TECHNICAL MEMORANDUM

DATE October 12, 2012 **PROJECT No.** 11-1365-0012/DCN-106

TO Veronica Chisholm
De Beers Canada Inc.

CC Gary Ash, John Faithful, and Amy Langhorne

FROM Cameron von Bratt and Kasey Clipperton **EMAIL** Cameron_vonBratt@golder.com

GAHCHO KUÉ FLOW MITIGATION: FIELD REPORT AND ASSESSMENT - 2012

1.0 INTRODUCTION

De Beers submitted a proposed flow mitigation plan, titled "Gahcho Kué Flow Mitigation Plan" (Plan) (Golder 2012a), to the Mackenzie Valley Review Board (MVEIRB) public registry on June 29, 2012. The intent of this plan is to augment flows downstream of Area 8 during the operation and closure (refilling of Kennady Lake) phases of the proposed Gahcho Kué Project (Project) to avoid potential harmful population level effects on the fish community due to reduced flows between Area 8 and Lake 410 while Kennady Lake remains isolated from these downstream waters. The Plan was developed in consultation with Fisheries and Oceans Canada (DFO) to focus on the duration and magnitude of peak flows to allow for spring spawning migrations and maintain seasonally appropriate flows for spawning, rearing and outmigration. An assumption was made in the Plan that some level of fish passage would be possible at a discharge of 0.40 m^3/s.

Field programs conducted in 2012, which supplement the field data collected in 2011, were designed to assess fish passage at a range of flows to help inform the Plan and further refine the data used in the EIS assessment. The flow range targeted for the field assessments in 2011 and 2012 included post-freshet flows between 0.20 cubic metres per second (m^3/s) and 0.80 m^3/s to supplement the fish passage assessments previously conducted for the Environmental Impact Statement (EIS) (De Beers 2010). In addition, a summer assessment in 2012 was conducted to evaluate the suitability of using 0.10 m^3/s as a base flow target for the flow mitigation plan.

This memo presents the field data and assessment of the 2011 and 2012 monitoring work conducted on the streams and barriers downstream of Kennady Lake to Lake 410. The intent of the monitoring work was to validate the flows at which barriers to fish migration persist and assess the availability and suitability of spawning and rearing habitat at a wide range of flows. An assessment of the Plan, relative to unmitigated flows, is presented using the same assessment approach described in Section 9.10 of the EIS (De Beers 2010).

1.1 Background

Results of barrier surveys conducted in 2004 and 2005 indicated that natural barriers to fish movement between Kennady Lake and Lake 410 were reported to persist at a Kennady Lake outflow of 0.23 m^3/s and be absent at a discharge of 0.78 m^3/s (De Beers 2010); however, it is expected that under natural conditions, Arctic grayling are likely able to migrate and spawn in most years. Without mitigation, the reduction in flows predicted in the EIS during the operations and closure (refilling) phases of the Project have the potential to restrict or prevent Arctic grayling spawning migrations due to natural barriers that persist at low flows, and to reduce the available habitat area for spawning and rearing through reductions in wetted area (De Beers 2010). Therefore, it is important to identify possible barrier locations, the flows at which these barriers exist, and propose a flow mitigation plan to mitigate impacts on the Arctic grayling population downstream of Kennady Lake as a result of the Project.

2.0 FIELD METHODS

2.1 Fish Barrier and Discharge Sites

Five potential fish barrier sites in streams downstream of Kennady Lake were identified in the 2010 EIS (De Beers 2010) and were investigated during the 2011 and 2012 flow monitoring programs (Figure 1). Photographs of the sites are presented in Appendix A. The uppermost site (Site K5 [Stream K5]) was used as the upstream discharge point from which the flows for the five fish barrier sites were assessed. All reported discharges and fish passage assessments are relative to the calculated discharge at Site K5 to remain consistent with the EIS assessment. The following stream sites were assessed in the flow monitoring program:

- K5 – discharge site;
- L1a;
- L1b;
- L1c;
- L3; and
- M4.

