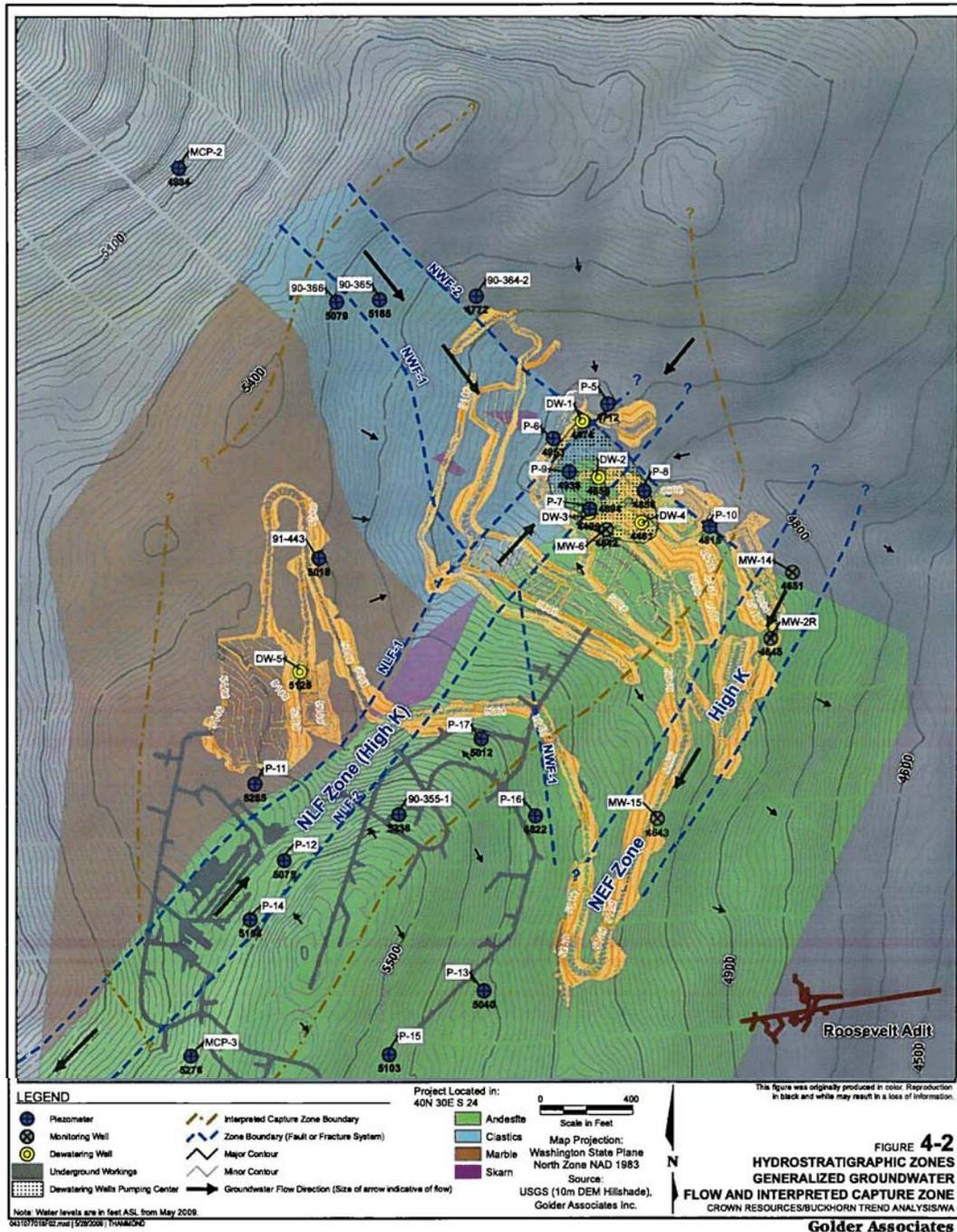


Figure 3. Groundwater flow directions, faults, and interpreted capture zone in the Buckhorn Mountain Mine area.

Source: Golder Associates, 2009, Figure 4-2. Note: Water levels are in feet above sea level from May 2009.

3.3 Effects on Surface Water

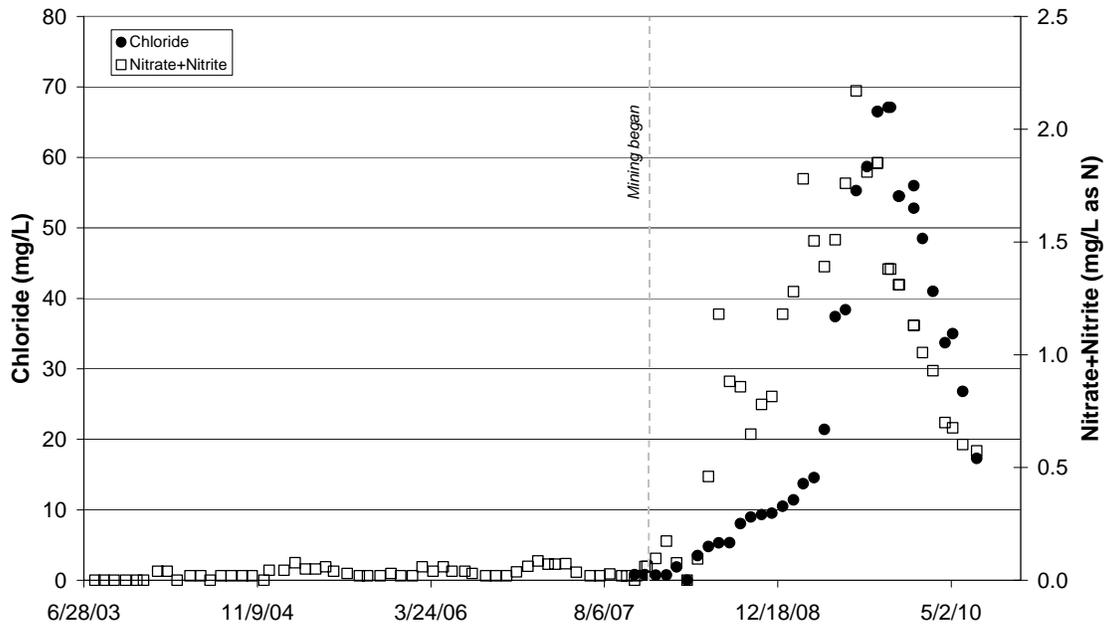
Surface water sampling points located downstream of Outfall 2,³ in Marias Creek, and in drainages to the west of the mine have had increasing concentrations of mine-related contaminants relative to baseline values since mining began. The primary constituents that have increased in concentration are chloride, nitrate+nitrite, sulfate, and TDS; in some locations, pH values have decreased over time. Generally, locations with elevated chloride concentrations also have elevated nitrate concentrations. As noted in Section 3.2, treated effluent has had elevated concentrations of chloride and nitrate. More recently, concentrations of nitrate and chloride have decreased in treatment plant effluent, largely related to the use of RO.

As shown in Figure 4, concentrations of chloride and nitrate+nitrite increased in South Fork Nicholson Creek (SW7), Gold Bowl Creek (SW9), and Upper South Fork Bolster Creek (SW14) shortly after mining and effluent discharge to Outfall 002 began. Concentrations of mine-related contaminants are higher in SW9, which is located closer to the mine and the effluent discharge location (see Figure 1 for location of Outfall 002).

