Technical Memorandum

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To: Kosta Sainis, Environmental Superintendent, Gibraltar Mines Ltd.

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RE: Overview of the Gibraltar Mine Environmental Effects Monitoring Program - Development and Results

Background

The Gibraltar Mine has completed three phases of Environmental Effects Monitoring (EEM), including biological monitoring completed in 2010, 2013, and 2016. A fourth phase of EEM is currently underway - field sampling was completed in 2019 and data analysis and interpretation are in progress. These studies evaluate physical, chemical, and biological conditions in the Fraser River immediately downstream of the Gibraltar effluent outfall, comparing these conditions to upstream reference conditions. EEM is required under the Metal and Diamond Mining Effluent Regulations (MDMER, formerly the Metal Mining Effluent Regulations or MMER) and under British Columbia *Environmental Management Act* (*EMA*) Permit PE-00416. Conditions related to these regulations are outlined in Table 1, along with information related to the temporal development of biological monitoring in response to program findings and discussion with the Technical Advisory Committee (TAC). This memorandum provides an overview of the study design development process, from Phase 1 through Phase 4, and a summary of the results associated with the first 3 Phases of EEM at the Gibraltar Mine.

Study Design Development

The initial Study Design report for the Gibraltar Mine EEM (Phase 1) was submitted to Environment Canada (EC) and the British Columbia Ministry of Environment (BCMOE) in November 2009 (Golder 2009). The TAC had not yet been established[1] for inclusion in the study design review; however, the Study Design report was reviewed by both regulators. Concerns were raised by EC regarding the feasibility of the initial design (Table 1), and a revised

[1] The first TAC meeting was held on June 23, 2010.

design was submitted in April 2010 (Minnow 2010). The Phase 1 EEM biological survey was implemented in 2010 (August to October), with an Interpretive Report prepared in 2011 (Minnow 2011). Based on the results of the initial study, recommendations were made within the report for additional biological monitoring elements to be considered for Phase 2 EEM (Table 1).

The Study Design report for the Phase 2 EEM was prepared in March 2013 (Minnow 2013) and was presented to the TAC at the April 2013 TAC meeting. Components added for this study included sediment quality monitoring, the inclusion of a second benthic invertebrate reference area, a fish health survey, and a fish tissue quality survey (Table 1). No further sampling was added following the presentation of the study design to the TAC. The Phase 2 EEM biological surveys were implemented in 2013 (August to October), an Interpretive Report was prepared in 2014 (Minnow 2014), and results were presented and discussed at the February 2015 TAC meeting.

The third phase of EEM was initiated while Gibraltar was applying for a temporary amendment to *EMA* Permit PE-00416 to allow for a higher effluent discharge rate[2] during the allowable discharge window (April 10 to November 10). As part of the application, a draft study design was provided to the BCMOE and TAC in November 2015 for comment. One addition was made to the design prior to TAC input - the addition of a second fish reference area to better characterize natural variability within the river. Gibraltar received approval for the temporary amendment (October 13, 2015) to discharge at 0.285 m^3/s for the remainder of the 2015 discharge window and the full 2016 window. Through the TAC review process and in discussion among TAC members, several monitoring components were added to the 2016 sampling program as permit requirements[3], including additional effluent mixing validation, larger sample size for fish tissue, additional water quality monitoring, and primary productivity sampling (Table 1). A final Study Design report was submitted in March 2016 (Minnow 2016), with additional permit requirements added in July 2016. The Phase 3 EEM biological surveys were implemented in 2016 during the period of higher discharge from the Gibraltar Mine. Results of the Phase 3 EEM (Minnow 2017) and the additional monitoring components were presented to the TAC at the November 2017 meeting. Recommendations within the Phase 3 Interpretive Report included repeating the same design for Phase 4 but discontinuing primary productivity sampling as conditions within the Fraser River in the vicinity of the diffuser are not conducive to algal growth.

Similar to Phase 3, Gibraltar was applying to increase effluent discharge to the Fraser River during the design stage of the Phase 4 EEM. A draft Phase 4 EEM Study Design report was provided to the TAC in April 2018 for review and the final draft Study Design report (Minnow 2018) was

[2] Gibraltar Mine applied for an increase in discharge rate of 50% from 0.190 m^3/s to 0.285 m^3/s.
[3] Some components required within the temporary permit amendment were reported separately, as they did not directly relate to the biological monitoring required within the EEM.

presented to the TAC at the September 2018 meeting. TAC members had until December 1, 2018 to provide feedback on the design. Comments were incorporated and a final study design was submitted in February 2019 (Minnow 2019). As Gibraltar Mine received another temporary permit amendment to increase effluent discharge for three years (2019 to 2021), the Phase 4 EEM was implemented in 2019 under conditions of higher effluent discharge (at a permitted rate of 0.285 m^3/s). An overview of the Phase 4 EEM monitoring components (no results were available) was presented at the December 2019 TAC meeting and preliminary (expedited) sediment quality results were provided at the March 2020 TAC meeting. Data analysis and interpretation is still underway for the Phase 4 EEM, and an Interpretive Report will be prepared later this year.

EEM Overview

EEM at the Gibraltar Mine has included the characterization of Gibraltar effluent mixing (Phases 1 to 4), effluent sublethal toxicity testing (Phases 1 to 4), water quality (Phases 1 to 4), sediment quality (Phases 2, 3, and 4), primary productivity sampling (Phase 3), benthic invertebrate community and tissue quality surveys (Phases 1 to 4), fish health and tissue quality surveys (Phases 2, 3, and 4), and collection of additional supporting environmental variables (Phases 1 to 4). The EEM studies fulfil the requirements of the federal MDMER and *EMA* Permit PE-00416. The following sections summarize the findings of the Phase 3 EEM (Minnow 2017) and include comparisons to and information from previous EEMs (Phases 1 and 2) as relevant. Analysis and interpretation of Phase 4 EEM data is in progress but, as indicated above, sediment quality data have been evaluated and presented to TAC, and are also summarized below.

Effluent Mixing

Gibraltar Mine has developed a sophisticated three-dimensional environmental model to characterize effluent mixing in the Fraser River (Hayco 2009; Tetra Tech EBA 2015). During each EEM, effluent mixing was characterized using conductivity as a tracer. Results from the Phase 1 and 2 EEMs suggested a larger effluent mixing zone (delineated to 1% effluent or lower) than predicted by the model, which triggered the requirement for a fish survey in Phase 2[4]. The discrepancy between the model and field measures was investigated prior to the Phase 3 EEM. The investigation identified that the mixing of ions from a concentrated solution into a dilute waterbody results in non-proportional dilution. To address and quantify the non-proportional results of conductivity-based in-situ determinations of effluent mixing in the Fraser River, titrations were completed by adding Gibraltar Mine effluent to Fraser River reference water in a controlled manner while measuring conductivity. Laboratory titrations confirmed that

[4] Under MDMER, a fish survey is required if 1% effluent is present at 250 meters or more from the point of discharge.

field-based measurement of specific conductance without correction overestimates effluent concentration in the Fraser River downstream of discharge and therefore overestimates the spatial extent of the effluent mixing zone. Titration data were used to develop a correction factor that was then applied to measured conductivity within the river during mixing validations. Using this method[5], effluent mixing validations have provided excellent corroboration to the model.

