Berry Pit Expansion Project, Assimilative Capacity Study Update Report

Final Report

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Prepared for:

Marathon Gold Corporation
36 Lombard Street
Suite 600
Toronto, ON M5C 2X3

Prepared by:
Stantec Consulting Ltd.
141 Kelsey Drive
St. John's, NL A1B 0L2
Tel: (709) 574-1458

File: 121417555

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<original signed by>

Prepared by ___________________________________
(signature)

Igor Iskra, Ph.D., P.Eng.

<original signed by>

Reviewed by ___________________________________
(signature)

Andrew Sinclair, Ph.D., P.Eng.

<original signed by>

Approved b ___________________________________
(signature)

Sheldon Smith, MES, P.Geo.

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Abbreviations

AC	Assimilative Capacity
Approved Project	Valentine Gold Project
CCME	Canadian Council of Ministers of the Environment
CWQG-FAL	Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life
DOC	Dissolved organic carbon
EA	Environmental Assessment
EIS	Environmental Impact Statement
FDP	Final Discharge Point
LAA	Local Assessment Area
MAF	Mean annual flow
Marathon	Marathon Gold Corporation
MDMER	*Metal and Diamond Mining Effluent Regulations*
mg/L	milligrams per litre
POPC	Parameters of Potential Concern
Project Expansion	Berry Pit Expansion Project
TMF	Tailings Management Facility
µg/L	micrograms per litre

1.0 INTRODUCTION

Marathon Gold Corporation (Marathon) is constructing two open gold mine pit complexes (Leprechaun and Marathon), waste rock piles, crushing and stockpiling areas, conventional milling and processing facilities (the mill), a tailings management facility (TMF), personnel accommodations, and supporting infrastructure, including roads, on-site power lines, buildings, and water and effluent management facilities for the Valentine Gold Project (the Approved Project). An Environmental Impact Statement (EIS) for the Approved Project was submitted to the Impact Assessment Agency of Canada on September 29, 2020, and to the Environmental Assessment (EA) Division of the Newfoundland and Labrador Department of Environment and Climate Change on November 3, 2020, by Marathon. The Approved Project was released from the provincial EA process in March 2022 and was given conditional approval to proceed by the federal government in August 2022. Construction of the Approved Project was initiated in October 2022.

Based on recent and successful geological exploration and assessment work and associated feasibility assessment, Marathon is proposing the development of a third open pit within the mine site of the Approved Project. The Berry Pit Expansion Project (the Project Expansion) is proposed to include an open pit (Berry pit), new stockpiles for waste rock and topsoil, expansion of the low-grade ore and overburden stockpiles associated with Marathon pit, and additional water management infrastructure. While the Approved Project planned for tailings to be disposed of in the exhausted Leprechaun pit near the end of mine life, it is now proposed as part of the Project Expansion that tailings would instead be disposed of in the Berry pit from Year 10 of the mine life onwards, reducing the distance that tailings would need to be transported by pipeline. Waste rock will also be deposited in the proposed Berry pit.

Stantec Consulting Ltd. (Stantec) was retained by Marathon to complete an updated Assimilative Capacity (AC) Assessment for Valentine Lake, as the ultimate receiver of the effluent discharge during the operation phase in support of the Project Expansion. This AC Assessment is prepared in support of the Surface Water Resources VC Chapter (Chapter 8) of the EA Update / Environmental Registration that is being prepared for the Project Expansion. The original AC Assessment was built to support the effects assessment for the Approved Project (Marathon 2020) and remains valid and unaffected by the Project Expansion AC assessment results.

The AC for the Project Expansion was assessed for the operation phase of the Project Expansion, as this phase is anticipated to represent the worst-case conditions with respect to effluent quality. The AC Assessment was completed at the Project Expansion's effluent Final Discharge Points (FDPs) located in Valentine Lake. FDPs are where effluent is discharged to the receiving environment. Water quality was assessed using a mass balance approach under two discharge conditions: regulatory and normal. The regulatory operating conditions are considered worst case and conservative, while normal operating conditions are considered representative of the expected average discharge conditions during Project operation. Input parameters for these two operating conditions were:

- Regulatory Operating Conditions:
  - MDMER limits for Parameters of Potential Concern (POPCs) listed in the *Metal and Diamond Mining Effluent Regulations* (MDMER) for effluent
  - 95^{th} percentile water quality for POPCs not listed in MDMER
  - 75^{th} percentile baseline water quality in the receiving watercourses
  - 7Q10 flow conditions (7-day low flow, 10-year return period) in the receiving watercourses based on regression analysis
  - Seepage (toe and basal) flow out of the ponds to represent effluent discharge during dry conditions
- Normal Operating Conditions:
  - Maximum mean monthly water quality concentrations for POPCs predicted in modelling
  - Mean concentrations for baseline water quality in the receiving watercourses
  - Mean annual flow (MAF) conditions in the receiving watercourses based on a regression analysis (Stantec 2020)
  - Predicted effluent flow modelled using regional equations and contact areas.

The assimilative capacity assessment for Valentine Lake, as the ultimate receiver, was completed using the near-field mixing model Cornell Mixing Zone Expert System, CORMIX, Version 12.0 (Doneker and Jirka 2017). The CORMIX model was used to model mixing zones in Valentine Lake under both the regulatory and normal operating conditions.

