TECHNICAL MEMORANDUM

DATE 29 June 2020 **Reference No.** 18114181-062-TM-Rev0

TO Merle Keefe, Manager, Environmental Permitting
Sabina Gold & Silver Corp.

CC Jen Range, Curtis VanWerkhoven

FROM Cam Stevens **EMAIL cestevens@golder.com**

FISH PASSAGE EVALUATION, MITIGATION, AND MONITORING FOR THE RASCAL STREAM DIVERSION

Introduction

Sabina Gold & Silver Corporation (Sabina) plans to advance the construction of the Back River Project where a key construction activity will be the extension of the existing airstrip. An environmental constraint for planned works requires that Rascal Stream East, a fish-bearing stream, be diverted through a constructed channel to Gosling Pond 1, where flows will combine with Rascal Stream West. As per conditions of the Back River Project *Fisheries Act* Authorization and commitments for the Nunavut Impact Review Board (NIRB) Project Certificate, Sabina must demonstrate that the diversion of water can provide suitable conditions for the migration of Arctic Grayling from Goose Lake to access upstream spawning habitats on Rascal Stream East and West (Figure 1).

Although the diversion of water has the potential to increase the abundance and quality of habitat downstream of the diversion channel, including habitats in Rascal Stream West Reach 2 and 3, the presence of existing physical barriers or impediments to passage under baseline conditions in Reach 1 (Sabina 2017) may limit the productive capacity of habitat to support Arctic Grayling populations. As a follow up to the 'Rascal Stream Fishway Hydrotechnical Assessment' (Golder 2020), the goal of this technical memorandum was to evaluate how the proposed diversion channel may affect spring flow conditions for upstream passage of spawning Arctic Grayling in the Rascal Stream system, followed by recommendations to mitigate potential barriers for movements that may ultimately enhance the productive capacity of habitat for Arctic Grayling.

The first objective of this technical memorandum was to evaluate upstream passage of Arctic Grayling for the hydrological estimates below the diversion channel that were provided for spring (June) in the 'Rascal Stream Fishway Hydrotechnical Assessment' (Golder 2020). The evaluation was completed by applying fish passage criteria derived from previously published fatigue equations for salmonids (Katopodis and Gervais 2016).
Given that physical barriers or impediments to passage may be present under baseline conditions in lower Rascal Stream West (Sabina 2017), the second objective was to provide recommendations on the design of naturalized, in-stream structures to mitigate the potential effects of high velocities on upstream passage of Arctic Grayling. Although recommendations on where to deploy mitigation were also provided, the specific locations will be field-fit to best address 'pinchpoints' in the lower reach of Rascal Stream West (Sabina 2017). Proposed fish habitat features for the diversion channel itself are also presented. The third objective of this technical memorandum was to provide recommendations to monitor the effects of the diversion channel and the diversion of water on Arctic Grayling in the Rascal Stream system.

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433000 433500

7270000

Goose Lake

XS15

XS64

XS109

XS115

XS154

XS194

Rascal Stream West Reach 1



VIEW UPSTREAM TOWARDS BRIDGE CROSSING AT SHALLOW RUN HABITAT TYPE AT RSW1 (20 JUNE 2019).



VIEW DOWNSTREAM TOWARDS BRIDGE CROSSING IN RIFFLE HABITAT AT RSW1 (20 JUNE 2019).

SEE FIGURE 2, DETAILS A AND B FOR CONCEPTUAL ROCK WEIR DESIGNS AT 7 m SPACING FOR 75 m UPSTREAM OF THE BRIDGE, AND AT 17 m SPACING FOR 59 m STARTING APPROXIMATELY 95 m UPSTREAM OF THE BRIDGE

Gander Pond

433500 434000

7269000

Gosling Pond 2

Rascal Stream West Reach 3

Main Goose Pit Stream Reach 3

Rascal Stream East Reach 4

Gosling Pond 1

SEE FIGURE 2, DETAILS C AND D FOR CONCEPTUAL DIVERSION CHANNEL DESIGN.
CHANNEL LENGTH IS 115 m WITH AN APPROXIMATE SLOPE OF 0.002 m/m

Rascal Stream East Reach 5

Rascal Stream West Reach 7

Little Rascal Pond

7268500

Goose Lake

Gander Pond

Gosling Pond 2

Gosling Pond 1

Little Rascal Pond

Pond 4

LEGEND

- CONTOUR (1m INTERVAL)
- HEC-RAS MODELLED CROSS SECTIONS (XS#)
- RASCAL STREAM
- WATERCOURSE
- WATERBODY

PROPOSED INFRASTRUCTURE

- AREA REQUIRES VELOCITY MITIGATION AT 7 m SPACING
- AREA REQUIRES VELOCITY MITIGATION AT 17 m SPACING
- RASCAL STREAM DIVERSION CHANNEL
- AIRSTRIP EXTENSION
- PROPOSED CONTAINMENT BERM
- PROPOSED DIVERSION BERM

0 100 200

1:4,000 METRES

REFERENCE(S)

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PROJECTION: UTM ZONE 13 DATUM: NAD 83

CLIENT
SABINA GOLD & SILVER CORP.

PROJECT
BACK RIVER PROJECT ENVIRONMENT AND PERMITTING

TITLE
RASCAL STREAM CONCEPTUAL DIVERSION FISHWAY AND FISH PASSAGE VELOCITY MITIGATION

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-19
DESIGNED	NG
PREPARED	CO
REVIEWED	CV
APPROVED	CS

PROJECT NO.	CONTROL	REV.	FIGURE
18114181	4500/4530	0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

0

Fish Passage Evaluation

Methods

Barriers to fish can occur through the occurrence of natural or artificial obstacles for upstream movements, which can be in the form of permanent barriers that occur under all flow conditions (e.g., topography barriers such as waterfalls) or temporary/seasonal barriers that may only restrict fish passage under certain flow conditions, such as high velocities. The main concern related to the diversion of flows from Rascal Stream East to Rascal Stream West is effects of high velocities downstream of the diversion channel during spring conditions when adult Arctic Grayling migrate to upstream spawning habitats. Specifically, the hydrotechnical assessment identified the reach in the vicinity of the road crossing (Rascal Stream West Reach 1) as the area with highest modelled velocities under baseline conditions and the greatest modelled changes in velocities under diverted flows (Golder 2020). Therefore, the spatial extent of this evaluation focused on the lower 220 m of Rascal Stream West Reach 1 (Figure 1), relying on hydraulic model results summarized for Station No. 15, 64, 115, 154, and 194 in Golder (2020). Results for Station No. 15 and Station No. 64 were assumed to represent hydrological conditions in the vicinity of the clear-span bridge that was constructed (fall 2018) approximately 50 m upstream of Goose Lake. Above Station No. 194, the stream gradient is reduced closer to the outlet of Gander Pond and remains relatively flat through upstream sections of Rascal Stream West and East (Golder 2020).