Effluent Sublethal Toxicity

Effluent mixing characterizations indicate that effluent mixes quickly within the Fraser River with a maximum concentration of 3% measured 46 m downstream of the discharge during 2016 field surveys and concentrations of 1% or less measured at a distance of 250 m downstream of the discharge. These field measurements agreed well with modelled results (Tetra Tech 2017). Sublethal toxicity testing conducted between 2014 and 2016 (i.e., the Phase 3 EEM period) indicated that effluent had limited influence on fathead minnow, the invertebrate *Ceriodaphnia dubia,* the plant *Lemna minor*, and the alga *Pseudokirchneriella subcapitata*. Only *L. minor* frond increase (but not dry weight) showed consistent impairment at a geometric mean effluent concentration of 58.6% (far greater than the maximum observed in the river). However, these results simply indicate that effort was directed towards larger fronds as opposed to increasing the number of fronds; overall growth was not impaired. Given the low effluent concentrations observed in the Fraser River, no sublethal effects to aquatic organisms would be expected downstream of the discharge.

Water Quality

Gibraltar effluent had a limited influence on water quality of the Fraser River. Elevated concentrations of analytes relative to British Columbia Water Quality Guidelines (BCWQG; BCMOE 2015, 2017) were observed both upstream and downstream of the mine's discharge point, including elevated concentrations of chromium, copper[6], iron, zinc, and dissolved aluminum (Table 2). These elevated concentrations are a result of upstream natural and anthropogenic influences and were most often lower downstream of the discharge relative to upstream. While concentrations of nitrate, nitrite, sulphate, and molybdenum were significantly higher downstream of the discharge relative to upstream, concentrations of these mine-indicator analytes remained well below BCWQG (Table 3), representing 20% or less of applicable guideline concentrations.

[5] This method is an improvement upon standard guidance for EEM (EC 2003; ECCC 2017).
[6] The BC copper guideline has been updated (BCMECCS 2019) and is now based on the biotic ligand model (for screening dissolved concentrations). The Phase 4 EEM will use this updated method for evaluating dissolved copper concentrations.

Sediment Quality

Limited sediment deposition occurs within the Fraser River in the vicinity of the Gibraltar Mine discharge, and deposits generally consist of a thin layer of silt overlying coarse sand or cobble. This component of the study has been discussed during multiple TAC meetings (Table 1). Metal concentrations measured in sediment collected from effluent-exposed areas were similar to those measured at reference areas upstream of the discharge (Table 4). Some metals had significantly higher concentrations at the exposed replicate stations relative to reference, however differences were attributable to differences in particle size distribution and organic content (which were also significant) found between sampling areas (Table 4). Metals that did have higher concentrations in sediment were not those elevated in effluent; therefore, the differences were not related to Gibraltar Mine discharge. For the Phase 4 EEM, sediment metals were assessed using both the whole sample and the <63 um fraction (based on comments received during the December 2019 TAC meeting). Results of this analysis indicated that there were no differences attributable to Gibraltar Mine effluent downstream of the discharge; again, metals that did have higher concentrations in sediment were not those elevated in effluent (Table 5). Overall, sediment quality monitoring has indicated no influence of the Gibraltar Mine on Fraser River sediment quality.

Primary Productivity

Primary productivity results indicated that most of the material accumulated on sampling devices (artificial substrates) was fine sediment; periphyton growth was very limited. Ash free dry mass and chlorophyll-a samples generally returned low mass/concentrations (or were undetectable), confirming limited organic matter and/or periphyton growth (Figure 1). Similarly, periphyton community analysis indicated low biomass and cell count results. Despite elevated nitrate concentrations in effluent, concentrations in the Fraser River downstream of the discharge were well below BCWQG, and there was no detectable influence of nutrients on periphyton downstream of the diffuser. These results suggested naturally unproductive conditions within the Fraser River near the effluent discharge.

Benthic Invertebrates

The benthic invertebrate community of the Gibraltar Mine effluent-exposed area did not differ from both reference areas[7] based on any EEM-effect metric or any supplementary metric (Table 6). In addition, metal concentrations in invertebrates collected in the effluent-exposed area were similar to those collected at the upstream reference areas, with no metal concentrations in the

[7] Two reference areas have been used since the Phase 2 EEM and allow the study to better distinguish differences that may have been related to the mine from those that may just be due to natural variability among similar areas in the river.

effluent-exposed area significantly higher than those observed at both reference areas. Results from the Phase 3 EEM were consistent with those observed in the Phase 2 EEM (Table 6). Under the MDMER (Schedule 5, Section 9 [b]), no benthic invertebrate sampling was required for Phase 4 as no effects had been observed over the previous two studies. Nonetheless, benthic invertebrate sampling was completed in Phase 4 to meet *EMA* permit requirements.

Fish Health

Fish communities in the Gibraltar Mine effluent-exposed and reference areas were similar during EEM sampling, as would be expected within a large system with no barriers between areas and the limited spatial extent of the effluent plume. Non-lethal fish health measurements were collected from populations of two small-bodied fish[8] - leopard dace and peamouth chub. During the Phase 3 EEM, leopard dace from the effluent-exposed area were significantly longer and heavier than those from the reference-1 population but were similar to those from reference-2 (Table 7). Condition of effluent-exposed leopard dace was significantly lower than both reference areas, but the difference was small (<5%) and well below the EEM critical effect size[9] (10%). The direction of this difference was also opposite of what was observed in Phase 2. Effluent-exposed peamouth chub showed small size differences relative to those collected at reference-1. No consistent differences were observed for either leopard dace or peamouth chub over the Phase 2 and 3 EEM studies (i.e., the studies that included fish health assessments; Table 7). Differences observed between reference areas highlight the natural variability within the Fraser River. Leopard dace and peamouth chub tissue metal concentrations at the effluent-exposed area were similar to those at the upstream reference areas with no concentrations of metals elevated in Gibraltar Mine effluent that were significantly higher in effluent-exposed fish than those from both reference areas. Overall, no influence of the Gibraltar Mine effluent was evident in the EEM fish endpoints. Under the MDMER (Schedule 5, Section 9 [a]), a fish health study was required in the Phase 4 EEM due to a difference in the condition of leopard dace (higher) in Phase 2 that was greater than the critical effect size (Table 7).