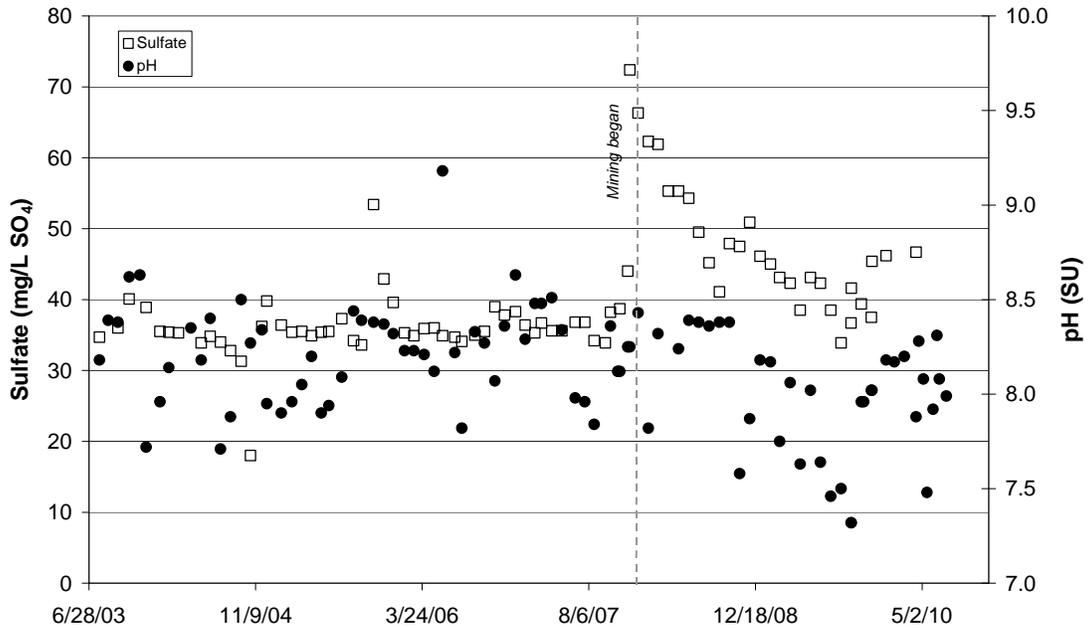
No water quality exceedences have occurred at SW7, but sulfate concentrations increased shortly after mining began, possibly mirroring the elevated initial sulfate concentrations in the effluent (see Figure 2b). Although not noted as an exceedence in Kinross's monthly discharge monitoring reports (DMRs), concentrations of chloride, nitrate, and sulfate in SW9 exceeded Federal and State water quality standards at different points in 2009 and 2010 (Figures 4c and d). In December 2008 and January 2009, chloride concentrations exceeded U.S. drinking water standards (250 mg/L), and in February 2009, values exceeded U.S. CWA criteria for the protection of aquatic life (230 mg/L; Figure 4c). Nitrate concentrations in SW9 exceeded U.S. and State of Washington drinking water standards in June 2009 (Figure 4c). Under premining conditions at SW9, sulfate and pH values were roughly inversely proportional, with the lowest pH values and highest sulfate concentrations occurring during the snowmelt period in the spring, and sulfate concentrations were at or below 100 mg/L (Figure 4d). In April and May 2010, sulfate concentrations in SW9 exceeded U.S. drinking water standards, as shown in Figure 4d.

Surface water monitoring point SW14, in Upper South Fork Bolster Creek, is located on the west side of the mine and is not downstream of a treatment plant outfall location. As shown in Figures 4e and 4f, concentrations of mine-related contaminants, including chloride, nitrate, and TDS, that are present in mine water have increased after mining began. Golder Associates (2010b) confirmed that maximum concentrations of TDS, chloride, and nitrate measured in

3. Outfall 2 infiltrates to Gold Bowl Creek; Gold Bowl Creek is upgradient of South Fork Nicholson Creek close to the mine. See Figure 5 inset for locations.



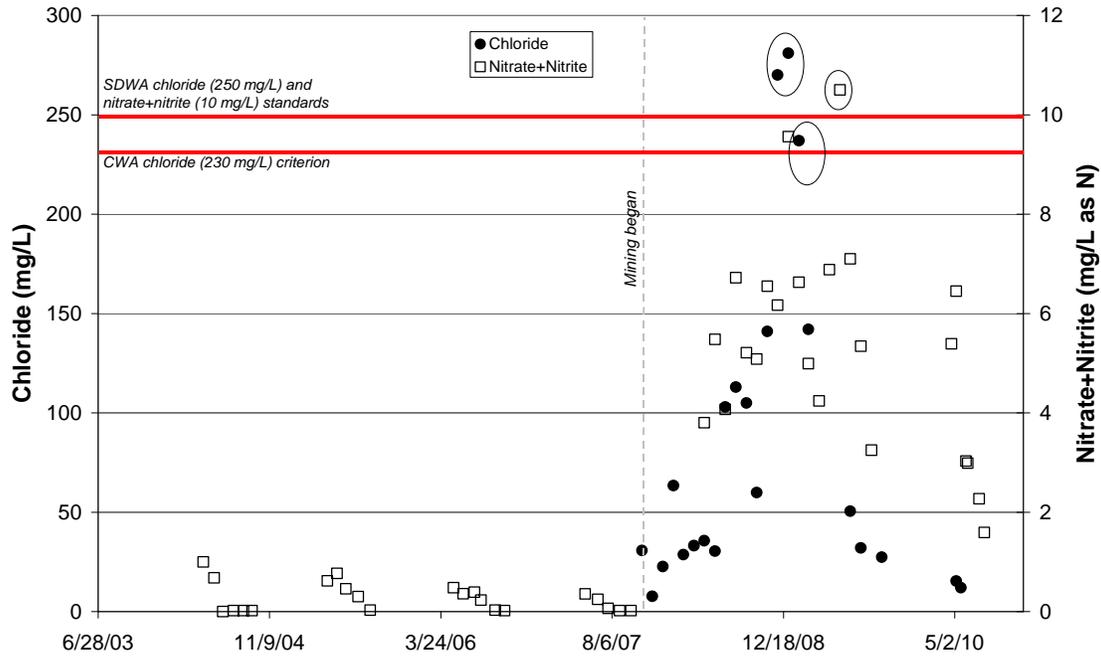
(a) chloride and nitrate+nitrite



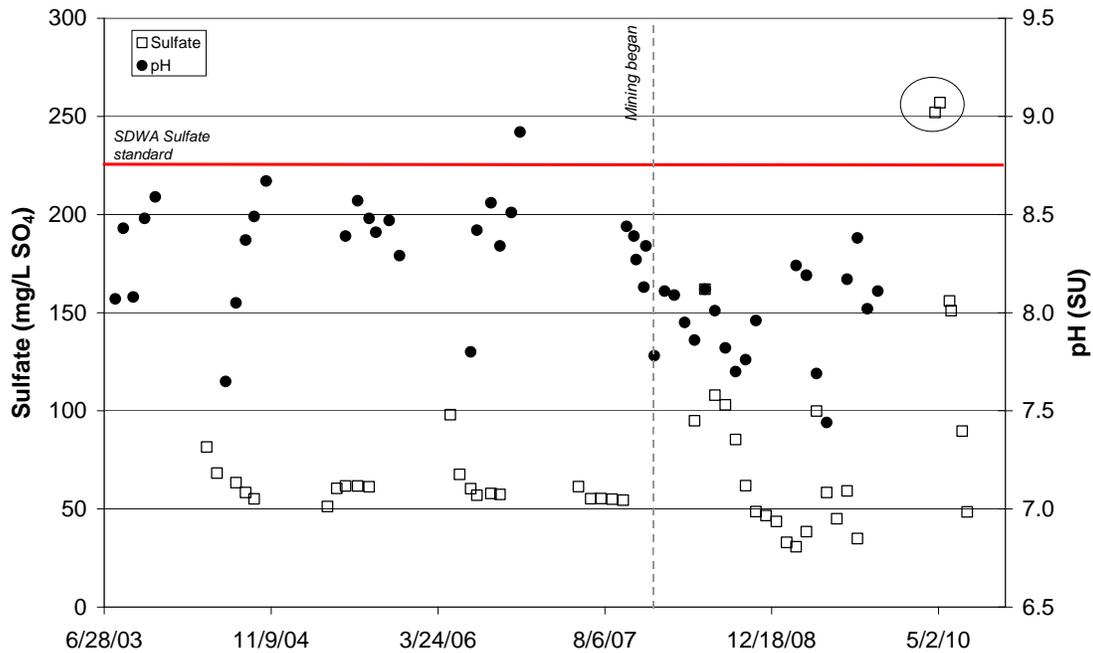
(b) sulfate and pH

Figure 4 (a–b). Concentrations of mine-related contaminants and pH values in South Fork Nicholson Creek (SW7) over time.

Data source: Kinross, 2010b.



