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25 June 2018

Proj. No.: 307071-01259

Ministry of Transportation and Infrastructure
5D 940 Blanshard Street
Victoria, BC

Attention: Callum Campbell, Manager, Marine Branch

Dear Mr. Campbell:

Re: Balfour Terminal Dredging Hydrological Assessment

1. Introduction

WorleyParsons Services Canada Ltd. (WorleyParsons), operating as Advisian, has been retained by the British Columbia Ministry of Transportation and Infrastructure (MOTI) to assess the hydrological effects of dredging on the existing navigation channel in the West Arm of Kootenay Lake.

MOTI plans to improve the navigational channel in the West Arm of Kootenay Lake in order to promote safe navigation by Kootenay Lake ferry vessels. The proposed work includes dredging the localized high points within the navigation channel between the Balfour Terminal and the mouth of Kootenay Lake. The total dredging volume is approximately 11,020 m^3 (including overdredging allowance). The dredged material is proposed to be disposed back into Kootenay Lake.

This document outlines the potential effects on the lake hydrological conditions caused by the proposed dredging work. Other potential effects, (e.g. environmental and social) if any, caused by the work were not assessed under the scope of this work.

2. Hydrologic Review

2.1 Hydrology

Kootenay Lake has a catchment area of approximately 45,000 km^2 and drains through the West Arm of Kootenay Lake to the Columbia River. Water levels within Kootenay Lake are controlled at the Corra Linn Dam (45 km downstream of the Balfour Terminal) and the Grohman Narrows (34 km downstream of the Balfour Terminal).

Water Survey of Canada (WSC) operates several hydrometric stations at Kootenay Lake. Water levels recorded at Queens Bay, (Station No. 08NJ064) which is 1.5 km upstream of the Balfour Terminal, are approximately representative of the Kootenay Lake water levels experienced at the Balfour Terminal.

The WSC hydrometric station at Nelson (Station No. 08NJ008) is 32 km downstream of the Balfour Terminal. Long term water level records are available at this station. Water levels recorded at Nelson represents the water level downstream of the West Arm of Kootenay Lake. The location of various reference points is illustrated in Figure A.

Kootenay Lake Outflow Near Corra Linn (Station No. 08NJ158) has a long term flow record (WSC 2018). The flow rates recorded at Corra Linn are approximately representative of the West Arm outflow. The minimum monthly flow at Corra Linn between 1975 and 2015 is 248 m^3/s. The average flow in the past 40 years is 767 m^3/s.

Figure A shows the hydrometric stations relative to the Balfour Terminal.

