APPENDIX X

CLOSURE DESIGN REPORTS

APPENDIX X-1

Fish Habitat Design – A154 Dike/Pit Area

REPORT ON

FISH HABITAT DESIGN FOR THE PIT SHELF AREAS AT THE DIAVIK DIAMOND MINE

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012-2331

EXECUTIVE SUMMARY

This report presents the detailed design for the creation of fish habitat on the interior of the water retention dikes (dikes) for the Diavik Diamond Mines Inc. diamond mine located on Lac de Gras in the Northwest Territories, Canada. This design was prepared in accordance with the "No Net Loss" plan prepared by Diavik Diamond Mines Inc.

This design is applicable to the A154, A418, and A21 pits; however, since only the A154 dike has been constructed, the majority of the information is based on A154. This design has been prepared by developing criteria for the end result, thus providing flexibility on the part of Diavik Diamond Mines Inc. as to how the end result is achieved.

The fish habitat creation on the interior of the dikes consists of placing material excavated from the open pits in the area between the pit crest and the toe of the dikes, to create an area generally varying from 3 m to 5 m below the mean normal water level for Lac de Gras. During mining operations, the toe of the fill will be set back from the edge of the pit crest for safety. At the completion of mining, the fill will be extended to the pit crest.

Detailed design drawings have been prepared for A154, and construction guidelines have been presented that can be applied to A418 and A21, once the dike location and pit geometry are determined.

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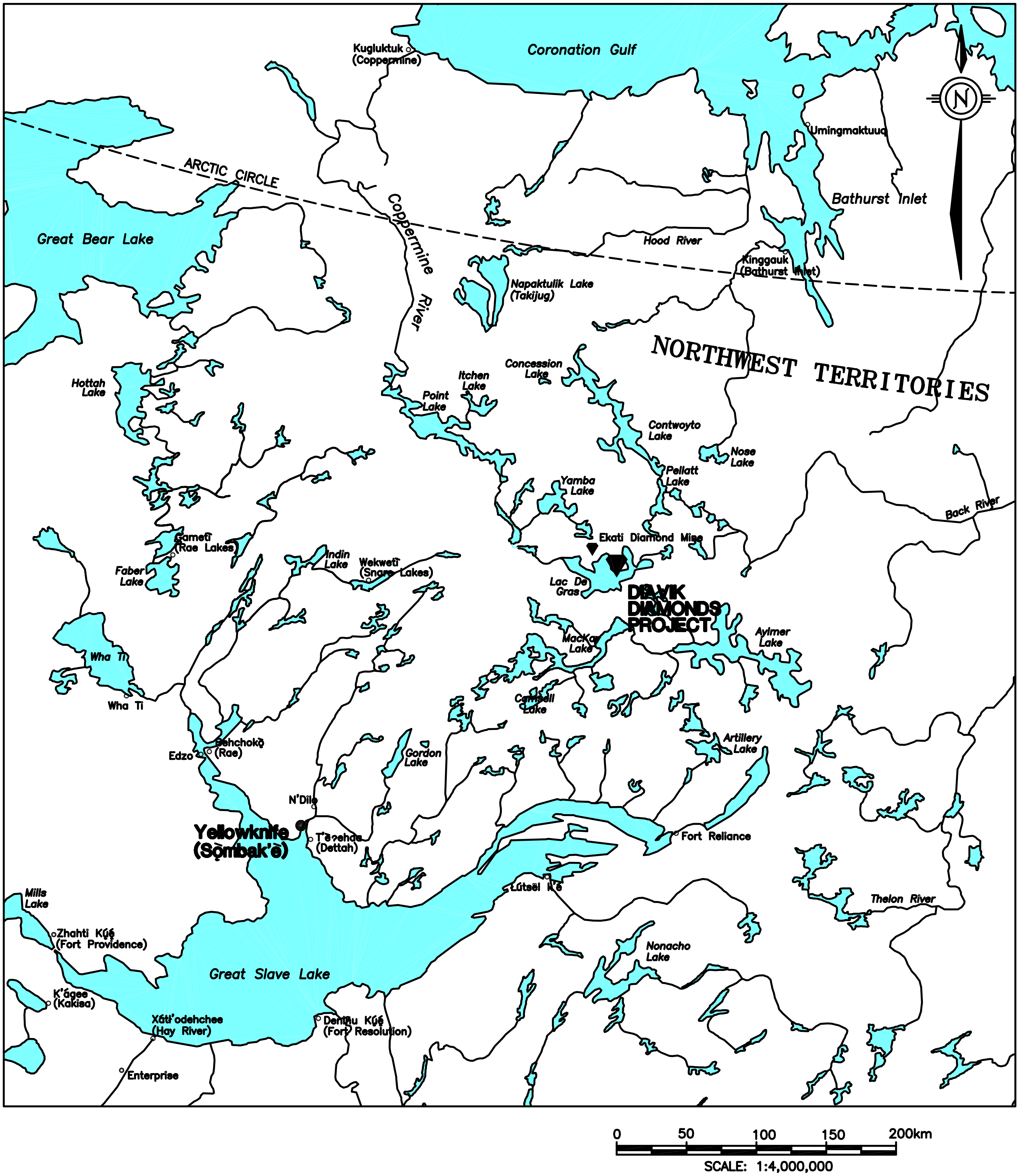
1.0 INTRODUCTION

This report presents the detailed design for the fish habitat compensation plan for the interior of the water retention dikes (*i.e.*, the pit shelf) at the Diavik Diamond Mines Inc. (DDMI) diamond mine in the Northwest Territories. The location of the mine is shown in Figure 1. This detailed design is based on the "No Net Loss" (NNL) Plan (Diavik 1998), and the conceptual fish habitat plan prepared by Golder Associates Ltd. (Golder). The conceptual fish habitat compensation plan for the pit shelf is to construct habitat on the shelf, by filling in the lower elevation (deeper water) areas. The general plan is to fill in the areas on the shelf that are deeper than 5 m of water depth with materials excavated during development of the pits.

As stated, this document provides the detailed design for the fish habitat compensation for the pit shelf; however, it does not provide specifications for construction. Rather, this document provides details for achieving the desired end result, while providing flexibility in how the end result is achieved. The requirement for this flexibility is due to some of the unknowns with respect to material parameters, mine operations (*i.e.*, blasting details, availability of various materials), and construction timing. The habitat design parameters were developed considering fish habitat, surface water runoff, and geotechnical issues. Design details with respect to surface water handling, material selection, construction, and other issues would be addressed by DDMI, to achieve the desired habitat compensation prior to reflooding of the diked areas.

This design applies to the A154, A418, and A21 pits; however, only A154 has been constructed to date. A418 is scheduled for construction in approximately 2007, with A21 currently scheduled for about 2013. Since the water retention dike (dike) locations and pit layouts for A418 and A21 have not been finalized, some of the design details may be modified for these two pits. It is intended that the design details (particularly setback distances and slope angles) be reviewed prior to construction of fish habitat compensation measures for A418 and A21, to incorporate knowledge gained from the construction and performance of A154. Also, it was understood that the pits will be developed in a series of expansion cuts, thus permitting the opportunity to monitor slope stability and pore-pressures in the in-situ materials in each pit well in advance of the excavation of the final pit slopes, and construction of the fish habitat fills.



LEGEND

- ○ COMMUNITY
- ▼ DIAMOND MINE/EXPLORATION

REFERENCE

SELECTED MINERAL DEPOSITS OF THE NORTHWEST TERRITORIES, DEPARTMENT OF ENERGY, MINES AND RESOURCES, MINERAL INITIATIVES 1991 TO 1996 REVISED OCTOBER, 1996

PROJECT

DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE

PROJECT LOCATION

Golder Associates
Saskatoon, Saskatchewan

PROJECT	012-2331.5310		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
CADD	RML	02/17/03	**FIGURE: 1**	
CHECK				
REVIEW				

N:\Active\2000\012-2331 Diavik Habitat Compensation\cad\LDD\ Drawing file: KeyplanA.dwg Mar 27, 2003 - 5:37pm

2.0 BACKGROUND

The objective of the fish habitat compensation measures on the interior of the water retention dikes is to provide nursery and rearing habitat similar to the pre-mine habitat in the north inlet. The conceptual design for the fish habitat compensation, as outlined in Golder's report entitled "Conceptual Design and Compensation Workplan for the Fish Habitat Compensation Program, Diavik Diamond Mines Inc., Lac de Gras", dated August 2001 consisted of:

- Re-contouring the pit shelf (area between the interior toe of the water retention dike and the crest of the pit slope) to provide habitat with a water depth of approximately 5 m after the dike is breached. New habitat will only be constructed where the water depth exceeded 5 m, the shallower areas of the shelf will not be excavated, as these areas already provide shallow water habitat. If fill is placed in this area during mine operations, setbacks will be required between the pit crest and the toe of the slope, as well as between the interior toe of the dike and the toe of the fill slope. These areas could be filled near the end of mining, or after completion of mining, if required.

- Constructing long, narrow, rocky reefs extending from the interior slope of the dike to the crest of the open pit. The reefs would be built in areas where the water depth is 5 m and would be approximately 2 m to 3 m high. Areas of granular and soft substrates between the reefs would be based on the conditions that existed in the north inlet.

- Modification of disturbed shoreline areas to establish conditions similar to pre-development. This may include placement of boulders in water depths up to about 5 m.

- Flooding the area after completion of habitat construction.

- Breaching the dikes to create shallow (minimum 2-m depth from low water) entrances, to deter the movement of larger fish into the nursery and feeding habitat, similar to the rearing habitat in the north inlet.

3.0 DESIGN PARAMETERS

3.1 Geotechnical Parameters

The information that was available to carry out the design consisted of bathymetric contours, till thickness isopachs, sediment thickness isopachs, till and sediment grain size and strength parameters, and earthquake seismic parameters. Production blasts have only recently begun, and thus some assumptions were made, and will be used in conjunction with the observational method to account for the potential of blast-induced instability. The majority of the information provided was specifically for the A154 dike and pit. However, the material parameters and construction guidelines for the fish habitat compensation on the pit shelves are similar for all three proposed open pits.

The till and sediment shear strength parameters used for slope stability analyses were obtained from the final A154 dike design report prepared by Nishi-Kohn/SNC-Lavalin (NKSL). The till and sediment were also observed and sampled to check that the material appeared consistent with the shear strength parameters used for the dike design. The till was also sampled to determine if the grain size of the material sampled was similar to that presented in the dike design report.

The till was sampled at the till dumps, as the active excavation areas were inaccessible at the time of sampling. Inactive excavation areas could not be sampled, as the till was frozen. The till that was sampled at the till dumps is considered representative of the till that was being excavated on October 14 and 15, 2002. It is not considered representative of the till throughout the A154 pit shelf area, as this is a very large area and the till is likely to vary across the shelf, as reflected in the range of grain sizes presented in the dike design report. The results of the grain size analyses are shown in Table 1. The grain size of the till that was sampled generally fall within the range of samples reported in the design report, but on average the samples obtained on October 14 and 15 contain more silt and less sand than the typical samples from the design report. The grain size information from the design report and the October 2002 samples are compared in Table 2.

Table 1
Grain Size Analysis Results

Location	Moisture Content (%)	Gravel Content (%)	Sand Content (%)	Silt/Clay Content (%)	Clay Content (%)
South Dump	6.2	52	23	25	nm
South Dump	9.5	23	34	43	nm
Upper Quarry	11.0	18	39	43	5
Upper Quarry	19.2	27	37	36	4
Batch Plant	7.6	33	35	32	nm
Batch Plant	31.2	7	46	47	nm
Average	14.1	26.7	35.7	37.7	NA

Notes: nm = not measured.
NA = not applicable, insufficient values measured.

Table 2
Summary of Grain Size Analyses

Material	Gravel Content (%)	Sand Content (%)	Silt/Clay Content (%)	Clay Content (%)
From Dike Design Report				
Till (range)	0 to 45	40 to 90	3 to 50	0 to 6
Till (average)	26	51	23	NA
Sediments (range)	0 to 15	0 to 75	10 to 100	0 to 33
Sediments (average)	2	29	63	6
From samples obtained in October 2002				
Till (range)	7 to 52	23 to 46	25 to 47	4 to 5
Till (average)	27	36	38	NA

Note: values from dike design report are approximate.
NA = not applicable, insufficient values measured.

The shear strength results reported in the design report are listed in Table 3. The samples were tested in a disturbed state and thus are considered appropriate for the placed material and are conservative for the in-situ material. The design parameters are considered reasonable for the till and sediments, considering the variability of the grain size of these materials.

Table 3
Shear Strength Parameters (from Final Dike Design Report)

Material	Measured Friction Angle (°)	Measured Cohesion (kPa)	Design Friction Angle (°)	Design Cohesion (kPa)
Sediments	32 to 38.7 (average = 34)	0	26	0 to 10 (0 used in this study)
Till	36 to 41.5 (average = 39)	0	35	0

Note: Strength parameters are based on effective stresses.
kPa = kilopascal.

The bathymetric measurements carried out by DDMI prior to dewatering A154 indicate that the maximum water depth was 22 m. The deepest water around the pit crest appears to be approximately 17 m, and the deepest water near the toe of the dike is also approximately 17 m. Consequently, the highest expected long-term face of placed fill for A154 is expected to be 12 m to 14 m, depending on surface water drainage requirements.

Based on available information from exploration boreholes, the lakebed sediments range from 0 m to 7 m thick and are typically less than 2 m thick, except for a few localized pockets. The in-situ till, beneath the sediment, ranges up to 13 m thick and is typically 5-m to 10-m thick. The till is significantly thicker above the pit than on the pit shelf area. The till thickness information is relatively scant on the east side of the A154 pit and thus the till thicknesses could vary from the interpreted values.

3.2 Fish Habitat Parameters

3.2.1 Overview of No Net Loss Requirements related to Insides of Dike Areas

The Fisheries Authorization identified the requirements for achieving NNL of habitat for all aspects of the DDMI Diamond Project. Specific requirements for the inside of all three dike areas included:

- the development of shallow rearing habitat and shoreline habitat; and,
- ensuring that the habitat features within the dikes areas are modeled after those features found in other productive areas of Lac de Gras, including depth, substrate type, size, and configuration.

Four key zones of habitat were identified in the NNL Plan (Diavik 1998) for the area found inside the constructed dikes during the post closure phase. These included:

1. Inside edge of the dike. The area of water depths from 0 m to 2 m along constructed sections of the dike representing new shoreline habitat.

2. Reclaimed shorelines. Areas of pre-existing shorelines.
3. The pit shelf. The area between the inside edge of the dike, the shorelines, and the pit crest.
4. Deep water. The pit itself as it will have a depth of approximately 250 m.

The NNL Plan provided habitat unit calculations based on the available design information for the dikes and pits at the time. Some modifications to the design dike and pit dimensions were made subsequent to the submission of the NNL plan, and as-built information is now available for the A154 dike. The habitat units calculated as part of the NNL Plan Addendum (DDMI April 1999), along with re-calculated values based on this updated information are presented in Appendix I.

The following sections outline the general principles and criteria to be used in developing the final layout for all three dike areas. As discussed in the NNL, the primary focus for habitat creation inside of all dikes is based on maximizing rearing habitat value. Target species include lake trout (*Salvelinus namaycush*), arctic grayling (*Thymallus arcticus*), burbot (*Lota Lota*), longnose sucker (*Catostomus catostomus*), round whitefish (*Prosopium cylindraceum*), cisco (*Coregonus artedi*), lake whitefish (*Coregonus clupeaformis*), and slimy sculpin (*Cottus cognatus*).

3.2.2 Overall Criteria

Several overall governing criteria can be applied to the habitat creation activities inside the dikes. First of all, areas inside the dike on the pit shelf that are already at a depth of 4 m or less should not be disturbed if possible. This will allow the maintenance of habitat features not easily re-created. In areas where final depth is between 4 m and 5 m, it would be desirable to maintain existing habitat depending upon grading requirements for drainage, or other construction considerations. Existing shoreline features should also be maintained to the extent feasible. Construction crews should avoid driving on, dumping on, scraping, or otherwise impacting these areas. Leaving these areas intact will decrease the amount of work required to restore the shoreline at closure and will speed the recovery process of the altered areas inside the dike as a variety of organic properties, including the possibility that dormant life stages of some plants or animals will be present in the substrate.

The storage and handling of materials, particularly hydrocarbons or other types of contaminants, should be closely monitored on the shorelines, pit shelf, and inside edges of the dike. Heavy equipment in the area should be maintained and fuelled in a manner that avoids the possibility of spills occurring in areas to be reclaimed as fish habitat.

3.2.3 Inside Edges of Dike

The inside edge of the dike is intended to provide new shoreline features for foraging and rearing habitat for most species as well as other values, including spawning, for slimy sculpin. The dike itself will resemble existing shoreline and reef habitat and is expected to provide a rocky (boulder/cobble), moderate slope area with low to moderate wind and wave action. The NNL plan habitat evaluation completed for the inside edge the dikes treated this area as shoreline habitat.

Suitable materials for this habitat feature are a mix of primarily large boulder with some smaller cobble. Slopes should also ensure a stable profile and range from gentle to moderate. The range of slopes for existing shorelines should be used as a guideline. The area of habitat predicted in the NNL plan for this habitat type, for all three dikes is provided in Table 4. For A154, based on constructed dike configuration and the design criteria presented in this report, 3.41 ha of new shoreline habitat are expected to be created.

Table 4
Inside Edge of the Dike Shoreline Habitat Areas

Dike	No Net Loss Predicted Area (ha)	Current Predicted Area [1] (ha)
A154	1.37	3.41
A418	0.48	n/a
A21	1.07	n/a

[1] Note: Based on final constructed configuration of dikes, where available.
ha = hectare.

3.2.4 Reclaimed Shorelines

The objectives for the pre-existing shoreline along the edge of the diked area, and around any islands within diked areas, are to:

- minimize change to existing substrates or other features; and,
- re-configure disturbed portions to pre-development conditions as much as possible.

This will allow the shoreline areas to be restored to pre-existing conditions once the dikes are breached. Any areas of disturbed shoreline are to be re-configured to provide fish habitat resembling that which was temporarily lost during the project. This may include placement of boulders in water up to 5 m deep to provide a sloping shoreline. The area of habitat predicted in the NNL plan for this habitat type, for all three dikes, is provided in Table 5. For A154, based on constructed dike configuration and the design criteria presented in this report, 2.36 ha of shoreline habitat are expected to be reclaimed and includes shoreline areas around one island on the pit shelf.

Table 5
Reclaimed Shoreline Habitat Areas

Dike	No Net Loss Predicted Area (ha)	Current Predicted Area [1] (ha)
A154	0.52	2.36
A418	0.61	n/a
A21	0.82	n/a

[1] Note: Based on final constructed configuration of dikes, where available.
ha = hectare.

3.2.5 Pit Shelf

The pit shelf area extends from the lower inside edges of the dike to the edges of the pit. The reclaimed pit shelf area is intended to provide shallow foraging and rearing habitat for most species of fish present in Lac de Gras. Material excavated from the pit will be used to fill in deeper portions of the pit shelf area. The area of the pit shelf will be covered by water that ranges from 3 m to 5 m deep. As per the *Navigable Waters Protection Act* Permit for the project, no dike breach or constructed shoal features will be less than 2 m from the expected low water level in Lac de Gras.

As indicated in the NNL plan and the Fisheries Authorization, the objectives for the selection of substrate type are based on reflecting physical characteristics of other areas of good foraging and rearing in Lac de Gras. The pit shelf configuration is also to be based on reflecting the physical characteristics of foraging and rearing habitats within Lac de Gras. In order to address these objectives, substrate information from baseline data collections was used and a basic configuration evaluation of the North Arm and two other nearby inlets identified as rearing areas within Lac de Gras was completed. The configuration evaluation was completed through air photo interpretation. Key features identified by assessing other rearing areas included:

- Rocky Shoal Shape – rocky shoals should be somewhat irregular in size and shape and relatively long and narrow. Some may also be constructed like a series of submerged rocky humps like links in a chain. Longer and narrower reefs have more “edge” habitat. Edges are important to fish that feed in one habitat type and rest or seek refuge in another.

- Isolated Pond-like Areas - In some cases it is beneficial to small fish to have the reefs forming a disjointed “ring” to provide pond-like conditions where circulation is limited.

- Hard to Soft Substrate Ratio - The hard substrate (shoals areas) to soft substrate (depositional areas) ratio in other nearby rearing areas ranged from 25% to 40% hard with the remainder as soft substrate.

- Access to Refuge Habitat – Rocky reefs provide refuge or cover for small fish. It is important for fish to have connectivity between rocky areas and reefs to avoid exposing themselves for extended distances or periods of time to predators. Keeping the distance between rocky reef areas less than 30 m to 40 m will allow fish reasonable access refuge, or hiding places.

Shape Configuration

With regard to water circulation within the diked area, several features should be incorporated to reduce circulation. The shallow nature of the breaches, shallow nature of the pit shelf, and the creation of shoals on the pit shelf will reduce circulation and wind and wave action. The shallow water is expected to warm up quickly in the spring, relative to open areas of the lake, because of the limited water circulation within the enclosed area. As with other rearing habitats in Lac de Gras, warmer water should therefore assist in increasing biological productivity inside the dike by providing a warmer, refuge, and foraging area.