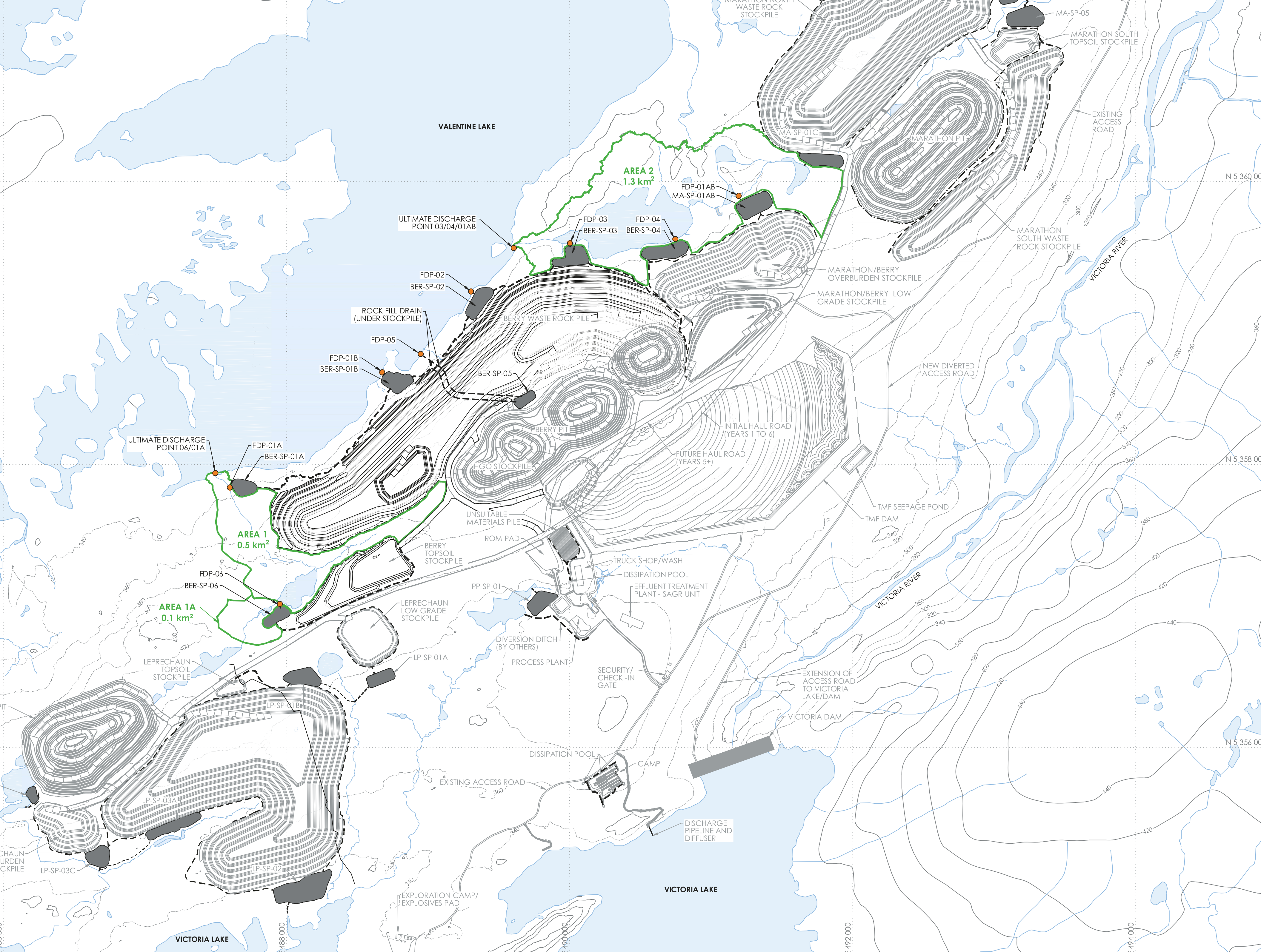
The Canadian Council of Ministers of the Environment (CCME) defines the mixing zone as "an area contiguous with a point source (effluent) where the effluent mixes with ambient water and where concentrations of some substances may not comply with water quality guidelines or objectives" (CCME 2003). The purpose of this study is to define the extent of the mixing zone and model concentrations of POPC at the end of the mixing zone. Mixing zones in the ultimate receiver (i.e., Valentine Lake) were modelled using CORMIX, and the mixing zone boundary (i.e., the location in the ultimate receiver where the water quality will meet the CWQG-FAL once fully mixed) in the ultimate receiver was expected to occur between 100 and 300 m from the onshore outlet. Conditions within the mixing zone should not result in the bioconcentration of POPC to levels that are harmful to organisms, aquatic-dependent wildlife, or human health. Accumulation of toxic substances in water or sediment to toxic levels should not occur in the mixing zone (CCME 2003).

1.1 BACKGROUND

The Approved Project and Project Expansion are in the central region of the Island of Newfoundland. The Approved Project and Project Expansion are centered on a topographic ridge that divides the Valentine Lake watershed to the north and west, and the Victoria Lake Reservoir and Victoria River watersheds to the south and east, respectively. Valentine Lake drains to the Victoria River and subsequently to Beothuk Lake.

The Berry complex consists of one open pit comprised of three basins (southern, central and northern) and stockpiles (i.e., new waste rock pile and topsoil stockpile, shared Berry / Marathon overburden stockpile, and shared Berry / Marathon low-grade ore stockpile), and water management ponds.
As outlined in the Water Management Plan Update for the Berry Pit Expansion (Stantec 2023b), a design objective for water management infrastructure is to keep non-contact water and contact water separate.

Contact water is directed to water management ponds to allow for flow attenuation and water quality treatment prior to discharge to the environment at the FDP locations shown in Figure 1-1. Non-contact water has been assumed to be represented by baseline water quality. Contact water quality was predicted using GoldSim software and is further discussed in the Water Quantity and Water Quality Model Update Report (Stantec 2023a). A total of eight water management ponds and associated FDPs are present in the Project Expansion including MA-SP-01AB which receives seepage and runoff from combined Berry and Marathon overburden and low-grade ore stockpiles. Of the eight FDPs there are ultimately five discharge points to Valentine Lake. A conceptual flow diagram with mine facilities, water management ponds, and final discharge points is presented in Figure 1-2.