2.2 Stream Discharge Measurement

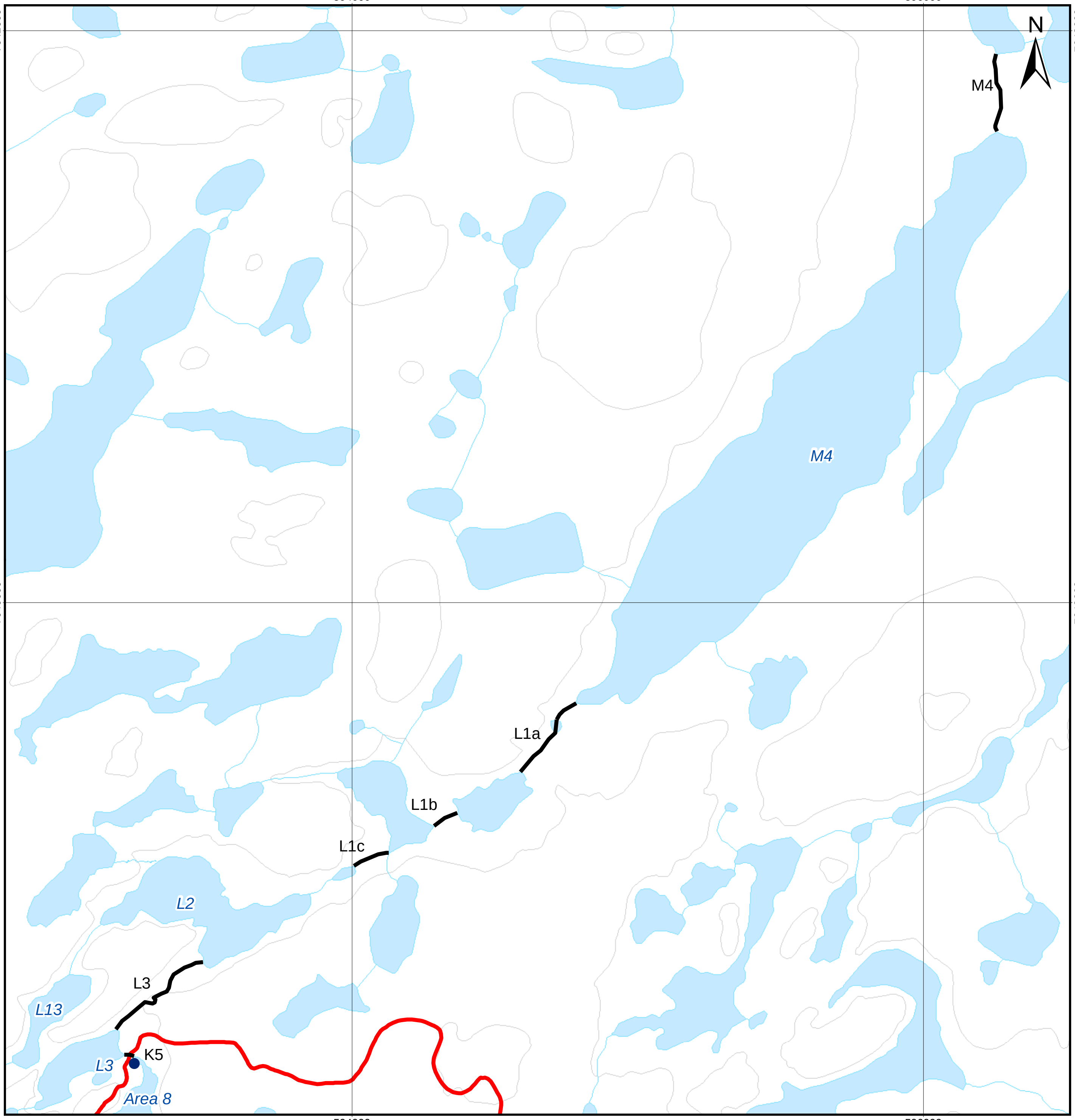
The discharge transects was established during the July 2011 field program and was marked with rebar pins to allow for consistent measurements during subsequent field visits. Stream discharge data were collected using a Marsh-McBirney FloMate 2000 digital velocity meter and a top-setting wading rod. During each site visit, the discharge transects were established using a tag line or tape measure. Velocities and depths were recorded at a minimum of 20 stations across each transect. Velocities were measured at 60% depth for water depths less than 0.75 m, and at 20% and 80% depth for water depths greater than 0.75 m.

2.3 Fish Passage and Habitat Assessment

Fish passage was visually assessed at each site for each measured discharge by an experienced fish habitat biologist or field technician. Potential barriers to upstream fish movement were identified as being caused by either a vertical drop, lack of surface depth, or velocity barriers. Sections of dry channels were identified as full barriers to both upstream and downstream movement. Photographs were taken at each discharge to document the conditions creating the potential barrier to fish movement.

Available fish habitat at each site was visually assessed at each measured discharge based on the suitability of the habitat observed at the discharge to provide spawning and rearing habitat for Arctic grayling based on suitable depth and substrate. Habitat suitability for Arctic grayling was assessed relative to published habitat requirements of each life stage (Deegan et al. 2005; Evans et al. 2002; Hubert et al. 1985; Stewart et al. 2007), the professional experience of the field crew, and visual observations of fish during the assessment.

Transects were established at sites L1b, L1c, L3, and M4 to document changes to depth and wetted width at each discharge to assist with the assessment of habitat suitability under each discharge condition.



LEGEND

Watercourse

Waterbody

Contour (10m interval)

Discharge Location

L2 Lake Identifier

Fish Passage Assessment and Reach

Kennady Lake Watershed Boundary

NOTES

Base data source: National Topographic Base Data (NTDB) 1:50,000

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GAHCHO KUÉ PROJECT

Downstream Flow Assessment Field Program Study Sites

PROJECTION: UTM Zone 12

DATUM: NAD83

Scale: 1:20,000

250 125 0 250

Metres

DE BEERS CANADA

FILE No: DSFlow-Fish-001-GIS

DATE: October 2, 2012

JOB NO: 11-1365-0012

REVISION NO: 1

OFFICE: GOLD-CAL

DRAWN: CW

CHECK: KC

Figure 1

3.0 STREAM DISCHARGE

The target discharge range at Site K5 for the fish passage assessment was between 0.20 m^3/s and 0.80 m^3/s in order to better define the flow at which fish passage becomes restricted. Selecting a suitable discharge transect was difficult due to the general lack of a well defined single channel at this site, and the presence of large boulders throughout the channel. The discharge transect at Site K5 is shown in Appendix A, Plate 01 through Plate 04.

Stream discharge was recorded at Stream K5 on three dates in 2011 and four dates in 2012 (Table 1). In 2011, an early and relatively low freshet occurred and the discharges present at the time of the barrier assessment were already at low stage and below the targeted range of the assessment. Continuous flow monitoring conducted in 2011 at Stream L1 (analogous to the outlet flow of Kennady Lake) recorded a freshet beginning at the end of May with a peak flow of about 0.54 m^3/s in the first week of June (Golder 2012b). Although there was a malfunction with the continuous flow logger after June 7th, based on the low discharge encountered on July 8th, it is assumed that the duration of the flow peak was relatively short.

In 2012, flows encountered during the June assessment ranged from 0.36 to 0.62 m^3/s (Table 1). The peak of the spring freshet occurred prior to the assessment, with flows gradually declining for the duration of the June assessment period throughout the target assessment flow range. Later summer flows from 2011 and 2012 were at or below the base flow of 0.10 m^3/s, which has been proposed as the summer base flow for the flow mitigation plan.

Table 1: Stream Discharge Calculated at Site K5 during the Summers of 2011 and 2012

Date	Discharge (m^3/s)	Wetted Width (m)
July 8, 2011	0.14	9.6
July 9, 2011	0.13	9.6
August 7, 2011	0.08	9.6
June 20, 2012	0.62	10.7
June 25, 2012	0.38	10.1
June 27, 2012	0.36	10.2
August 17, 2012	0.10	9.9

Note: m^3/s = cubic metres per second; m = metre.