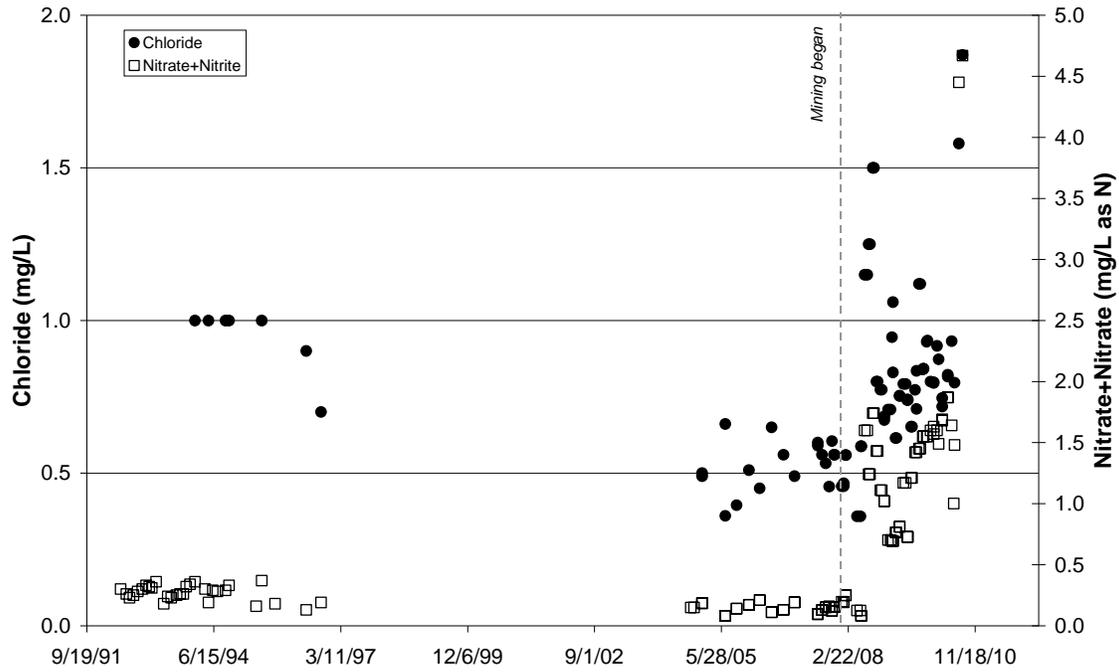
(c) chloride and nitrate+nitrite



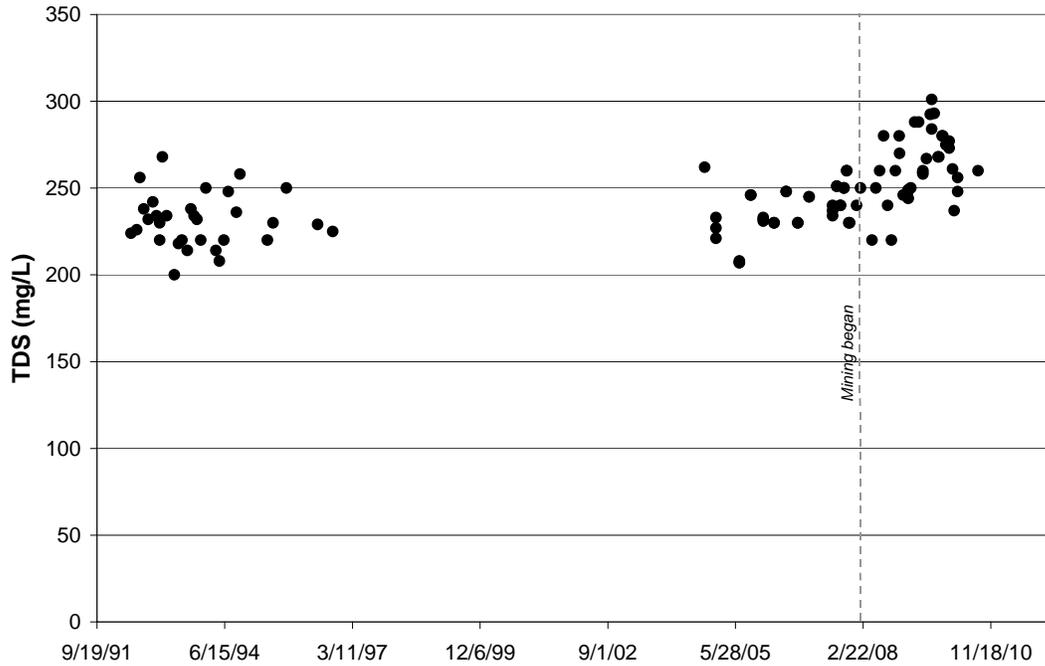
(d) sulfate and pH

Figure 4 (c–d). Concentrations of mine-related contaminants and pH values in Gold Bowl Creek (SW9) over time. SDWA = Safe Drinking Water Act. Circled points exceed water quality standards.

Data sources: Kinross, 2010b; source for water quality standards: U.S. EPA, 2009.



(e) chloride and nitrate+nitrite



(f) TDS

Figure 4 (e–f). Concentrations of mine-related contaminants in Upper South Fork Bolster Creek (SW14) over time. Note: Early chloride values were above detection but likely reflect higher detection limits at the time.

Data source: Kinross, 2010b.

Water Year⁴ 2009 exceeded baseline values (UTLs developed by Golder Associates and Ecology) at this location. Seepage from the underground mine has traveled along faults or other geologic features and reached South Fork Bolster Creek (Golder Associates, 2010b; also see Figure 3). The investigation of the increasing concentrations in SW14 was ordered by Ecology in April 2009 as part of AO 6674 and as related to penalty 6675. However, as shown in Figures 4e and 4f, concentrations of contaminants are still increasing, even though additional dewatering wells have been installed to capture the mine seepage.

Finally, increasing concentrations of chloride have been noted in the Marias Creek watershed in monitoring points MC2 and MC3 (Kinross, 2010b). Unlike the increasing chloride concentrations closer to the mine site, noted above, the source of chloride at the Marias Creek locations is attributed to runoff or infiltration from the haul road that runs along Marias Creek (Golder Associates, 2010b). However, the source of the chloride is still uncertain. MC2 has higher concentrations than MC3, which is located farther downstream. Concentrations of magnesium and sodium (if chloride increases are related to the use of magnesium or sodium salts on the road) show some increases, but sodium values for MC3 are higher than those at MC2, and magnesium values are higher at the upstream location, MC1. The pH values at all three Marias Creek locations have been decreasing since early 2009 (see Golder Associates, 2010b, Figure K-3.9).

A number of water quality parameters, including nitrate, ammonia, sulfate, pH, certain metals, and TDS, were plotted against time for all surface water, groundwater, seep/spring, and mine water sampling locations using the Kinross database (Kinross, 2010b). Water quality standards were plotted on the graphs, which were examined visually to identify locations with obvious changes in concentrations since mining began in December 2007/January 2008. Figures 5 through 8 show the surface water, groundwater, and seep/spring monitoring points with increasing concentrations and exceedences of water quality standards resulting from mining operations.

Surface water locations downstream of the outfalls have shown increases in chloride and nitrate concentrations (Figures 5 and 6), but locations to the west of the mine in the Bolster Creek drainage (SW13 and SW14) have also shown increasing concentrations of nitrate and/or chloride. As shown in Figure 5, large faults that intersect the underground workings connect with the upper reaches of the Bolster Creek drainage. As indicated on a map showing the location and capacity of sumps in the underground mine, there are two unlined sumps on the southwestern side of the underground mine with a combined capacity of nearly 860,000 gallons (Kinross, 2010a). Water stored in the underground mine might have leaked into upper Bolster Creek via the faults. As shown in Figure 7, three surface water locations on the east side of the mine, SW9, SW7, and GW2, have shown increasing sulfate concentrations. SW9 and SW7 are downstream