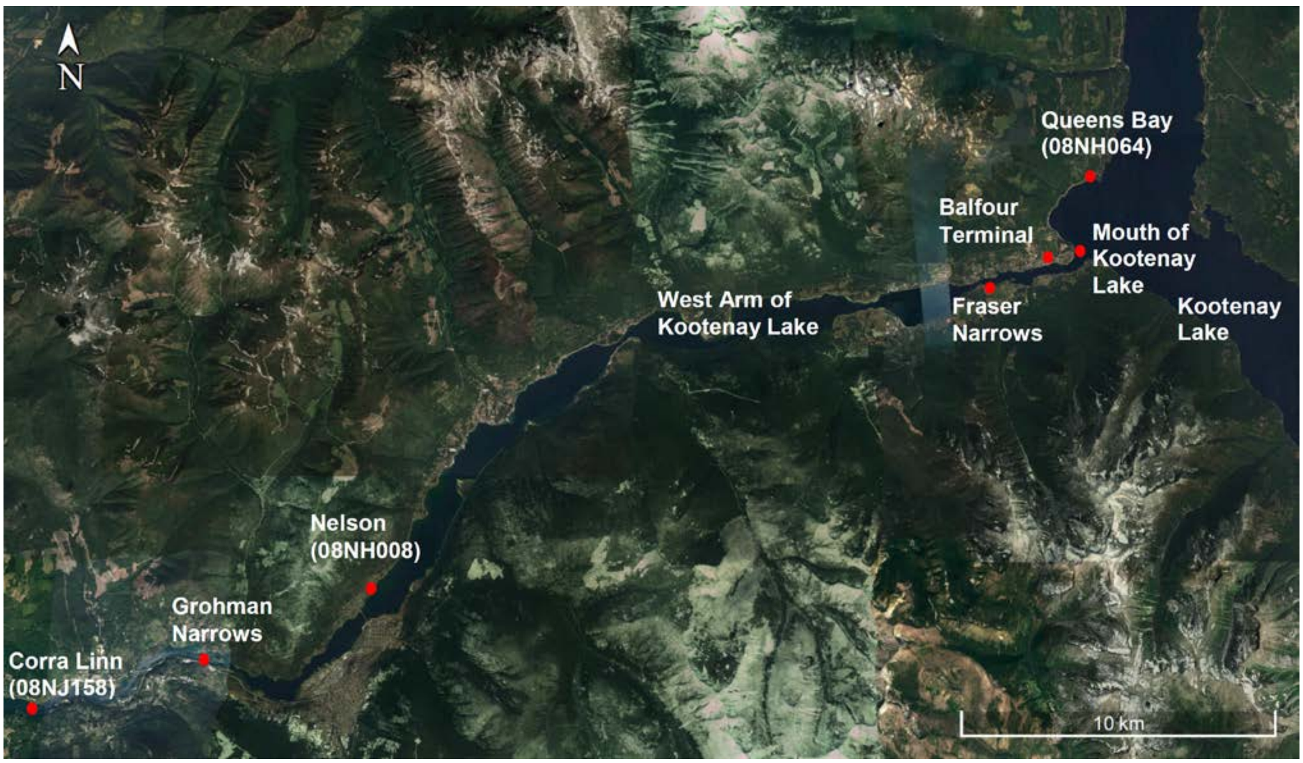

Figure A Location Plan

2.2 Water Levels in Kootenay Lake

The water level of Kootenay Lake at Queens Bay peaks during freshet, commonly in June, before dropping to a steady level, generally between 531 m and 532 m, from August through to December. Starting in January, the water level in Kootenay Lake drops gradually through to April. Water levels are generally lowest in March/April just prior to freshet, and frequently dip below 530 m Geodetic Datum (GD). The lowest water level recorded at Queens Bay between 1975 and 2015 is 529.71 m or 0.27 m Chart Datum (CD). Chart Datum within the West Arm is equivalent to 529.44 m geodetic elevation (Advisian 2017). The 0.1% low frequency of water level at Queens Bay is 529.76 m GD or 0.32 m CD (Advisian 2017). The annual average water level is 531.45 m GD (WSC 2018).

Water levels at Nelson follow similar seasonal trends as at Queens Bay. According to WSC water level records, during March and April when water levels are low, Queens Bay water levels are on average 15 cm higher than water levels at Nelson. The water level drop between Queens Bay and Nelson is approximately 22 cm over a distance of 33 km in annual average. The water level differences between Queens Bay and Nelson fluctuate with flow rates. The water levels drop over the channel length represents the hydraulic grade line slope between Queens Bay and Nelson. The differences of the water levels between Queens Bay and Nelson are mainly controlled by the hydraulic channel narrowing at several pinch points downstream. Fraser Narrows (2 km downstream of the Balfour Terminal) is the most controlling point among the others.

3. Potential Impacts on Hydrology

3.1 Change to Upstream Water Levels Caused by Dredging

The proposed dredging would remove approximately 11,000 m^3 of material from the lake bed between Balfour Terminal and the mouth of Kootenay Lake. The total length of the channel sections to be dredged is 454 m. The dredging would slightly modify the channel bathymetry by increasing the channel cross-sectional areas up to 4% where the most dredging is proposed.

Increasing the channel cross-sectional area by dredging will theoretically reduce the flow velocity at the dredged channel sections and reduce water levels upstream.

The water level effect in Kootenay Lake was estimated under two conditions:

- Scenario 1 - Annual average water level and mean flow rate (Water level: 531.45 m; Flow: 767 m^3/s)
- Scenario 2 - Low water level and minimum monthly flow rate (Water level: 529.76 m; Flow: 248 m^3/s)

Based on the analysis results detailed in Appendix 1, the proposed dredged channel can reduce the water level less than 1 mm under both low and mean flow conditions. The flow velocity at the dredged channel can reduce 0.01 m/s. Therefore, the proposed work will not noticeably affect the properties in Kootenay Lake.