4.0 FISH BARRIER AND HABITAT ASSESSMENT

Major barriers to upstream and downstream fish passage were confirmed under low flow conditions ranging from 0.08 m^3/s to 0.14 m^3/s at streams L1a, M4 and L3 during the 2011 assessment (Table 2). Restrictions to fish movement and potential upstream barriers to adult fish movement were also noted at streams L1b and L1c at the low flows observed in 2011. Passage was possible at flows ranging from 0.36 m^3/s to 0.62 m^3/s at all streams assessed during June 2012, with some potential restrictions to movement in Stream L1a starting to be observed at 0.364 m^3/s.

All streams assessed contained abundant cover and suitable depth to support adult and juvenile Arctic grayling at all flows observed, including under low flow conditions during the August (summer) assessments. Abundant cover and suitable velocity refuge was present under all flow conditions suitable for Arctic grayling rearing. Spawning habitat for Arctic grayling was present in small amounts in streams L3, L1a, L1b, and L1c, and was more abundant in Stream M4. A summary of average and maximum depths and substrate characteristics recorded at the habitat transects within each stream for a high and low flow is shown in Table 3. Supplemental habitat descriptions of the five streams included in the fish passage assessed in 2011 and 2012 are provided in Annex J of the EIS (De Beers 2010).

Table 2: Assessment of Potential Barriers to Fish Movement in Streams between Kennady Lake and Lake 410

Date	Discharge @ Site K5 (m^3/s)	Barrier Assessment [a]				
		Stream M4	Stream L1a	Stream L1b	Stream L1c	Stream L3
June 20, 2012	0.62	none	none	none	none	none
June 25, 2012	0.38	none	none	none	none	none
June 27, 2012	0.36	none	restricted	none	none	none
July 8, 2011	0.14	upstream	upstream	restricted	none	full
August 17, 2012	0.10	upstream	upstream	restricted	none	full
August 7, 2011	0.08	full	full	restricted	restricted	full

Note: m^3/s = cubic metres per second
[a] Barrier Descriptions: "none" = no barriers observed for any life stage; "restricted" = upstream passage could be possible but likely limited, downstream movements possible; "upstream" = upstream movements by adults blocked, downstream movements possible; "full" = full barrier to upstream and downstream movements by all life stages.

Table 3: Assessment of depth characteristics in streams between Kennady Lake and Lake 410

Date	Discharge @ Site K5 (m^3/s)	Stream	Transect	Average Depth (m)	Maximum Depth (m)	Dominant / Subdominant Substrate Characteristics
June 20, 2012	0.62	M4	T1	0.22	0.40	gravel / boulder
			T2	0.47	0.94	cobble / boulder
			T3	0.24	0.32	boulder / cobble
		L1b	T1	0.24	0.51	boulder / cobble / gravel
			T2	0.22	0.42	cobble / boulder / gravel
		L1c	T1	0.31	0.55	boulder / sand
			T2	0.28	0.36	boulder / cobble
		L3	T1	0.26	0.54	boulder
			T2	0.22	0.42	boulder / cobble

Table 3: Assessment of depth characteristics in streams between Kennady Lake and Lake 410 (continued)

Date	Discharge @ Site K5 (m^3/s)	Stream	Transect	Average Depth (m)	Maximum Depth (m)	Dominant / Subdominant Substrate Characteristics
August 17, 2012	0.10	M4	T1	0.10	0.16	gravel / boulder
			T2	0.31	0.74	cobble / boulder
			T3	0.12	0.37	boulder / cobble
		L1b	T1	0.17	0.46	boulder / cobble / gravel
			T2	0.16	0.25	cobble / boulder / gravel
		L1c	T1	0.14	0.26	boulder / sand
			T2	0.13	0.17	boulder / cobble
		L3	T1	0.17	0.35	boulder
			T2	0.08	0.15	boulder / cobble

Note: m = metre.

4.1 Stream M4

Photographs of habitat transects, barrier locations and aerial views are presented in Appendix A (Plate 05 through Plate 16). Stream M4 maintained good connectivity upstream to Lake M4 under all flow conditions assessed. Near the downstream end of the channel, the watercourse widens and disperses into a large boulder field with the channel splitting into multiple small braided and discontinuous channels, with lower flows resulting in a barrier to upstream and downstream movement of adult fish (Appendix A, Plates 06, 09, and 10). Some potential downstream movement by fry might be possible, although difficult, at flows down to 0.10 m^3/s through sub-surface channels that are likely present between boulders; however, a complete barrier was likely present at 0.08 m^3/s. The braided channels were passable over the full range of higher flows observed in June 2012 (Appendix A, Plates 11 and 12).

Habitat consists of primarily deep and shallow runs with boulder, cobble, and gravel substrates throughout (Appendix A, Plate 13 through Plate 16). Good Arctic grayling spawning and rearing habitat was observed throughout the upper portion of the channel. Numerous adult and juvenile Arctic grayling were observed throughout Stream M4 during July and August trips in 2011 and in June 2012. Juvenile northern pike were also observed in August 2011. A small number of juvenile Arctic grayling were observed in August 2012. As larger bodied fish were observed within Stream M4 at discharges where downstream movement was likely not possible, it is assumed that these fish likely move upstream to Lake M4 to overwinter.

4.2 Stream L1A

Stream L1a has a major barrier to upstream fish movement caused by a boulder ledge that lacks surface flow under low flow conditions (Appendix A, Plates 21 and 22). Downstream movement by fry is likely possible at flows down to 0.10 m^3/s, as water flow was observed moving underneath and between small gaps in the boulders; a complete barrier was beginning to form at 0.08 m^3/s. Upstream passage was possible at 0.38 m^3/s and higher; however, shallow depths may have started to restrict upstream passage at 0.36 m^3/s, although passage was still likely possible (Appendix A, Plates 23 and 24).