4. The Water Year begins on October 1 and ends on September 30.

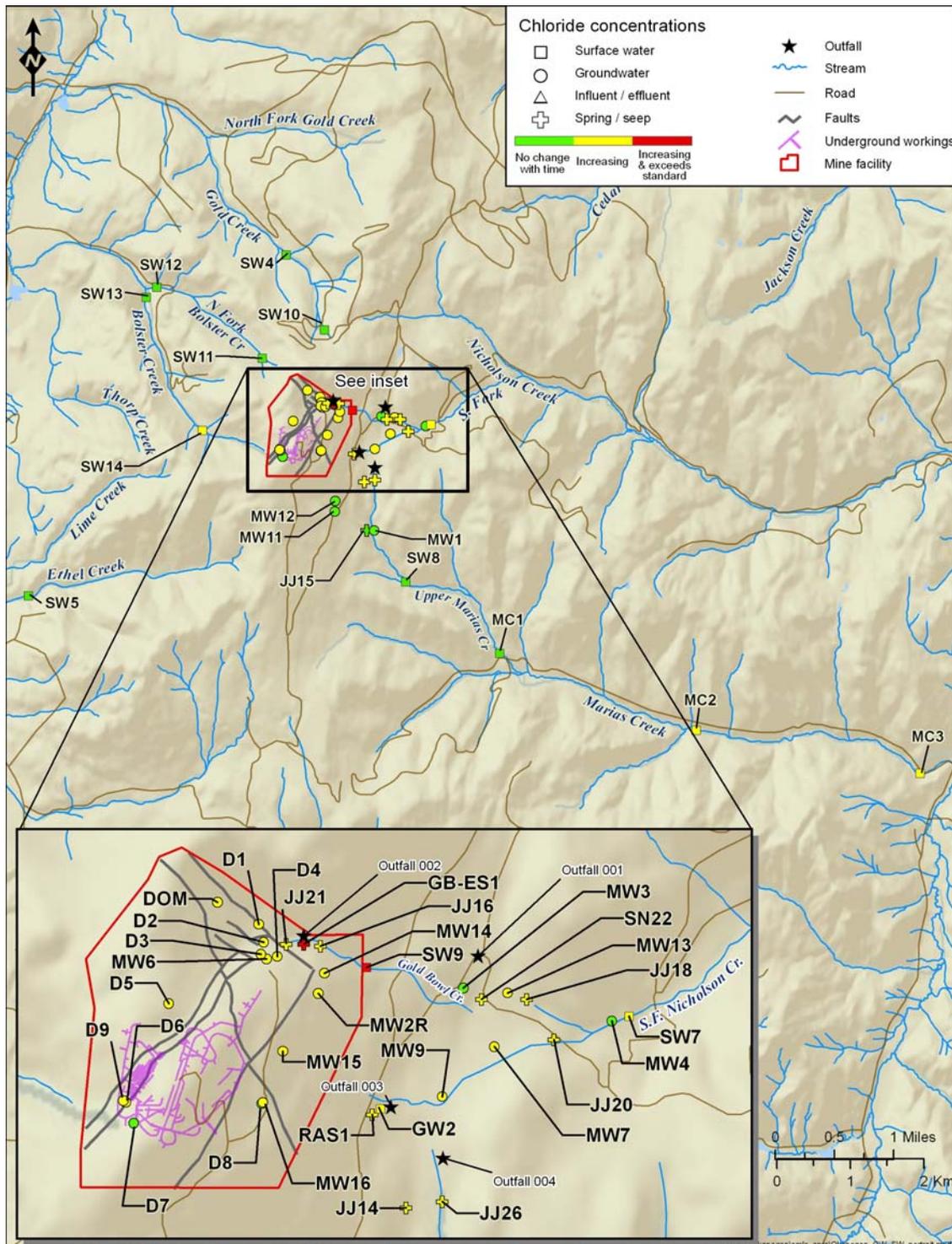


Figure 5. Surface water, groundwater, spring, and seep monitoring points with increasing chloride concentrations.

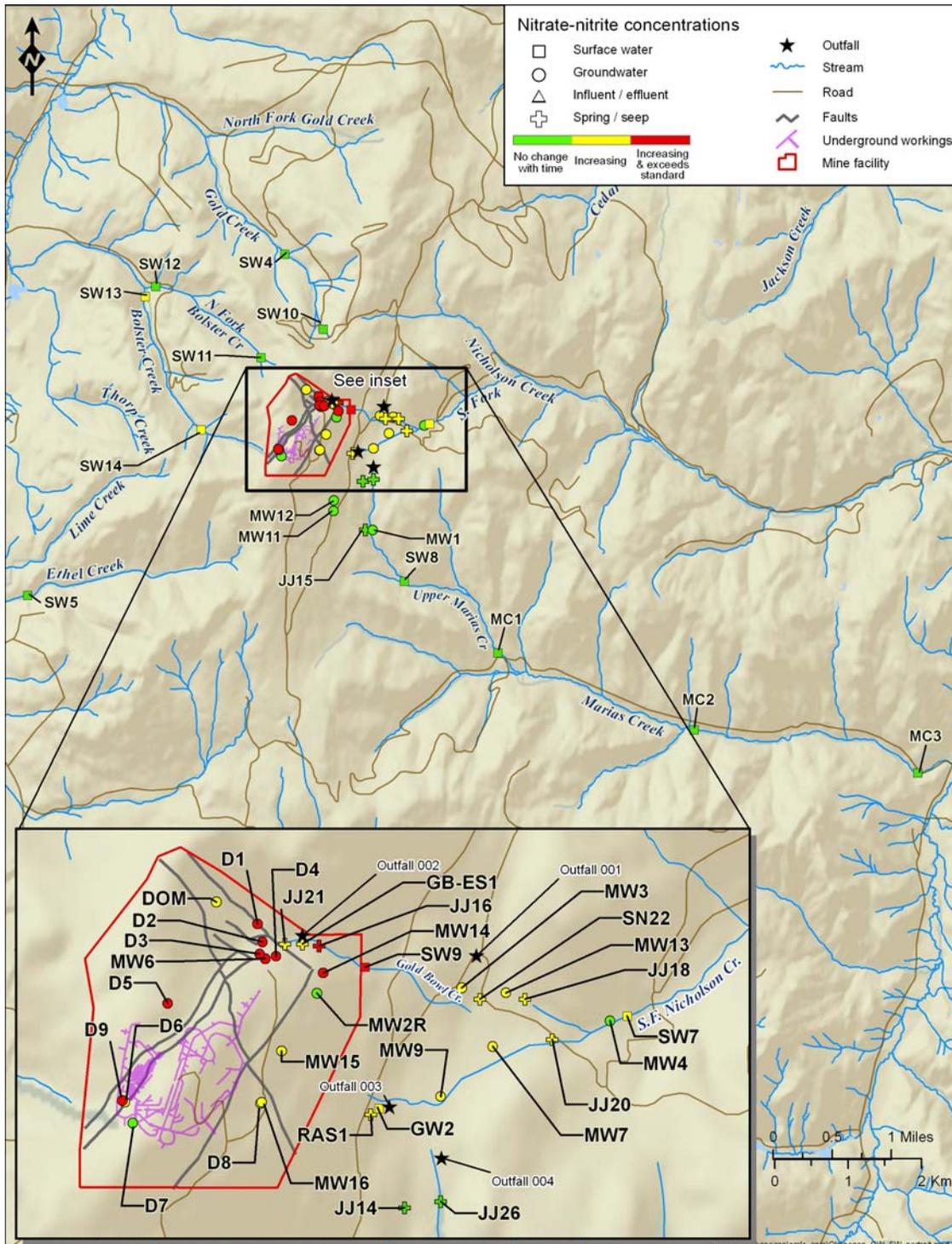


Figure 6. Surface water, groundwater, and spring/seep monitoring locations with increasing nitrate+nitrite or ammonia concentrations.

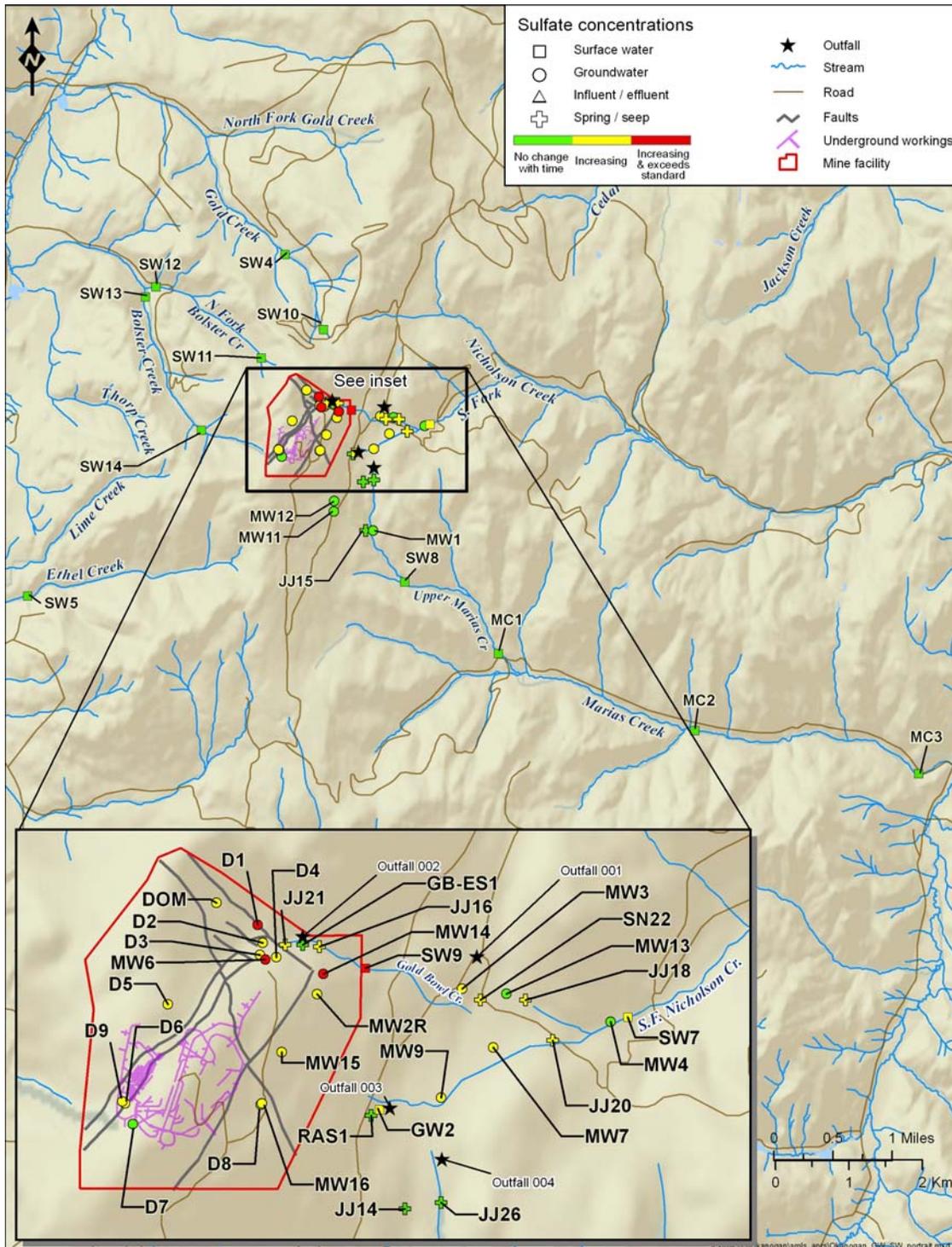


Figure 7. Surface water, groundwater, and spring/seep concentrations with increasing sulfate concentrations.

