APPENDIX D: Baseline Environmental Geochemistry Evaluation

Appendices (Electronic Only)

D-A. Baseline Environmental Geochemistry, 2012 Johnny Lee Decline
D-B. Wetlands Functional Assessment Report
D-C. Water Rock Kinetic Data
D-D. Static and Kinetic Tailings Data

DRAFT

BLACK BUTTE COPPER PROJECT

BASELINE ENVIRONMENTAL GEOCHEMISTRY EVALUATION

2015 Operating Permit

Prepared for

Tintina Resources
White Sulphur Springs, MT

Prepared by

1807 W. Dickerson St., Suite D
PO Box 1685 (59771)
Bozeman, Montana 59715

November 18, 2015

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Executive Summary

The acid generation and metal release potential of waste rock, construction rock, and tailings to be produced by the Project has been characterized using static multi-element analysis, acid-base accounting, net acid generation potential, and kinetic methods. Mineralogical analyses of metal residence and asbestiform mineral analyses were also completed. Results are reported through October 2015, although some tests are ongoing.

Waste rock from the Lower-Zone Footwall (*LZ-FW*, 35% of waste rock tonnage), the Lower Newland basal shale and conglomerate (*Ynl* B, 32%), the Upper Sulfide Zone (*USZ*, 28%), and the Undifferentiated Lower Newland (*Ynl*, 4%) will be produced by the Project. This rock will be exposed in underground access workings and, temporarily, in active stopes. It will also be stockpiled for up to 2 years on a lined surface pad prior to being co-disposed with cemented tailings early in mine life. Additional waste lithotypes representing tonnages less than 1% (including *IG*, *Ynl 0*, *Yne*, and *Yc*) have also been characterized. Shallow, weathered near-surface bedrock deposits of the *Ynl* and sill-form granodiorite intrusives will be excavated in a 2:1 ratio during construction and used to build mine facilities. Static ABA, NAG and SPLP tests, along with asbestiform mineral characterization, are underway for the granodiorite and will be reported at a later time.

Tintina proposes to produce tailings via flotation and to blend them with cement/binders to create cemented paste tailings. Tintina proposes to use a drift and fill mining method, placing 45% of produced tailings as 4% cemented backfill into mined out underground stopes and access headings during operations. All remaining tailings (approximately 55%) will be placed as 0.5 to 2% cemented paste into a double lined surface tailing impoundment (the CTF). The tailings impoundment is designed to have little or no water stored in the facility. Most waste rock will be produced during construction of the decline and other underground workings and will be placed into the lowermost CTF, where it will subsequently be covered by paste tailings. Run-of-mine (ROM) waste rock will also be placed around the sump to develop a positive drain within the CTF, and later encapsulated with paste tailings. It is possible that alternative management strategies including dry stack tailings and a subaqueous tailing impoundment will be considered during the MEPA assessment. The testing program has addressed all proposed management options and anticipated alternatives. Raw (non-amended) tailings were, therefore, tested along with cemented paste tailings with 2 and 4% cement binders, and 4% cement binder mixed with 10%, by weight, ROM to simulate alternative disposal methods. Tailings were tested under both subaerial weathering and saturated conditions.

Waste Rock Geochemistry. A total of 7,497 whole rock samples were statistically analyzed to characterize overall geochemical variability within multiple lithotypes and to identify representative sample subsets for static testing. No asbestiform minerals were identified in any lithotype to be mined from the Project. A total of 156 static tests of acid generation potential, using both acid-base accounting (ABA) and net acid generation (NAG) methods, were completed by ALS Laboratories (Sparks NV) for the dominant waste rock lithotypes. Results of ABA and NAG tests indicate that the majority of *Ynl B* and *Ynl* samples (90%) are unlikely to form acid, while many *USZ* and *LZ-FW* samples have an uncertain potential or are likely to generate acid.

Kinetic tests of *Ynl B*, *USZ*, and *Ynl* waste rock collected from the vicinity of the previously proposed Johnny Lee decline were completed by McClelland Laboratories

(Sparks NV) following ASTM protocol D5744 in 2012. The *Ynl* composite tested in 2012 was comprised of subsamples that were representative of this lithotype site wide, but the *Ynl B* and *USZ* composites were not. To address this limitation, additional tests of these two waste rock lithotypes were initiated in 2015 using representative subsamples collected site wide. Also, as a result of 2015 changes in the mine plan, the *LZ-FW* was identified as roughly one-third of the waste rock tonnage to be produced; representative samples were, therefore, identified, analyzed, and composited for kinetic testing of this unit as well. For this reason, three kinetic tests of waste rock remained online at the end of October 2015. The *USZ* and *LZ-FW* kinetic tests were in week 19 and the *Ynl B* was in week 17. They will remain online until steady state geochemical conditions are attained and regulatory approval for termination is obtained, to ensure that all testing objectives have been met.

Sulfide oxidation was observed in HCT tests for the four volumetrically significant waste rock units. However, consistent with static test results and the presence of abundant carbonate minerals, oxidation in the *Ynl B*, *Ynl*, and *LZ-FW* tests has not produced sufficient acidity to deplete alkalinity nor have these tests produced acidic pH values. Despite indications of sulfide oxidation, depleted alkalinity and increased acidity with lower pH was only evident in the 2015 *USZ* test. Some of these tests are ongoing and this interpretation is therefore subject to change.

All assessments of metal release potential for waste rock lithotypes (tonnage >1%) and tailings have been based on metal concentrations measured in kinetic test effluents in weeks 0, 1, 2, 4, and every 4 weeks thereafter. Despite maintaining neutral pH in the test cells, the *Ynl B*, and *Ynl* units showed potential to exceed surface water quality standards for some metals in early weeks of kinetic testing. However, they do not exceed groundwater standards after week 2. The *LZ-FW* and *USZ* units, however, have shown potential for release of several metals in excess of surface water standards in multiple weeks. With the exception of week 0, no groundwater criteria were exceeded in leachate from the 2012 test of *USZ* rock, but the 2015 sample did exceed groundwater standards for Ni and Hg, in weeks 1 and 2, and for Sr and Tl throughout the test. Because each of the waste rock lithotypes has some, if not significant, potential to generate acid or release concentrations of metals in excess of water quality standards, waste rock will be encapsulated in paste tailings in the lined and monitored CTF impoundment. Furthermore, Tintina proposes to collect all seepage from the waste rock stockpile, the CTF, and the underground workings for treatment to non-degradation standards for groundwater prior to discharge. Potential for impact to surface and groundwater is therefore low.

Mineralogical analyses, using the Mineral Liberation Analysis/scanning electron microscopy method, were completed by MT Tech Center for Advanced Mineral Processing on samples of waste rock pre- and post-weathering in 2013, to evaluate the mineral residence of metals of interest, such as Tl and Se. The *Ynl B* (2012 sample) was comprised of quartz, dolomite, muscovite, potassium feldspar and pyrite (1.6%); the *Ynl* sample was similar but also contained biotite, barite and 10.8 % pyrite. The 2012 *USZ*, like the undifferentiated Ynl unit, contained quartz, dolomite, muscovite, and potassium feldspar; it also contained 45% pyrite. No discrete mineral phases containing Tl or Se were identified, but analysis of the Tl and Se content of heavy liquid separates (which separated the light feldspars from the heavy sulfides) suggested that these elements which occurred commonly in humidity cell effluent occur as trace substitutes in the sulfides.

Predictive models of water quality from the underground workings during operations and at closure, from the waste rock stockpile, and from the CTF sump are also being developed and will be reported at a later time.

Tailings Geochemistry. Splits of homogenized tailings reject produced in bench-scale metallurgical testing were used for all tests. While there is some variation in acid generation potential and neutralization potential, the ABA and NAG tests indicate that the tailings will have a strong potential to generate acid with or without paste amendment. The neutralization potential resulting from the addition of 2 and 4% cement binder is not sufficient to neutralize the sulfide in the tailings. This was not the intent of cement addition, however. Cement was added to provide structural strength in support of drift and fill mining methods underground, and to change the physical properties of the material to a stable, non-flowable material with low hydraulic conductivity: on the order of 1^{-9} m/sec in both surface and underground settings.

Cemented paste tailing cylinders were tested (without crushing) in conventional ASTM method D5744 humidity test cells to simulate sub-aerial weathering and in ASTM C1308 diffusion tests to simulate diffusion through backfill in saturated underground workings. Raw (non-amended) tailings were tested using ASTM method D5744, both sub-aerially and in a modified, saturated test, to represent the alternative scenarios of dry stack surface placement and subaqueous deposition impoundment, respectively.

Although metal concentrations measured in kinetic tests exceeded one or more surface water standards in several tests, discharge to surface water is unlikely because mine-affected water will be collected and treated prior to discharge to groundwater. The following discussion, therefore, focuses primarily on comparing results to groundwater standards, with the exception of the saturated humidity cell test of raw tailings, which represents surface water in a subaqueous tailing facility pond.

The 2% and 4% binder and 4%+ROM cylinders showed different trends in sulfide oxidation in the diffusion tests. The 4% binder cylinder maintained a variable, but overall higher, pH between 6.5 and 9.5, with available alkalinity, and produced less sulfate throughout the test than the 4%+ROM cylinder. This suggests that the massive character of cemented paste tailings may be important in controlling sulfide exposure for oxidation. Rates of metal release were significantly lower in diffusion tests of saturated cement paste tailings than in unsaturated humidity cell tests of cemented paste tailings. In fact, only relevant As and Tl groundwater standards were exceeded in the 4% binder and 4%+ROM cylinders, respectively. Furthermore, because the backfilled paste tailings have very low transmissivity they will react slowly with groundwater and are unlikely to create acidity or release concentrations of metals above groundwater standards.

The paste tailings were also studied in conventional, aerated humidity cell tests to evaluate their behavior in surface deposits within the CTF. Acid and sulfate production varied between the cemented paste treatments, with the 2% test exhibiting greater release than the 4% test, which, was similar to the 4% with ROM test. All tests began at a pH above 6, which was maintained for 0-3 weeks depending on treatment. As of week 2, the 2% paste cement treatments began to trend downward in pH, followed by the 4% with ROM sample in week 3. The 4% paste amended material held a pH over 6 in week 4. Tintina proposes to place 0.5 to 2% paste cement amended materials in its surface CTF, and to collect and remove water from that impoundment continuously. Although the initial rates of metal release for cemented paste tailings was lower than for raw tailings for most metals, the rates of Al, Cu, Cd, Ni, and Tl release from the 2% cement paste HCT approached that of the unsaturated raw tailings HCT after 4 weeks. Metal

concentrations in effluent from the 4% paste cement backfill were lowest, and only regularly exceeded the groundwater quality standard for Tl, with isolated exceedances of Cu and Ni groundwater standards. This suggests that groundwater interacting with oxidized 4% cemented paste tailings backfill could exceed standards for Tl prior to water treatment. These tests remain online, and this interpretation is subject to change based on future results.

Both saturated and unsaturated kinetic tests of raw, non-amended tailings are being conducted by McClelland Labs (Sparks NV). The raw "non-amended" tailings sample tested in the conventional, subaerial kinetic test was strongly acidic and showed a correspondingly high potential to generate sulfate and several metals at low pH. In contrast, as of week 19, the saturated kinetic test showed much lower sulfide oxidation and release of metals, and had maintained a circum-neutral pH of 6.9. At the lower oxidation rate in the saturated HCT, which is intended to represent tailings deposited in a subaqueous impoundment pond, fewer metals exceeded relevant surface water quality standards and were detected at much lower concentrations. These cells are also still online and this interpretation is also subject to change.

Conclusions. The four volumetrically significant waste rock units showed evidence of sulfide oxidation in the HCT tests. However, consistent with static test results and the presence of abundant carbonate mineralization, oxidation in the *Ynl B*, *Ynl*, and *LZ-FW* tests has not produced sufficient acidity to deplete alkalinity nor have these tests produced acidic pH values. Despite indications of sulfide oxidation, depleted alkalinity and increased acidity with lower pH was only evident in the 2015 *USZ* test and not in the 2012 test.

The concentrations of regulated metals were measured in humidity cell effluent from weeks 0, 1, 2, 4, and every 4 weeks thereafter. Despite maintaining neutral pH in the test cells, the *Ynl B*, *Ynl*, and *LZ-FW* units have shown potential to exceed surface water quality standards for some metals in early weeks of kinetic testing, but do not exceed groundwater standards after week 2. The *USZ*, however, has shown potential for release of several metals in excess of surface water standards in multiple weeks. With the exception of week 0, no groundwater criteria were exceeded in leachate from the 2012 test of *USZ* rock, but the 2015 sample did exceed groundwater standards for Ni and Hg, in weeks 1 and 2, and for Sr and Tl throughout the test. Due to the potential for release of various metals at different times in the predicted weathering process, waste rock will be encapsulated in paste tailings in the lined CTF impoundment. Furthermore, Tintina proposes to collect all seepage from the waste rock stockpile, the CTF, and the underground workings for treatment prior to discharge via underground infiltration galleries. Potential for impact to surface and groundwater is therefore low.

Results of the diffusion kinetic tests indicate that saturated 4% cemented paste tailing in backfill is unlikely to become acid and has potential to release only Tl in concentrations above groundwater standards. Also, because of the extremely low hydraulic conductivity of this material, potential to impact groundwater in a backfill setting is low. Results indicate that all of the cemented paste amended tailings treatments have potential to oxidize after a lag time and to release at least some sulfate, acidity, and metals if left exposed to air and water. Importantly, this is not observed immediately in test cells, and the rate of weathering in a humidity cell is recognized to be up to 10 times greater than in the field. In the CTF, each new lift of cemented paste tailings will behave as a massive block of material with low transmissivity, with a thin upper surface that will be exposed to some degree of oxidation before being covered by fresh paste tails within days of placement. If material is covered in a timely manner (on the scale of weeks), relatively

little oxidation, acidity, and leaching of metals is expected to occur and it would be limited to the immediate surface of the cemented paste tailings. Any water interacting with oxidized tailings will react with dominantly net neutralizing waste rock before being collected in a sump in a lined facility for treatment.

At closure, the paste tailings deposit will be covered with a geotextile membrane, eliminating long-term exposure of the final lifts to oxygen and water. The double lined CTF with drainage collection is designed to prevent discharge to surface water and groundwater. Thus, any solutes resulting from oxidation and release of metals by cement-amended tailings within the CTF are unlikely to reach or affect surface water or groundwater. The inclusion of ROM waste rock in the 2% cement amended tailings may increase alkalinity (as suggested by the 4% +ROM test results, to date) and further delay the onset of any acid production in the CTF, thus reducing potential concentrations of metal in water reporting to the water treatment plant. Subaqueous placement of tailings appears to be most effective at limiting sulfide oxidation, followed by placement of 4% cement amended tailings in saturated underground workings. However, if a subaqueous impoundment alternative were to be considered, some release of metals to the tailings pond would be expected to occur in concentrations that exceed surface water standards. Significant acid rock drainage should be expected to develop in subaerially weathered, fine-grained “raw” tailings, suggesting that a “dry stack” alternative management scenario may not be effective.

1 Introduction

Tintina Resources is preparing an operating permit application for its Black Butte Copper Project, located approximately 17 miles north of the town of White Sulphur Springs, MT (**Figure 1-1** and **Figure 1-2**). In support of the proposed underground mining operation, extensive environmental geochemical testing has been conducted by Enviromin, Inc. over the past five years. Tintina plans to advance underground operations through the proposed 2012 Johnny Lee Decline (2012 Decline) into the Upper Copper Zone (UCZ) and deeper into the Lower Copper Zone (LCZ) (**Figure 1-3**). In order to produce an operational plan that complies with Montana Department of Environmental Quality (MT DEQ) regulations, Tintina has conducted a thorough baseline characterization of acid generation and trace element release potential for waste rock and tailings materials. These data are useful for design of mined rock storage facilities and represent a summary of geochemical baseline conditions for the mining operation.

1.1 Project History

Mineral exploration in the vicinity of the Black Butte Copper Project has been ongoing for more than 30 years. As a result, there is a substantial amount of exploration geochemistry data available (Tintina, unpublished data; Resource Modeling, Inc., 2012). These historical efforts focused primarily on assay and multi-element geochemical analyses for exploration purposes, with only limited collection of environmental geochemistry data. More recent efforts to characterize acid generation and trace element release potential of mined materials utilized the multi-element exploration data to guide sample selection for environmental geochemical testing.

In 2011, an environmental geochemical testing program was initiated to support development of the proposed 2012 Decline, which will be used to access mine workings under the currently proposed plan. The length of the decline is approximately 5200 ft (a horizontal distance of 5000 ft). It will be collared in the Undifferentiated Lower Newland (*Ynl*) just above the Dolomite (*Ynl 0*), and driven through a section of interbedded *Ynl* and *Ynl 0* until it intercepts the *0/1 Sulfide Zone* horizon just above the Upper Sulfide Zone (*USZ)*. The 2012 Decline is also expected to intercept the *Ynl B* footwall unit at depth. The initial baseline geochemical testing program therefore included static and kinetic testing of the lithotypes that comprised significant tonnage (defined as more than 1%) to be produced by the 2012 Decline as it was initially proposed. These lithotypes included: igneous dikes (*IG)*, *Ynl*, *Ynl 0*, Lower Newland shale and conglomerate (*Ynl B)*, and the Upper Sulfide Zone (*USZ)*.

In late 2014, Tintina Resources shifted focus from the 2012 Decline to an operational-scale plan, which expanded on the proposed 2012 Decline, by extending the workings through the *USZ* and into the previously uncharacterized Lower Copper Zone (*LCZ)*. As a result, the environmental geochemical testing program was updated to include additional, previously uncharacterized lithotypes and to address any geochemical variation throughout the proposed mine in addition to the immediate vicinity of the 2012 decline. During the course of the 2015 geochemical testing program, the expected waste rock tonnages changed in response to the evolving mine plan. As a result, some materials characterized initially (in 2012) ultimately represent less than 1 % of the total expected waste rock tonnage. For completeness, all available geochemical data are included in this report (**Table 1-1**), but the discussion and analysis focuses specifically on lithotypes occurring with greater than 1% frequency, which are the Lower Zone Footwall (*LZ-FW*), *Ynl B*, *USZ*, and *Ynl*. Additionally, this report addresses geochemical characterization for tailings under various proposed management scenarios.

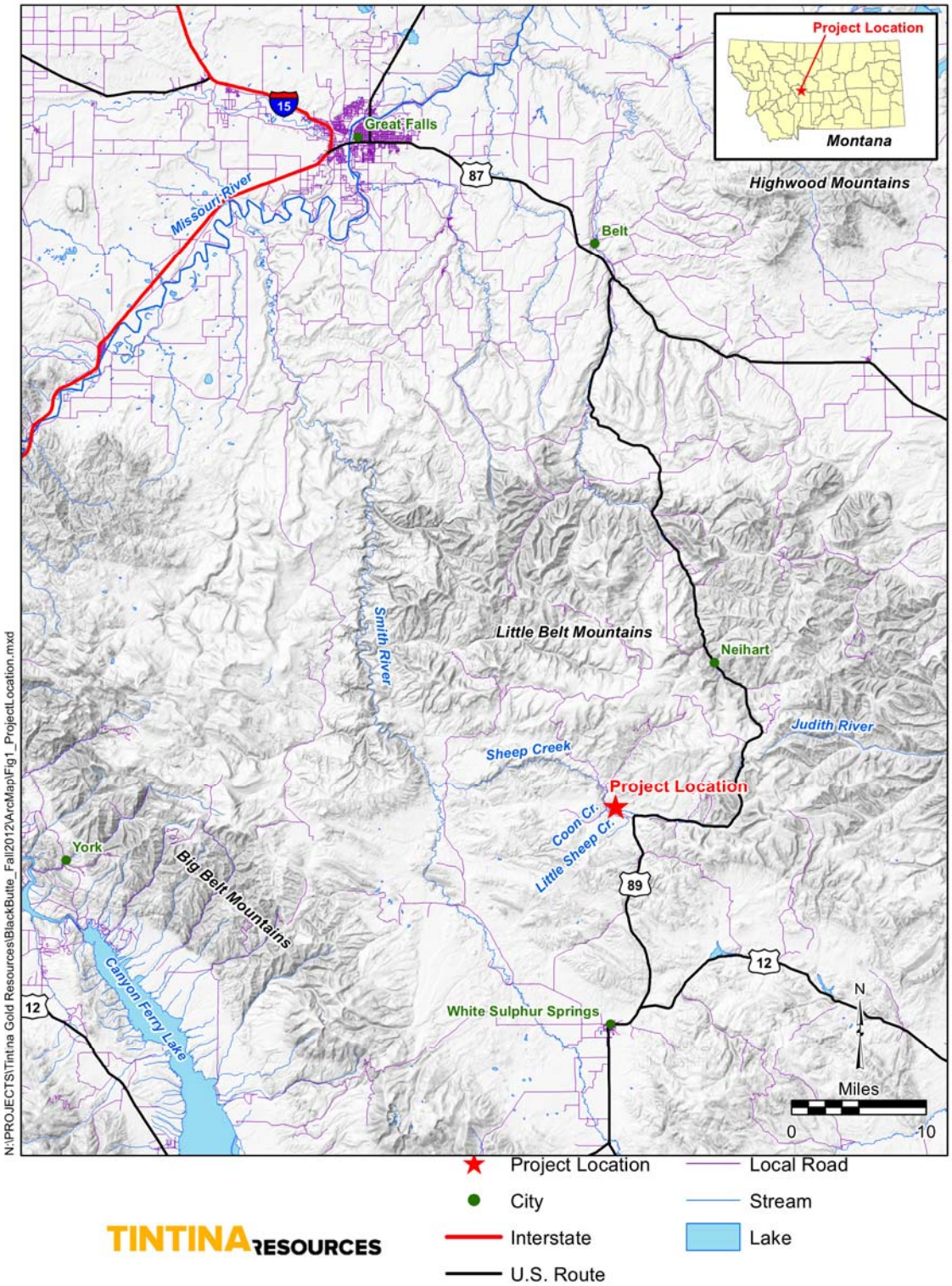
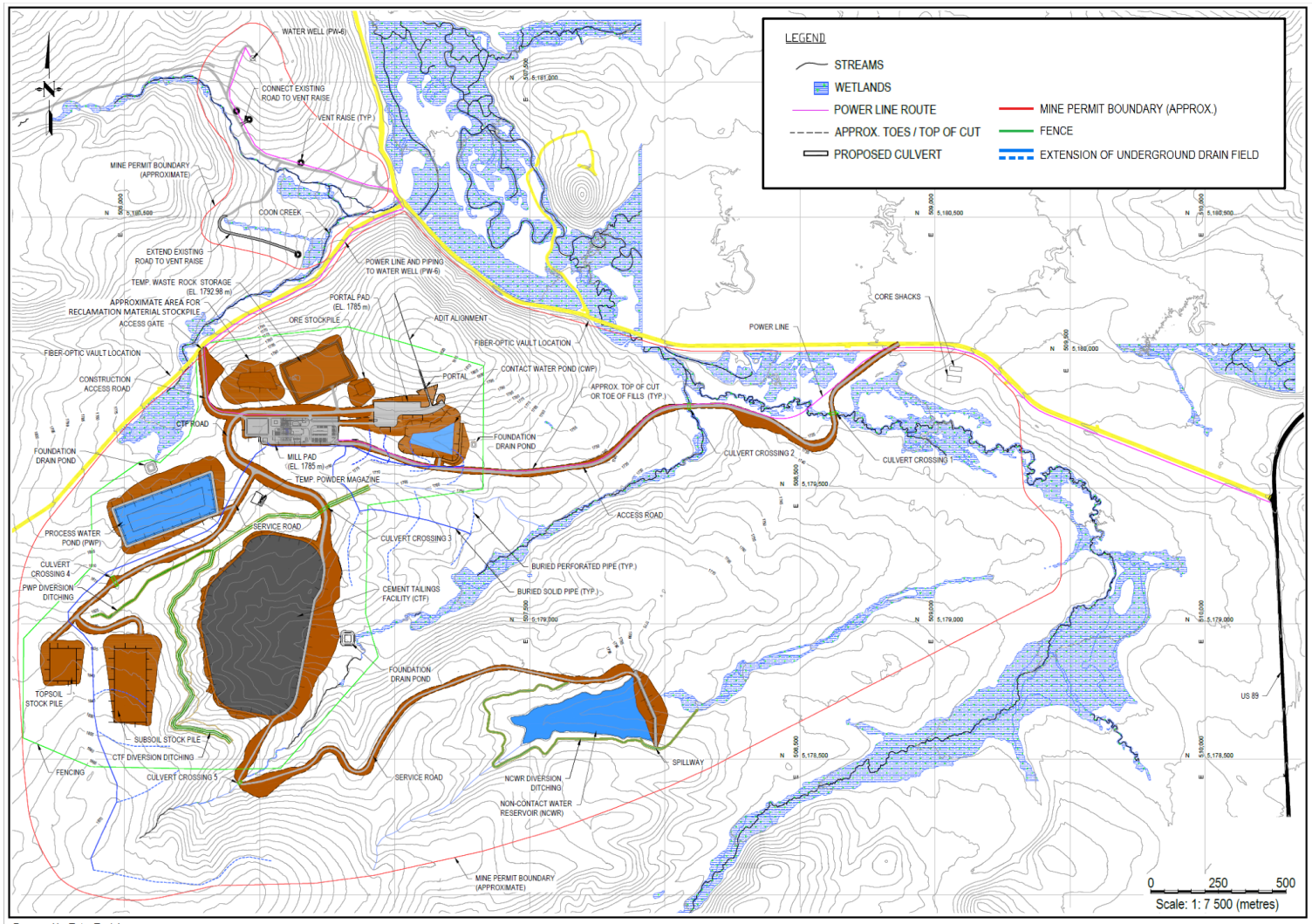


FIGURE 1-1. Black Butte Copper Project Location Map



Prepared by Tetra Tech Inc.

FIGURE 1-2. Black Butte Copper Project Facility Map

TABLE 1-1. Black Butte Copper Project Waste Rock Tonnage and Environmental Geochemical Analyses by Lithotype

Lithotypes	Description	Waste Rock % Tonnage	ICP	ABA/ NAG	SPLP	Mineralogy	AM	HCT
LZ-FW	Silicified shale and debis flow	35	542	15	0	*0**	1	*1*
Ynl B	Lower Newland shale and conglomerates	32	1334	35	2	1	2	*2*
USZ	Lower Newland upper sulfide	28	3590	49	2	1	2	*2*
Ynl	Undifferentiated Lower Newland	4	1129	57	2	1	2	1
Ynl 0	Lower Newland dolomite/dolomitic shale	<1	62	10	1	1	1	1
Yc	Chamberlain shale	<1	51	9	0	0	1	*1*
Yne	Neihart Quartzite	<1	43	8	1	0	1	0
IG	Igneous Dike	<1	37	8	1	0	1	0
Granodiorite	Surface Construction Material	50	123	*8*	*1**	*0*	*1**	*0*
Ynl	Surface Construction Material	50	1129	57	2	1	2	1

Italicized text indicates ongoing testing
AM=Asbestos Mineral testing
**Tests planned*

TABLE 1-2. Black Butte Copper Project Tailings Treatments and Related Testing

Tailing Test Table	ABA	NAG	ICP metals	Sat. HCT	Unsat HCT	Diffusion Test
Raw Tailings	X	X	X	*X*	*X*	-
Paste Tailings 2%	X	X	X	-	*X**	X
Paste Tailings 4%	X	X	X	-	*X**	X
Paste Tailings 4% and Waste Rock	-	-	-	-	*X**	X

**Unsaturated HCTs conducted on intact cylinders, not crushed materials, as is indicated in the ASTM standard.*
Italicized text indicates ongoing testing

1.2 Operational Plan and Data Application

The design of the Black Butte Copper Project has been directly informed by the environmental geochemical data presented here. Mine facilities potentially influenced by geochemistry include the temporary waste rock storage pad, contact water pond (CWP), water treatment facility, land application discharge (LAD) system, a process water pond (PWP), cemented tailings facility (CTF), and subsurface workings. These facilities (**Figure 1-2)** are described in detail in Tintina's 2015 Mine Operation Plan Application and summarized below.

In recognition of the sulfide content of the tailings to be produced from the Black Butte Copper deposit, Tintina has proposed an innovative, cemented tailings storage design. By incorporating binders into the tailings material as they are placed in the lined and monitored CTF, Tintina will encapsulate sulfidic materials and limit their exposure to oxygen and water, as well as reduce the potential for these materials to be transported in the event of dam failure. Further, following temporary storage of waste rock on a lined pad, Tintina proposes to encapsulate all mined waste rock within the CTF, thereby limiting acid and metal release potential for the waste rock.

This report presents all geochemical data available for use in predicting the environmental impacts of the proposed facilities and anticipated alternative scenarios for Tintina's Black Butte Copper Project. For example, tailings have been tested using different rates of binder amendment, in both subaerial weathering (as in a surface CTF) and within saturated zones (when placed as backfill, following closure). Tailings were also tested without amendment under subaerial and saturated conditions, to evaluate tailings chemistry under alternative management scenarios. **Table 1-3** describes the intended application of the kinetic oxidation and metal release data in assessments of proposed and alternative facilities.

In addition to their use in facility design, geochemical data characterizing waste rock and tailings have been used to predict hydrogeochemical performance for those facilities, based on:

- models predicting seepage from temporary waste rock storage, which will be collected in the CWP;
- models of water collected in the CTF, which will ultimately return to the PWP and water treatment facility for release in the LAD;
- predictions of water quality data for design of an appropriate water treatment facility; and
- prediction of groundwater quality in the underground workings, during operations and at closure.

These models are reported elsewhere (Enviromin, 2015b) and not discussed further here.

TABLE 1-3. Kinetic tests of waste rock and tailings treatments and facility scenarios

Waste Rock Material	Test Method	Facility Represented	Action Scenario
HCT by Lithotype	ASTM method D5744 (HCT)	Underground Water Quality	**Proposed**
HCT by Lithotype	ASTM method D5744 (HCT)	Temporary Waste Rock Storage	**Proposed**
Tailings Characteristics	**Test Method**	**Facility Represented**	**Action Scenario**
4% binder	ASTM C1308 diffusion test	Backfilled in flooded workings	**Proposed**
4% co-disposed with waste rock	ASTM C1308 diffusion test	Backfilled in flooded workings	*Alternative*
2% binder	ASTM method D5744 (HCT)	Cement paste in CTF, subaerial weathering	**Proposed**
4% binder	ASTM method D5744 (HCT)	Cement paste in CTF, subaerial weathering	*Alternative*
4% co-disposed with waste rock*	ASTM method D5744 (HCT)	Cement paste in CTF, subaerial weathering	**Proposed**
Raw (non-amended)	Modified ASTM method D5744 (saturated HCT)	Saturated tailing e.g., subaqueous impoundment	*Alternative*
Raw (non-amended)	ASTM method D5744 (HCT)	Subaerial weathering, e.g., dry stack tailing pile	*Alternative*

**Because of the limited amount of tailings available for testing, the waste rock co-disposal option was evaluated in the 4% binder paste cement, although Tintina plans to use 2% binder paste amendment in the surface impoundment, where the waste rock will be encapsulated.*

1.3 Geology

The Black Butte Copper deposit consists of a massive sulfide Cu-Co-Ag ore body within the mid-Proterozoic-aged Newland Formation of the Belt Supergroup. The Newland Formation is typically divided into a lower member that consists of primarily argillaceous dolomite and an upper member of interbedded shales and carbonates (Mogk D., 2015, personal communication; Graham et al., 2012). A detailed cross-section that includes the proposed mine workings is included as **Figure 1-3**.