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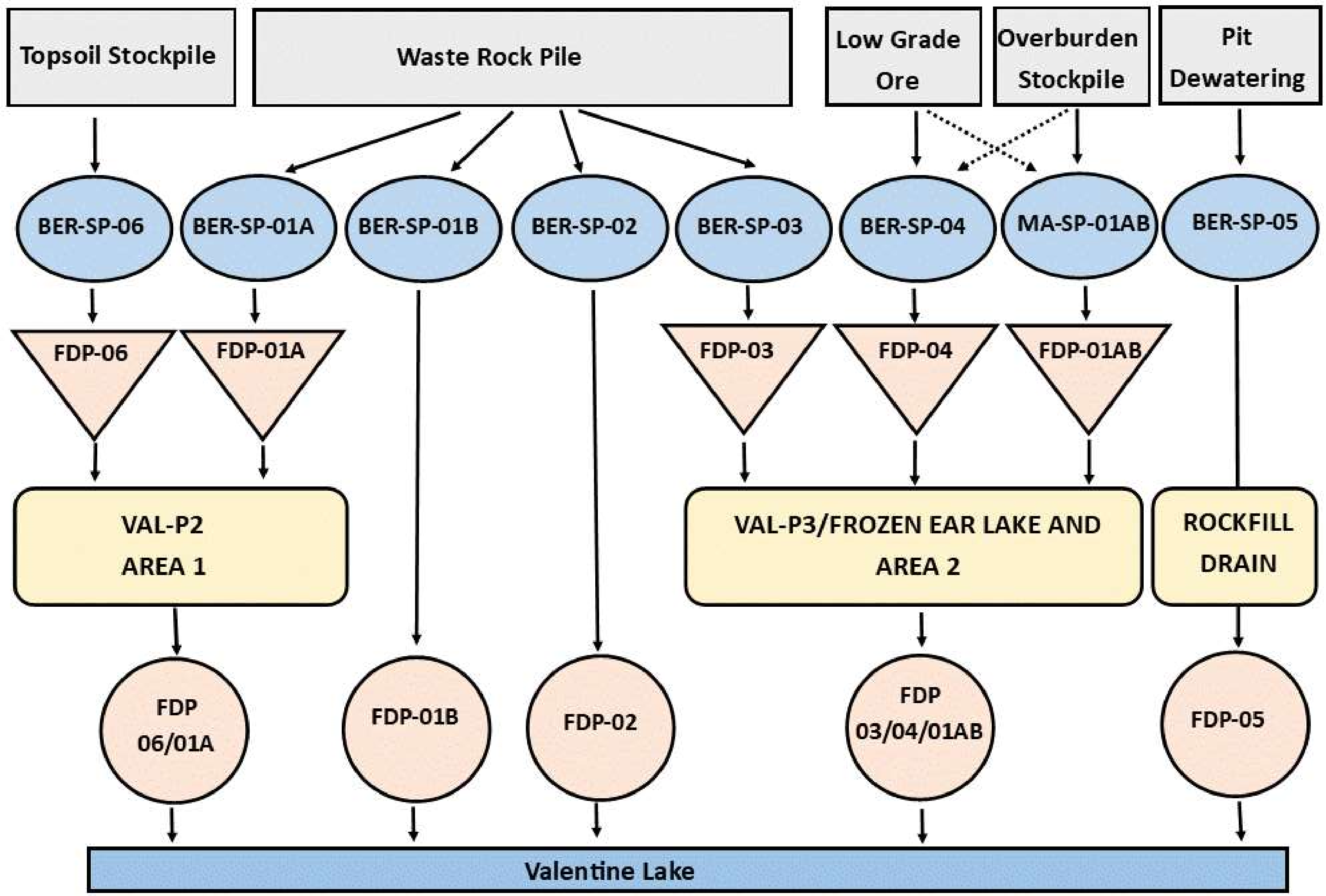

Figure 1-2 Project Expansion Mine Effluent Flow Diagram

1.2 REGULATORY CRITERIA

The following regulatory criteria were considered in the completion of this AC assessment:

- Effluent limits will be below the MDMER. As per the MDMER, the daily concentration limits are set at two (2) times the monthly average concentration limits. Effluent limits modelled in this AC study, which are legally enforceable requirements, will represent the monthly average effluent concentration limits.
- Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (CWQG-FAL; CCME 2003) in the receivers.
- Environmental effects of mine effluent in relation to receiving watercourses or waterbodies baseline water quality to satisfy requirements of the EIS.

2.0 RECEIVING ENVIRONMENT

2.1 HYDROLOGY

A description of local hydrological conditions has been provided in the Surface Water Resources VC, Chapter 8 of the Berry Pit Environmental Registration/EA document. For this AC assessment, the hydrology of watercourses and waterbodies receiving discharges at the FDPs, as well as at the ultimate receiver (i.e., Valentine Lake) is considered. The hydrology of the receiving environment is assessed under climate normal and dry discharge conditions. Regional regression relationships, presented in the Surface Water VC, between watershed area and flow are used to estimate the natural flow contribution from Areas 1, 1a and 2 at Valentine Lake (Figure 1-1 and Figure 1-2). The expected average condition is based on the MAF (mean annual flow) regression relationship. The low flow statistic selected to represent conservative dry conditions is the 7Q10 (the minimum 7-day average low flow with a recurrence period of 10 years).

Seepage flow out of stockpiles (ore, overburden, and topsoil) and waste rock piles to and from the water management ponds is modelled using GoldSim (Stantec 2023a) and is used to represent effluent discharge during a dry condition (i.e., regulatory scenario). Effluent flow from the management ponds during the average discharge conditions represents the base case for assessment and is also modelled in GoldSim. Table 2.1 provides the watershed area, MAF and 7Q10 for the non-contact areas at the mixing points of FDP 06/01A and FDP 03/04/01AB.

Table 2.1 Flow Statistics for Non-Contact Areas During Operation

FDPs	Watershed Area, km^2	MAF, L/s	7Q10, L/s
Area 1 & 1a. FDP 06/01A	0.6	15.0	0.7
Area 2. FDP 03/04/01AB	1.3	32.9	1.6

2.2 BASELINE WATER QUALITY

A complete description of local water quality is characterized in the Surface Water Resources VC (Chapter 8) of the EA Update / Environmental Registration. For this AC assessment, the water quality at the ultimate receivers is considered. POPCs have been identified for the Project Expansion and include parameters with MDMER discharge limits, common parameters to the processing of the ore rock, and other locally elevated parameters that have a listed CWQG-FAL guideline. Receiving water quality (i.e., background conditions) for the POPCs is summarized in Table 2.2 and 2.3 (Valentine Lake and tributaries, respectively) and is representative of the identified FDPs.

Background concentrations of phosphorus in Valentine Lake are above the CWQG-FAL guidelines due to high detection limits of this parameter; the laboratory analytical results returned a “non-detect” value, and a half detection limit is used for calculations. Therefore, the CWQG-FAL exceedances for phosphorus are not representative of actual concentrations of this parameter in Valentine Lake.