Fish speed and stamina, locomotion, and the mechanics of fish swimming are important considerations in the assessment of fish passage (Katopodis and Gervais 2016). To determine whether adult Arctic Grayling (25-cm length) are able to navigate lower Rascal Stream West, a fatigue curve (or formula) for Salmonids (Katopodis and Gervais 2016) was applied to generate endurance values (seconds) and distances (m) at a range of swimming speeds. The selected parameter coefficients for the formula were those representing the median statistic. A more conservative set of parameters was deemed unrealistic for setting velocity criteria because Arctic Grayling have been described as very efficient swimmers, capable of swimming fast over long periods of time (Deegan et al. 2005), and also because the predicted flows represent average channel velocities that would be greater than bottom or margin velocities that can be exploited by fish (Katopodis and Gervais 2016).

The fatigue equation was defined by the following relationship between dimensionless (fish speed, U*) and dimensionless endurance time (t*) (Katopodis and Gervais 2016):

$$U_* = 4.004(t_*)^{-0.25}$$

Where: $U_* = U / \sqrt{gl}$ and $t_* = t / \sqrt{l/g}$

Where:

U = fish swimming speed

t = endurance time (seconds)

l = fish length (metres)

g = gravitational acceleration (9.81 m/s^2)

Results from the application of the fatigue equation show that for example, in a flow velocity of 1.0 m/s, the maximum distance that an adult Arctic Grayling can swim before fatigue would be 26 m based on an optimal swim speed of 1.4 m/s. If the predicted velocity for a section of Rascal Stream West Reach 1 was above the distance-specific threshold calculated for Arctic Grayling using the fatigue equation from Katopodis and Gervais (2016), then that reach section was deemed impassable for that velocity. Predicted velocities were also provided over a range of discharge conditions for the month of June (0.5 to 2.0 m^3/s; where 2.0 m^3/s was the calculated Q90 [90^{th}-percentile of flows] flow for June). Each velocity prediction was then linked to the predicted number of days in June that are above the respective discharge flow for each velocity (to characterize the duration of higher flow conditions). The predicted velocity at the 1.8 m^3/s discharge was also explicitly assessed for fish passage unless otherwise stated in the results. This approach assumed that high velocities during peak freshet that delay migrations by up to 3 days do not have any measurable effect on reproductive success for Arctic Grayling (Stewart et al. 2007).

The baseline and diversion scenario modelled hydraulic parameters and statistics for fish passage for Rascal Stream West Reach 1 are provided in Tables 1 to 5.

Results and Discussion

Rascal Stream West Reach 1

The flow velocity estimates for the lowermost section of Rascal Stream West (HEC-RAS modelled Station No. 15) (hereinafter, all stations are referenced to the HEC-RAS modelled stations, not chainage from the Goose Lake inlet) were deemed passable for upstream movement of adult Arctic Grayling under a range of flow scenarios in June (Table 1). The maximum daily averaged velocity for the month of June was 0.47 m/s, which will be passable over an assessment distance of 49 m (Station No. 15 to 64). Under a velocity of 0.47 m/s, an adult Arctic Grayling was predicted to swim 249 m before fatigue.

The velocity estimates for Station No. 64 were deemed non-passable for upstream movement of adult Arctic Grayling (Table 2). Even under late June conditions, velocities remain relatively high at 0.89 m/s and non-passable over an assessment distance of 51 m (Station No. 64 to 115). The recommended spacing for velocity mitigation is a minimum of 7 m to maintain passage under velocities of 1.58 m/s, which was the maximum daily velocity for Station No. 64. Unlike other stations, Station No. 64 was characterized by peak velocities at a discharge of approximately 1.3 m^3/s (versus 2.0 m^3/s), which was assumed to reflect the channel morphology and depth of the banks at that location where higher flows can spill over into a wider floodplain, reducing the predicted mean velocity through the cross-section of the stream.

The velocity estimates for Station No. 115 were determined to be passable for upstream movement of adult Arctic Grayling under a range of flow scenarios in June (Table 3). The maximum daily velocity for the month of June was 0.56 m/s, which is predicted to be passable over an assessment distance of 39 m (Station No. 115 to 154). Under a velocity of 0.56 m/s, an adult Arctic Grayling was predicted to swim 148 m before fatigue.

The velocity estimates for Station No. 154 were deemed non-passable for upstream movement of adult Arctic Grayling through most of June, assuming an assessment distance of 40 m (Station No. 154 to 194) (Table 4). Although velocities were deemed passable under late June conditions of 0.55 m^3/s or less, velocities at discharge conditions of 0.60 m^3/s or greater were not passable for fish. The recommended spacing for velocity mitigation was set at 17 m (or less) to maintain fish passage at a discharge of 1.80 m^3/s.

The velocity estimates for Station No. 194 were deemed passable for upstream movement of adult Arctic Grayling under a range of flow scenarios in June (Table 5). The maximum daily velocity for the month of June was 0.83 m/s, which would be passable over an assessment distance of 26 m (Station No. 194 to 220). Under a velocity of 0.83 m/s, an adult Arctic Grayling was predicted to swim 46 m before fatigue. Fish passage above Station No.194 is not expected to be an issue for migrating Arctic Grayling because of the flatter topography that characterizes upper regions of the Rascal Stream basin.

Table 1: Fish Passage Statistics for Rascal Stream West Outflow Station No. 15 (Station No. 15 to 64)

Average Daily Discharge (m^3/s)	Water Top Width (m)	Average Water Depth (m)	Channel Velocity (m/s)	[a]Distance Before Fatigue (m)	[b]Passable based on Velocity? (yes/no)	No. of Days Above Average in June	
						Baseline Case	Diverted Case
0.50	28.33	0.05	0.34	662	Yes	3	19
0.55	29.82	0.05	0.35	602	Yes	3	18
0.60	31.27	0.05	0.35	602	Yes	2	16
0.65	32.63	0.06	0.36	553	Yes	2	15
0.70	33.36	0.06	0.36	553	Yes	2	14
0.75	33.96	0.06	0.37	513	Yes	1	13
0.80	34.54	0.06	0.38	474	Yes	1	12
0.85	35.10	0.06	0.39	434	Yes	1	11
0.90	35.65	0.06	0.39	434	Yes	1	10
0.95	36.18	0.07	0.40	405	Yes	1	10
1.00	36.69	0.07	0.40	405	Yes	0	9
1.05	37.19	0.07	0.41	378	Yes	0	8
1.10	37.67	0.07	0.42	351	Yes	0	8
1.15	38.15	0.07	0.42	351	Yes	0	7
1.20	38.61	0.07	0.43	324	Yes	0	7
1.25	39.07	0.07	0.43	324	Yes	0	7
1.30	40.32	0.07	0.43	324	Yes	0	6
1.35	41.68	0.07	0.43	324	Yes	0	6
1.40	42.97	0.08	0.43	324	Yes	0	5
1.45	44.21	0.08	0.44	305	Yes	0	5
1.50	45.24	0.08	0.44	305	Yes	0	5
1.55	46.21	0.08	0.44	305	Yes	0	4
1.60	47.16	0.08	0.44	305	Yes	0	4
1.65	48.07	0.08	0.44	305	Yes	0	4
1.70	48.86	0.08	0.45	286	Yes	0	4
1.75	49.11	0.08	0.45	286	Yes	0	4
1.80	49.34	0.08	0.45	286	Yes	0	3
1.85	49.57	0.08	0.46	267	Yes	0	3
1.90	49.81	0.08	0.46	267	Yes	0	3
1.95	50.04	0.08	0.47	249	Yes	0	3
2.00	50.26	0.08	0.47	249	Yes	0	3