The channel in Stream L1a is confined with a steeper gradient than the other channels observed downstream of Kennady Lake. At higher flows, some areas of high velocity and shallow depth were observed within chute areas, with point velocities measured between 1.29 m/s and 1.79 m/s (Appendix A, Plate 20); however, adult and juvenile Arctic grayling were observed above this point and a barrier was not likely. As flows receded in 2012, shallower depths within the chute habitats present may also begin to restrict upstream movements of adult fish (Appendix A, Plate 19). Fish in the lower section of Stream L1a would not likely be able to move upstream as flows recede throughout the summer.

Arctic grayling fry were observed in the July 2011 survey and adult and juvenile Arctic grayling observed throughout the stream in July 2012, suggesting that this stream is used for spawning and rearing. Abundant rearing habitat is present; however, clean spawning gravel is limited to a few small areas. Abundant deeper water habitat with good cover created by boulders was present at all flows observed. No fish were observed during the August field visits in 2011 or 2012, which may suggest the fry observed in the spring had emigrated out of the stream earlier in the summer.

4.3 Stream L1B

Fish passage at Stream L1b was likely restricted as water flowed through a boulder field near the outlet (Appendix A, Plate 28). At flows less than 0.14 m^3/s, surface water was flowing overtop small interstitial spaces of the boulders and cobble, which would allow for downstream movements of fry and small juvenile fish; however, adult movement would be restricted. No barriers to upstream or downstream fish movements were noted for flows between 0.36 m^3/s and 0.62 m^3/s during the field assessments conducted in June 2012.

Arctic grayling fry were observed in the July 2011 assessment; however, no fish were observed in the August 2011 assessment. One juvenile Arctic grayling was observed during the August 2012 assessment. The habitat within Stream L1b is comprised mainly of moderate to shallow run habitat with suitable depth and cover present for all life stages of Arctic grayling at all flows investigated during 2011 and 2012 (Appendix A, Plate 25 though Plate 27).

4.4 Stream L1C

Fish passage for all life stages of Arctic grayling is possible at all flows observed during the 2011 and 2012 surveys (Appendix A, Plate 33 through Plate 36). Flows passed through a boulder field near the mouth of the stream, which results in the flow becoming dispersed with the absence of a single clearly defined channel. Movements likely become restricted at flows of 0.10 m^3/s and lower; however, a suitable flow path was still present amongst the boulders.

During both 2011 and 2012, no barriers to fish movement through the site were found at Stream L1c, and both adult and juvenile Arctic grayling were observed throughout the site in both years, and during spring and summer seasons. Suitable depth and cover is provided for all life stages of Arctic grayling throughout the stream with abundant boulders and cobble. Small areas of gravel provided suitable spawning habitat at all flows observed. Terrestrial vegetation was becoming flooded in some sections at a flow of 0.62 m^3/s.

4.5 Stream L3

In Stream L3, fish movement would be completely restricted for all life stages at flows of 0.14 m^3/s and lower (Appendix A, Plate 38). A large section of completely dry channel located at the downstream end of the stream was observed during July and August 2011 and again in August 2012 (Appendix A, Plates 41 and 42). This section was wetted and passable during all flows observed in June 2012 ranging from 0.36 m^3/s to 0.62 m^3/s (Appendix A, Plates 43 and 44).

Upstream of the barrier, habitat consists of primarily moderate to shallow runs and flats with depth and cover suitable for all life stages of Arctic grayling at all flow conditions assessed (Appendix A, Plate 45 through

Plate 48). Arctic grayling fry and juvenile life stages were observed in the 2011 and 2012 surveys. Near the upstream end of Stream L3, areas of flooded vegetation provide suitable spawning and rearing habitat for northern pike. Juvenile northern pike were observed in July 2011 and June 2012. Juvenile Arctic grayling were observed during the August 2011 assessment, and with the downstream barrier present, this suggests that fish in this stream likely move upstream to Kennady Lake to overwinter.

5.0 FLOW MITIGATION ASSESSMENT AND UPDATE TO EIS CONCLUSIONS

Barriers to fish passage form in streams between Kennady Lake and Lake 410 as a result of low flows, creating unsuitable depths for fish movements. Results of barrier surveys conducted in 2004 and 2005 indicated that a barrier to adult Arctic grayling movement exists at Stream L1a, Stream L3, and Stream M4, when the discharge at the outlet of Kennady Lake is at 0.23 m^3/s (De Beers 2010). At a discharge of 0.78 m^3/s, no apparent barriers to adult Arctic grayling movement exist in any of the nine streams between Kennady Lake and Lake 410 (De Beers 2010). The results of the 2011 and 2012 barrier assessment confirmed the findings of the previous studies and found additional barriers at flows less than 0.14 m^3/s in Stream L1b and a likely additional barrier at site L1c at flows less than 0.10 m^3/s.

Reductions in flow downstream of Kennady Lake were predicted to occur during operations and closure, and without mitigation, would likely result in impacts to the downstream habitat and fish populations (De Beers 2011). As a result, a flow mitigation plan was developed to offset the impacts of the Project. The objective of the flow mitigation plan that was presented in the Plan is to:

- sustain the Arctic grayling population and avoid a harmful alteration to fish habitat during operations and refilling by providing upstream migration access for Arctic grayling three out of four years;
- maintain suitable habitat conditions during egg incubation and for fry rearing in each of the spawning years;
- allow for outmigration in the late summer to overwintering habitats; and
- provide a seasonally appropriate hydrograph based on the natural timing and duration of high flow and low flow events.

Three intermediate flows were assessed in 2012 between 0.36 and 0.62 m^3/s, and fish passage was assessed as possible at all sites across this entire range in flows. Based on these results, the assumption presented in the Plan that fish passage would be possible at flows greater than 0.4 m^3/s is validated. Habitat conditions observed at flows at and just above 0.10 m^3/s found suitable depth and cover throughout the reaches for all life stages of Arctic grayling that would support the use of 0.10 m^3/s as a summer base flow for the flow mitigation plan. The current information available would support maintaining the flow mitigation plan in its current form pending future monitoring results.