Also, zinc had a detection limit above the CWQG-FAL guidelines. Similar to phosphorus, a half detection limit is used for “non-detect” values. The CWQG-FAL for zinc is a function of water hardness, pH and DOC (dissolved organic carbon). Based on available water quality samples, a limit of 4 µg/L is used for Valentine Lake.

Total chromium was monitored as part of the baseline study. There is no CWQG-FAL guideline for total chromium, but there are guidelines for the oxidation states +3 (trivalent; III) and +6 (hexavalent; VI). The total chromium baseline and model results are assessed in comparison to the hexavalent guideline value (1 µg/L) as it is the lower of the two guideline values.

Baseline fluoride results had a detection limit at the CWQG-FAL, which skew the mixing zone results. It is recommended to use analytical methods with lower detection limits for these three parameters (phosphorus, dissolved zinc, total chromium (III and VI) and fluoride) for future monitoring programs.

Table 2.2 Baseline Water Quality Data in Valentine Lake

Parameter	Units	MDMER, Max Monthly Mean	CWQG-FAL Long-term	Detection Limit [e]	Valentine Lake	
					Mean	75th Percentile
Aluminum (Total)	µg/L	-	100 [b]	5.0	14.2	15.0
Arsenic (Total)	µg/L	100	5	1.0	0.5	0.5
Cadmium (Total)	µg/L	-	0.04 [b]	0.01	0.005	0.005
Chromium (Total)	µg/L	-	1 [f]	1	**1.1**	**1.9**
Copper (Total)	µg/L	100	2 [b]	0.5	0.52	0.75
Iron (Total)	µg/L	-	300	50	25	25
Lead (Total)	µg/L	80	1 [b]	0.5	0.25	0.25
Manganese (Total)	µg/L	-	210	2.0	5.5	6.7
Mercury (Total)	µg/L	-	0.026	0.013	0.0065	0.0065
Molybdenum (Total)	µg/L	-	73	2.0	1.0	1.0
Phosphorus (Total)	µg/L	-	4	**100**	**50**	**50**
Selenium (Total)	µg/L	-	1	1	0.25	0.25
Silver (Total)	µg/L	-	0.25	0.1	0.05	0.05
Uranium (Total)	µg/L	-	15	0.10	0.05	0.05
Zinc (Total)	µg/L	400	4 [d]	5.0	2.5	2.5
Nitrite (as N)	µg/L	-	60	10	9	12
Nitrate (as N)	µg/L	-	3,000	50	25	25
Ammonia (N), total	µg/L	-	689	0.05	25	25
Ammonia (N), Unionized	µg/L	500	16	0.01	0.95	0.95
Cyanide (total) [a]	µg/L	500	-	20	10	10
Cyanide (WAD) [a]	µg/L	-	5 (as free CN)	2.0	1.0	1.0
Sulphate	µg/L	128,000 [c]	-	2,000	1,000	1,000
Fluoride [a]	µg/L	-	120	120	60	60

Notes:

a Indicates parameters that do not have baseline water quality data. Mean and 95th percentile concentrations for these parameters outlined in the Water Quantity and Water Quality Model Update report (Stantec 2023a).

b Calculated for receiver specific conditions

c Sulphate Guideline is for British Columbia Ministry of Environment and Climate Change Strategy (2017) for the protection of aquatic life

d 4 µg/L for Valentine Lake (based on hardness, pH and DOC)

e Half Detection Limit was used for “non detect” samples

f Total chromium assumed to be in the form Cr (VI)

Bold indicates exceedance of CWQG-FAL

Table 2.3 Baseline Water Quality Data in Valentine Lake Tributaries

Parameter	Units	MDMER, Max Monthly Mean	CWQG-FAL Long-term	Valentine Lake Tributaries (Area 1 and 2)	
				Mean	75th Percentile
Aluminum (Total)	µg/L	-	100 [b]	16	19
Arsenic (Total)	µg/L	100	5	0.5	0.5
Cadmium (Total)	µg/L	-	0.04 [b]	0.01	0.01
Chromium (Total)	µg/L	-	1 [e]	**1.10**	**1.50**
Copper (Total)	µg/L	100	2 [b]	0.61	0.77
Iron (Total)	µg/L	-	300	25	25
Lead (Total)	µg/L	80	1 [b]	0.25	0.25
Manganese (Total)	µg/L	-	210	5.5	6.4
Mercury (Total)	µg/L	-	0.026	0.0065	0.0065
Molybdenum (Total)	µg/L	-	73	1	1
Phosphorus (Total)	µg/L	-	4	**50**	**50**
Selenium (Total)	µg/L	-	1	0.25	0.25
Silver (Total)	µg/L	-	0.25	0.05	0.05
Uranium (Total)	µg/L	-	15	0.05	0.05
Zinc (Total)	µg/L	400	4 [d]	2.5	2.5
Nitrite (as N)	µg/L	-	60	9.9	12.0
Nitrate (as N)	µg/L	-	3,000	25	25
Ammonia (as N), Total	µg/L	-	689	25	25
Ammonia (as N), Un-ionized	µg/L	500	19	0.06	0.08
Cyanide (Total) [a]	µg/L	500		10	10
Cyanide (WAD) [a]	µg/L	-	5 (as free CN)	1	1
Sulphate	µg/L	-	128,000 [c]	1,000	1,000
Fluoride [a]	µg/L	-	120	60	60

Notes:

a Indicates parameters that do not have baseline water quality data. Mean and 95th percentile concentrations for these parameters outlined in the Water Quantity and Water Quality Modelling reports (Stantec 2023a)

b Calculated for receiver specific conditions

c Sulphate Guideline is for British Columbia Ministry of Environment and Climate Change Strategy (2017) for the protection of aquatic life

d 4 µg/L for Valentine Lake Tributaries (based on hardness, pH and DOC)

e Total chromium assumed to be in the form Cr (VI)

Bold indicates exceedance of CWQG-FAL

3.0 EFFLUENT DISCHARGE DURING OPERATION

3.1 EFFLUENT FLOWS

The expected effluent flow rate from each FDP is calculated for both climate normal and dry conditions at the FDP mixing point (Table 3.1). Outflows from the water management ponds are simulated using a GoldSim model as described in the Water Quantity and Water Quality Model Update report (Stantec 2023a).

