In 2004, Dillon Consulting Ltd (Dillon) developed a design for fish habitat compensation works to be constructed in West Island Stream (ws1), which runs from West Island Lake to Lac de Gras, Northwest Territories (Figure 1). The proposed work is as part of Diavik Diamond Mines Inc. (DDMI) Fish Habitat Compensation Plan for the Diavik Mine. As described in Dillon (2004), stream ws1 currently provides limited access to West Island Lake during spring and summer months, and the stream is not being used by fish for migration and/or spawning habitat due to a series of cascades which form a barrier to passage near the outlet to Lac de Gras. The habitat compensation works proposed by Dillon included instream deflector berms, stream channelization, bank armouring, a step-pool sequence and the development of instream spawning habitats. The proposed works were intended to improve fish migration, spawning and nursery habitats.

Due to limited availability of timber and challenges of construction using large boulders, DDMI requested that Golder modify Dillon’s design to include the use of gabion baskets instead of timber cribbing and boulder structures, and to prepare issued-for-construction (IFC) drawings for the proposed works. This Memorandum describes the proposed modifications based on the use of gabion baskets. The modifications described in this Memorandum are provided to DDMI for review and approval prior to finalizing the detailed design package. Golder understands that the consultation with relevant regulatory agencies will be conducted independently by DDMI, and that DDMI will also engage with the University of Alberta (UofA) to provide review on the proposed design modification from the aquatic biology perspective.

The scope of work described in this Memorandum is limited to the hydrotechnical engineering aspects only, and does not include any specific provisions for geotechnical engineering, the investigation, testing or assessment of the potential presence or impact of soil or groundwater contamination at the site, or bioscience services.
1.0 DESIGN CONSIDERATIONS

1.1 ws1 Hydrology

As shown in Figure 2 (from Praetorian, 2011), Stream ws1 appears to have a fairly well defined, low-gradient (0.15%) channel from Lake w1 to about Sta. 0+100 where it splits into at least two channels within an area of bog, before converging back into a single main channel again at about Sta.0+250. Between Sta. 0+250 and 0+350 the single main channel is well defined with a moderate gradient (1.3-2.2%). Below Sta. 0+350, the main channel again splits into at least two channels, and includes the steep, cascade reach (12.8%) between Sta. 0+420 and 0+440, before entering Lac de Gras at about Sta. 0+465. The steep cascade section currently acts as a barrier for fish migration. It also appears that the poorly-defined channel between 0+100 to 0+250 may act as an additional barrier to migration upstream to Lake w1.

Dillon Report

As described by Dillon (2004), flows entering ws1 stream originate mainly from West Island Lake, and to a minor extent from water entering into the intervening area between Lake w1 and Lac de Gras. Dillon (2004) estimated the drainage area at about 1.6 km²; and, estimated the mean annual and 1 in 5 year return period peak flows at approximately 0.08 m³/s and over 0.5 m³/s, respectively. Maximum flows in ws1 Stream from the Dillon report are about 3 m³/s (Figure 4.1 in Dillon, 2004).

University of Alberta Measurements

Students from the University of Alberta measured flows at three sections of ws1 Stream channel during the summer months of 2009, 2010 and 2011. Based on un-published data collected during this time, daily average flows for the months of June and July at the downstream end of Stream ws1 generally average between 0.04 and 0.07 m³/s, but have been observed to be as high as 0.4 m³/s.

Based on the above information, the following channel design flows have been adopted for the Golder has assumed that, for our proposed design modifications presented herein:

- Average low flow of 0.05 m³/s;
- Annual maximum flow of 0.4 m³/s; and
- Maximum flow of 3 m³/s.

1.2 Fish Habitat Requirements

Golder understands that the fish habitat compensation works for ws1 are intended to meet two main objectives:

- Remove the cascade located near the outlet of ws1 Stream to Lac de Gras and improve fish passage/migration opportunities along the lower section of the channel.
- Increase fish habitat in the channel segment immediately upstream of the cascade by better defining the highly braided channel and installing spawning habitat.
Golder understands that the target species of the proposed habitat compensation works is Arctic grayling (*Thymallus arcticus*). Based on available literature and design considerations provided by Dillon (2004), it is estimated that sustained water velocities of up to 0.8 m/s and maximum jump heights of 0.4 m would be required to allow for migration of adult Arctic grayling. Furthermore, it is understood that spawning habitats for this species require water velocities under 0.4 m/s and water depths of about 0.1 m to 0.6 m.

### 2.0 PROPOSED DESIGN CONCEPT

The following sections describe the proposed fish habitat compensation design modifications based on Golder’s understanding of the design proposed by Dillon (2004), and the construction materials and equipment available to DDMI.