Notes: Outlier at 0.05 m^3/s removed; Q90 June velocity = 0.47 m/s; [a] Assuming a fork length of 25 cm for an adult Arctic Grayling; based on 50% prediction interval from salmonid fatigue equation (Katopodis and Gervais 2016); [b] Successful fish passage is based on a 49 m assessment distance

Table 2: Fish Passage Statistics for Rascal Stream West Outflow at Station No. 64 (Station No. 64 to 115)

Average Daily Discharge (m^3/s)	Water Top Width (m)	Average Water Depth (m)	Channel Velocity (m/s)	[a]Distance Before Fatigue (m)	[b]Passable based on Velocity? (yes/no)	No. of Days Above Average in June	
						Base Case	Diverted Case
0.50	11.35	0.05	0.89	37	No	3	19
0.55	11.34	0.05	0.99	27	No	3	18
0.60	11.29	0.05	1.13	18	No	2	16
0.65	11.33	0.05	1.17	16	No	2	15
0.70	11.34	0.05	1.26	13	No	2	14
0.75	11.36	0.05	1.32	11	No	1	13
0.80	11.40	0.05	1.36	10	No	1	12
0.85	11.43	0.05	1.40	9	No	1	11
0.90	11.46	0.05	1.44	9	No	1	10
0.95	11.50	0.06	1.47	8	No	1	10
1.00	11.54	0.06	1.50	8	No	0	9
1.05	11.58	0.06	1.52	7	No	0	8
1.10	11.62	0.06	1.54	7	No	0	8
1.15	11.68	0.06	1.53	7	No	0	7
1.20	11.71	0.07	1.56	7	No	0	7
1.25	11.76	0.07	1.58	7	No	0	7
1.30	11.82	0.07	1.57	7	No	0	6
1.35	11.86	0.07	1.58	7	No	0	6
1.40	12.56	0.10	1.10	20	No	0	5
1.45	12.61	0.10	1.12	19	No	0	5
1.50	12.65	0.10	1.13	18	No	0	5
1.55	12.69	0.11	1.15	17	No	0	4
1.60	12.74	0.11	1.16	17	No	0	4
1.65	12.77	0.11	1.18	16	No	0	4
1.70	12.81	0.11	1.19	15	No	0	4
1.75	12.85	0.11	1.21	15	No	0	4
1.80	12.89	0.11	1.22	14	No	0	3
1.85	12.93	0.12	1.24	14	No	0	3
1.90	12.97	0.12	1.25	13	No	0	3
1.95	13.01	0.12	1.26	13	No	0	3
2.00	13.05	0.12	1.27	13	No	0	3

Notes: Outliers at 0.35 and 0.4 m^3/s removed; Q90 June velocity = 1.27 m/s; [a] Assuming a fork length of 25 cm for an adult Arctic Grayling; based on 50% prediction interval from salmonid fatigue equation (Katopodis and Gervais 2016); [b] Successful fish passage is based on a 51 m assessment distance

Table 3: Fish Passage Statistics for Rascal Stream West Outflow at Station No. 115 m (Station No. 115 to 154)

Average Daily Discharge (m^3/s)	Water Top Width (m)	Average Water Depth (m)	Channel Velocity (m/s)	[a]Distance Before Fatigue (m)	[b]Passable based on Velocity? (yes/no)	No. of Days Above Average in June	
						Base Case	Diverted Case
0.50	8.00	0.15	0.42	351	Yes	3	19
0.55	8.00	0.16	0.42	351	Yes	3	18
0.60	8.00	0.18	0.42	351	Yes	2	16
0.65	8.00	0.19	0.43	324	Yes	2	15
0.70	8.00	0.20	0.44	305	Yes	2	14
0.75	8.00	0.21	0.44	305	Yes	1	13
0.80	8.00	0.22	0.45	286	Yes	1	12
0.85	8.00	0.24	0.45	286	Yes	1	11
0.90	8.00	0.25	0.46	267	Yes	1	10
0.95	8.00	0.26	0.46	267	Yes	1	10
1.00	8.00	0.27	0.47	249	Yes	0	9
1.05	8.00	0.28	0.47	249	Yes	0	8
1.10	8.00	0.29	0.48	235	Yes	0	8
1.15	8.00	0.30	0.48	235	Yes	0	7
1.20	8.00	0.31	0.49	221	Yes	0	7
1.25	8.00	0.32	0.49	221	Yes	0	7
1.30	8.00	0.33	0.50	207	Yes	0	6
1.35	8.00	0.34	0.50	207	Yes	0	6
1.40	8.00	0.35	0.51	195	Yes	0	5
1.45	8.00	0.36	0.51	195	Yes	0	5
1.50	8.00	0.36	0.52	185	Yes	0	5
1.55	8.00	0.37	0.52	185	Yes	0	4
1.60	8.00	0.38	0.52	185	Yes	0	4
1.65	8.00	0.39	0.53	175	Yes	0	4
1.70	8.00	0.40	0.53	175	Yes	0	4
1.75	8.00	0.41	0.54	164	Yes	0	4
1.80	8.00	0.42	0.54	164	Yes	0	3
1.85	8.00	0.43	0.54	164	Yes	0	3
1.90	8.00	0.43	0.55	156	Yes	0	3
1.95	8.00	0.44	0.55	156	Yes	0	3
2.00	8.00	0.45	0.56	148	Yes	0	3

Notes: Outlier removed at 0.15 m^3/s; Q90 June velocity = 0.56 m/s; [a] Assuming a fork length of 25 cm for an adult Arctic Grayling; based on 50% prediction interval from salmonid fatigue equation (Katopodis and Gervais 2016); [b] Successful fish passage is based on a 39 m assessment distance

Table 4: Fish Passage Statistics for Rascal Stream West Outflow at Station No. 154 (Station No. 154 to 194)