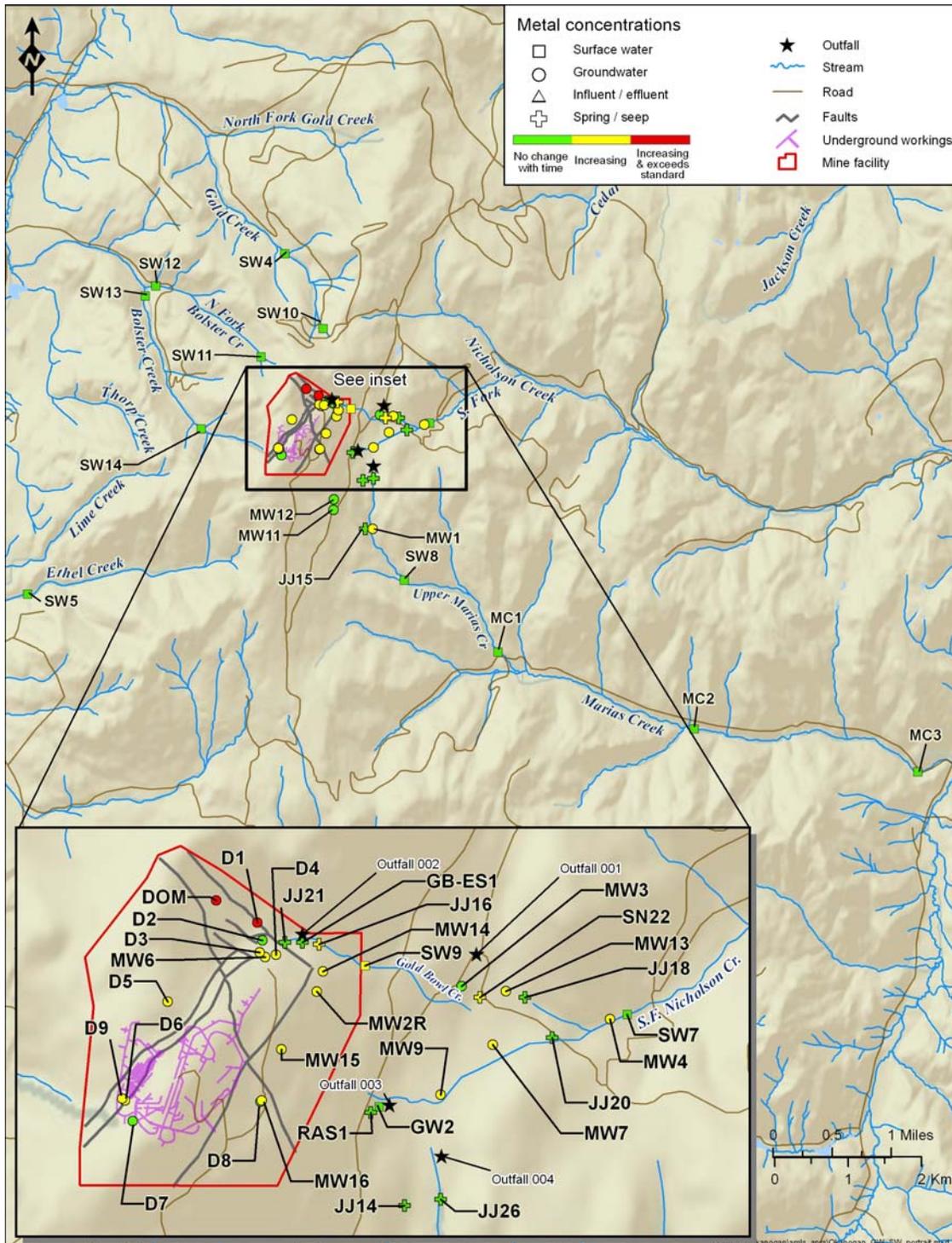


Figure 8. Surface water, groundwater, and spring/seep concentrations with increasing metal concentrations.

of Outfall 002, and GW2 (Roosevelt Adit) is the Outfall 3 location. SW9 also has increasing concentrations of copper and aluminum. In addition to the three locations in Marias Creek, SW7 has shown decreasing pH values, which could indicate the beginning of acid drainage.

3.4 Effects on Groundwater, Springs, and Seeps

3.4.1 Groundwater quality

The effects of mining on water quality in dewatering wells and monitoring wells are discussed in this section. The comparison to water quality standards for dewatering wells is considered valid because of the lack of a capture zone at the mine. If dewatering efforts were creating a reliable groundwater capture zone, groundwater inside the zone would flow to the mine dewatering system (dewatering wells or mine sumps), and mine contaminants would not be present in groundwater, seeps, or surface water. The five older dewatering wells, D1 through D5, located in Upper South Fork Nicholson Creek, have had increasing concentrations of nitrate, ammonia (D1 only), chloride, sulfate, TDS, and metals (D2 is an exception), and decreasing pH (see Figures 5 through 8). The primary metals with increasing concentrations are copper, selenium, manganese, mercury, and zinc; total zinc concentrations in well D1 have exceeded the drinking water standard of 5 mg/L. The five older dewatering wells have exceeded the State groundwater standard for nitrate+nitrite (10 mg/L as N), and four of the five wells (D2 excepted) have exceeded State secondary groundwater standard for TDS. Dewatering well D1 has also exceeded the State secondary groundwater standard for sulfate. The period of record is shorter for the newer dewatering wells installed in 2009 (D6, D8, D9); however, all measured nitrate and TDS concentrations in well D9 exceeded State drinking water standards of 10 mg/L as N and 500 mg/L TDS, respectively. The increasing nitrate concentrations indicate that blasting residue has affected water quality in these wells, and increasing concentrations of sulfate and certain metals and decreasing pH values suggest that the wells are also affected by acid drainage in the underground mine. The lowering of the water table by the dewatering wells could cause acid drainage to develop in sulfide-rich ore and rock above the water table near the wells, even though the pH of water in the mine sumps is neutral or basic, possibly as a result of backfilling with cement.

A domestic well located near the lower portal in Gold Bowl Creek has had increasing concentrations of nitrate, ammonia, chloride, sulfate, TDS, and metals and decreasing pH values. Arsenic concentrations increased through late 2009 (up to 9 µg/L) but started to decrease in January 2010 to background levels (~ 4 µg/L). Concentrations of manganese and lead have exceeded drinking water standards, and concentrations of copper, mercury, cadmium, selenium, and zinc have also increased in the domestic well.

Concentrations of nitrate, chloride, sulfate, and TDS in monitoring well MW14, located in Gold Bowl Creek drainage, are plotted in Figure 9. The trends in MW14 are typical of those in other groundwater wells affected by mining. In MW14, concentrations of nitrate, chloride, sulfate, and TDS increased shortly after mining began in early 2008. Concentrations, which peaked again in mid-2009 and mid-2010, may be related to flushes of contaminants after snowmelt. Baseline data for this location are minimal. MW6, located near the lower portal, has a longer baseline record (beginning in 2003). At this location, concentrations of arsenic decreased after mining began (from ~4 to 1–2 µg/L), but concentrations of nearly all other mining-related constituents have increased, including aluminum, chloride, copper, hardness, manganese, nitrate+nitrite, selenium, sulfate, and TDS.