Determining the locations of the reefs should take several factors into consideration. Reefs should have some connectivity to the dikes and other reefs to allow fish to travel throughout the area without being fully exposed to predators for long distances. If the reefs are long, winding, and finger-like, a large amount of "edge" habitat will be created to allow fish to feed in the fine substrate while maintaining close proximity to the cover provided by the rocky reefs. Ideally the reefs will be placed in areas where the final water depth will be 3-m to 5-m deep and the tops of the reefs will remain under at least 2 m of water at all times. This will allow the reef habitat to remain functional even in winter with ice thickness of up to 2 m. Widths of the reefs should vary between 5 m and 30 m, averaging from 10 m to 20 m in width. Distance between the reefs could range from 10 m to 40 m, averaging from 20 m to 30 m apart. Habitat diversity is important and varying the size and shape of the reefs throughout the pit shelf area is expected to improve its value as fish habitat.

Substrate Material

Based on the substrate materials within the North Arm, substrates on the pit shelf should be mostly fine material, primarily sand and silt interspersed with rocky reefs for habitat diversity. The till (existing lake substrate) is primarily sand and silt with some gravel (Tables 1 and 2). The till material will therefore be an appropriate substrate for the expected biological zone of the sediments (*i.e.*, approximately top 10-cm layer represents the biological zone). The fine substrate areas will support a variety of benthic organisms that will provide forage for small fish.

If till is placed over angular rock to provide the soft substrate zone, it should be a layer deep enough to maintain at least 0.5 m depth of soft substrate after settling, accounting for some migration of fines into the voids in the rock fill.

Reefs should be constructed of granular material of a range of sizes. The primary material should be large boulder size rock with some smaller cobble material. The objective is to create refuge habitat, or hiding areas, among the rocks. Angular, unconsolidated material would provide this benefit. Run of mine blast rock is expected to be acceptable for this purpose.

The area of habitat predicted in the NNL plan for this habitat type, for all three dikes, is provided in Table 6. For A154, based on constructed dike configuration and the design criteria presented in this report, 61.35 ha of shallow rearing and foraging habitat are expected to be created.

Table 6
Pit Shelf Habitat Areas

Dike	No Net Loss Predicted Area (ha)	Current Predicted Area [1] (ha)
A154	59.89	61.35
A418	8.68	n/a
A21	54.13	n/a

[1] Note: Based on final constructed configuration of dikes, where available.
ha = hectare.

3.2.6 Deep Water (Pit Area)

The deep water habitat created by the project will be located in each of the mine pits near the center of the diked area. The deep water will provide a cooler environment for fishes and was considered a pelagic zone in the NNL plan. This area will likely be used by pelagic feeding fish such as cisco and may provide other benefits. The maximum depth of the pit areas is anticipated to be 250 m. The area of habitat predicted in the NNL plan for this habitat type, for all three dikes is provided in Table 7. For A154, based on constructed dike configuration and the design criteria presented in this report 52.3 ha are actually expected to be created.

Table 7
Deep Water Habitat Areas

Dike	No Net Loss Predicted Area (ha)	Current Predicted Area [1] (ha)
A154	55.21	52.3
A418	41.94	n/a
A21	29.29	n/a

[1] Note: Based on final constructed configuration of dikes, where available.
ha = hectare.

3.3 Construction Considerations

There are a number of construction considerations that arise due to the variabilities in the material parameters, pore-pressure conditions, blasting effects and construction timing. The following construction considerations were evaluated with respect to the detailed design of the fish habitat compensation measures for the pit shelf areas:

- It was understood that flowing artesian conditions were present the southeast portion of the A154 pit shelf. Artesian conditions may cause build-up of porewater pressures within the fill on the pit shelf, depending on drainage conditions and the development of frozen layers.

- The fine-grained lake-bottom sediments are expected to provide poor trafficability, particularly where artesian conditions exist, and when the materials are thawing.

- A berm will be required between the pit crest and the toe of the fish habitat fill to provide safety with respect to equipment travelling too close to the pit crest and to reduce the potential for fill materials spilling into the pit during placement. The berm could also be used as a construction access road prior to pit development adjacent to the berm.

- The majority of the fill volume may consist of either till or rock fill, depending on construction timing and material availability. The final surface of the fill will consist of till, or lake-bottom sediments, to support aquatic life. The thickness of the final till/sediment layer will depend on whether a filter is used between the rock and till. DDMI will be responsible for picking the construction methods, and materials handling such that adequate quantities of till are available for the final fill surface.

- Based on gradation information for the till, summarized in Section 3.1, and predicted blast rock gradations from the feasibility study, it is anticipated that at least two, and possibly three graded aggregate filters would be required. The gradations of the till and blast rock, along with tentative filter gradations are shown in Appendix II.

Production of filter material would be relatively expensive, since it would involve crushing, screening, stockpiling, and double handling of the materials. It has been assumed that use of a filter between the rockfill and the till would not be utilized, due to logistical and economic considerations. As an alternative to using a filter, the thickness of the till cover on a rock fill can be varied as a function of the total fill thickness. The premise for this approach is that a certain portion of the till will migrate into the void spaces in the rock fill, so the thickness of the till cover must be such that a minimum of 0.5 m of till remains on top of the rock. For design purposes, it has been assumed that the porosity of the rock fill would be approximately 30 percent, and that with time, till would migrate into the rock such that 50 percent of the available voids would be filled. Thus, the thickness of till required over the rock is equal to 15 percent of the rock fill thickness, plus 0.5 m. Theoretically, where rocky reefs are to be constructed, till would not be required between the rock fill and reef material.

- Rock fill has the advantages of higher shear strength and better potential for drainage/dissipation of pore-water pressures. Rock fill may require a smaller thickness than till to provide a stable trafficking surface for the initial lifts.

- Rock fill would permit faster infiltration than till, which may provide a more stable trafficking surface after precipitation events and during spring thaw.

- Till will be available earlier in the mining cycle for each pit, since it overlies the bedrock. Materials may be transported between pits, if required.

4.0 STABILITY ANALYSES

4.1 Overall Pit Stability

The overall pit stability was assessed in Golder's report entitled "Revised A154 Ultimate Pits Stability Review", dated August 16, 2002. The summary of the ultimate pit stability review, and recommendations were as follows:

The pit slope configurations incorporated into the revised A154 ultimate pit plan are consistent with recommendations previously made by Golder in December 1999, November 2000, and February 2002.

Based on the overall slope stability and deformation analyses of the revised A154 pit design, the pit slopes are anticipated to be stable.

The haulage ramp crosses the northeast wall at the 190 m elevation, and coincides with the contact between the granitic waste rocks and the A154 north kimberlite pipe. The slope above the ramp on the northeast wall is single benched and consist of kimberlite rocks. The kimberlite is highly fractured, with a low rock mass strength, and ravelling of benches excavated within kimberlite is expected to occur. The bench configuration within the kimberlite should provide adequate catchment for ravelled material. However, the kimberlite exposures must be closely monitored for signs of excessive ravelling on to the haulage ramp.

The stability and deformation review of the revised A154 ultimate pit slopes, highlight the following geotechnical considerations:

- *If localized areas of bench scale toppling are encountered, additional operational considerations such as scaling and installation of ground support in problem areas may be necessary.*

- *The orientation and nature of the structures exposed along the exposed pit slopes should be detailed as excavation of these slopes begins. This can be achieved by continuous geotechnical mapping of new exposures, and comparison of these data with those previously collected through drillcore.*

- *The sensitivity of the northwest wall deformation analyses highlights the need for slope and dike movement monitoring program as outlined in Golder's February 2002 report.*

Analyses indicated that the overall pit stability is not significantly impacted by the presence of the fish habitat fills on the pit shelf.

4.2 Stability of Fish Habitat Fills

Slope stability analyses were carried out to determine the stability of the face of the fish habitat fills, and the required setback from the pit crest. The impact of the placed material on the stability of the pit was also checked.

Stability analyses were carried out using the computer programs, XSTABL and SLOPE/W. Factors of safety were calculated on the principle of limit equilibrium against potential sliding along a failure surface for each of the selected cross-sections. Factors of safety were computed using both Spencer's method and the Morgenstern-Price method, which satisfy both force and moment equilibrium. Based on the type of soil and the configuration of the habitat, both circular and wedge failure mechanisms were assessed.

DDMI indicated that flowing artesian conditions have been measured in the southeast portion of the A154 pit shelf. It is expected that these conditions would be affected by the development of the pit, but it is not possible/feasible to quantify these conditions until pit development commences. Thus, the factor of safety was assessed for various phreatic levels within the fill. Surface grading towards the sumps along the toe of the dike will help to drain surface water, reducing infiltration of the water into the fill, particularly if the surface of the fill consists of till or lake-bottom sediments.

The effects of blasting in the pit on the stability of the fill were assessed parametrically by using a pseudo-static limit equilibrium analysis with varying levels of pseudo-static loading. As production blasting data is accumulated, the impact of blasting may be reassessed and the design refined.

The results of the stability analyses are summarized in Appendix III. The stability analyses indicate that the critical slip surface impacting both the fish habitat fill and the in-situ till slope in the pit only impacts a small portion of the fish habitat fill. The factor of safety is sensitive to both the phreatic surface and the pseudo-static loading; therefore, a conservative approach with respect to setback distances and slope angles is proposed, combined with monitoring to assess modifications to the proposed design as mining proceeds. The recommended setback from the pit crest (*i.e.*, top of the in-situ till slope to the toe of the fish habitat fill) is 4 times the height of the fill (taken as the difference between the ultimate top of the fill and the elevation of the pit crest), with a minimum of 15 m. The slope of the faces of the fish habitat fill facing the pit and the interior of the dikes should be 3H:1V or flatter. As mining progresses, it may be possible to modify the setback and slope angle parameters.

5.0 CONSTRUCTION GUIDELINES

The recommended configuration of the fish habitat on the pit shelves is based on the following guidelines:

- Construct fills with face slopes of 3H:1V during mining, and final slopes at the angle of repose adjacent to the pit crest at the completion of mining.

- Setback from the pit crest to the toe of the fill equal to 4 times the elevation difference between the top of fill and the pit crest, with a minimum of 15 m.

- To the extent feasible, areas of existing shallow habitat (*i.e.*, water depth less than 5 m below mean normal water level) should remain untouched.

- Construction of a berm between the toe of the till slope and the crest of the pit. This berm will help retain material that erodes from the slope away from the pit, and will reduce the potential for any material rolling down the slope and into the pit. A minimum setback of 5 m from the crest of the pit to the toe of the berm has been used. As a minimum, the berm would be approximately 2 m high, with a 2-m crest width and 2H:1V sideslopes. The geometry of this berm may be modified on the basis of construction techniques.

- A setback from the interior toe of the water retention dike, to the upstream toe of the fill may also be required. This setback distance should be determined by DDMI, based on operational requirements and surface water handling requirements.

- Construction in one lift is acceptable.

- The materials used to construct the fill may consist of till, rock fill, or a combination of materials. If rock fill is used to construct the lower portion of the fill, the thickness of till to create the final surface should be equal to 0.15 times the height of rock fill, plus 0.5 m. Alternatively, filter zones could be provided between the rock fill and the till. Details of the filter zones would have to be developed further, once construction techniques and material gradations are determined. Processing of the blast rock will be required to produce filter materials, and is likely to be expensive. If the filter zone approach is taken, it is likely that at least two, and possibly, three filters would be required.

- Grading of the surface of the fill at a nominal grade of 1% is recommended, to direct surface water towards the water collection system at the toe of the dike.

- Final contouring of the surface will be required to establish some relief to provide fish habitat (*i.e.*, some hummocks and hollows, rather than an evenly graded surface).

- Rock ridges or reefs are also required for fish habitat. These reefs should be constructed of non-acid generating country rock, and conform to the parameters discussed in Section 3.2.5.

6.0 DETAILED DESIGN DRAWINGS

A set of detailed design drawings is included in Appendix IV for the A154 pit. Detailed design drawings for the A418 and A21 pits have not been prepared, since the dikes have not been constructed, and the pit layout may change prior to construction. The detailed design guidelines presented in this document are considered sufficient to develop drawings for the A418 and A21 pits once the dike and pit details have been finalized.

7.0 MONITORING RECOMMENDATIONS

Monitoring of various parameters is recommended to confirm the design assumptions, and to provide information for refining the design of the fish habitat on the pit shelves. It is recommended that monitoring consist of:

- Monitoring pore-water pressures in the lake-bottom sediments and till that will form the foundation for the fish habitat fills to assess drainage due to pit development, as well as pore-pressures due to fill placement and blasting.
- Monitor pore-pressures within the fish habitat fills, so that the slope stability analyses can be confirmed.
- Monitor production blasting to assess accelerations and peak particle velocities (PPV) for the fish habitat fills.
- Monitor movements of the fish habitat fills using a series of monitoring prisms, and potentially slope inclinometers. Visual inspections should also be conducted to check for signs of instability, such as bulging, slumping or the development of tension cracks.

Monitoring programs have previously been recommended for the water retention dikes and for monitoring the overall pit stability. It is recommended that the monitoring for the fish habitat fills on the interior of the dikes be integrated into the overall monitoring program, to provide consistency, and improve the efficiency of the monitoring efforts.

8.0 CLOSURE

We trust this report presents the information that you require. Please feel free to call at anytime if you have any questions or concerns.

GOLDER ASSOCIATES LTD.

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APPENDIX I

HABITAT UNITS

Appendix I, Table 1. No Net Loss Habitat Summary "Accounting" Showing Habitat Units Only in the Proposed Areas of Disturbance, from No Net Loss Addendum, 1999

Life Stage	Species	North Inlet (2001 - 2023)		A418 (2009-2023)		A154 (2001-2023)		A21 (2012-2018)		**Available (pre-1988)	**Available (post-2024)	Net Change
		loss	gain	loss	gain	loss	gain	loss	gain			
Spawning	LKTR	0.32	0.00	0.10	0.07	0.68	0.15	0.79	0.14	1.88	0.37	-1.51
	ARGR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CISC	0.31	0.00	0.11	0.06	0.95	0.12	0.80	0.11	2.16	0.29	-1.87
	RNWH	0.05	0.00	0.02	0.05	0.18	0.29	0.14	0.26	0.39	0.60	0.21
	LKWH	0.12	0.00	0.04	0.02	0.24	0.04	0.30	0.04	0.70	0.11	-0.59
	LNSC	0.07	0.00	0.02	0.01	0.06	0.02	0.17	0.02	0.33	0.04	-0.29
	BURB	0.04	0.00	0.02	0.00	0.16	0.01	0.12	0.01	0.33	0.02	-0.31
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SLSC	0.11	0.00	0.03	0.21	0.23	0.78	0.27	0.66	0.65	1.65	1.01
Rearing	LKTR	1.60	0.00	1.00	3.60	5.65	10.53	3.46	8.31	11.71	22.44	10.73
	ARGR	0.17	0.00	0.17	0.26	1.03	0.76	0.44	0.60	1.81	1.62	-0.19
	CISC	1.06	0.00	1.53	3.47	6.37	10.17	3.83	8.02	12.78	21.66	8.87
	RNWH	0.40	0.00	0.26	0.61	1.21	2.06	0.72	1.69	3.90	4.35	0.46
	LKWH	0.52	0.00	0.28	0.62	1.27	2.31	1.00	1.93	3.07	4.85	1.79
	LNSC	0.34	0.00	0.30	0.48	1.40	1.63	0.80	1.34	2.85	3.45	0.60
	BURB	0.27	0.00	0.19	0.27	0.99	0.90	0.65	0.74	2.09	1.91	-0.18
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SLSC	0.36	0.00	0.26	0.43	1.36	1.57	0.87	1.32	2.86	3.32	0.47
Foraging	LKTR	0.70	0.00	0.90	0.96	4.03	2.76	2.44	2.19	8.08	5.91	-2.17
	ARGR	0.11	0.00	0.10	0.13	0.54	0.39	0.27	0.31	1.01	0.83	-0.18
	CISC	0.77	0.00	0.88	1.65	3.90	4.31	2.37	3.31	7.92	9.27	1.35
	RNWH	0.23	0.00	0.17	0.28	0.88	0.80	0.51	0.63	2.37	1.71	-0.66
	LKWH	0.21	0.00	0.15	0.28	0.73	0.94	0.44	0.77	1.54	1.99	0.46
	LNSC	0.18	0.00	0.21	0.24	0.88	0.81	0.55	0.67	1.82	1.72	-0.10
	BURB	0.10	0.00	0.11	0.12	0.51	0.34	0.31	0.27	1.04	0.73	-0.31
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SLSC	0.07	0.00	0.14	0.21	0.61	0.77	0.40	0.64	1.23	1.62	0.39
Nursery	LKTR	0.32	0.00	0.10	0.06	0.68	0.12	0.79	0.12	1.88	0.30	-1.58
	ARGR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CISC	0.31	0.00	0.11	0.06	0.95	0.12	0.80	0.11	2.16	0.29	-1.87
	RNWH	0.05	0.00	0.02	0.05	0.18	0.29	0.14	0.26	0.39	0.60	0.21
	LKWH	0.12	0.00	0.04	0.02	0.24	0.04	0.30	0.04	0.70	0.11	-0.59
	LNSC	0.07	0.00	0.02	0.01	0.06	0.02	0.17	0.02	0.33	0.04	-0.29
	BURB	0.04	0.00	0.02	0.00	0.16	0.01	0.12	0.01	0.33	0.02	-0.31
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SLSC	0.11	0.00	0.03	0.21	0.23	0.78	0.27	0.66	0.65	1.65	1.01
Total		9.10	0.00	7.33	14.45	36.38	43.84	24.27	35.19	78.95	93.49	14.54
Total by life stage	Spawning	1.01	0.00	0.34	0.43	2.50	1.41	2.59	1.24	6.44	3.09	-3.35
	Rearing	4.71	0.00	4.00	9.73	19.29	29.93	11.78	23.94	41.07	63.61	22.54
	Foraging	2.37	0.00	2.66	3.86	12.09	11.11	7.30	8.80	25.00	23.77	-1.22
	Nursery	1.01	0.00	0.34	0.42	2.50	1.38	2.59	1.22	6.44	3.02	-3.42
Total by species	LKTR	2.93	0.00	2.11	4.69	11.04	13.56	7.48	10.76	23.55	29.02	5.47
	ARGR	0.27	0.00	0.27	0.40	1.57	1.15	0.71	0.91	2.83	2.45	-0.37
	CISC	2.44	0.00	2.62	5.23	12.18	14.72	7.80	11.55	25.03	31.51	6.48
	RNWH	0.72	0.00	0.47	0.99	2.46	3.44	1.52	2.84	7.05	7.26	0.22
	LKWH	0.97	0.00	0.51	0.94	2.48	3.34	2.05	2.79	6.00	7.06	1.06
	LNSC	0.67	0.00	0.55	0.74	2.40	2.48	1.69	2.03	5.31	5.25	-0.07
	BURB	0.45	0.00	0.34	0.40	1.81	1.26	1.21	1.03	3.80	2.68	-1.12
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SLSC	0.65	0.00	0.47	1.06	2.45	3.91	1.82	3.28	5.38	8.25	2.87

Note:
Minor variation in numbers, when compared with 1999 documentation, due to rounding

** - habitat units available the pre-1998 and post-2024 represent the number of habitat units present on shoals, shorelines, and 'in deep/shallow water areas within the proposed boundaries of the three dikes (A154, A418, A21) and the north inlet.
LKTR = lake trout; ARGR = Arctic grayling; CISC = cisco; RNWH = round whitefish; LKWH = lake whitefish; LNSC = longnose sucker; BURB = burbot; NRPK = northern pike; SLSC = slimy sculpin.