There is no detrimental effect on any properties if the flow velocity at the dredged channel sections and water levels upstream are reduced slightly under high water level conditions.

3.2 Effect on Downstream Flow

The outflows from Kootenay Lake are controlled at the Corra Linn Dam and the Grohman Narrows. The typical flow rates through the Corra Linn Dam range from approximately 500 m^3/s in late March to approximately 2,000 m^3/s at the peak of freshet. The proposed modifications on channels bathymetry upstream of Corra Linn Dam and the Grohman Narrows would not affect the outflow.

The analysis results reported in this document are consistent with the conclusions drawn from the previous analysis using hydraulic modeling (SNC-Lavalin Inc. 2016). The previous analysis concluded that the bathymetric change to the West Arm of Kootenay Lake at Balfour from the proposed dredging would not affect river flows downstream or the lake levels in any noticeable way for the community.

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4. Conclusion

In summary, the hydrological changes in Kootenay Lake are anticipated to be negligible. No properties are anticipated to be detrimentally affected by the proposed dredging work.

Sincerely,

PROFESSIONAL
PROVINCE OF
J.B. CROFTON
24980
BRITISH COLUMBIA
ENGINEER

June 25, 18

Jeff Crofton, M.A.Sc., P.Eng.
Director, Surface Water Engineering

Advisian, Americas

5. References

Advisian 2017. Improvements to Navigation Study Report – Draft Balfour Ferry Terminal, October 26, 2017.

SNC-Lavalin Inc. 2016. Technical Review of Dredging Options West Arm of Kootenay Lake near Balfour Ferry Terminal. Prepared For: The BC Ministry of Transportation and Infrastructure, November 07, 2016. Document No.: 636974-1000-41ER-0001 Rev.01

WSC (Water Survey of Canada) 2018. Historical Hydrometric Data https://wateroffice.ec.gc.ca/google_map/google_map_e.html?map_type=historical&search_type=province&province=BC. Access in June 2018

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Appendix 1 Estimation of Water Level Change in Kootenay Lake

The proposed dredging would remove approximately 11,000 m^3 of material from the lake bed between Balfour Terminal and the mouth of Kootenay Lake. The total length of the channel sections to be dredged is 454 m. The dredging plan is shown in Figure A1.

The dredging would slightly modify the channel bathymetry by increasing the channel cross-sectional areas. The channel cross-sectional areas after the proposed dredging were compared to the areas before dredging at three most dredged locations, Station 0+625, 1+175, and 1+475. The area measurements based on the bathymetry data are shown in Table A1.

Table A1 Channel Cross-sectional Areas (m^2)

Water Levels	Channel Station*								
	0+625			1+175			1+475		
	Before Dredging	After Dredging	Cross-sectional Area Change (%)	Before Dredging	After Dredging	Cross-sectional Area Change (%)	Before Dredging	After Dredging	Cross-sectional Area Change (%)
Scenario 1 - Mean Water Level (2.01m CD/531.45m GD)	2012	2065	3%	2693	2741	2%	2868.6	2891.0	1%
Scenario 2 - 1% Low Water Level (0.32m CD/ 529.76m GD)	1256	1309	4%	1511	1559	3%	1541.8	1564.2	1%

*see Figure A1 for station plan.

As shown in Table A1, the channel cross-sectional areas increase 4% under the low water level condition at Station 0+625 where the most dredging is proposed. The channel cross-sectional areas increase up to 3% in areas under the average water level condition. To be conservative for the water level calculation, it is assumed that the cross-sectional areas would increase by 4% for the entire 454 m channel sections to be dredged.

Increasing the channel cross-sectional by dredging will theoretically reduce the flow velocity at the dredged channel sections and reduce water levels upstream.