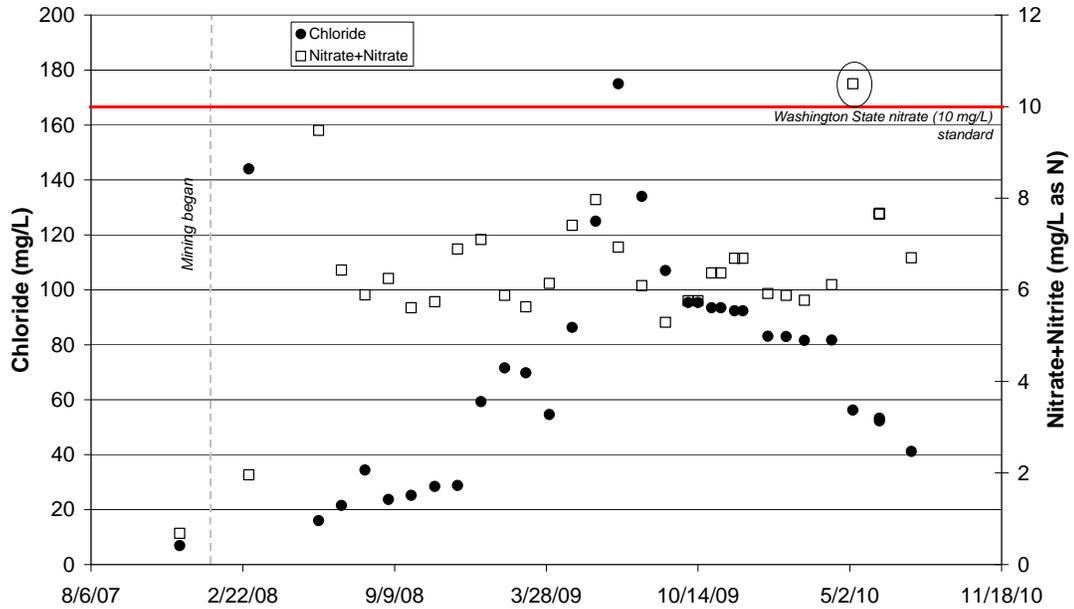
Chloride concentrations have increased in the same wells, with the exception of MW3, and in MW2R, which is located south of Gold Bowl Creek (Figure 5). As shown in Figure 6, groundwater nitrate or ammonia concentrations have increased in monitoring wells MW3, MW7, MW9, MW13, MW14, MW15, and MW16. These wells are located near the Upper Portal, in the Southwest Zone, and in Upper South Fork Nicholson Creek, which is near the treated water infiltration site. Nitrate values in well MW6, located near the lower portal, exceeded State drinking water standards for nitrate five times after mining began; values decreased after September 2008 but have increased recently, peaking at more than 15 mg/L in July 2010.

As shown in Figure 7, sulfate concentrations increased in the same wells, including MW3 and MW2R, with exceedences of the State secondary standard (250 mg/L) in wells MW6 and MW14. Metal concentrations have increased in many of the same wells and in MW1 in Upper Marias Creek and MW4 in Upper South Fork Nicholson Creek. Increasing groundwater metal concentrations were most commonly seen for aluminum, copper, mercury, arsenic, and manganese, and for selenium in well MW6 (Figure 8). Although pH values have increased at some locations recently, the older dewatering wells (D1 through D5), DOM, MW14, and MW15 have all shown decreasing pH values since mining began in 2008.

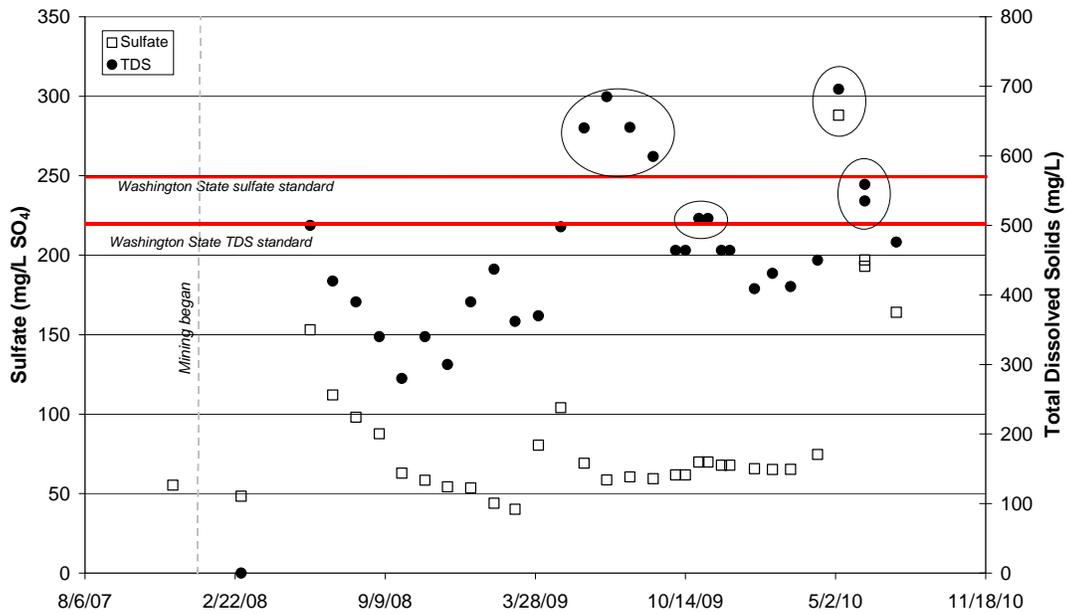
Overall, many of the monitoring wells close to the mine have shown increases in mine-related contaminants and acidity. Although concentrations are decreasing at some locations downstream of outfalls, other locations are still showing increasing contaminant concentrations.

3.4.2 Seep and spring water quality

Seep and spring water shows increases in the same mine-related contaminants as groundwater and surface water, including nitrate, ammonia, chloride, sulfate, and TDS. Metal concentrations, including iron, mercury, copper, aluminum, and antimony, have increased in certain springs and seeps. Several seeps had decreasing pH values after mining began.



(a)



(b)

Figure 9. Concentrations of mine-related contaminants in groundwater well MW-14, located near Gold Bowl Creek: (a) chloride and nitrate+nitrite; (b) sulfate and TDS. Values in excess of Washington State water quality standards are circled.

Data source: Kinross, 2010b.

Figure 10 depicts trends in mine-related contaminants in two seeps in South Fork Nicholson Creek located downstream of Outfall 002. For all springs and seeps, more recent baseline water quality data collection started immediately before mining began in January 2008; however, baseline seep data are also available in the original Crown Jewel Final Environmental Impact Statement (Volume 3, Appendix C). In JJ18, sulfate concentrations peaked about one year after mining began, while chloride concentrations peaked almost two years after mining began.

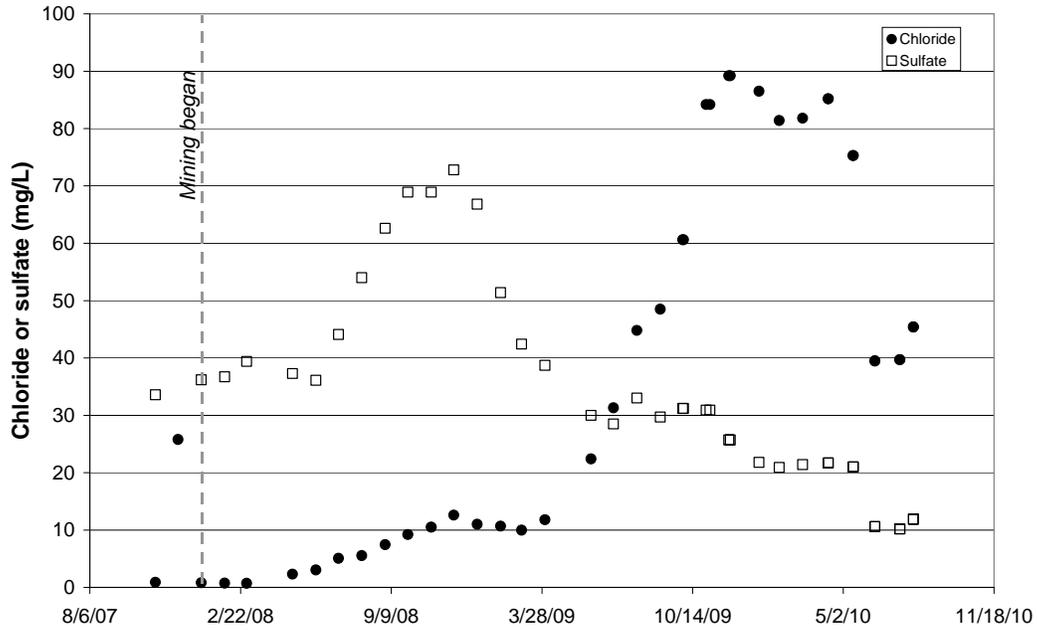
When chloride concentrations increased, sulfate concentrations decreased, suggesting that if treated effluent is the source of the contaminants, the effluent may have been diluting rising sulfate concentrations from the onset of acid generation.