Appendix I, Table 2 No Net Loss Habitat Summary "Accounting" Showing Habitat Units Only in the Proposed Areas of Disturbance, Recalculated with 2002 Dike A154 Constructed Dimensions

Life Stage	Species	North Inlet (2001 - 2023)		A418 (2009 2023)		A154 (2001 2023)		A21 (2012 2018)		**Available (pre-1988)	**Available (post-2024)	Net Change
		loss	gain	loss	gain	loss	gain	loss	gain			
Spawning	LKTR	0.32	0.00	0.10	0.07	0.68	0.24	0.79	0.14	1.88	0.45	-1.43
	ARGR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
	CISC	0.31	0.00	0.11	0.03	0.95	0.27	0.80	0.16	2.16	0.37	-1.79
	RNWH	0.05	0.00	0.02	0.05	0.18	0.31	0.14	0.26	0.39	0.63	0.24
	LKWH	0.12	0.00	0.04	0.02	0.24	0.09	0.30	0.04	0.70	0.15	-0.55
	LNSC	0.07	0.00	0.02	0.01	0.06	0.02	0.17	0.02	0.33	0.05	-0.28
	BURB	0.04	0.00	0.02	0.00	0.16	0.02	0.12	0.01	0.33	0.03	-0.30
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
	SLSC	0.11	0.00	0.03	0.21	0.23	0.83	0.27	0.66	0.65	1.70	1.05
Rearing	LKTR	1.60	0.00	1.00	3.60	5.65	10.82	3.46	8.31	11.71	22.73	11.01
	ARGR	0.17	0.00	0.17	0.26	1.03	0.79	0.44	0.60	1.81	1.65	-0.16
	CISC	1.06	0.00	1.53	2.48	6.37	3.42	3.83	1.86	12.78	21.89	9.10
	RNWH	0.40	0.00	0.26	0.61	1.21	2.14	0.72	0.31	3.90	3.06	-0.84
	LKWH	0.52	0.00	0.28	0.62	1.27	2.42	1.00	1.93	3.07	4.97	1.90
	LNSC	0.34	0.00	0.30	0.48	1.40	1.69	0.80	1.34	2.85	3.51	0.67
	BURB	0.27	0.00	0.19	0.27	0.99	0.95	0.65	0.74	2.09	1.95	-0.14
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
	SLSC	0.36	0.00	0.26	0.43	1.36	1.66	0.87	1.32	2.86	3.41	0.56
Foraging	LKTR	0.70	0.00	0.90	0.96	4.03	2.87	2.44	2.19	8.08	6.03	-2.05
	ARGR	0.11	0.00	0.10	0.13	0.54	0.40	0.27	0.31	1.01	0.85	-0.17
	CISC	0.77	0.00	0.88	1.59	3.90	4.27	2.37	3.20	7.92	9.36	1.43
	RNWH	0.23	0.00	0.17	0.28	0.88	0.83	0.51	0.63	2.37	1.74	-0.62
	LKWH	0.21	0.00	0.15	0.28	0.73	0.98	0.44	0.77	1.54	2.03	0.49
	LNSC	0.18	0.00	0.21	0.24	0.88	0.84	0.55	0.67	1.82	1.74	-0.08
	BURB	0.10	0.00	0.11	0.12	0.51	0.36	0.31	0.27	1.04	0.75	-0.29
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
	SLSC	0.07	0.00	0.14	0.21	0.61	0.81	0.40	0.64	1.23	1.65	0.42
Nursery	LKTR	0.32	0.00	0.10	0.06	0.68	0.21	0.79	0.12	1.88	0.39	-1.49
	ARGR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
	CISC	0.31	0.00	0.11	0.05	0.95	0.55	0.80	0.11	2.16	0.37	-1.79
	RNWH	0.05	0.00	0.02	0.05	0.18	0.31	0.14	0.26	0.39	0.62	0.23
	LKWH	0.12	0.00	0.04	0.02	0.24	0.09	0.30	0.04	0.70	0.15	-0.55
	LNSC	0.07	0.00	0.02	0.01	0.06	0.02	0.17	0.02	0.33	0.05	-0.28
	BURB	0.04	0.00	0.02	0.00	0.16	0.02	0.12	0.01	0.33	0.03	-0.30
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
	SLSC	0.11	0.00	0.03	0.21	0.23	0.83	0.27	0.66	0.65	1.70	1.05
Total		9.10	0.00	7.33	13.38	36.38	39.04	24.27	27.59	78.95	94.01	15.06
Total by life stage	Spawning	1.01	0.00	0.34	0.41	2.50	1.78	2.59	1.28	6.44	3.39	-3.05
	Rearing	4.71	0.00	4.00	8.75	19.29	23.88	11.78	16.41	41.07	63.16	22.10
	Foraging	2.37	0.00	2.66	3.81	12.09	11.35	7.30	8.69	25.00	24.14	-0.86
	Nursery	1.01	0.00	0.34	0.41	2.50	2.03	2.59	1.21	6.44	3.31	-3.12
Total by specie s	LKTR	2.93	0.00	2.11	4.69	11.04	14.13	7.48	10.76	23.55	29.59	6.04
	ARGR	0.27	0.00	0.27	0.40	1.57	1.19	0.71	0.91	2.83	2.49	-0.33
	CISC	2.44	0.00	2.62	4.16	12.18	8.50	7.80	5.32	25.03	31.99	6.96
	RNWH	0.72	0.00	0.47	0.99	2.46	3.60	1.52	1.47	7.05	6.05	-0.99
	LKWH	0.97	0.00	0.51	0.94	2.48	3.57	2.05	2.79	6.00	7.30	1.29
	LNSC	0.67	0.00	0.55	0.74	2.40	2.58	1.69	2.03	5.31	5.35	0.03
	BURB	0.45	0.00	0.34	0.40	1.81	1.34	1.21	1.03	3.80	2.76	-1.04
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SLSC	0.65	0.00	0.47	1.06	2.45	4.13	1.82	3.28	5.38	8.47	3.09

Note:
Minor variation in numbers, when compared with 1999 documentation, due to rounding

** - habitat units available the pre-1998 and post-2024 represent the number of habitat units present on shoals, shorelines, and 'in deep/shallow water areas within the proposed boundaries of the three dikes (A154, A418, A21) and the north inlet.
LKTR = lake trout; ARGR = Arctic grayling; CISC = cisco; RNWH = round whitefish; LKWH = lake whitefish; LNSC = longnose sucker; BURB = burbot; NRPK = northern pike; SLSC = slimy sculpin.

APPENDIX II

TENTATIVE FILTER GRADATIONS

012-2331: DDMI Fish Habitat Compensation - Interior of Dikes
Tentative Filter Gradations

Specification Bands

Sieve Size mm	SHT Type 31 Percent Passing Coarse Ra	SHT Type 31 Percent Passing Fine Rang	SHT Type 33 Percent Passing Coarse Ra	SHT Type 33 Percent Passing Fine Range
31.5	100%			
25				
18	75%	90%	100%	
12.5	65%	83%	75%	100%
5	40%	69%	50%	75%
2	26%	47%	32%	52%
0.9	17%	32%	20%	35%
0.4	12%	22%	15%	25%
0.16	7%	14%	8%	15%
0.071	6%	11%	6%	11%

Manitoba Highways Class A

Sieve Size mm	Percent Passing Coarse Ra	Percent Passing Fine Range
19	100%	
16	80%	100%
4.75	40%	71%
2	25%	55%
0.425	15%	30%
0.075	8%	15%

Mean Till Gradation

Diam	% Passing	
80	100.0%	
50	100.0%	
40	100.0%	
20	97.4%	
10	89.3%	D_{85}
5	80.5%	7.0
2.5	74.0%	
1.25	68.0%	
0.63	62.3%	
0.315	55.9%	
0.16	48.9%	D_{15}
0.08	39.1%	0.08

Filter 1 - Concrete Sand

Sieve Size	Coarse % Passing	Fine % Passing	
10	100%	100%	
5	95%	100%	D_{85}
2.5	80%	100%	1.9
1.25	50%	90%	
0.63	25%	65%	D_{15}
0.315	10%	35%	0.4
0.16	2%	10%	

Filter 2

Diam Fine	Diam Coarse	Fine % Passing	
		100%	
12.5	40	95%	
8	25	85%	D_{85}
3	12.5	60%	21
1.2	5	15%	
0.9	4	10%	D_{15}
			3.3

Filter 3

Diam Fine	Diam Coarse	Fine % Passing
		100%
75	200	95%
50	150	85%
25	75	60%
10	25	15%
9	22	10%

Blast Rock

Diam	% Passing
490	80%
280	50%
130	20%

REPORT NUMBER: ________________

Golder Associates

Grain Size Analysis

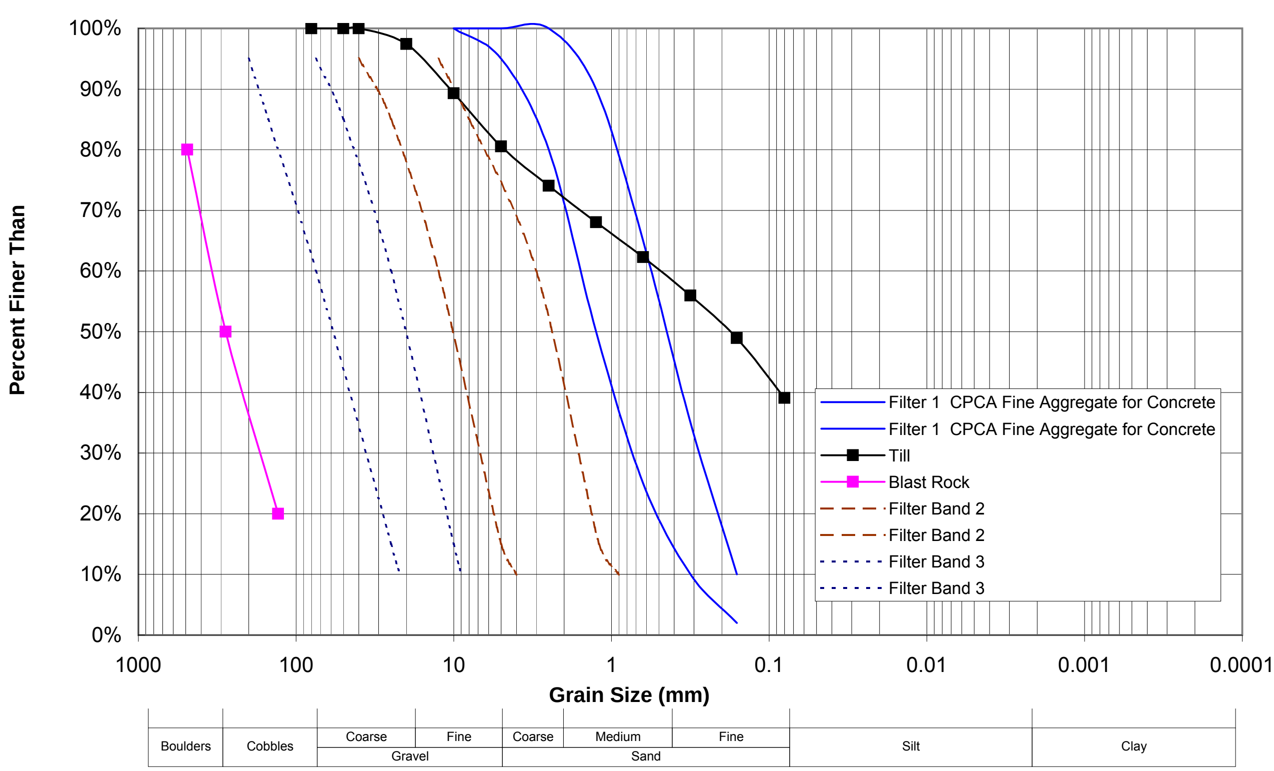
PROJECT No. 012-2331
PROJECT: Diavik - Fish Habitat Compensation - Dikes
LOCATION: Lac de Gras, NWT
SITE:
TESTED BY: N/A
DATE: March 2003

		SIEVE No.	Size of Opening (Inches)	Size of Opening (mm)	WEIGHT RETAINED (grams) per sieve	WEIGHT RETAINED (grams) cumulative	Total Weight Finer Than (grams)	Percent Finer Than (%)	% Finer Than Original Sample
Tare Weight (grams) =	0						0		
Moist Weight + Tare (grams) =	0						0		
Dry Weight + Tare (grams) =	0						0		
Washed, Dry Wt. + Tare (grams) =	0				0	0	0		
					0	0	0		
Moisture Content (%) =	#DIV/0!				0	0	0		
Total Dry Weight of Sample (grams) =	0				0	0	0		
Passing Total Weight					0	0	0		
					0	0	0		
					0	0	0		
					0	0	0		
					0	0	0		
					0	0	0		
					0	0	0		

Total Retained on Sieves (grams) = 0

LABORATORY SAMPLE IDENTIFICATION NUMBER:
DESCRIPTION OF SAMPLE:

REMARKS:
This spreadsheet is being used to illustrate tentative grain-size distributions for filters between rock fill and till for the fish habitat compensation plans on the pit shelf.



UNIFIED SOIL CLASSIFICATION SYSTEM

Checked By:__________________ Reviewed By:________________

APPENDIX III

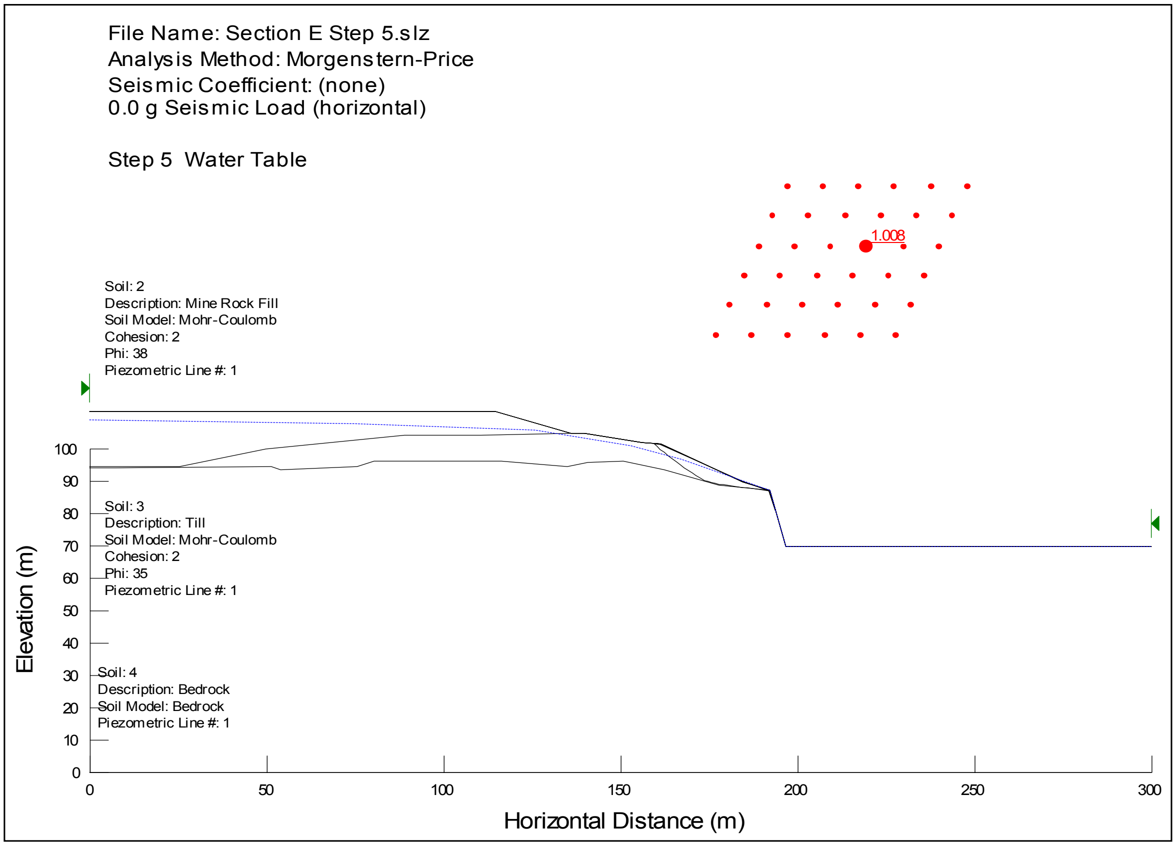
SUMMARY OF SLOPE STABILITY ANALYSES

Section E With 25 m Setback

Water Table Elevation	Seismic Coefficient (horizontal)		With 35 ϕ Till & 38 Fill: F of S (through Till)	With 35 ϕ Till & 38 Fill: F of S (global)		With 35 ϕ Fill & 35 Till: F of S (through Till)	With 35 ϕ Fill & 35 Till: F of S (global)
Base Case	0		1.50	2.66			
Base Case	0.05		1.33	2.24			
Base Case	0.1		1.19	1.94			
Base Case	0.15		1.07	1.71			
Step 1 Water Table	0		1.34	2.43			
Step 1 Water Table	0.05						
Step 1 Water Table	0.1						
Step 1 Water Table	0.15						
Step 2 Water Table	0		1.19	2.22			
Step 2 Water Table	0.05						
Step 2 Water Table	0.1						
Step 2 Water Table	0.15						
Step 3 Water Table	0		1.18	2.05		1.18	2.04
Step 3 Water Table	0.05		1.04	1.76		1.04	1.74
Step 3 Water Table	0.1		0.92	1.53		0.92	1.52
Step 3 Water Table	0.15		0.82	1.35		0.82	1.34
Step 4 Water Table	0		1.01	1.82		1.01	1.81
Step 4 Water Table	0.05						
Step 4 Water Table	0.1						
Step 4 Water Table	0.15						
Step 5 Water Table	0		1.01	1.67		1.01	1.66
Step 5 Water Table	0.05		0.88	1.43		0.88	1.42
Step 5 Water Table	0.1		0.78	1.25		0.78	1.24
Step 5 Water Table	0.15		0.69	1.11		0.69	1.10
Step 5 Water Table							
Step 5 Water Table							

Project Number: 012-2331
Project: DDMI - Diavik
Fish Habitat Comp.