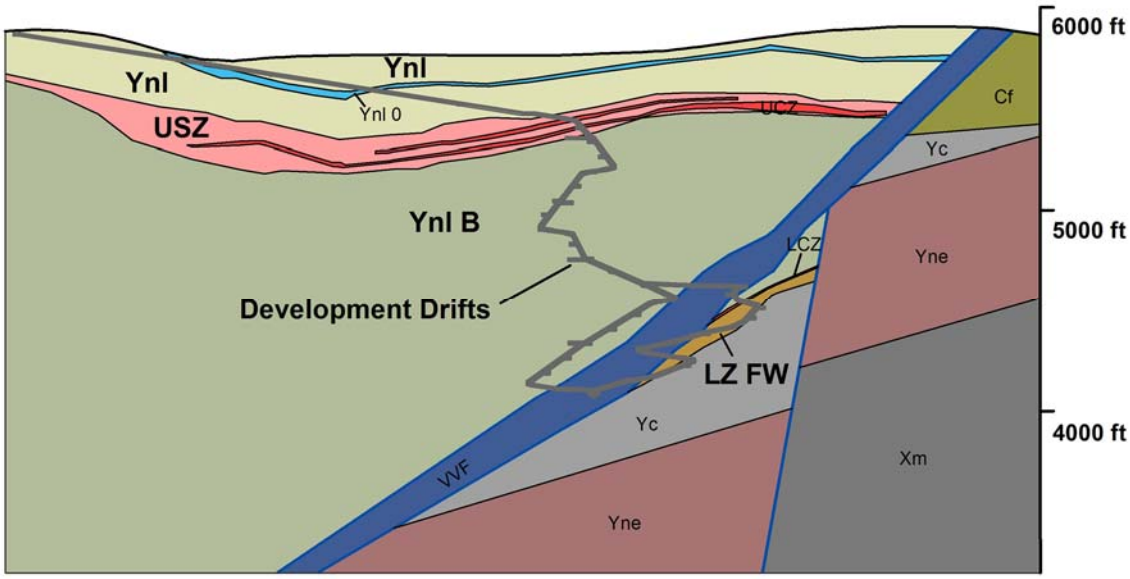


FIGURE 1-3. Cross Section of Black Butte Copper Project

These locally massive sulfide sediments were deposited within the Helena embayment and exposed along the Volcano Valley thrust fault (*VVF*) at the end of the Laramide orogeny (Resource Modeling Inc., 2012). Ore is hosted in sulfide within marine sediments associated with submarine hydrothermal vents and contains varying amounts of primary and secondary pyrite, chalcopyrite, bornite, barite, and silica. Microfossils identified in the sulfides at Black Butte Copper project are suggestive of vent fauna grown on submarine hydrothermal vents. Approximately 750 m of interbedded sulfide mineralization has been defined, with approximately 350 m of overlying and interbedded carbonate (Resource Modeling, Inc., 2012).

The stratigraphy of the Newland Formation shales, dolomites, and interbedded sulfides is shown in **Figure 1-4**. The uppermost member of the Upper Newland Formation (*Ynu*) in the vicinity of the workings, which is designated as Unit II (or *Ynu II*) in Tintina's geological model, is a black-gray silty dolomite. Black chert layers and nodules appear in core and outcrops, and are a diagnostic feature of the unit. A thin sulfide horizon known as the *II SZ* sulfide zone is developed at the contact between the *Ynu II* and the underlying Unit I (*Ynu I*). This thinly laminated to well-bedded stylolitic, silty dolomite is typically less than 15 m thick. Sheets of sulfide localized immediately below *Ynu I* provide a definitive stratigraphic marker, known as the *0/1 SZ* sulfide zone, which indicates the transition to the more sulfidic Lower Newland Formation.

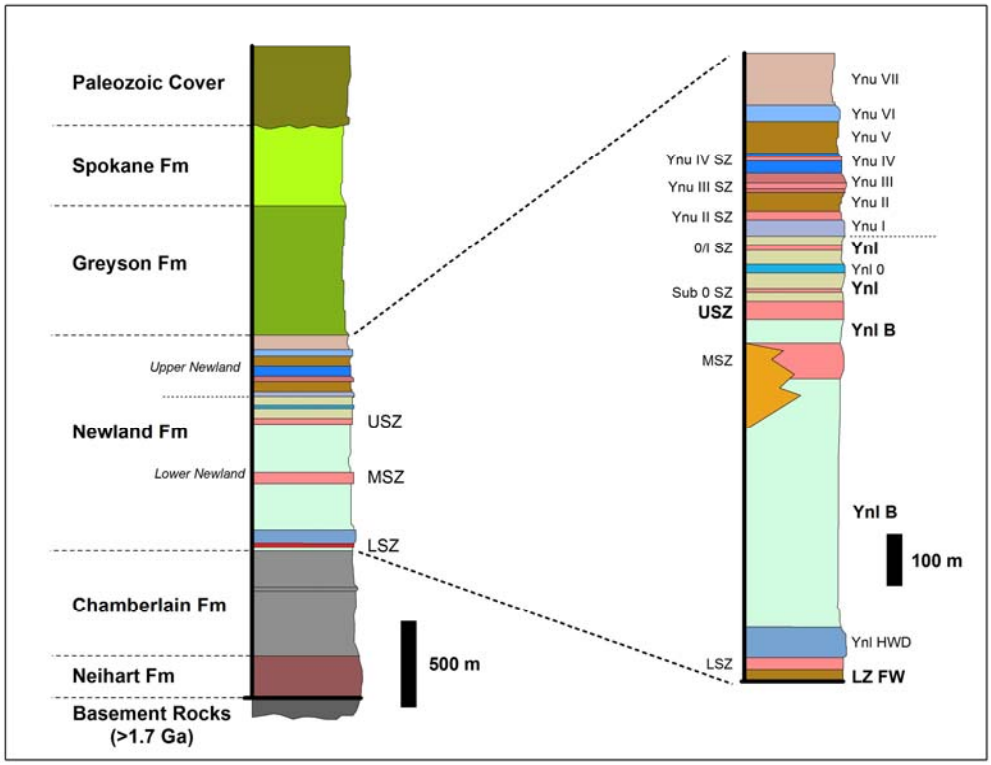


FIGURE 1-4. Black Butte Copper Project, Generalized Stratigraphic Column

The uppermost portion of the Lower Newland Formation that will be intercepted by the decline is identified operationally as undifferentiated *Ynl*. This unit is comprised of interbedded black-grey laminar silts, dolostones and shales. Upper and lower blocks of *Ynl* are separated by a relatively thin interbed of stylolitic, medium grey dolomite known as Unit 0 (*Ynl 0*) or “the Nose”. The *Ynl 0* is the closest distinguishable carbonate bed overlying the *USZ*. Above the *Ynl 0*, trace sulfide occurs in local zones of faulting and remineralization, commonly in association with calcite. Below the *Ynl 0*, the *Ynl* contains visible pyrite and barite laminations that increase with depth. The *USZ*, which hosts significant copper mineralization known as the Upper Copper Zone (*UCZ*), immediately underlies the lower block of undifferentiated *Ynl* and can be up to 100 meters thick (Resource Modeling, Inc., 2012). The *Ynl B* unit that lies between the *USZ* and the underlying Lower Sulfide Zone (*LSZ)* is comprised of shale and conglomerate.

The *USZ*, which hosts Cu-Co-Ag mineralization in the calcareous shale of the Lower Newland Formation, contains fine-grained bedded pyrite up to 55 m thick with three chalcopyrite-rich zones. Bornite and chalcopyrite occur more frequently in the southern part of the *USZ*. The cobalt minerals are unknown but are most likely cobaltite or glaucodot. Economic grade mineralization with the USZ is specifically hosted in the Upper Copper Zone *(UCZ).*

Economic grade mineralization known as the Lower Copper Zone (*LCZ*) is hosted within the *LSZ*. The proposed mine workings will access the LCZ and are oriented to address the structural definition of this zone by the *VVF* and the Buttress Fault. The VVF is a clay-rich shear zone approximately 10 m thick. The Buttress Fault is a steeply dipping

normal fault that traverses through the Neihart Quartzite unit (*Yne*). Due to its close proximity to mine workings, *Yne* has been included in the geochemical characterization program for potential use as a construction material. The LCZ is also proximal to the Chamberlain Shale (*Yc*), which contains disseminated pyrite and proportionally less carbonate than the *Ynl*. Between the lower zone footwall and the top of the *Yc* is a silicified unit comprised of shale and debris flow material which has been designated as the Lower Zone Footwall (*LZ-FW*). This unit contains highly altered dolomite and is locally silicified below the *VVF*. The *LZ-FW* is characterized by erratic sulfide mineralization, including disseminated chalcopyrite and pyrite as well as some stringers of ore. There are very isolated occurrences of gold ore in the *LZ-FW*, which is almost completely devoid of Co and arsenic (As).

A list of the minerals relevant to the environmental geochemistry of waste rock for each major lithotypeis provided in Table 1-4.

TABLE 1-4. Mineralogy, by lithotype, for Tintina's Black Butte Copper Project

	Mineral	Formula	*USZ*	*LZ-FW*	*Ynl B*	*Yc*	*Ynl*	*Ynl 0*	*Yne*
Silicates	Quartz	SiO_2	▯	▯		▯			▯
	Chert	SiO_2	▯					▯	
Carbonates	Dolomite	$CaMg(CO_3)_2$	▯	▯	▯		▯	▯	
	Calcite	$CaCO_3$	▯		▯		▯	▯	
	Strontianite	$SrCO_3$	▯						
Sulfides	Pyrite	FeS_2	▯	▯	▯	▯	▯		
	Marcasite	FeS_2	▯						
	Chalcopyrite	$CuFeS_2$	▯	▯					
	Bornite	Cu_5FeS_4	▯						
	Tennantite	$Cu_{12}Sb_4S_{13}$	▯						
	Chalcocite	Cu_2S	▯						
	Galena	PbS	▯						
	Sphalerite	ZnS	▯						
	Siegenite	$(Ni,Co)_3S_4$	▯						
	Carrollite	$Cu(Co,Ni)_2S_4$	▯						
	Cobaltite	$CoAsS$	▯						
	Glaucodot	$(Co,Fe)AsS$	▯						
Sulfates	Barite	$BaSO_4$	▯	▯					
	Celestine	$SrSO_4$	▯						

2 Sampling

The environmental geochemistry of rocks that will be mined from the Black Butte Copper Project will be influenced by sulfide, carbonate, and metal-bearing minerals. Representative samples of waste rock, tailings, and construction (excavation) materials were therefore identified for analysis. Samples of homogenized "raw" tailings were created by flotation during metallurgical testing (conducted at SGS Laboratories, Vancouver, CA). AMEC Foster- Wheeler produced the various paste-amended tailings samples. Enviromin was provided splits of all "raw" non-amended tailings and paste tailings for geochemical testing.

To ensure representative sample selection for waste rock and construction materials, statistical sampling techniques were applied to the multi-element whole rock data (from exploration database) to select sample subsets for environmental geochemical testing. Comparable, but not identical methods, were used in the identification of representative samples by Tetra Tech in 2012 for the *Ynl*, *Ynl B*, and *USZ* lithotypes, and by Enviromin in 2015 for the *USZ*, *Ynl B*, and *LZ-FW*. Tetra Tech selected representative samples across the distribution of each multi-element data set visually, as described in the Final Black Butte Copper Project Baseline Environmental Geochemistry Evaluation for the 2012 Johnny Lee Decline, which is included as **Appendix A**. This approach was revised during the 2015 environmental geochemical testing program to determine the number of subsamples needed to represent the mean exhibited by the larger pool of available data for each lithotype using a method based on Runnells *et al*, 1997. The number of samples identified for each lithotype is shown with boxplots comparing the sample subsets with the overall population in **Appendix B**.

An initial group of eight samples was selected across the range of observed chemistry for each lithotype, based on the histogram approach defined by Tetra Tech, with the initial goal of representing the range of sulfur (S) concentration. Enviromin chose to begin with S distribution, because S is a master variable of environmental geochemical concern to Tintina and is directly associated with the potential release of metal(oid) elements of environmental interest. Following the selection of the initial eight subsamples, additional subsamples were progressively added through random selection until the means of the subset were equivalent to the means of the original lithotype exploration dataset.

Subsequent to completion of the 2012 Decline report (**Appendix A**), kinetic humidity cell tests were conducted on most of the composites constructed during the 2012 Decline geochemical testing program. Specifically, equal proportions of the two *USZ* composites (one designated "High Fe" and the other "Low Fe") were combined to form a single composite labeled "*USZ 1/2*"; the two *Ynl* composites were combined to form a single composite labeled "*Ynl 1/2*"; and the *Ynl 0* and *Ynl B (2012 Decline)* composites were used as originally designed for kinetic testing. The *IG* and *Ynl B (original 2011 decline)* composites were not included in the kinetic testing program, as they did not represent significant tonnage to be mined from the 2012 Decline.

Sample subsets selected in 2015 were individually tested for static parameters and then composited. Specifically, acid-base accounting (ABA) and net-acid generation (NAG) tests were conducted on each sample, after which samples were composited for metal mobility, asbestiform mineral analysis, and kinetic tests. These composites were constructed by using equal masses of each sample in the lithotype subsets. For

example, for the *USZ* material, the 15 selected *USZ* subsamples, which had been individually analyzed for ABA and NAG, were composited into a single sample.

3 Waste Rock Characterization

The geochemical testing of waste rock for the Black Butte Copper Project was initially focused on the 2012 Decline, which included static and kinetic testing of the relevant lithotypes: *IG*, *Ynl*, *Ynl 0*, *Ynl B*, and *USZ*. When the focus was shifted from the 2012 Decline to an operational-scale plan, the baseline geochemical testing program was updated to address the full range of chemistry identified in ICP-MS exploration data site-wide where 2012 work was inadequate, and to include previously uncharacterized waste rock lithotypes. For example, the 2012 analysis of *Ynl* involved samples that were representative of multi-element chemistry site-wide, while the 2012 analysis of *Ynl B* and *USZ* did not. Also, the *LZ-FW*, *Yne,* and *Yc* were added as lithotypes. Due to changes in the mine plan during 2014 and 2015, however, the *Yne*, *Ynl 0*, *IG*, and *Yc* were determined to represent <1% of waste rock tonnage; while they have been characterized thoroughly, they are not relevant to Tintina's final mine plan. The entire waste rock characterization program is described here, but the discussion is focused on results for the lithotypes currently expected to contribute significantly to waste rock tonnages: *Ynl, USZ, Ynl B,* and *LZ-FW*.

3.1 Static Testing of Waste Rock

Static testing methods were primarily used to evaluate acid generation potential, although some static testing also investigated metal release potential. Static testing refers to analysis at a fixed point in time and differs from kinetic testing, which measures changes in oxidation and solute release over time. Multi-element analyses of rock composition (ICP, collected as part of assay tests) were used to evaluate whole rock metal content. The acid base accounting (ABA) and net acid generation (NAG) tests were used to evaluate potential for acid generation, and the EPA method 1312 Synthetic Precipitation Leachability Procedure (SPLP) was used to evaluate potential metal mobility for some lithotypes. Additional static testing included in the Black Butte Copper Project geochemistry program included testing to rule out the presence of asbestiform minerals and mineralogical analyses (**Table 1-1**). A detailed description of the tests used to characterize the waste rock, and a summary of results, is provided below.

3.1.1 Multi-Element Whole Rock Chemistry

Multi-elemental analyses of rock composition, measured during the exploration program, provided a solid basis for the selection of subsamples for use in environmental geochemical characterization. Whole-rock data are also useful for "fingerprinting" samples during mining operations and can be correlated with those included in this baseline geochemical study.

Elemental composition was determined using inductively coupled plasma-atomic emission spectroscopy (ICP-AES) following a 4-acid digestion with a mixture of perchloric, nitric, hydrofluoric, and hydrochloric acids to dissolve the mineral matrix, including the silicates. The results of the multi-element analyses are presented in **Appendix B**, and demonstrate the elemental variation between lithotypes.

3.1.2 Acid Base Accounting and Net Acid Generation

Sulfide minerals in waste rock, particularly pyrite, react with water and oxygen to produce sulfuric acid (H_2SO_4), which can be neutralized by minerals capable of consuming acid, such as calcite. Two tests were used to measure potential for acid production, acid base accounting (ABA) and the net acid generation test (NAG). Results of these tests allow rock to be classified as Potentially Acid Generating (PAG) rock or Non-Acid Generating (NAG) rock, as discussed below.

The ABA test measures the relative acid production and neutralization properties of a mine waste material based on the conservative assumption that all sulfide present will oxidize, releasing acidity. The ABA test quantifies the acid production potential (AP) and neutralization potential (NP) of a sample in units of tons $CaCO_3$ / kiloton of rock (Sobek et al. 1978), allowing calculation of the net neutralization potential (NNP) as NP less AP, as well as the ratio of NP to AP (INAP, 2012). The ABA test uses a relatively complete digestion of finely ground rock, and therefore conservatively estimates the reactivity of available sulfide minerals.

To determine NP, a sample is treated with excess standardized hydrochloric acid (HCl) at ambient temperatures for 24 hours. The remaining acid is titrated with a standardized base to pH of 8.3 after the test is complete to allow the calculation of calcium carbonate equivalent for acid consumed. Early analyses used the Sobek method, and later analyses followed the modified Sobek method of ABA analysis (Lawrence and Wang, 1996). The difference between these two methods is that the latter uses a fizz test to adjust the amount of acid used in alkalinity titration. Because of the change in method, a comparison of select samples from key rock types was conducted and showed that these methods produced consistent results in this style of mineralization.

As part of the ABA analysis, S was fractionated to identify the sulfide content, acid-soluble and -insoluble sulfate, and residual S fractions. Total S was determined by LECO S, and sulfate S was measured by analysis of the carbonate-soluble and HCl-soluble fractions. Sulfide was then calculated by subtracting total sulfate from total S. In this study, AP was calculated based on sulfide S, which was the dominant form of S measured in the majority of samples.

The acid generation potential of rock samples is assessed based on calculated values of NNP and NP:AP using the ABA criteria shown in **Table 3-1**. The criteria are also used to identify materials that require kinetic testing in humidity cells to evaluate acid generation and metal release potential under prolonged weathering stress.

TABLE 3-1. Criteria for Classifying Acid Generation Potential from ABA Data

Classification	ABA Criteria
Potentially Acid Generating (PAG)	NP:AP < 1 and NNP < -20 tons/kton as $CaCO_3$
Uncertain Acid Generation Potential	NP:AP between 1 and 3 and/or NNP between -20 and +20 tons/kton as $CaCO_3$
Unlikely to Generate Acid (NAG)	NP:AP > 3 and NNP > +20 tons/kton as $CaCO_3$

From BLM (1996) and USEPA (1994).

The net acid generation pH (NAG pH) test is another method of evaluating acid generation potential, which relies on the oxidation of a ground sample using hydrogen peroxide (H_2O_2, Miller et al, 1997). All sulfides are oxidized, and available minerals neutralize any acid produced. The NAG pH method avoids the potential bias of assumptions implicit in the ABA method, including the assumed stoichiometry of sulfide mineralogy and the relative efficiency of speciation methods.

A 2.5 gram sample is pulverized and 250 mL of 15% H_2O_2 is added. The sample reacts overnight, and is then heated for up to 2 hours to remove excess H_2O_2 and encourage the release of inherent neutralizing capacity. The sample is allowed to cool, ending pH (NAG pH) is measured, and the solution is then titrated with sodium hydroxide, to endpoints of pH 4.5 and 7.0. Samples with a NAG pH of less than 4.5 at completion of the NAG test indicate potential to generate acid and the titration results further indicate the material's acid-production ability (**Table 3-2**).

TABLE 3-2. Criteria for Classifying Net Acid Generation Potential

NAG Prediction	Detailed Prediction	Final NAG pH	NAG Value (t H_2SO_4/ 1000 t)
Potentially net acid generating (PAG)	High capacity	<4.5	>5 (up to 10, depending on site-specific factors)
	Low capacity	<4.5	0-5
Potentially non-net acid generating (NAG)		>4.5	0

Adapted from: Miller et al. 1997, and INAP 2012

Figures 3-1 and **3-2**, as well as **Tables 3-3a** and **3-3b** present a summary of ABA and NAG results, for all tested lithotypes. ABA and NAG results for individual samples are compared with the guidelines presented in **Table 3-1** and **Table 3-2**; lab reports for samples analyzed following completion of the 2012 Decline report are presented in **Appendix B**. Lab reports for ABA and NAG analyses completed prior to 2013 are included in the 2012 Decline report (**Appendix A**).

Results for the *Ynl* lithotype indicate that most of this unit will be non-acid generating. However, there are sulfidic stringers present in the undifferentiated Lower Newland Formation, especially in proximity to the *USZ*. The presence of locally greater sulfide content is reflected by the "uncertain" and potentially acid-generating characteristics of a small number of samples (**Appendix B**).

The results of ABA and NAG analyses demonstrate that of the four dominant lithotypes, only the *USZ* material is consistently rated as potentially acid generating (PAG), with no samples rated as NAG and select samples rated as having an "uncertain acid generation potential." Because this material represents approximately 28 % of the expected waste rock tonnage, Tintina has conducted two kinetic tests of this material.

The *Ynl B* lithotype is also expected to contribute significantly to the waste rock tonnage (32 %). Based on ABA and NAG test results, this material is not expected to produce significant acid. These static results include data collected in both the 2012 and 2015 geochemical testing programs, and represent a robust dataset for this material (**Figures 3-1a, 3-1b,** and **3-2**; **Tables 3-3a** and **3-3b**; and **Appendix B**). Kinetic tests of samples collected near the 2012 decline, and site-wide, have been conducted.

The *LZ-FW* lithotype, which constitutes approximately 35 % of the expected waste rock tonnage, exhibited an uncertain potential for acid generation. This unit is defined spatially and contains multiple lithologies with variable mineralogy ranging from acid neutralizing to potentially acid generating (**Appendix B**). This material is being further evaluated in a kinetic humidity cell test.

The 2012 and 2015 geochemical testing programs also included more limited testing of lithotypes representing less than 1% tonnage. All static data for the *Ynl 0* and *IG* lithotypes were reported in the 2012 Decline Report (**Appendix A**) and are only included in this report for comparison with other lithotypes. The ABA and NAG results for the two remaining lithotypes, *Yne* and *Yc*, are briefly described here. Both the *Yne* and *Yc* lithotypes exhibited varying potential for acid production ranging from uncertain to non-acid generating. None of the individual samples was classified as PAG. Kinetic testing was not conducted for the *Yne*, as its tonnage in insignificant, but potential use of the *Yc* lithotype in construction supported its testing in a humidity cell

TABLE 3-3a. Summary of ABA Data: Major Waste Rock Lithotypes (>1%)

	Analyte	Units	Min.	Median	Mean	Max.	St. Dev.
Ynl n=44	Paste pH	s.u.	4.7	8.4	8.2	9.2	0.8
	AP*	$tCaCO_3/Kt$	0.3	37.2	49.6	339.1	58.7
	NNP	$tCaCO_3/Kt$	-312.0	132.5	172.0	852.0	218.3
	NP	$tCaCO_3/Kt$	1.0	200.0	224.9	860.0	198.4
	NP:AP*	s.u.	0.2	4.0	10.4	114.7	18.7
	Total S	%	0.1	1.3	1.7	11.6	1.9
	S Sulfide	%	0.0	1.2	1.6	10.9	1.9
	NAG pH 4.5	kgH_2SO_4/t	0.0	0.0	7.1	237.0	35.9
	NAG pH 7.0	kgH_2SO_4/t	0.0	0.0	9.8	272.0	41.4
	NAG pH	s.u.	2.1	8.3	7.5	9.7	2.1
USZ n=39	Paste pH	s.u.	2.7	7.1	6.4	8.7	1.8
	AP*	$tCaCO_3/Kt$	53.4	515.6	626.2	1341.0	428.9
	NNP	$tCaCO_3/Kt$	-1410.0	-431.0	-516.1	220.0	495.9
	NP	$tCaCO_3/Kt$	0.1	112.0	143.8	399.0	118.5
	NP:AP*	s.u.	0.0	0.3	0.6	2.8	0.7
	Total S	%	3.7	18.7	21.1	44.2	13.7
	S Sulfide	%	1.7	16.5	20.0	42.9	13.7
	NAG pH 4.5	kgH_2SO_4/t	0.0	233.0	211.9	617.0	171.5
	NAG pH 7.0	kgH_2SO_4/t	0.0	254.0	251.9	734.0	201.7
	NAG pH	s.u.	2.0	2.4	3.5	8.3	2.2
Ynl B n=34	Paste pH	s.u.	7.2	8.6	8.5	9.2	0.4
	AP*	$tCaCO_3/Kt$	1.3	32.8	33.9	145.0	32.7
	NNP	$tCaCO_3/Kt$	-95.0	189.0	173.4	370.0	131.0
	NP	$tCaCO_3/Kt$	4.0	240.0	208.5	423.0	139.8
	NP:AP*	s.u.	0.0	7.8	16.5	128.9	26.1
	Total S	%	0.0	1.1	1.1	4.7	1.1
	S Sulfide	%	0.0	1.1	1.1	4.6	1.0
	NAG pH 4.5	kgH_2SO_4/t	0.0	0.0	2.8	70.0	12.3
	NAG pH 7.0	kgH_2SO_4/t	0.0	0.0	3.7	81.5	14.8
	NAG pH	s.u.	2.4	9.1	8.7	10.8	2.0
LZ-FW n=15	Paste pH	s.u.	7.1	7.9	7.9	8.6	0.4
	AP*	$tCaCO_3/Kt$	1.6	33.8	59.0	270.3	70.8
	NNP	$tCaCO_3/Kt$	-169.0	-8.0	-30.5	51.0	55.7
	NP	$tCaCO_3/Kt$	4.0	25.0	29.9	103.0	25.4
	NP:AP*	s.u.	0.1	0.8	1.4	6.4	2.0
	Total S	%	0.1	1.1	1.9	8.7	2.3
	S Sulfide	%	0.1	1.1	1.9	8.7	2.3
	NAG pH 4.5	kgH_2SO_4/t	0.0	0.6	21.4	120.0	34.2
	NAG pH 7.0	kgH_2SO_4/t	0.0	6.2	26.3	132.5	38.6
	NAG pH	s.u.	2.4	4.0	4.9	8.9	2.6

**Calculated from Sulfide S*

TABLE 3-3b. Summary of ABA Data: Low Tonnage Lithotypes (<1%)

	Analyte	Units	Min.	Median	Mean	Max.	St. Dev.
Yc n=9	Paste pH	s.u.	7.8	8.7	8.5	9.3	0.5
	AP*	$tCaCO_3/Kt$	0.6	3.8	7.3	30.3	9.8
	NNP	$tCaCO_3/Kt$	6.0	17.0	22.3	57.0	16.0
	NP	$tCaCO_3/Kt$	10.0	19.0	29.8	87.0	24.0
	NP:AP*	s.u.	2.4	4.3	12.0	46.4	15.4
	Total S	%	0.0	0.1	0.2	1.0	0.3
	S Sulfide	%	0.0	0.1	0.2	1.0	0.3
	NAG pH 4.5	kgH_2SO_4/t	0.01	0.01	0.01	0.01	0.0
	NAG pH 7.0	kgH_2SO_4/t	0.01	0.01	1.1	4.8	2.1
	NAG pH	s.u.	5.5	8.3	7.7	8.4	1.1
Ynl 0 n=8	Paste pH	s.u.	4.3	9.1	8.4	9.2	1.7
	AP*	$tCaCO_3/Kt$	0.3	9.7	154.8	1175.0	412.2
	NNP	$tCaCO_3/Kt$	-1035.0	713.5	448.6	827.0	639.0
	NP	$tCaCO_3/Kt$	147.0	723.5	604.8	836.0	291.3
	NP:AP*	s.u.	0.1	76.8	117.2	476.8	149.1
	Total S	%	0.0	0.3	5.0	37.9	13.3
	S Sulfide	%	0.0	0.3	5.0	37.6	13.2
	NAG pH 4.5	kgH_2SO_4/t	0.0	0.0	85.5	684.0	241.8
	NAG pH 7.0	kgH_2SO_4/t	0.0	0.0	94.8	758.0	268.0
	NAG pH	s.u.	2.1	9.8	8.8	10.5	2.7
Yne n=8	Paste pH	s.u.	7.0	7.4	7.5	8.5	0.4
	AP*	$tCaCO_3/Kt$	0.3	0.3	0.5	1.3	0.3
	NNP	$tCaCO_3/Kt$	-1.0	1.0	0.8	2.0	1.0
	NP	$tCaCO_3/Kt$	0.1	1.0	1.2	2.0	0.8
	NP:AP*	s.u.	0.3	3.2	3.0	6.4	2.5
	Total S	%	0.0	0.0	0.0	0.0	0.0
	S Sulfide	%	0.0	0.0	0.0	0.0	0.0
	NAG pH 4.5	kgH_2SO_4/t	0.0	0.0	0.0	0.0	0.0
	NAG pH 7.0	kgH_2SO_4/t	0.0	4.7	3.7	6.2	2.4
	NAG pH	s.u.	6.2	6.4	6.5	7.1	0.4
IG n=8	Paste pH	s.u.	8.2	8.5	8.5	8.7	0.1
	AP*	$tCaCO_3/Kt$	1.6	4.2	4.7	12.5	3.6
	NNP	$tCaCO_3/Kt$	48.0	56.0	71.1	185.0	46.2
	NP	$tCaCO_3/Kt$	52.0	60.0	76.1	198.0	49.4
	NP:AP*	s.u.	10.1	15.3	20.6	41.6	12.1
	Total S	%	0.1	0.1	0.2	0.4	0.1
	S Sulfide	%	0.1	0.1	0.2	0.4	0.1
	NAG pH 4.5	kgH_2SO_4/t	0.01	0.01	0.01	0.01	0.00
	NAG pH 7.0	kgH_2SO_4/t	0.01	0.01	0.01	0.01	0.00
	NAG pH	s.u.	9.0	9.4	9.3	9.5	0.2

**Calculated from Sulfide S*

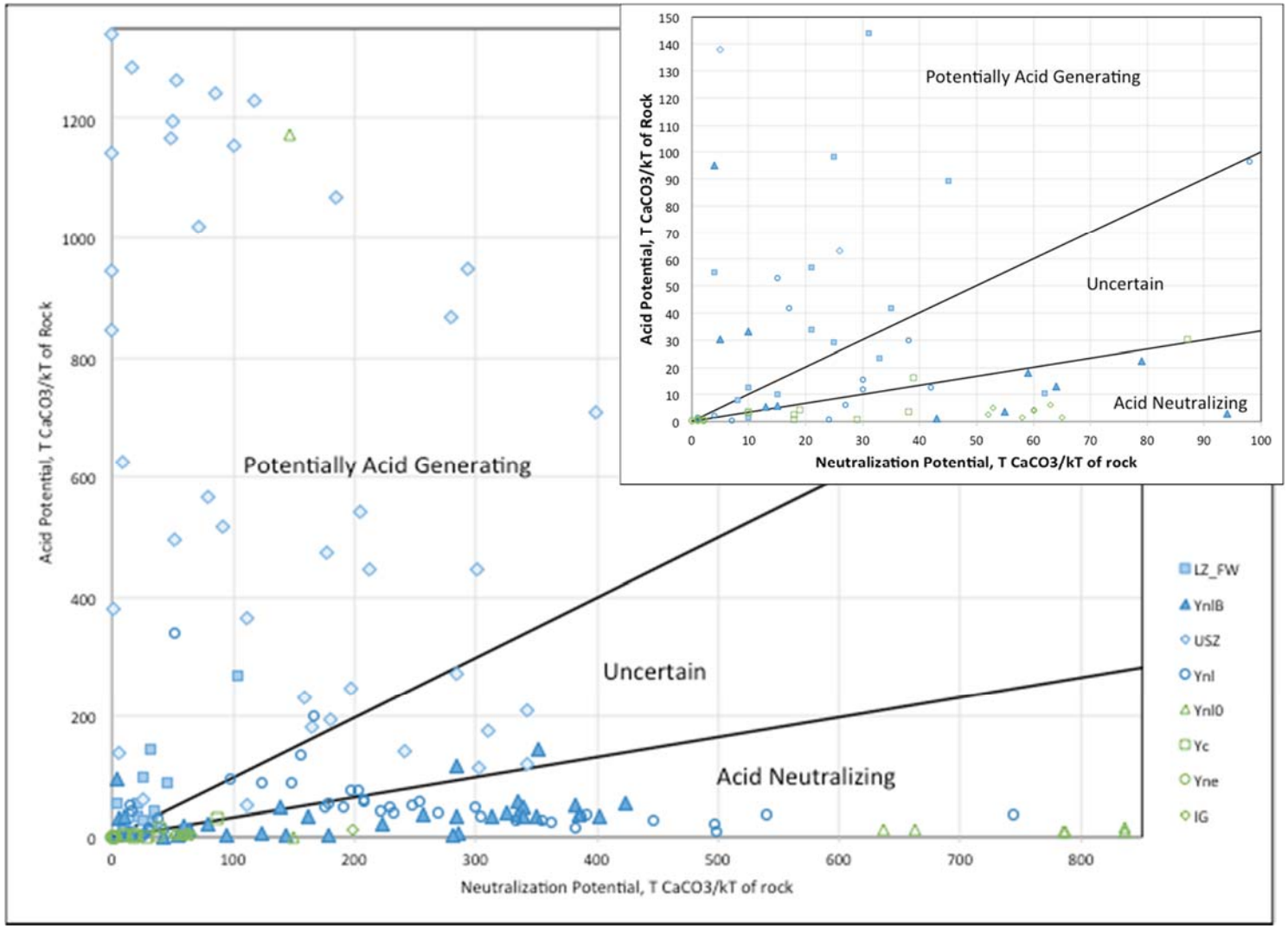


FIGURE 3-1. Acid Generation Potential for the Black Butte Copper Project.