Average Daily Discharge (m^3/s)	Water Top Width (m)	Average Water Depth (m)	Channel Velocity (m/s)	[a]Distance Before Fatigue (m)	[b]Passable based on Velocity? yes/no	No. of Days Above Average in June	
						Base Case	Diverted Case
0.50	9.29	0.07	0.82	47	Yes	3	19
0.55	9.59	0.07	0.85	42	Yes	3	18
0.60	9.86	0.07	0.87	40	No	2	16
0.65	10.11	0.07	0.89	37	No	2	15
0.70	10.31	0.07	0.92	33	No	2	14
0.75	10.52	0.08	0.94	31	No	1	13
0.80	10.81	0.08	0.94	31	No	1	12
0.85	11.03	0.08	0.96	29	No	1	11
0.90	11.16	0.08	0.99	27	No	1	10
0.95	11.39	0.08	1.00	26	No	1	10
1.00	11.63	0.09	1.00	26	No	0	9
1.05	11.84	0.09	1.01	25	No	0	8
1.10	12.03	0.09	1.02	25	No	0	8
1.15	12.19	0.09	1.04	23	No	0	7
1.20	12.38	0.09	1.04	23	No	0	7
1.25	12.48	0.09	1.07	21	No	0	7
1.30	12.64	0.09	1.08	21	No	0	6
1.35	12.82	0.10	1.09	20	No	0	6
1.40	12.99	0.10	1.10	20	No	0	5
1.45	13.18	0.10	1.10	20	No	0	5
1.50	13.36	0.10	1.10	20	No	0	5
1.55	13.46	0.10	1.12	19	No	0	4
1.60	13.60	0.10	1.13	18	No	0	4
1.65	13.78	0.11	1.13	18	No	0	4
1.70	13.90	0.11	1.15	17	No	0	4
1.75	14.04	0.11	1.16	17	No	0	4
1.80	14.18	0.11	1.16	17	No	0	3
1.85	14.38	0.11	1.16	17	No	0	3
1.90	14.40	0.11	1.19	15	No	0	3
1.95	14.55	0.11	1.19	15	No	0	3
2.00	14.67	0.11	1.20	15	No	0	3

[a] Assuming a fork length of 25 cm for an adult Arctic Grayling; based on 50% prediction interval from salmonid fatigue equation (Katopodis and Gervais 2016); [b] Successful fish passage is based on a 40 m assessment distance; Notes: Q90 June velocity = 1.2 m/s

Table 5: Fish Passage Statistics for Rascal Stream West Outflow at Station No. 194 (Station No. 194 to 220)

Average Daily Discharge (m^3/s)	Water Top Width (m)	Average Water Depth (m)	Channel Velocity (m/s)	[a]Distance Before Fatigue (m)	[b]Passable based on Velocity? (yes/no)	No. of Days Above Average in June	
						Base Case	Diverted Case
0.50	19.87	0.04	0.62	109	Yes	3	19
0.55	20.85	0.04	0.63	104	Yes	3	18
0.60	21.95	0.04	0.64	99	Yes	2	16
0.65	23.08	0.04	0.65	95	Yes	2	15
0.70	23.93	0.04	0.66	90	Yes	2	14
0.75	24.69	0.05	0.67	87	Yes	1	13
0.80	25.28	0.05	0.68	83	Yes	1	12
0.85	25.81	0.05	0.68	83	Yes	1	11
0.90	26.14	0.05	0.70	76	Yes	1	10
0.95	26.67	0.05	0.71	73	Yes	1	10
1.00	27.34	0.05	0.71	73	Yes	0	9
1.05	27.97	0.05	0.72	70	Yes	0	8
1.10	28.56	0.05	0.72	70	Yes	0	8
1.15	29.13	0.05	0.73	67	Yes	0	7
1.20	29.65	0.06	0.73	67	Yes	0	7
1.25	29.99	0.06	0.75	62	Yes	0	7
1.30	30.55	0.06	0.75	62	Yes	0	6
1.35	31.04	0.06	0.76	59	Yes	0	6
1.40	31.56	0.06	0.76	59	Yes	0	5
1.45	32.05	0.06	0.76	59	Yes	0	5
1.50	32.58	0.06	0.77	57	Yes	0	5
1.55	32.92	0.06	0.77	57	Yes	0	4
1.60	33.23	0.06	0.78	55	Yes	0	4
1.65	33.55	0.06	0.78	55	Yes	0	4
1.70	33.86	0.06	0.79	53	Yes	0	4
1.75	34.16	0.06	0.79	53	Yes	0	4
1.80	34.46	0.07	0.80	51	Yes	0	3
1.85	34.78	0.07	0.80	51	Yes	0	3
1.90	35.00	0.07	0.81	49	Yes	0	3
1.95	35.27	0.07	0.82	47	Yes	0	3
2.00	35.57	0.07	0.83	46	Yes	0	3

[a] Assuming a fork length of 25 cm for an adult Arctic Grayling; based on 50% prediction interval from salmonid fatigue equation (Katopodis and Gervais 2016); [b] Successful fish passage is based on a 26 m assessment distance; Notes = Q90 June velocity = 0.83 m/s

Diversion channel

The diversion channel is proposed between the Rascal Stream East Reach 5 and the Gosling Pond 1. The channel is approximately 115 m in length with a slope of 0.002 m/m (0.2%). The diversion channel consists of a low-flow channel section and a high flow channel section (Figure 2) where the high flow channel section ties-in with the existing ground. The low-flow channel has a sinuosity (ratio of actual low-flow channel path length divided by shortest path length) of 1.2 within the diversion channel to reflect the sinuosity observed in the upstream Rascal Stream East Reach 5. The geometry of the diversion channel is provided in Figure 2 Cross-Section D. The conceptual diversion channel design includes well-graded rock (100 to 200 mm diameter) lining the channel, with the voids filled in with gravel or smaller cobbles as available on site. The channel lining for the diversion channel is designed to the 1-in-100-year flow event.

For the diverted scenario, flows from Rascal Stream East Reach 5 are diverted into the constructed channel. Representative flows were modelled to support channel sizing and assessment of fish passage through the channel. In June, the Q90 flow is estimated to be 1.1 m^3/s (Golder 2020) for the diversion channel, resulting in an estimated maximum water depth of 0.36 m for a typical cross-section, an average water depth of 0.18 m, a top width of 8.3 m, and an average flow velocity of 0.69 m/s. The flow velocities at the June Q90 flow within the diversion channel are expected to result in a swim distance before fatigue for Arctic Grayling of 78 m (Assuming a fork length of 25 cm for an adult Arctic Grayling; based on 50% prediction interval from salmonid fatigue equation [Katopodis and Gervais 2016]). The mapped diversion channel length is 115 m, but it is anticipated that backwater effects from Gosling Pond 1 will reduce the effective velocities in the downstream reach.

Velocity Mitigation

There are a number of engineering methods or tools that have been proven or have the potential to increase fish productivity. Many of these methods are described in detail in Department of Fisheries and Oceans' (DFO) review of methods to offset or mitigate impacts of development projects (Loughlin and Clarke 2014). Physical habitat manipulations are a commonly applied method in fish habitat management (Loughlin and Clarke 2014), and a common type of physical habitat manipulation is the installation of in-stream structures (reviewed in Stewart et al. 2009; reviewed in Whiteway et al. 2010). In-stream structures are typically installed with the expectation that the improved and/or created physical habitat will result in the increase in the abundance or biomass of salmonids (Roni et al. 2006). The installation of structures or enhancement of the natural channel to address physical barriers to fish, for example, through the creation of a fish ladders or boulder weirs, are obvious methods of increasing fish access and productivity (Loughlin and Clarke 2014).

