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REPORT ON

HYDRAULIC ASSESSMENT OF PROPOSED ALIARUHIK RIVER CROSSING, KUGAARUK NU

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Golder Associates (Golder) is pleased to present the following hydraulic assessment of the proposed Aliaruhik River Crossing in support of permit applications. This report provides a overview of the objectives of this assessment, a description of the field surveys and analytical methods , a summary of findings and design recommendations.

1.0 OBJECTIVES

The objective of this study is to supply data and estimate hydraulic impacts, sufficient to support a permit application for a bridge crossing. Specific requirements for the study are as follows:

1. Characterize the Aliaruhik River and evaluate the effects of the proposed bridge on its flow regime.

2. Assess the ability of the proposed design to withstand existing and expected future flood flow conditions.

3. Assess potential ice problems due to flow constriction at the proposed crossing.

2.0 METHODS

2.1 Field Investigation

Golder visited the site on August 12 and 13, 2001 to conduct a river investigation that included:

- a level survey of cross sections in the vicinity of the proposed bridge crossing;
- a level survey of river centerline and high water marks (edge of vegetation) profile;
- discharge measurements at the proposed bridge crossing location – using a price current meter;
- substrate characterization at the location of the proposed bridge abutments – random measurement of 50 rocks/abutment located between the high water marks and the edge of the abutments; and
- visual inspection of the main watershed and the small tributary watershed to the west of the site.

Mr. Guido Tigvareark, Assistant Senior Administrative Officer for the Town of Kugaaruk and Mr. Jivko Jivkov from Jivko Engineering assisted in the site investigation and data collection.

2.2 Hydrology

The drainage area to the Aliaruhik River at the mouth of Barrow Lake (Lat. 68°28'N, Long. 89°35'W) is composed of two watersheds. Its main watershed drains the area adjacent to the lake in a southerly direction and covers 218km^2. A secondary watershed west of the river mouth near the lake drains an area of 16km^2. The flow from this secondary watershed is split and drains in part to the lake and in part to a small stream that joins the Aliaruhik River immediately downstream of the proposed crossing. It is estimated, based on field observations, that approximately 1/3 of the flow from this secondary drainage area is tributary to the lake. Hence the total drainage area at the proposed crossing is estimated to be 223km^2.

Discharge estimates for the Aliaruhik River were derived based on regional stream flow records collected by the Water Survey of Canada (WSC). Two gauges were historically operated by the WSC in the vicinity of the proposed site. The nearest gauge operated on the Hayes River above Chantrey Inlet (Lat. 67°31’30”N, Long. 94°03’30”W) between 1971 and 1992 and had a drainage area of 18,100km^2. A gauge on the Brown River above Brown Lake (Lat. 66°02’32”N, Long. 90°50’04”W) operated between 1986 and 1995 and had a drainage area of 2,040km^2. The hydrology of these watersheds is snowmelt dominated with peak flows normally occurring between mid June to mid July.

A flood frequency analysis was conducted on the peak flow observations and the results were fitted to a three parameter log-normal distribution. The unit discharge values for the Aliaruhik River were computed by plotting the unit discharges for the two surrogate watersheds on a semi-log plot and extrapolating (Figure 1). The unit area discharges extracted from this plot were adjusted to reflect flood routing through the Barrow lake. The lake storage adjustment factor was computed by routing the largest flood event from the Brown River system (adjusted for area) through Barrow Lake (with an area of 33.3km^2). From this analysis, it was determined that peak discharges from the lake are approximately 96% of the peak inflows.

2.3 Hydraulic analysis

The river survey information along with the discharge estimates from our hydrologic analysis were used to establish a simple hydraulic model (using HEC-RAS Ver. 3.0, U.S. Army Corps of Engineers, 2001) of the reach. The reach of interest for this project was short due to the presence of the Barrow Lake approximately 30m upstream of the proposed crossing and the confluence with a tributary stream approximately 30m downstream from the proposed crossing location.