As shown in Figure 10b, nitrate and chloride concentrations peaked at similar times in seep JJ16, also located in South Fork Nicholson Creek. Concentrations of chloride peaked in mid-2009, and nitrate values reached their peak and exceeded Washington State groundwater quality standards in November 2009. Chloride and nitrate concentrations have been decreasing since these times, possibly as a result of improvements in treatment plant operations.

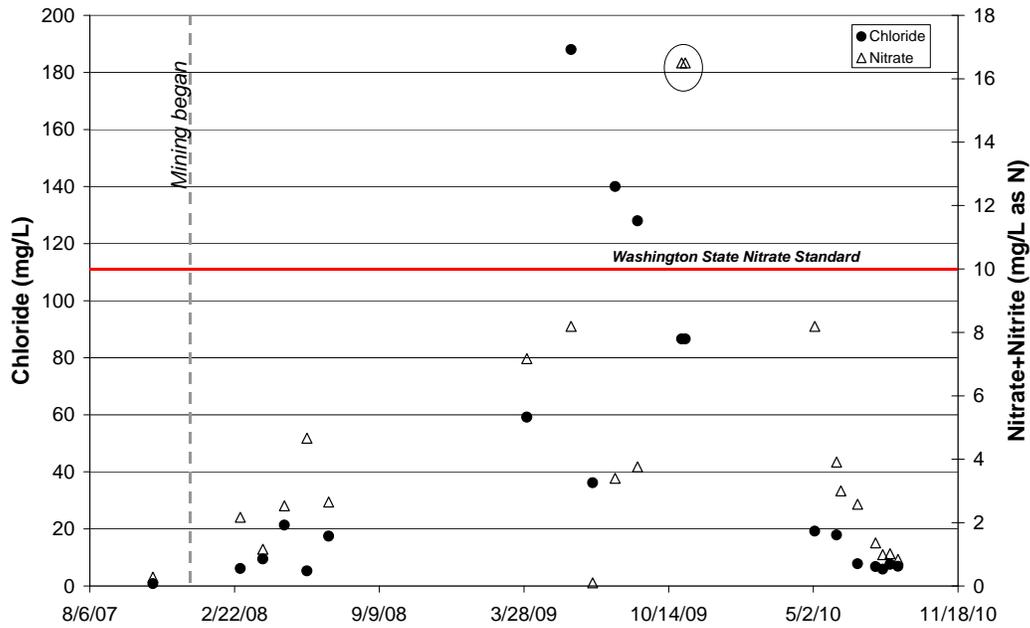
As shown in Figures 5 through 8, seeps located close to the Outfalls and the mine, in particular in the Nicholson Creek drainage, Marias Creek, and near the Roosevelt Adit, have had increasing concentrations of nitrate, ammonia, chloride, sulfate, and TDS since mining began. Several springs and seeps have shown decreasing pH values, including three in South Fork Nicholson Creek and one in Marias Creek. Most of the locations that have had increasing nitrate concentrations have also had increasing chloride concentrations (Figures 5 and 6). Seep JJ16 has had the highest concentrations of contaminants in seeps and has seen increasing concentrations of copper and mercury. The seeps in South Fork Nicholson Creek have had increasing concentrations of both sulfate and TDS since mining began. Hardness has also increased over time in a number of springs and seeps.

3.5 Predicted vs. Actual Water Quality in the Underground Mine and the Effectiveness of the Capture Zone

Mine water quality was predicted in the Final Supplemental Environmental Impact Statement (FSEIS; Washington State Department of Ecology, 2006) for the Southwest Zone, which is currently being mined, and the Gold Bowl area, which has not yet been mined. Water quality was predicted to be worse in the Gold Bowl workings, with a minimum pH of 2.6, milligram-per-liter concentrations of copper, and higher concentrations of aluminum, nickel, zinc, sulfate, and other contaminants (Table 3). Water quality in the underground mine, and therefore in treatment plant influent, is expected to worsen considerably as mining progresses into the Gold Bowl area. These predicted mine concentrations were used to estimate treatment plant influent concentrations before mining began (Golder Associates, 2010b).



(a)



(b)

Figure 10. Concentrations of mine-related contaminants in two seeps in South Fork Nicholson Creek: (a) JJ18, chloride and sulfate; (b) JJ16, chloride and nitrate+nitrite. Values in excess of Washington State water quality standards are circled.

Data source: Kinross, 2010b.

Table 3. Comparison between worst-case predicted and actual water quality in the Southwest Zone, and predicted Gold Bowl water quality in the Buckhorn Mountain underground mine (mg/L except as noted)

	Southwest Zone			Gold Bowl	
	Worst-case prediction	Actual (n = 26)			Worst-case prediction
		Min	Max	Mean ^a	
pH (SU)	4.9	8.12	12.6	9.63	2.6
Ammonia (mg/L as N)	2	0.35	127	28.3	2
Nitrate+nitrite (mg/L as N)	50	13	289	82.6	50
Chloride	0.91	12.7	234	67.5	0.94
Sulfate	138	83.9	272	152	535
TDS	251	373	1,740	1,010	749
Aluminum	2.8	< 0.08	11.6	3.1	9.0
Arsenic	0.018	0.004	0.061	0.019	0.02
Chromium	0.02	< 0.006	0.072	0.021	0.07
Copper	0.4	0.01	2.06	0.14	1.2
Iron	20	0.23	23	5.9	76
Manganese	0.41	< 0.004	0.41	0.13	1.6
Nickel	0.11	< 0.01	0.041	0.008	0.28
Selenium	0.013	0.001	0.01	0.003	0.03
Zinc	0.06	< 0.01	0.54	0.06	0.14

Note: Predicted metal concentrations are dissolved; actual concentrations were measured as total recoverable. Actual values are from the sample Southwest Zone in Kinross (2010b). Values in yellow exceed predicted concentrations; for pH, values in the Southwest Zone are highlighted if they exceed State of Washington groundwater standards (6.5 to 8.5; State of Washington, 2010a).

n = number of samples.

SU = standard pH units.

a. Average values were calculated using one-half detection limit for values below detection.

Sources: Washington State Department of Ecology, 2006, Table 3.7-11 (worst-case predicted values); Kinross, 2010b.

There are 26 water quality samples from water in the Southwest Zone sump, collected from October 2009 through August 2010. As shown in Table 3, the concentrations of a number of constituents (using maximum values for the Southwest Zone) exceed predicted values, including pH (high), ammonia (by up to 64 times), nitrate (by up to 6 times), chloride (by more than 250 times), sulfate (by 2 times), and a number of metals, including arsenic, chromium, copper, and zinc. These higher values are related to the presence of cement (high pH), blasting

(nitrate+nitrite and ammonia), surge pond water stored in the underground mine (nitrate and chloride), and sulfate and metals (oxidation of sulfides in the ore body). The elevated concentrations of sulfate and metals likely indicate that acid drainage has begun to form, but in the Southwest Zone the acid may have been neutralized by the cement used to backfill the primary stopes in the mine.

The higher concentrations of mine-related contaminants have put a strain on the treatment plant. Kinross was required by Ecology AO 6079 to modify the treatment plant and compare predicted and actual influent water quality. This comparison was made by Golder Associates (2008). Because the treatment plant influent water is now a mix of dewatering water and Southwest Zone mine water, only arsenic, zinc, and chloride influent concentrations exceeded predicted mine water concentrations (Golder Associates, 2010b, Table D-2). However, because the treatment plant was not operating properly and the capture zone had not successfully contained mine contaminants, the discharged water has caused concentrations of mine-related contaminants to increase in groundwater, springs, and surface water. In addition, the quality of the water pumped from the dewatering wells has worsened over time.

AO 6079 also required Kinross to evaluate water quality trends and explain the observed changes. According to the report, the increases in nitrate and chloride in summer 2008 in the South Fork Bolster Creek (SW14) are related to seepage from mine water that was stored in the underground mine near the Upper Portal (Golder Associates, 2009). The report notes that chloride concentrations are now close to pre-mining levels and that only slightly elevated nitrate concentrations remain. However, as shown in Figures 4e and 4f, nitrate concentrations were higher in the summer of 2010 than in the summer of 2008. The recent water monitoring data indicate that water quality problems are continuing and preferential pathways between sources of contamination, including sumps and drifts in the underground mine, and SW14 still exist. The NPDES permit requires that the mine establish and maintain a groundwater capture zone to include all underground mine workings, the surge pond, and all surface stockpiles of ore and development rock (permit condition S1.D).