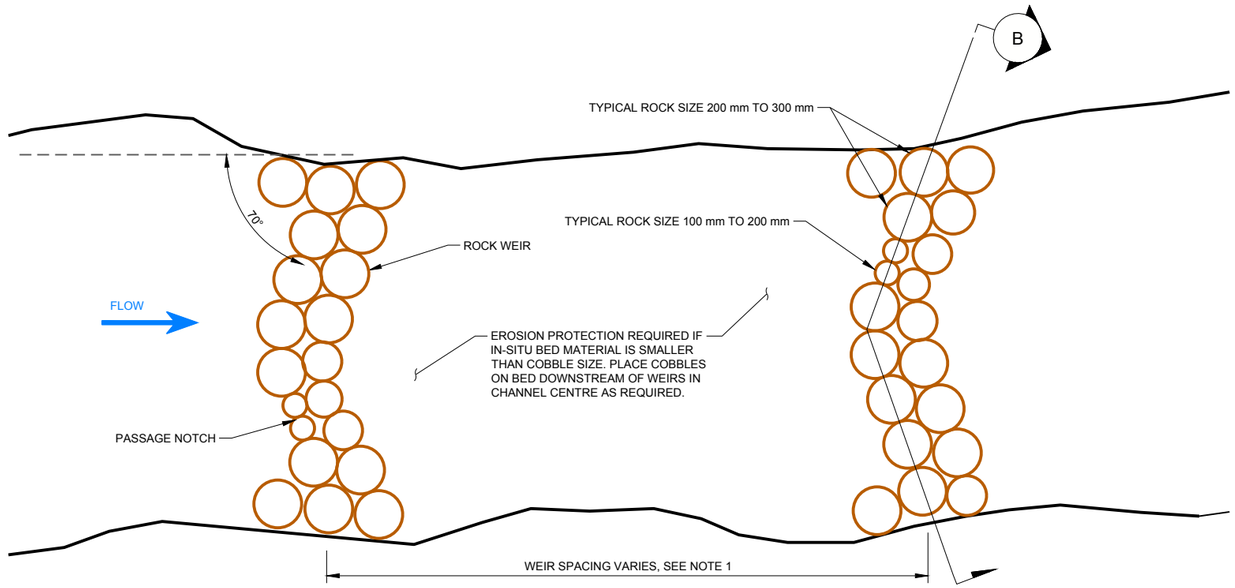
For Rascal Stream West Reach 1, the installation of large rocks at high flow velocity locations is proposed as a means to dissipate energy, reduce flow velocities, and increase water depth to mimic riverine habitats that would be passable for fish (Franklin et al. 2012). The boulders will be combined with natural substrate in the channel to provide greater surface roughness and flow complexity compared to existing conditions. The boulders will also be positioned in rows forming weirs at regular intervals to produce a series of pools where fish are likely to find resting zones (Baki et al. 2019). Both small and large boulders will be used to provide small openings, hereafter called passage notches, which provide a minimum water level in each pool and maintain habitat connectivity between pools. The notches allow for fish passage criteria to be met for low to high flows (Gordon et al. 2016; Baki et al. 2019). It is also expected that the fish will preferentially pass through weir notches rather than over weir crests during high flows (Turek et al. 2016).

The proposed rock weir design for lower Rascal Stream West will follow the concept evaluated in Baki et al. (2019), who demonstrated that the rock weir with notch design can provide suitable hydraulics for fish migrations and sufficient fish resting areas in weir pools (Figure 2). Design considerations include the following:

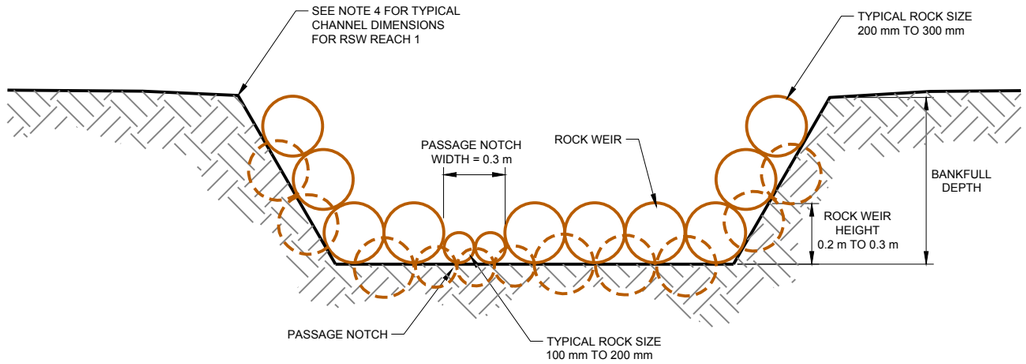
- Based on the fish passage evaluation, rock weirs are recommended with an approximate spacing of 7 m for the stream section between Station No. 40 (halfway between Station No. 15 and 64) and Station No. 115, which includes the stream section under the bridge, and rocks weirs are also recommended with a spacing of 17 m for the stream section between Station No. 135 (halfway between Station No. 115 and 154) and Station No. 194, which starts approximately 95 m upstream of the bridge
- Targeted locations for rock weir installation include channel sections where there are well-defined banks and a narrowing in the channel relative to typical channel dimensions for the reach
- Each rock weir will be positioned across the channel with a slight point or bend mid-channel to form a wide V-shape facing upstream
- Boulders (200 to 300 mm diameter) will be used to form the base of the weir, spanning the width of the stream channel, and reinforced with multiple layers of boulders, as needed
- A notch (200 to 300 mm width) with typical rock size 100 to 200 mm diameter will be created within each weir (alternating sides for consecutive weirs) to enable fish passage during high or low-flow conditions
- Cobble-size substrate (64 to 200 mm diameter) will be placed on the downstream side of the weir to provide erosion protection for the natural stream bed
- Rock weirs installation should occur during low-flow conditions (late summer) prior to operation of the diversion channel, and future monitoring will confirm migration functions are maintained over long-term
- Stability of rock is designed to the 1-in-100-year flow event

For the diversion channel, the hydraulic parameters (water depth, top width, and average flow velocities) estimated for the diversion channel were made without inclusion of fish habitat features (i.e., boulder clusters). Boulder clusters (150 to 200 mm diameter) are recommended to be placed at a maximum spacing of 20 m within the low-flow channel to diversify habitat and to attract fish to move through the diversion channel during a range of flow conditions. Furthermore, the installed boulder clusters will provide sufficient fish resting areas in pools downstream of the boulder clusters at high flows. Design considerations include the following, and are shown in Figure 2:

- Each boulder cluster will be positioned within the low-flow channel covering approximately one-third of the channel to form a wide V-shape facing upstream
- Boulders (150 to 200 mm diameter) will be used to form the base of the boulder cluster and reinforced with multiple layers of boulders, as needed
- Boulder cluster installation should occur in dry conditions prior to flows diverted into the diversion channel
- Stability of rock is designed to the 1-in-100-year flow event