5.1 Mitigation Flow Assessment

Site observations and habitat measurements conducted during the 2011 and 2012 assessment would indicate that the available habitat within the assessed streams would be suitable to support all life stages of Arctic grayling at all flows observed. Adequate depth, cover, and substrates are available across the full range of flows assessed (i.e., from 0.08 m^3/s up to 0.62 m^3/s). In addition to the visual habitat assessment, the mitigation flow regime was also used to evaluate changes in wetted width, depth, and velocity using the available hydraulic modelling information and the predicted hydrology time series under operations and closure with flow mitigation in place. The evaluation followed the same methods as presented in Section 9.10 of the 2010 EIS (De Beers 2010).

5.1.1 Mitigation of Changes to Fish Habitat Availability

Table 4 presents the changes in wetted width from baseline conditions to operations (unmitigated), as well as the mitigated improvements with the flow mitigation plan in place. Changes in the wetted width of the channel from baseline to operations vary by stream and type of water year (Table 4). Reduction in wetted width is observed at both high and low flows, and during all seasons at most sites; the magnitude of change from baseline generally declines moving downstream, with the largest changes found in Streams K5 and L3 (Table 4).

Mitigated flows show an improvement in wetted width under all conditions (Table 4). Although a reduction in wetted width is still predicted under the mitigation flow regime, field observations across the range of flows provided under the flow mitigation plan would indicate that there is abundant habitat available for the numbers of fish that have been documented in the streams between Kennady Lake and Lake 410.

Table 4: Comparison of Average July Wetted Widths in Streams in the L and M Watersheds between Baseline, Operations, and Mitigated Conditions

Stream	Phase	Wetted Width (m) by Return Period for July				
		1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry
K5	Baseline	39.98	36.52	18.41	11.85	10.67
	Operations	11.50	9.37	6.18	5.67	5.27
	Mitigation	18.00	15.66	13.39	7.50	5.42
L3	Baseline	49.99	47.33	37.86	29.30	8.67
	Operations	25.01	8.22	5.38	4.61	4.49
	Mitigation	38.21	36.32	32.17	8.06	4.84
L2	Baseline	36.60	26.61	18.91	13.74	11.93
	Operations	16.08	13.31	11.38	9.81	9.06
	Mitigation	22.42	18.95	15.67	12.73	11.49
L1	Baseline	54.81	49.14	43.91	36.45	21.25
	Operations	43.96	39.54	19.90	11.55	9.63
	Mitigation	44.86	42.29	37.24	23.88	17.85
M4	Baseline	65.14	57.11	50.27	35.81	28.35
	Operations	51.88	45.19	29.09	18.98	14.51
	Mitigation	54.84	51.83	42.05	29.60	22.23
M3	Baseline	51.08	49.98	47.04	43.93	39.79
	Operations	47.60	45.64	42.24	34.38	24.28
	Mitigation	49.74	47.57	45.03	41.07	34.75
M2	Baseline	42.45	40.45	27.37	17.01	12.75
	Operations	29.19	23.87	15.88	10.05	7.86
	Mitigation	39.81	29.27	22.29	15.36	9.54
M1	Baseline	59.07	56.77	46.83	27.41	20.08
	Operations	50.77	41.72	21.66	18.13	16.36
	Mitigation	54.24	47.68	36.08	21.21	17.82

Note: m = metre.

5.1.2 Mitigation of Changes to Fish Habitat Suitability

The depth and velocity of streams in the L and M watersheds are largely insensitive to changes in discharge, both from augmentation and reductions in flow (De Beers 2010). Late summer is likely a critical period in suitability of habitat as flows naturally decline. Depth is slightly more sensitive to flow reductions than velocity, although the depths under the mitigation plan remain within the range necessary for Arctic grayling spawning and for young-of-the-year (YOY) rearing (Table 5). Although reductions in depth are still predicted under the flow mitigation plan, the change from baseline conditions is small (i.e., less than 10 centimetres [cm] under all flow conditions and generally less than 5 cm). The average velocity in the channels remains almost unchanged from baseline for median flow conditions, with a small reduction occurring at both wet and dry periods (Table 6).

Table 5: Simulated Maximum Depths for Streams between Kennady Lake and Lake 410 under Baseline and Mitigation Flow Regimes for August

Stream	Phase	Maximum Depth (m) by Return Period for August				
		1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry
K5	Baseline	0.51	0.40	0.33	0.27	0.24
	Mitigation	0.41	0.35	0.24	0.19	0.17
L3	Baseline	0.66	0.62	0.53	0.41	0.37
	Mitigation	0.61	0.58	0.43	0.33	0.28
L2	Baseline	0.61	0.54	0.45	0.40	0.38
	Mitigation	0.52	0.47	0.41	0.37	0.34
L1	Baseline	0.58	0.54	0.49	0.44	0.42
	Mitigation	0.54	0.51	0.45	0.41	0.40
M4	Baseline	0.55	0.51	0.44	0.38	0.36
	Mitigation	0.50	0.46	0.40	0.35	0.33
M3	Baseline	0.66	0.60	0.54	0.48	0.46
	Mitigation	0.61	0.57	0.51	0.46	0.43
M2	Baseline	0.61	0.56	0.49	0.44	0.42
	Mitigation	0.57	0.52	0.46	0.41	0.39
M1	Baseline	0.58	0.54	0.46	0.42	0.40
	Mitigation	0.54	0.50	0.43	0.40	0.38

Note: m = metre

Table 6: Simulated Average Water Velocity Predicted for Baseline Flow Conditions and Under the Mitigation Flow Regime for August

Stream	Phase	Average Velocity (m/s) by Return Period for August				
		1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry
K5	Baseline	0.18	0.22	0.19	0.17	0.16
	Mitigation	0.20	0.17	0.17	0.15	0.14
L3	Baseline	0.14	0.13	0.14	0.16	0.16
	Mitigation	0.13	0.12	0.17	0.15	0.13
L2	Baseline	0.21	0.20	0.18	0.16	0.15
	Mitigation	0.20	0.19	0.16	0.14	0.13
L1	Baseline	0.15	0.14	0.13	0.12	0.12
	Mitigation	0.14	0.13	0.12	0.11	0.11

Table 6: Simulated Average Water Velocity Predicted for Baseline Flow Conditions and Under the Mitigation Flow Regime for August (continued)

Stream	Phase	Average Velocity (m/s) by Return Period for August				
		1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry
M4	Baseline	0.12	0.11	0.10	0.10	0.09
	Mitigation	0.11	0.11	0.10	0.09	0.09
M3	Baseline	0.10	0.09	0.08	0.07	0.06
	Mitigation	0.09	0.08	0.07	0.06	0.06
M2	Baseline	0.30	0.28	0.27	0.26	0.25
	Mitigation	0.29	0.28	0.26	0.25	0.24
M1	Baseline	0.19	0.19	0.20	0.18	0.17
	Mitigation	0.19	0.18	0.19	0.17	0.17

Note: m/s = metres per second.