Summary

Overall, EEM has indicated that the influence of the Gibraltar Mine effluent discharge on the Fraser River is minor. A small but detectable influence on water quality was evident in higher

[8] Small-bodied fish are preferred from EEM due to their small home ranges, which means they are exposed to effluent for meaningful period of the life spans (e.g., relative to migratory fish such as salmon).
[9] A critical effect size is a magnitude of difference used under MDMER to define ecologically relevant differences between study areas.

nitrate, nitrite, sulphate, and molybdenum concentrations immediately downstream of the discharge relative to upstream, but concentrations of these analytes were well below BCWQG. There has been no influence of the Gibraltar mine effluent on sediment quality, benthic invertebrate tissue quality, or fish tissue quality. Biological monitoring has indicated no differences in benthic invertebrate community relative to both references and only a small difference in condition (energy storage) in leopard dace relative to both references. The latter was less than 50% of the magnitude considered to be ecologically relevant. An opposite difference was observed during the Phase 2 EEM that likely reflected natural variability within the River.

References

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ATTACHMENTS

Table 1: Overview of Gibraltar Mine EEM Programs, Including Revisions to Design Based on TAC Input and Results

Study	Permit 416 Requirements (as related to Fraser River monitoring)	MMER Requirements	Design Adjustments	Technical Advisory Committee (TAC) Input	Recommendations and/or Other Communication Following Study Implementation
Phase 1 EEM (completed when mine was discharging at 0.190 m^3/s) 2010 implementation (Aug to Oct)	- Water quality monitoring - Verify mixing model - Biological monitoring consistent with MMER - Benthic invertebrate tissue quality monitoring completed to satisfy metal bioaccumulation related to sturgeon health - (Sediment quality monitoring not included in first EEM, completed under a separate program)	- Water quality monitoring - Benthic invertebrate community monitoring - Fish health monitoring if effluent >1% at 250 m downstream of the discharge (not triggered) - Fish tissue quality monitoring if mercury concentrations in effluent >0.1 mg/L (not triggered)	- Based on modelling, effluent predicted to be <1% at 250 m, therefore no fish study required or conducted. - Environment Canada had concerns with the initial design by Golder. Minnow proposed a different method used for fast flowing rivers - substrate baskets specifically designed for fast flowing rivers and for retrieval using a protective cone.	None; the TAC was established after the Study Design report was submitted to Environment Canada (EC) and BC Ministry of Environment (BCMOE) - Results of the Phase 1 EEM presented at the March 2011 and April 2012 TAC meetings	- Fish study required during next EEM (Phase 2) as effluent concentrations >1% 250 m downstream of the discharge based on effluent mixing validation results - Addition of a second benthic invertebrate reference area
Phase 2 EEM (completed when mine was discharging at 0.190 m^3/s) 2013 implementation (Aug to Oct)	- Water quality monitoring - Verify mixing model - Biological monitoring consistent with MMER - Benthic invertebrate and fish tissue quality monitoring completed to address metal bioaccumulation - Sediment quality monitoring	- Water quality monitoring - Benthic invertebrate community monitoring - Fish health monitoring if effluent >1% at 250 m downstream of the discharge - Fish tissue quality monitoring if mercury concentrations in effluent >0.1 mg/L (not triggered)	- Second benthic invertebrate reference area added - Sediment sampling added based on baseline sampling design. Sample collection adjusted during the field program based on in-river conditions and objectives - Fish health and tissue quality monitoring added. Fish health due to in-situ determination of effluent concentrations and fish quality tissue due to TAC request. Design modified during field program to sample young-of-year based on resident fish available, habitat range	- EEM design presented and discussed at TAC meeting in April 2013 - EEM results presented and discussed at the April 2015 TAC meeting	- BCMOE reviewed the report and had no concern requiring further comment on the report. Just some statistical questions to be discussed with Minnow (April 27, 2015 letter)
PE-416 Amended August 11, 2015, Temporary Amendment October 13, 2015					
Phase 3 EEM (completed when mine was discharging at 0.285 m^3/s) 2016 implementation (Aug to Oct)	- Water quality monitoring - Verify mixing model - Biological monitoring to assess effects to benthic invertebrate communities and tissue quality - Fish tissue quality monitoring completed to address metal bioaccumulation - Sediment quality monitoring <u>Specific to Temporary Amendment:</u> - Assessment of primary productivity - Fish tissue metals analysis sample size	- Water quality monitoring - Benthic invertebrate community monitoring - Fish health monitoring if effluent >1% at 250 m downstream of the discharge - Fish tissue quality monitoring if mercury concentrations in effluent >0.1 mg/L (not triggered)	Draft design submitted to TAC in November 2015 as part of permit application process. Design modifications based on input: - Additional effluent mixing validation - Larger sample size for fish tissue quality - Primary productivity - Additional water quality monitoring completed by Gibraltar Mine Other modifications: - Second fish reference area added to better characterize natural variability	- February 2016 - presentation and discussion on fully history of EEM sampling design and results, including information from Dr. Phil Owens on sediment sampling ("current program captures the intent it was meant to"). - Winter 2016 - comments received from BCMOE, TNG; responses provided - Approval of design from BCMOE, dated April 29, 2016, with some additional conditions - Results presented and discussed at the March and November 2017 TAC meetings	- Recommended discontinuing primary productivity sampling
PE-416 Temporary Amendment March 18, 2019					
Phase 4 EEM (completed when mine was discharging at 0.285 m^3/s) 2019 implementation (Aug to Oct)	- Water quality monitoring - Verify mixing model - Biological monitoring to assess effects to benthic invertebrate communities and tissue quality - Fish tissue quality monitoring completed to address metal bioaccumulation - Sediment quality monitoring	Now under MDMER - Water quality monitoring - Benthic invertebrate community monitoring if effluent >1% at 100 m downstream of the discharge - Fish health monitoring if effluent >1% at 250 m downstream of the discharge - Fish tissue quality monitoring if mercury concentrations in effluent >0.1 mg/L or selenium concentrations in effluent > 0.005 (avg)/0.01 (max) mg/L (not triggered)	- Benthic invertebrate tissue quality monitoring specifically mentioned in temporary permit amendment - Primary productivity discontinued - No specific components added relative to the Phase 3 study	- Initial Phase 4 Study Design report provided to TAC in April 2018 and presented and discussed at September 2018 TAC meeting. Comments from TAC were provided by Dec 1, 2018 - Written responses were prepared providing clarification for some comments provided - Presentation and discussion of the Phase 4 EEM Study Design at the March 2019 TAC meeting - Field program review presented at the December 2019 TAC meeting. Additional analysis of sediment chemistry completed (<63 um) based on TAC input.	- Data analysis and interpretation is in progress

Abbreviations: EEM = Environmental Effects Monitoring; MMER = Metal Mining Effluent Regulations; MDMER = Metal and Diamond Mining Effluent Regulations; TAC = Technical Advisory Committee; BCMOE = British Columbia Ministry of Environment; TNG = Ŧsilhqot'in National Government.