The climate normal discharge from the water management ponds is used to simulate the average condition. The seepage flow (toe and basal) from source stockpiles flowing into and out of the ponds is used to represent discharge during a dry condition, and assumed there are no precipitation contributions.

Table 3.1 FDP Effluent Discharge Flow Rates (Operation)

FDP	Climate Normal	July Average Toe and Basal Seepage to Pond
	FDP Flow Rate (m^3/day)	
MA-SP-01AB	545	29
BER-SP-01A	427	116
BER-SP-01B	691	168
BER-SP-02	508	148
BER-SP-03	594	118
BER-SP-04	678	47
BER-SP-05	3,481	1,797
BER-SP-06	515	0

3.2 EFFLUENT QUALITY

The effluent water quality at each FDP during operation is simulated using a GoldSim model, as described in the Water Quantity and Quality Model Update report (Stantec 2023a). Simulated water quality statistics (mean and 95th percentile) for the POPCs at each FDP are summarized in Table 3.1.

For modeling purposes, the regulatory operating condition for POPCs with MDMER limits were assumed to have concentrations at the MDMER maximum authorized monthly mean limit. The monthly limit is used for the following reasons:

- Water management pond water quality design and GoldSim water quality predictions indicated MDMER effluent parameters would not exceed the monthly limit.
- The monthly limit is a more conservative lower effluent threshold than the daily limits.
- The monthly limit is also better aligned with GoldSim modelled water quality predictions, which are based on a monthly model output.

The effluent water quality for the POPCs without MDMER limits is assumed to be at the predicted 95th percentile of the GoldSim predicted concentrations. For a normal operating condition, the mean effluent water quality values predicted by GoldSim are assumed for the POPCs.

P Effluent Water Quality – Operation (Year 1-9)

nits	MDMER, Max Monthly Mean	MA-SP-01AB		BER-SP-01A		BER-SP-01B		BER-SP-02		BER-SP-03		BER-SP-04		BER-FDP-	
		Mean	95%	Mean	95%	Mean	95%	Mean	95%	Mean	95%	Mean	95%	Mean	
L	-	426.1	535.4	600	600.0	600.0	600.0	600.0	600.0	600.0	600.0	279.8	322.0	592.1	5
L	100	15.7	20.3	33.6	39.8	34.0	40.3	33.4	39.6	17.1	20.2	11.8	18.1	3.1	
L	-	0.06	0.08	0.25	0.29	0.25	0.29	0.25	0.29	0.13	0.15	0.05	0.07	0.05	
L	-	4.6	6.2	4.3	5.3	4.3	5.4	4.3	5.3	3.8	5.0	2.4	5.0	2.3	
L	100	11.08	12.97	39.29	49.45	40.00	50.45	39.21	49.45	32.71	41.20	9.98	11.96	2.39	
L	-	793	900	329	520	324	520	324	520	325	520	319	520	270	
L	80	1.00	1.29	1.27	1.44	1.28	1.46	1.27	1.44	0.78	0.99	0.44	0.63	0.29	
L	-	443.60	586.90	562.40	643.30	570.20	651.60	562.90	642.80	414.50	501.70	219.80	442.60	260.00	4
L	-	0.0303	0.0378	0.222	0.278	0.226	0.283	0.221	0.278	0.1853	0.2292	0.0262	0.0299	0.0155	0
L	-	20	24	75	86	76	87	75	86	38	43	15	19	7	
L	-	50	50	50	50	50	50	50	50	50	50	50	50	50	
L	-	1.57	2.04	3.08	3.52	3.10	3.55	3.06	3.50	1.75	1.97	1.21	1.49	0.62	
L	-	0.14	0.17	0.85	1.07	0.87	1.09	0.85	1.07	0.72	0.88	0.13	0.15	0.06	
L	-	5.94	7.69	60.56	75.80	61.34	76.67	60.35	75.31	29.98	38.10	5.08	6.87	3.24	
L	400	12.24	15.88	35.05	43.70	35.67	44.47	35.03	43.65	29.52	36.01	6.36	7.50	4.72	
L	-	148	215	284	390	284	388	401	517	194	249	88	117	130	
L	-	6005	8387	12190	16781	12192	16680	17165	22223	8151	10577	3522	4752	5128	8
L	-	832	1207	1565	2146	1564	2133	2212	2848	1073	1370	486	638	719	
L	500	31.61	45.87	59.47	81.55	59.43	81.05	84.06	108.22	40.77	52.06	18.45	24.26	27.31	4
L	50-0	31	40	10	10	10	10	10	10	10	10	10	10	10	
L	-	3	4	1	1	1	1	1	1	1	1	1	1	1	
L	-	36689	42091	80923	95575	81892	96573	80603	94909	51839	65896	31027	36295	10840	1
L	-	287	327	1026	1106	1038	1118	1023	1097	901	960	253	284	138	

4.0 WATERCOURSE MIXING ZONE ASSESSMENT

A total of eight water management ponds and associated FDPs are present in the Project Expansion including MA-SP-01AB which receives seepage and runoff from combined Berry and Marathon overburden and low-grade ore stockpiles. FDPs are where effluent is discharged to the receiving environment.

Mixing zones in the ultimate receiver (i.e., Valentine Lake) were modelled using CORMIX. The mixing zone boundary (i.e., the location in the ultimate receiver where the water quality will meet the CWQG-FAL once fully mixed) in the ultimate receivers was expected to occur between 100 and 300 m from the onshore outlet. CORMIX mixing zone assessment boundaries were assigned at 100 and 200 m distances to validate this expectation.

Three water management ponds and associated FDPs (FDP-01B, FDP-02 and FDP-05) discharge treated effluent directly to Valentine Lake, as shown on Figure 1-1.

Three water management ponds and associated FDPs (FDP-03, FDP-04 and FDP-01AB) discharge treated effluent to Frozen Ear Lake (VAL-P3), which drains into Valentine Lake and has a catchment area of 1.3 km^2 (Figure 1-2). This is illustrated conceptually on Figure 4-1. As a conservative assumption, the volume and assimilative capacity of Frozen Ear Lake is ignored. However, runoff generated from the catchment area of 1.3 km^2 is accounted for in dilution and mixing calculations. Regional regressions are used to generate flows from undisturbed catchments, and tributary baseline water quality are used to generate loads.