Discharge measurements at the time of the river survey and high water marks were used to calibrate the model under existing river conditions. The proposed bridge crossing was modeled using the bridge routine within HEC-RAS. The modeled bridge opening was 34m (abutment face to abutment face) less riprap material placed at a slope of 1.5H:1V around the base of the abutments (see attached Figure 2).

Water levels were modeled for various flood frequencies (1:100, 1:50 and 1:2-yr return periods) and for the observed flows at the time of the field investigation.

3.0 RESULTS

3.1 Field Investigation

The bankfull width of the Aliaruhik River in the reach of interest is approximately 72m with a wetted width at the time of investigation, of approximately 55m. Of this distance, only 40m is unobstructed by boulders (less than 30% in plan view) protruding from the water surface. Apart from the easternmost 10m, the bankfull width is characterized by glacially deposited boulders with extensive amounts protruding from the water surface in the westernmost part of the channel. The easternmost area of the channel is composed of glacially deposited cobbles (Table 1). Figures 3 and 4 illustrate the character of the substrate near the face of the proposed abutments.

Table 1 : River Substrate Gradation (average diameter in mm)

Percent Passing	West Abutment	East Abutment
100	1,000	550
80	520	250
50	390	160
30	250	77

The measured discharge at the time of the investigation was $3.3m^3/s$.

3.2 Hydrology

Table 2 summarizes the results of the regional flow analysis conducted on the two historical flow gauging stations in the vicinity of the proposed site. The flow per unit area values for the two stations were utilized to derive discharge values for the Aliaruhik River. Despite the order of magnitude difference in watershed size between the Brown an Hayes River watersheds, the per unit area discharges were comparable.

Table 2: Summary of Regional Flow Analysis

Watershed	Brown River		Hayes River		Aliaruhik River*	
Area	$2,040km^2$		$18,100km^2$		$223km^2$	
Return Period	(m^3/s)	$(m^3/s/km^2)$	(m^3/s)	$(m^3/s/km^2)$	$(m^3/s/km^2)$	(m^3/s)
1:2	358	0.175	2120	0.117	0.221	49.2
1:50	714	0.350	5410	0.299	0.379	84.6
1:100	779	0.382	6050	0.334	0.413	92.1

* Peak discharges adjusted for flood routing through Barrow Lake.

3.3 Hydraulic Analysis

A summary of the hydraulic analysis undertaken for the Aliaruhik River and the proposed bridge crossing is presented in Tables 3 and 4. These tables provide four flow profiles including the measured flow during the field investigation, the 1:2-year return period flow (assumed to represent bankfull conditions) and the 1:50 and 1:100-year design flood conditions. A total of 3 river stations are tabulated with station numbers increasing in an upstream direction. Station 1+000 is located approximately 8m upstream of the confluence with the small watershed to the west. Stations 1+027 and 1+023 represent the upstream and downstream faces of the proposed crossing location and Station 1+053 is located at the mouth of the river. Two model configurations were modeled: the existing river without any modifications (labeled River in the tables) and the river with the proposed bridge (labeled Bridge).