5.2 Future Monitoring

Initially, the focus of the flow mitigation plan monitoring was to test the assumptions of fish passage and habitat suitability under a range of flows. Future monitoring, once the flow mitigation plan has been implemented, will be used to inform aspects of the flow mitigation plan (such as, ramping rates to avoid fish stranding, duration of flow augmentation targets for each life stage, etc.), but are not critical to the development of the plan at this stage of project planning. The details of the monitoring program will be incorporated into the overall Aquatic Effects Monitoring Program (AEMP) as part of the permitting process. A successful flow mitigation plan will be measured by achieving the desired biological objective while minimizing the level of disturbance to the adjacent landscape.

6.0 CONCLUSIONS

The objectives of the Plan focus on maintaining fish passage and habitats to sustain the fish populations downstream of Kennady Lake for the duration of operations and closure, until the flow regime returns to near baseline conditions at post-closure. Based on the field results and the analysis of changes to wetted width, depth and velocity under the mitigation flow regime, the Plan is expected to satisfy the stated objectives. Future monitoring programs will be developed as part of the AEMP to confirm the Plan is achieving the stated objectives, and if required, modifications to the Plan will be implemented.

Due to the early timing and short duration of peak flows in the spring of 2011, a direct assessment of fish passage was not achieved; however, Arctic grayling were observed throughout the streams downstream of Kennady Lake and successful spawning was confirmed. With a short duration peak flow in 2011 of less than 0.60 m^3/s, it was confirmed that fish passage was possible at a lower flow than previously identified, and that the flow mitigation plan could achieve fish passage at a moderate flow occurring throughout the month of June. The assessment results from 2012 further refined the assumption of when fish barriers persist, with no barrier to fish passage observed within the flow range of 0.36 m^3/s and 0.62 m^3/s. Restrictions to passage were becoming evident at 0.36 m^3/s; however, fish passage was possible.

Based on the assessment of the downstream barriers to fish movement in the L and M watersheds conducted in 2011 and 2012, it can be concluded that the Plan, with an assumed passage threshold of 0.40 m^3/s and a passage augmentation period lasting four weeks after ice-out should be adequate to provide seasonal access to the streams between Kennady Lake and Lake 410. Furthermore, the base flow target of 0.10 m^3/s also appears to provide suitable fish habitat to allow for rearing and outmigration to occur.

Although a reduction in wetted width would still occur (Section 5.1.1), the availability and suitability of habitat provided under the mitigation flow regime would support the fish populations between Kennady Lake and Lake 410. This is based on the observed habitat conditions within the flow range provided by the flow mitigation plan and the results of the updated assessment of changes to depths and velocity over a wider range of flows. At a moderately high flow of 0.62 m^3/s, which would be frequently achieved under the Plan, flooding of terrestrial vegetation was observed and lateral habitat connectivity would be maintained under the flow mitigation plan.

Adult and juvenile Arctic grayling were observed within the assessment streams during periods when migration was blocked or restricted, suggesting that outmigration to overwintering habitat is likely limited to adjacent habitats under natural conditions. Fry have the potential to move to downstream habitats through several streams and lakes; however, adults and juveniles would be more restricted in their movements. Due to the number of barrier occurrences observed between Lake M4 and Kennady Lake, it is unlikely that late season migrations through multiple lakes and streams would be possible for adult and juvenile grayling under normal summer low flow conditions. The extent of Arctic grayling migrations downstream of Kennady Lake is still unknown and will be one of the focal points of future monitoring.

7.0 CLOSURE

We trust this technical memorandum provides you with the information you require at this time. Should you have any questions, or require further information please contact the undersigned.

GOLDER ASSOCIATES LTD.

Cameron von Bratt, M.Sc. (Zoology: Aquatic Health)
Aquatic Ecologist

Reviewed by:

Kasey Clipperton, B.Sc., M.E.Des.
Associate, Senior Fisheries Biologist

Kristine Mason, M.Sc., P.Biol.
Associate, Fisheries Biologist

John Faithful, B.Sc. (Hons)
Associate, Senior Water Quality Specialist

CVB/KC/cvb

8.0 REFERENCES

De Beers (De Beers Canada Inc.). 2010. Environmental Impact Statement for the Gahcho Kué Project. Volumes 1, 2, 3a, 3b, 4, 5, 6a, 6b, 7 and Annexes A through N. Submitted to Mackenzie Valley Environmental Impact Review Board. December 2010.

De Beers. 2011. Environmental Impact Statement for the Gahcho Kué Project. Volumes 3a Revision 2, 3b Revision 2, 4 Revision 2, and 5 Revision 2. Submitted to the Mackenzie Valley Environmental Impact Review Board in Response to the Environmental Impact Statement Conformity Review. July 2011.

Deegan, L.A., H.E. Golden, J. Harrison, and K. Kracko. 2005. Swimming Performance and Metabolism of 0+ year Thymallus arcticus. Journal of Fish Biology 67:910-918.

Golder (Golder Associated Ltd.). 2012a. Gahcho Kué Flow Mitigation Plan (June 2012). Technical Memorandum prepared by Golder Associates Ltd. for De Beers Canada Inc., June 29, 2012.

Golder. 2012b. 2011 Climate and Hydrology Supplemental Monitoring Report. Report No. 11-1365-0001/ DCN-049. Submitted to De Beers Canada Inc. March 2012.