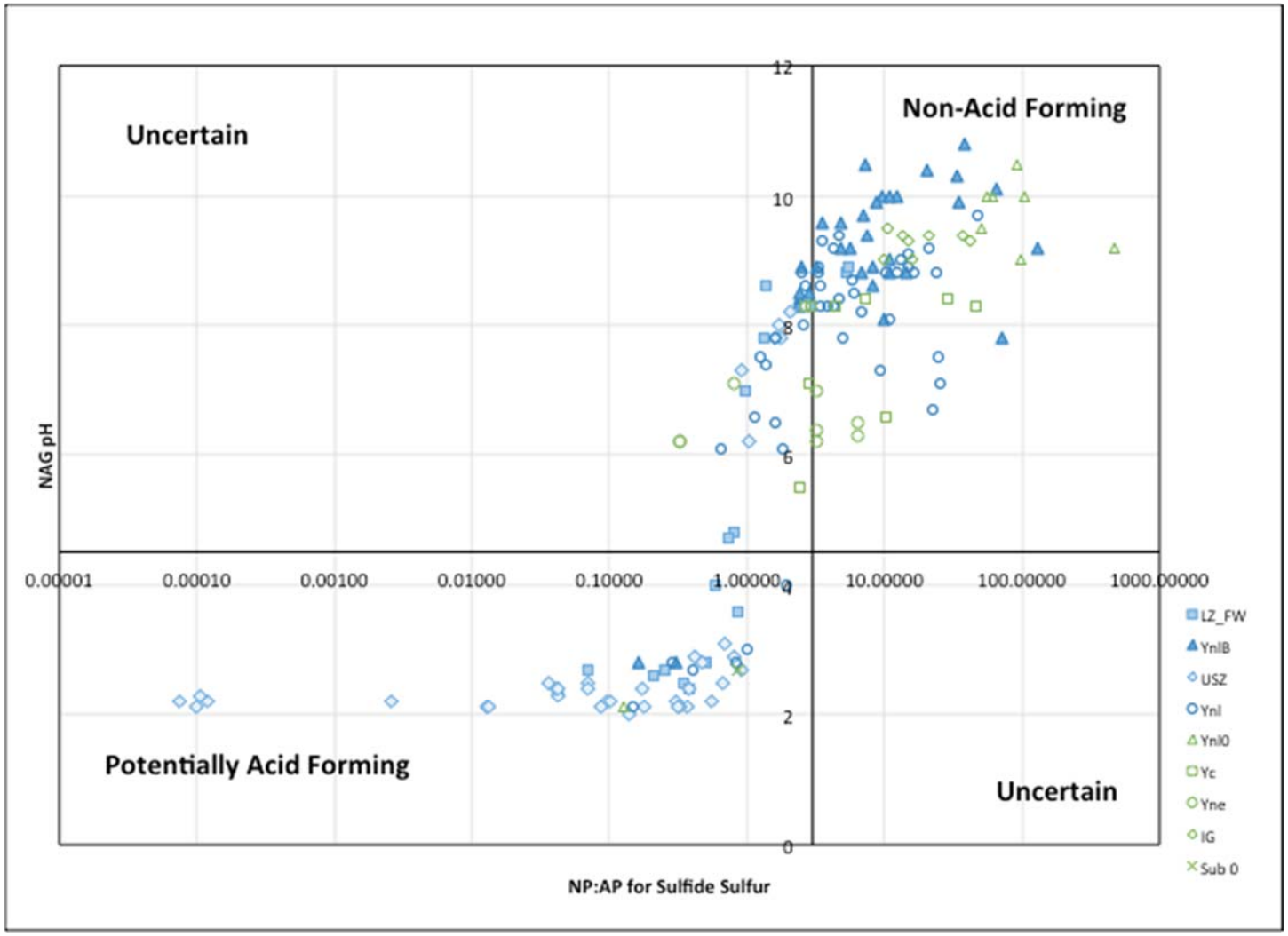


FIGURE 3-2. Black Butte Copper Project Comparison of NAG pH with NP:AP

3.1.3 Metal Mobility Tests

The Synthetic Precipitation Leaching Procedure (SPLP) is U.S. EPA method 1312 (2007). This test is designed to determine the mobility of metals in soils and mine wastes. For mines in the western U.S., waste rock is digested using an unbuffered pH 5 solution acidified with 60% sulfuric acid and 40% nitric acid, at a liquid-solid ratio of 20:1. The sample is rolled in a bottle for 18 hours, after which the sample is filtered using a 0.6-0.8 µm filter and analyzed for total recoverable concentrations of constituents of interest at detection levels appropriate to regulatory standards, typically using ICP-AES or ICP-MS. The final pH is also measured.

The SPLP provides an indication of the metals that have potential to be released from rock exposed to meteoric water, but the actual concentrations are sensitive to the rock:water ratio used in the test, as well as the final pH. For rock which may undergo oxidation-related changes in pH, the SPLP may not fully represent metal release. Concentrations measured in extracts should therefore be interpreted with caution (Fey, 2003).

The SPLP test was used for all lithotypes studied in 2012, but problems were encountered with elevated pH resulting from the presence of carbonate in the samples. Metal mobility predictions were therefore based on subsequent kinetic tests, as described below. In the current geochemical testing program, only the *Yne* quartzite lithotype was evaluated using SPLP. Due to its low tonnage and minimal metal release potential (based on whole rock chemistry), Enviromin recommended that Tintina use an SPLP test to assess potential metal release from the *Yne* material. A representative composite for SPLP was developed using the eight *Yne* subsamples analyzed in the ABA and NAG testing (using equal proportions). The results of this and the 2012 SPLP analyses (for comparison) are presented along with relevant MT DEQ surface water standards in **Table 3-4.** In these alkaline solutions, where final pH was 9.9, most metal concentrations were below detection and surface water standards were only exceeded for aluminum (Al), iron (Fe), and lead (Pb). Metal release potential for all other lithotypes in the 2015 testing program have relied on kinetic testing to evaluate predicted metal release potential in association with oxidation.

The lab report for the *Yne* sample is included in **Appendix B**, while lab reports from the 2012 Decline investigation were presented in the 2012 Decline Report, which is included here as **Appendix A**.

TABLE 3-4. Black Butte Copper Project SPLP Testing Results

Analyte	MT WQ Standard	*Yne*	*IG*	*USZ 1,*	*USZ 2,*	*Ynl 0*	*Ynl 1*	*Ynl 2*	*Ynl B 1*	*Ynl B 2*
pH (s.u.)	none	9.9	9.5	8.4	8.9	9.9	9.2	9.6	9.6	9.7
Al	0.087	***6.07***	***3.2***	0.03	***0.09***	0.07	***0.17***	***0.16***	***0.64***	***0.12***
Sb	0.0056	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
As	0.01	0.005	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.006	<0.003
Ba	1	0.096	0.059	0.023	0.007	<0.005	0.011	<0.005	0.015	0.006
Be	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cd	0.00033	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.0002[2]	<0.00008
Ca	none	<1	4	25	15	6	7	5	5	7
Cr	0.011	*0.01*	***0.012***	<0.001	0.003	0.009	0.003	0.008	0.004	0.001
Co	none	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cu	0.012	0.007	<0.002[2]	<0.001	<0.002[2]	<0.001	<0.001	<0.001	<0.001	<0.001
Fe	1	***2.47***	***1.91***	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	<0.05
Pb	0.004	***0.0042***	0.0014	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Mg	none	<1	3	18	10	4	4	4	4	3
Mn	none	0.006	0.03	0.092	0.006	<0.005	<0.005	<0.005	<0.005	<0.005
Hg	0.00005	0.00003	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Mo	none	<0.001	<0.001	<0.001	<0.001	<0.001	0.006	0.01	0.02	<0.001
Ni	0.065	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K	none	3	2	1	1	<1	<1	<1	2	<1
Se	0.005	<0.001	<0.001	***0.005***	<0.001	<0.001	***0.005***	<0.001	***0.005***	<0.001
Ag	0.0064	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Na	none	21	56	50	21	34	16	72	28	18
Sr	4	0.02	0.09	0.25	0.03	<0.01	0.04	<0.01	0.08	0.03
Tl	0.00024	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
U	0.03	0.0004	0.00024	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003
Zn	0.15	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

All units are in mg/L unless otherwise noted
Results that exceed relevant MT-DEQ water quality standards are bolded and italicized
2012 SPLP data are presented here for comparison with the 2015 *Yne* SPLP data.
[1] Chronic aquatic life criteria hardness dependent criteria based on 130 mg/L hardness. Silver value shown is acute criterion, as no chronic standard exists.
[2]Reporting limit for Cd in the sample from *Ynl B 2, Original Decline*, and those for Cu in *IG* and *USZ 2* were increased due to sample matrix interference.

3.1.4 Asbestiform Minerals

Asbestiform serpentine and amphibole minerals are generally associated with metamorphic processes and do not typically occur in carbonaceous sedimentary deposits. Chrysotile fibers are most commonly found in serpentinized ultramafic and dolomitic marbles. Although amphibole minerals are widely found throughout the earth's crust, only a few varieties exhibit the rare asbestiform habit resulting from mechanical shearing and/or high temperature metamorphism which pose health risks. Asbestiform mineralization is therefore highly unlikely in the Black Butte copper deposit. Nevertheless, composites of lithotypes were screened for the presence of asbestiform minerals at the request of the Montana Department of Environmental Quality.

The presence/absence of chrysotile, amosite, crocidolite, anthophyllite, tremolite, and actinolite was evaluated by the R.J. Lee Group using Polarized Light Microscopy (PLM) methods at a 400 point count, followed by evaluation of any identified asbestiform fibers following U.S. EPA regulations. Any samples found to contain uncertain or demonstrated asbestiform mineral content were to be analyzed using Transmission Electron Microscopic (TEM) analysis to clearly distinguish between mineral cleavage and fibers, along with elemental analysis of the samples. For this project, detection between 0.001 and 0.1 weight percent was required

In the 2012 Decline geochemical investigation, no asbestiform minerals wee identified in the *USZ*, *Ynl*, *Ynl 0*, *Ynl B*, and *IG.* These results are presented in the March 2013 Baseline Environmental Geochemistry Report, included as **Appendix A**.

In the current geochemical characterization program, additional lithotypes, including *Yc*, *Yne*, and *LZ-FW*, were also screened for the presence of asbestiform minerals. Lab reports for samples analyzed after 2012 are provided in **Appendix E.** None of the samples submitted for asbestiform mineral screening contained detectable asbestos using PLM analysis (**Table 3-5**). For this reason, confirmation testing using TEM methods was not warranted.

TABLE 3-5. Results of 2012 and 2015 Asbestiform Mineral Testing

Lithotype	Homogeneous	Layers	Asbestos Detected	Non-Asbestos Fibers %	Non-Fibrous Materials %
LZ-FW	Yes	1	ND	0	100
Ynl B	Yes	1	ND	0	100
Ynl B 2	Yes	1	ND	0	100
USZ 1	Yes	1	ND	0	100
USZ 2	Yes	1	ND	0	100
Ynl 1	Yes	1	ND	0	100
Ynl 2	Yes	1	ND	0	100
Ynl 0	Yes	1	ND	0	100
Yc	Yes	1	ND	0	100
Yne	Yes	1	ND	0	100
IG	Yes	1	ND	0	100

ND=Non Detect
2012 Asbestiform mineral data are presented here for comparison with the 2015 data.

3.2 Kinetic Testing of Waste Rock

Humidity cell tests (HCTs) are designed to study the rate of sulfide mineral oxidation and are often used to simulate long-term metals leaching in aerobic (accelerated weathering) environments. Typically, HCTs are run using established American Society for Testing and Materials (ASTM) testing protocols. Crushed rock is placed in a column and aerated with alternating cycles of humid and dry air, followed by weekly flushing with a relatively large volume of water (approximately 2 pore volumes). The column is allowed to drain and the cycle is repeated weekly for what has conventionally been a 20–week period. However, there are no fixed timelines for HCT duration, which should be determined by evidence of steady state in key reaction rates, such as sulfide oxidation and depletion of alkalinity

Kinetic tests that are strongly alkaline and show no evidence of metal release, and contain little to no sulfide mineralization, or those that are strongly acidic, may not require more than 20 weeks of testing. A shorter period of testing may be sufficient to meet risk management and data objective requirements. However, tests of materials that are equivocal and show ongoing sulfide oxidation may require much longer periods of testing to evaluate the potential for development of acidic conditions.

Alternatively, termination of tests can be determined based on risk management protocols. For example, although the 2012 HCT test of *USZ* rock from the 2012 Decline did not produce acidic leachate, the high potential for acid production indicated by static testing led Tintina to stipulate that the *USZ* waste would be handled as PAG. As a result, this HCT was terminated at 24 weeks in spite of continued sulfate production. A subsequent need was identified to predict metal release under sulfide oxidizing conditions in this unit, site-wide, and so a second test was initiated. In most cases, as a practical matter, humidity cell duration is currently determined by the supervising geochemist with regulatory and other stakeholder input.

Water collected from the column is analyzed for sulfide oxidation and neutralization parameters (e.g., pH, redox potential (Eh), sulfate, alkalinity, acidity, andFe speciation) each week, and for metals periodically. The suite of metals is typically determined based on style of mineralization and regulatory requirements, and the reporting limits for analysis are based on both regulatory requirements and data quality objectives (i.e., modeling goals).

All waste rock HCTs for the Tintina Black Butte Project were conducted by McClelland Laboratories of Sparks, Nevada using the (ASTM) 5744-07 method. Sulfide oxidation and acid neutralization parameters were measured weekly in the column lab, which are presented the following sections, as well as in **Appendix C**. A comprehensive suite of metals has been analyzed for effluent collected during weeks 0, 1, 2, 4, and every fourth week thereafter by Energy Laboratories until the termination of the columns for each respective lithotype.

The Tintina Black Butte Project kinetic tests were conducted in two series. During the 2012 Decline geochemical testing program, four HCTs were commissioned, one for each of the following lithotypes: *USZ*, *Ynl 0*, *Ynl B*, and *Ynl*. When the focus shifted to the operational scale plan in late 2014, and new lithotypes were added to the waste rock characterization program, a second set of kinetic HCTs were initiated, including the *USZ, Ynl B, LZ-FW,* and *Yc* lithotypes.

A final laboratory report of 2012 kinetic HCT results from McClelland Laboratories is included in **Appendix C**, which also includes Energy Labs' reports of effluent analyses. A similar report will be produced once the 2015 HCTs are concluded, however these tests are still ongoing. Tables summarizing all results are presented in **Tables C1-C2** of **Appendix C** and compared with applicable MT DEQ water quality standards (MT DEQ, 2012) based on hardness-dependent criteria adjusted for an average background water hardness of 130 mg/L.

3.2.1 2012 Decline Kinetic Testing

Subsequent to completion of the 2012 Decline report, Tintina elected to proceed with kinetic testing of the *USZ, Ynl, Ynl 0*, and *Ynl B* materials, which would have contributed significant proportions of the waste rock tonnage for the 2012 Decline. Composites for HCTs were constructed as follows: equal proportions of the two *USZ* composites (one designated "High Fe" and the other "Low Fe") were combined to form a single composite labeled "*USZ 1/2*"; the two *Ynl* composites were combined to form a single composite labeled "*Ynl 1/2*"; and the *Ynl 0* and *Ynl B (2012 Decline)* composites were used, as originally designed, for kinetic testing. The *IG* and *Ynl B (original decline)* composites were not included in the kinetic testing program, as they were no longer considered a significant lithotypes. Both the *USZ* and the *Ynl 0* columns were decommissioned after week 24. The *Ynl B* and *Ynl* columns were decommissioned after weeks 62 and 88, respectively. The results of each kinetic humidity cell test are discussed below, including figures of select weekly parameters and periodic metals, by lithotype. Tabulated data are presented in **Tables C-1** and **C-2** of **Appendix C**.

An understanding of the sulfide and carbonate mineralogy of the tested materials, as well as the mineral residence of elements detected in humidity cell effluent, is important to the correct interpretation of kinetic tests results. The results of all mineralogical analyses of humidity cell leached rock are discussed below and presented in detail in Appendix F of this report.

The mineral residence of Thallium (Tl) and selenium (Se), which were elevated in some HCT effluents, was of particular importance in interpreting the results for this project. The Black Butte Copper deposit is hosted in interbedded shales and dolomitic carbonates, with locally massive sulfide mineralization containing primary and secondary pyrite, chalcopyrite, bornite, barite, and silica. Commonly recognized, naturally-occurring Tl-rich minerals such as lorandite ($TlAsS_2$) and crookesite [$Cu_7(Tl,Ag)Se_4$] are not known to occur in the deposit. Because Tl occurs naturally in soils, predominantly as the charged ion Tl^+, and can occur as a cationic substitute for potassium in aluminosilicate minerals, the Tl in leachate from the *USZ* and *Ynl* columns may result from desorption or weathering of those minerals. Tl also displays chalcophile characteristics and has been found to occur with sulfides such as pyrite, sphalerite, and galena.

In order to better understand the sources of sulfate production and metal release (particularly of Tl and Se in the humidity cells), weathered samples were analyzed by mineral liberation analysis (MLA) in 2012 on samples collected from the humidity cells at the following times:

- USZ collected at 24 weeks;
- Ynl 0 collected at 24 weeks;
- Ynl B collected at 33 weeks; and
- Ynl collected at 33 weeks.

Additionally, a non-weathered sample of *Ynl* from the composite used for HCT construction was analyzed as a basis for comparison, based on the assumption that the trace element content would be highest in non-weathered material. All mineralogical analyses were conducted by the Center for Advanced Mineral & Metallurgical Processing (CAMP) at Montana Tech in Butte, Montana.

Analyses conducted on the four weathered samples included MLA by scanning electron microscope-electron dispersive spectroscopy (SEM-EDS), and sparse phase liberation (SPL), as well as x-ray mapping, which was implemented only on the weathered specimens. The non-weathered *Ynl* sample was subjected to heavy liquid separation (HLS) to separate the heavy (dense, sulfide-rich) and light (silica-rich) mineral fractions, followed by inductively-coupled plasma analysis of a 4-acid digested sample and MLA of the two fractions.

No specific Se- and Tl-bearing minerals were detected in any of the analyses of *USZ*, *Ynl 0*, *Ynl B*, and *Ynl* undifferentiated rock. ICP analysis of the HLS "float" and "sink" fractions of the non-weathered *Ynl* sample revealed higher concentrations of cadmium (Cd), Fe, nickel (Ni), and Tl in the dense, sulfide-rich "sink" fraction. This suggests that Tl is present at trace levels in pyrite, because no specific Tl-bearing mineral was identified

The CAMP report describing these analyses is included as **Appendix C**.

3.2.2 2015 Kinetic Testing

In 2015, Tintina elected to begin kinetic tests on the previously uncharacterized *Yc* and *LZ-FW* lithotypes, while also conducting tests on newly generated composites of the *USZ* and *Ynl B* materials, which were developed to better represent these lithotypes at the site-wide operational scale. Although changes in mine design altered the waste rock proportions, rendering *Yc* insignificant in terms of tonnage, this baseline test was continued.

The 2015 kinetic tests were initiated in June 2015 and are currently in weeks 19 and 21 of testing. Data received through October 30, 2015 are presented below and in **Tables C-3 and C-4** of **Appendix C**. Laboratory results of all ongoing HCTs will be made available at the completion of testing. Because these tests are ongoing, mineralogical analyses have not been conducted.

3.2.2.1 2012 Ynl - Undifferentiated Lower Newland Formation (4 % Waste Rock Tonnage)

The lower Newland Formation composite was comprised of highly carbonaceous, locally sulfidic black shale collected from multiple intervals within the stratigraphic section between the *Ynl 0* "nose" and the *USZ* unit. As one approaches the *USZ* from above, the frequency and magnitude of sulfide stringers increases. While there is some sulfidic material included in the *Ynl*, and thus in the sample of rock used to construct the column, the NNP and NP:AP characteristics summarized above and in Appendix C indicate that it is strongly net neutralizing. The consistently circum-neutral pH observed throughout the 2012 kinetic testing supports this assessment. The cumulative production of sulfate from this cell is approximately 40% of that observed in 24 weeks of testing of the *USZ*. Nevertheless, like the *USZ*, this cell showed stable, ongoing sulfate production, which increased sharply at 20 weeks, peaked mid-test, and then slowly returned to original rates. The very slow drop in sulfate required a prolonged period of humidity cell testing,

with this terminated only when sulfate stabilized at values close to original rates of release in week 88 (**Figure 3-3** and **Appendix C**).

- Effluent pH was principally alkaline for the duration of the test with some values slightly below 7. Values for pH went from 6.77 in week 0 to 7.36 in week 88, with a maximum pH of 7.75 observed in week 55.
- With the exception of week 0, redox potential was oxidizing for the duration of the test.
- After an initial period of high conductivity (e.g. 1,100 µS/cm in week 1), values remained fairly stable with a minimum of 232 µS/cm (week 19) and a final value of 409 µS/cm in week 88.
- With the exception of week 0, Fe release was consistently low and mostly below detection.
- Sulfate production declined significantly in initial weeks of testing with a pronounced lag followed by an accelerated release of sulfate between weeks 20 and 28. The rate of sulfate release returned to that of the pre-20 week time frame after week 79. Maximum sulfate release was observed in weeks 0 and 1 (600 mg/L) and was 130 mg/L at week 88.
- Acidity was detected during week 0, and then was not detected again until week 48. Thereafter, acidity ranged from 0 mg/L to 4 mg/L for the remainder of the test, and was consistently below detection at the conclusion of testing.
- Alkalinity was detected in all weekly extracts and concentrations ranged from 53 mg $CaCO_3$/L in week 0 to 27 $CaCO_3$/L in week 88, with a minimum alkalinity observed in week 20 (12 mg $CaCO_3$/L).

In terms of metal production (**Figures 3-4a** and **b**, and **Appendix C**), transient concentrations of Cd, Fe, and Ni were observed to exceed surface water standards in week 0 effluent from the *Ynl* test. With no further evidence of release of these metals during the test, these week 0 exceedances were more likely related to sample preparation rather than to weathering in the column. Se was observed to exceed surface water standards in weeks 0, 1, and 2, but not thereafter, while Tl was detected in concentrations that exceeded groundwater standards in weeks 0, 1, and 2, and in concentrations that exceed surface water concentrations thereafter.

MMA analysis indicted that the weathered *Ynl* contains 31.5 wt.% quartz, 25.1 wt.% muscovite, 17.6 wt.% dolomite, 10.8 wt.% pyrite, 9.8 wt.% potassium feldspar, 2.2 wt.% biotite, and 0.95 wt.% barite. Analyses of the non-weathered *Ynl* sample generally agreed with those of weathered *Ynl*. However, slightly altered mineralogical composition was observed, which has been attributed to sub-sampling variability and the weathering of materials over 33 weeks of column testing.

The *Ynl* represents a low proportion of the expected waste rock tonnage (4%). The multi-element chemical characteristics of the subsamples selected for the 2012 Decline test aligned well with the overall, site-wide population, and so additional testing was not pursued in 2015.

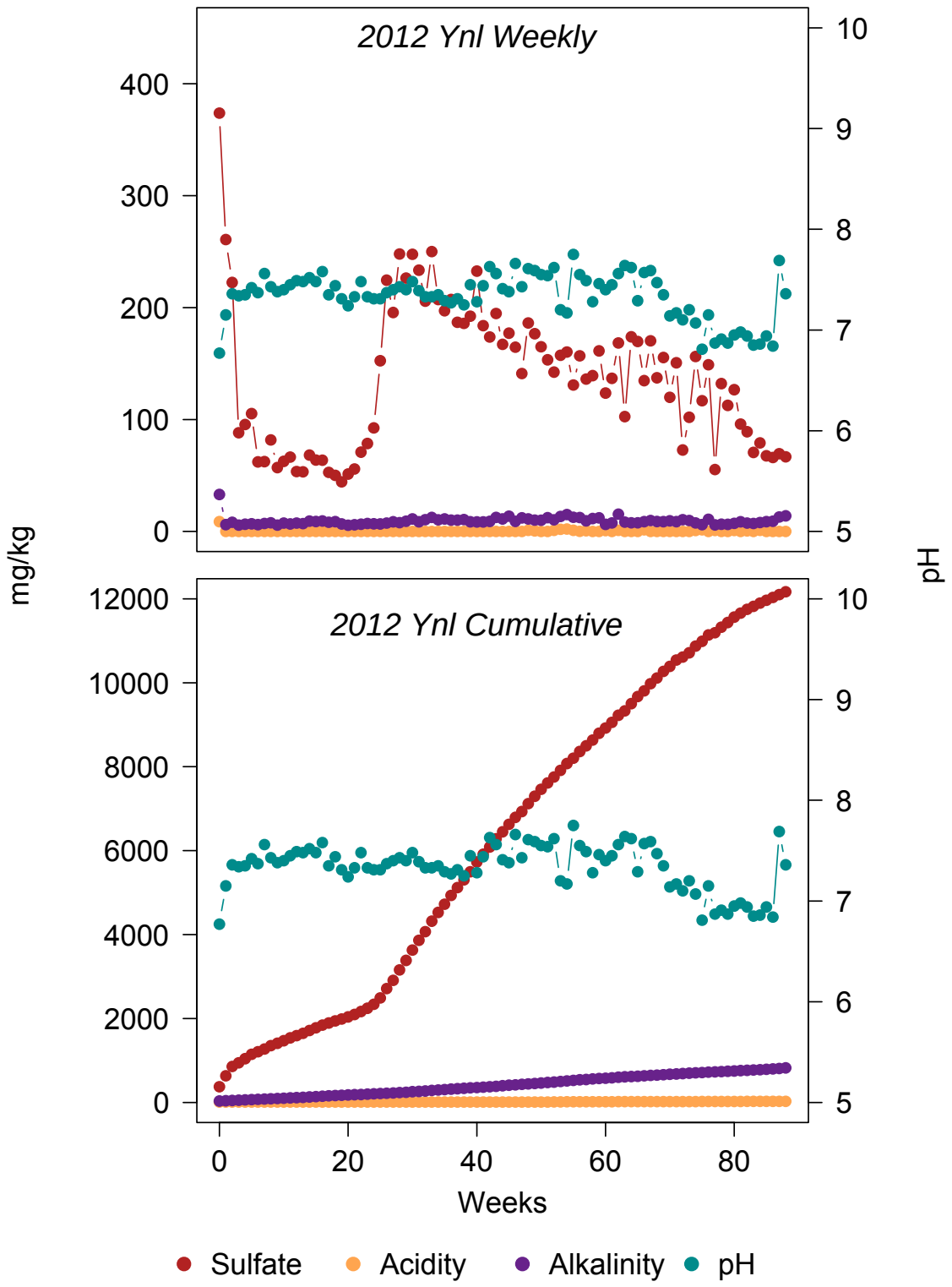


FIGURE 3-3. 2012 *Ynl* HCT Weekly and Cumulative Parameters

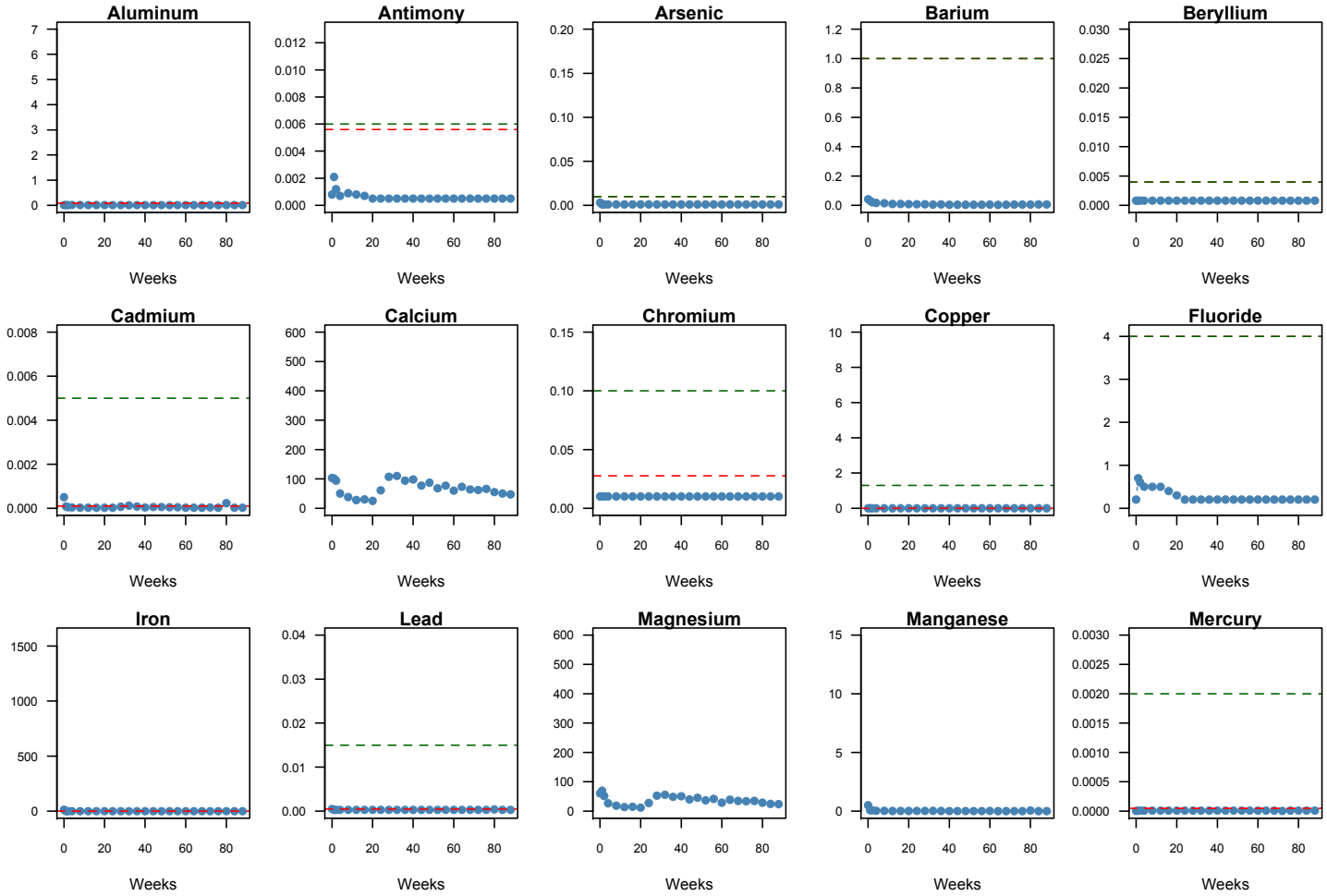


FIGURE 3-4a. 2012 *Ynl* HCT Periodic Metals

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Total weeks of testing=88.