Table 2: Annual Mean Water Quality at Fraser River Reference and Exposed Stations Relative to Water Quality Guidelines, Routine Monitoring 2014 to 2016

Parameter	Unit	BCWQG[a]		2014 Annual Mean		2015 Annual Mean		2016 Annual Mean	
		30-d Chronic	Maximum	Reference	Exposed	Reference	Exposed	Reference	Exposed
Physical Tests									
Conductivity	µS/cm	-	-	165	137	135	130	139	162
Hardness (as $CaCO_3$)	mg/L	-	-	64	64	60	61	65	72
pH	pH	6.5 to 8.5	6.5 to 8.5	7.2	7.5	7.6	7.9	7.9	7.8
Anions and Nutrients									
Total Suspended Solids	mg/L	-	-	76	69	44	48	50	49
Alkalinity, Total (as $CaCO_3$)	mg/L	-	-	56.2	55.4	57.8	57.0	61.6	61.3
Ammonia as N	mg/L	1.1	5.7	0.0059	0.0052	0.0054	0.0053	0.0068	0.0066
Bromide (Br)	mg/L	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrate (as N)	mg/L	3.0	31.3	0.065	0.063	0.049	0.048	0.046	0.075
Nitrite (as N)	mg/L	0.02	0.06	0.0020	0.0020	0.0014	0.0012	0.0024	0.0020
Sulfate	mg/L	218	-	8.6	8.6	8.9	8.9	9.5	16.4
Total Metals									
Aluminum (Al)	mg/L	-	-	2.10	1.98	1.34	1.45	1.24	1.17
Antimony (Sb)	mg/L	0.009	-	0.00012	0.00013	0.00011	0.00011	0.00011	0.00012
Arsenic (As)	mg/L	-	0.005	0.00110	0.00104	0.00080	0.00086	0.00075	0.00074
Barium (Ba)	mg/L	1.0	5.0	0.032	0.032	0.026	0.027	0.026	0.025
Boron (B)	mg/L	-	1.2	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (Cd)	mg/L	-	-	0.000033	0.000032	0.000021	0.000021	0.000026	0.000026
Calcium (Ca)	mg/L	-	-	18.3	18.3	18.2	18.2	19.5	21.8
Chromium (Cr)	mg/L	-	0.001	0.0043	0.0041	0.0035	0.0029	0.0026	0.0024
Cobalt (Co)	mg/L	0.004	0.11	0.0017	0.0016	0.0010	0.0011	0.0010	0.0010
Copper (Cu)	mg/L	0.0028	0.0086	0.0051	0.0048	0.0036	0.0039	0.0031	0.0030
Iron (Fe)	mg/L	-	1.00	3.25	3.06	2.10	2.24	1.92	1.86
Lead (Pb)	mg/L	0.005	0.052	0.0015	0.0013	0.0010	0.0009	0.0007	0.0007
Magnesium (Mg)	mg/L	-	-	4.51	4.41	4.47	4.52	4.81	4.79
Manganese (Mn)	mg/L	0.91	1.31	0.072	0.068	0.051	0.054	0.050	0.049
Mercury (Hg)	mg/L	0.00001	-	<0.000012	<0.000012	0.000006	0.000006	0.000005	0.000006
Molybdenum (Mo)	mg/L	0.0073	-	0.00061	0.00060	0.00097	0.00092	0.00063	0.00191
Nickel (Ni)	mg/L	-	0.073	0.0057	0.0055	0.0038	0.0040	0.0037	0.0036
Potassium (K)	mg/L	-	-	0.94	0.91	0.80	0.82	0.77	0.89
Selenium (Se)	mg/L	0.002	-	0.00013	0.00012	<0.00010	<0.00010	<0.00010	<0.00010
Sodium (Na)	mg/L	-	-	2.4	2.4	2.6	2.6	2.7	3.2
Strontium (Sr)	mg/L	-	-	0.098	0.100	0.095	0.095	0.104	0.116
Zinc (Zn)	mg/L	0.008	0.033	0.0122	0.0109	0.0077	0.0096	0.0072	0.0075

Mean concentration exceeds a BCWQG 30-day value.

Mean concentration exceeds a BCWQG maximum value.

Notes: Annual means based on four sampling events in 2014 and 2015, and 13 sampling events in 2016, "-" indicates no guidelines for those analytes.

[a] British Columbia Water Quality Guidelines (BCMOE 2015, 2017) except for molybdenum (CCME 2017). Mean Fraser River hardness of 70 mg/L for used for hardness based guidelines.

Table 3: **Mean Water Quality at EEM Reference and Exposed Areas from August, September, and October, Gibraltar Phase 3 EEM, 2016**