SUMMARY OF SLOPE STABILITY ANALYSIS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Seismic Coefficient: (none)
0.0 g Seismic Load (horizontal)
Step 5 Water Table
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Soil: 2
Description: Mine Rock Fill
Soil Model: Mohr-Coulomb
Cohesion: 2
Phi: 38
Piezometric Line #: 1
Soil: 3
Description: Till
Soil Model: Mohr-Coulomb
Cohesion: 2
Phi: 35
Piezometric Line #: 1
Soil: 4
Description: Bedrock
Soil Model: Bedrock
Piezometric Line #: 1
Elevation (m)
Horizontal Distance (m)
0
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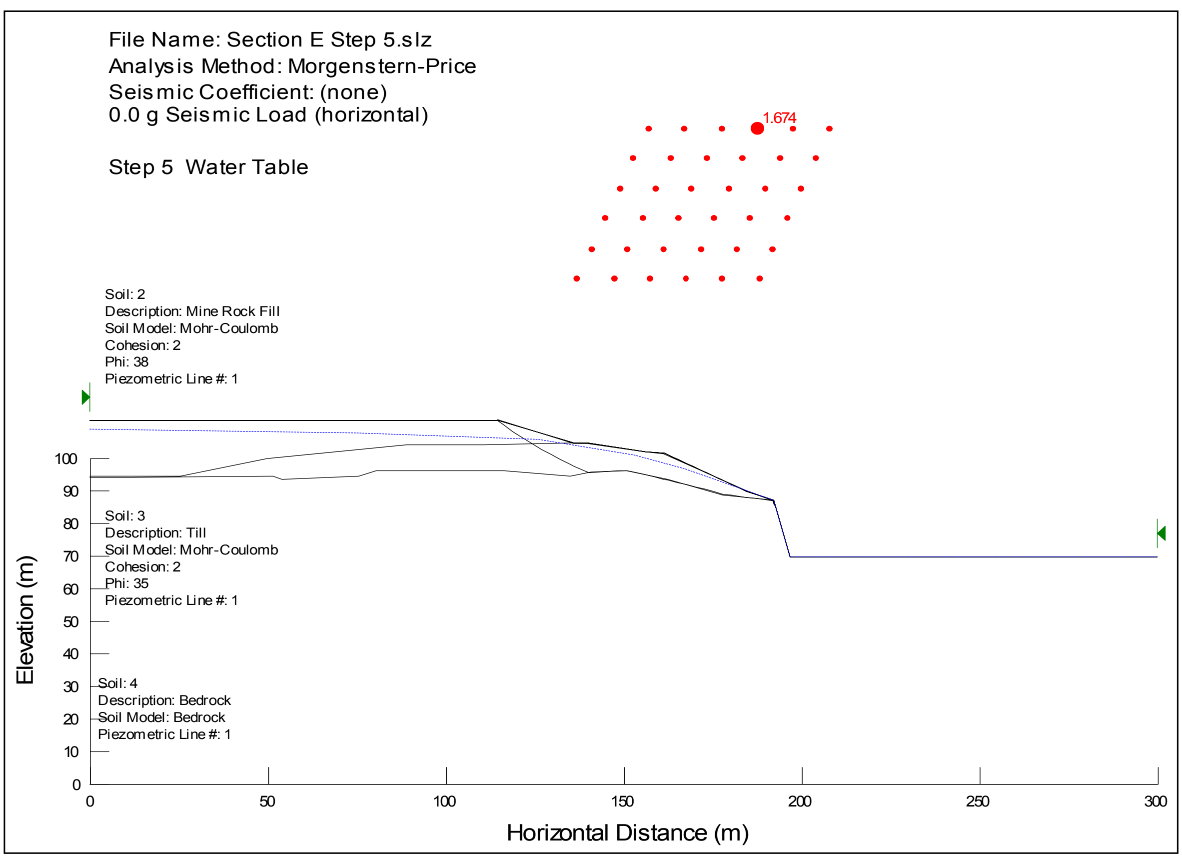
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300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0.0 g Seismic Load (horizontal)
Step 5 Water Table
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Soil Model: Mohr-Coulomb
Cohesion: 2
Phi: 38
Piezometric Line #: 1
Soil: 3
Description: Till
Soil Model: Mohr-Coulomb
Cohesion: 2
Phi: 35
Piezometric Line #: 1
Soil: 4
Description: Bedrock
Soil Model: Bedrock
Piezometric Line #: 1
Elevation (m)
Horizontal Distance (m)
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20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
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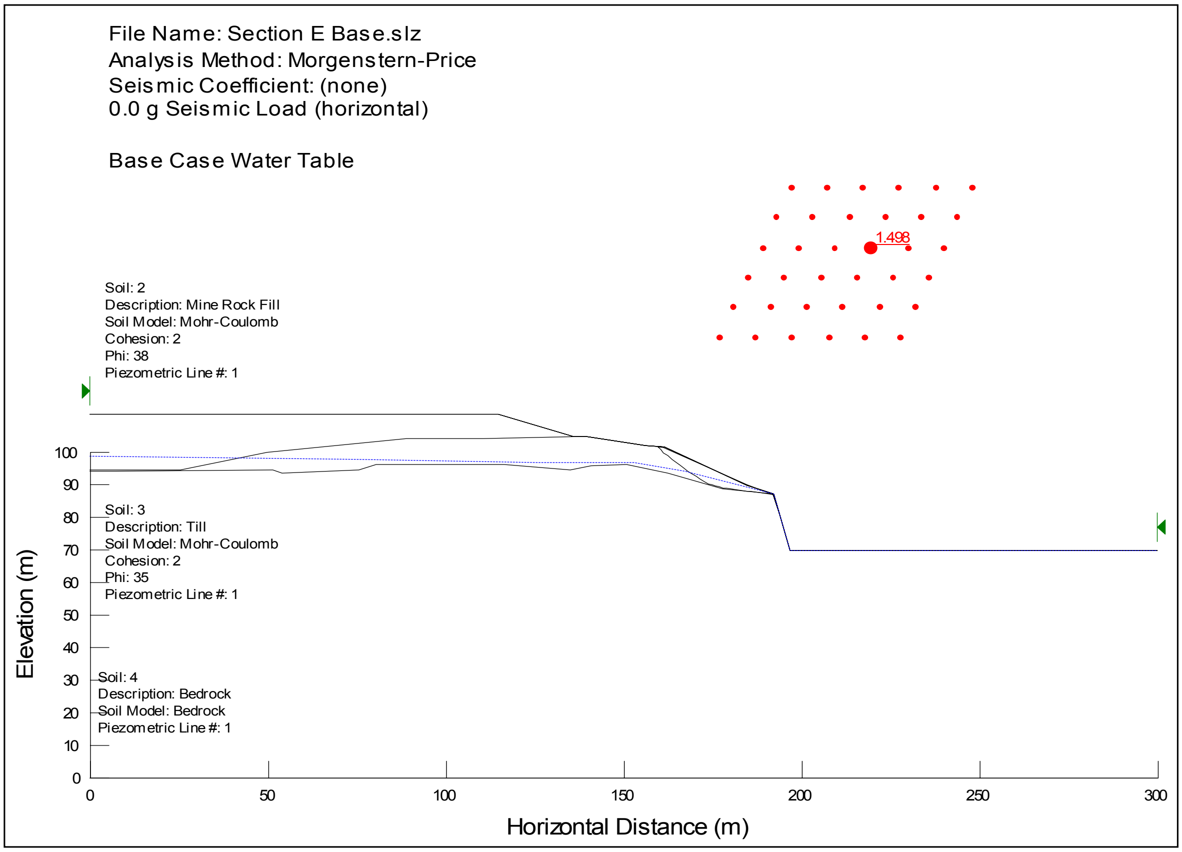
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Base Case Water Table
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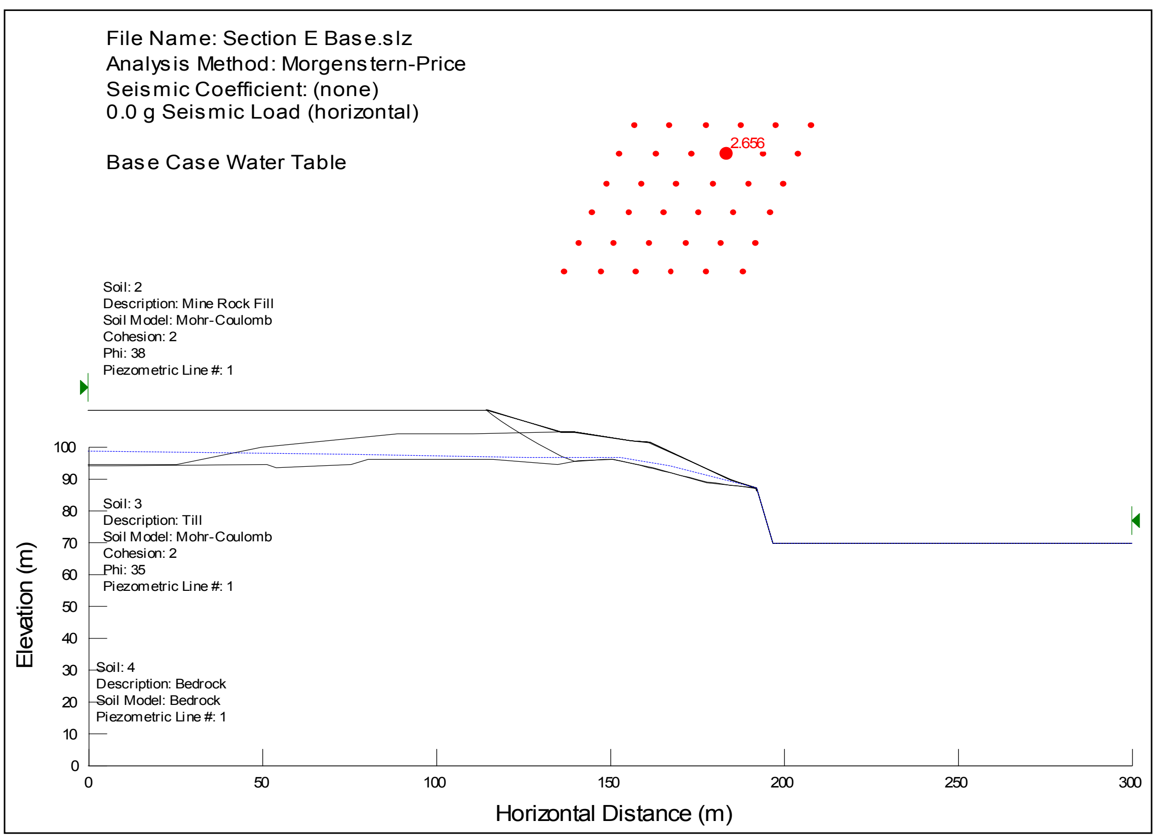
Soil Model: Mohr-Coulomb
Cohesion: 2
Phi: 38
Piezometric Line #: 1
Soil: 3
Description: Till
Soil Model: Mohr-Coulomb
Cohesion: 2
Phi: 35
Piezometric Line #: 1
Soil: 4
Description: Bedrock
Soil Model: Bedrock
Piezometric Line #: 1
Elevation (m)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
Horizontal Distance (m)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0.0 g Seismic Load (horizontal)
Base Case Water Table
2.656
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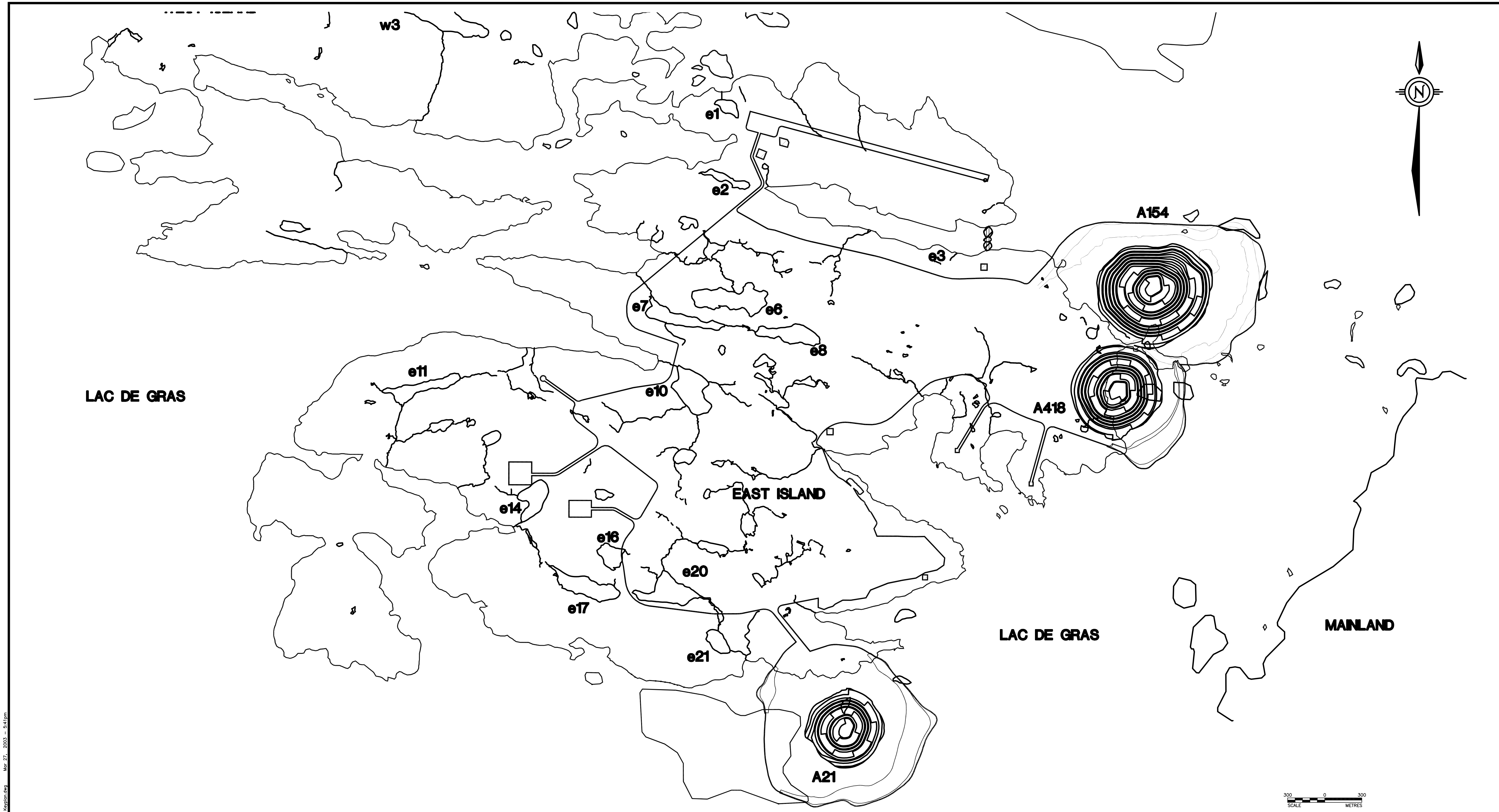
Soil Model: Mohr-Coulomb
Cohesion: 2
Phi: 38
Piezometric Line #: 1
Soil: 3
Description: Till
Soil Model: Mohr-Coulomb
Cohesion: 2
Phi: 35
Piezometric Line #: 1
Soil: 4
Description: Bedrock
Soil Model: Bedrock
Piezometric Line #: 1
Elevation (m)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
Horizontal Distance (m)

APPENDIX IV

DETAILED DESIGN DRAWINGS



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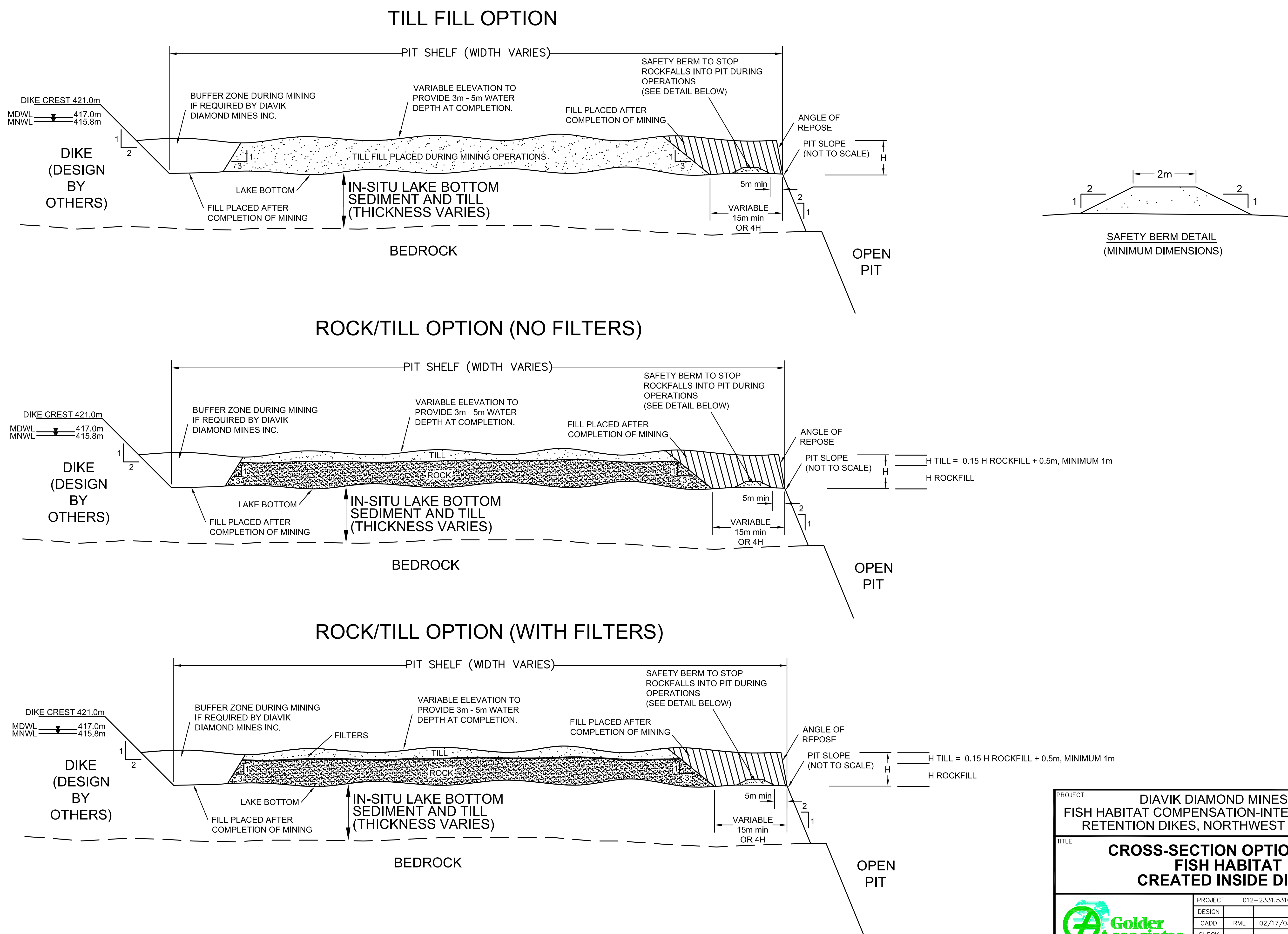

PROJECT
DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE
CROSS-SECTION OPTIONS FOR FISH HABITAT CREATED INSIDE DIKES

Golder Associates
Saskatoon, Saskatchewan

PROJECT	012-2331.5310		FILE No.	
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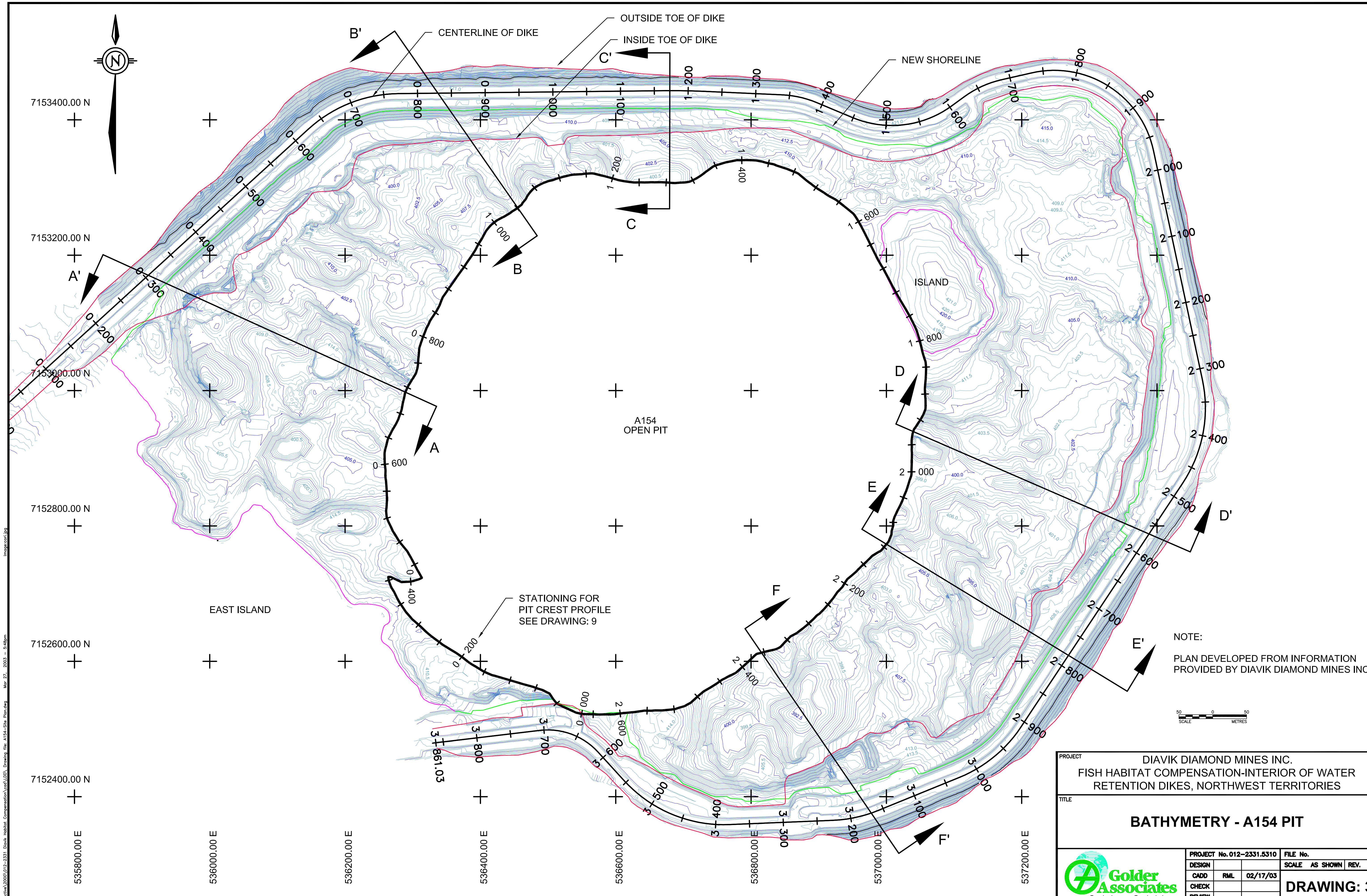

PROJECT

DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER
RETENTION DIKES, NORTHWEST TERRITORIES

TITLE

BATHYMETRY - A154 PIT

Golder Associates
Saskatoon, Saskatchewan

PROJECT No. 012-2331.5310		FILE No.	
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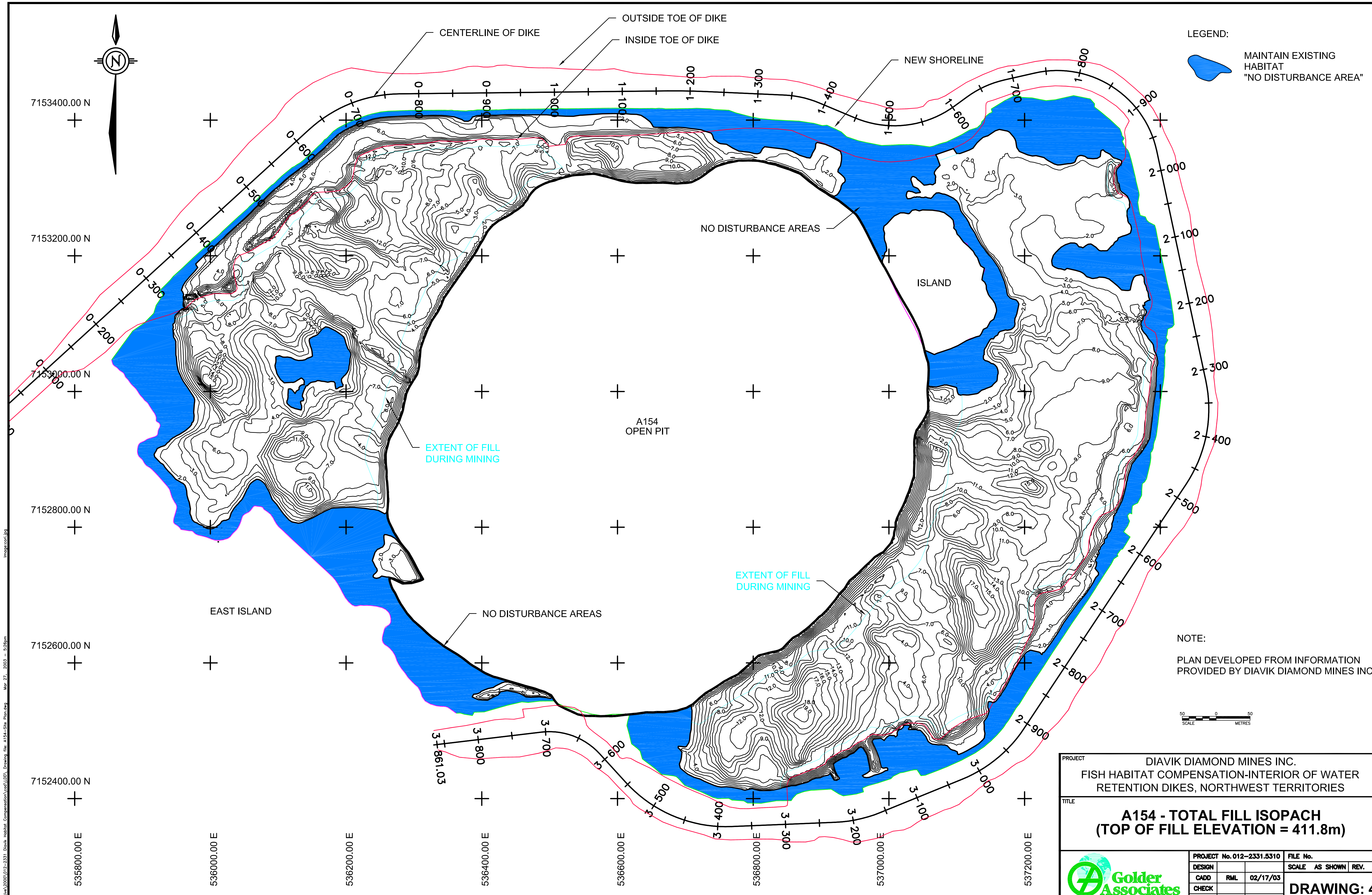