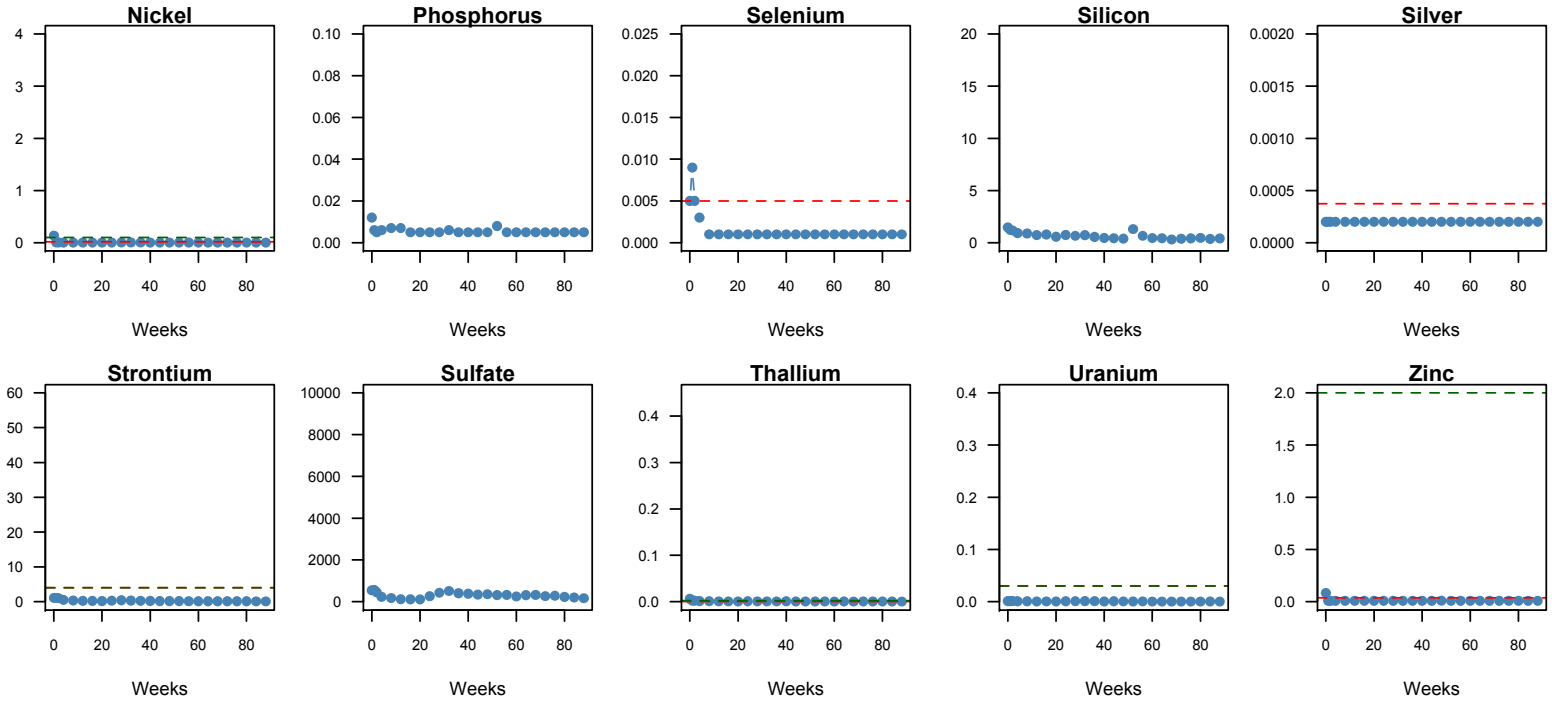


FIGURE 3-4b. 2012 *Ynl* HCT Periodic Metals, continued.

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Total weeks of testing=88

3.2.2.2 2012 USZ - Upper Sulfide Zone (28 % Waste Rock Tonnage)

The *USZ* is a portion of the Lower Newland dolomitic shale that contains locally massive sulfide mineralization. As a result, this waste lithotype is identified as potentially acid generating based on static test data. In spite of its strongly negative NNP and low NP:AP ratio (Section 3.1.2), however, this rock maintained a net alkaline pH throughout the HCT test, apart from week 0 and week 2, which had values of 5.95 and 6.44, respectively. The final pH was 7.28 after 24 weeks of leach testing. This reflects the strongly alkaline character of the host rock, despite the relatively high rate of sulfide oxidation that was consistently observed in this humidity cell test, which released 7,736 mg/kg of cumulative sulfate. During week 6, results reported for *USZ* appeared anomalous, with sulfate and redox values dropping suddenly, indicating an unknown procedural error, such as loss of oxygen flow to the cell. This outlier was removed from the analysis, but these data are included in **Figure 3-5** and in **Table C-1** of **Appendix C**.

- Effluent pH was alkaline for the vast majority of the test and ranged from pH 5.95 (week 0) to 7.28 in week 24, with a maximum pH of 7.38 observed in week 13.
- Redox potential was oxidizing for the duration of the test.
- Conductivity values began fairly high and steadily decreased before stabilizing. Values dropped consistently from 2090 µS/cm (week 1) to a final value of 940 µS/cm in week 0, with a minimum of 828 µS/cm (week 19).
- With the exception of week 0 (102 mg/L), Fe release was consistently low.
- As expected for a sulfide-bearing deposit, sulfate release was fairly high, but also showed a declining trend. Values ranged from 1160 mg/L (week 1) to 340 mg/L at the end of testing (week 24).
- Acidity was only detected in weeks 0-2 and ranged from 162 mg/L (week 0) to 1 mg/L (weeks 1 and 2) and was subsequently below detection for the remainder of testing.
- Alkalinity was detected in all weekly extracts and remained relatively stable, ranging from 9 mg $CaCO_3$/L (week 2) to 25 mg $CaCO_3$/L (week 18) with a final alkalinity of 17 mg $CaCO_3$/L in week 24.

In terms of metal release, concentrations of Al, Cd, Fe, and Zn exceeded surface water criteria in week zero leachate, while concentrations of As, Pb, Ni, and Tl exceeded both surface and groundwater criteria in week zero leachate (**Figures 3-6a and b, and Table C-2 of Appendix C**). However, this is more likely a reflection of the sample preparation for placement into the leach test than of equilibrium weathering chemical reactions within the test itself. Following week 0, this pattern changed entirely, and the majority of these metals were not detected. In weeks 1, 2, and 4, Se and Tl were observed to exceed surface water criteria; in later weeks, only Tl exceeded the surface water criterion. With the exception of week 0, no groundwater criteria were exceeded.

MLA analysis showed that the *USZ* composite contained pyrite (45.6 weight %), with quartz (18.6 wt.%), dolomite (16.5 wt.%), muscovite (9.7 wt.%), and potassium feldspar (4.85 wt.%). While this mineral composition supports the sulfate production observed during kinetic testing, MLA did not identify any Se- or Tl-bearing minerals. This may be due to the detection limit of this instrument, which is approximately 1000-10,000 ppm or approximately 0.1 to 1% by weight depending on the element.

Figure 3-5 shows that the rate of sulfate production was elevated and steady and, based on ABA and NAG analyses of both sulfide and carbonate, would have likely remained so for many weeks if the kinetic test had been continued. Because Tintina chose to designate this lithotype as PAG for the 2012 Decline Management Plan, the test was not continued to a point where alkalinity was depleted and pH dropped. Recognizing that this is a volumetrically important and reactive lithology, additional samples were collected for a second HCT that is represented of the *USZ* site-wide. This test is ongoing and will be allowed to continue until solutes stabilize.

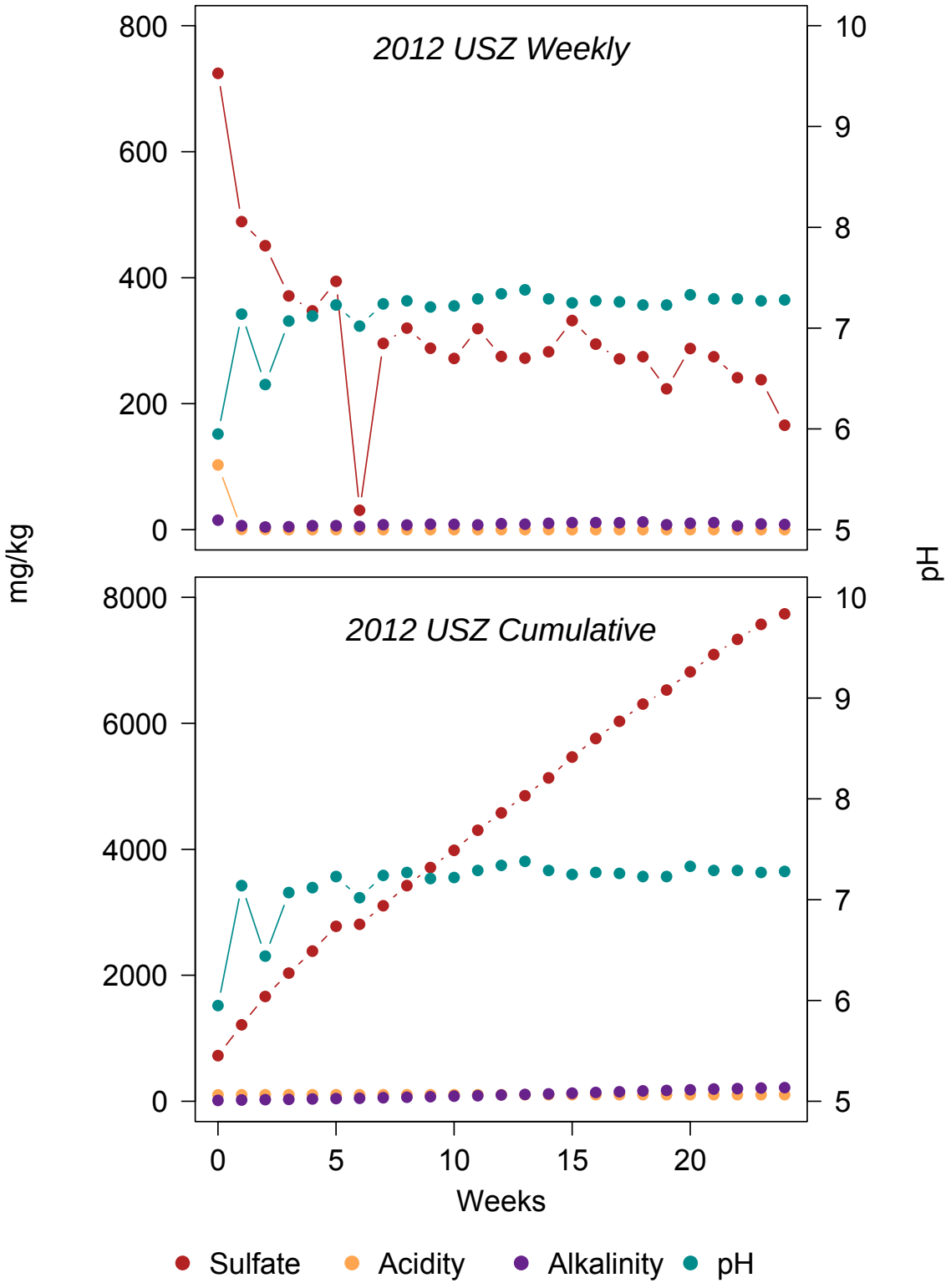


FIGURE 3-5. 2012 *USZ* HCT Weekly and Cumulative Parameters

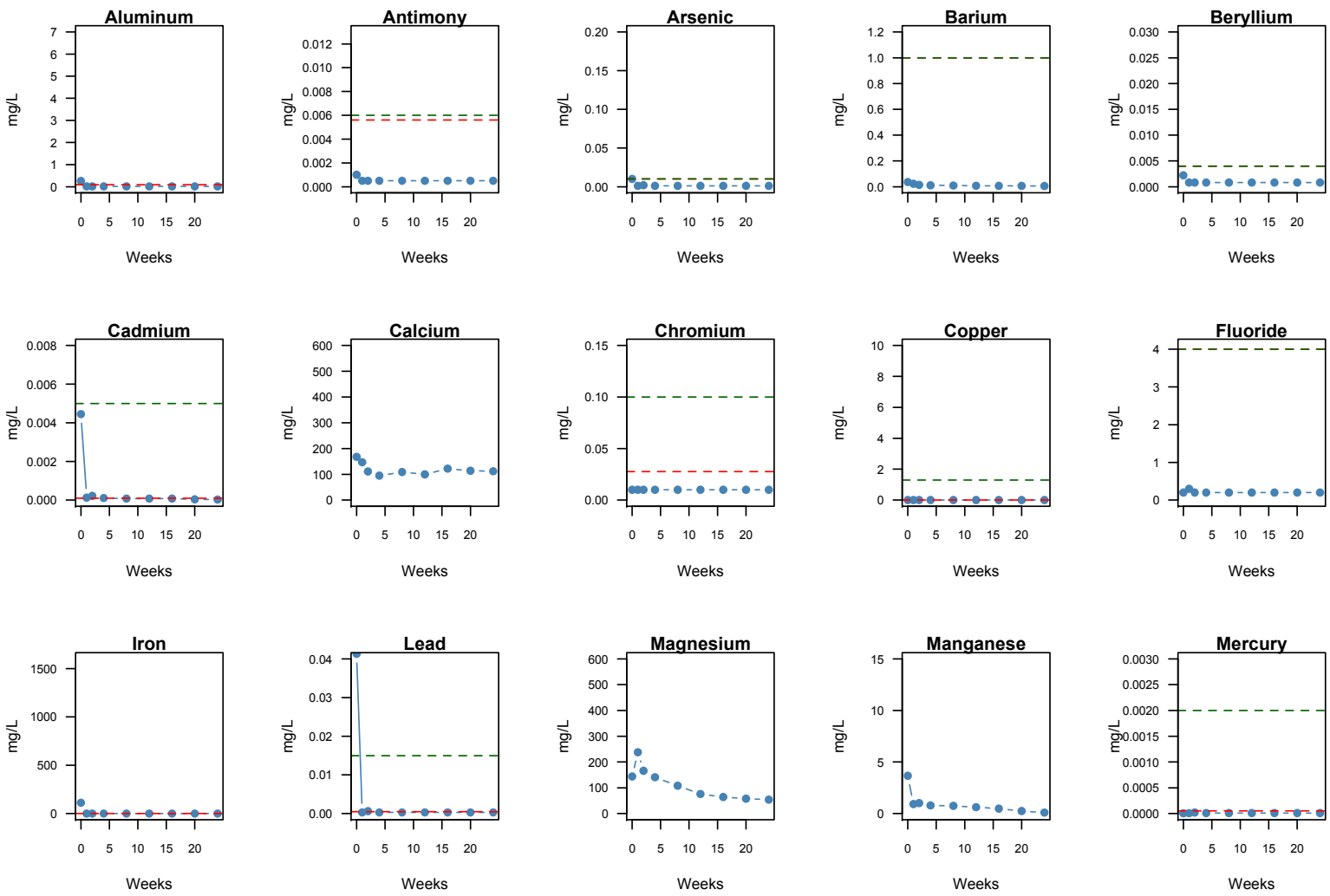


FIGURE 3-6a. 2012 *USZ* HCT Periodic Metals

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Total weeks of testing=24

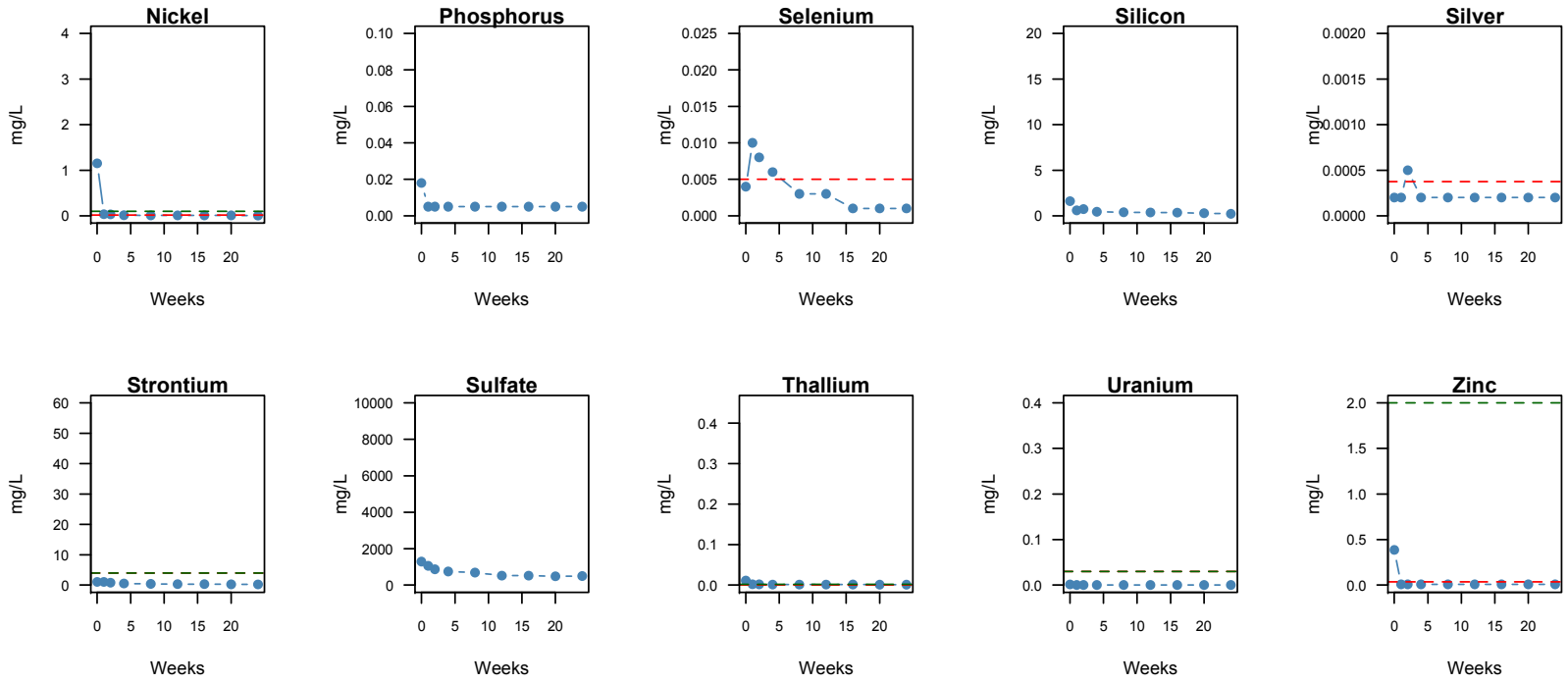


FIGURE 3-6b. 2012 *USZ* HCT Periodic Metals, continued.

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Total weeks of testing=24

3.2.2.3 2015 USZ – Upper Sulfide Zone (28 % Waste Rock Tonnage)

The 2015 *USZ* HCT was started in June 2015 and is currently online, in week 21 of testing. Below is a summary of observed chemistry to-date.

- The initial effluent pH was relatively low, but climbed steadily to be nearly neutral for the duration of testing (to-date). Ranges for pH were 4.13 (week 0) to 5.92 in the most recent week of testing (week 19) and a maximum pH of 6.87 in week 6.
- Redox potential has remained oxidizing to-date, ranging from 133 mV (week 1) to 428 mV (weeks 5 and 8) and most recently 308 mV in week 19.
- Conductivity values have remained fairly high, thus far with a maximum of 5,360 µS/cm (week 0), which decreased and has been stable around 2,500-2,800 µS/cm.
- High Fe release in weeks 0 and 1 appear to be relics of sample preparation, as subsequent Fe production has remained below 2 mg/L, and is predominantly detected as Fe^{3+}.
- Following an initial rinse (in week 0), sulfate production has remained high thus far in testing, with a minimum value of 1,801 mg/L (week 19) and recent maximum (except week 0) of 3,000 mg/L (weeks 4 and 5).
- Similar to sulfate, following an initially high acidity, values have, thus far, ranged from (excepting week 0) <1 mg/L (week 3) to 50 mg/L (week 1), but has most recently remains stable around 10 mg/L.
- Alkalinity has been detected in all weekly extracts thus far, except week 0. Detected concentrations ranged from 3 mg $CaCO_3$/L (week 2) to 46 mg $CaCO_3$/L (week 3), but recently remained stable between 7 and 9 mg/L.

Generally, the current 2015 *USZ* HCT has exhibited greater potential for acid generation and metal release than the 2012 *USZ* HCT. Specifically, while the 2012 *USZ* HCT only exceeded Se (weeks 1 and 2) and Tl (all weeks) after the initial week 0 flush, the 2015 *USZ* HCT has consistently exhibited surface water quality exceedances for Cd, Cu, and Ni, and ground water quality exceedances for strontium, and Tl. Additionally, release of Al, Fe, and Zn exceeded surface water quality standards during weeks 0 and/or 1, and As, beryllium (Be), Cd, Cu, Ni, and Pb exceeded ground water quality standards during weeks 0 and/or 1. Finally, repeated occurrences of Pb, mercury (Hg), and Se, in exceedance of surface water quality standards have been observed at various times during this test.

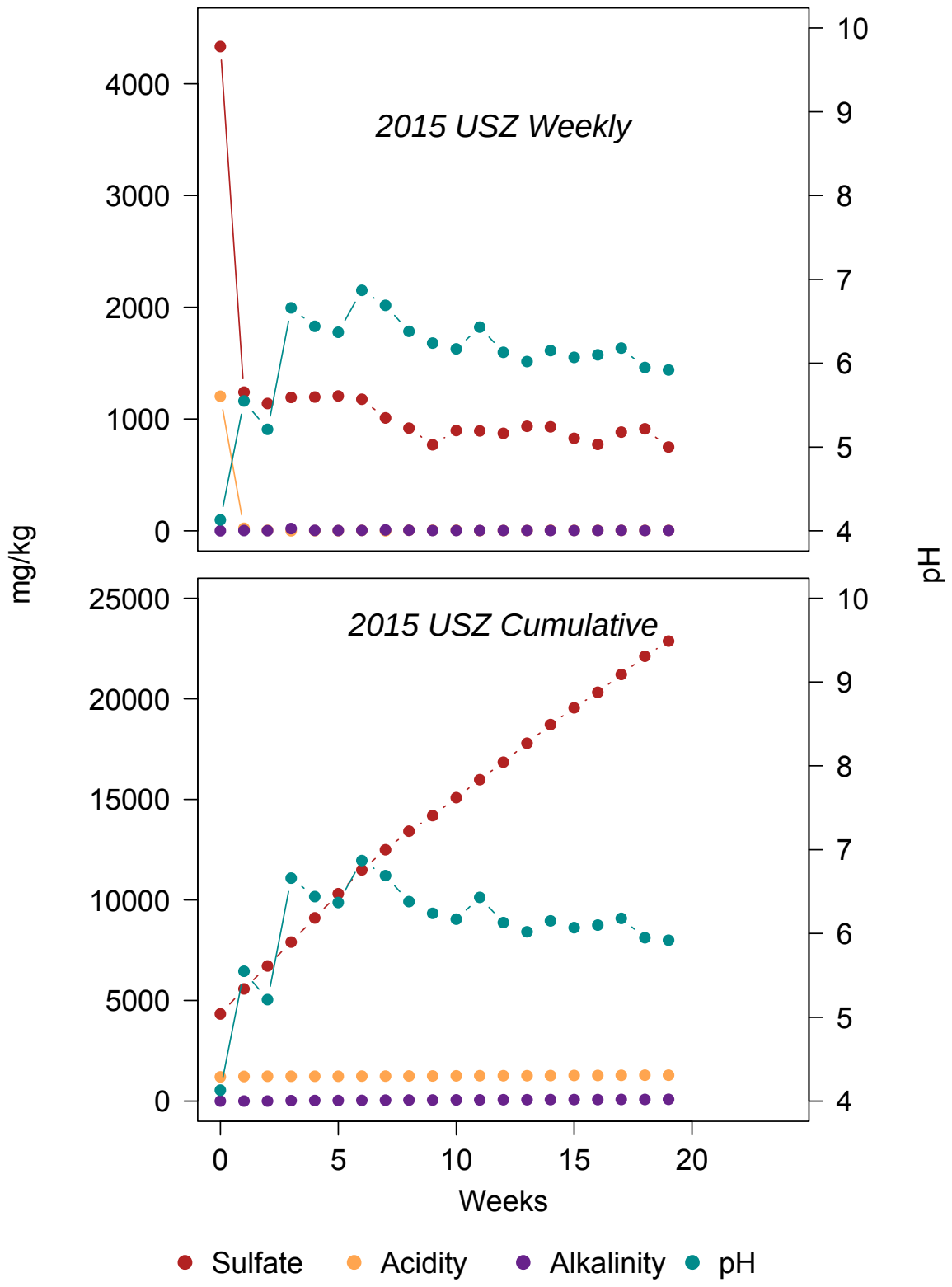


FIGURE 3-7. 2015 *USZ* HCT Weekly and Cumulative Parameters

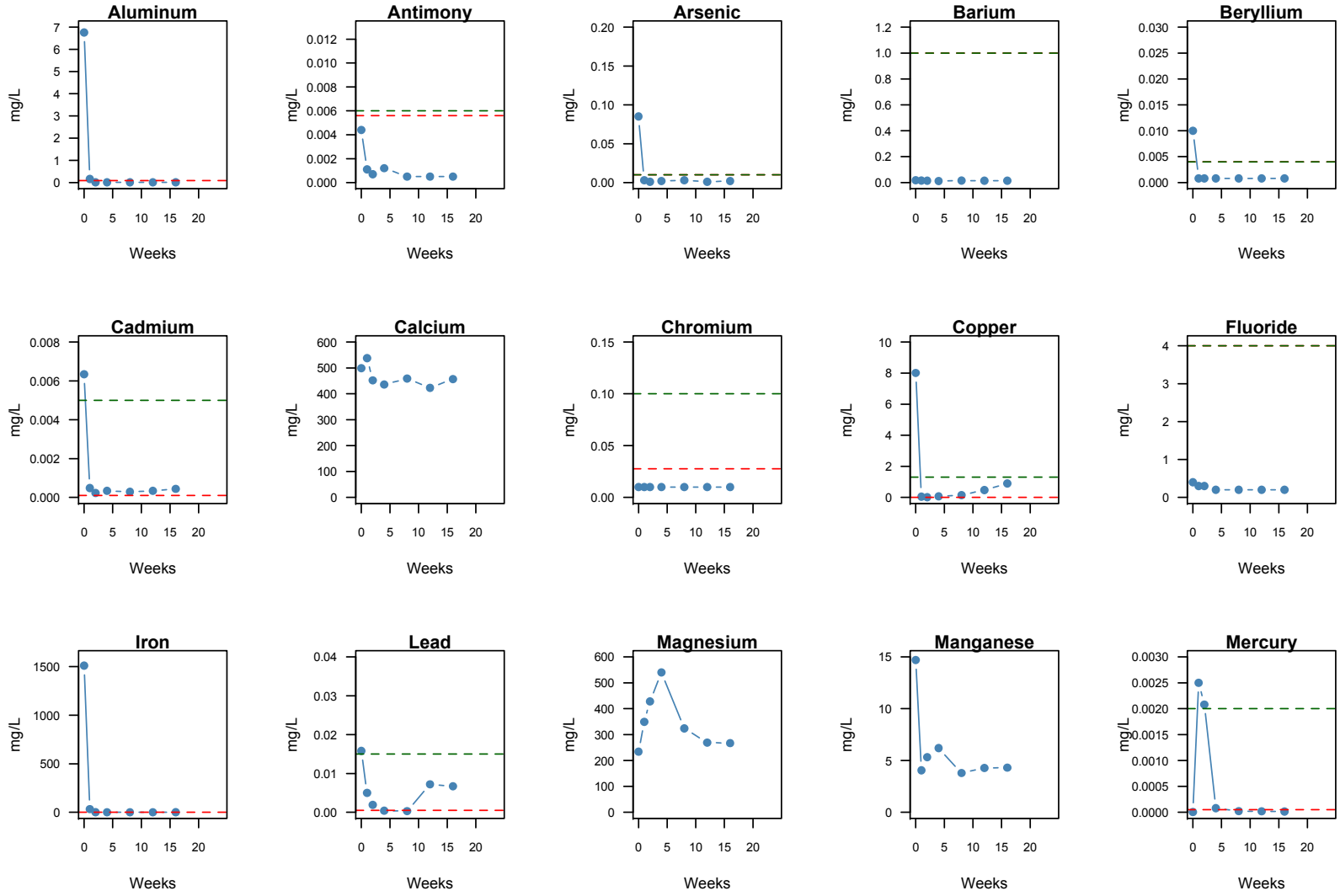


FIGURE 3-8a. 2015 USZ HCT Periodic Metals

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Test ongoing, current data available for 19 weeks

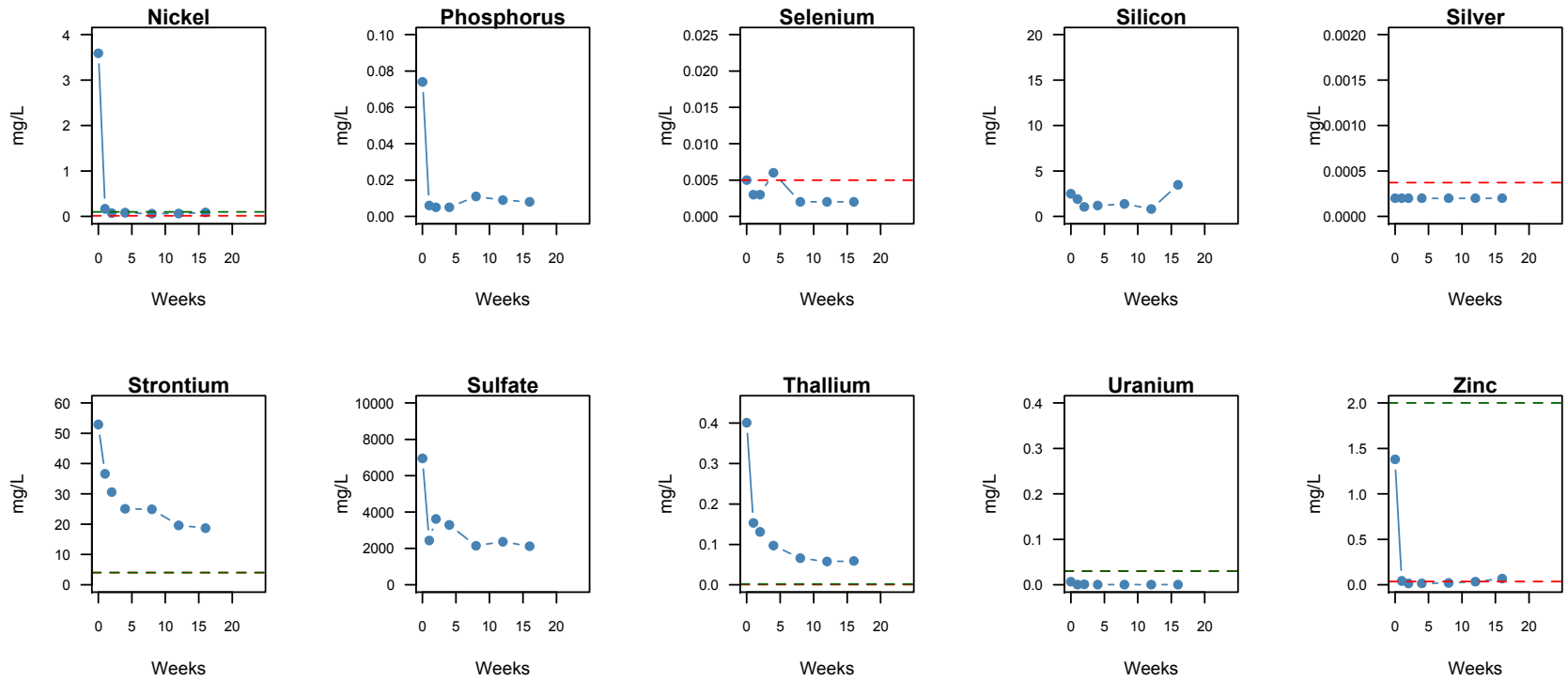


FIGURE 3-8b. 2015 *USZ* HCT Periodic Metals, continued.