Parameter	Unit	BCWQG[a]		August 2016					September 2016					October 2016				
		30-d Chronic	Maximum	Reference 1	Reference 2	Exposed	RPD from REF-1	RPD from REF-2	Reference 1	Reference 2	Exposed	RPD from REF-1	RPD from REF-2	Reference 1	Reference 2	Exposed	RPD from REF-1	RPD from REF-2
Physical Tests																		
Temperature	°C	-	-	17.4	17.4	17.1	-2%	-2%	10.2	10.2	10.2	-2%	-2%	6.4	6.5	6.3	-2%	-3%
Dissolved Oxygen	% Sat.	8.0	5.0 min	11	-	10.7	-3%	-	12.2	12.3	12.1	-2%	-2%	12.2	11.8	12.1	-1%	3%
Conductivity	µS/cm	-	-	123	114	161	**31%**	**41%**	150	150	184	**23%**	**23%**	124	123	150	**21%**	**22%**
Hardness (as CaCO3)	mg/L	-	-	60	62	73	**22%**	**18%**	71	70	84	**18%**	**19%**	65	65	74	**15%**	**14%**
pH	pH	6.5 to 8.5	6.5 to 8.5	8.2	8.1	8.1	**-1%**	0%	8.0	7.8	8.0	0%	**3%**	8.1	8.1	8.2	1%	1%
Anions and Nutrients																		
Total Suspended Solids	mg/L	-	-	39	34	35	**-10%**	4%	25	24	23	**-9%**	**-4%**	39	36	36	**-8%**	0%
Ammonia as N	mg/L	1.1	5.7	0.0058	<0.005	0.0064	9%	**27%**	<0.005	<0.005	<0.005	0%	0%	<0.005	<0.005	0.0058	**16%**	**16%**
Bromide (Br)	mg/L	-	-	<0.05	<0.05	<0.05	0%	0%	<0.05	<0.05	<0.05	0%	0%	<0.05	<0.05	<0.05	0%	0%
Nitrate (as N)	mg/L	3.0	31.3	0.03	0.03	0.10	**242%**	**248%**	0.04	0.04	0.11	**201%**	**201%**	0.06	0.06	0.11	**92%**	**93%**
Nitrite (as N)	mg/L	0.020	0.060	0.002	<0.001	0.004	**152%**	**308%**	<0.001	<0.001	0.0027	**174%**	**174%**	<0.001	<0.001	0.0019	**90%**	**90%**
Sulphate (diss SO_4)	mg/L	218	-	10.4	10.4	26.9	**158%**	**158%**	11.0	11.0	27.7	**153%**	**153%**	8.7	8.7	21.5	**147%**	**148%**
Total Metals																		
Aluminum (Al)	mg/L	-	-	1.11	0.81	1.03	-7%	**28%**	0.88	0.77	0.89	0%	**16%**	1.22	1.39	1.13	-8%	-19%
Antimony (Sb)	mg/L	0.009		<0.0001	<0.0001	<0.0001	0%	0%	<0.0001	<0.0001	<0.0001	0%	0%	<0.0001	<0.0001	<0.0001	0%	0%
Arsenic (As)	mg/L	-	0.0050	0.00068	0.00061	0.00070	3%	**15%**	0.00057	0.00056	0.00055	-3%	-2%	0.00078	0.00079	0.00076	-3%	-4%
Barium (Ba)	mg/L	1	5	0.022	0.020	0.022	0%	**10%**	0.022	0.021	0.022	3%	8%	0.027	0.029	0.027	-2%	-7%
Boron (B)	mg/L	1.2	-	<0.01	<0.01	<0.01	0%	0%	<0.01	<0.01	<0.01	0%	0%	<0.01	<0.01	<0.01	0%	0%
Cadmium (Cd)	mg/L	-	-	0.000023	0.000026	0.000018	**-22%**	**-33%**	0.000015	0.000016	0.000014	-7%	-13%	0.000030	0.000031	0.000028	-6%	-11%
Calcium (Ca)	mg/L	-	-	18.5	19.7	23.4	**27%**	**19%**	21.8	21.5	27.2	**25%**	**26%**	19.4	19.6	23.3	**20%**	**19%**
Chromium (Cr)	mg/L	-	0.001	0.0020	0.0015	0.0020	-4%	**29%**	0.0017	0.0016	0.0016	-4%	5%	0.0027	0.0029	0.0026	-5%	-12%
Cobalt (Co)	mg/L	0.0040	0.1100	0.00088	0.00069	0.00082	**-7%**	**20%**	0.00062	0.00061	0.00059	**-5%**	-3%	0.00091	0.00097	0.00088	-3%	-9%
Copper (Cu)	mg/L	0.0028	0.0086	0.0029	0.0022	0.0025	**-12%**	**17%**	0.0022	0.0021	0.0021	**-4%**	1%	0.0034	0.0035	0.0034	0%	-5%
Iron (Fe)	mg/L	-	1.00	1.72	1.38	1.61	**-6%**	**17%**	1.30	1.25	1.18	**-10%**	**-6%**	1.75	1.89	1.65	-5%	-13%
Lead (Pb)	mg/L	0.005	0.052	0.00074	0.00070	0.00068	-8%	-2%	0.00053	0.00052	0.00051	-4%	-2%	0.00069	0.00071	0.00063	-9%	-11%
Magnesium (Mg)	mg/L	-	-	4.4	4.5	4.3	-1%	**-5%**	5.1	5.0	5.0	0%	1%	5.2	5.2	5.2	1%	-1%
Manganese (Mn)	mg/L	0.91	1.30	0.041	0.034	0.038	**-5%**	**13%**	0.033	0.032	0.031	**-4%**	-2%	0.052	0.055	0.050	-4%	-10%
Mercury (Hg)	mg/L	0.00001	-	<0.000006	<0.000005	<0.000005	-11%	0%	<0.000005	<0.000005	<0.000005	0%	0%	0.0000058	0.0000059	0.0000058	0%	-2%
Molybdenum (Mo)	mg/L	0.0073	-	0.0007	0.0007	0.0034	**391%**	**413%**	0.0006	0.0005	0.0037	**566%**	**574%**	0.0006	0.0006	0.0026	**354%**	**345%**
Nickel (Ni)	mg/L	-	0.073	0.0031	0.0024	0.0029	**-6%**	**21%**	0.0024	0.0023	0.0023	-2%	1%	0.0038	0.0040	0.0037	-3%	-9%
Potassium (K)	mg/L	-	-	0.84	0.78	1.14	**36%**	**46%**	0.71	0.68	1.09	**53%**	**61%**	0.89	0.93	1.11	**25%**	**20%**
Selenium (Se)	mg/L	0.002	-	<0.0001	<0.0001	<0.0001	0%	0%	<0.0001	<0.0001	<0.0001	0%	0%	0.00011	0.00012	0.00012	9%	-5%
Sodium (Na)	mg/L	-	-	3.0	3.0	4.5	**51%**	**48%**	2.7	2.6	4.2	**58%**	**63%**	2.9	3.0	4.1	**40%**	**37%**
Strontium (Sr)	mg/L	-	-	0.10	0.10	0.12	**20%**	**18%**	0.12	0.11	0.14	**24%**	**25%**	0.11	0.11	0.12	**12%**	**11%**
Zinc (Zn)	mg/L	0.008	0.033	0.0065	0.0052	0.0058	-10%	**12%**	0.0051	0.0057	<0.0050	-2%	**-13%**	0.0063	0.0056	0.0063	0%	13%

Mean concentration exceeds a BCWQG 30-day value.
Mean concentration exceeds a BCWQG maximum value.

Notes: RPD from Ref - Relative Percent Difference = ((exposure - reference)/reference)*100, **Bold** - Concentrations significantly different ($p < 0.1$), "-" indicates no guidelines for those analytes, each mean value is based on a replication level of five (n = 5).

[a] British Columbia Water Quality Guidelines (BCMOE 2015, 2017) except for molybdenum (CCME 2017). Mean Fraser River hardness of 70 mg/L for used for hardness based guidelines.