The potential changes on water levels upstream were estimated using Manning's equation.

$$V = \frac{1}{n} R_h^{2/3} S^{1/2} \quad \text{or} \quad Q = \frac{1}{n} R_h^{2/3} S^{1/2} A$$

where:

- V is the cross-sectional average velocity (m/s);
- n is the Manning coefficient. s/($m^{1/3}$). 0.03 for the natural water channel;
- R_h is the hydraulic radius (m);
- S is the slope of the hydraulic grade line or the linear hydraulic head loss;
- Q is the flow rate (m^3/s); and
- A is the cross-sectional area (m^2).

With constant flow rate, increasing the cross-sectional area A would reduce the slope of the hydraulic grade line S, hence, the water level upstream.

The flow rates recorded at Corra Linn were considered approximately representative of the Balfour channel flow and were used in the water level calculation. The monthly low flow recorded at Corra Linn between 1975 and 2015 is 248 m^3/s, which represents the flow during low water level condition. The 40 years average flow is 767 m^3/s, which represents the average discharge rate under average water level condition.

The water level effect in Kootenay Lake was estimated under two conditions:

- Scenario 1 - Annual mean water level and mean flow rate (Water level: 531.45 m; Flow: 767 m^3/s); and
- Scenario 2 - Low water level and minimum monthly flow rate (Water level: 529.76 m; Flow: 248 m^3/s).

Table A2 summarizes the calculation results of water level changes for both scenarios using Manning's equation.

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Table A2 Water Level Changes due to Channel Dredging

	Scenario 1 - Mean Water Level (2.01m CD/531.45m GD)		Scenario 2 - 1% Low Water Level (0.32m CD/ 529.76m GD)	
	Before Dredging	After Dredging	Before Dredging	After Dredging
Cross-sectional Area (m^2)	2012	2065	1256	1309
Wetted Perimeter (m)	513	513	385	385
Hydraulic Radius (m)	3.9	4.0	3.3	3.4
Flow (m^3/s)	767	767	248	248
Velocity (m/s)	0.38	0.37	0.20	0.19
Slope	0.0021%	0.0019%	0.0007%	0.0006%
Channel Length (m)	454	454	454	454
Hydraulic Head Loss (m)	0.0096	0.0088	0.0033	0.0029
Water Level Change before and after dredging (m)	-0.0008		-0.0004	

As shown in Table A2, it was estimated that the water level upstream of Balfour drops 0.8 mm under Scenario 1 - average flow and water level conditions, and the water level drops approximately 0.4 mm during Scenario 2 - low flow conditions. The flow velocity at the dredged channel reduces 0.01 m/s for both scenarios.

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PLAN – WEST ARM KOOTENAY LAKE
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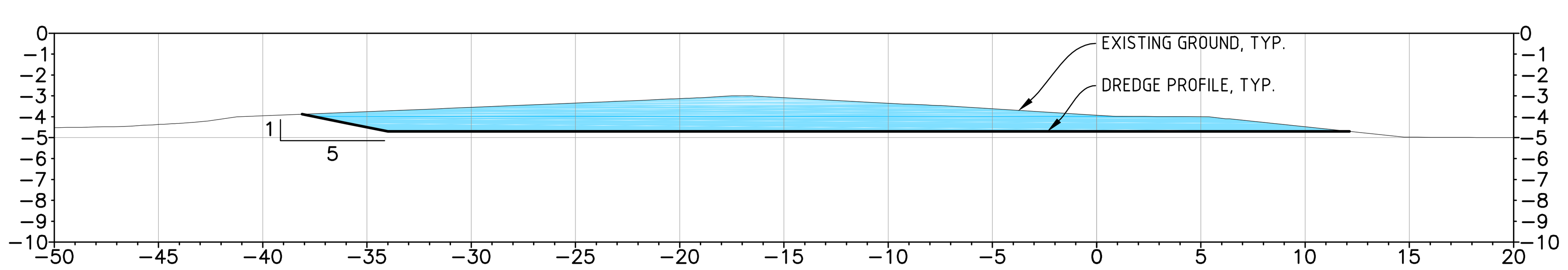