Evans, C.L., J.D. Reist, and C.K. Minns. 2002. Life History Characteristics of Freshwater Fishes Occurring in the Northwest Territories and Nunavut, with Major Emphasis on Riverine Habitat Requirements. Canadian Manuscript Report of Fisheries and Aquatic Sciences. 2614: xiii + 169 p.

Hubert, W.A., R.S. Helzner, L.A. Lee, and P.C. Nelson. 1985. Habitat suitability index models and instream flow suitability curves: Arctic grayling riverine populations. U.S. Fish Wild. Serv. Rep. 82(10.110). 34 p.

Stewart, D.B., N.J. Mochnacz, J.D. Reist, T.J. Carmichael, and C.D. Sawatzky. 2007. Fish Life History and Habitat Use in the Northwest Territories: Arctic Grayling (*Thymallus arcticus*). Canadian Manuscript Report of Fisheries and Aquatic Sciences 2797: vi + 55 p.

APPENDIX A

REFERENCE PHOTOGRAPHS

Site: K5 (Photo comparisons at various discharges 2011/2012)

Plate 01: Site K5 looking from right downstream bank.
Photo taken July 8, 2011; Q = 0.08 m^3/s.

Plate 02: Site K5 looking downstream from left downstream bank.
Photo taken July 8, 2011; Q = 0.14 m^3/s.

Plate 03: Site K5 looking downstream. J
Photo taken June 25, 2012; Q = 0.38 m^3/s.

Plate 04: Site K5 looking across from right downstream bank.
Photo taken June 20, 2012; Q = 0.62 m^3/s.

Site: M4 (Aerial photos)

Plate 05: Site M4 - 2011 survey at the upstream inlet .
Photo taken July 8, 2011; Q=0.14 @ K5.

Plate 06: Site M4 - 2011 fish barrier at the downstream mouth.
Photo taken July 8, 2011; Q=0.14 @ K5).

Plate 07: Site M4 - 2012 survey at the upstream inlet.
Photo taken June 21, 2012, Q=0.62 @ K5.

Plate 08: Site M4 - 2012 with no barrier present .
Photo taken June 21, 2012; Q=0.62 @ K5.

Site: M4 (Photo comparisons at various discharges 2011/2012 at downstream barrier)

Plate 09: Stream M4 looking at fish barrier near outlet.
Photo taken August 7, 2011; Q = 0.08 m^3/s @ K5).

Plate 10: Stream M4 looking at fish barrier near outlet.
Photo taken July 8, 2011; Q = 0.14 m^3/s @ K5).

Plate 11: Stream M4 looking at fish barrier location identified at lower flows, no barrier present .
Photo taken June 27, 2012; Q = 0.36 m^3/s @ K5.

Plate 12: Stream M4 looking typical channel that was dry under lower flows, no barrier present.
Photo taken June 20, 2012; Q = 0.62 m^3/s @ K5.

Site: M4 (Photo comparisons of typical habitat conditions at various discharges 2011/2012 at Transect 3)

Plate 13: Stream M4 looking downstream from Transect 3 showing general habitat conditions.
Photo taken August 7, 2011; Q = 0.08 m^3/s @ K5.

Plate 14: Stream M4 looking downstream from Transect 3 showing general habitat conditions.
Photo taken July 8, 2011; Q = 0.14 m^3/s @ K5.

Plate 15: Stream M4 looking downstream from Transect 3 showing general habitat conditions.
Photo taken June 25, 2012; Q = 0.38 m^3/s @ K5.

Plate 16: Stream M4 looking downstream at Transect 3 showing general habitat conditions.
Photo taken June 20, 2012 Q = 0.62 m^3/s @ K5.

Site: L1A (Aerial Photos and fish observations)

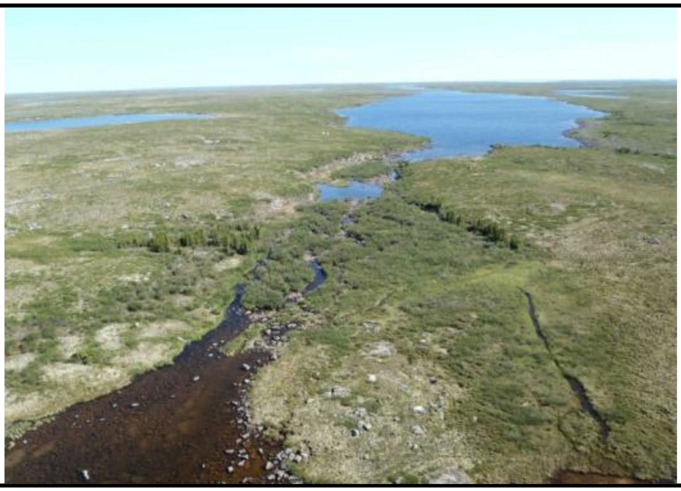

Plate 17: Stream L1A – 2011 survey
Photo taken: July 8, 2011; Q = 0.14 @ K5.

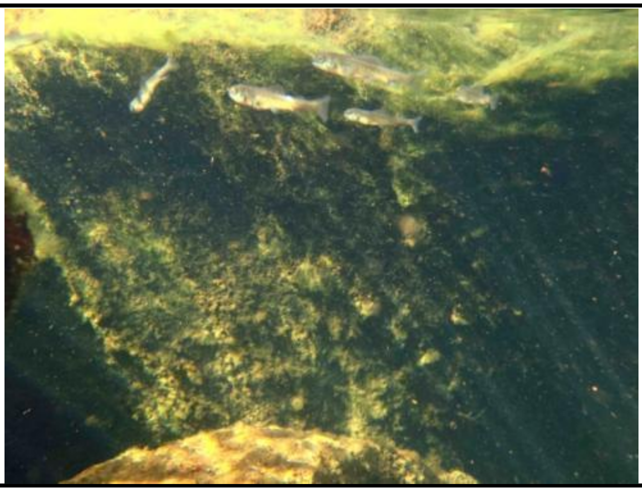

Plate 18: Stream L1A Arctic Grayling (ARGR) fry observed in flat open water area between barriers.
Photo taken July 9, 2011.