Table 4: Mean Sediment Quality at Reference and Exposed Areas, Gibraltar Phase 3 EEM, 2016

Analyte	BC Sediment Quality Guideline[a] (LEL/PEL)	Units	Reference Mean		Exposed Mean		Relative Percent Difference	
			all stations[b]	replicate stations (Ref-1)	all stations[b]	replicate stations (Exp-1)	all stations	replicate stations
Particle Size								
Gravel	-	%	<1.0	1.5	<1.0	<1.0	0%	-33%
Sand	-	%	39.1	60.4	49.6	47.7	27%	**-21%**
Silt	-	%	50.8	30.9	41.2	41.2	-19%	**33%**
Clay	-	%	9.3	6.4	8.7	9.6	-7%	**49%**
Non-Metals								
pH (1:2 soil:water)	-	pH	8.00	8.00	8.08	7.93	1%	-1%
Total Organic Carbon	-	%	0.73	0.66	0.74	0.96	1%	**45%**
Metals								
Aluminum (Al)	-	mg/kg	12,068	11,040	11,482	12,080	-5%	9%
Antimony (Sb)	-	mg/kg	0.50	0.44	0.45	0.48	-9%	7%
Arsenic (As)	5.9/17	mg/kg	6.1	5.5	5.7	6.3	-6%	**14%**
Barium (Ba)	-	mg/kg	97	90	90	96	-7%	7%
Beryllium (Be)	-	mg/kg	0.33	0.30	0.31	0.32	-6%	6%
Bismuth (Bi)	-	mg/kg	<0.20	<0.20	<0.20	<0.20	0%	0%
Boron (B)		mg/kg	<5.0	<5.0	<5.0	<5.0	0%	0%
Cadmium (Cd)	0.6/3.5	mg/kg	0.22	0.16	0.19	0.19	-15%	**14%**
Calcium (Ca)	-	mg/kg	10,880	8,202	10,224	9,968	-6%	**22%**
Chromium (Cr)	37/90	mg/kg	35.8	33.5	32.8	36.4	-8%	9%
Cobalt (Co)	-	mg/kg	12.8	11.5	12.0	12.9	-6%	**12%**
Copper (Cu)	35.7/197	mg/kg	25.7	22.6	24.0	25.3	-7%	**12%**
Iron (Fe)	21,200/43,766	mg/kg	27,792	26,060	25,912	28,560	-7%	10%
Lead (Pb)	35/91	mg/kg	7.7	6.4	7.1	7.8	-8%	**22%**
Lithium (Li)	-	mg/kg	16.9	15.3	15.7	16.9	-7%	10%
Magnesium (Mg)	-	mg/kg	8,974	8,000	8,606	8,882	-4%	**11%**
Manganese (Mn)	460/1,100	mg/kg	646	573	724	752	12%	**31%**
Mercury (Hg)	0.17/0.486	mg/kg	<0.050	<0.050	<0.050	<0.050	0%	0%
Molybdenum (Mo)	-	mg/kg	0.76	0.72	0.69	0.73	-10%	1%
Nickel (Ni)	16/75	mg/kg	40.2	37.1	37.8	39.7	-6%	7%
Phosphorus (P)	-	mg/kg	702	604	636	641	-9%	6%
Potassium (K)	-	mg/kg	1,002	918	954	1,010	-5%	10%
Selenium (Se)	2.0	mg/kg	0.33	0.27	0.32	0.31	-3%	**15%**
Silver (Ag)	0.5	mg/kg	<0.10	<0.10	<0.10	<0.10	0%	0%
Sodium (Na)	-	mg/kg	196	204	199	198	1%	-3%
Strontium (Sr)	-	mg/kg	48.4	38.7	44.7	44.3	-8%	**15%**
Thallium (Tl)	-	mg/kg	0.089	0.077	0.088	0.086	0%	11%
Tin (Sn)	-	mg/kg	<2.0	<2.0	<2.0	<2.0	0%	0%
Titanium (Ti)	-	mg/kg	655	681	609	651	-7%	-4%
Uranium (U)	-	mg/kg	0.76	0.63	0.69	0.73	-10%	**15%**
Vanadium (V)	-	mg/kg	42.1	44.0	39.8	45.5	-6%	3%
Zinc (Zn)	123/315	mg/kg	62.5	56.3	58.2	61.5	-7%	**9%**
Zirconium (Zr)	-	mg/kg	4.66	3.68	4.72	4.10	1%	11%

Indicates sediment analyte concentration exceeds Interim Sediment Quality Guideline (ISQG) or Lowest Effect Level (LEL).
Indicates sediment analyte concentration exceeds Probable Effect Level (PEL) or Severe Effect Level (SEL).

Notes: **Bold** - Concentrations significantly different ($p < 0.1$), each mean value is based on a replication level of five ($n = 5$), "-" indicates no guidelines for those analytes, RPD - relative percent difference; ((exposure - reference)/reference)*100.

[a] BCMOE 2015, 2017.

[b] Calculated using the mean of replicate data.

Table 5: Average Sediment Quality and Statistical Comparisons between Exposed and Reference Areas, Gibraltar Mine Phase 4 EEM, 2019