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Test ongoing, current data available for 19 weeks

3.2.2.4 2012 Ynl B - Lower Newland Conglomerate and Shale (32% Waste Rock Tonnage)

The *Ynl B* is comprised of conglomerate and shale from the basal portion of the lower Newland Formation. The static parameters summarized above indicate varying levels of acid and neutralizing potential for the samples included in the tested composite. This variability was also reflected in the 2012 Decline HCT, in which sulfide oxidation peaked in week 16 and slowly declined for the remaining weeks of the test. The pH remained strongly neutral (7.69 in week 62), despite the cumulative release of 5,291 mg/kg by week 62 in the 2012 HCT. Also, an abundance of alkalinity was observed despite increased sulfide oxidation between weeks 10 and 20 (**Figure 3-9**, and **Table C-1**).

- Effluent pH was alkaline for the duration of the test and ranged from 8.66 in week 0 to 7.69 in week 62, with a maximum pH of 7.27 in week 54.
- Redox potential was oxidizing for the duration of the test and remained relatively stable (133 in week 0 and 154 in week 62) with minimum and maximum values of 20 mV (week 57) and 335 mV (week 40).
- Following week 10, conductivity transitioned from low to mid-range, where it remained, with a slight downward trend. Values range from 120 µS/cm (week 6) to 690 µS/cm (week 17).
- Iron release was consistently low and was predominantly below detection.
- Sulfate production was low until week 10, after which it rose to peak in week 16 (350 mg/L) and subsequently dropped, reaching steady state concentrations around week 32, with a final sulfate concentration of 120 mg/L. Sulfate ranged from 20 mg/L (week 0) to 350 mg/L (week 16).
- Acidity was not detected in any weeks.
- Alkalinity was detected in all weekly extracts and with a generally stable trend around 25 mg/L, and a range from 47 mg $CaCO_3$/L (week 54) to 18 mg $CaCO_3$/L (week 42). The final alkalinity was 28 mg/L.

The *Ynl B* did not show significant release of metals in week 0, apart from Sb, which exceeded surface water quality standards in weeks 0 and 2, and Tl, which was only detected at concentrations exceeding surface water quality standards in week 0, but not thereafter (**Figures 3-10a** and **b,** and **Table C-2**). Similar to the other rock types, Se exceeded surface water standards in weeks 1, 2, and 4, but not thereafter. Enviromin continued the *Ynl B* kinetic test until it stabilized with low release of sulfate and a neutral pH, consistent with its strongly net neutralizing static characteristic. The results suggest that the leaching has exposed and oxidized pyritic mineralization, but the available alkalinity was able to neutralize any produced acid. This column was taken off line with MT DEQ approval after week 62.

MLA analysis indicated that the *Ynl B* composite was comprised of 41.5 wt.% quartz, 29.0 wt.% dolomite, 19.6 wt.% muscovite, 3.9 wt.% potassium feldspar, and 1.6% pyrite. These results are consistent with the low levels of sulfate and metal release observed during kinetic testing.

During the 2015 review of previous geochemical test results, Tintina and Enviromin agreed that additional samples of *Ynl B* were needed to characterize this lithotype site-wide and, a second HCT of the *Ynl B* was initiated as described below.

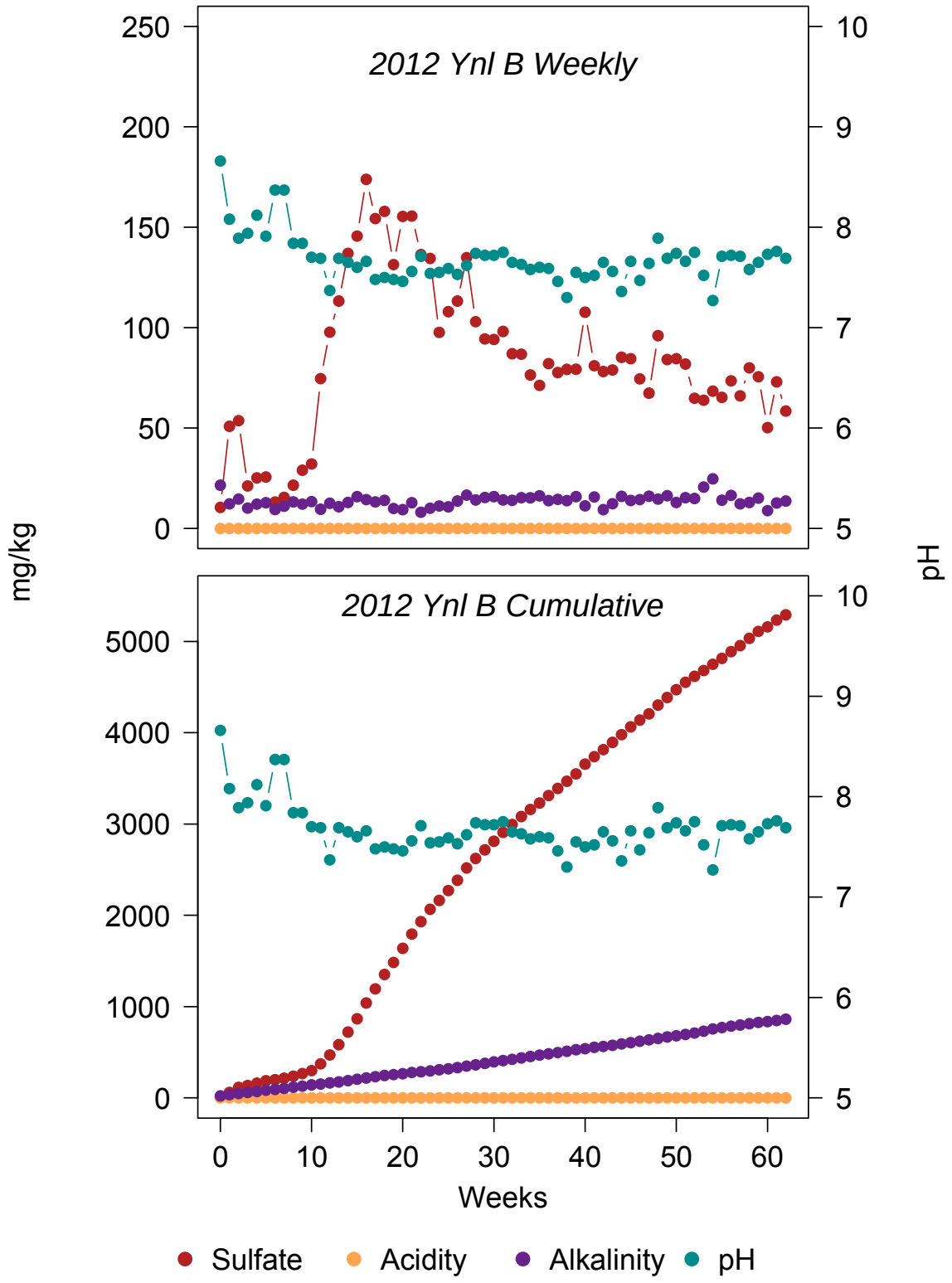


FIGURE 3-9. 2012 *Ynl B* HCT Weekly and Cumulative Parameters

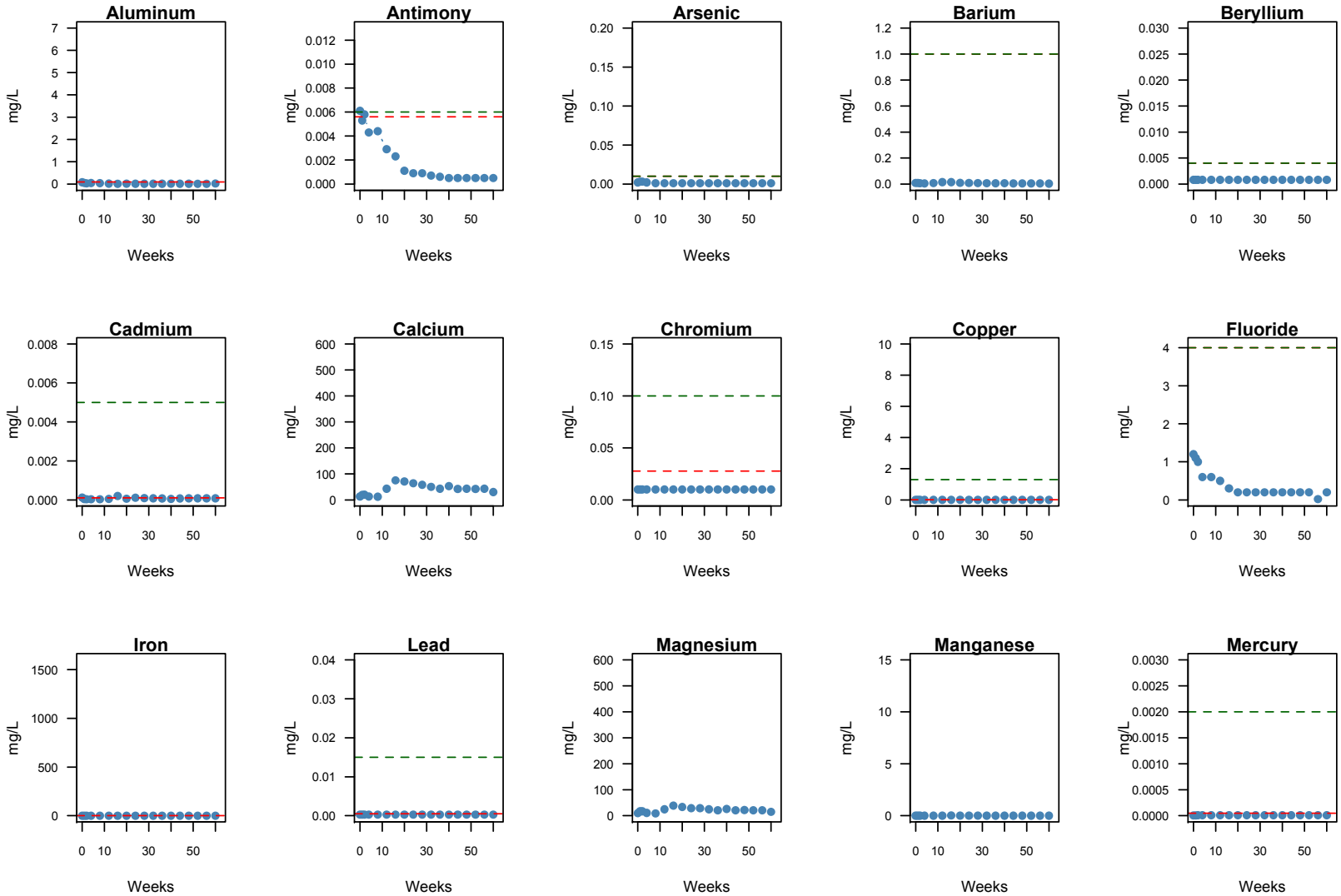


FIGURE 3-10a. 2012 *Ynl B* HCT Periodic Metals

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Total weeks of testing=62.

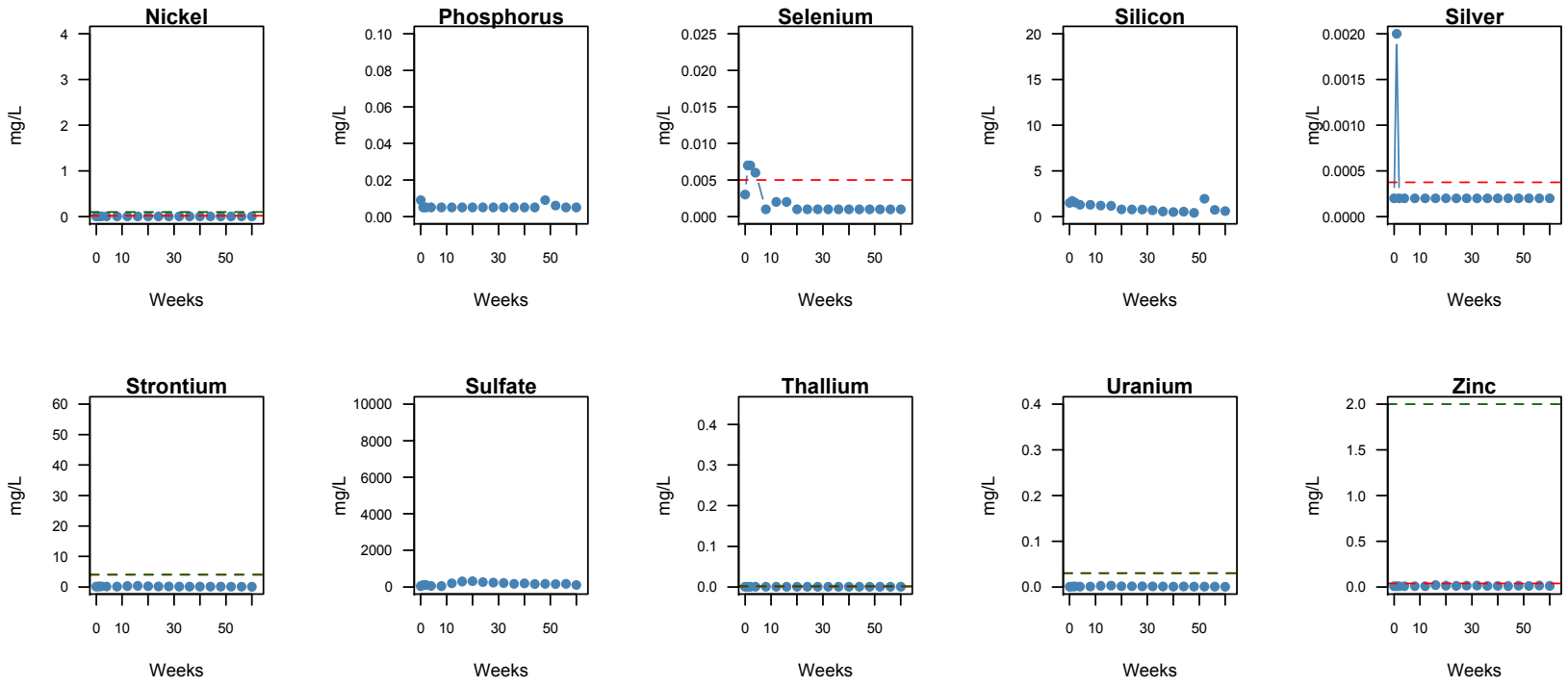


FIGURE 3-10b. 2012 *Ynl B* HCT Periodic Metals, continued.

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Total weeks of testing=62

3.2.2.5 2015 Ynl B – Lower Newland Conglomerate and Shale (32% Waste Rock Tonnage)

The *Ynl B* material used to construct the 2015 *Ynl B* HCT included samples representing the site-wide variation in this unit. Interestingly, the initial test results shows that the 2015 *Ynl B* HCT is producing pH, sulfate, acidity, and alkalinity values that are comparable to the early weeks of the 2012 *Ynl B* HCT. One exception is that sulfate production increased, peaked, and dropped off earlier in this test. The 2015 *Ynl B* HCT is currently in week 19 of testing, as summarized below (**Figure 3-11**, and **Table C-3**).

- Thus far, effluent pH has remained above neutral trending from 7.76 in week 0 to 7.in week 17, with a maximum pH of 7.86 (week 3) and a minimum pH of 7.19 (week 16).
- Redox potential has been oxidizing and stable for the duration of the test, thus far.
- Conductivity has varied greatly, with an initial flush in week 0, followed by a lag and subsequent resurgence. Ranges have been from 331 µS/cm (week 3) to 1723 µS/cm (week 7).
- Iron release has been consistently below detection for total Fe, Fe^{2+} and Fe^{3+}.
- Sulfate production has followed a similar trend to conductivity with an initial flush, followed by a lag and then a rebound in concentrations. Recent weeks have exhibited a decreasing sulfate production trend. Sulfate has ranged from 120 mg/L (week 3) to 1,016 mg/L (week 6), with a most recent sulfate of 254 mg/L in week 17.
- Acidity has not been detected thus far in testing.
- Alkalinity has been detected in all weekly extracts and concentrations ranging from 90 mg $CaCO_3$/L (week 0) to 18 mg $CaCO_3$/L (week 6), with a most recent concentration of 27 mg/L (week 17).

The metal release signature of the 2015 *Ynl B* HCT differed from that of the 2012 *Ynl B* HCT. Specifically, the 2015 *Ynl B* HCT has produced concentrations of Pb, Se, and Tl above the surface water quality standards. Tl was also detected in exceedance of its relevant ground quality standard in week 0.

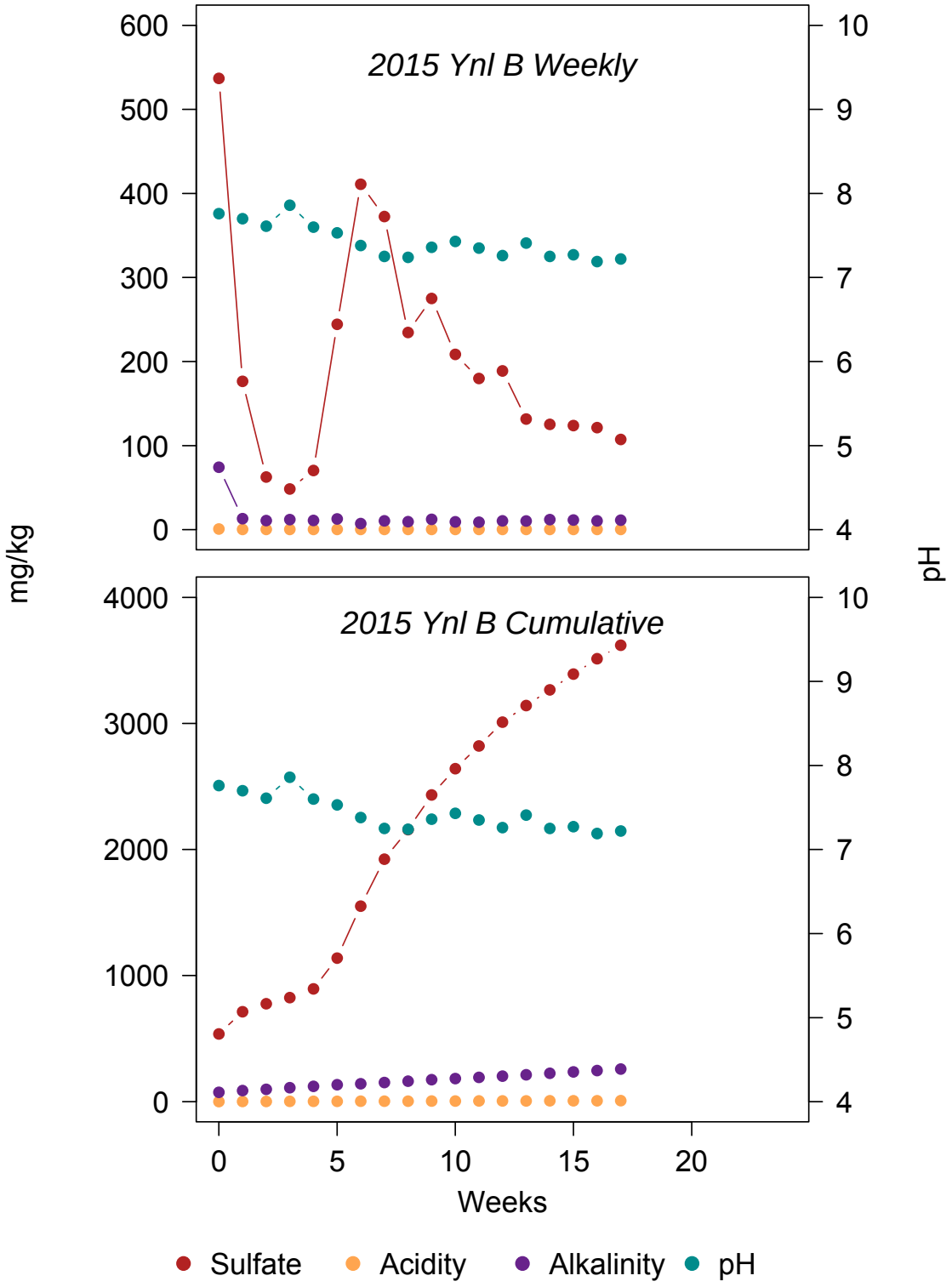


FIGURE 3-11. 2015 *Ynl B* HCT Weekly and Cumulative Parameters

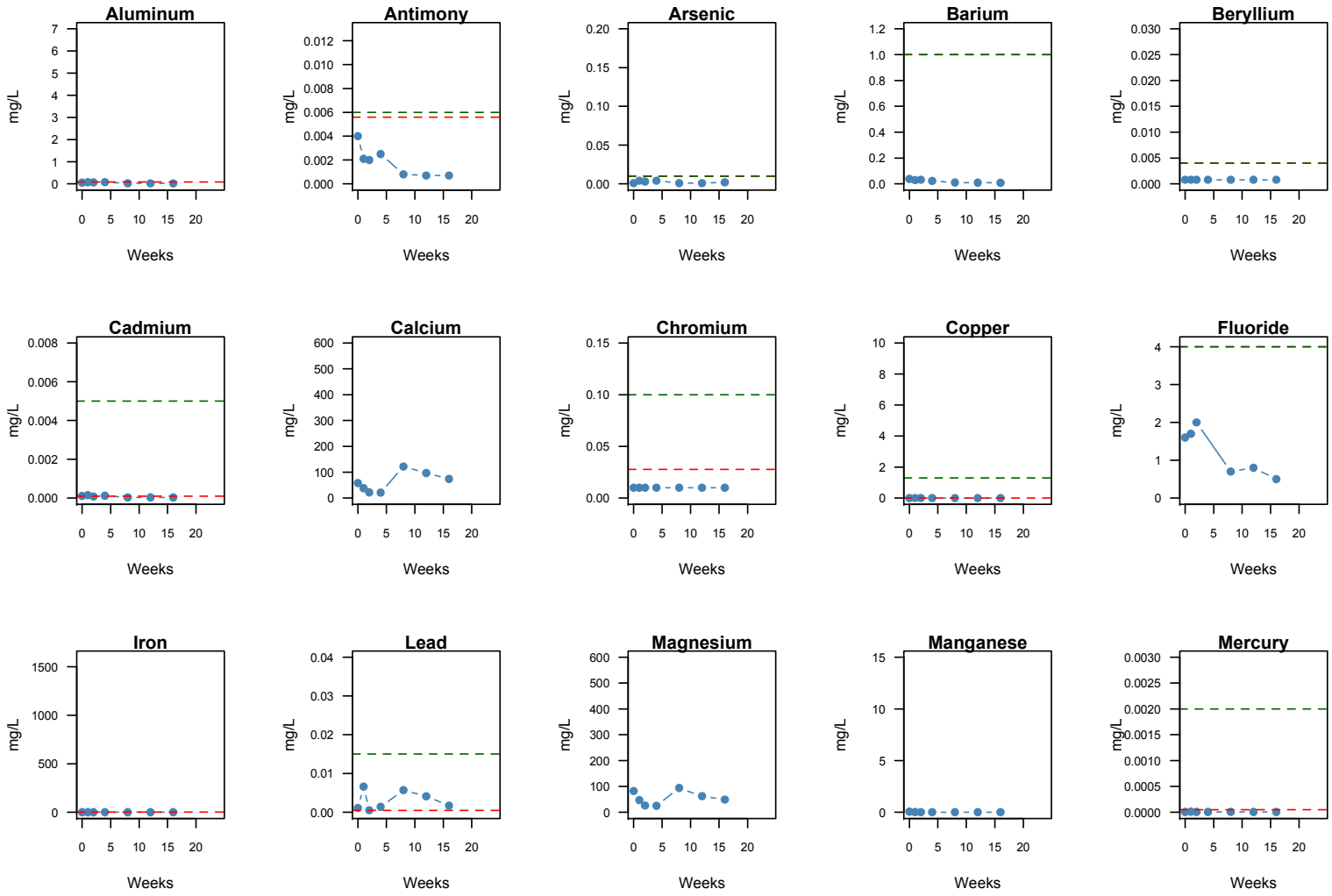


FIGURE 3-12a. 2015 *Ynl B* HCT Periodic Metals

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Test ongoing, current data available for 17 weeks.

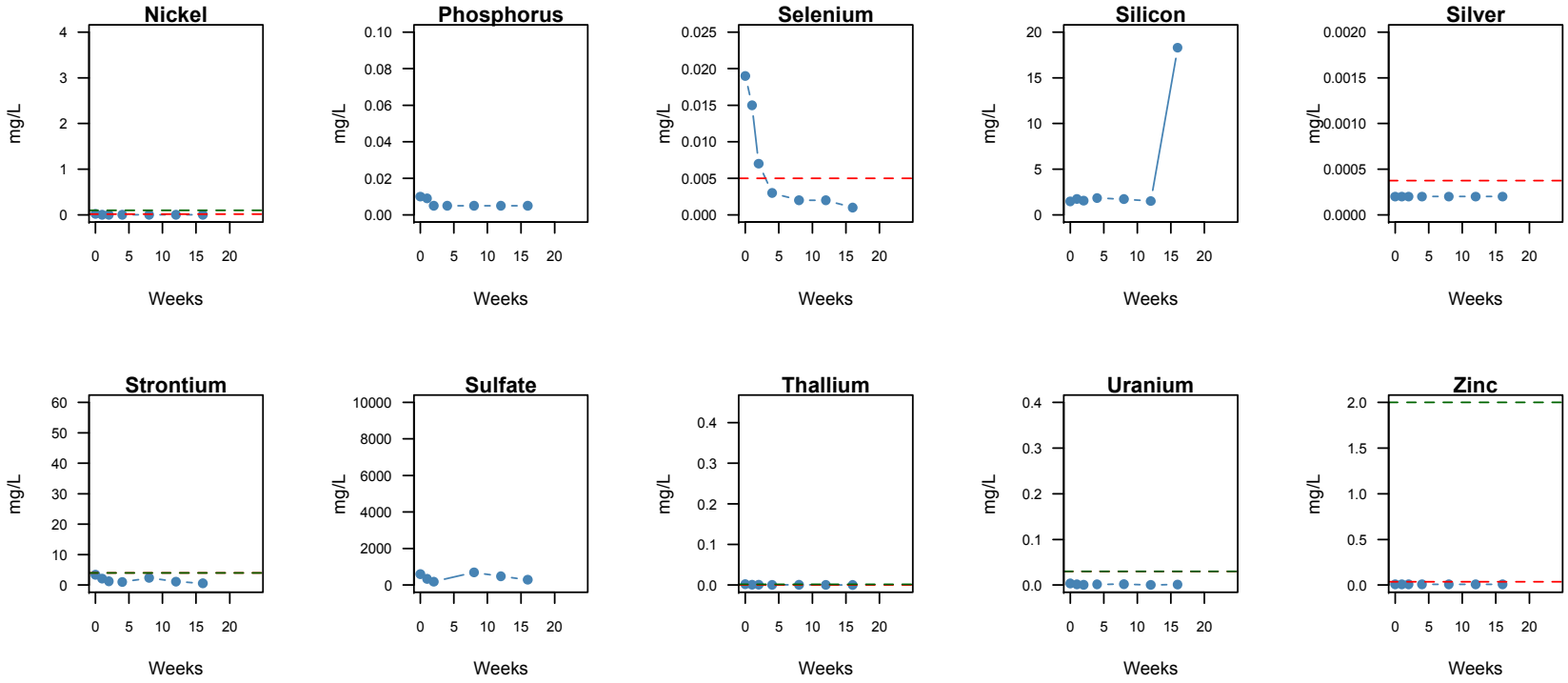


FIGURE 3-12b. 2015 *Ynl B* HCT Periodic Metals, continued.

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Test ongoing, current data available for 17 weeks.

3.2.2.6 2015 LZ-FW – Lower Zone Footwall (35% Waste Rock Tonnage)

At the time this report was prepared, the *LZ-FW* HCT was in week 19 of testing. Available data are presented in **Figure 3-13** and **Table C-3**:

- Effluent pH has been principally alkaline thus far in testing and demonstrates a slight downward trend. A maximum pH was observed in week 0 (7.62), and 7.14 was the minimum, thus far, in week 16.
- Redox potential has remained oxidizing and stable, thus far in testing.
- After an initial period of high conductivity, values have dropped, trending from 1,094 µS/cm (week 0) to lower and more stable values in later weeks, e.g., 258 µS/cm (week 17).
- No Fe has been detected in HCT effluent thus far.
- Sulfate production has not been insignificant, thus far, and has shown a steady decline, ranging from a high value of 480 mg/L (week 1) to 77 mg/L (week 17).
- Acidity has not been detected thus far.
- Alkalinity has been detected in all weekly extracts with concentrations ranging from an initial flush of 61 mg $CaCO_3$/L (week 0) to a very stable trend ranging from 26 mg $CaCO_3$/L (week 1) to 18 mg $CaCO_3$/L (week 6), with a most recent value of 21 in week 17 mg $CaCO_3$/L.

The metal release signature for this material is indicative of the diversity of mineralogy included in it. Repeated release of antimony (Sb), As, and uranium (U) in excess of ground water quality standards was observed. Additionally, Pb, Se, and Tl were observed above surface water standards at isolated period of this test, thus far. An isolated exceedance of the ground water standard was also observed for Ni in week 0.