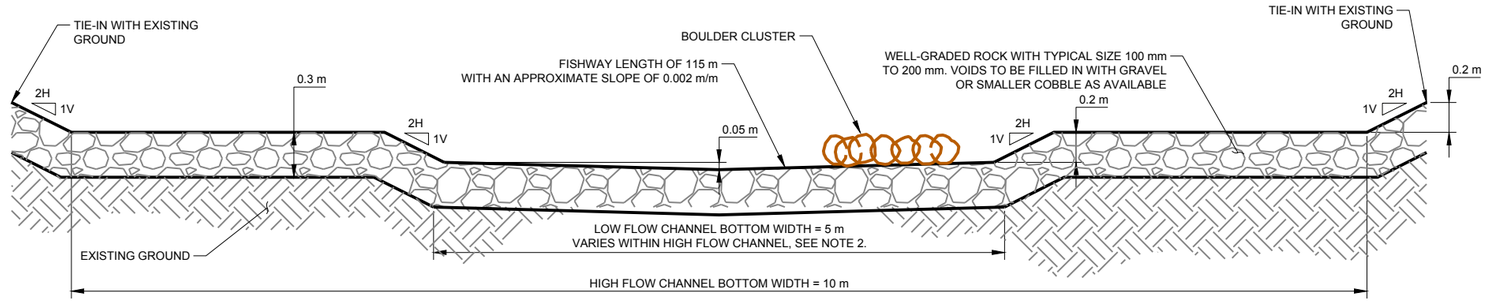


NTS A RSW REACH 1 ROCK WEIR



NTS B CROSS-SECTION RSW REACH 1 ROCK WEIR

NTS C DETAIL - RASCAL STREAM FISHWAY BOULDER CLUSTER



NTS D CROSS-SECTION - CONSTRUCTED RASCAL STREAM FISHWAY

NOT FOR CONSTRUCTION

NOTES

1. ROCK WEIRS ARE PLACE AT 7 m SPACING FOR 75 m UPSTREAM OF THE BRIDGE, AND AT 17 m SPACING FOR 59 m STARTING APPROXIMATELY 95 m UPSTREAM OF THE BRIDGE.
2. THE CONSTRUCTED FISHWAY LOW FLOW CHANNEL SHOULD ACHIEVE A SINUOSITY OF 1.2 TO MIMIC THE NATURAL RASCAL STREAM EAST REACH 5.
3. ALL DESIGNS PRESENTED ARE CONCEPTUAL DESIGNS AND THEREFORE ALL GEOMETRY AND MATERIALS SHALL BE CONFIRMED DURING ADVANCED DESIGN AND PRIOR TO CONSTRUCTION.
4. TYPICAL CHANNEL DIMENSIONS IN RSW REACH 1 AT RUN AND RIFFLES IDENTIFIED FOR ROCK WEIR INSTALLS TYPICALLY HAVE BANKFULL WIDTHS OF 2 m TO 8 m AND BANKFULL DEPTHS OF 0.1 m TO 0.5 m
5. BOULDER CLUSTERS TO BE SPACED A MAXIMUM OF 20 m WITHIN THE RASCAL STREAM FISHWAY.

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SABINA GOLD & SILVER CORP.

PROJECT
BACK RIVER PROJECT ENVIRONMENT AND PERMITTING

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-29
DESIGNED	NG
PREPARED	MSH
REVIEWED	CV
APPROVED	NS

TITLE
RASCAL STREAM CONCEPTUAL DIVERSION FISHWAY AND FISH PASSAGE VELOCITY MITIGATION DESIGNS

PROJECT NO.	CONTROL	REV.	FIGURE
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Monitoring Plan

A monitoring program will be implemented to determine if the proposed diversion channel and downstream rock weir velocity migration are functioning effectively for Arctic Grayling. Monitoring will commence during Year 1, following the expansion of the airstrip, and implementation of fish passage mitigation activities, and may continue for up 6 years in total. The duration and frequency of monitoring may be adjusted depending on results from early monitoring efforts, for example, if results from Year 2 clearly demonstrate that fish passage and rock weir integrity can be maintained during high flows, then the frequency of monitoring could be reduced.

The proposed monitoring schedule includes annual hydrotechnical and fish habitat inspections, and annual reports during the monitoring period with detailed biological monitoring and reporting starting Year 2 (or earlier depending on when the Goose Camp is open). Three years of detailed biological monitoring is recommended, including detailed biological monitoring during Year 6, which would be the first year that recruits could return from adults that spawned in Year 1 (based on age at maturity statistics provided in Stewart et al. [2007]).
The conceptual Construction Erosion and Sediment Control Plan (ESCP) to be implemented during construction of the diversion channel and rock weir mitigation is provided in Appendix A.

The duration of monitoring when combined with the proposed level of annual effort is expected to adequately demonstrate that the mitigation objectives have been achieved. The monitoring effort will allow Sabina to confirm assessment predictions made as part of the environmental assessment (e.g., that increased flows on Rascal Stream West have the potential to benefit the Arctic Grayling population).

Two types of monitoring activities will be completed: annual inspections (as functional monitoring) and biological monitoring (as effectiveness monitoring). Annual inspections by a qualified aquatic specialist is recommended to collect data to characterize habitat functions and suitability, including data on the physical integrity of the rock weirs, natural channel below the diversion and the diversion channel. Field measurements related to annual inspections are recommended to include (but not limited to) the following:

- Rascal Stream West Reach 1
  - Measurement of discharge and characterization of depths, velocities, channel widths (wetted and bankfull), and substrate composition collected at three representative cross-sections between rock weirs to demonstrate the effectiveness of the installed rock weirs and measure hydraulic parameters between weir pools
  - Rock weir habitat characterization such as depths, velocities, channel widths (wetted and bankfull), and substrate composition collected on transects deployed within the weir pool and immediately downstream of the weir
  - Physical dimensions of each rock weir and notch mapped either on-screen or on grid paper showing measurements of width, depth and length of the rock weir and notch
  - Qualitative characterization of the integrity of each rock weir and the passability of each rock weir, supported by photographs (upstream, downstream, left downstream bank, and right downstream bank views)

- Diversion Channel
  - Measurement of discharge and characterization of depths, velocities, channel widths (wetted and bankfull), and substrate composition collected at a representative transect of the fishway
  - Qualitative inspection of the diversion channel bed and banks, and any evidence of channel erosion, migration, and sediment transport, supported by photographs
  - Boulder cluster habitat characterization such as depths, velocities, channel widths (wetted and bankfull), and substrate composition collected on transects deployed within the cluster pool and immediately downstream of the cluster
  - Qualitative characterization of the integrity of each boulder cluster and the passability of each boulder cluster, supported by photographs (upstream, downstream, left downstream bank, and right downstream bank views)
- Rascal Stream West (Gosling Pond 1 to Gander Pond)
  - Characterization of pond outlets (number, locations, condition, etc.) at Gosling Pond 1, Gosling Pond 2, and Gander Pond, supported by photographs
  - Quantitative measurements of depths, velocities, channel widths (wetted and bankfull), and substrate composition collected at four representative cross-sections on Rascal Stream West Reach 2 and 3 (two cross-sections per reach)
  - Qualitative inspection of the stream bed and banks, and any evidence of channel erosion, migration, and sediment transport, supported by photographs

Based on the outcome of an annual inspection of the diversion channel and rock weirs, maintenance or installation of erosion and sediment control mitigation measures will be immediately conducted where needed for minor disturbances such as boulders displaced due to high flows or ice scour. If major repairs or improvements are noted during the inspection, recommendations for additional work will be provided in the annual inspection report. Inspection reports will be submitted to DFO by January 31 of any given year that observational monitoring is carried out.