Plate 19: Stream L1A chute becoming shallow and potential restriction to upstream movement.
Photo taken June 27, 2012; Q = 0.36 @ K5.

Plate 20: Stream L1a high velocity chute with maximum velocity of 1.79 m/s
Photo taken June 20, 2012; Q = 0.62 @ K5.

Site: L1A (Photo comparisons at various discharges 2011/2012)

Plate 21: Stream L1A barrier near outlet looking upstream.
Photo taken August 7, 2011; Q = 0.08 @ K5.

Plate 22: Stream L1A barrier near outlet looking upstream.
Photo taken July 9, 2011; Q = 0.13 @ K5.

Plate 23: Stream L1A near outlet looking upstream with fish passage possible.
Photo taken June 27, 2012; Q = 0.36 @ K5.

Plate 24: Stream L1A barrier near outlet looking across boulder ledge, fish passage possible.
Photo taken June 20, 2012; Q = 0.62 @ K5.

Site: L1B (Photo comparisons at various discharges 2011/2012)

Plate 25: Stream L1B looking downstream at Transect 2.
Photo taken August 7, 2011; Q = 0.08 m^3/s @ K5.

Plate 26: Stream L1B looking downstream at Transect 2.
Photo taken July 9, 2011; Q = 0.13 m^3/s @ K5.

Plate 27: Stream L1B looking downstream at Transect 2.
Photo taken June 21, 2012; Q = 0.62 m^3/s @ K5.

Plate 28: Stream L1b restriction to fish passage for adult fish
Photo taken July 9, 2011; Q = 0.13 m^3/s @ K5.

Site: L1C (Photo comparisons at various discharges 2011/2012)

Plate 29: Stream L1c looking at upstream under low flows.
Photo taken July 9, 2011; Q = 0.13 m^3/s @ K5.

Plate 30: Stream L1c looking at downstream end under high flows.
Photo taken June 21, 2012; Q = 0.62 m^3/s @ K5.

Plate 31: Stream L1c riffle-pool habitat where adult Arctic grayling were observed.
Photo take June 21, 2012; Q = 0.62 m^3/s @ K5.

Plate 32: Adult Arctic grayling observed at site L1C during the August 2011 survey.

Plate 33: Stream L1C looking upstream from Transect 1 at potential fish passage restriction.
Photo taken August 7, 2011; Q = 0.08 m^3/s @ K5.

Plate 34: Stream L1C looking upstream from Transect 1 at potential fish passage restriction.
Photo taken August 17, 2012; Q = 0.10 m^3/s @ K5.

Plate 35: Stream L1C looking upstream towards Transect 1 at the potential fish passage restriction .
Photo taken July 9, 2011; Q = 0.13 m^3/s @ K5.

Plate 36: Site L1C looking upstream towards Transect 1 with no restriction to fish passage.
Photo take June 21, 2012; Q = 0.62 m^3/s @ K5.

Site: L3 (Aerial photos)

Plate 37: Stream L3 - 2011 survey at the upstream inlet .
Photo taken August 7, 2011; Q = 0.08 m^3/s @ K5.

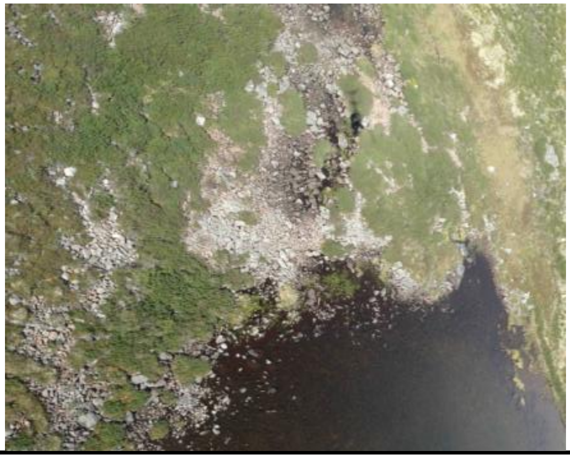

Plate 38: Stream L3 - 2011 survey at the downstream mouth showing no connectivity.
Photo taken August 7, 2011; Q = 0.08 m^3/s @ K5.

Plate 39: Site L3 - 2012 survey at the upstream inlet .
Photo taken June 20, 2012; Q = 0.62 m^3/s @ K5.

Plate 40: Site L3 - 2012 survey at the downstream mouth .
Photo taken June 20, 2012; Q = 0.62 m^3/s @ K5.

Site: L3 (Photo comparisons of fish barrier at various discharges 2011/2012)

Plate 41: Stream L3 looking upstream at the complete fish barrier near outlet. Photo taken August 7, 2011; Q = 0.08 m^3/s @ K5.

Plate 42: Stream L3 looking upstream at the potential fish barrier near outlet. Photo taken July 8, 2011; Q = 0.14 m^3/s @ K5.

Plate 43: Stream L3 looking upstream near outlet, no barrier present. Photo taken June 25, 2012; Q = 0.38 m^3/s @ K5.

Plate 44: Stream L3 looking upstream near outlet, no barrier present. Photo taken June 20, 2012; Q = 0.62 m^3/s @ K5.

Site: L3 (Photo comparisons of fish habitat at various discharges 2011/2012)

Plate 45: Stream L3 looking upstream at Transect 1 at shallow and moderate depth run habitat.
Photo taken August 7, 2011; Q = 0.08 m^3/s @ K5.

Plate 46: Stream L3 looking upstream at Transect 1 at shallow and moderate depth run habitat.
Photo taken July 8, 2011; Q = 0.14 m^3/s @ K5.

Plate 47: Stream L3 looking upstream at Transect 1, some flooded vegetation observed.
Photo taken June 27, 2012; Q = 0.36 m^3/s @ K5.

Plate 48: Stream L3 looking upstream at Transect 1, some flooded vegetation observed
Photo taken June 20, 2012; Q = 0.62 m^3/s @ K).