PROJECT
DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE
A154 - TOTAL FILL ISOPACH (TOP OF FILL ELEVATION = 411.8m)

Golder Associates
Saskatoon, Saskatchewan

PROJECT No. 012-2331.5310			FILE No.	
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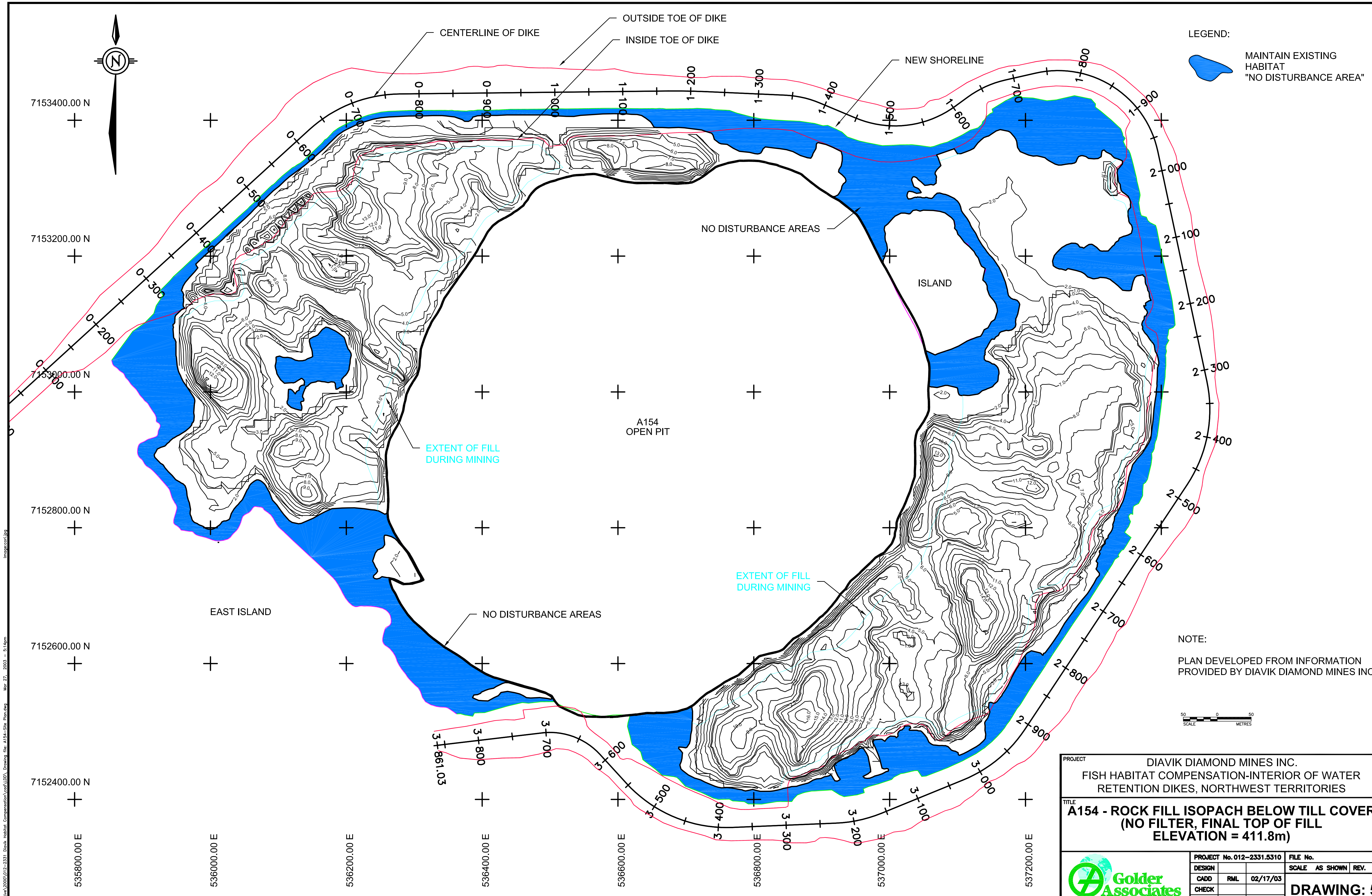

NOTE:

PLAN DEVELOPED FROM INFORMATION PROVIDED BY DIAVIK DIAMOND MINES INC.

PROJECT

DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE

A154 - ROCK FILL ISOPACH BELOW TILL COVER (NO FILTER, FINAL TOP OF FILL ELEVATION = 411.8m)

Golder Associates
Saskatoon, Saskatchewan

PROJECT	No. 012-2331.5310		FILE No.			
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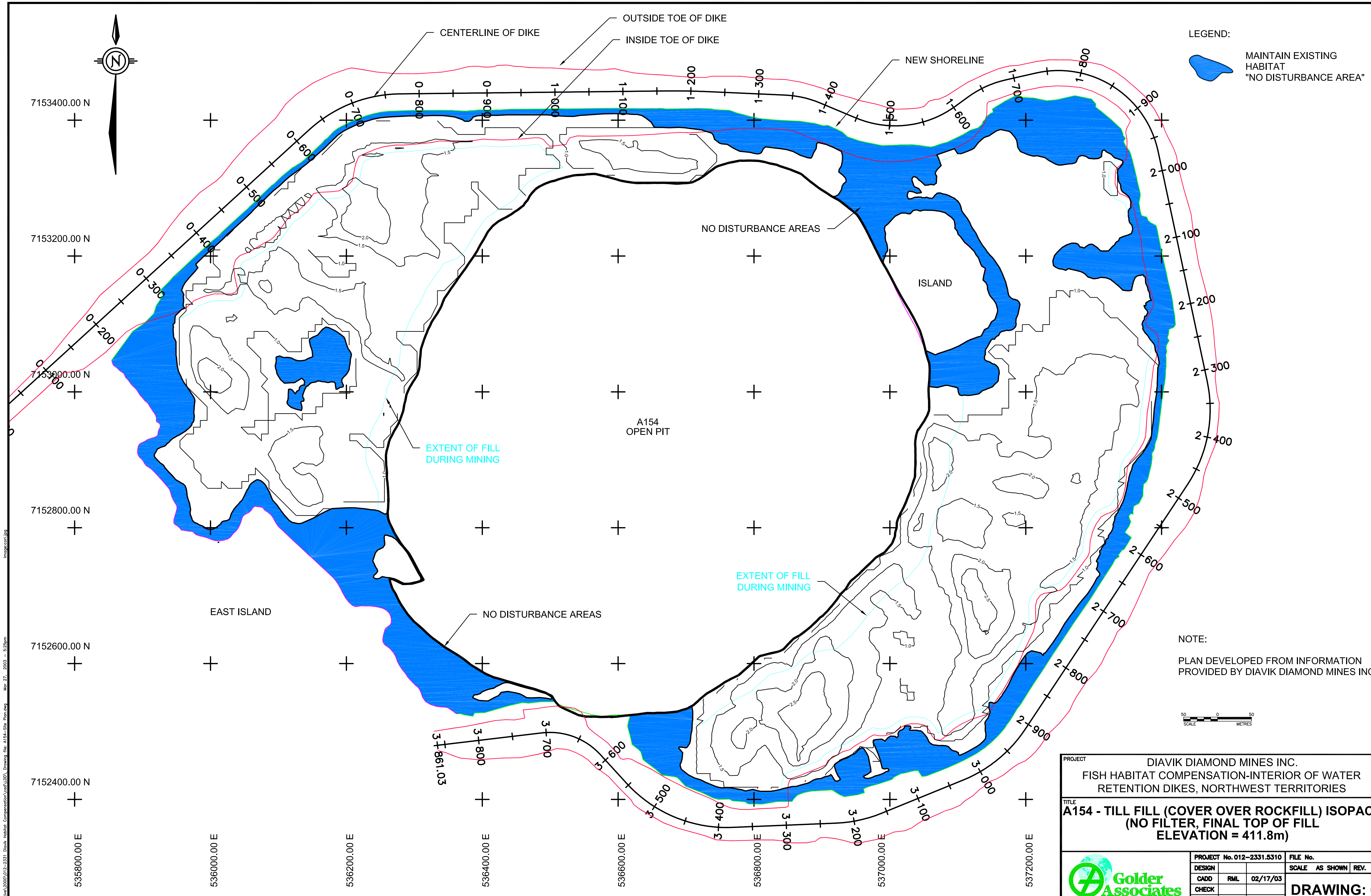

PROJECT

DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE

A154 - TILL FILL (COVER OVER ROCKFILL) ISOPACH (NO FILTER, FINAL TOP OF FILL ELEVATION = 411.8m)

Golder Associates
Saskatoon, Saskatchewan

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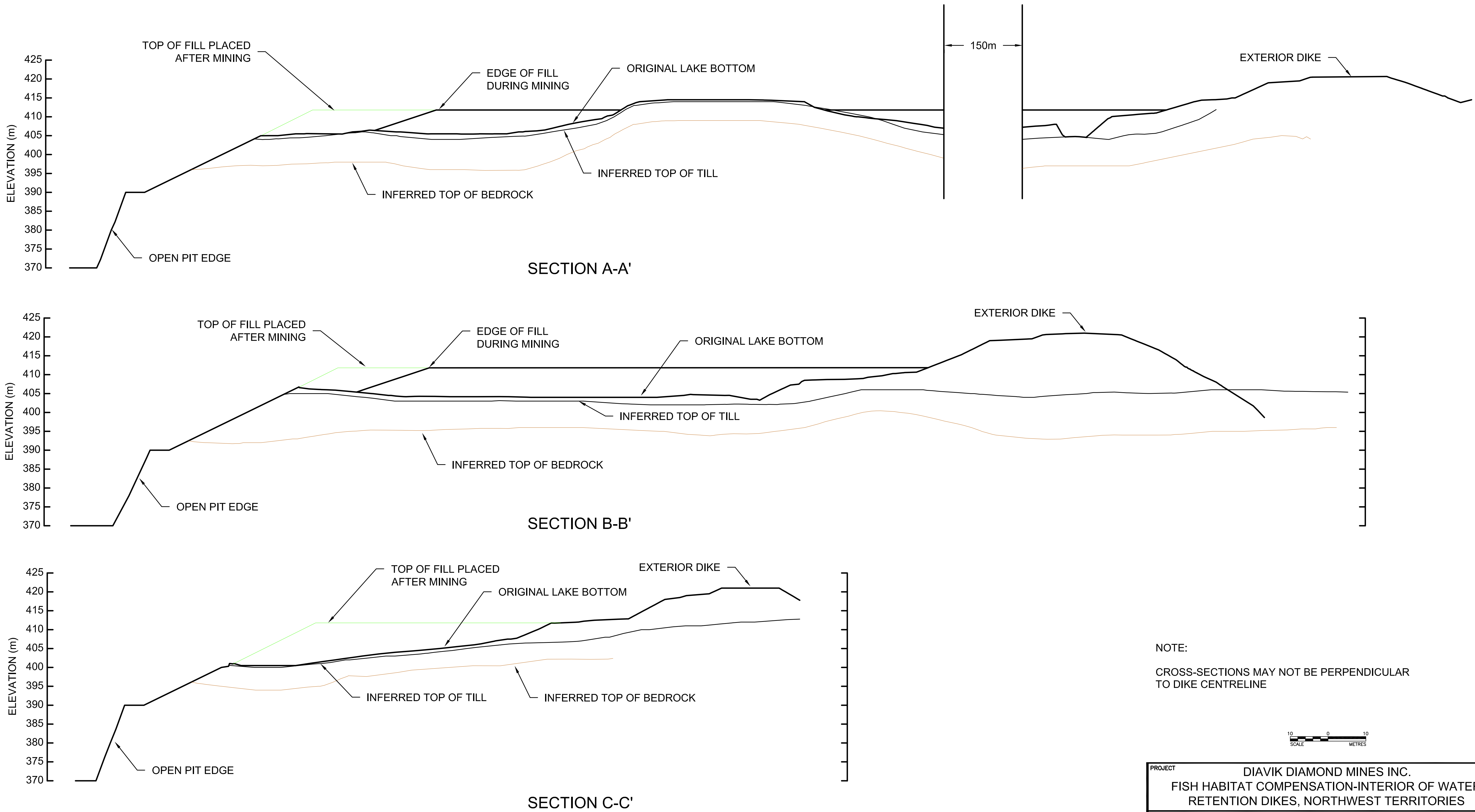

NOTE:

CROSS-SECTIONS MAY NOT BE PERPENDICULAR TO DIKE CENTRELINE

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TITLE	A154 PIT - CROSS SECTIONS OF FISH HABITAT FILL ON EXTERIOR DIKES			
Golder Associates Saskatoon, Saskatchewan	PROJECT No. 012-2331.5310		FILE No.	
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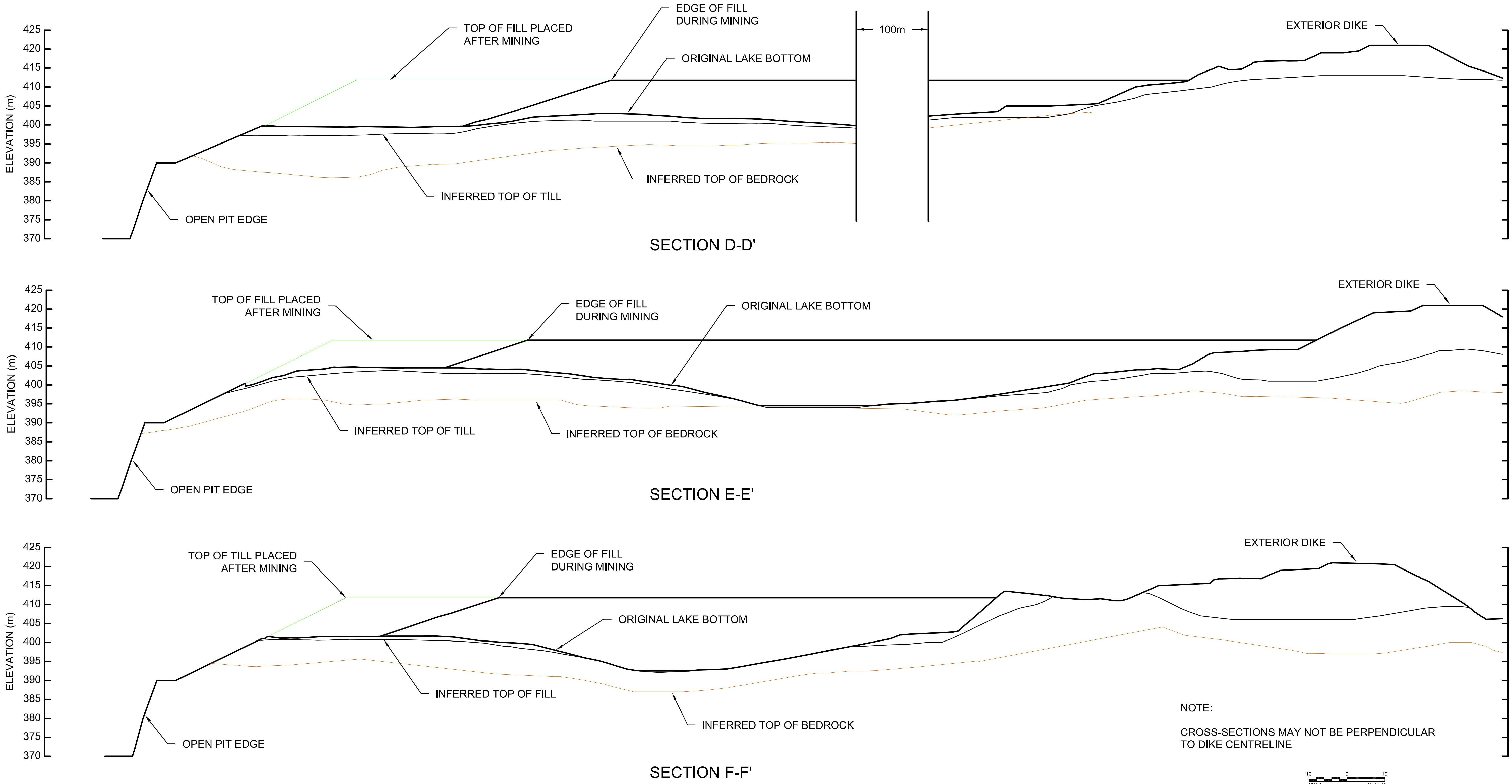

NOTE:

CROSS-SECTIONS MAY NOT BE PERPENDICULAR TO DIKE CENTRELINE

PROJECT
DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE
A154 PIT - CROSS SECTIONS OF FISH HABITAT FILL ON EXTERIOR DIKES

Golder Associates
Saskatoon, Saskatchewan

PROJECT	No. 012-2331.5310	FILE No.	
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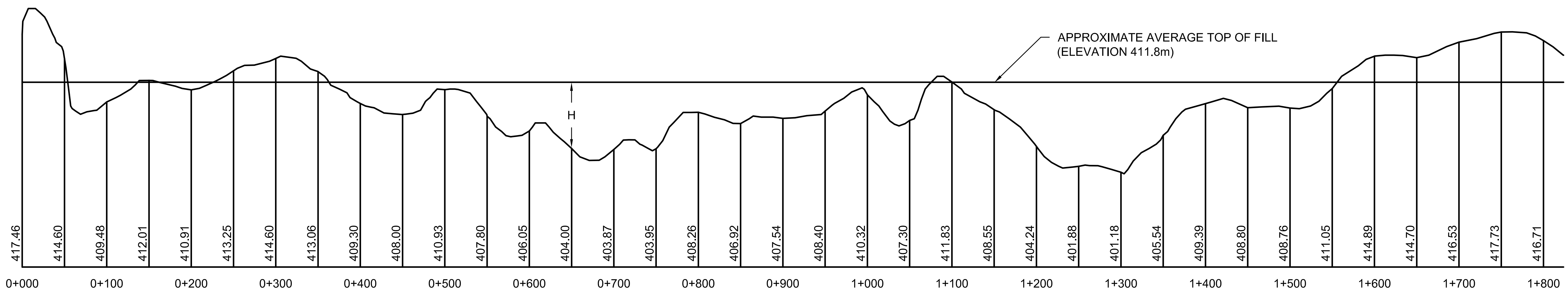

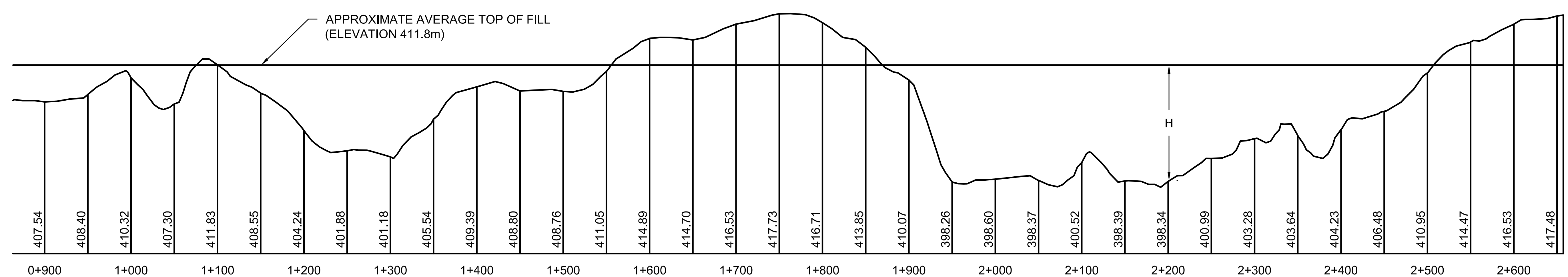

50 0 50
SCALE METRES

10x VERTICAL EXAGGERATION

NOTES:

1. SEE DRAWING : 3 FOR STATIONING

2. SETBACK FROM PIT CREST TO TOE OF FISH HABITAT FILL (DURING MINING) EQUAL TO 4H WITH A MINIMUM OF 15m.

PROJECT

DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE

A154 PIT - PIT CREST PROFILE

Golder Associates
Saskatoon, Saskatchewan

PROJECT No. 012-2331.5310			FILE No.	
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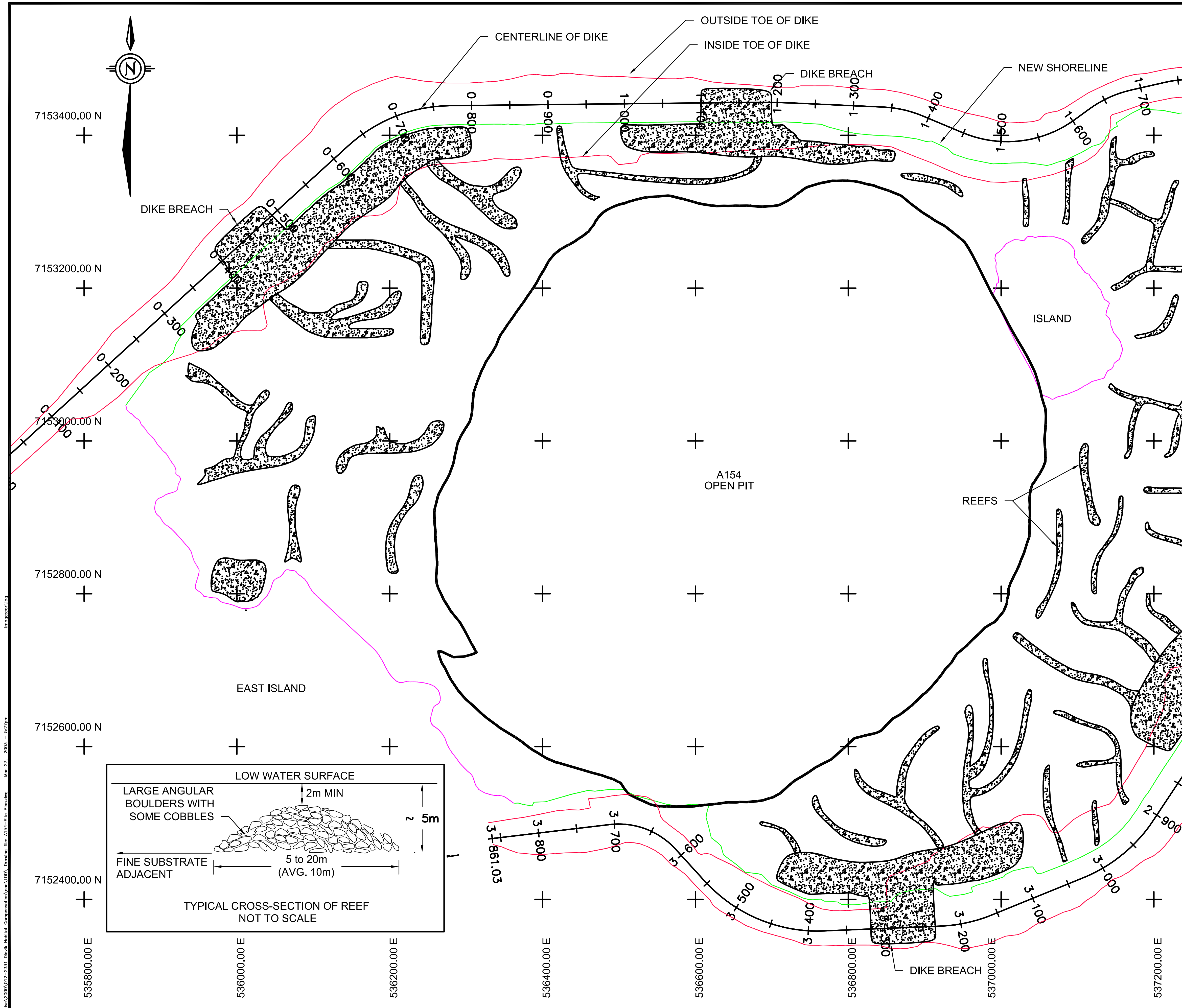

NOTE:

PLAN DEVELOPED FROM INFORMATION PROVIDED BY DIAVIK DIAMOND MINES INC.