Analyte	Units	Replicate Samples (REF-5 and EXP-1)								Stations (5 km upstream and downstream)							
		Whole Sample				<63 um Fraction				Whole Sample				<63 um Fraction			
		MCT		P-value	MOD (%)	MCT		P-value	MOD (%)	MCT		P-value	MOD (%)	MCT		P-value	MOD (%)
		Reference	Exposed			Reference	Exposed			Reference	Exposed			Reference	Exposed		
Physical Tests																	
Moisture	%	28	35	0.0045	24	ND	ND	ND	ND	32	36	0.22	12	ND	ND	ND	ND
Particle Size																	
% Gravel (>2 mm)	%	ND	ND	ND	ND	ND	ND	ND	ND	1.0	1.0	0.42	0	ND	ND	ND	ND
% Coarse Sand (2.0 mm - 0.2 mm)	%	37	23	0.0071	-38	ND	ND	ND	ND	20	20	0.95	-2.4	ND	ND	ND	ND
% Fine Sand (0.2 mm - 0.063 mm)	%	44	40	0.26	-9	ND	ND	ND	ND	42	36	0.43	-14	ND	ND	ND	ND
% Silt (0.063 mm - 4 µm)	%	16	31	0.015	97	ND	ND	ND	ND	32	38	0.57	20	ND	ND	ND	ND
% Clay (<4 µm)	%	2.5	5.2	0.010	109	ND	ND	ND	ND	5.2	6.4	0.51	23	ND	ND	ND	ND
Organic / Inorganic Carbon																	
Total Organic Carbon	%	0.39	0.75	0.10	92	ND	ND	ND	ND	0.55	0.79	0.24	43	ND	ND	ND	ND
Metals																	
Aluminum (Al)	mg/kg	8,920	10,834	0.011	21	13,120	14,800	0.0072	13	10,570	11,122	0.64	5.2	14,300	16,700	0.17	17
Antimony (Sb)	mg/kg	0.37	0.42	0.093	14	0.50	0.49	0.67	-0.81	0.42	0.45	0.33	7.2	0.51	0.51	1.0	0
Arsenic (As)	mg/kg	4.5	5.1	0.017	14	6.6	6.7	0.91	0.48	5.1	5.5	0.44	6.8	6.9	7.0	0.71	1.2
Barium (Ba)	mg/kg	72	90	0.017	26	94	99	0.094	5.4	86	88	0.78	2.5	101	107	0.20	5.6
Beryllium (Be)	mg/kg	0.23	0.28	0.014	23	0.32	0.34	0.017	6.9	0.27	0.29	0.41	9.0	0.35	0.36	0.81	1.7
Bismuth (Bi)	mg/kg	ND	ND	ND	ND	0.13	0.14	0.098	11	0.20	0.20	0.42	0	0.14	0.14	0.83	1.4
Boron (B)	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium (Cd)	mg/kg	0.15	0.17	0.18	15	0.23	0.22	0.17	-3.5	0.16	0.17	0.92	4.3	0.23	0.23	0.91	-0.7
Calcium (Ca)	mg/kg	9,920	10,824	0.11	9.1	18,280	18,040	0.57	-1.3	10,842	11,860	0.41	9.4	17,240	17,940	0.33	4.1
Chromium (Cr)	mg/kg	28	30	0.23	7.4	37	36	0.29	-2.7	31	32	0.69	3.6	39	39	0.79	1.2
Cobalt (Co)	mg/kg	9.1	11	0.030	16	12	13	0.032	9.0	11	11	0.63	4.0	13	13	0.45	3.4
Copper (Cu)	mg/kg	17	21	0.034	20	26	28	0.11	6.2	20	22	0.53	7.4	28	29	0.74	1.3
Iron (Fe)	mg/kg	20,740	22,760	0.055	9.7	29,140	30,380	0.098	4.3	23,480	25,160	0.42	7.2	31,300	32,100	0.52	2.6
Lead (Pb)	mg/kg	4.4	5.4	0.048	23	7.3	7.9	0.054	9.4	5.5	6.2	0.42	12	7.9	8.2	0.56	4.0
Lithium (Li)	mg/kg	9.5	12	0.020	26	17	18	0.031	9.4	13	13	0.66	6.1	19	20	0.78	2.5
Magnesium (Mg)	mg/kg	7,506	8,368	0.094	11	10,432	11,160	0.011	7.0	8,288	8,568	0.68	3.4	10,920	11,320	0.34	3.7
Manganese (Mn)	mg/kg	453	522	0.027	15	673	670	0.88	-0.51	501	569	0.19	13	684	728	0.36	6.5
Mercury (Hg)	mg/kg	ND	ND	ND	ND	0.032	0.034	0.18	8.1	ND	ND	ND	ND	0.034	0.035	0.72	1.7
Molybdenum (Mo)	mg/kg	0.60	0.63	0.41	4.6	0.74	0.76	0.61	1.9	0.63	0.66	0.54	4.4	0.79	0.80	0.61	2.0
Nickel (Ni)	mg/kg	31	35	0.033	14	37	39	0.039	6.1	35	36	0.67	2.8	40	41	0.62	2.1
Phosphorus (P)	mg/kg	595	581	0.64	-2.3	1,010	878	0.15	-13	618	638	0.71	3.2	925	923	0.97	-0.2
Potassium (K)	mg/kg	596	752	0.023	26	868	990	0.019	14	734	786	0.59	7.1	960	1,092	0.14	14
Selenium (Se)	mg/kg	0.21	0.23	0.46	9.5	0.36	0.35	0.28	-4.9	0.24	0.27	0.29	13	0.36	0.35	0.82	-1.7
Silver (Ag)	mg/kg	ND	ND	ND	ND	0.084	0.088	0.14	4.8	0.10	0.10	0.42	0	0.093	0.095	0.87	1.3
Sodium (Na)	mg/kg	182	183	0.89	0.55	231	225	0.34	-2.6	184	180	0.73	-2.4	223	239	0.088	6.9
Strontium (Sr)	mg/kg	43	49	0.027	14	69	69	0.48	0.93	47	50	0.46	7.0	69	71	0.21	3.6
Sulfur (S)	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium (Tl)	mg/kg	0.058	0.068	0.093	17	0.079	0.086	0.019	8.6	0.070	0.075	0.51	8.0	0.086	0.089	0.54	4.2
Tin (Sn)	mg/kg	ND	ND	ND	ND	0.30	0.31	0.26	2.6	ND	ND	ND	ND	0.31	0.34	0.27	7.0
Titanium (Ti)	mg/kg	638	617	0.53	-3.2	802	762	0.40	-4.9	646	625	0.63	-3.2	758	812	0.097	7.2
Tungsten (W)	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Uranium (U)	mg/kg	0.52	0.57	0.012	9.6	0.82	0.79	0.64	-2.7	0.60	0.63	0.72	4.1	0.80	0.81	0.66	1.8
Vanadium (V)	mg/kg	38	37	0.82	-1.3	47	45	0.25	-5.3	38	39	0.91	1.0	46	47	0.71	1.6
Zinc (Zn)	mg/kg	47	54	0.039	15	62	67	0.0058	9.0	55	57	0.75	3.2	68	71	0.50	3.5
Zirconium (Zr)	mg/kg	5.3	5.5	0.38	4.2	ND	ND	ND	ND	5.4	4.9	0.18	-9.2	ND	ND	ND	ND

P-value < 0.05.

Exposed Magnitude of Difference greater than 20% above reference.

Exposed Magnitude of Difference greater than 20% below reference.

Notes: Units for concentrations are in mg/kg dw. Comparisons were made using a T-Test unless assumption of normality was violated or there were values at the laboratory reporting limit (LRL) forcing the use of a Mann-Whitney U test (M-W). Magnitude of Difference (MOD) was calculated as $(MCT_{Exposure} - MCT_{Reference})/MCT_{Reference} *100$ using the measure of central tendency related to the statistics, MCT = Measure of Central Tendency; each MCT value is based on a replication level of five (n = 5); MOD = Magnitude of Difference.