Table 3: Summary of Hydraulic Analysis

River Station	Profile	Flow (m^3/s)	Water Surface Elevation (m)				Flow Velocity (m^3/s)		
			River	Observed	Bridge	Change	River	Bridge	Change
1+053	Measured	3.3	98.49	98.51	98.48	-0.01	0.31	0.32	0.01
1+027	Measured	3.3	98.39	98.40	98.41	0.02	0.59	0.52	-0.07
1+023	Measured	3.3	98.39	98.40	98.39	0.00	0.59	0.59	0.00
1+000	Measured	3.3	98.17	98.17	98.17	0.00	0.77	0.77	0.00
1+053	1:2	49.2	99.04	98.88*	99.23	0.19	1.04	0.78	-0.26
1+027	1:2	49.2	98.82	98.76*	99.01	0.19	1.52	1.97	0.45
1+023	1:2	49.2	98.82	98.76*	98.84	0.02	1.52	2.49	0.97
1+000	1:2	49.2	98.49	98.42*	98.49	0.00	1.87	1.87	0.00
1+053	1:50	84.6	99.25	-	99.64	0.39	1.32	0.87	-0.45
1+027	1:50	84.6	98.99		99.31	0.32	1.89	2.44	0.55
1+023	1:50	84.6	98.99	-	99.12	0.13	1.89	2.97	1.08
1+000	1:50	84.6	98.65	-	98.65	0.00	2.22	2.23	0.01
1+053	1:100	92.1	99.29	-	99.71	0.42	1.38	0.89	-0.49
1+027	1:100	92.1	99.02		99.37	0.35	1.96	2.52	0.56
1+023	1:100	92.1	99.02	-	99.17	0.15	1.96	3.06	1.10
1+000	1:100	92.1	98.68	-	98.68	0.00	2.28	2.28	0.00

* High water marks (edge of vegetation), Barrow lake high water mark located at elevation 98.90m

Table 4: Summary of Hydraulic Analysis (continued)

River Station	Profile	Flow (m^3/s)	Flow Area (m^2)		Top Width (m)		Energy Grade Line	
			River	Bridge	River	Bridge	River	Bridge
1+053	Measured	3.3	10.5	10.3	53.1	52.9	0.14%	0.14%
1+027	Measured	3.3	5.6	6.3	36.0	30.9	0.68%	0.40%
1+023	Measured	3.3	5.6	5.6	36.0	30.9	0.68%	0.68%
1+000	Measured	3.3	4.3	4.3	57.3	57.3	3.00%	3.00%
1+053	1:2	49.2	47.9	63.1	79.5	84.7	0.31%	0.12%
1+027	1:2	49.2	32.4	25.0	74.2	31.6	1.09%	0.32%
1+023	1:2	49.2	32.4	19.8	74.2	31.6	1.09%	2.02%
1+000	1:2	49.2	26.4	26.3	75.2	75.2	2.22%	2.22%
1+053	1:50	84.6	65.4	97.2	85.0	90.0	0.34%	0.09%
1+027	1:50	84.6	45.3	34.7	79.4	32.0	1.09%	0.29%
1+023	1:50	84.6	45.3	28.5	79.4	32.0	1.09%	1.75%
1+000	1:50	84.6	38.4	37.9	79.8	79.8	1.94%	1.95%
1+053	1:100	92.1	68.7	103.5	86.8	90.0	0.35%	0.09%
1+027	1:100	92.1	47.8	36.5	83.7	32.1	1.10%	0.29%
1+023	1:100	92.1	47.8	30.1	83.7	32.1	1.10%	1.75%
1+000	1:100	92.1	41.0	40.4	81.6	81.6	1.87%	1.87%

As indicated on the tables, the modeled results for the measured and bankfull (1:2-year) discharge agree relatively well with observed water levels and high water marks along the river. The design flow conditions were modeled with a constant Manning’s n (roughness) representing conservative backwater conditions since the roughness elements (boulders) are proportionately smaller compared to the flow depth as depth increases.

Under the measured discharge conditions, the model results indicate no significant change in water surface elevation or velocities. Under bankfull and design flow conditions, water surface elevations at the lake will increase by 0.19 to 0.42m above existing river conditions depending on location and discharge. The constriction of the proposed crossing will backwater upstream of the bridge will cause a decrease in velocities upstream of the bridge by up to 34% compared to existing conditions. The constriction will increase velocities by 29 to 56% at the bridge opening under design conditions.

4.0 DISCUSSION

4.1 Potential Ice Problems

The potential for the proposed crossing to cause or be subject to ice problems is considered to be low because this reach of river is subject to minimal ice cover formation (according to local residents) and because little ice traffic is expected on this reach of river. Ice on lakes typically melt within the lakes and is not entrained within the rivers. Furthermore, since we are dealing with a very short reach of river upstream of the proposed bridge, ice traffic from within the river at this location is expected to be limited.