SCALE 50 0 50 METRES

PROJECT

DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE

A154 PIT - SCHEMATIC REEF CONFIGURATION

Golder Associates
Saskatoon, Saskatchewan

PROJECT	No. 012-2331.5310	FILE No.	
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REVIEW			

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APPENDIX X-2

Fish Habitat Design – A418 Dike/Pit Area

REPORT ON

FISH HABITAT DESIGN FOR THE A418 PIT SHELF AREA AT THE DIAVIK DIAMOND MINE

Submitted to:

Diavik Diamond Mines Inc.
P.O. Box 2498
5007 – 50th Avenue
Yellowknife, Northwest Territories
1XA 2P8

Attention: Mr. Gord MacDonald

DISTRIBUTION:
1 Copy - Diavik Diamond Mines Inc., Yellowknife (+1 CD)
1 Copy - Golder Associates Ltd., Saskatoon
1 Copy - Golder Associates Ltd., Vancouver

December 2008
07-1328-0001 Doc No. RPT-788 Ver.0 Rev.1

EXECUTIVE SUMMARY

This report presents the detailed design for the creation of fish habitat on the interior of the A418 water retention dike for the Diavik Diamond Mines Inc. diamond mine located on Lac de Gras in the Northwest Territories, Canada. This design was prepared in accordance with the "No Net Loss" plan prepared by Diavik Diamond Mines Inc.

This design is applicable to the A418 pit and has been prepared by developing criteria for the end result. This approach provides flexibility on the part of Diavik Diamond Mines Inc. as to how the end result is achieved.

The fish habitat creation on the interior of the dikes consists of placing material excavated from the open pits in the area between the pit crest and the toe of the dikes, to create an area generally varying from 3 to 5 m below the mean normal water level for Lac de Gras. During mining operations, the toe of the fill will be set back from the edge of the pit crest for safety. At the completion of mining, the fill will be extended to the pit crest.

TABLE OF CONTENTS

SECTION PAGE

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LIST OF FIGURES

TABLE OF CONTENTS (Continued)

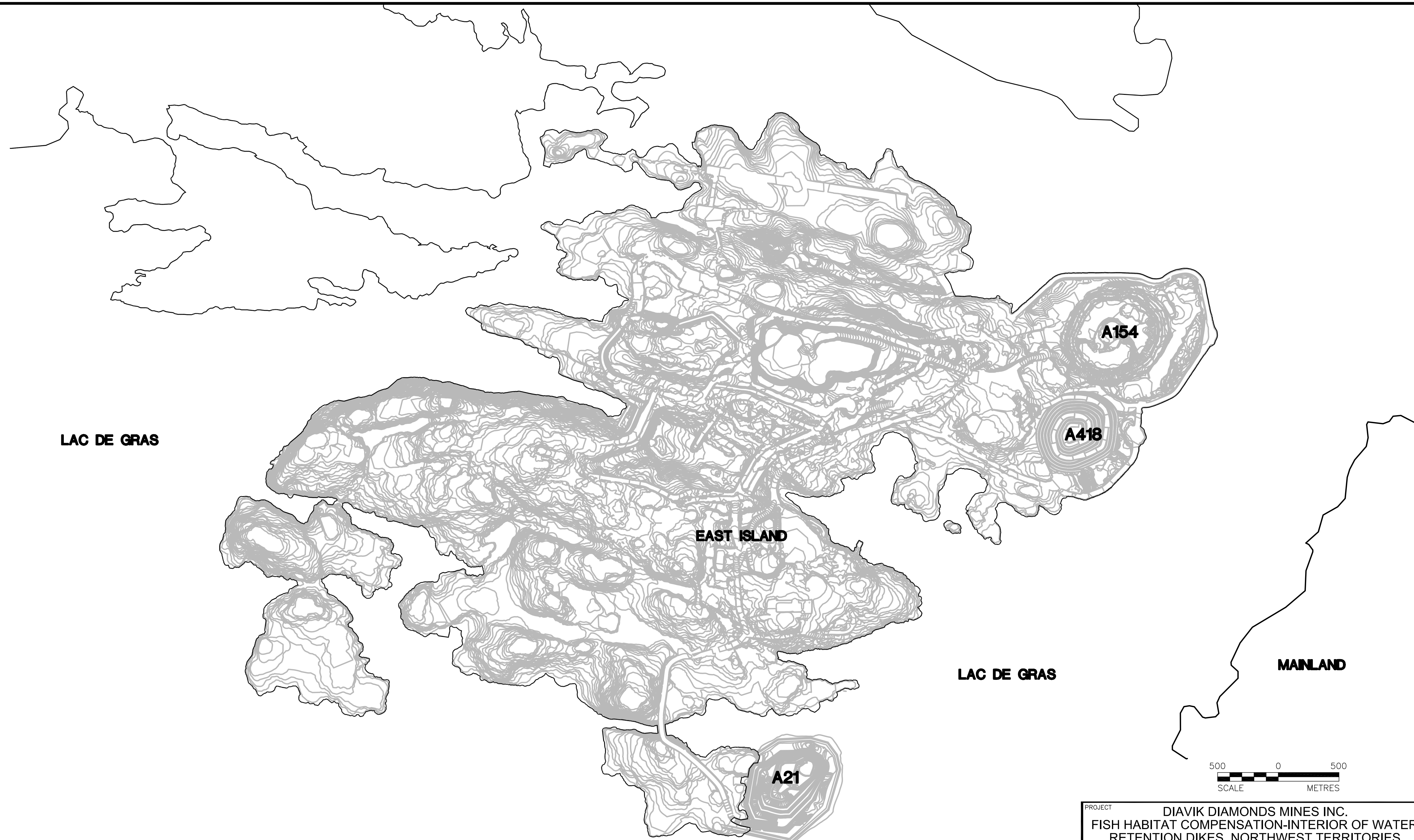
LIST OF APPENDICES

1.0 INTRODUCTION

This report presents the detailed design for the fish habitat compensation plan for the interior of the water retention dikes (i.e., the pit shelf) at the Diavik Diamond Mines Inc. (DDMI) diamond mine in the Northwest Territories. The location of the mine is shown in Figure 1. This detailed design is based on the "No Net Loss" (NNL) Plan (Diavik 1998), and the conceptual fish habitat plan prepared by Golder Associates Ltd. (Golder 2001). The conceptual fish habitat compensation plan for the pit shelf is to construct habitat on the shelf, by filling in the lower elevation (deeper water) areas. The general plan is to fill in the areas on the shelf that are deeper than 5 metres (m) of water depth with materials excavated during development of the pits.

As stated, this document provides the detailed design for the fish habitat compensation for the pit shelf; however, it does not provide specifications for construction. Rather, this document provides details for achieving the desired end result, while providing flexibility in how the end result is achieved. The requirement for this flexibility is due to some of the unknowns with respect to material parameters, mine operations (i.e., blasting details, availability of various materials), and construction timing. The habitat design parameters were developed considering fish habitat, surface water runoff, and geotechnical issues. Design details with respect to surface water handling, material selection, construction, and other issues would be addressed by DDMI, to achieve the desired habitat compensation prior to reflooding of the diked areas.

This design applies specifically to the A418 pit; however, it is similar in concept to plans developed for the A154 and A21 pits. Both A154 and A418 have been constructed with the A418 construction completed in 2006. A21 is currently under financial review and has no scheduled construction timeline. The water retention dike (dike) locations and pit layouts for A418 were modified slightly during construction, and have resulted in minor changes in habitat areas when compared with the original NNL Plan predictions. It is intended that the design details (particularly setback distances and slope angles) be reviewed prior to construction of fish habitat compensation measures to incorporate knowledge gained from the construction and performance of A154, as well as any additional studies, investigations and analyses conducted after the preparation of this report. It will also be important to consider mine operations, seepage control measures for the dikes, overall pit stability and instrumentation/monitoring requirements. It was understood that the pits will be developed in a series of expansion cuts, thus permitting the opportunity to monitor slope stability and pore-pressures in the in situ materials in each pit well in advance of the excavation of the final pit slopes, and construction of the fish habitat fills.



PROJECT
DIAVIK DIAMONDS MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE
PROJECT LAYOUT

Golder Associates
Calgary, Alberta

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REVIEW	PGB	18/12/08				

G:\2007\1328\07-1328-0001 Diavik\Phase 2000\cad\07-1328-0001 Figure 1.dwg Dec 18, 2008 - 4:43pm

2.0 BACKGROUND

The objective of the fish habitat compensation measures on the interior of the water retention dikes is to provide spawning, nursery, rearing and foraging habitat for lake trout (*Salvelinus namaycush*), cisco (*Coregonus artedi*), round whitefish (*Prosopium cylindraceum*), lake whitefish (*Coregonus clupeaformis*), longnose sucker (*Catostomus catostomus*), burbot (*Lota lota*), northern pike (*Esox lucius*), and slimy sculpin (*Cottus cognatus*), in addition to rearing and foraging habitat for Arctic grayling (*Thymallus arcticus*). The primary gains in habitat are expected to relate to rearing habitat for lake trout, cisco, and slimy sculpin. The habitat on the insides of the dikes was to be designed to be similar to the pre-mine habitat in the north inlet which was considered a shallow, productive area of the lake. The objectives and conceptual design for the fish habitat compensation, were outlined in Golder's report entitled "*Conceptual Design and Compensation Workplan for the Fish Habitat Compensation Program, Diavik Diamond Mines Inc., Lac de Gras*", dated August 2001. The conceptual design consisted of:

- Re-contouring the pit shelf (area between the interior toe of the water retention dike and the crest of the pit slope) to provide habitat with a water depth of approximately 5 m after the dike is breached. New habitat will only be constructed where the pre-mining water depth exceeded 5 m; the shallower areas of the shelf will not be excavated, as these areas already provide shallow water habitat. If fill is placed in this area during mine operations, setbacks will be required between the pit crest and the toe of the slope, as well as between the interior toe of the dike and the toe of the fill slope. These areas could be filled near the end of mining, or after completion of mining, if required.
- Constructing long, narrow, rocky reefs extending from the interior slope of the dike to the crest of the open pit. The reefs would be built in areas where the water depth is 5 m and would be approximately 2 to 3 m high. Areas of granular and soft substrates between the reefs would be based on the conditions that existed in the north inlet.
- Modification of disturbed shoreline areas to establish conditions similar to pre-development. This may include placement of boulders in water depths up to about 5 m.
- Flooding the area after completion of habitat construction.
- Breaching the dikes to create shallow (minimum 2 m depth from low water) entrances, to deter the movement of larger fish into the nursery and feeding habitat, similar to the rearing habitat in the north inlet.

3.0 DESIGN PARAMETERS

3.1 Geotechnical Parameters

Geotechnical parameters used were similar to those used in the fish habitat design for pit A154, as the material composition and construction guidelines for the fish habitat compensation on the pit shelves are similar. Bathymetric contours, till thickness isopachs, and sediment thickness isopachs for the A418 pit area were updated in the analysis, as were till strength properties and seismic parameters. During the final design and construction stage, these input parameters can be re-evaluated as necessary if new information becomes available.

Till and sediment samples were characterized as part of the fish habitat design for A154, as described in the Golder report number 012-2331, "*Fish Habitat Design for the Pit Shelf Areas at the Diavik Diamond Mine",* dated March 2003 (Golder 2003). Since then, additional testing has been conducted on the till; therefore, updated material properties for the till material on site were incorporated into the fish habitat design for the A418 pit. Due to the thickness of the lake sediments and its similarity to the till material, the sediments were modelled as till in the analysis. Material properties used in the stability analysis are summarized in Table 1.

Table 1
Material Strength Properties Used for Stability Analysis

Material	Unit Weight (kN/m^3)	Effective Angle of Internal Friction (°)	Effective Cohesion (kPa)
Till	22	34	0
Sediment	22	34	0

Notes: kN/m^3 = kiloNewtons per cubic metre; ° = degrees; kPa = kilopascal.

The bathymetric information in the A418 area indicated that the maximum water depth was about 22 m. The deepest water around the pit crest appears to be approximately 17 m, and the deepest water near the toe of the dike is also approximately 17 m. The highest expected face of placed aquatic habitat fill over the long-term for A418 is expected to be approximately 11 m.

Based on available information from exploration boreholes, the lakebed sediments range from about 0 to 5 m thick and are typically less than 2 m thick, except for a few localized pockets. The in situ till, beneath the sediment, ranges up to approximately 10 m thick and is typically 5 to 9 m thick.

3.2 Fish Habitat Parameters

3.2.1 Overview of No Net Loss Requirements related to Insides of Dike Areas

The Fisheries Authorization identified the requirements for achieving NNL of habitat for all aspects of the DDMI Diamond Project. Specific requirements for the inside of the A418 dike include:

- the development of shallow rearing habitat, spawning shoals, and shoreline habitat within the dikes areas around the open pits in Lac de Gras upon completion of mining in each open pit; and
- ensuring that the habitat features within the dikes areas are modelled after those features found in other productive areas of Lac de Gras, including depth, substrate type, size, and configuration.

Four key zones of habitat were identified in the NNL Plan (Diavik 1998) for the area found inside the constructed dike during the post closure phase. These included:

1. Inside edge of the dike. The area of water depths from 0 to 2 m along constructed sections of the dike representing new shoreline habitat.
2. Reclaimed shorelines. Areas of pre-existing shorelines.
3. The pit shelf. The area between the inside edge of the dike, the shorelines, and the pit crest.
4. Deep water. The pit itself as it will have a depth of approximately 210 m.

The NNL Plan provided Habitat Unit (HU) calculations based on the available design information for the dikes and pits at the time. Some modifications to the dike design and pit dimensions were made subsequent to the submission of the NNL plan, and the new HU calculations reflect these changes. The HUs calculated as part of the NNL Plan Addendum (DDMI April 1999), along with re-calculated values based on this updated information are presented in Appendix I.

The following sections outline the general principles and criteria to be used in developing the final layout for the A418 dike area. As discussed in the NNL, the primary focus for habitat creation inside of all dikes is based on providing spawning, nursery, rearing and foraging habitat. Target species include lake trout, arctic grayling, burbot, longnose sucker, round whitefish, cisco, lake whitefish, northern pike, and slimy sculpin.

3.2.2 Overall Criteria

Several overall governing criteria can be applied to the habitat creation activities inside the dike. First of all, areas inside the dike on the pit shelf that are already at a depth of 4 m or less should not be disturbed if possible. This will allow the maintenance of habitat features not easily re-created. In areas where final depth is between 4 and 5 m, it would be desirable to maintain existing habitat depending upon grading requirements for drainage, or other construction/operational considerations. Existing shoreline features should also be maintained to the extent feasible. Construction crews should avoid driving on, dumping on, scraping, or otherwise impacting these areas. Leaving these areas intact will decrease the amount of work required to restore the shoreline at closure and will speed the recovery process of the altered areas inside the dike as a variety of organic properties, including the possibility that dormant life stages of some plants or animals will be present in the substrate.

The storage and handling of materials, particularly hydrocarbons or other types of contaminants should be closely monitored on the shorelines, pit shelf, and inside edges of the dike. Heavy equipment in the area should be maintained and fuelled in a manner that avoids the possibility of spills occurring in areas to be reclaimed as fish habitat.

3.2.3 Inside Edges of Dike

The inside edge of the dike is intended to provide new shoreline features for foraging and rearing habitat for most species as well as other values, including spawning, for slimy sculpin. The dike itself will resemble existing shoreline and reef habitat and is expected to provide a rocky (boulder/cobble), moderate slope area with low to moderate wind and wave action. The NNL plan habitat evaluation completed for the inside edge the dike treated this area as shoreline habitat.

Suitable materials for this habitat feature are a mix of primarily large boulder with some smaller cobble. Slopes should also ensure a stable profile and range from gentle to moderate. The range of slopes for existing shorelines should be used as a guideline. The area of habitat gain predicted in the NNL plan as well as the area based on the constructed dike alignment for this habitat type is provided in Table 2. For A418, based on constructed dike configuration and the design criteria presented in this report, 0.34 hectares (ha) of new shoreline habitat are expected to be created.

Table 2
Inside Edge of the Dike Shoreline Habitat Areas

Dike	No Net Loss Predicted Area (ha)	Current Predicted Area[a] (ha)
A418	0.48	0.34

Notes: ha = hectare.
(a) = Based on final constructed configuration of the A418 dike.

3.2.4 Reclaimed Shorelines

The objectives for the pre-existing shoreline along the edge of the diked area, and around any islands within diked areas, are to:

- minimize change to existing substrates or other features; and
- re-configure disturbed portions to pre-development conditions as much as possible.

This will allow the shoreline areas to be restored to pre-existing conditions once the dike is breached. Any areas of disturbed shoreline are to be re-configured to provide fish habitat resembling that which was temporarily lost during the project. This may include placement of boulders in water up to 5 m deep to provide a sloping shoreline. The area of habitat predicted in the NNL plan for this habitat type is provided in Table 3. For A418, based on the dike configuration and design criteria presented in this report, 1.2 ha of shoreline habitat are expected to be reclaimed and includes shoreline areas around one island on the pit shelf.

Table 3
Reclaimed Shoreline Habitat Areas

Dike	No Net Loss Predicted Area (ha)	Current Predicted Area[a] (ha)
A418	0.61	1.2

Notes: ha = hectare.
(a) = Based on final constructed configuration of the A418 dike.

3.2.5 Pit Shelf

The pit shelf area extends from the lower inside edges of the dike to the edges of the pit. The reclaimed pit shelf area is intended to provide shallow foraging and rearing habitat for most species of fish present in Lac de Gras. Material excavated from the pit will be used to fill in deeper portions of the pit shelf area. The area of the pit shelf will be covered by water that ranges from 3 to 5 m deep. As per the *Navigable Waters*

Protection Act Permit for the project, no dike breach or constructed shoal features will be less than 2 m below the expected low water level in Lac de Gras.

As indicated in the NNL plan and the Fisheries Authorization, the objectives for the selection of substrate type are based on reflecting physical characteristics of other areas of good foraging and rearing in Lac de Gras. The pit shelf configuration is also to be based on reflecting the physical characteristics of other productive habitats within Lac de Gras. In order to address these objectives, substrate information from baseline data collections was used and a basic configuration evaluation of the North Arm and two other nearby inlets identified as rearing areas within Lac de Gras was completed. The configuration evaluation was completed through air photo interpretation. Key features identified by assessing other rearing areas included:

- Rocky Shoal Shape – Rocky shoals should be somewhat irregular in size and shape and relatively long and narrow. Some may also be constructed like a series of submerged rocky humps like links in a chain. Longer and narrower reefs have more "edge" habitat. Edges are important to fish that feed in one habitat type and rest or seek refuge in another.
- Isolated Pond-like Areas - In some cases it is beneficial to small fish to have the reefs forming a disjointed "ring" to provide pond-like conditions where circulation is limited.
- Hard to Soft Substrate Ratio - The hard substrate (shoals areas) to soft substrate (depositional areas) ratio in other nearby rearing areas ranged from 25 to 40% hard with the remainder as soft substrate.
- Access to Refuge Habitat – Rocky reefs provide refuge or cover for small fish. It is important for fish to have connectivity between rocky areas and reefs to avoid exposing themselves for extended distances or periods of time to predators. Keeping the distance between rocky reef areas less than 30 to 40 m will allow fish reasonable access refuge, or hiding places.