Golder Associates believes that a capture zone has existed under the Main Portal and surge pond from the beginning of mining (January 2008) to the present, but not from early May to mid-July 2008 (Golder Associates, 2009). During this time, the dewatering wells were only operating intermittently because of problems at the treatment plant (Golder Associates, 2009). Some monitoring wells (e.g., MW14, MW2R, and MW15) are outside of the capture zone, and Golder Associates attributes the increasing concentrations of contaminants in these wells and in surface water to movement of mine water along large faults (Golder Associates, 2009; see Figure 4-2). New dewatering wells have been installed on the west side of the site. These wells (D6 through D9) have not been effective at decreasing concentrations of mine-related contaminants on the west side of the mine.

4. Summary

The Buckhorn Mountain Mine is a relatively new gold mining operation that does not process ore on site. It has been operating for less than three years yet has accumulated more than 125 permit violations (permit exceedences and non-reporting violations), 6 NOVs, and 3 AOs from the Washington Department of Ecology related to the mine's environmental performance. The findings of the report include:

- ▶ Concentrations of mine-related contaminants have increased in a number of streams, springs, and groundwater near the mine since mining began. The principal contaminants that have increased relative to premining conditions are chloride, nitrate, ammonia, sulfate, and TDS.
- ▶ Although not noted as exceedences in Kinross's monthly DMRs, concentrations of chloride, nitrate, and sulfate in certain surface water and groundwater monitoring locations exceeded Federal and State water quality standards in 2008, 2009, and 2010.
- ▶ The primary causes for the increases in mine-related contaminants in groundwater and surface water are the discharge of inadequately treated water (chloride, sulfate, nitrate, and ammonia), use and storage of surge pond water in the underground mine (chloride and nitrate), blasting in the underground mine (ammonia, nitrate, and oil and grease), leaching of cemented backfill (higher pH), and the impact of incipient acid drainage from mined materials (sulfate, metals, and lower pH).
- ▶ Water quality in the underground mine is worse than predicted in the FSEIS. These underestimates were used to design the water treatment plant. Plant upgrades have been required because the original predictions were overly optimistic. The upgrades have effectively lowered concentrations of mine-related contaminants in treatment plant effluent.
- ▶ Some locations have recently shown improvements in water quality. Improvements in water treatment, especially the use of RO, have lowered concentrations of chloride at locations downstream of the outfalls. However, nitrate concentrations, which may be related to a combination of blasting and the effects of treated discharge, have been decreasing more slowly.
- ▶ Water treatment improvements have lowered hardness values in the effluent to < 10 mg/L as CaCO₃. The toxicity of certain metals to aquatic biota increases as hardness decreases. Stream locations downstream of Outfall 2 had pre-mining hardness values ranging from 115 to 266 mg/L as CaCO₃.

- ▶ Water quality in the underground mine (Southwest Zone) is substantially worse than predicted in the FSEIS. Water quality in the underground mine, and therefore in treatment plant influent, is expected to worsen considerably as mining progresses in the Gold Bowl portion of the deposit.
- ▶ A reliable groundwater capture zone has not been established around the mine. Consequently, contaminated water from the underground mine has traveled along large fractures and contaminated streams and groundwater on the western and eastern sides of the mine.

5. Recommendations

Based on the findings in this report, we recommend the following actions to improve water quality and oversight of the mine:

- ▶ Note any violation of State water quality standards in streams, groundwater, seeps, or springs in the monthly DMRs and annual monitoring reports. Following procedures for violation of NPDES permit limits, if a water quality standard is exceeded in groundwater or surface water, retest the water and subsequently test more often.
- ▶ Consider all mine management that differs from the original operations plan as adaptive management and include in the AMP annual reports (e.g., storing surge pond water in the underground mine).
- ▶ Consider adding calcium bicarbonate to the effluent before discharging treated water to the environment.
- ▶ Monitor surface water and groundwater locations, especially those close to the underground mine, for oil and grease or total petroleum hydrocarbons. Blasting agents (ANFO) have been used in the underground mine, and high oil and grease concentrations have been measured in mine water.
- ▶ Kinross should implement shotcreting of PAG headings as required by the DRMP and AMP. In addition, Kinross should monitor water quality and levels and estimate the effect of PAG pile and ore stockpile leakage on groundwater quality. Depending on the results of this investigation, Kinross should consider covering and lining (with a synthetic liner and leachate collection system) any new PAG piles.
- ▶ Predicted concentrations in the underground mine from the FSEIS should be compared to actual mine water concentrations rather than or in addition to treatment plant influent

concentrations in the Kinross annual reports. Knowing how mine water quality is evolving will help inform future treatment plant modifications.

- ▶ Evaluate the possible sources of chloride in the underground mine and in downgradient groundwater and surface water.
- ▶ As promised in 2008 by Buckhorn Mountain Mine's previous General Manager, Lauren Roberts, the mine needs to be brought under environmental control before expanding into the Gold Bowl portion of the deposit. Demonstrate that the mine can operate for an extended period of time without significant violations, orders, or AMP triggers.
- ▶ Monitor water quality of all surface water locations west of the mine and all mine sumps storing more than 500 gallons of water, and report results in the monthly DMR.
- ▶ Because of the rapid travel times for water along faults in the underground mine, do not use mine sumps or underground workings to store water unless they are securely lined.
- ▶ Regularly monitor water quality at the PAG and development rock piles. Leachate from these piles could be migrating along faults and escaping capture, and this possibility should be investigated.

References

AMEC Geomatrix. 2010. All Known, Available, and Reasonable Methods of Prevention, Control, and Treatment (AKART) Engineering Report. Buckhorn Mountain Mine water treatment facility, Okanogan County, Washington. Prepared for Crown Resources Corporation by AMEC Geomatrix, Inc. February 1.

Crown Resources. 2010. Letter to Department of Ecology (Bob Raforth) Re: Action Plan for Observed Seepage in Gold Bowl Creek. June 24.

Golder Associates. 2006a. Buckhorn Mt. Project Development Rock Management Plan. Prepared for: Kinross Gold USA, Inc. and Crown Resources. November 10.

Golder Associates. 2006b. Buckhorn Mt. Project Engineering Report Addressing WAC 173-240. March 15. Appendix C. Technical Memorandum: Buckhorn Mt. Project – Statistical Analysis of Background Water Quality for Use in Water Management Plan. December 21, 2004.

Golder Associates. 2007a. Buckhorn Mt. Project Adaptive Management Plan. Submitted to Crown Resources and Kinross Gold USA. June 25.

Golder Associates. 2007b. Report on Buckhorn Mt. Project Engineering Report Addressing WAC 173-240, Revision 1. August 31.

Golder Associates. 2008. Technical Memorandum to Lauren Roberts and Larry Perino, Kinross Gold USA, Re: Response to Department of Ecology Administrative Order 6079: Comparison of treatment plant operational influent water quality to predicted water quality – Buckhorn Mine from Kristin Salzsauler and Rens Verburg, Golder Associates Inc., Redmond, WA. October 22.

Golder Associates. 2009. Report on Water Quality Trend Analysis, Buckhorn Mountain Mine. Submitted to Crown Resources Corporation. June 1.

Golder Associates. 2010a. Buckhorn Mountain Mine, Adaptive Management Plans – Water Year 2009. March 3.

Golder Associates. 2010b. Buckhorn Mountain Mine, Hydrological Data Report – Water Year 2009. March 3.

Kinross. 2010a. Map of sump locations and capacity, Buckhorn Mine, 8/18/09. Provided by Falcon Price by e-mail on September 23.

Kinross. 2010b. Water quality and level data delivered to the Washington Department of Ecology and Stratus Consulting in electronic format.

State of Washington. 2010a. Ground Water Quality Criteria. WAC 173-200-040. Available: <http://apps.leg.wa.gov/WAC/default.aspx?cite=173-200-040>. Accessed September 22, 2010.

State of Washington. 2010b. Surface Water Criteria. Available: <http://www.ecy.wa.gov/programs/wq/swqs/criteria.html>. Accessed September 22, 2010.

U.S. EPA. 1999. *National Recommended Water Quality Criteria*. Document #822-Z-99-001. U.S. Environmental Protection Agency. April.

U.S. EPA. 2009. National Recommended Water Quality Criteria. Office of Water, Office of Science and technology (4304T). Available: <http://www.epa.gov/waterscience/criteria/wqcriteria.html>. Accessed September 22, 2010.

Washington State Department of Ecology. 2006. Buckhorn Mountain Project, Final Supplementary Environmental Impact Statement.

Washington State Department of Ecology. 2007. National Pollutant Discharge Elimination System Waste Discharge Permit No. WA-00524304. Crown Resources Corporation.