The proposed bridge design, which spans the portion of the river channel unaffected by protruding boulders, is expected to pass the limited ice traffic that is anticipated.

4.2 River Degradation and Aggradation

The proposed bridge configuration is not expected to cause any significant river channel degradation. Based on the modeling results, the stable rock size in the channel will have an average diameter of 190mm during the 1:100-yr return. T he rock size observed under the proposed east abutment was slightly smaller than this (d_{50}=160mm), however, the size of substrate increases rapidly beyond the footprint of the proposed abutment with large boulders present in the main river channel. Riprap will protect the abutment area and therefore the occurrence of smaller size rock at the east abutment is not a concern. The bed material encountered under the west abutment is more representative of the large size bed material present across the river section at the proposed crossing location.

Since the Aliaruhik River is lake headed and virtually free of suspended sediments, backwater effects from the proposed bridge are not expected to cause any significant sediment deposition or bed aggradation.

5.0 RECOMMENDATIONS

5.1 Riprap and Filter

Riprap protection is required for the toe of the abutments. A nominal size of 500mm diameter, will provide adequate erosion protection. The following rock gradation is recommended:

Table 5: Recommended Riprap Gradation

Percent Passing	Diameter (mm)	Mass (kg)
100	800 to 1000	700 to 1400
80	600 to 750	300 to 600
50	500 to 625	200 to 350
20	300 to 375	40 to 75

The riprap should be placed at a minimum thickness of 1000mm with a slope no steeper than 1:5 horizontal to 1 vertical. A filter, in form of a graded gravel/cobble should be provided between any fill material and the riprap. The recommended filter material gradation is provided in Table 6.

Table 6: Recommended Filter Gradation

Percent Passing	Diameter (mm)
85	Greater than 60
15	7.5 to 60

5.2 Bridge Deck Height

The proposed bridge bottom chord elevation is high enough to pass flood waters and debris. Modeling results indicate that the maximum flow depth expected is about 1.5m (minimum channel elevation of 98.0m – flood elevation of 99.5m). The proposed 2.0m vertical clearance from the normal water surface elevation (±98.5) would yield a bottom chord elevation of 100.5m for a freeboard of 1m.