Shape Configuration

With regard to water circulation within the diked area, several features should be incorporated to reduce circulation. The shallow nature of the breaches, shallow nature of the pit shelf, and the creation of shoals on the pit shelf will reduce circulation and wind and wave action. The shallow water is expected to warm up quickly in the spring, relative to open areas of the lake, because of the limited water circulation within the enclosed area. As with other rearing habitats in Lac de Gras, warmer water should, therefore, assist in increasing biological productivity inside the dike by providing a warmer refuge, and foraging area.

Determining the locations of the reefs should take several factors into consideration. Reefs should have some connectivity to the dikes and other reefs to allow fish to travel throughout the area without being fully exposed to predators for long distances. If the reefs are long, winding, and finger-like, a large amount of "edge" habitat will be created to allow fish to feed in the fine substrate while maintaining close proximity to the cover provided by the rocky reefs. Ideally, the reefs will be placed in areas where the final water depth will be 3 to 5 m deep and the tops of the reefs will remain under at least 2 m of water at all times. This will allow the reef habitat to remain functional even in winter with ice thickness of up to 2 m. Widths of the reefs should vary between 5 and 30 m, averaging from 10 to 20 m in width. The distance between the reefs could range from 10 to 40 m, averaging from 20 to 30 m apart. Habitat diversity is important and varying the size and shape of the reefs throughout the pit shelf area is expected to improve its value as fish habitat.

Substrate Material

Based on the substrate materials within the North inlet substrates on the pit shelf should be mostly fine material, primarily sand and silt interspersed with rocky reefs for habitat diversity. The till (existing lake substrate) is primarily sand and silt with some gravel. The till material will therefore be an appropriate substrate for the expected biological zone of the sediments (i.e., approximately top 10 centimetre (cm) layer represents the biological zone). The fine substrate areas are expected to support a variety of benthic organisms that will provide forage for small fish.

If till is placed over angular rock to provide the soft substrate zone, it should be a layer deep enough to maintain at least 0.5 m depth of soft substrate after settling, accounting for some migration of fines into the voids in the rock fill.

Reefs should be constructed of granular material of a range of sizes. The primary material should be large boulder size rock with some smaller cobble material. The objective is to create refuge habitat, or hiding areas, among the rocks. Angular, unconsolidated material would provide this benefit. Run of mine blast rock is expected to be acceptable for this purpose.

The area of habitat predicted in the NNL plan for this habitat type is provided in Table 4. For A418, based on constructed dike configuration and the design criteria presented in this report, 9.4 ha of shallow rearing and foraging habitat are expected to be created.

Table 4
Pit Shelf Habitat Areas

Dike	No Net Loss Predicted Area (ha)	Current Predicted Area[(a)] (ha)
A418	8.68	9.4

Notes: ha = hectare.
(a) = Based on final constructed configuration of the A418 dike.

3.2.6 Deep Water (Pit Area)

The deep water habitat created by the project will be located in the mine pit, near the center of the diked area. The deep water will provide a cooler environment for fish and was considered a pelagic zone in the NNL plan. This area will likely be used by pelagic feeding fish such as cisco and may provide other benefits (e.g., over wintering habitat). The maximum depth of the pit areas is anticipated to be 210 m. The area of habitat predicted in the NNL plan for this habitat type is provided in Table 5. For A418, based on constructed dike configuration and the design criteria presented in this report, 34.13 ha are actually expected to be created.

Table 5
Deep Water Habitat Areas

Dike	No Net Loss Predicted Area (ha)	Current Predicted Area[(a)] (ha)
A418	41.94	34.13

Notes: ha = hectare.
(a) = Based on final constructed configuration of the A418 dike.

3.3 Construction Considerations

There are a number of construction considerations that arise due to the variability in the material parameters, pore-pressure conditions, blasting effects, and construction timing. The following construction considerations were evaluated with respect to the detailed design of the fish habitat compensation measures for the pit shelf areas:

- It was understood that flowing artesian conditions were present in the southeast portion of the A154 pit shelf. Artesian conditions may cause build-up of porewater pressures within the fill on the pit shelf, depending on drainage conditions and the development of frozen layers. It is unknown if similar conditions exist on the A418 pit shelf.

- The fine-grained lake-bottom sediments are expected to provide poor trafficability, particularly where artesian conditions exist, and when the materials are thawing. Portions of the A418 dike are expected to encounter permafrost, which would also present poor trafficability conditions if it thaws.
- A berm will be required between the pit crest and the toe of the fish habitat fill to provide safety with respect to equipment travelling too close to the pit crest and to reduce the potential for fill materials spilling into the pit during placement. The berm could also be used as a construction access road prior to pit development adjacent to the berm.
- The majority of the fill volume may consist of either till or rock fill, depending on construction timing and material availability. The final surface of the fill will consist of till, or lake-bottom sediments, to support aquatic life. The thickness of the final till/sediment layer will depend on whether a filter is used between the rock and till. DDMI will be responsible for picking the construction methods, and materials handling such that adequate quantities of till are available for the final fill surface.
- Based on gradation information for the till from the A154 pit shelf, it is anticipated that at least two, and possibly three graded aggregate filters would be required to prevent the till from migrating into the voids within the rock fill. Production of filter material would likely be relatively expensive, since it would involve crushing, screening, stockpiling, and double handling of the materials. It has been assumed that a filter between the rockfill and the till would not be utilized, due to logistical and economic considerations. As an alternative to using a filter, the thickness of the till cover on a rock fill can be varied as a function of the total fill thickness. The premise for this approach is that a certain portion of the till will migrate into the void spaces in the rock fill, so the thickness of the till cover must be such that a minimum of 0.5 m of till remains on top of the rock. For design purposes, it has been assumed that the porosity of the rock fill would be approximately 30 percent, and that with time, till would migrate into the rock such that 50 percent of the available voids would be filled. Thus, using this approach, the minimum thickness of till required over the rock is equal to 15 percent of the rock fill thickness, plus 0.5 m. If this approach is adopted, some overbuilding of the till layer should be considered to maintain the desired water depths after the till migrates into the rock fill, especially where the till thicknesses are greater. Theoretically, where rocky reefs are to be constructed, till would not be required between the rock fill and reef material.
- Rock fill has the advantages of higher shear strength and better potential for drainage/dissipation of pore-water pressures. Rock fill may require a smaller thickness than till to provide a stable trafficking surface for the initial lifts.
- Rock fill would permit faster infiltration than till, which may provide a more stable trafficking surface after precipitation events and during spring thaw.

- Till will be available earlier in the mining cycle for each pit, since it overlies the bedrock. Materials may be transported between pits, if required.

4.0 STABILITY ANALYSES

4.1 Overall Pit Stability

Golder prepared various reports regarding the stability of the A154 pit (Golder 1999, 2000, 2002, 2002a). The overall pit stability for A418 was assessed in Golder's report entitled, "*A418 Feasibility Pit Slope Design*" (Document No. Rpt-138, dated January 11, 2007). Pertinent items from this report related to the fish habitat compensation fills are as follows:

- Fractured rock zones similar to Dewey's Fault in the vicinity of the A154N/S pipes have not been encountered in the A418 area; however, a bathymetric low, trending a north-south direction, occurs in the south through southeast area of the planned pit. This feature is not fully understood, although while it has been speculated that it could potentially be a zone of high hydraulic conductivity, there is currently no evidence to support this.
- Modelling showed that depressurization will be necessary for Section 130 in order to achieve the required safety factor for the overall slope. Recommendations were provided for piezometer installations to monitor the depressurization of the pit wall.

Construction of the fish habitat compensation fill will require a setback from the crest of the pit to the toe of the fill, such that the overall pit stability is not significantly impacted by the presence of the fish habitat fills on the pit shelf during operations.

4.2 Stability of Fish Habitat Fills

Slope stability analyses were carried out to determine the stability of the fish habitat fills, and the required setback from the pit crest. The impact of the placed material on the stability of the pit was also checked.

Stability analyses were carried out using the computer program, SLOPE/W. Factors of safety were calculated using the principle of limit equilibrium, for potential sliding along assumed failure surfaces for each of the selected cross-sections. Factors of safety were computed using both Spencer's method and the Morgenstern-Price method, which satisfy both force and moment equilibrium. Based on the type of soil and the configuration of the habitat, both circular and wedge failure mechanisms were assessed. The factor of safety was assessed for a phreatic level which was situated at the top of the till/lake sediment surface, simulating saturated conditions in the pit shelf. This is considered conservative due to cut-off measures to be implemented during the dyke construction.

The effects of blasting in the pit on the stability of the fill were assessed by using a pseudo-static limit equilibrium analysis using a 1:2500 year return earthquake value of 0.06 g in the horizontal direction. As production blasting data is accumulated, the impact of blasting may be reassessed and the design refined.

The results of the stability analyses are summarized in Appendix II. The stability analyses indicate that computed factors of safety for the fills are in excess of 1.4 for the conditions during mining. A conservative approach with respect to setback distances and slope angles is proposed, combined with monitoring to assess modifications to the proposed design as mining proceeds, due to the critical importance of maintaining stability during operations. The recommended setback from the pit crest (i.e., top of the in-situ till slope to the toe of the fish habitat fill) is four times the height of the fill (taken as the difference between the ultimate top of the fill and the elevation of the pit crest), with a minimum of 15 m. The slope of the faces of the fish habitat fill facing the pit and the interior of the dikes should be 3H:1V or flatter. As mining progresses, it may be possible to modify the setback and slope angle parameters.

5.0 CONSTRUCTION GUIDELINES

The recommended configuration of the fish habitat on the A418 pit shelf is based on the following guidelines:

- Construct fills with face slopes of 3H:1V during mining, and final slopes at the angle of repose adjacent to the pit crest at the completion of mining.
- Setback from the pit crest to the toe of the fill equal to four times the elevation difference between the top of fill and the pit crest, with a minimum distance of 15 m.
- To the extent feasible, areas of existing shallow habitat (i.e., water depth less than 5 m below mean normal water level) should remain untouched.
- A berm should be constructed between the toe of the till slope and the crest of the pit. This berm will help retain material that erodes from the slope of the fish habitat fill and keep it away from the pit, and will also reduce the potential for any material rolling down the slope and into the pit during fill placement. A minimum setback of 5 m from the crest of the pit to the toe of the berm has been used. As a minimum, the berm would be approximately 2 m high, with a 2 m crest width and 2H:1V sideslopes. The geometry of this berm may be modified on the basis of construction techniques.
- A setback from the interior toe of the water retention dike, to the upstream toe of the fill may also be required. This setback distance should be determined by DDMI, based on operational requirements and surface water handling requirements. Construction must also accommodate instrumentation for monitoring seepage through the dike, and overall pit slope stability.
- Construction in one lift is acceptable.
- The materials used to construct the fill may consist of till, rock fill, or a combination of materials. If rock fill is used to construct the lower portion of the fill, the thickness of till to create the final surface should be a minimum of 0.15 times the height of rock fill, plus 0.5 m. Alternatively, filter zones could be provided between the rock fill and the till. Details of the filter zones would have to be developed further, once construction techniques and material gradations are determined. Processing of the blast rock will be required to produce filter materials, and is likely to be expensive. If the filter zone approach is taken, it is likely that at least two, and possibly, three filters would be required.
- Grading of the surface of the fill at a nominal grade of 1% is recommended, to direct surface water towards the water collection system at the toe of the dike.
- Final contouring of the surface will be required to establish some relief to provide fish habitat (i.e., some hummocks and hollows, rather than an evenly graded surface).
- Rock ridges or reefs are also required for fish habitat. These reefs should be constructed of non-acid generating country rock.

6.0 DETAILED DESIGN DRAWINGS

A set of detailed design drawings is included in Appendix III for the A418 pit. The design drawings indicate the desired end results, and provide DDMI with flexibility in regards to construction materials, methods, and timing. Operational considerations and the results of monitoring programs to assess seepage through/below the dike, and overall pit slope stability should be taken into account when planning the construction of the fish habitat fills. At the end of mining, construction of angle of repose slopes adjacent to the pit crest will be required. The exact extent of the fill, placement procedures, and safety protocols should be developed prior to construction.

7.0 MONITORING RECOMMENDATIONS

Monitoring of various parameters is recommended to confirm the design assumptions, and to provide information for refining the design of the fish habitat on the pit shelves. It is recommended that monitoring consist of:

- Monitoring pore-water pressures in the lake-bottom sediments and till that will form the foundation for the fish habitat fills to assess drainage due to pit development, as well as pore-pressures due to fill placement and blasting.
- Monitor pore-pressures within the fish habitat fills, so that the slope stability analyses can be confirmed.
- Monitor movements of the fish habitat fills using a series of monitoring prisms, slope inclinometers or other technologies, consistent with monitoring of the overall pit slopes. Visual inspections should also be conducted to check for signs of instability, such as bulging, slumping, or the development of tension cracks.

Monitoring programs have previously been recommended for the water retention dikes and for monitoring the overall pit stability. It is recommended that the monitoring for the fish habitat fills on the interior of the dikes be integrated into the overall monitoring program, to provide consistency, and improve the efficiency of the monitoring efforts.

8.0 CLOSURE

We trust this report presents the information that you require. Please feel free to call at anytime if you have any questions or concerns.

GOLDER ASSOCIATES LTD.

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APPENDIX I

SUMMARY OF HABITAT UNIT ACCOUNTING FOR A418

Table I-1
No Net Loss Habitat Summary "Accounting" Showing Habitat Units for A418, from No Net Loss Addendum, 1999

Life Stage	Species	A418 (2009-2023)		Net Change
		loss	gain	
Spawning	LKTR	0.10	0.07	-0.03
	ARGR	0.00	0.00	0.00
	CISC	0.11	0.06	-0.05
	RNWH	0.02	0.05	0.03
	LKWH	0.04	0.02	-0.02
	LNSC	0.02	0.01	-0.01
	BURB	0.02	0.00	-0.01
	NRPK	0.00	0.00	0.00
	SLSC	0.03	0.21	0.18
Rearing	LKTR	1.00	3.60	2.60
	ARGR	0.17	0.26	0.09
	CISC	1.53	3.47	1.94
	RNWH	0.26	0.61	0.34
	LKWH	0.28	0.62	0.34
	LNSC	0.30	0.48	0.19
	BURB	0.19	0.27	0.08
	NRPK	0.00	0.00	0.00
	SLSC	0.26	0.43	0.17
Foraging	LKTR	0.90	0.96	0.06
	ARGR	0.10	0.13	0.04
	CISC	0.88	1.65	0.77
	RNWH	0.17	0.28	0.11
	LKWH	0.15	0.28	0.13
	LNSC	0.21	0.24	0.03
	BURB	0.11	0.12	0.00
	NRPK	0.00	0.00	0.00
	SLSC	0.14	0.21	0.06
Nursery	LKTR	0.10	0.06	-0.04
	ARGR	0.00	0.00	0.00
	CISC	0.11	0.06	-0.05
	RNWH	0.02	0.05	0.03
	LKWH	0.04	0.02	-0.02
	LNSC	0.02	0.01	-0.01
	BURB	0.02	0.00	-0.01
	NRPK	0.00	0.00	0.00
	SLSC	0.03	0.21	0.18
Total		7.33	14.45	7.12

Table I-1

No Net Loss Habitat Summary "Accounting" Showing Habitat Units for A418, from No Net Loss Addendum, 1999 (continued)

Life Stage	Species	A418 (2009-2023)		Net Change
		loss	gain	
Total by life stage	Spawning	0.34	0.43	0.10
	Rearing	4.00	9.73	5.74
	Foraging	2.66	3.86	1.20
	Nursery	0.34	0.42	0.08
Total by species	LKTR	2.11	4.69	2.59
	ARGR	0.27	0.40	0.13
	CISC	2.62	5.23	2.61
	RNWH	0.47	0.99	0.51
	LKWH	0.51	0.94	0.43
	LNSC	0.55	0.74	0.19
	BURB	0.34	0.40	0.06
	NRPK	0.00	0.00	0.00
	SLSC	0.47	1.06	0.60

Notes: LKTR = lake trout; ARGR = Arctic grayling; CISC = cisco; RNWH = round whitefish; LKWH = lake whitefish; LNSC = longnose sucker; BURB = burbot; NRPK = northern pike; SLSC = slimy sculpin.

Table I-2

No Net Loss Habitat Summary "Accounting" Showing Habitat Units for A418, Recalculated with Constructed Dimensions for A418 Dike

Life Stage	Species	A418 (2009-2023)		Net Change
		loss	gain	
Spawning	LKTR	0.10	0.09	-0.01
	ARGR	0.00	0.00	0.00
	CISC	0.11	0.07	-0.03
	RNWH	0.02	0.06	0.04
	LKWH	0.04	0.03	-0.01
	LNSC	0.02	0.01	-0.02
	BURB	0.02	0.01	-0.01
	NRPK	0.00	0.00	0.00
	SLSC	0.03	0.21	0.17
Rearing	LKTR	1.00	3.25	2.24
	ARGR	0.17	0.24	0.06
	CISC	1.53	3.11	1.58
	RNWH	0.26	0.56	0.30
	LKWH	0.28	0.59	0.31
	LNSC	0.30	0.45	0.15

Table I-2

No Net Loss Habitat Summary "Accounting" Showing Habitat Units for A418, Recalculated with Constructed Dimensions for A418 Dike (continued)

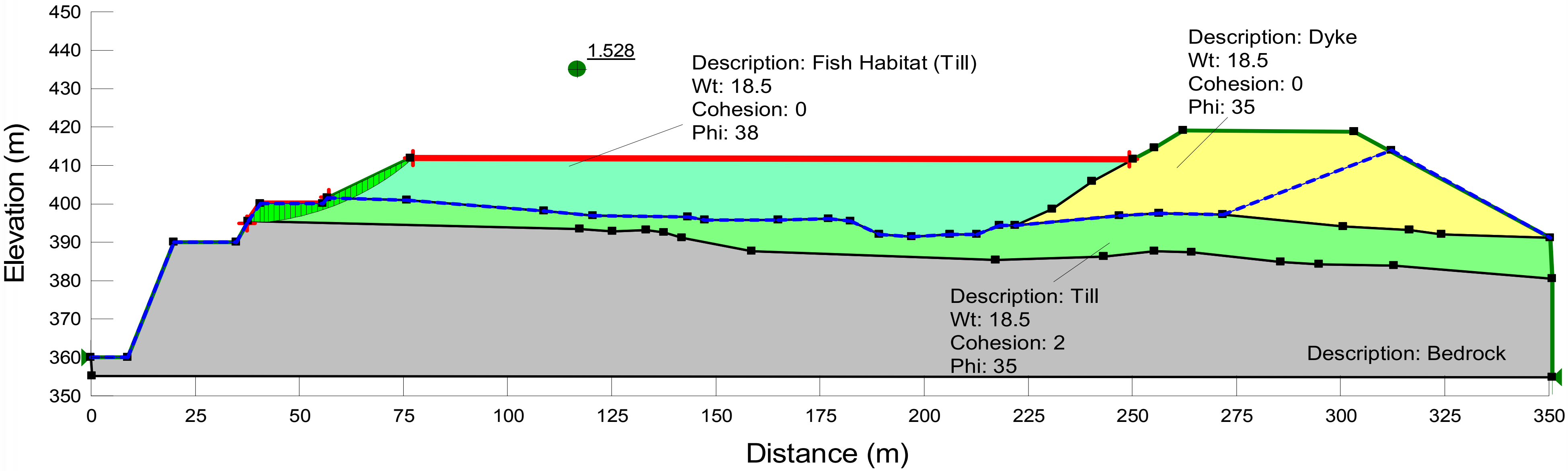
Life Stage	Species	A418 (2009-2023)		Net Change
		loss	gain	
Rearing (continued)	BURB	0.19	0.25	0.06
	NRPK	0.00	0.00	0.00
	SLSC	0.26	0.41	0.16
Foraging	LKTR	0.90	0.88	-0.03
	ARGR	0.10	0.12	0.03
	CISC	0.88	1.47	0.59
	RNWH	0.17	0.25	0.09
	LKWH	0.15	0.26	0.11
	LNSC	0.21	0.22	0.02
	BURB	0.11	0.11	-0.01
	NRPK	0.00	0.00	0.00
	SLSC	0.14	0.19	0.05
Nursery	LKTR	0.10	0.08	-0.02
	ARGR	0.00	0.00	0.00
	CISC	0.11	0.07	-0.03
	RNWH	0.02	0.06	0.04
	LKWH	0.04	0.03	-0.01
	LNSC	0.02	0.01	-0.02
	BURB	0.02	0.01	-0.01
	NRPK	0.00	0.00	0.00
	SLSC	0.03	0.21	0.18
Total		**7.33**	**13.28**	**5.95**
Total by life stage	Spawning	0.34	0.46	0.13
	Rearing	4.00	8.85	4.86
	Foraging	2.66	3.51	0.85
	Nursery	0.34	0.45	0.12
Total by species	LKTR	2.11	4.29	2.18
	ARGR	0.27	0.36	0.09
	CISC	2.62	4.72	2.10
	RNWH	0.47	0.93	0.45
	LKWH	0.51	0.90	0.40
	LNSC	0.55	0.69	0.14
	BURB	0.34	0.38	0.04
	NRPK	0.00	0.00	0.00
	SLSC	0.47	1.02	0.56

Notes: LKTR = lake trout; ARGR = Arctic grayling; CISC = cisco; RNWH = round whitefish; LKWH = lake whitefish; LNSC = longnose sucker; BURB = burbot; NRPK = northern pike; SLSC = slimy sculpin.