Survey information provided by Praetorian Construction Management (Praetorian 2011) has been used as a basis for the design modifications and location of proposed works (Figure 2). Note that the stations in Praetorian’s survey differ from those reported by Dillon (2004).

The fish habitat compensation works described below are provided for preliminary review and comment by DDMI. Details and quantities will be reviewed and confirmed during detailed design.

### 2.1 Channel Excavation

It is proposed that a channel be excavated from Sta.0+330 downstream to Lac de Gras, to create a new main channel (Figure 3). The inlets of existing channels would be blocked with gabion baskets or boulders (where available), where required, to concentrate low flows into the main channel. The proposed channel would have a bottom width of 1 m wide, 2H:1V side slopes, and longitudinal bed slope between 1.4 to 4% (Table 1).

**Table 1: Characteristics of Excavated Channel (to be confirmed during detailed design)**

<table>
<thead>
<tr>
<th>Channel Section</th>
<th>Bed Width (m)</th>
<th>Bed Slope (%)</th>
<th>Invert Elevation (m) upstream / downstream</th>
<th>Approx. Channel Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sta.0+330 to Sta.0+400</td>
<td>1</td>
<td>2</td>
<td>419 / 417.5</td>
<td>0.4 – 1.3</td>
</tr>
<tr>
<td>Sta.0+400 to Sta.0+435</td>
<td>1</td>
<td>4</td>
<td>417.5 / 416.1</td>
<td>1.2 – 1.5</td>
</tr>
<tr>
<td>Sta.0+435 to Sta.0+470</td>
<td>1</td>
<td>1.4</td>
<td>416.1 / 415.7</td>
<td>0.2 – 1.2</td>
</tr>
</tbody>
</table>

1 Finished channel (after installation of spawning substrate)

### 2.2 Riffle Pool Configuration (Sta. 0+330 to 0+400)

Fourteen riffle-pool complexes at an approximate spacing of 5m are proposed between Sta.0+330 to 0+400 (Figures 4 and 5). Each riffle-pool complex would be constructed with a gabion basket deflector approximately 0.5 m high x 0.3 m wide and 1.0 m long, filled with 8” minus jaw run. Deflectors would be placed adjacent to the stream banks at an approximately 450 pointing downstream, embedded at least 0.3 m, and keyed into the channel banks about 0.5 m. A layer of spawning material (filled up to the finished channel bed) approximately 0.5 m wide, 2 m long and 0.2 m thick would be placed downstream of each deflector. For each complex, a pool
would be excavated adjacent to the spawning material, along the opposite bank. A section of the opposite bank toe approximately 2 m long would be armoured along the length of the pool using a 0.5 m wide x 0.7 m tall x 2 m long gabion basket filled with 8” minus jaw run or; alternatively, using 0.5 m diameter (minimum) boulders, if available.

The banks along this segment of the channel shall be re-vegetated to provide over-hanging vegetation cover for fish. Methodologies and materials for bank re-vegetation should be prescribed by a vegetation specialist. Vegetation requirements have not been included in the preliminary estimate of quantities presented in this report.

Also, as recommended by Dillon (2004), boulders shall be randomly placed along this segment of the channel to provide resting locations and additional cover habitat. These rocks shall have a diameter of at least 500 mm and be embedded into the channel bed at least 200 mm.

### 2.3 Step Pool Complexes (Sta. 0+400 to 0+440)

The design of step-pool structures are based on a jump height of 0.2m, which is half of the maximum jump height for Arctic grayling (Thymallus arcticus), in order to accommodate migration. Step pool complexes are proposed approximately every 5 m from Sta. 0+400 to Sta. 0+440 (Figures 6 to 8). About 9 of these structures shall be distributed along the channel and spaced as required to maintain water depth along the entire channel.

Each step pool complex shall consist of a geomembrane-lined v-shaped rock filled gabion basket and a 0.4 m (minimum) deep resting pool constructed immediately downstream. Each basket shall be 4.0 m long x 0.5 m wide (at the base and shaped to be narrower at the top) x 0.5 m high, and shall be embedded in the channel by at least 0.3 m. The gabion basket weirs shall be shaped to concentrate flows at the center of the channel.

Also, as recommended by Dillon (2004), boulders shall be randomly placed downstream of the weirs and within the pools to provide resting locations for migrating fish. These rocks shall have a diameter of at least 500 mm and be embedded into the channel bed at least 200 mm.

### 3.0 PRELIMINARY ESTIMATE OF MATERIALS QUANTITIES

Table 2 summarized our estimate of materials for the proposed works based on the design concept described above. This estimate should be considered preliminary, and may require adjustments during the detailed design of the proposed works.