Biological monitoring by qualified aquatic specialists is recommended to confirm passage of Arctic Grayling through lower Rascal Stream West. The scope of monitoring includes detailed habitat measurements collected concurrently with monitoring of the Arctic Grayling spawning migration. The biological monitoring scope should span a minimum of two years of data collection using RFID (radio frequency identification) tags inserted within adult fish that would be tracked using multiple detection arrays deployed throughout the Rascal Stream system. The first two years of RFID fish tracking would be combined with a two-way trap installed at the mouth of the creek where fish would be enumerated and tagged during their migration, subsequent biological monitoring years would only include data collected from the remotely deployed detection arrays (assuming sufficient numbers of fish were tagged during the previous trapping years). The seasonal timing of detailed biological monitoring will cover the upstream migration during spring freshet conditions, assumed to be a minimum 2-week window in early to mid-June.

Field measurements related to biological monitoring are recommended to include (but not be limited to) the following:

- Daily discharge and continuous water temperature data at predetermined locations for Rascal Stream West Reach 1 for the duration of the upstream migration period
- Length and weight of captured adult fish, enumeration of migrating adult fish captured in the two-trap installed at the confluence with Goose Lake for the duration of the upstream migration period
- 'Recapture' movement data of tagged fish to be collected at antennae array loggers positioned at multiple locations in Rascal Stream East and West

Closure

This technical memorandum was prepared and reviewed by the undersigned.

Golder Associates Ltd.

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Water Resources Specialist

Cam Stevens, MSc, PhD
Aquatic Biologist, Associate

REGISTERED PROFESSIONAL ENGINEER
29 JUN 20
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PERMIT NUMBER: P 049
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Nathan Schmidt, PhD, PEng, CPESC
Principal, Senior Water Resources Engineer

https://golderassociates.sharepoint.com/sites/101666/technical work/4000_hydrology/2020 rascal report update and velocity assessment/may 2020 fish passage and conceptual drawings/rev0 (working)/18114181-062-tm-rev0-rascal diversion eval 29jun_20.docx

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APPENDIX A

Conceptual Construction Erosion and Sediment Control Plan

Introduction and General Notes

The following recommended conceptual construction erosion and sediment control plan (ESCP) is aimed to minimize sediment runoff and effects to the fish communities during construction of the velocity mitigation measures at Rascal Stream West Reach 1 and the diversion channel downstream of Rascal Stream East Reach 5 connecting Gosling Pond 1 (see Figure 1 in the main body of the Technical Memorandum). Sediment runoff is considered a deleterious substance that can adversely affect fish and fish habitat.

The following represents a conceptual-level ESCP, that should be formalized prior to construction. In addition, these measures are not exhaustive and should be adapted by the Contractor as necessitated by changing site conditions. This ESCP is intended to provide Erosion and Sediment Control procedures and measures associated with construction, with the long-term erosion and sediment control monitoring described in the main Technical Memorandum.

During general construction activities, the objective is to prevent erosion and sediment mobilization into Rascal Stream downstream of the proposed works. The work area must be isolated from all flowing water without disrupting flow to downstream areas.

Machinery crossing (fording) of a stream or watercourse shall be avoided unless necessary. If fording cannot be avoided, machinery crossing shall be limited to a one-time event (i.e., over and back), and only if no alternative crossing method is available. If repeated crossings of the watercourse are required, a temporary crossing structure must be constructed. Spill kits shall have enough capacity to contain the largest potential spill on-site and accessible at all times.

Construction Sequence

The proposed fish passage mitigation activities will include the hand-placement of rock weirs in the Rascal Stream West Reach 1 at selected areas, and the construction of the Rascal Stream Diversion Channel. The proposed construction sequence is summarized below.

- Hand-placement of rock weirs in Rascal Stream West Reach 1 for reaches and spacing as described in the “Velocity Mitigation” Section of the main Technical Memorandum and Figure 1 and 2.
- Isolation of the construction area for the Rascal Stream Diversion Channel without creation of fish barriers in all natural stream reaches during construction.
- Construction of the Rascal Stream Diversion Channel and in-stream boulder clusters as described in the “Velocity Mitigation” Section of the main Technical Memorandum and Figure 1 and 2.
- Construction of diversion berm along Rascal Stream East Reach 5 and Rascal Stream Diversion Channel. Isolation of the construction areas for the diversion berm and silt fencing erosion and sediment control shall be completed prior to construction of the diversion berm. The timing of the complete diversion of flows into the Rascal Stream Diversion Channel with construction of the diversion berm may be delayed until a later date, if desired based on the construction schedule for the airstrip extension.

Construction Erosion and Sediment Control in Rascal Stream West Reach 1

It is recommended that the installation of rock weirs in Rascal Stream West Reach 1 should take place during low flow open water season, preferably in August or September after migration of fish, to minimize effects to spawning activity, egg stranding and fish migration. The installation of rock weirs should commence before completion of the Rascal Stream Diversion Channel.

The rock weirs will be manually placed (hand-placement), with no heavy equipment required around the watercourse for installation of these weirs. Material used for construction of the weirs and erosion protection downstream of the weirs will composed of clean (free of silts, clays and organics), non-potentially acid generating rock. It is recommended that material stockpiles be placed at the edge of the haul road near the bridge to reduce disturbance to the riparian zone and Rascal Stream. Temporary material stockpiles must be located at least 15 m away from watercourses or other potential off-site transport pathways (i.e., ditches) on flat, stable ground.

Construction Erosion and Sediment Control for Rascal Stream Diversion Channel

There are two phases of the Rascal Stream Diversion Channel:

(1) construction of the diversion channel between Rascal Stream East Reach 5 and Gosling Pond 1; and

(2) construction of a diversion berm to the east of the diversion channel, which can be completed at a later date if desired depending on the schedule for construction of the airstrip extension.