NAV–CHANNEL – STATION: 0+625
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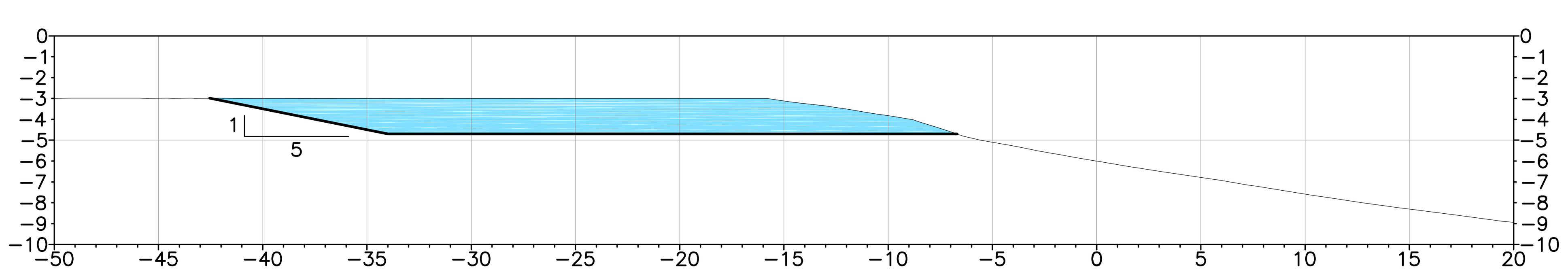

NAV–CHANNEL – STATION: 1+175
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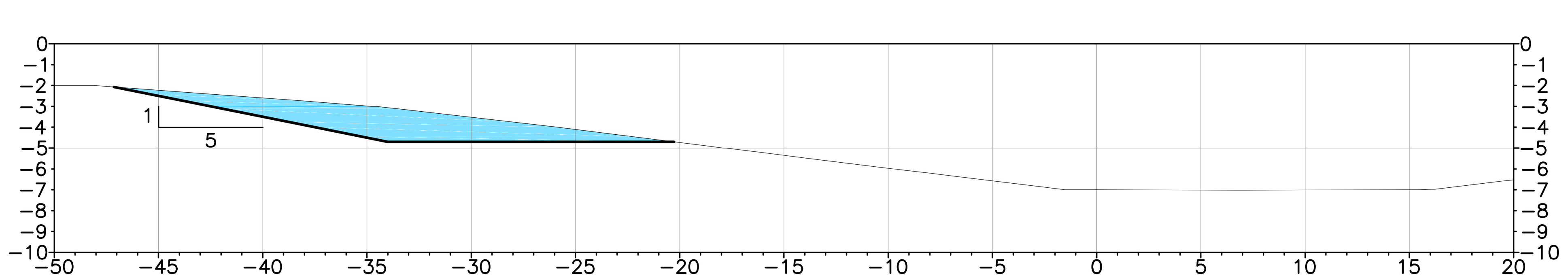

NAV–CHANNEL – STATION: 1+475
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DREDGE DEPTHS, AREAS, AND VOLUMES

RANGE	LOWER DREDGE DEPTH (m)	UPPER DREDGE DEPTH (m)	AREA (m^2)	COLOUR	VOLUME (m^3)
1	−1.72	−1.00	2,627		927
2	−1.00	0.00	8,442		6,776
OVERDREDGE ALLOWANCE (300mm)					3,320
TOTAL DREDGE (INCLUDING OVERDREDGE ALLOWANCE)					11,020

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NOTES:

1. FOR GENERAL NOTES, SEE DWG. 307071–01259–00–MA–DGA–1501.

Consultant
WorleyParsons resources & energy
307071-01259

REVISION IN PROGRESS

Rev	Date	Description	Init
P1	JUNdd/18	ISSUED FOR CLIENT REVIEW	AAL

R E V I S I O N S

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
Southern Interior Region

KOOTENAY LAKE

WEST ARM 2018 DREDGING
DREDGING PLAN

PREPARED UNDER THE DIRECTION OF
N/A
ENGINEER OF RECORD
DATE

DESIGNED N/A DATE JUN 2018
CHECKED N/A DATE JUN 2018
DRAWN N/A DATE JUN 2018
SCALE: SHOWN
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.	
		2	FIGA1	P1