For the preparation of this preliminary estimate, it has been assumed that boulders required in this design will be readily available on site and that vegetation requirements will be addressed by others.
Table 2: Preliminary Estimate of Materials Quantities

### Riffle Pool Complexes

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Dimensions</th>
<th>Quantity</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gabion baskets for toe armouring</td>
<td>0.5 m x 0.7 m x 2 m</td>
<td>14</td>
<td>un</td>
</tr>
<tr>
<td>Gabion baskets for deflectors</td>
<td>0.3 m x 0.5 m x 1 m</td>
<td>16</td>
<td>un</td>
</tr>
<tr>
<td>8&quot; minus (gabion baskets fill)</td>
<td>0.3 m x 0.5 m x 1 m</td>
<td>12</td>
<td>m³</td>
</tr>
<tr>
<td>Spawning material</td>
<td>2 m x 0.5 m x 0.2 m</td>
<td>3</td>
<td>m³</td>
</tr>
</tbody>
</table>

### Step Pool Complexes

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Dimensions</th>
<th>No.</th>
<th>Un.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gabion basket weirs</td>
<td>4 m x 0.5 m x 0.2-0.5 m</td>
<td>9</td>
<td>un</td>
</tr>
<tr>
<td>8&quot; minus (gabion baskets fill)</td>
<td>4 m x 0.5 m x 0.2-0.5 m</td>
<td>9</td>
<td>m³</td>
</tr>
<tr>
<td>Bituminous Liner</td>
<td>4 m x 1 m</td>
<td>36</td>
<td>m²</td>
</tr>
<tr>
<td>Spawning material</td>
<td>1.5 m x 1 m x 0.2 m &amp; 2 m x 1 m x 0.2 m (around pool)</td>
<td>4.5</td>
<td>m³</td>
</tr>
</tbody>
</table>

### 4.0 OTHER CONSIDERATIONS

Based on our cursory review of the existing site conditions, it appears that ws1 channel is ill-defined from Sta.0+100 to 0+250; however, this section of the channel was not targeted for improvement in Dillon’s design and has not been included in the design modifications presented in the document. Golder suggests that DDMI considers evaluating whether there are potential gains to fish migration/habitat that could be achieved by changes to this segment of the channel and/or if the works proposed for the downstream sections would be affected by these conditions.

A few recommendations by Dillon (2004) should be considered when planning construction works at West Island:

- **Vegetation Restoration:** The existing design incorporates re-vegetation of sections of the channel. It is recommended that a vegetation specialist is consulted to identify specific requirements of vegetation restoration.

- **Fisheries Biologist Monitoring and Review:** As recommended by Dillon (2004) a fisheries biologist shall be on site during construction to ensure constructed works meet the requirements to achieve fish passage.
5.0 CLOSURE

We trust that this information is sufficient for your immediate requirements. Should you have any questions regarding the above, or if you require further information, please do not hesitate to contact our office.

GOLDER ASSOCIATES LTD.

Jocelyn Ramsey, P.Eng.
Water Resources Engineer

Dan R. Walker, Ph.D., P.Eng.
Associate, Hydrotechnical/Water Resource Engineer

Attachments: Figures 1 to 8

JR/DRW/aw

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6.0 REFERENCES

Baki, A.B.M., 2011. An Eco-hydrological Investigation of Stream Fish Habitat in the Lac de Gras Watershed, N.W.T., Canada. 34th IAHR World Congress – Balance and Uncertainty, 33rd Hydrology and Water Resources Symposium, 10th Hydraulics Conference. 26 June to 1 July 2011, Brisbane, Australia.


This sketch is not a design drawing and shall be used for planning purposes only.
Lac de Gras

Route A (Blue)

Route B (Red)

Approx. extent of excavation

Riffle Pool Complex
Step Pool Complex

Proposed channel invert

This sketch is not a design drawing and shall be used for planning purposes only.
**Figure 4**

**West Island Design - STA 01330 - 01400**

- **Bank toe armour**: 0.5m wide x 0.7m high x 2m long gabion basket (embedded 0.3m)
- **0.2m deep pool**
- **Gabion basket deflector**

**Riffle Pool Complex - Plan View**

- **0.2m thick spawning material (filled up to channel bed)**
FIGURE 6

STEP POOL COMPLEXES - PROFILE

Exaggerated Vertical Scale

For Discussion Only
FIGURE 8

Channel Bed

- 1m
- 5m
- 0.5m
- 0.5m
- 0.2m
- 1.5-2m
- Gabion Basket
- Weir
- 0.2m layer of spawning material (filled up to channel bed).