The following ESC measures should be implemented for construction of the diversion channel:

- Placement of silt fences (two rows) at the Rascal Stream Diversion Channel inlet to Gosling Pond 1 across the entire channel transect in a U-shape (convex) with the bulge facing upstream to capture transported sediment during flushing of the diversion channel when under controlled flows. Once the diversion channel is activated, silt fences shall be re-installed as to not span the entire channel. See Figure 1 below.
- Placement of silt fence (one row) parallel to the Rascal Stream Diversion Channel in J-shapes outside of the zone of construction on the topographically lower (north) side of the channel to prevent mobilized sediment due to construction from entering downstream watercourses (i.e., Main Goose Pit Stream Reach 3). See Figure 1 below.
- Construct a sump at the downstream end of the Rascal Stream Diversion Channel to collect groundwater or runoff and any mobilized sediment from the construction zone. See Figure 1 below.
- Sediment laden water that accumulates in the isolated work area during construction (from groundwater, rainfall, or potential flooding) must be pumped to a vegetated buffer in an area that will prevent direct flow to a watercourse. Determining a sufficient distance from the watercourse will be at the discretion of the environmental monitor to allow the water to infiltrate to ground, prior to re-entering the watercourse and without causing further erosion. The pump outlet must be stabilized to prevent erosion from discharge flow velocity.

- Installation of a temporary berm (using well-graded gravels and cobbles along with a layer of impervious poly sheeting) installed to bankfull height at the upstream end of the Rascal Stream Diversion Channel, to keep fish and water out of the construction zone with continued passage from Rascal Stream East Reach 5 through Rascal Stream East Reach 4.
- All equipment and materials (e.g., cobbles and gravel) used to construct the diversion must be clean (borrowed material should be washed on-site prior to placement) and not contain any substances that could be harmful to fish, wildlife or aquatic ecosystems. Vehicles and equipment shall arrive on-site in a clean condition (i.e., pressure-washed prior to arrival on-site and clean and free of deleterious substances such as oil, grease, and soil).
- Fines and substrates used for lining the diversion channel must be composed of clean rock (i.e., non-potentially acid generating rock).
- Refuelling equipment (e.g., pumps) or other mobile or large equipment, refilling small field containers, and conducting fuel transfers must be completed a minimum of 30 metres from any watercourse.
- If access roads are required, grade roads in such a manner as to avoid materials from being directed into any watercourses when practical.
- Should turbidity values increase beyond those stipulated in environmental permits or regulatory guidelines, work should slow, or potentially halt, until background turbidity values have re-established before continuing.
- During excavations, temporary material stockpiles must be located at least 15 m away from watercourses or other potential off-site transport pathways (i.e., ditches) on flat, stable ground. Temporary stockpiles should be inspected twice daily and if sediment from temporary stockpiles is mobilized due to precipitation, silt fences shall be installed downstream of stockpiles to intercept mobilized sediment from entering watercourses.
- Soil disturbance must not occur during heavy rain conditions.
- Prior to introducing flow into the new channel, wash fines/substrate at the upstream end of the isolated new channel area, using pumped water (or from a partial diversion) from the Rascal Stream East Reach 5, and pump it out at the downstream end of the isolated area into an upland area (location/distance from the stream channel determined by the Environmental Monitor), until it flows clear.
- Upon completion of project works, remove the temporary silt fences and restore the sump area from the upstream end first to minimize sediment disturbance.

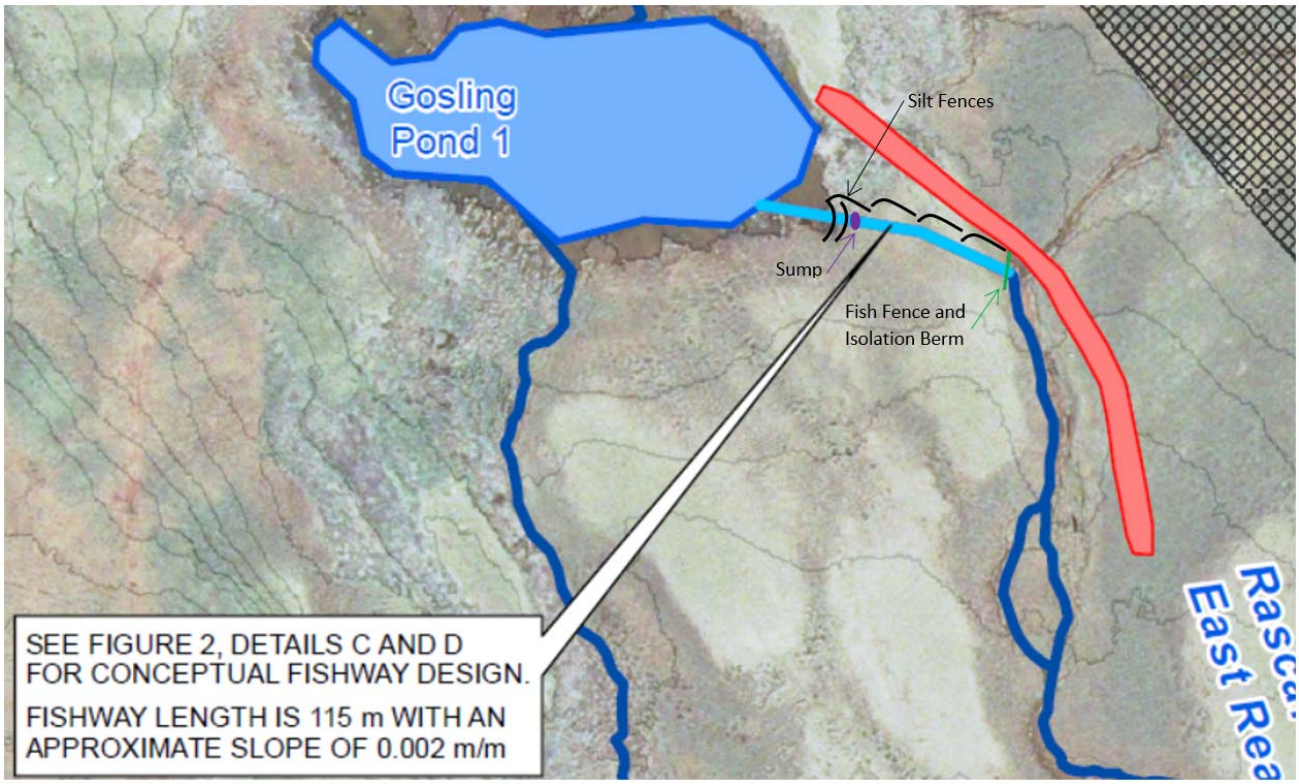


Figure 1: Conceptual Erosion and Sediment Control Measures

Construction Monitoring

The implemented ESC measures need to be regularly monitored to identify any maintenance or repair required, particularly during and after rainfall events. Twice daily visual inspections of the Rascal Stream Diversion Channel and Rascal Stream Reach 1 are recommended.

Water quality monitoring upstream and downstream of the Rascal Stream Diversion Channel, and at Rascal Stream at the Mouth during construction will confirm adherence to water quality standards. Additionally, it will help to identify exceedances early, so that measures can be implemented to manage effects and help to quantify the geographical extent, duration, and magnitude of the release for potential restoration requirements and incident reporting. The Environmental Monitor will dictate water sampling locations, parameters, frequencies, and monitor criteria threshold limits consistent with applicable water quality guidelines for characterization of unauthorized discharges of sediment-laden run-off.