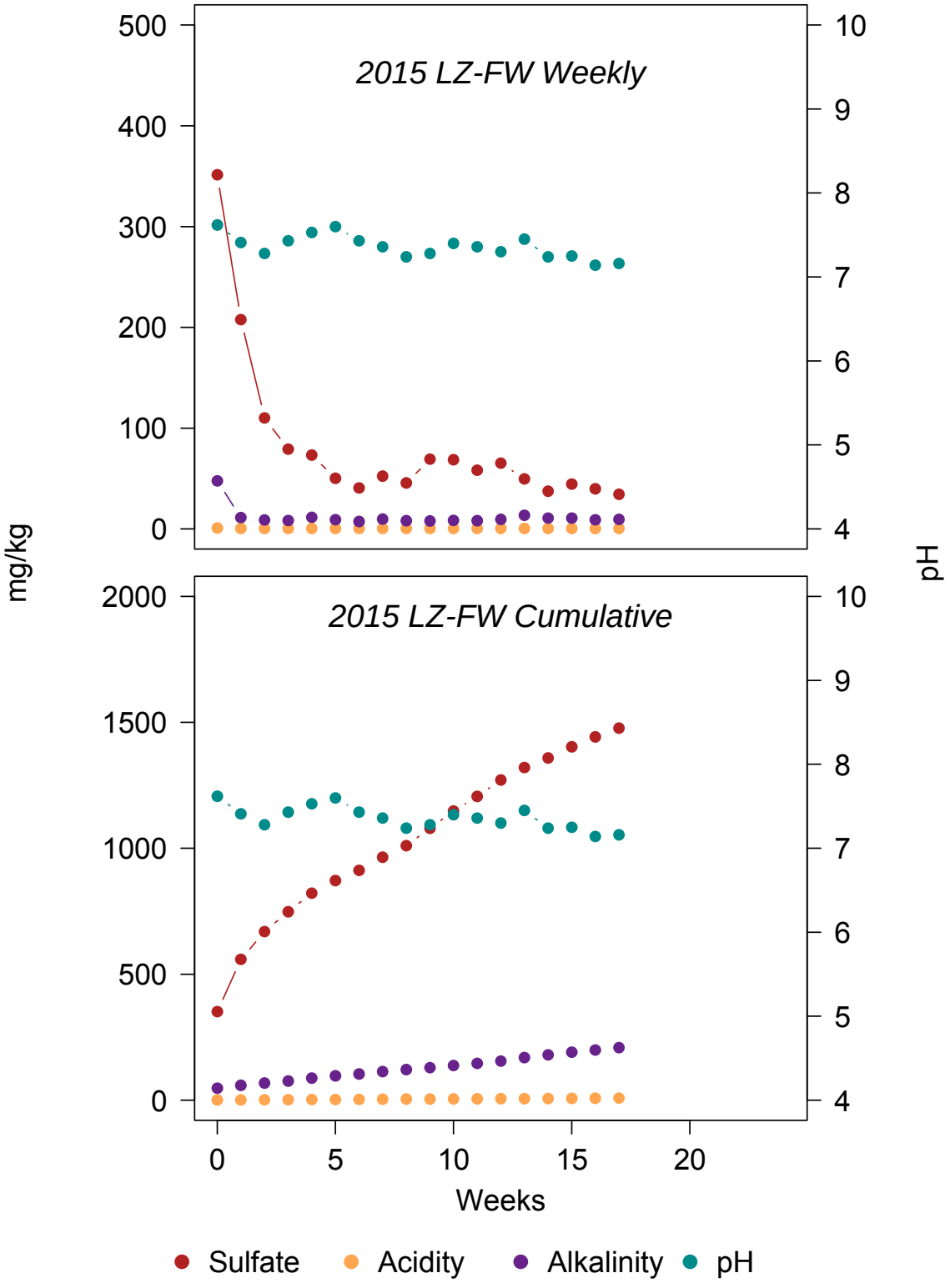


FIGURE 3-13. 2015 *LZ-FW* HCT Weekly and Cumulative Parameters

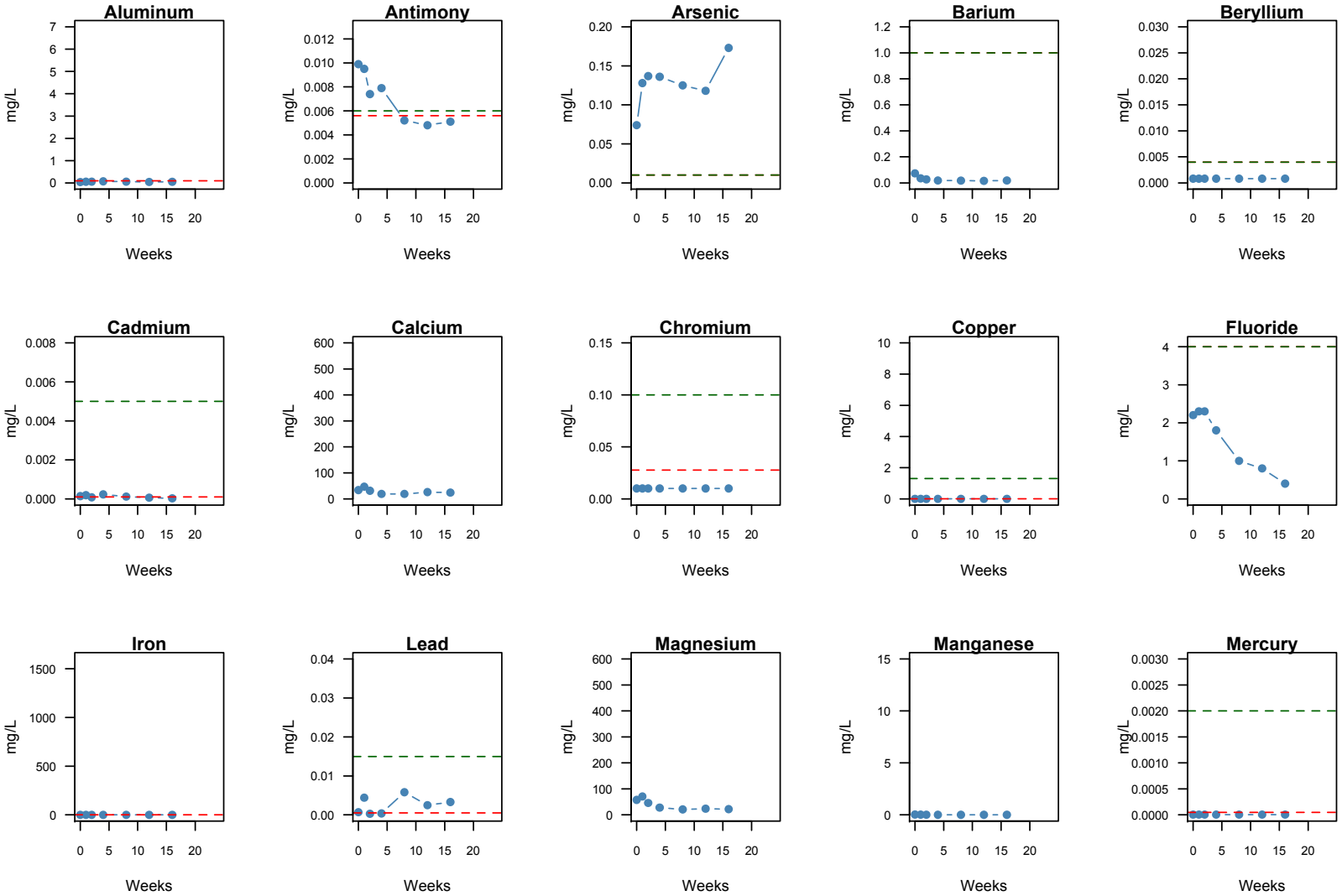


FIGURE 3-14a. 2015 *LZ-FW* HCT Periodic Metals

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Test ongoing, current data available for 17 weeks.

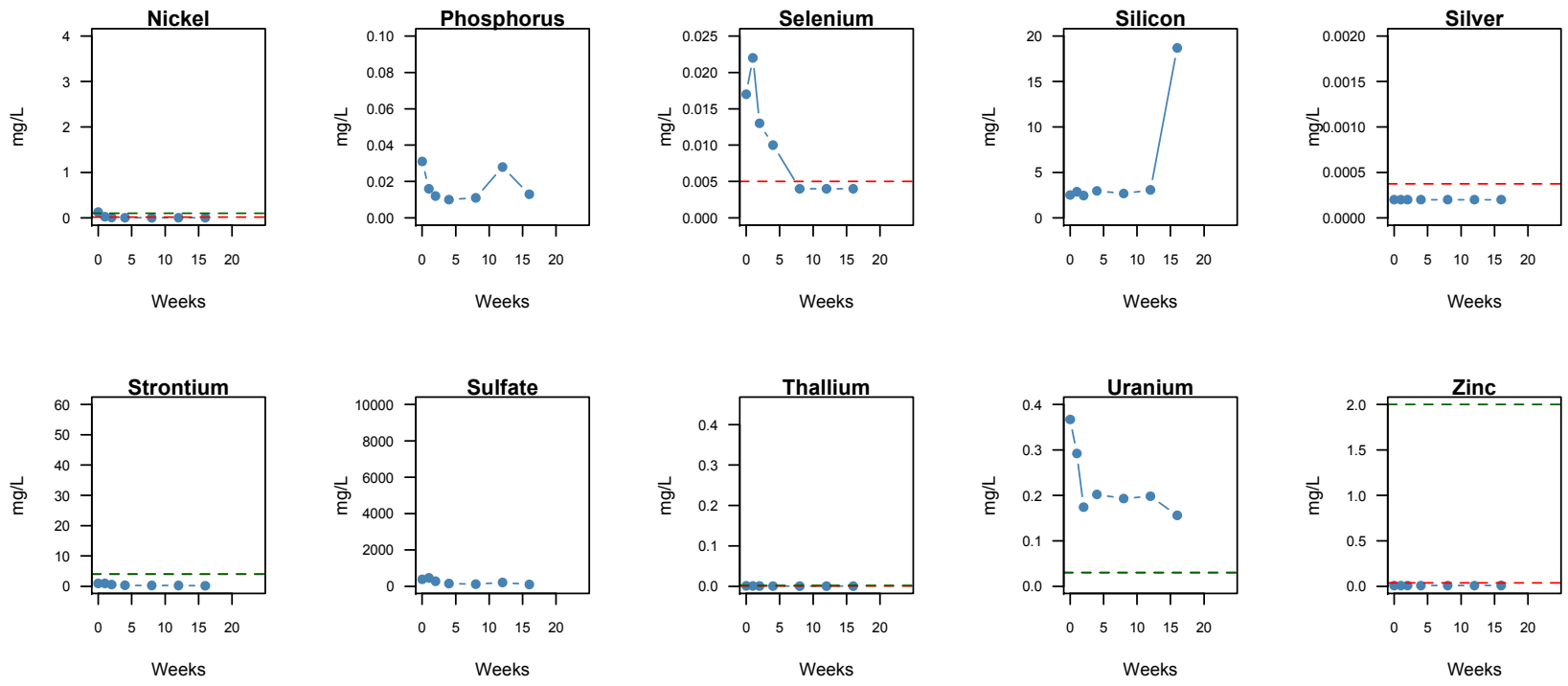


FIGURE 3-14b. 2015 *LZ-FW* HCT Periodic Metals, continued.

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Test ongoing, current data available for 17 weeks.

3.2.2.7 2012 Ynl 0 - Dolomite "Nose" Lower Newland Formation (<1 % Waste Rock Tonnage)

The *Ynl 0* is a dolomitic interbed within the upper part of the lower Newland Formation. This unit serves as a marker that defines the transition to the lower Newland Formation, and while it represented 6 % of the tonnage from the 2012 Decline, it represents less than 1% of the operational scale waste rock tonnage. It contains very little sulfide and is strongly alkaline (**Figure 3-15**). During kinetic humidity cell testing, it exhibited very low potential for metal-release (**Figures 3-16a and b** and **Table C-2** of **Appendix C**), apart from Se and Tl in concentrations that exceeded surface water criteria during initial weeks of testing.

- Effluent pH was alkaline for the duration of the test trending from 9.19 in week 0 to 7.74 in week 24, with a minimum pH observed in week 17 (7.46).
- Redox potential was oxidizing for the duration of the test and ranged from 7 mV (week 0) to 197 mV (week 17), with a final redox of 182 mV in week 24.
- Conductivity values were fairly low and ranged from 240 µS/cm (week 1) to 62 µS/cm (week 17) with a final value of 72 µS/cm (week 24).
- Iron was consistently low and was below detection in most weeks.
- Sulfate release was also consistently low, ranging from an initial "rinse" of 78 mg/L in week 1 to a final concentration of 7 mg/L in week 24.
- Acidity was not detected in any weeks.
- Alkalinity was detected in all weekly extracts and concentrations ranged from 42 mg $CaCO_3$/L (week 0) to 16 mg $CaCO_3$/L (week 17), but were regularly stable, ending with 20 mg CaCO3/L in week 24.

With 24 weeks of kinetic testing showing consistently low rates of sulfate production and metal release, the Ynl 0 unit was sufficiently well characterized in the 2012 tests and no further testing was conducted in 2015.

Mineralogical analysis of the *Ynl 0* material agreed with the static and kinetic test results and indicated that this material is comprised largely of dolomite (74.5 wt.%) with 18.7 wt.% quartz, 3.8 wt.% muscovite, and 1.0 wt.% potassium feldspar. One *Ynl 0* sample had static ABA/NAG results, suggesting that sulfide mineralization can occur locally. During kinetic testing, only Se and Tl were detected at concentrations greater than the relevant standards, but the MLA method was not successful in identifying Se- and Tl-bearing minerals. These findings agree with the previously reported mineralogy of this portion of the Lower Newland Formation. Certainly, the absence of sulfide mineralization agrees with the very low observed rates of sulfate release.

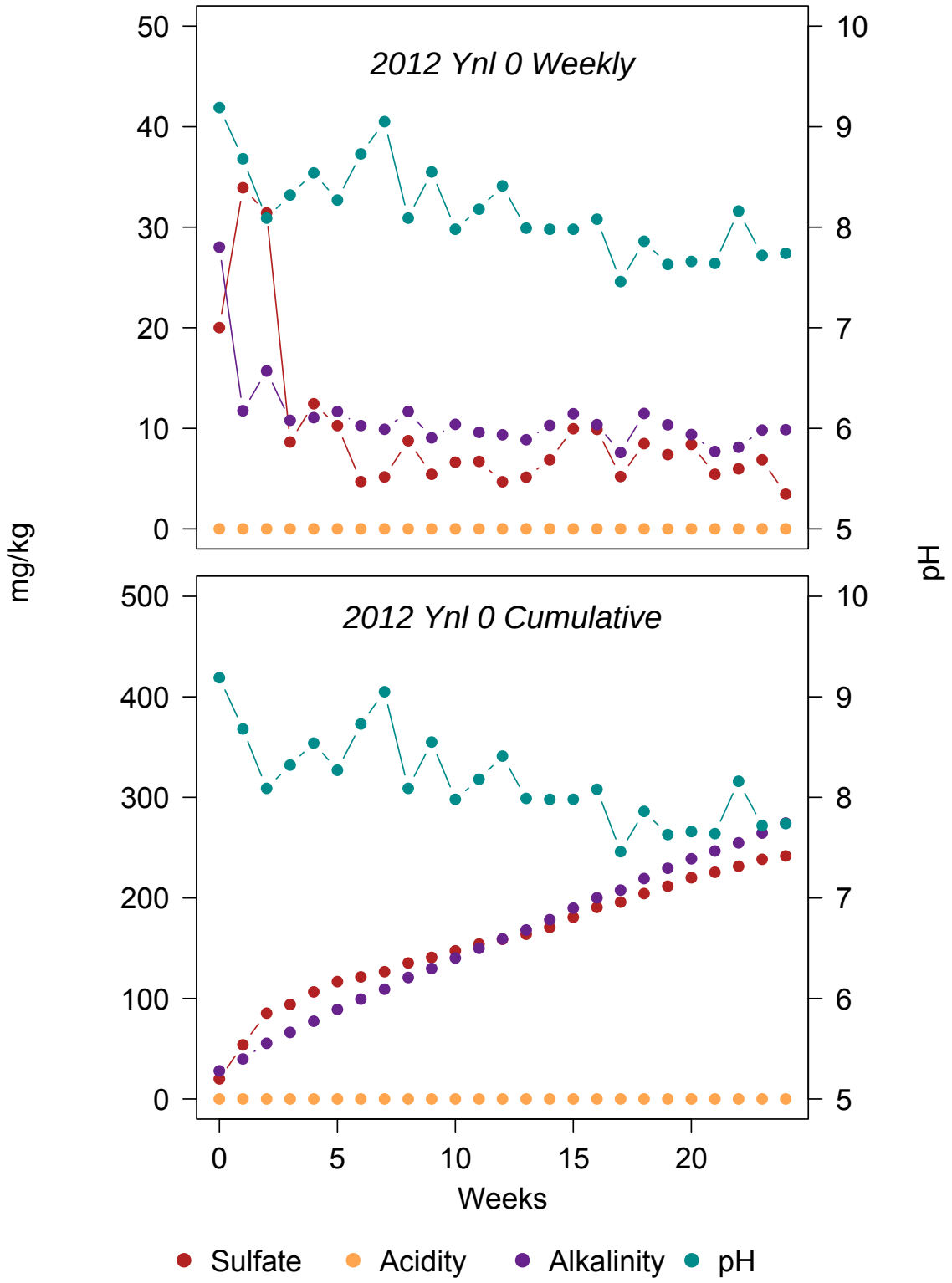


FIGURE 3-15. 2012 *Ynl 0* HCT Weekly and Cumulative Parameters

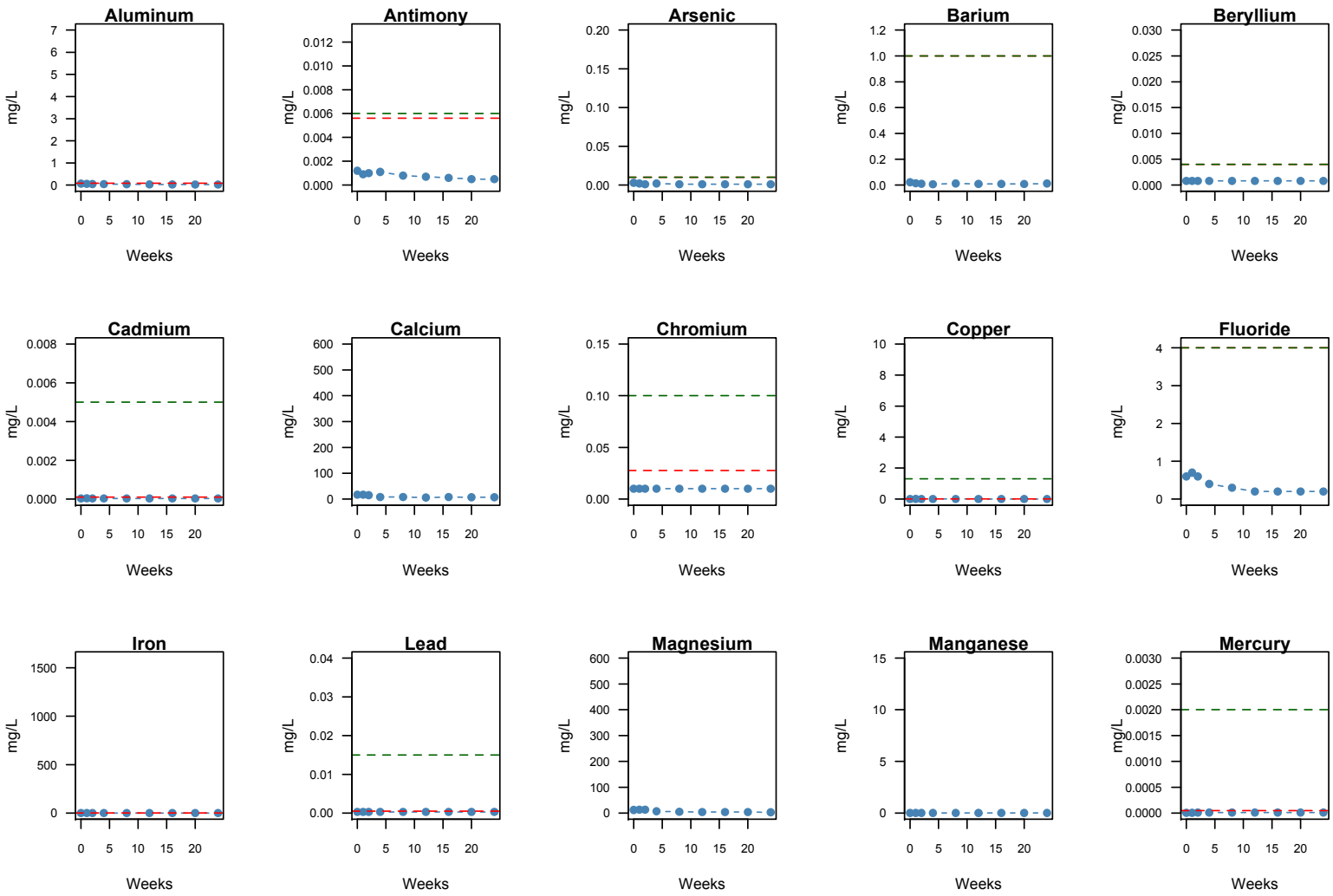


FIGURE 3-16a. 2012 *Ynl 0* HCT Periodic Metals

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Total weeks of testing=24

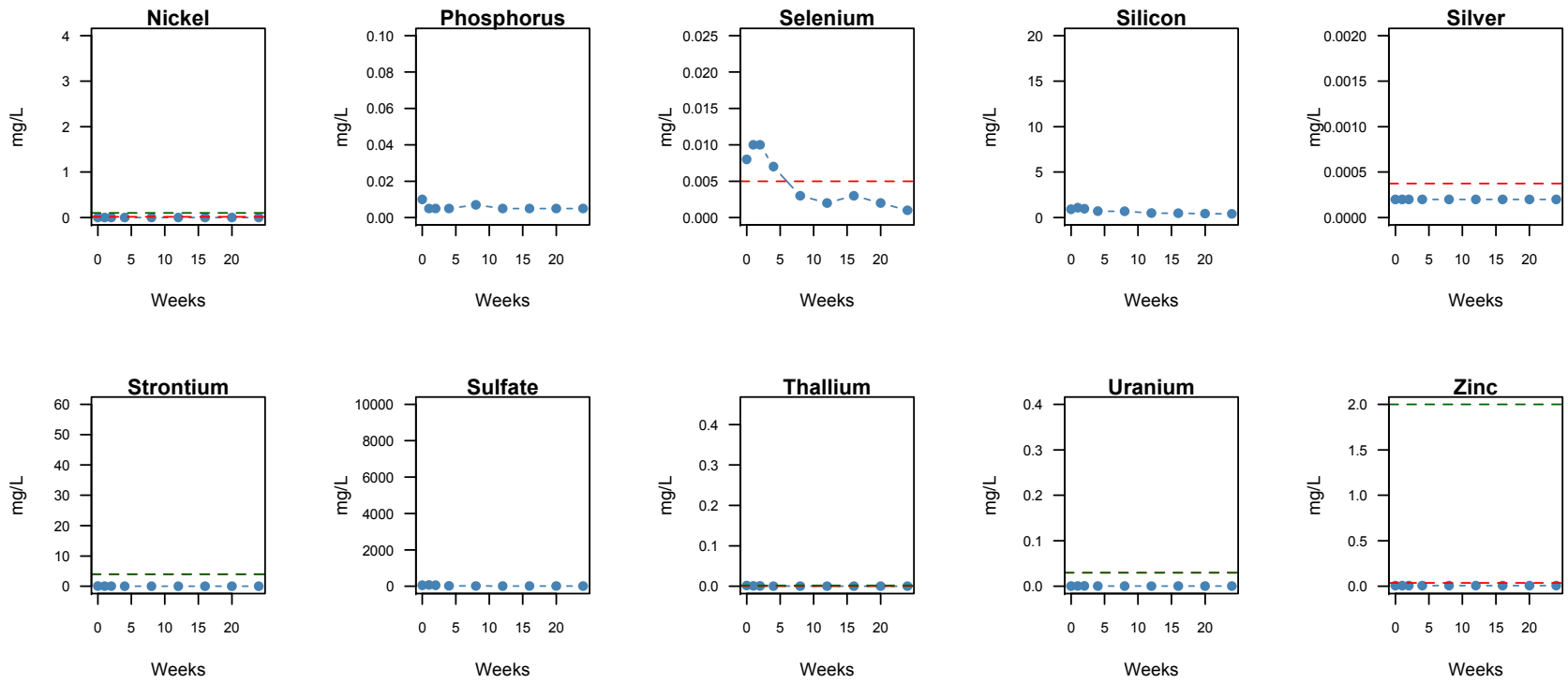


FIGURE 3-16b. 2012 *Ynl 0* HCT Periodic Metals, continued.

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Total weeks of testing=24

2015 Yc – Chamberlain Shale (<1 % Waste Rock Tonnage)

Although the current mine design does not include development of the *Yc* lithotype, earlier versions of the Black Butte Copper Project mine design had incorporated it, and it is possible that this unit could be encountered at depth if mine plans change in the future. It was included in the geochemical testing program for this reason. As described above, this test was started in June 2015, and remains online, in its 21 week of testing. Below is a summary of observed chemistry to-date.

- Effluent pH has been strongly neutral, and values have trended slightly downward: initial pH of 7.72 (week 0) and a most recent value of 7.40 (week 19) with a maximum value of 8.18 (week 4) and a minimum of 7.34 (week 18).
- Redox potential has remained oxidizing and stable, with values ranging from 222 mV (week 0) to 396 mV (week 11).
- After initially high conductivity values, conductivity has remained low and stable, ranging from 450 µS/cm (week 0) to 170 µS/cm (week 4), with a recent value of 189 µS/cm (week 19).
- Iron release has been consistently low and comprised primarily of Fe^{3+}, with detected concentrations ranging from of total Fe from 0.14 mg/L (week 4) to 1.61 mg/L (week 7).
- After an initial flush, sulfate production has been steady, and possibly declining. Ranges of sulfate concentrations, thus far, are from 130 mg/L (week 0) to 29 mg/L (week 5), with a recent sulfate concentration of 35 (week 19).
- Acidity has not been detected in any effluent, thus far.
- Alkalinity has been detected in all weekly extracts, at relatively stable levels, and concentrations have ranged from 89 mg $CaCO_3$/L (week 0) to 33 mg $CaCO_3$/L (week 3) with recent concentrations of 43 mg/L in weeks 18 and 19.

Metal production during the *Yc* HCT has indicated a potentially high rate of metal release. Consistently elevated concentrations have been observed for As, which exceed the groundwater water quality standard, and for Al, which exceed the surface water quality standard in all weeks of testing thus far. Additional surface water quality standard exceedances have been observed for Cd, Pb, Se, and Tl.

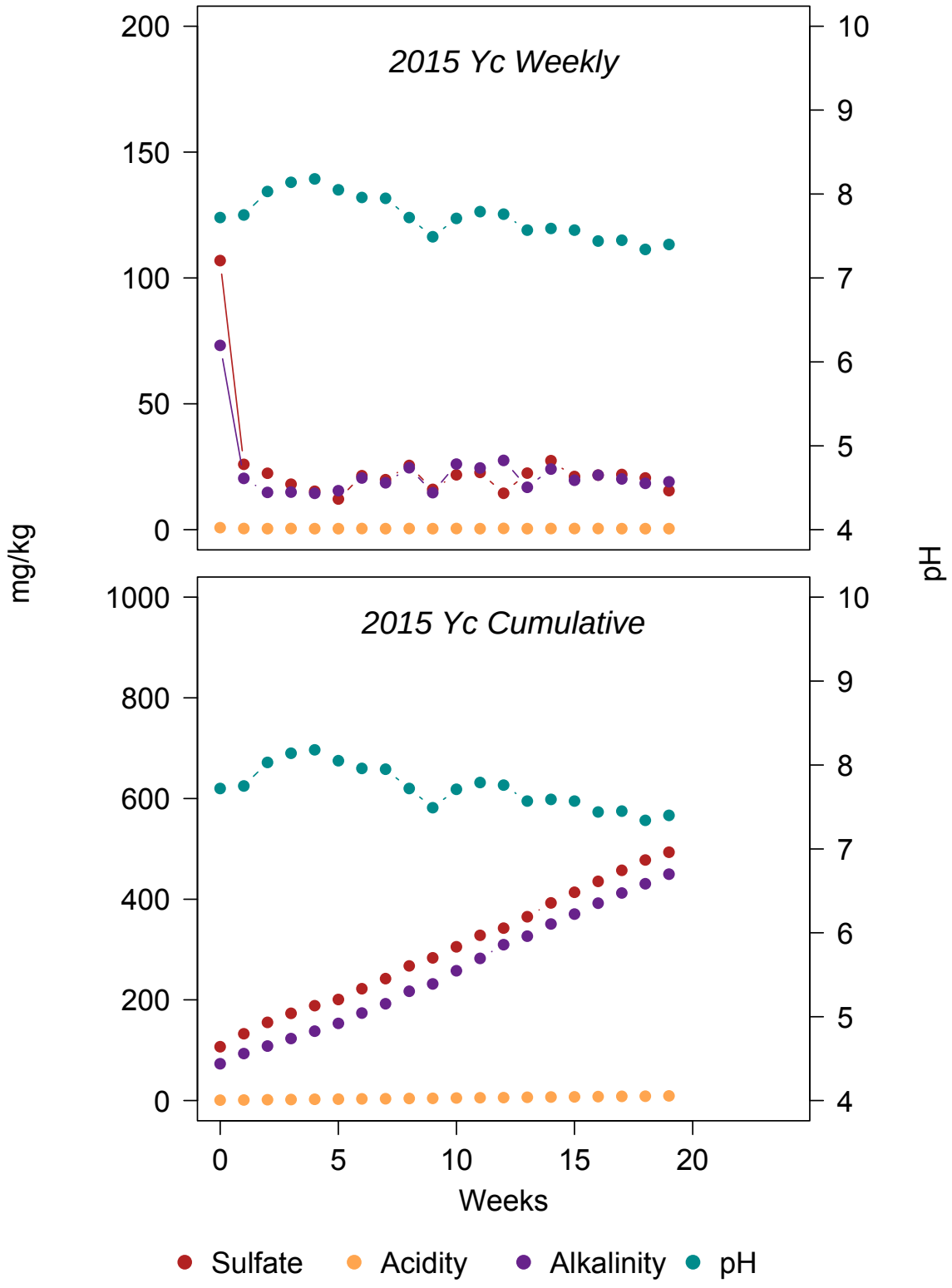


FIGURE 3-17. 2015 *Yc* HCT Weekly and Cumulative Parameters

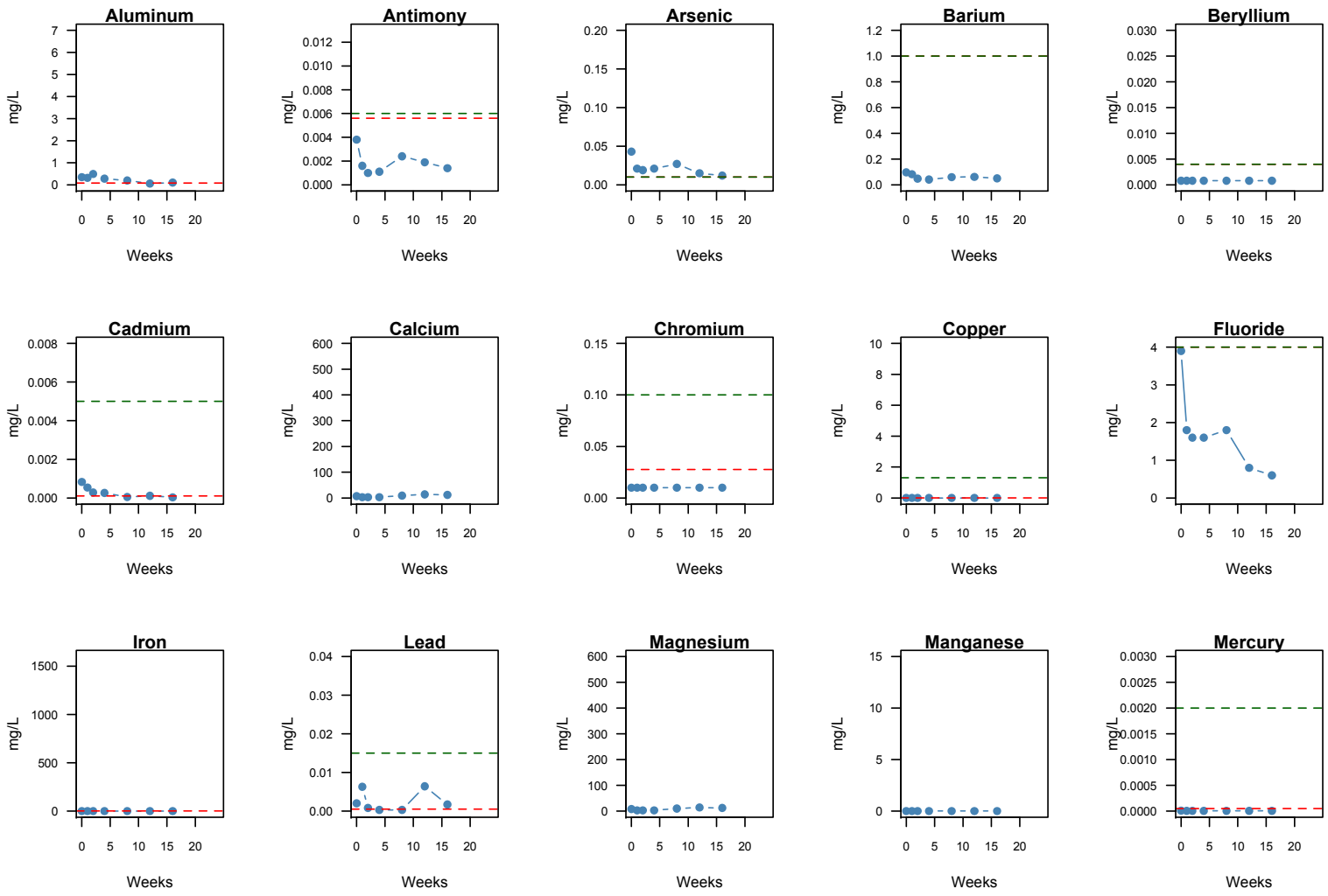


FIGURE 3-18a. 2015 *Yc* HCT Periodic Metals

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Test ongoing, current data available for 19 weeks.