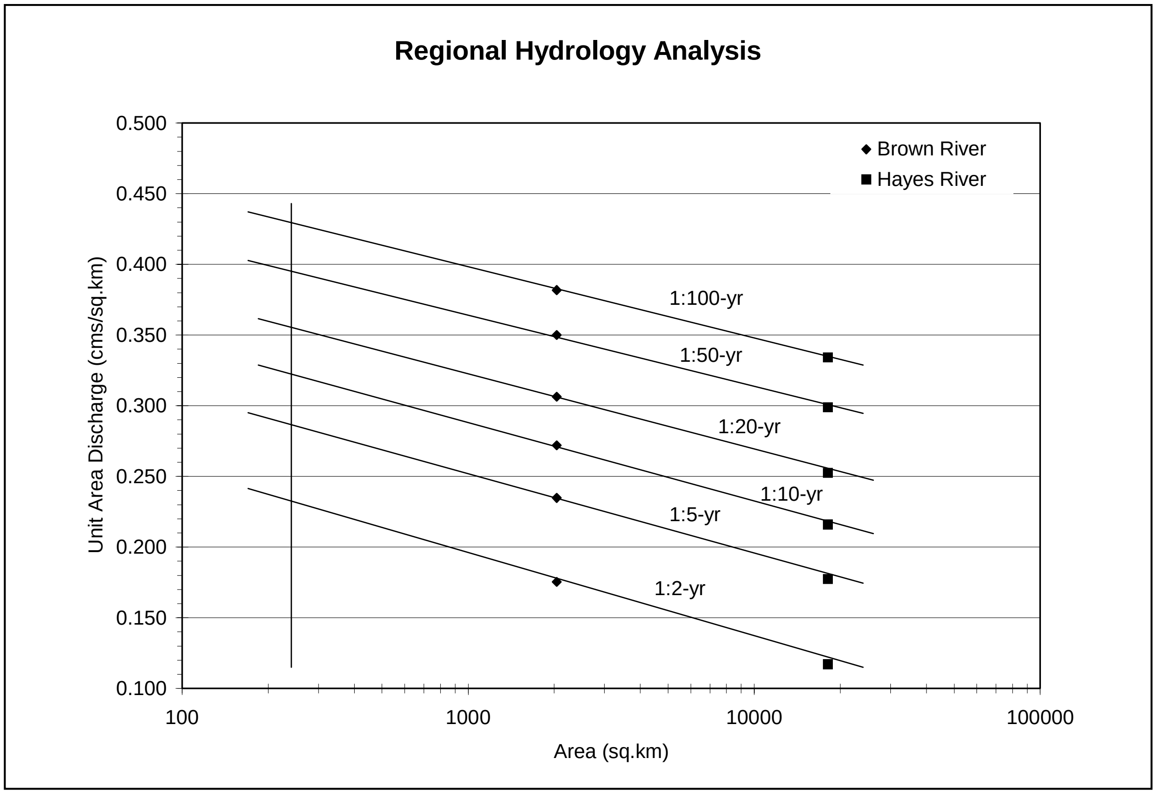

Figure 2: Regional Hydrology Analysis

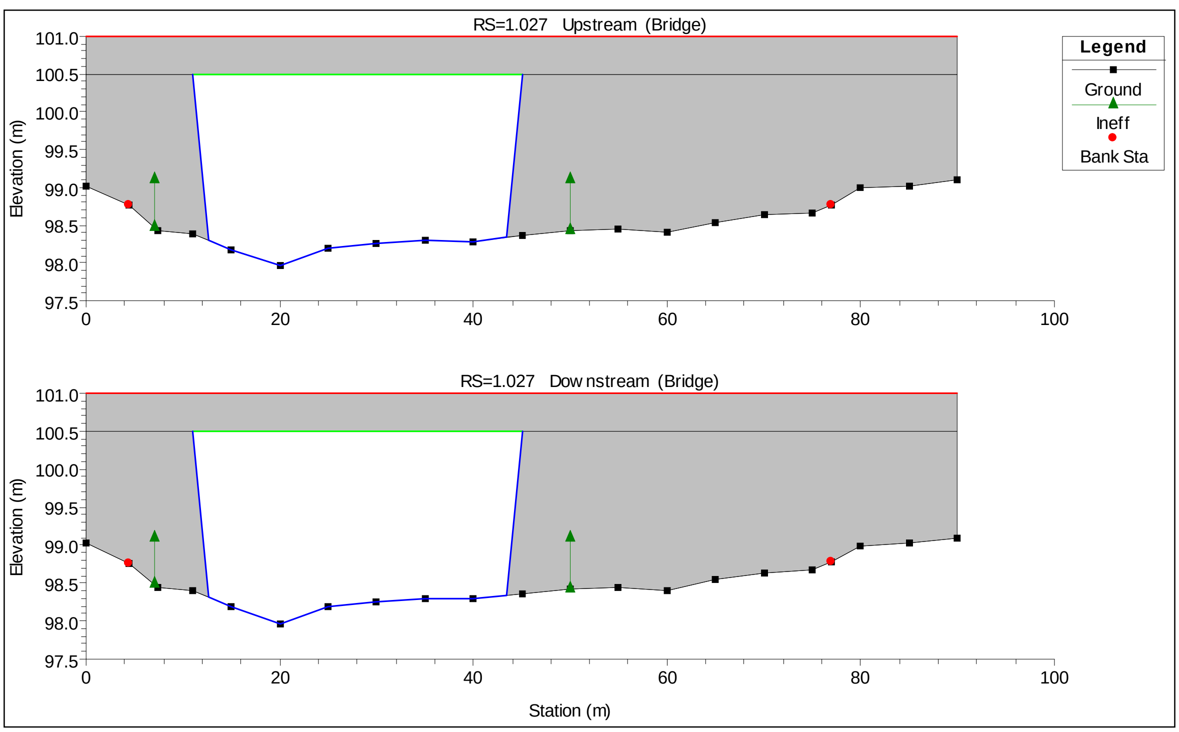

Figure 1: Bridge Cross-Section

Figure 4: Substrate at East Abutment (tip of survey rod [7.5m] is approx. at face of abutment)

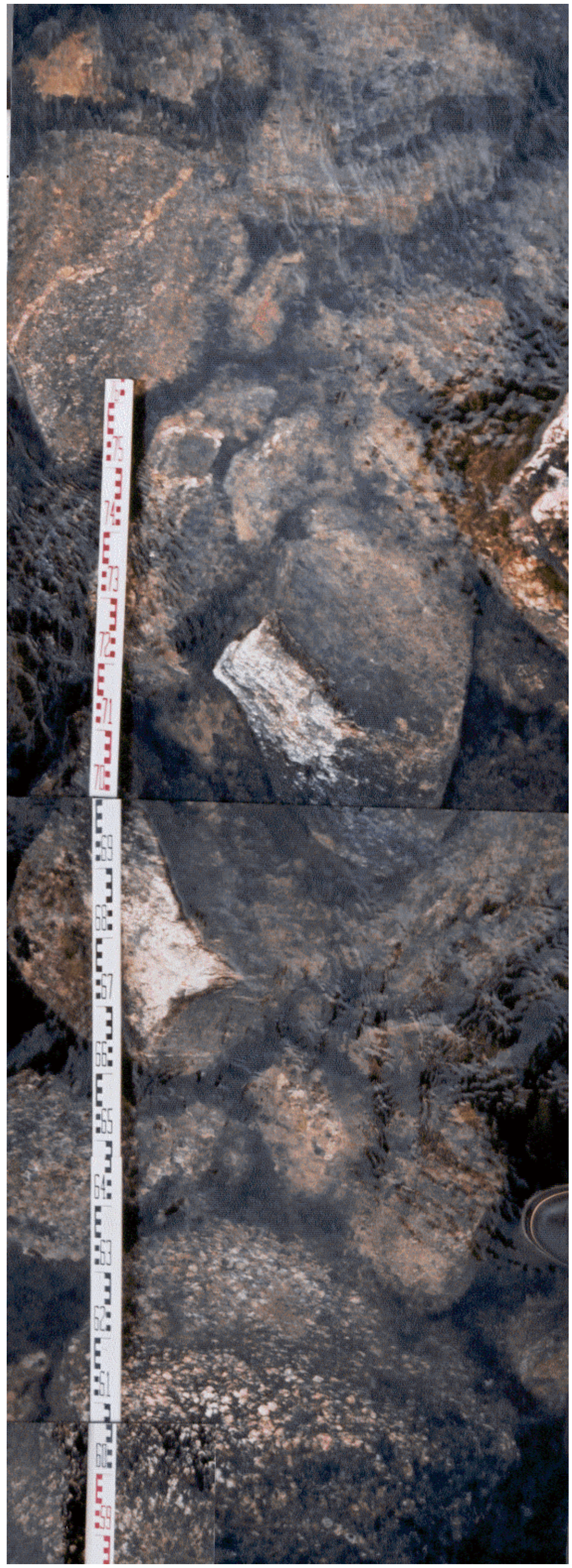

Figure 3: Substrate at West Abutment (tip of survey rod [7.5m] is approx. at face of abutment)