Two water management ponds and associated FDPs (FDP-01A and FDP-06) discharge treated effluent to the small outflow watercourse for VAL-P2 that discharges to Valentine Lake with a catchment area of 0.5 km^2. This is illustrated conceptually on Figure 4-1. Runoff generated from the catchment area of 0.5 km^2 is accounted for in dilution and mixing calculations. Regional regressions are used to generate flows from undisturbed catchments, and tributary baseline water quality is used to generate loads.

Water quality at FDP-01B, FDP-02, FDP-03, and the VAL-P2 (FDP-01 and FDP-06) and VAL-P3 (FDP-03, FDP-04 and FDP-01AB) outflow channel discharges to Valentine Lake is calculated based on the dilution ratios of the effluent and the background hydrology for dry (regulatory) and normal flow conditions.

The concentration of the POPCs at the end of the mixing zone is expected to reach the CWQG- FAL or baseline concentrations. The Province of Newfoundland and Labrador is a signatory party to CCME and has supported the establishment of CCME Canadian Environmental Quality Guidelines (CCME 2003), including those for the protection of aquatic life (i.e., CWQG-FAL). Where CWQG- FAL are not available for some discharge parameters, it is recommended that guidelines from other jurisdictions be used. In particular, those established by the British Columbia Ministry of Environment and Climate Change Strategy (2017) are appropriate and were used for sulphate.

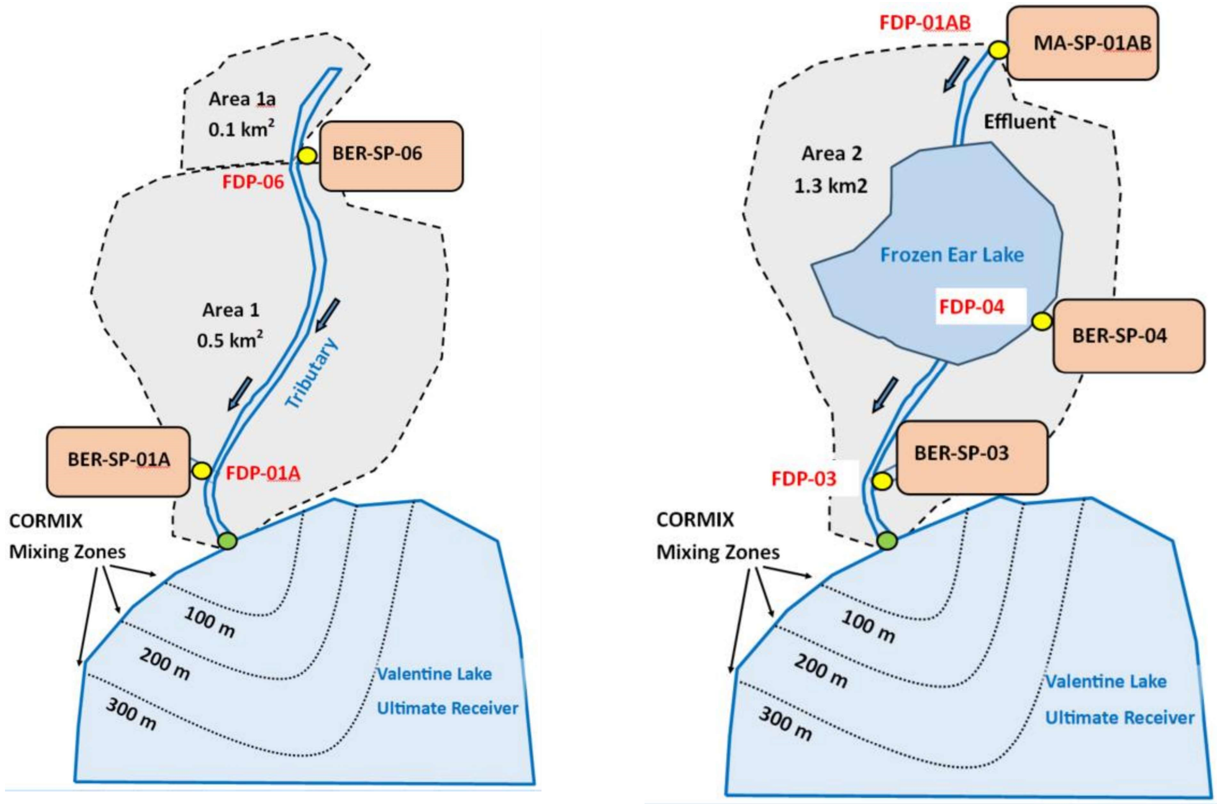

Figure 4-1 Conceptual Representation of Mixing Zone Assessment

5.0 MIXING ZONE ASSESSMENT FOR ULTIMATE RECEIVERS

An AC assessment for the ultimate receiver of Valentine Lake was completed to determine the assimilative capacity and mixing potential of the FDPs during the operation phase of the Project Expansion.

Near-field modelling of mixing in the ultimate receivers was performed using CORMIX, Version 12.0. CORMIX is a United States Environmental Protection Agency supported mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from point source discharges (Doneker and Jirka 2017). The system can be used for the analysis, prediction and design of aqueous toxic or conventional effluent discharges into diverse waterbodies. The major emphasis is on the geometry and dilution / assimilation characteristics of the initial mixing zone. The basic CORMIX methodology relies on the assumption of steady state ambient conditions, meaning CORMIX generates an instantaneous prediction of the effluent plume or mixing zone from the discharge point. The near-field CORMIX model incorporates effluent outfall design and provides high resolution of effluent mixing.

5.1 MODEL INPUTS

The required model inputs for the receiving environment include water temperature, flow velocity, and water depth. Average water depths for the outfall locations and over the plume length are estimated based on available bathymetry information.

Bottom roughness in CORMIX is expressed as Manning's "n" and converted internally to a friction factor based on average water depth. The friction factor has a limited impact on modelling results and is important only for far-field diffusion. A Manning's n value of 0.035 is selected for use in the model based on available information about bottom sediments.

Wind is not a sensitive variable in near-field mixing modelling. Wind is non-directional in CORMIX and it is used for surface heat transfer and ambient mixing only. A mean annual wind speed of 3.8 m/s is used in the model, which is derived based on CALMET data for 2017-2019 (ECCC 2020).