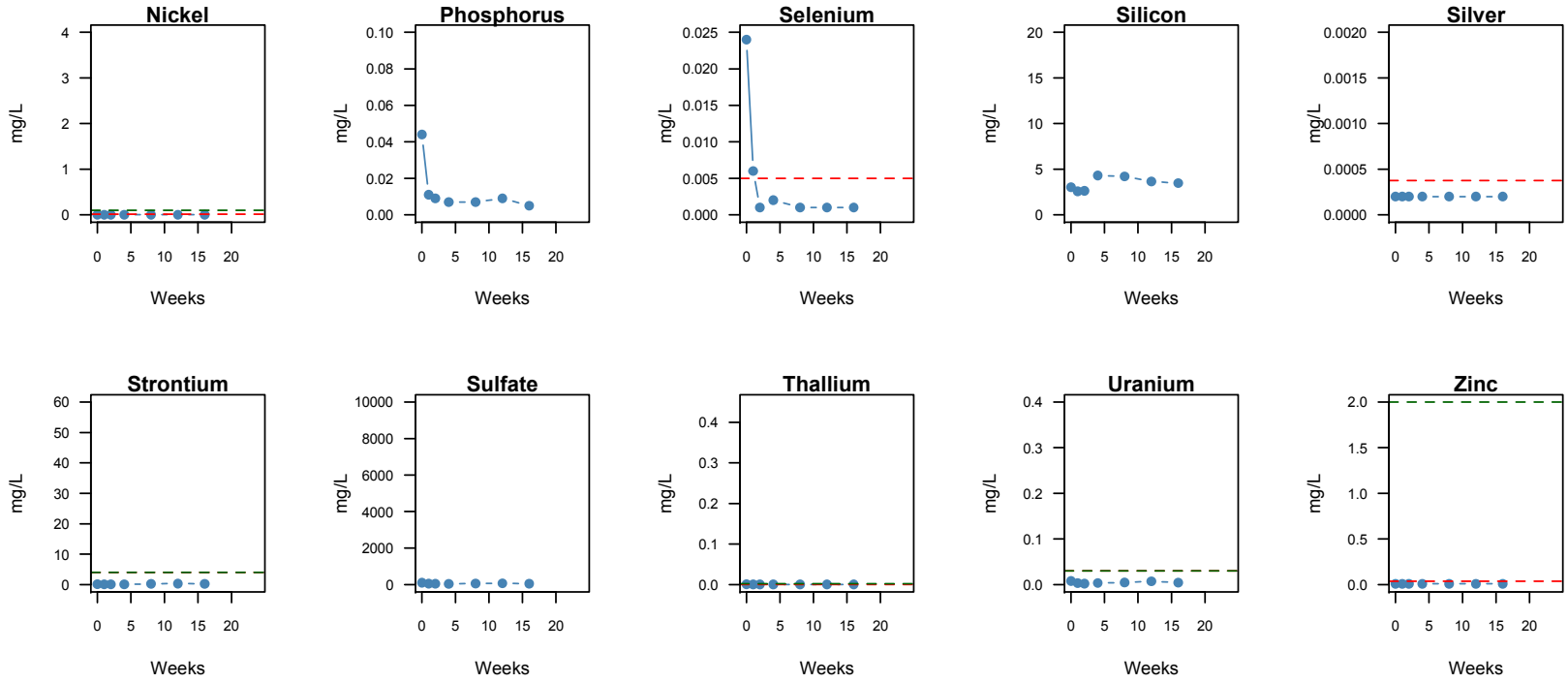


FIGURE 3-18b. 2015 *Yc* HCT Periodic Metals, continued.

Red dashed lines are relevant surface water standards. Green dashed lines are relevant groundwater water standards. Y-axes have been standardized, by element, for comparison with HCTs of other lithotypes. Test ongoing, current data available for 19 weeks.

4 Tailings Characterization

Geochemical evaluation of the tailings material for the Black Butte Copper Project has been designed to address various scenarios for tailings storage and disposal. A homogeneous and representative tailings composite was created during metallurgical testing for use in all geochemical tests. Geochemical testing was focused on Tintina's proposed placement of tailings as a cemented paste created through the addition of various combinations of binders, both underground as backfill and in the CTF. Both raw (non-amended) and cemented paste tailings were assessed under subaqueous and sub-aerial weathering scenarios. A summary of how test of these materials relate to Tintina's proposed actions, as well as forseeable alternatives, is presented in **Table 1-3**.

4.1 Paste Tailings

Varying proportions of binding agents have been added to the raw tailings to produce cemented pastes in order to address numerous possible scenarios for storage and backfill. A combination of 50 % cement and 50 % slag was used as the binding material. The binder was then added to the raw tailings at 2 and 4% (by weight) to evaluate changes in its physical weathering and geochemical behavior. A supplemental test of paste tailings with 10% run-of-mine (ROM) waste rock was also included in the geochemical testing program to simulate proposed co-disposal of the tailings and waste rock. The ROM was created using the following proportions of waste rock: *USZ*: 34 %, *LZ-FW*: 32 %, *Ynl B*: 17 %, *Yc*: 10 %, and *Ynl*: 5 %; it was evenly distributed through the paste amended tailings. These proportions reflect the estimated proportions of waste rock available *at the time* the ROM composite was constructed, and differ somewhat from the final proportions of lithotypes in ROM material as described in **Table 1-1**. The geochemical tests conducted on the different paste tailings scenarios are summarized in **Table 1-2**.

4.1.1 Static Testing

Replicate cylinders of the paste samples with 2 and 4 % binder were subjected to multi-element whole rock analysis using inductively coupled plasma-atomic emission spectroscopy (ICP-AES) following a 4-acid digestion with a mixture of perchloric, nitric, hydrofluoric, and hydrochloric acids, in order to fully dissolve the mineral matrix, including the silicates. ABA and NAG analyses were also completed, as described above. Results of the static testing of paste tailings are presented in **Tables 4-1** and **4-2**, and respective lab reports are found in **Appendix D.**

The results of static testing of paste tailings demonstrate that the 4 % cemented paste was very similar to the 2 % cemented paste in metal and sulfide content. Although the NP was higher in the 4 % cemented paste, the NNP, NP/AP ratio, and final NAG pH are comparable between the two cement paste treatments and suggested potential for acid production.

4.1.1.1 Diffusion Testing

ASTM method C1308 (diffusion testing) was used to evaluate the oxidation and leaching potential of the cement paste tailings in saturated environments. In the past three years, this method has been adopted by the state of Nevada, where certain labs are now state-certified to perform ASTM C1303 for the purpose of geochemical characterization of backfilled paste tailings (Moran et al, 2013).

TABLE 4-1. ICP metal results of three tailings materials.

Tailings Sample	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs
	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm
Raw Tailings	12.6	0.96	2160	20	0.72	218	0.3	0.23	0.63	1580	292	1.45
C601-15 (2% Paste)	10	0.83	1340	4830	<10	160	1	<10	NA	1100	290	NA
C586-15 (4% Paste)	10	1.02	1450	5970	<10	170	1.88	<10	NA	1110	290	NA

Tailings Sample	Cu	Fe	Ga	Ge	Hf	In	K	La	Li	Mg	Mn	Mo
	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	%	ppm	ppm
Raw Tailings	2620	22.5	5.7	0.16	**0.3**	0.416	0.68	<0.5	34.5	0.14	330	7.16
C601-15 (2% Paste)	2980	20.2	<50	NA	**NA**	NA	0.6	<50	NA	0.18	240	<10
C586-15 (4% Paste)	3170	20.4	<50	NA	**NA**	NA	0.6	<50	NA	0.22	270	<10

Tailings Sample	Na	Nb	Ni	P	Pb	Rb	Re	S	Sb	Sc	Se	Sn
	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm
Raw Tailings	0.03	1.3	**465**	260	751	14.9	0.002	>10.0	23.2	1.5	1	0.9
C601-15 (2% Paste)	<0.05	NA	**550**	250	760	NA	NA	>10.0	<50	<10	NA	NA
C586-15 (4% Paste)	<0.05	NA	**560**	240	780	NA	NA	>10.0	<50	<10	NA	NA

Tailings Sample	Sr	Ta	Te	Th	Ti	Tl	U	V	W	Y	Zn	Zr
	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Raw Tailings	**78.3**	0.08	0.06	<0.2	0.032	71.3	1.6	13	1.8	3.1	**96**	12.5
C601-15 (2% Paste)	**490**	NA	NA	<50	<0.05	70	<50	20	<50	NA	**140**	NA
C586-15 (4% Paste)	**480**	NA	NA	<50	<0.05	60	<50	20	<50	NA	**100**	NA

TABLE 4-2. ABA and NAG results of tailings materials

Sample Identification		NAG@ pH 4.5	NAG@ pH 7.0	NAG pH	AP [tCaCO3/Kt]	NNP [tCaCO3/Kt]	Fizz Rating	NP * [tCaCO3/Kt]	Paste pH	NP/AP [ratio]
Raw Tailings	CA12185-JUN15	NA	NA	NA	802	-799.88	1	2.0	3.23	0.0025
	CA15079-JUL15	NA	NA	NA	935	-937.40	1	***0.01***	3.30	0.00001
	CA12531-JUL15	NA	NA	NA	781	-783.42	1	***0.01***	3.31	0.00001
	CA15000-AUG15	NA	NA	NA	845	-835.60	1	9.4	3.58	0.0111
	CA14523-AUG15	NA	NA	NA	554	-493	1	61.1	3.92	0.1103
	Enviromin Tails Sample	282	406	2.2	775	-780	1	***0.01***	4	0.00001
Paste Tailings	C601-15 (2 % binders)	131.5	182	2.1	741	-749	1	***0.01***	3.8	0.00001
	C586-15 (4 % binders)	124	179.5	2.3	747	-738	1	9	7.9	0.012

Sample Identification		Total Sulfur [%]	NaOH-Leachable Sulfate [%]	HCl-Leachable Sulfate [%]	Sulfide [%]	Total Carbon [%]	Carbonate [%]
Raw Tailings	CA12185-JUN15	25.5	NA	<0.01	25.7	0.372	0.220
	CA15079-JUL15	28.9	NA	< 0.01	29.9	0.304	0.100
	CA12531-JUL15	24.1	NA	<0.01	25.0	0.459	0.145
	CA15000-AUG15	28.3	NA	1.29	27.0	0.406	0.295
	CA14523-AUG15	21.4	NA	3.70	17.7	1.19	3.20
	Enviromin Tails Sample	24.8	0.71	0.68	24.1	NA	NA
Paste Tailings	C601-15 (2 % binders)	23.7	2.08	1.15	21.6	NA	NA
	C586-15 (4 % binders)	23.9	1.99	1.19	21.9	NA	NA

**negative NP values changed to 0.01for NP:AP calculation*

The method specifically involves submersion of a solid cylinder (2:1 height to diameter ratio) in a solution with a volume equal to 10 times the surface area of the cylinder. Deionized water was used to simulate meteoric water, and this water was replaced periodically over an 11-day period. Specifically, the solution was replaced at 2 hrs, 7 hrs, and 24 hrs, and then every 24 hrs until the 11-day test was complete.

Tintina contracted WETLabs, of Sparks, NV (a state-certified lab) to conduct diffusion tests for the 2 %, 4 % and 4 % with ROM amended tailings. Results of diffusion testing are presented, along with HCT data (described below) in **Figures 4-1 through 4-7** and **Appendix D**, **Tables D1a-b**, and indicate the reactivity of the amended paste material under saturated conditions over time. These results are relevant to the prediction of the geochemical behavior of amended paste tailings when placed as backfill or following deposition of a new, overlying lift.

4.1.1.2 HCT Testing

In addition to assessing the acid production and metal release potentials of paste tailings under saturated conditions, modified HCTs of the paste tailings cylinders were completed. These aerated tests better represent the effects of cyclic oxidation and saturation conditions anticipated to occur in the surface storage facility. The procedure for these tests is identical to the ASTM method for kinetic humidity cell testing, except that the solid material loaded into the column was not crushed. The pasted tailing was added as an intact cylinder. Due to the cylinder small size of the 4 % with ROM (2 in wide: 4 in high), the minimum 1 kg requirement for sample mass was not met. Additionally, the amount of leachate added was altered to accommodate submersion of the cylinder. This adjustment is not, strictly speaking, an alteration in ASTM protocol, as it falls within the range of testing options of the method.

Three cylinders of paste tailings were subjected to this modified HCT method, as presented above in **Table 1-2**. These tests were in weeks 11 and 8 of testing at the time this report was prepared; data are provided through weeks 9 and 6, respectively. Available results are presented in **Figures 4-1 through 4-7** and **Appendix D**, **Tables D-2 and D-3**. Laboratory results of all ongoing HCTs will be made available at the completion of testing.

4.2 Raw (Non-amended) Tailings

The geochemical characteristics of the raw (non-amended) tailings material was also tested, to provide basic information about the acid generation and metal release potential of this material, as well as geochemical data for modeling of a possible dry stack storage alternative. Tintina does not plan to handle raw tailings material, however, and has proposed that all tailings placed underground as paste backfill or placed as paste in a lined and monitored cemented tailings facility.

4.2.1 Static Testing

Similar to the approach used in characterization of the waste rock and paste amended tailings, whole rock metal analysis, ABA and NAG methods were used to assess the acid generation potential of the raw tailings. Results of the static testing of raw tailings indicate that this material is likely to produce acid, and contains elevated levels of sulfur and metals.

4.2.2 Kinetic Testing

The raw tailings were subjected to two styles of kinetic HCT tests. One followed the ASTM standard HCT method (D5744-13) that is described above for waste rock. A second kinetic test was a modified version of the ASTM standard for HCTs, in which a constant head of water was maintained over the sample in the test column. Rock was submerged, and remained under suboxic conditions until the seventh day of each weekly cycle, at which time the leachate was allowed to freely drain from the sample, and fresh influent was subsequently added. In this version of the test, the typical forced-air technique was not employed, and contact with air (i.e., oxygen) was limited to 15 to 30 minutes exposure between the draining of effluent and addition of new influent deionized water, as well as any oxygen present in the water itself. All other aspects of the testing (weekly test parameters and periodic metal analysis) were identical to ASTM standard D5744-13. These kinetic tests were ongoing in week 21 of testing; all results available at the time of reporting are presented below.

There is a clear difference in the potential environmental impact of saturated and unsaturated tailings. Suboxic conditions, which are maintained in the saturated test using a constant head of water to limit the infiltration of oxygen, produce much lower amounts of sulfate, acidity and metals than the aerated tailing HCT. **Figures 4-1 through 4-7** clearly demonstrate these differences, which are also presented in **Appendix D**, **Table D-2 and D-3**.

4.3 Discussion of All Tailings Kinetic Results

The 2% and 4% binder and 4%+ROM cylinders in the diffusion tests showed different trends in sulfide oxidation. The 4% binder cylinder maintained a variable, but overall higher, pH between 6.5 and 9.5, with available alkalinity, and produced less sulfate throughout the test than the 4%+ROM cylinder. Rates of metal release were significantly lower in diffusion tests of saturated cemented paste tailings than in unsaturated humidity cell tests of corresponding material. Because these tests were intended to simulate underground backfill scenarios, the results have been compared to relevant groundwater standards in **Appendix D**, **Table D-1a and b**. Relevant As and Tl groundwater standards were exceeded in the 4% binder and 4%+ROM cylinders, respectively, with an isolated exceedance of Hg in the 4%+ROM cylinder. Although the kinetic HCTs of both paste-amended and raw tailings are still ongoing, current results indicate that the paste-amended treatments exhibit lower potential for acid, sulfate and metal release. The saturated conventional HCT of raw tailings exhibited the lowest sulfate, acid and metal release, while the corresponding sub-aerial test exhibited the highest. These results and interpretations are subject to change as testing continues.

Acid and sulfate production varied between the cemented paste HCTs, with the 2% test exhibiting greater release than the 4% + ROM test, which was in turn greater than the 4% with ROM test. All tests began at a pH above 6, which was maintained for up to 3 weeks depending on treatment. As of week 2, the 2% cemented paste treatments began to trend downward in pH, followed by the 4% with ROM sample in week 3. The 4% paste amended material held a pH over 6 in week 4. The 2% cemented paste HCT regularly released Hg in excess of surface water standards, and also exhibited isolated exceedances of Al, Cd, Pb, Se, and Zn, typically in the later weeks of testing. Furthermore, the 2% cement paste HCT exceeded relevant groundwater standards for As and Ni in all weeks tested. Groundwater standards were also exceeded in weeks 4 and 8 for Sb, Be, Cr, Cu, F, U, and Zn. Both groundwater and surface water standards

for Tl have also been exceeded during various weeks of testing for the 2% cement paste HCT.

In terms of metal release potential, the 4% cemented paste HCT exceeded far fewer surface and groundwater standards than the 2% cemented paste HCT. Specifically, the 4% cemented paste HCT released Cu and Ni in excess of relevant groundwater standards only in week 8. Groundwater standards for Tl were also exceeded during weeks 4 and 8 of the 4% cement paste HCT, which also exhibited surface water exceedances for Tl in weeks 0-2. Finally, the 4% cement paste HCT intermittently exceeded relevant surface water standards for Al and Hg.

Addition of ROM into the matrix of the 4% cemented paste tailings appears to have modestly affected sulfate and acid production, with the pH of the ROM amended test approximately one unit lower than the 4% cemented paste tailings. Metal release signatures of the 4% cemented paste and the 4% binder +ROM HCT followed similar trends but had variable magnitudes of release. For example, the 4% binder +ROM HCT has exhibited surface water exceedances for Hg (weeks 0-2), Al (week 4), and Ni (week 4), all of which are similar to the trend observed for the 4% paste cement HCT. Furthermore, groundwater exceedances in effluent from the 4% binder +ROM HCT have also not varied greatly from the 4% paste cement HCT, and thus exceeded standards for Tl in weeks 0-4, and for Ni in week 4.

Results of the raw “non-amended” tailings sample tested in the conventional, subaerial kinetic test have demonstrated strong acid generation and a correspondingly high potential to generate sulfate and several metals at low pH. Effluent from this test routinely exceeded groundwater standards for Sb, As, Be, Cd, Cr, Cu, Pb, Ni, Tl, and Zn. Surface water exceedances have also been observed consistently for Al, Fe, Se, and U; isolated surface water exceedances have been observed for Cd, Cu, Pb, Tl, and Zn.

In contrast, as of week 19, the saturated kinetic test showed much lower sulfide oxidation and release of metals, and had maintained a circum-neutral pH of 6.9. At the lower oxidation rate in the saturated HCT, fewer metals exceeded relevant groundwater and surface water quality standards. Specifically, surface water standards were regularly exceeded for Cu, with isolated exceedances also observed for Cd, Pb, and Hg. In all weeks of testing, thus far, relevant groundwater standards for As, Ni, and Tl have been exceeded in the saturated tailings HCT effluent. These cells are also still online and this interpretation is also subject to change.

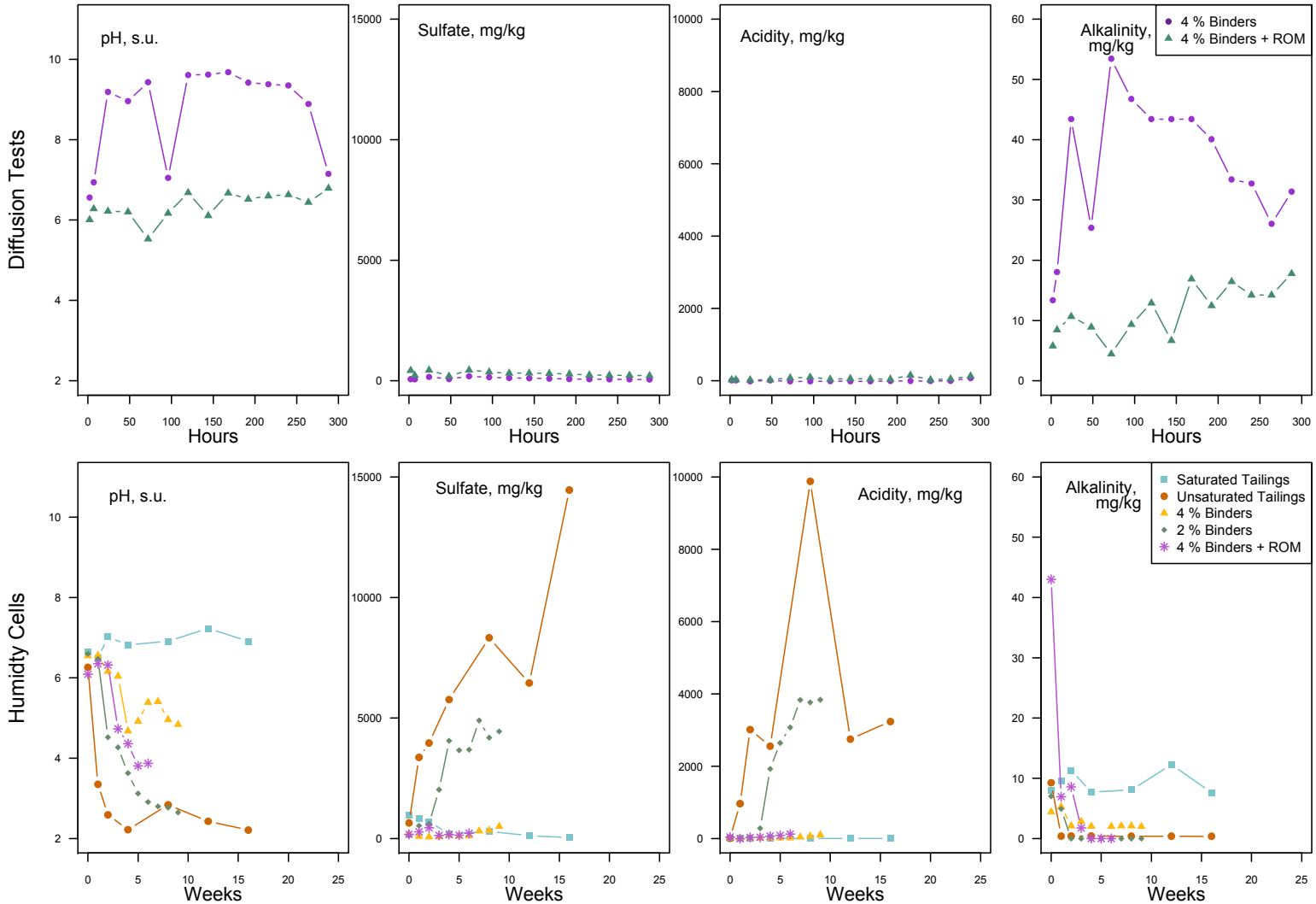


FIGURE 4-1. Tailings Kinetic Test Results: pH, Sulfate, Acidity, and Alkalinity.

Diffusion tests presented in top row, HCTs presented in bottom row.

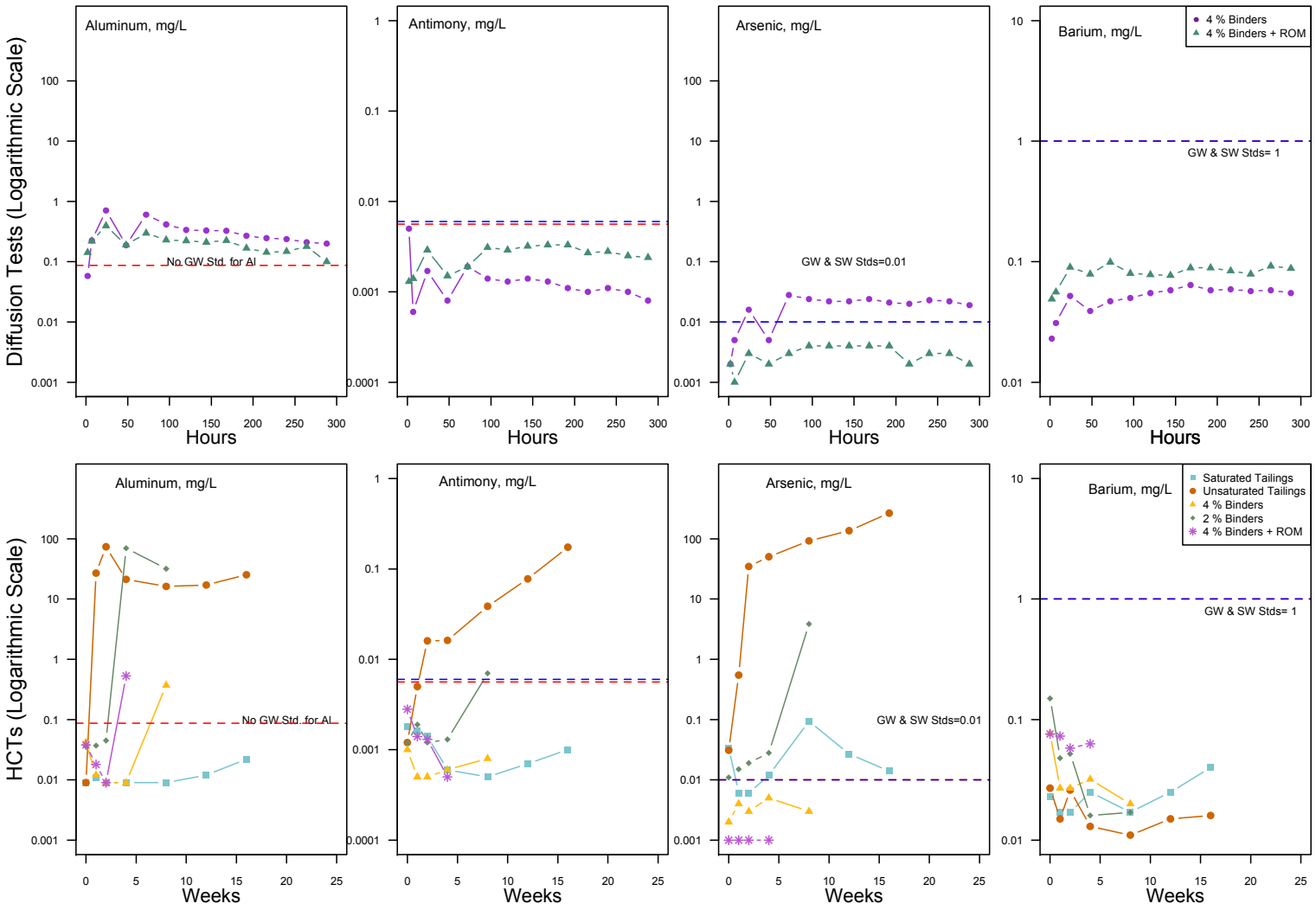


FIGURE 4-2. Tailings Kinetic Test Results: Aluminum, Antimony, Arsenic, and Barium.

Red dashed lines are relevant surface water standards. Blue dashed lines are relevant groundwater water standards.

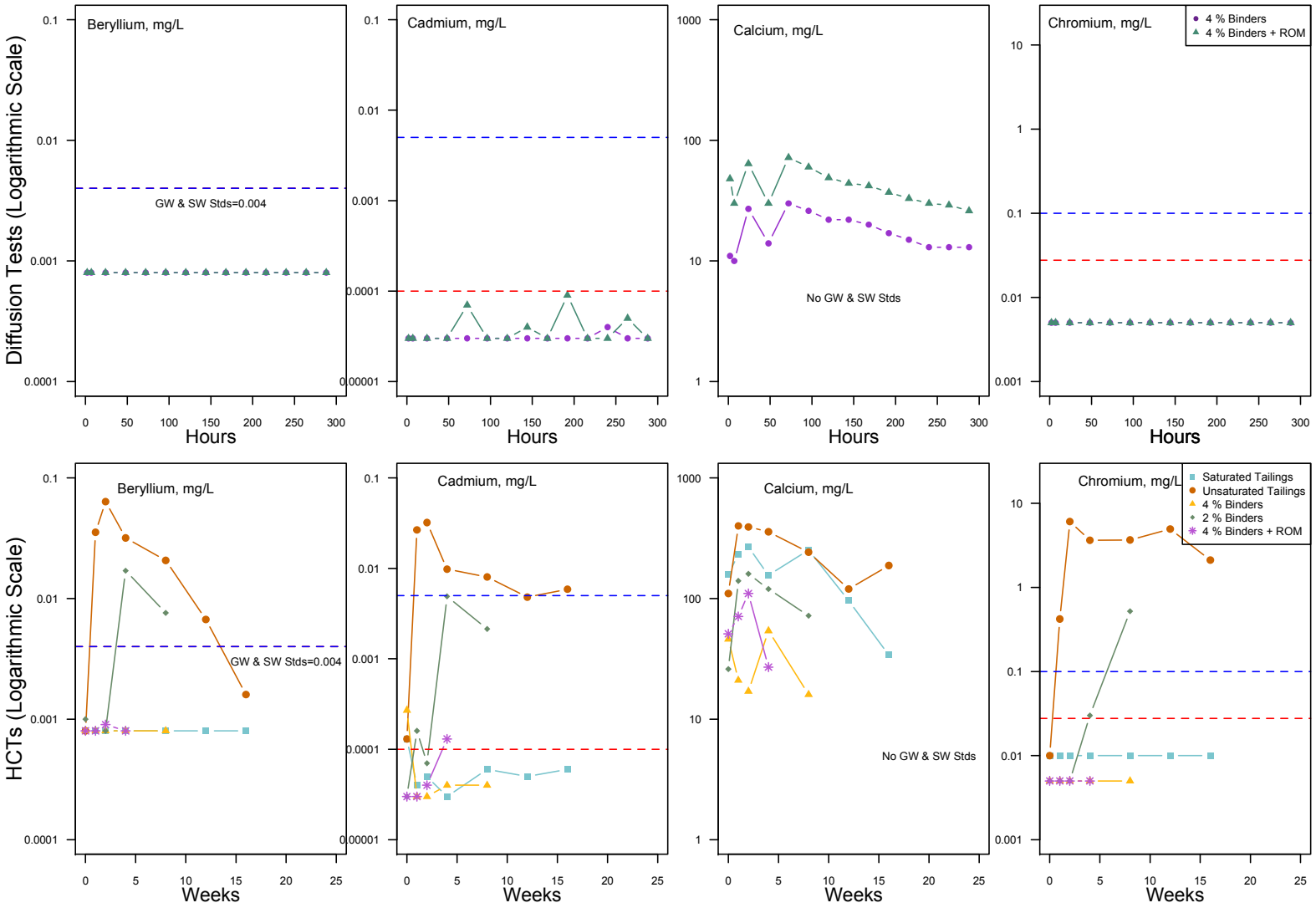


FIGURE 4-3. Tailings Kinetic Test Results: Beryllium, Cadmium, Calcium, and Chromium.