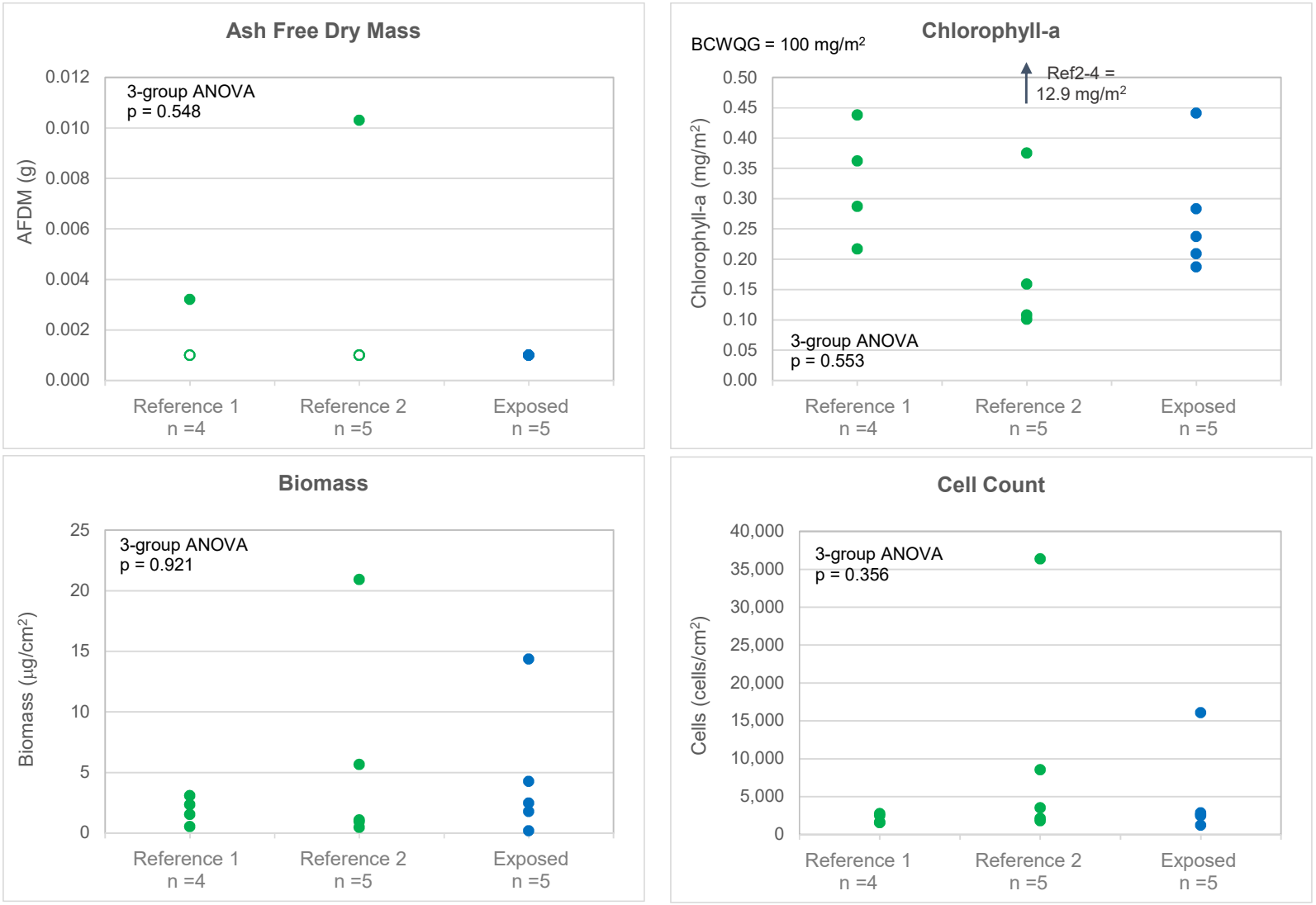

Figure 1: Ash Free Dry Mass, Chlorophyll-a, Biomass and Cell Count Results (Primary Productivity), Gibraltar Mine Phase 3 EEM, 2016

Note: Hollow points indicate value below the detection limit.

Table 6: Benthic Invertebrate Community Statistical Contrast Results among EEM Phases, Gibraltar Mine

Metric	Cycle 1 EEM		Cycle 2 EEM				Cycle 3 EEM			
	Exp vs. Ref		Exp vs. Ref 1		Exp vs. Ref 2		Exp vs. Ref 1		Exp vs. Ref 2	
	p-value	MOD	p-value	MOD	p-value	MOD	p-value	MOD	p-value	MOD
EEM Metrics										
Number of Taxa	0.077	-2.3	1.000	-	0.943	-	1.000	-	0.783	-
Density (organisms/substrate)	0.164	-	0.333	-	0.078	1.926	1.000	-	1.000	-
B-C Dissimilarity (Ref. Median)	0.126	-	0.120	-	0.176	-	0.693	-	0.929	-
Simpson's Evenness	0.048	-2.3	0.162	-	0.947	-	1.000	-	0.655	-
Supporting Metrics [a]										
EPT (%)	0.824	-	1.000	-	1.000	-	1.000	-	1.000	-
Chironomidae (%)	0.547	-	0.989	-	0.990	-	1.000	-	1.000	-
Hydropsychidae (%)	0.001	3.7	0.094	1.1	1.000	-	0.944	-	1.000	-

Shading indicates a statistically significant difference ($p<0.1$).

Notes: Ref = Reference Area; Exp = Effluent-exposed area, all statistical contrasts based on a replication level of five (n = 5), MOD = Magnitude of Difference in reference standard deviations, "-" indicates no MOD when non-significant.

[a] EPT = Ephemeroptera, Plecoptera, Trichoptera (mayflies, stoneflies, and caddisflies); Chironomidae = midge larvae; Hydropsychidae = an abundant species of net-spinning caddisfly.

Table 7: Fish Health Statistical Contrast Results among EEM Phases, Gibraltar Mine

Species	Response	Endpoint		Magnitude of Difference (%)			
				Phase 2	Phase 3		
		Parameter	Covariate	Exp vs. Ref	Ref 1 vs. Ref 2	Exp vs. Ref 1	Exp vs. Ref 2
Leopard Dace	Survival	Fork Length	none	**Yes**	**Yes**	**Yes**	**Yes**
	Energy Use	Fork Length	none	**4.0**	**9.2**	**11**	1.4
		Body Weight	none	**29.8**	**29.0**	**29.0**	-0.5
	Energy Storage (Condition)	Body Weight	Fork Length	**14.7**	-0.4	**-4.8**	**-4.4**
Peamouth Chub[a]	Survival	Fork Length	none	No	-	**Yes**	-
	Energy Use	Fork Length	none	2.0	-	**-4.2**	-
		Body Weight	none	2.2	-	**-12**	-
	Energy Storage (Condition)	Body Weight	Fork Length	**-2.3**	-	0.2	-

Magnitude of Difference > Critical Effect Size.

Notes: Ref = Reference Area; Exp = Effluent-exposed area, statistical contrasts based on a replication levels ranging from 71 to 110 (n = 71 to 110 fish), **Bold** Text indicates P-value <0.1, "-" indicates no data for Ref 2 therefore no contrasts possible.

[a] Young-of-year (YOY) results presented for Phase 2; age 1+ results presented for Phase 3 .