The receiving water and effluent are assumed to be freshwater with an average annual water temperature of 9 degrees Celsius (°C), based on data from water quality stations NF02YO0107 and NF02YN0001 (NLDMAE 2019).

The CORMIX methodology contains systems to model point source discharge, multiport diffuser discharges, and surface discharge sources. The surface discharge option is selected for FDPs discharging to tributaries and for the ultimate receiver (Valentine Lake),

CORMIX requires input parameters, which characterize the effluent, ambient environment and outfall design as summarized in Table 5.1

The conservative modeling conditions are based on maximum effluent concentrations, low flow (7Q10) conditions in the receiving environment, and assume no contaminant decay, sedimentation or reduction/oxidation kinetics in the mixing zones.

Table 5.1 CORMIX Input Parameters

Parameter, units	FDP-06/01A	FDP-01B	FDP-02	FDP-03/04/MA-FDP-01AB	FDP-05	Comments
Receiver	**Valentine Lake**	**Valentine Lake**	**Valentine Lake**	**Valentine Lake**	**Valentine Lake**	
Dry Conditions Total Flow at Valentine Lake, 7Q10, L/s	2.03	1.94	1.71	3.84	20.80	Regional Regression and GoldSim Predictions
Mean Total Flow at Valentine Lake, 7Q10, L/s	25.87	8.00	5.88	53.96	40.29	Regional Regression and GoldSim Predictions
Effluent and Receiver Water Temperature, ˚C	9	9	9	9	9	Average annual temperature at NF02YO0107 and NF02YN0001
Receiver Depth at Discharge, m	1	1	1	1	1	Assumed per Bathymetry information
Receiver Average Depth in Mixing Zone, m	1.3	1.3	1.3	1.3	1.3	30% increase from Depth at Discharge for CORMIX stability
Receiver Width, m	unbounded	unbounded	unbounded	unbounded	unbounded	
Receiver Velocity, m/s	0.02	0.02	0.02	0.02	0.02	Conservative Current Velocity in Lake.
Manning's n	0.035	0.035	0.035	0.035	0.035	Assumed based on bottom roughness
Horizontal Angle (sigma)	90º	90º	90º	90º	90º	Angle between the dominant ambient current direction to the plan projection of the outfall channel
Bottom slope at discharge, %	1	1	1	1	1	Estimates slope at outfall
Average Wind Speed, m/s	3.8	3.8	3.8	3.8	3.8	CALMET data for 2017-2019 (ECCC 2020)
Discharge outlet width, m	1	1	1	1	1	Outfall channel: 1 m wide and 0.5 m deep

5.2 MODEL RESULTS

For modeling purposes, the initial effluent concentration for an arbitrary parameter prior to discharge was assigned at 100 milligrams per litre (mg/L). The dilution ratios in the near-field mixing zone were calculated in CORMIX based on this effluent concentration.

The extent of the mixing zones in Valentine Lake was determined in terms of dilution ratios for the maximum effluent flow rate expected to enter each receiving waterbody. Table 5.2 and Table 5.3 summarize the dilution ratios expected in the lake under the regulatory and normal flow scenarios.

The expected water quality at 100 m from the discharge point in Valentine Lake for the POPCs is listed in Table 5.4. The expected water quality at 200 m is listed in Table 5.5

The baseline concentration of total phosphorus and total chromium in the receiver is above the CWQG-FAL and, therefore, the concentration of these parameters in the mixing zone is also above the CWQG-FAL. It is due to an artifact of the laboratory detection limit that these parameters are above the CWQG-FAL (Section 2.2).

The laboratory detection limit for zinc is above the CWQG-FAL, and the concentration in the receiver is below the detection limit. Therefore, the resulting concentration of zinc in the mixing zone is artificially high that results in some exceedances of the CWQG-FAL.

For the regulatory scenario at the Project Expansion, water quality within the first 100 m of the mixing zone meets the CWQG-FAL at most FDPs. The only exception is the combined effluent from FDP-05, which has potential exceedances at 100 m from the outfall for copper and lead . The lead concentration meets the CWQG-FAL at 200 m from the outfall. Extrapolated dilution ratios were used to estimate the mixing zone extents at 300 m, where copper is estimated to meet the guideline. The copper and lead exceedances are due to elevated concentrations in the effluent, conservative assumptions of effluent flow, and the lower assimilative capacity of the nearshore area. The effluent concentrations for these parameters were conservatively assumed to be at the MDMER monthly limits, which are higher than the predicted concentrations in the effluent discharge during operation.

Based on extrapolated dilution ratios for the regulatory scenario (i.e., dry conditions), the ultimate extent of the mixing zone is expected to extend approximately 300 m from the FDP-05 outfall. At this distance, all parameters will meet the CWQG-FAL. The mixing zone of other FDPs for all parameters is less than 100 m.

For average flow conditions at the Project Expansion, water quality within the first 100 m of the mixing zone meets the CWQG-FAL at all FDPs.

Mixing zones extend into Valentine Lake up to 100 m for all discharge points except FDP-05 which requires a mixing zone extension to 300 m into the lake. No mixing zone overlaps another within the lake and thus mixing zones do not converge. Water quality beyond the ultimate mixing zone extent is at CWQG-FAL or baseline conditions.