Red dashed lines are relevant surface water standards. Blue dashed lines are relevant groundwater water standards.

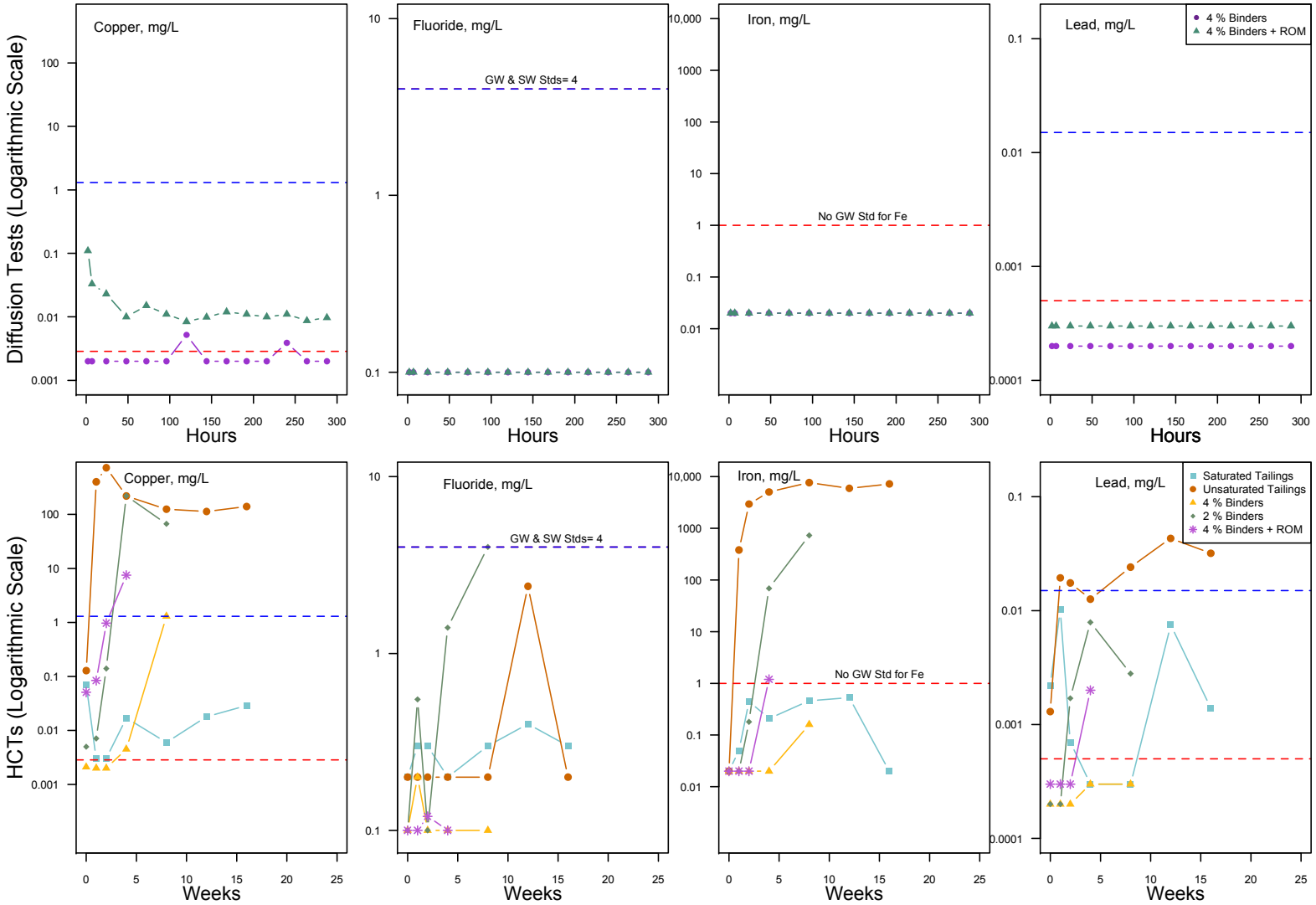


FIGURE 4-4. Tailings Kinetic Test Results: Copper, Fluoride, Iron, and Lead.

Red dashed lines are relevant surface water standards. Blue dashed lines are relevant groundwater water standards.

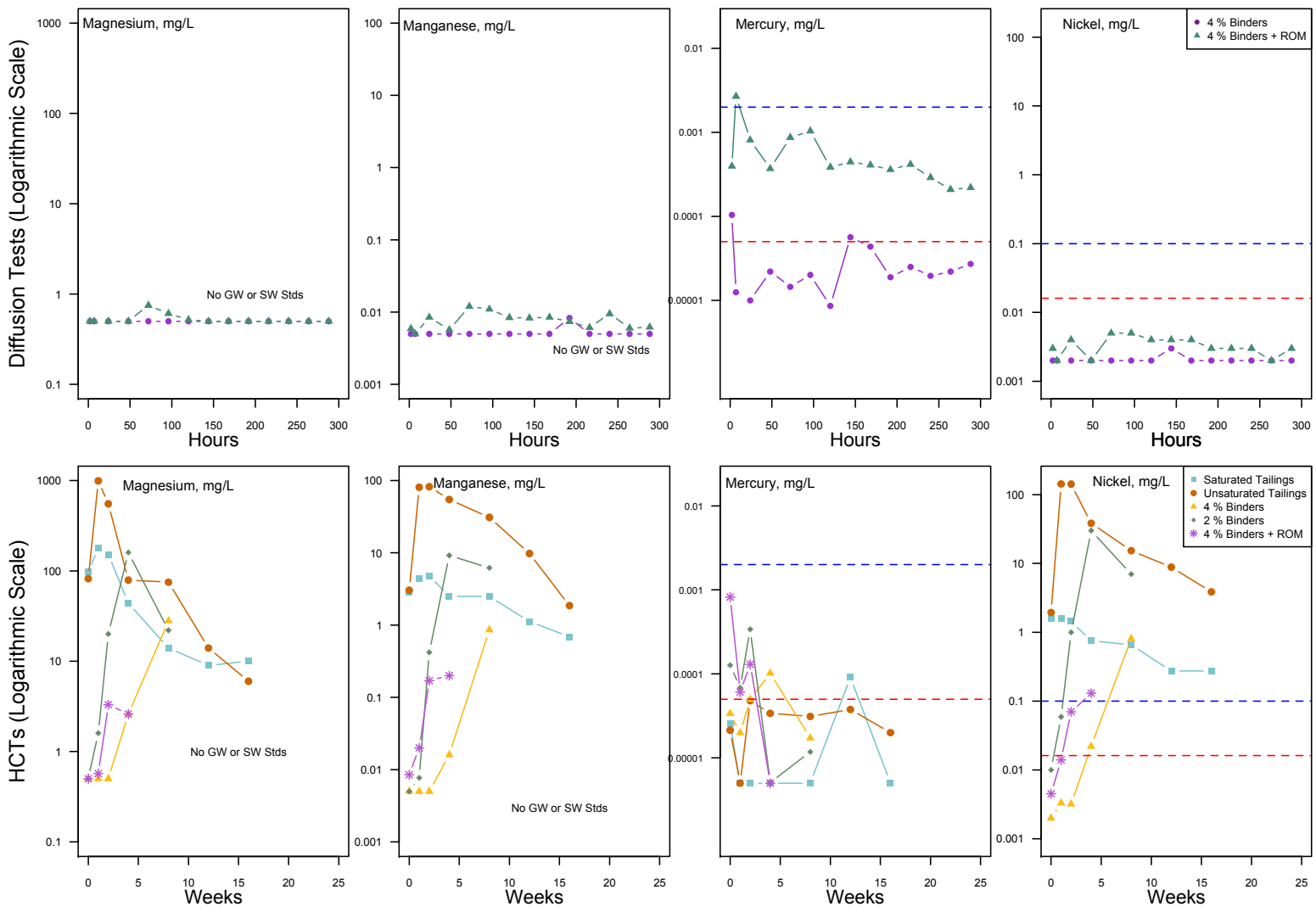


FIGURE 4-5. Tailings Kinetic Test Results: Magnesium, Manganese, Mercury, and Nickel.

Red dashed lines are relevant surface water standards. Blue dashed lines are relevant groundwater water standards.

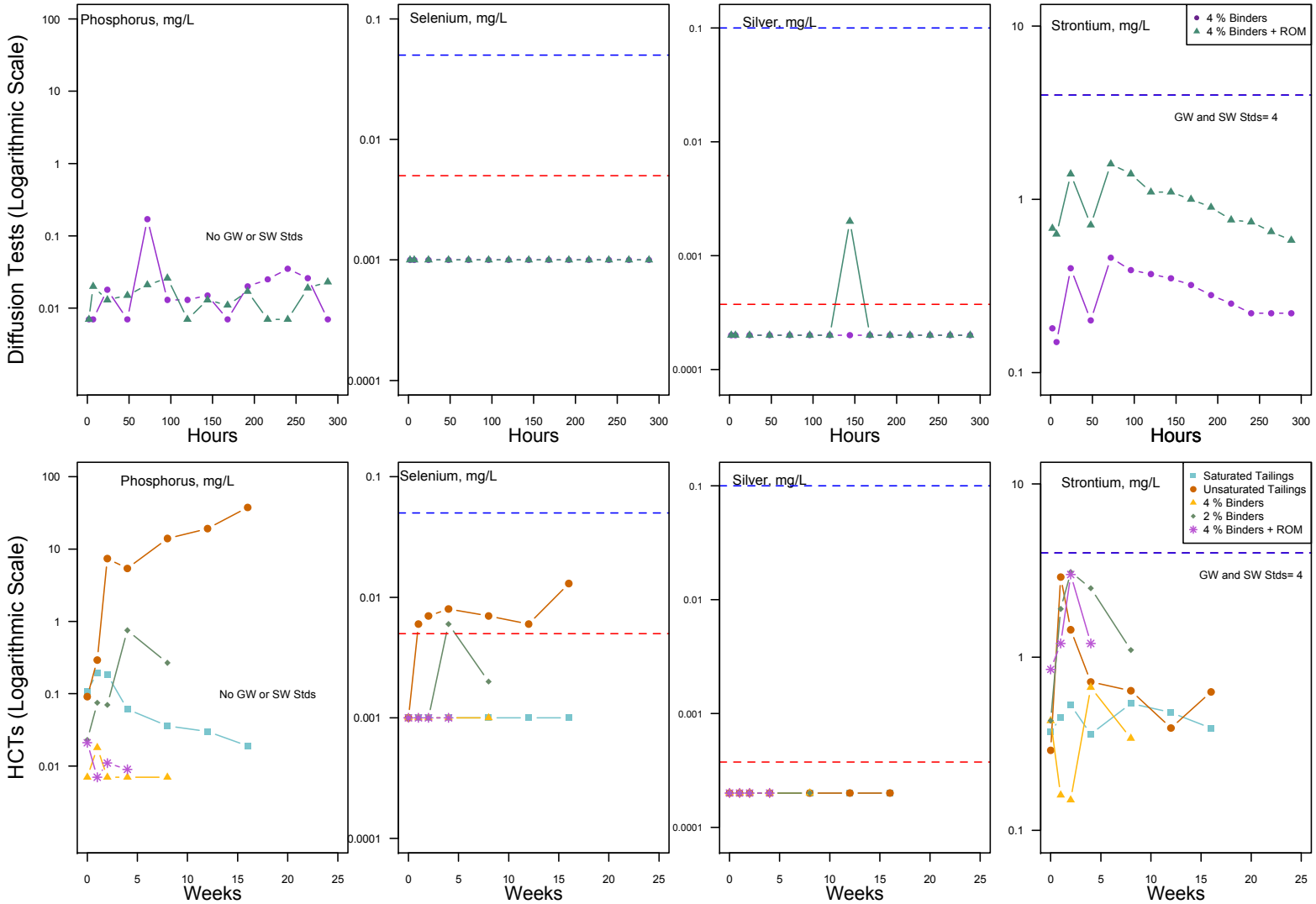


FIGURE 4-6. Tailings Kinetic Test Results: Phosphorus, Selenium, Silver, and Strontium.

Red dashed lines are relevant surface water standards. Blue dashed lines are relevant groundwater water standards.

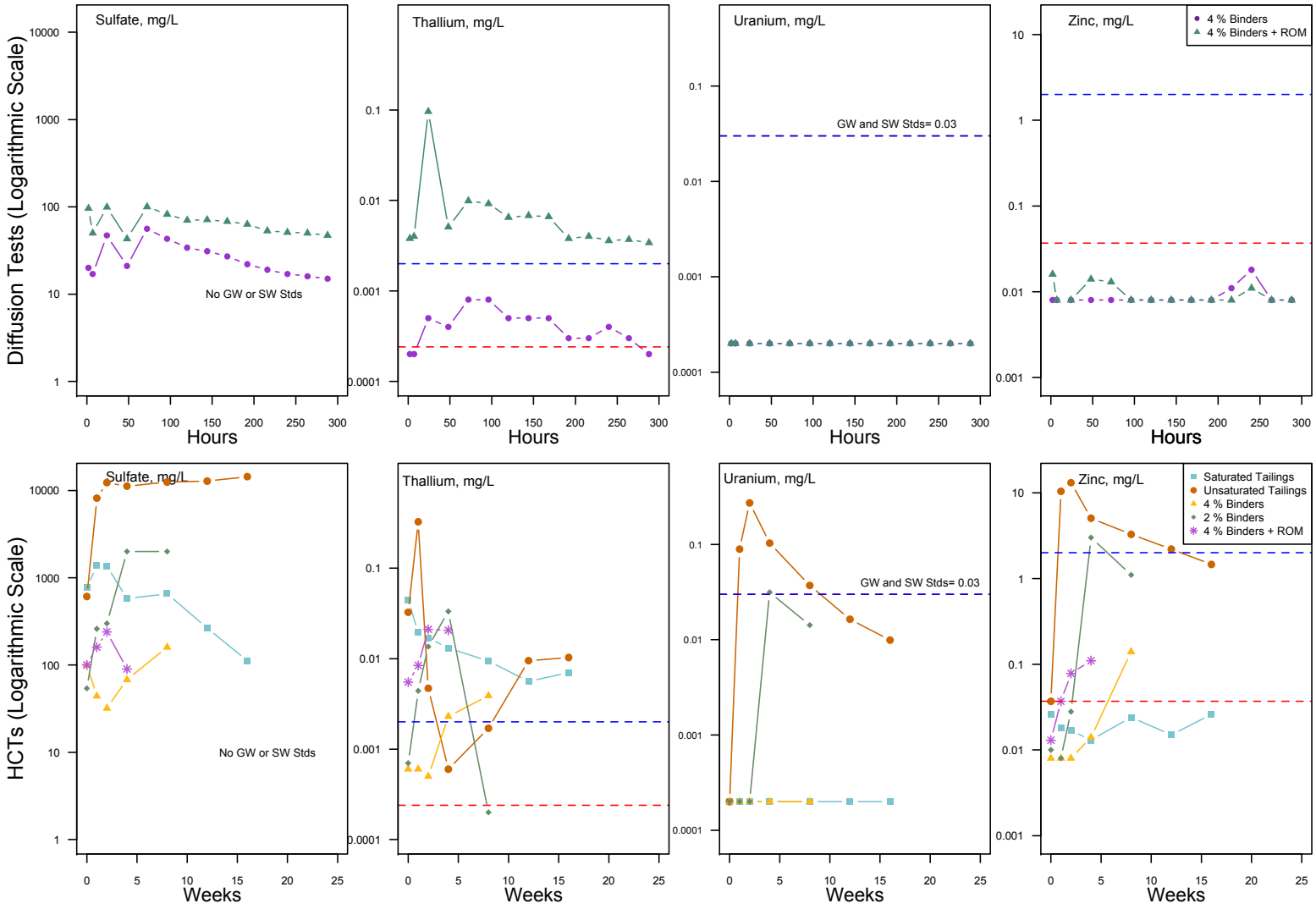


FIGURE 4-7. Tailings Kinetic Test Results: Sulfate, Thallium, Uranium, Zinc.

Red dashed lines are relevant surface water standards. Blue dashed lines are relevant groundwater water standards.

5 Conclusions and Recommendations

The acid generation and metal release potential of waste rock, construction rock, and tailings to be produced by Tintina's proposed Black Butte Copper Project has been characterized using static multi-element analysis, acid-base accounting, net acid generation potential, and kinetic methods. Mineralogical analyses of metal residence and asbestiform mineral analyses were also completed.

The testing program has addressed all proposed management options and anticipated alternatives. Static and kinetic tests of all waste rock with tonnage >1% have been completed, and additional waste lithotypes representing tonnages below 1% (including *IG, Ynl 0, Yne*, and *Yc)* have also been characterized. Raw (non-amended) tailings have been tested along with cemented paste tailings with 2% and 4% cement binder, and 4% cement binder mixed with run-of-mine rock to simulate alternative disposal methods. Tailings have been tested under both subaerial weathering and saturated conditions. Results are reported through October 2015; some kinetic tests are ongoing and final results will be reported at a later time. Predictive models of water quality for the underground workings during operations and at closure, for the waste rock stockpile, and for the tailings impoundment sump are also being developed and will be reported when complete.

5.1 Waste Rock Geochemistry.

Waste rock from the Lower-Zone Footwall (*LZ-FW*, 35% of waste rock tonnage), the Lower Newland basal shale and conglomerate (*Ynl B*, 32%), the Upper Sulfide Zone (*USZ*, 28%), and the Undifferentiated Lower Newland (*Ynl*, 4%) will be produced by the Project. A total of 7,497 whole rock samples were statistically analyzed to characterize overall geochemical variability within multiple lithotypes and to identify representative sample subsets for static testing and develop composites for metal mobility, kinetic and asbestiform mineral testing. No asbestiform minerals were identified in any lithotype to be mined from the Project. A total of 156 static tests of acid generation potential, using both acid-base accounting (ABA) and net acid generation (NAG) methods, were completed by ALS Laboratories (Sparks NV) for the dominant waste rock lithotypes. Results of ABA and NAG tests indicate that the majority of *Ynl B* and *Ynl* samples (90%) are unlikely to form acid, while many *USZ* and *LZ-FW* samples have an uncertain potential or are likely to generate acid.

Kinetic tests of *Ynl B*, *USZ*, and *Ynl* waste rock collected from the vicinity of the previously proposed Johnny Lee decline were completed by McClelland Laboratories (Sparks NV) following the ASTM protocol D5744 in 2012. The *Ynl* composite tested in 2012 was comprised of subsamples that were representative of this lithotype site wide, but the *Ynl B* and *USZ* composites were not. To address this limitation, additional tests of these two waste rock lithotypes were initiated in 2015 using representative subsamples collected site wide. Also, as a result of 2015 changes in the mine plan, the *LZ-FW* was identified as a significant portion of the waste rock tonnage to be produced; representative samples were therefore identified, analyzed and composited for kinetic testing of this unit as well. As of the end of October 2015, the *Ynl B*, *USZ*, and *LZ-FW* kinetic tests were in weeks 19, 19, and 17, respectively, and will remain online until steady state geochemical conditions are attained and regulatory approval for termination is obtained, to ensure that all testing objectives have been met.

Sulfide oxidation was observed in HCT tests for the four volumetrically significant waste rock units. However, consistent with static test results and the presence of abundant carbonate mineralization, oxidation in the *Ynl B, Ynl, and LZ-FW* tests has not produced sufficient acidity to deplete alkalinity nor have these tests produced acidic pH values. Despite indications of sulfide oxidation, depleted alkalinity and increased acidity with lower pH was only evident in the 2015 *USZ* test. Some of these tests are ongoing and this interpretation is therefore subject to change.

All assessments of metal release potential for waste rock lithotypes (tonnage >1%) and tailings have been based on metal concentrations measured in kinetic test effluents in weeks 0, 1, 2, 4, and every 4 weeks thereafter. Despite maintaining neutral pH in the test cells, the *Ynl B,* and *Ynl* units showed potential to exceed surface water quality standards for some metals in early weeks of kinetic testing. However, they do not exceed groundwater standards after week 2. Conversely, the *LZ-FW* and *USZ* have shown potential for release of several metals in excess of surface water standards in multiple weeks. With the exception of week 0, no groundwater criteria were exceeded in leachate from the 2012 test of *USZ* rock, but the 2015 sample did exceed groundwater standards for Ni and Hg, in weeks 1 and 2, and for Sr and Tl throughout the test. The *LZ-FW* lithotype exhibited regular exceedances of Sb, As, and U groundwater quality standards. Because each of the waste rock lithotypes has some, if not significant, potential to generate acid or release concentrations of metals in excess of water quality standards, Tintina proposes to encapsulate waste rock in cemented paste tailings within the lined and monitored CTF impoundment. Further, Tintina proposes to collect all water from the waste rock stockpile, the cement paste tailing impoundment, and the underground workings for treatment to non-degradation standards prior to discharge into underground infiltration galleries. Potential for waste rock drainage impact to surface and groundwater is therefore low.

Mineralogical analyses, using the Mineral Liberation Analysis/scanning electron microscopy method, were completed by MT Tech Center for Advanced Mineral Processing on samples of waste rock pre- and post-weathering in 2013, to evaluate the mineral residence of metals of interest, such as Tl and Se. The 2012 *Ynl B* sample was comprised of quartz, dolomite, muscovite, potassium feldspar and pyrite (1.6%); the *Ynl* sample was similar but also contained biotite, barite and 10.8 % pyrite. The 2012 *USZ*, like the undifferentiated *Ynl* unit, contained quartz, dolomite, muscovite, and potassium feldspar; but it also contained 45% pyrite. No discrete mineral phases containing Tl or Se were identified. Analysis of the Tl and Se content of heavy liquid separates (which separated the light feldspars from the heavy sulfides) suggested that these elements, which occurred commonly in humidity cell effluent, occur as trace substitutes in the sulfides.

5.2 Tailings Geochemistry

Splits of homogenized tailings reject produced in bench-scale metallurgical testing were used for all tests. While there is some variation in AP and NP, the ABA and NAG tests indicate that the tailings will have a strong potential to generate acid with or without paste amendment. The neutralization potential resulting from the addition of 2 to 4% cement binder is not sufficient to neutralize the sulfide in the tailings. This was not the intent of cement addition, however. Cement was added to provide structural strength in support of drift and fill mining methods underground, and to change the physical properties of the tailings to a stable, non-flowable material with low hydraulic conductivities on the order of 1^{-9} m/sec in both surface and underground settings.

Cemented paste tailing cylinders were tested (without crushing) in conventional ASTM method D5744 humidity test cells to simulate sub-aerial weathering and in ASTM C1308 diffusion tests to simulate diffusion through backfill in saturated underground workings. Raw (non-amended) tailings were also tested using ASTM method D5744, both sub-aerially and in a modified, saturated test, to represent dry-stack surface placement and subaqueous impoundment scenarios, respectively.

Although metal concentrations measured in kinetic tests of tailings exceeded one or more surface water standards in several tests, discharge to surface water is unlikely because, operationally, mine-affected water will be collected and treated to non-degradation standards prior to discharge only to groundwater. The following discussion, therefore, focuses primarily on comparing results to groundwater standards, with the exception of the saturated humidity cell test of raw tailings, which is representative of surface water in a subaqueous tailing facility pond.

The 2% and 4% binder and 4% binder +ROM cylinders showed different trends in sulfide oxidation in the diffusion tests. The 4%-binder tailing cylinder maintained a variable but overall higher pH between 6.5 and 9.7, with available alkalinity, and produced less sulfate throughout the 11-day test than the 4% binder +ROM cylinder. This suggests that the massive character of cemented paste tailings may be important in controlling sulfide exposure for oxidation. Rates of metal release were significantly lower in diffusion tests of saturated cemented paste tailings than in unsaturated humidity cell tests of weathered cemented paste tailings. In fact, only relevant As and Tl groundwater standards were exceeded in the 4% binder and 4%+ROM cylinders, respectively. Furthermore, because the backfilled cemented paste tailings and surrounding bedrock have very low transmissivity, the cemented paste will react slowly with groundwater and are unlikely to create acidity or release concentrations of metals above groundwater standards.

The cemented paste tailings were also studied in conventional, aerated humidity cell tests to evaluate their behavior in surface deposits within the CTF. Acid and sulfate production varied between the paste treatments, with the 2% test exhibiting greater release than the 4% test, which was similar to the 4% with ROM test. All tests began at a pH above 6, which was maintained for 0-3 weeks depending on treatment. As of week 2, the 2% paste cement treatment began to trend downward in pH, followed by the 4%+ROM sample in week 3. The 4% paste cement treatment held a pH over 6 in week 4. Tintina proposes to place 0.5 to 2% paste cement amended materials in its surface CTF, and to collect and remove water from that impoundment continuously. Although the initial rates of metal release for cemented paste tailings was lower than raw tailings for most metals, the rates of Al, Cu, Cd, Ni, and Tl release from the 2% cement paste HCT approached that of the unsaturated raw tailings HCT after 4 weeks. Metal concentrations in effluent from the 4% paste cement backfill were lowest, and only regularly exceeded the groundwater quality standard for Tl, with isolated exceedances of Cu and Ni groundwater standards. This suggests that groundwater interacting with oxidized 4% cement amended tailings backfill could exceed standards for Tl prior to water treatment. These tests remain online, and this interpretation is subject to change based on future results.

Both saturated and unsaturated kinetic tests of raw, non-amended tailings are presently being conducted by McClelland Labs (Sparks NV). The raw “non-amended” tailings sample tested in the conventional, subaerial kinetic test, simulating conditions in a dry-stack scenario, was strongly acidic and showed a correspondingly high potential to generate sulfate and several metals at low pH. In contrast, as of week 19, the saturated kinetic test, which is intended to represent a subaqueous impoundment pond, showed

much lower sulfide oxidation and release of metals, and maintained a circum-neutral pH of 6.9. At the lower oxidation rate in the saturated HCT, fewer metals exceeded relevant surface water quality standards and they were detected at much lower concentrations. These cells remain online and this interpretation is also subject to change.

5.3 Conclusions

The four volumetrically significant waste rock units showed evidence of sulfide oxidation in the HCT tests. However, consistent with static test results and the presence of abundant carbonate mineralization, oxidation in the *Ynl B, Ynl, and LZ-FW* tests has not produced sufficient acidity to deplete alkalinity nor have these tests produced acidic pH values. Despite indications of sulfide oxidation, depleted alkalinity and increased acidity with lower pH was only evident in the 2015 *USZ* test, and not in the 2012 test of *USZ* rock. Furthermore, metal release potential from the *Ynl B,* and *Ynl* units was low. The *USZ* and *LZ-FW* units each exhibited unique metal-release signatures, which will be treated to non-degradation standards and subsequently discharged in the underground infiltration gallery. Results of geochemical testing of these units are being used to generate various models predicting underground water and seepage from the temporary waste rock storage facility. The models are results are in development and will be presented elsewhere.

Results of the diffusion kinetic tests indicate that saturated 4% cemented paste tailing, which represents the likely backfill material, is unlikely to become acid and has potential to release only Tl in concentrations above groundwater standards, which will be treated to non-degradation standards prior to discharge in the underground infiltration gallery. Additionally, because of the extremely low hydraulic conductivity of 1^{-9} m/sec for this cemented paste backfill material, as well as for surrounding bedrock, the potential for this material to impact groundwater quality in a backfill setting is low.

Humidity cell test results of cemented paste amended tailings indicate that all of these treatments have potential to oxidize after a lag time and to release at least some sulfate, acidity, and metals if left exposed to air and water. Importantly, this is not observed immediately in test cells, and the rate of weathering in a humidity cell is recognized to be up to 10 times greater than in the field, e.g. 4 weeks in the HCT translates to as much as 40 weeks at the operational scale. In the CTF, each new lift of 2% cemented paste tailings will behave as a massive block of material with low transmissivity, with a thin upper surface that will be exposed to some degree of oxidation before being covered by fresh, paste tails within days of placement. If material is covered in a timely manner (on the scale of weeks to months), relatively little oxidation, acidity, and leaching of metals is expected to occur and it would be limited to the immediate surface of the paste tailings. Any water interacting with oxidized tailings will do so within the lined CTF, and will react with dominantly net neutralizing waste rock before being collected for treatment.

At closure, the paste tailings deposit will be covered with a geotextile membrane welded to the bottom liner, eliminating long-term exposure of the final lifts to oxygen and water. The double lined CTF with drainage collection is designed to prevent discharge to surface water and groundwater. Thus, any solutes resulting from oxidation and release of metals by 2% cement amended tailings within the CTF are unlikely to reach or affect surface water or groundwater. The inclusion of ROM waste rock in the 2% cement amended tailings may increase alkalinity (as suggested by the 4% +ROM test results, to date) and further delay the onset of any acid production in the CTF, thus reducing potential concentrations of metal in water reporting to the water treatment plant.

Subaqueous placement of tailings, an alternative to Tintina's proposed scenario, appears to be most effective at limiting sulfide oxidation, followed by placement of 4% cement amended tailings in saturated underground workings. However, some release of metals to the tailings pond would be expected to occur in concentrations that exceed surface water standards if a subaqueous impoundment alternative were to be considered. Furthermore, significant acid rock drainage should be expected to develop in subaerially weathered, fine-grained raw (non-amended) tailings, suggesting that a "dry stack" alternative management scenario may not be effective under local precipitation conditions.

6 References

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APPENDICES

Appendix A

FINAL Black Butte Copper Project

Baseline Environmental Geochemistry Evaluation,

2012 Johnny Lee Decline

Appendix B

Waste Rock Static Data

Table B-1 Summary of whole rock chemistry, by lithotype
Table B-2 Summary of all ABA, NAG Results

Figures B-1 through B-6 Boxplots subsets and site-wide lithotypes

2015 ABA/NAG Laboratory Reports from ALS
2015 SPLP Laboratory Report from Energy Labs
2015 Asbestiform Mineral Laboratory Reports from R.J. Lee Group

Appendix C

Waste Rock Kinetic Data

Table C-1 Weekly Parameters: 2012 HCTs
Table C-2 Periodic Metals: 2012 HCTs
Table C-3 Weekly Parameters: 2015 HCTs
Table C-4 Periodic Metals: 2015 HCTs

McClelland's Final report of 2012 HCTs (Includes Energy Lab Reports)
CAMP Mineralogy Report from 2012 HCTs

Appendix D

Static and Kinetic Tailings Data

Table D-1 a-b 2015 Diffusion Test Results
Table D-2 Weekly Parameters: 2015 HCTs
Table D-3 Periodic Metals: 2015 HCTs

Static Lab Reports (ICP and ABA/NAG, from ALS and SGS)
WETLab Diffusion Test Results