Table 5.2 CORMIX Dilution Ratios for Regulatory Scenario (Dry Conditions)

Distance from Outfall	FDP-06/01A	FDP-01B	FDP-02	FDP-03/04/01AB	FDP-05
5 m	9.9	10.6	11.4	6.8	2.3
10 m	21.4	22.1	24.4	13.4	2.5
25 m	53.5	55.7	62.2	30.6	3.0
50 m	124.5	129.0	146.6	69.0	7.6
75 m	212.5	221.9	250.2	116.6	15.3
100 m	316.1	330.2	372.9	171.8	24.5
150 m	559.4	585.9	662.6	300.7	46.8
200 m	845.1	883.6	1000.1	452.9	73.5

Table 5.3 CORMIX Dilution Ratios for Average Conditions

Distance from Outfall	FDP-06/01A	FDP-01B	FDP-02	FDP-03/04/01AB	FDP-05
5 m	2.1	4.1	5.6	1.9	1.9
10 m	2.3	6.4	10.0	2.4	2.3
25 m	2.9	14.9	21.6	3.3	3.2
50 m	4.6	33.2	47.1	4.2	3.9
75 m	10.4	55.8	79.0	4.6	4.5
100 m	17.53	82.6	115.3	5.0	5.2
150 m	34.9	144.4	200.5	6.0	13.8
200 m	55.9	217.5	300.0	11.1	25.6

ORMIX Modeling at the End of 100 m Mixing Zone in Valentine Lake

CWQG-FAL Long-term	75th Percentile Baseline Valentine Lake	Regulatory Scenario (Dry Conditions)					Average Conditions		
		FDP-06/01A	FDP-01B	FDP-02	FDP-03/04/01AB	FDP-05	FDP-06/01A	FDP-01B	FDP-02
100	15.0	16.2	16.8	16.6	16.7	37.8	22.3	21.2	19.2
5	0.5	0.7	0.8	0.8	0.8	4.4	1.0	0.9	0.8
0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**	**2.0**	**1.2**	**1.1**	**1.1**
2	0.75	0.96	1.05	1.02	1.09	**4.64**	0.99	0.99	0.85
300	25	26	26	26	27	44	32	29	28
1	0.25	0.42	0.49	0.46	0.52	**3.38**	0.26	0.26	0.26
210	6.7	8.02	8.65	8.40	8.37	23.25	13.86	12.25	10.29
0.026	0.0065	0.007	0.007	0.007	0.0070	0.0069	0.009	0.009	0.008
73	1.0	1	1	1	1	1	2	2	2
4[a]	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**
1	0.25	0.26	0.26	0.26	0.26	0.27	0.28	0.28	0.27
0.25	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06
15	0.05	0.21	0.28	0.25	0.14	0.23	0.68	0.78	0.57
4	2.5	3.33	3.70	3.56	3.85	**18.09**	2.87	2.90	2.78
60	12	13	13	13	13	20	12	12	12
3,000	25	60	75	84	55	376	151	171	172
689	25	29	31	33	29	71	41	43	44
19	0.95	1.12	1.19	1.24	1.10	2.71	1.58	1.65	1.66
-	10	11	11	11	12	29	10	10	10
5	1	1	1	1	1	1	1	1	1
128,000 [b]	1,000	1,197	1,289	1,251	1,184	1,439	1,882	1,968	1,684
120	60	62	63	63	62	64	71	72	68

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ORMIX Modeling at the End of 200 m Mixing Zone in Valentine Lake

	CWQG-FAL Long-term	75th Percentile Baseline Valentine Lake	Regulatory Scenario (Dry Conditions)					Average Conditions		
			FDP-06/01A	FDP-01B	FDP-02	FDP-03/04/01AB	FDP-05	FDP-06/01A	FDP-01B	FDP-02
	100	15.0	15.5	15.7	15.6	15.7	22.8	16.8	16.9	16.1
	5	0.5	0.6	0.6	0.6	0.6	1.8	0.7	0.7	0.6
	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	1	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**	**1.1**	**1.1**	**1.1**
	2	0.75	0.83	0.86	0.85	0.88	**2.08**	0.67	0.70	0.65
	300	25	25	26	25	26	32	27	26	26
	1	0.25	0.31	0.34	0.33	0.35	1.32	0.25	0.25	0.25
	210	6.7	7.20	7.43	7.34	7.34	12.37	8.22	8.08	7.35
	0.026	0.0065	0.007	0.007	0.007	0.0067	0.0067	0.007	0.008	0.007
	73	1	1	1	1	1	1	1	1	1
	4a	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**
	1	0.25	0.25	0.25	0.25	0.25	0.26	0.26	0.26	0.26
	0.25	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	15	0.05	0.11	0.14	0.13	0.08	0.11	0.26	0.33	0.25
	4	2.5	2.81	2.95	2.90	3.01	**7.84**	2.62	2.65	2.61
	60	12	12	12	13	12	15	10	10	10
	3,000	25	38	44	47	36	145	66	81	82
	689	25	27	27	28	26	41	30	32	32
	19	0.95	1.01	1.04	1.06	1.01	1.55	1.15	1.22	1.23
	-	10	10	11	10	11	17	10	10	10
	5	1	1	1	1	1	1	1	1	1
	128,000 b	1,000	1,074	1,108	1,094	1,070	1,150	1,287	1,370	1,264
	120	60	61	61	61	61	61	64	64	63

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6.0 CONCLUSIONS

An assimilative capacity assessment was completed for the operation phase of the Project Expansion. This phase is anticipated to represent the worst-case conditions with respect to effluent quality. The assimilative capacity assessment was completed for the five Project Expansion's ultimate discharge points to Valentine Lake from the eight FDPs. The assessment was conducted using the near-field mixing CORMIX model.

Water quality in the mixing zone was assessed under regulatory (dry) and normal conditions. The regulatory operating conditions were considered worst case and conservative, while normal operating conditions were considered representative of the expected average discharge conditions.

For the regulatory scenario at the Project Expansion, water quality within the first 100 m of the mixing zone meets the CWQG-FAL at most FDPs. The only exception was the combined effluent from FDP-05, which has potential exceedances at 100 m from the outfall for copper and lead. The lead concentration meets the CWQG-FAL at 200 m from the outfall, and copper meets the guideline at about 300 m using extrapolated dilution ratios. These exceedances were due to elevated concentrations in the effluent, conservative assumptions of effluent flow, and the lower assimilative capacity of the nearshore area. The effluent concentrations for these parameters were assumed to be at the MDMER monthly limits, which are higher than the predicted concentrations in the effluent discharge during operation.

Based on extrapolated dilution ratios for the regulatory scenario, the ultimate extent of the mixing zone is expected to extend approximately 300 m from the FDP-05 outfall. At this distance, all parameters will meet the CWQG-FAL. The mixing zone of other FDPs for all parameters is less than 100 m.

For average flow conditions at the Project Expansion, water quality within the first 100 m of the mixing zone meets the CWQG-FAL at all FDPs. No ultimate mixing zones overlap or converge and water quality in Valentine Lake beyond the ultimate mixing zone returns to CWQG-FAL or baseline conditions.

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