APPENDIX II

SUMMARY OF SLOPE STABILITY ANALYSES

Date: 26/04/2007
Name: 07 apr 20 A418 Sect B final.gsz
Comments: Final Configuration



PROJECT	DIAVIK DIAMONDS MINES INC. FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES
TITLE	A418 STABILITY ANALYSIS RESULTS

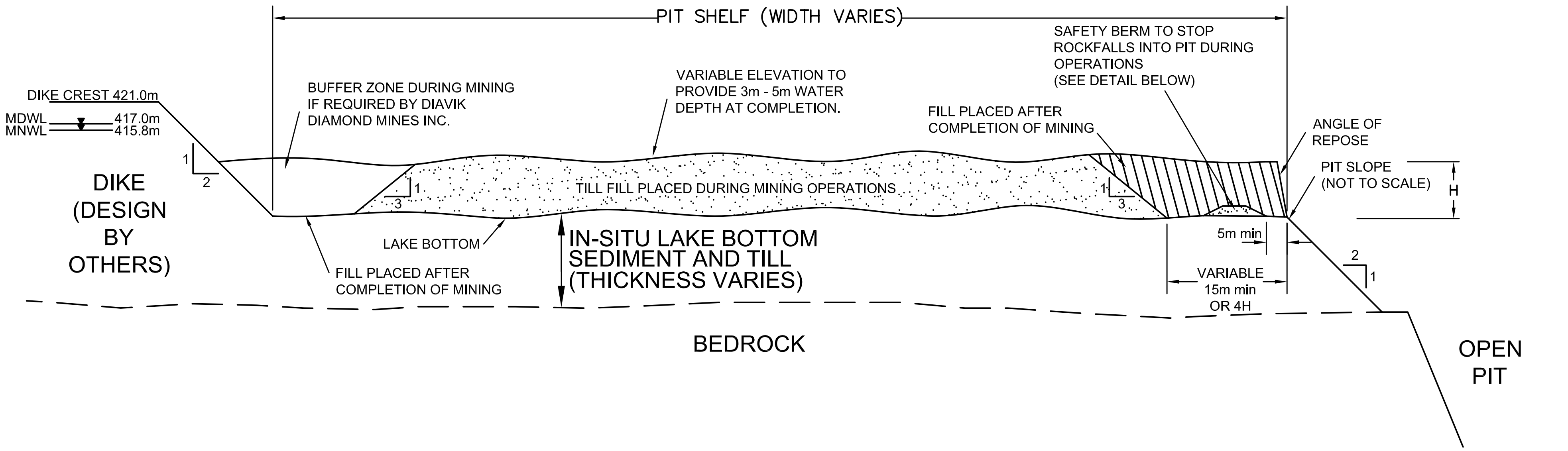
Golder Associates
Saskatoon, Saskatchewan

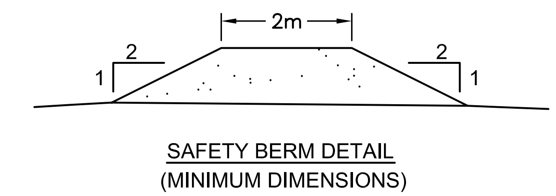
PROJECT	07-1328-0001		FILE No.		
DESIGN	EAM	23/09/08	SCALE	N/A	REV.
CADD			FIGURE:II-1		
CHECK	RML	18/12/08			
REVIEW	PGB	18/12/08			

APPENDIX III

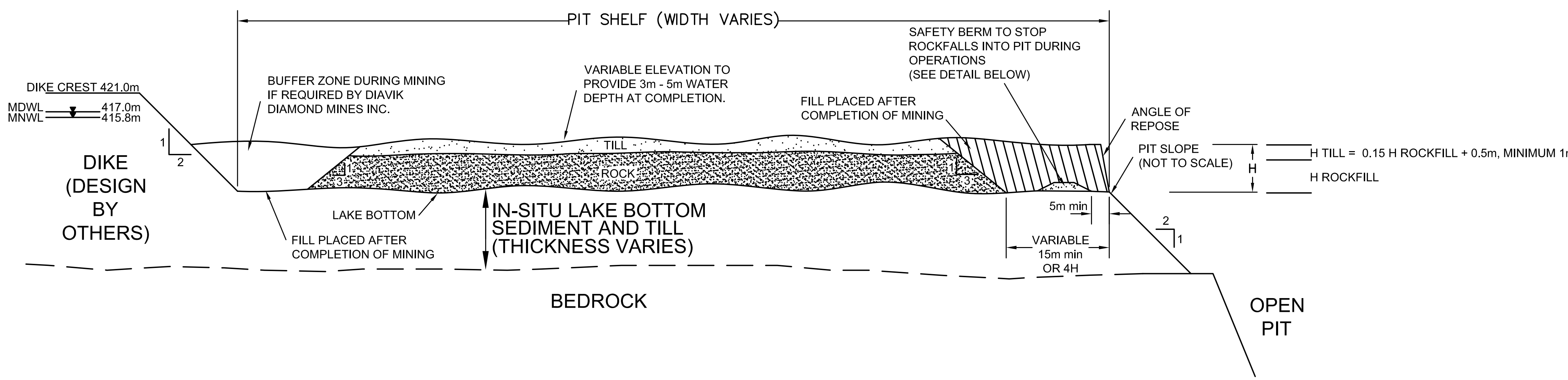
DETAILED DESIGN DRAWINGS

TILL FILL OPTION





ROCK/TILL OPTION (NO FILTERS)



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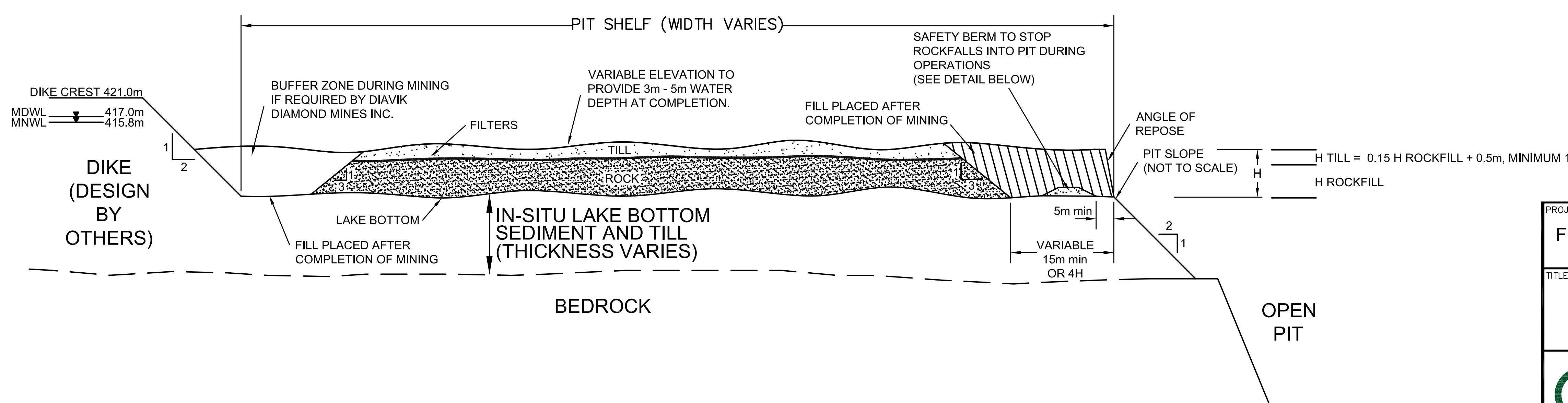

PROJECT
DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE
CROSS-SECTION OPTIONS FOR FISH HABITAT CREATED INSIDE DIKES

Golder Associates
Saskatoon, Saskatchewan

PROJECT	07-1328-0001		FILE No.	
DESIGN			SCALE NTS	REV. 0
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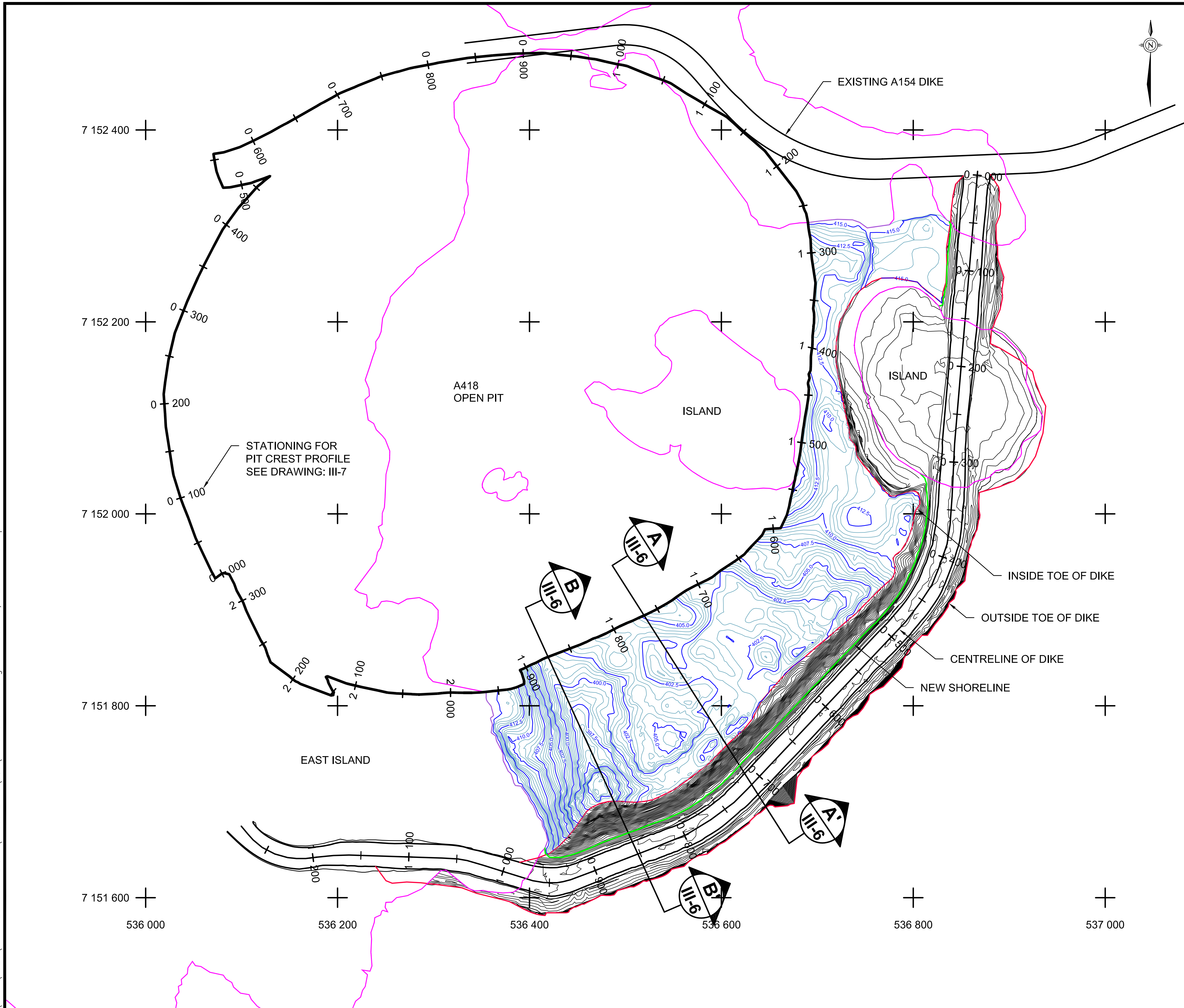
CHECK	AL	18/12/08		
REVIEW	PGB	18/12/08		



REFERENCE

PLAN DEVELOPED FROM INFORMATION PROVIDED BY DIAVIK DIAMOND MINES INC.

100 0 100

SCALE METRES

PROJECT

DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

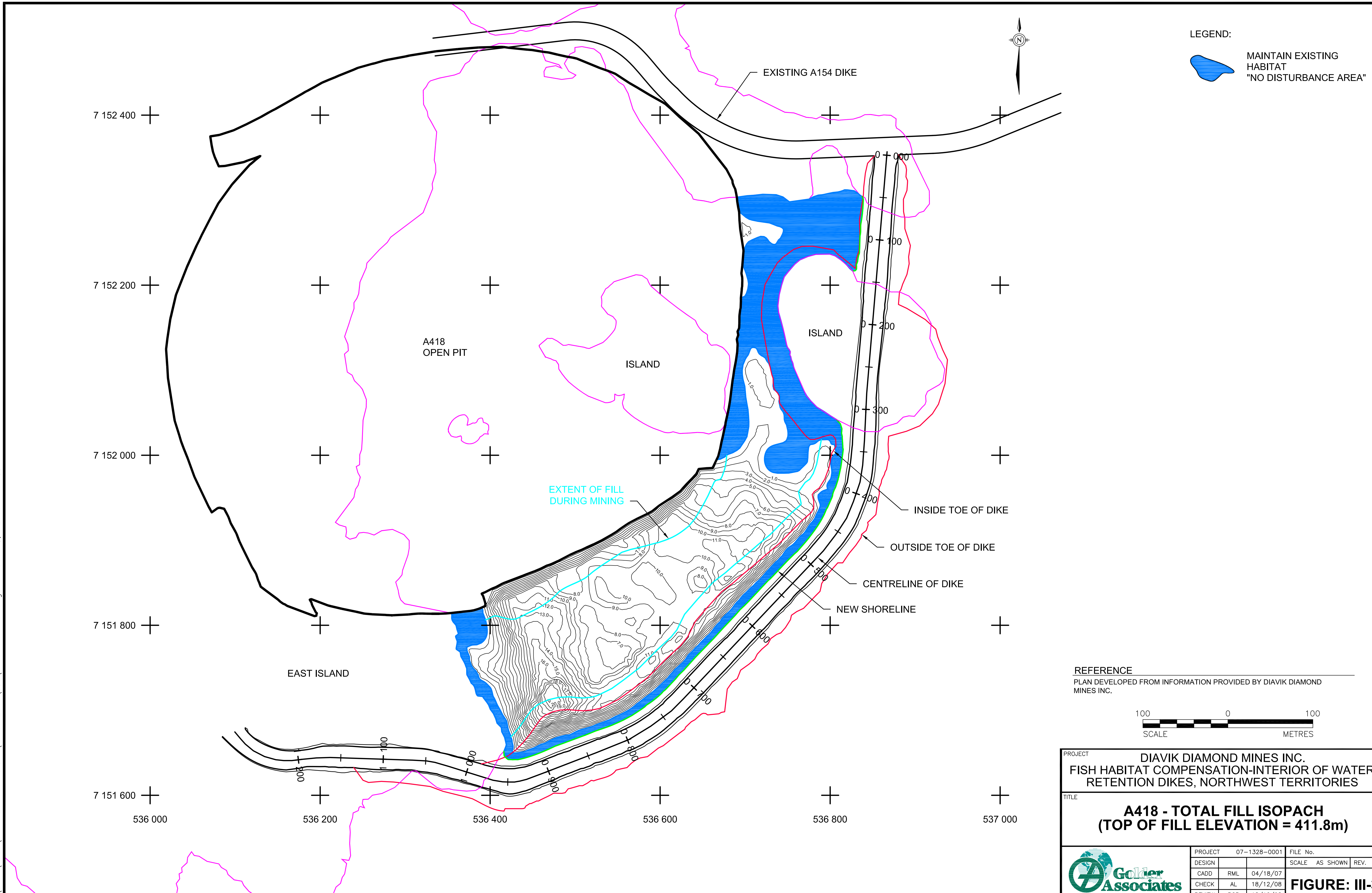
TITLE

BATHYMETRY - A418 PIT

PROJECT	07-1328-0001		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
CADD	RML	04/18/07		
CHECK	AL	18/12/08	**FIGURE: III-2**	
REVIEW	PGB	18/12/08		

Golder Associates
Calgary, Alberta

G:\2007\1328\07-1328-0001 Diavik\Phase 2000\cad\A418-Site Plan.dwg Dec 18, 2008 - 5:09pm



PROJECT
DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE
A418 - TOTAL FILL ISOPACH (TOP OF FILL ELEVATION = 411.8m)

Golder Associates
Calgary, Alberta

PROJECT	07-1328-0001		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
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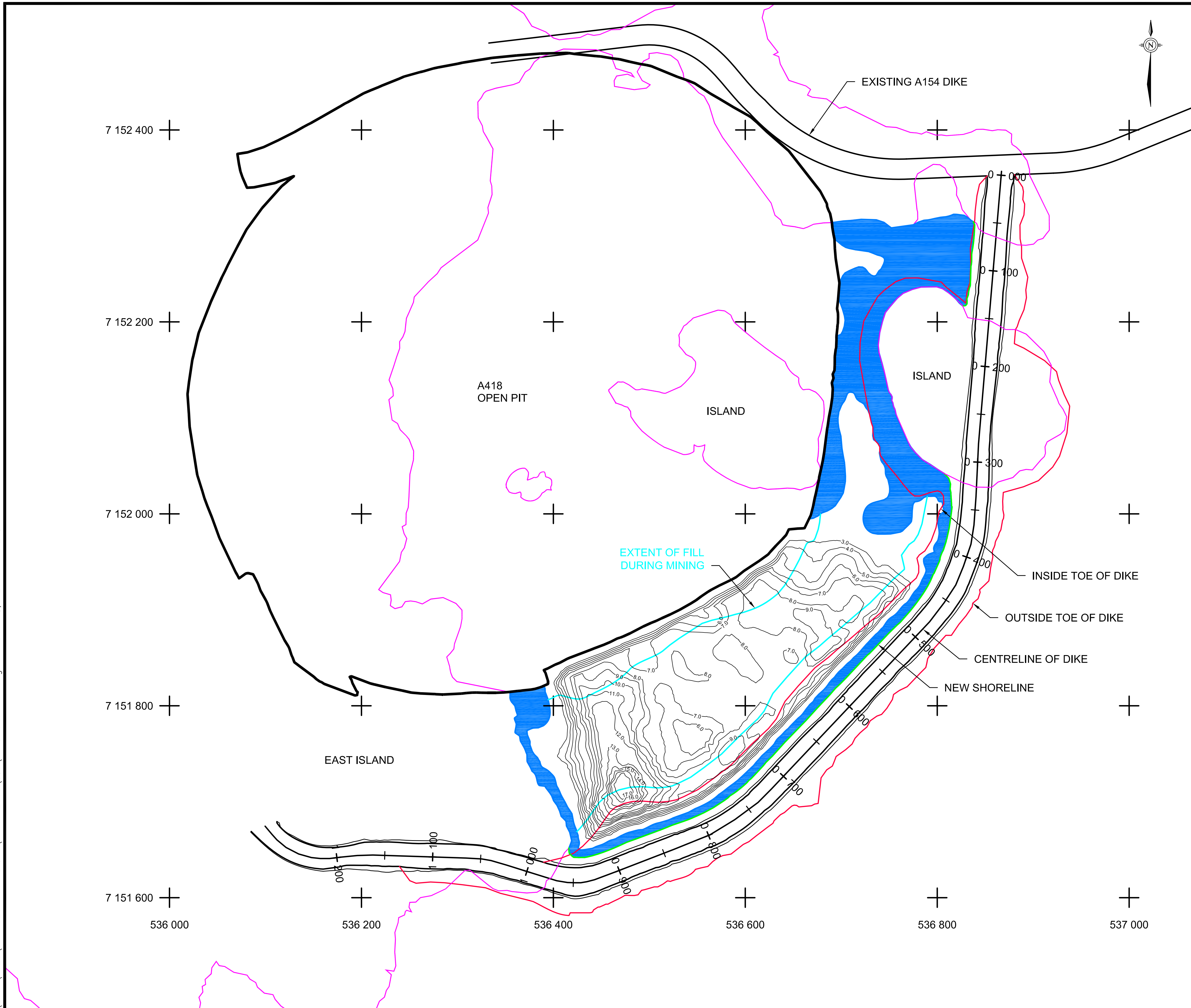
CHECK	AL	18/12/08	FIGURE: III-3	
REVIEW	PGB	18/12/08		



LEGEND:

MAINTAIN EXISTING HABITAT "NO DISTURBANCE AREA"

REFERENCE

PLAN DEVELOPED FROM INFORMATION PROVIDED BY DIAVIK DIAMOND MINES INC.

100 0 100

SCALE METRES

PROJECT

DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE

A418 - ROCK FILL ISOPACH BELOW TILL COVER (NO FILTER, FINAL TOP OF FILL ELEVATION = 411.8m)

Golder Associates
Calgary, Alberta

PROJECT	07-1328-0001		FILE No.
DESIGN			SCALE AS SHOWN REV. 0
CADD	RML	04/18/07	
CHECK	AL	18/12/08	**FIGURE: III-4**
REVIEW	PGB	18/12/08	

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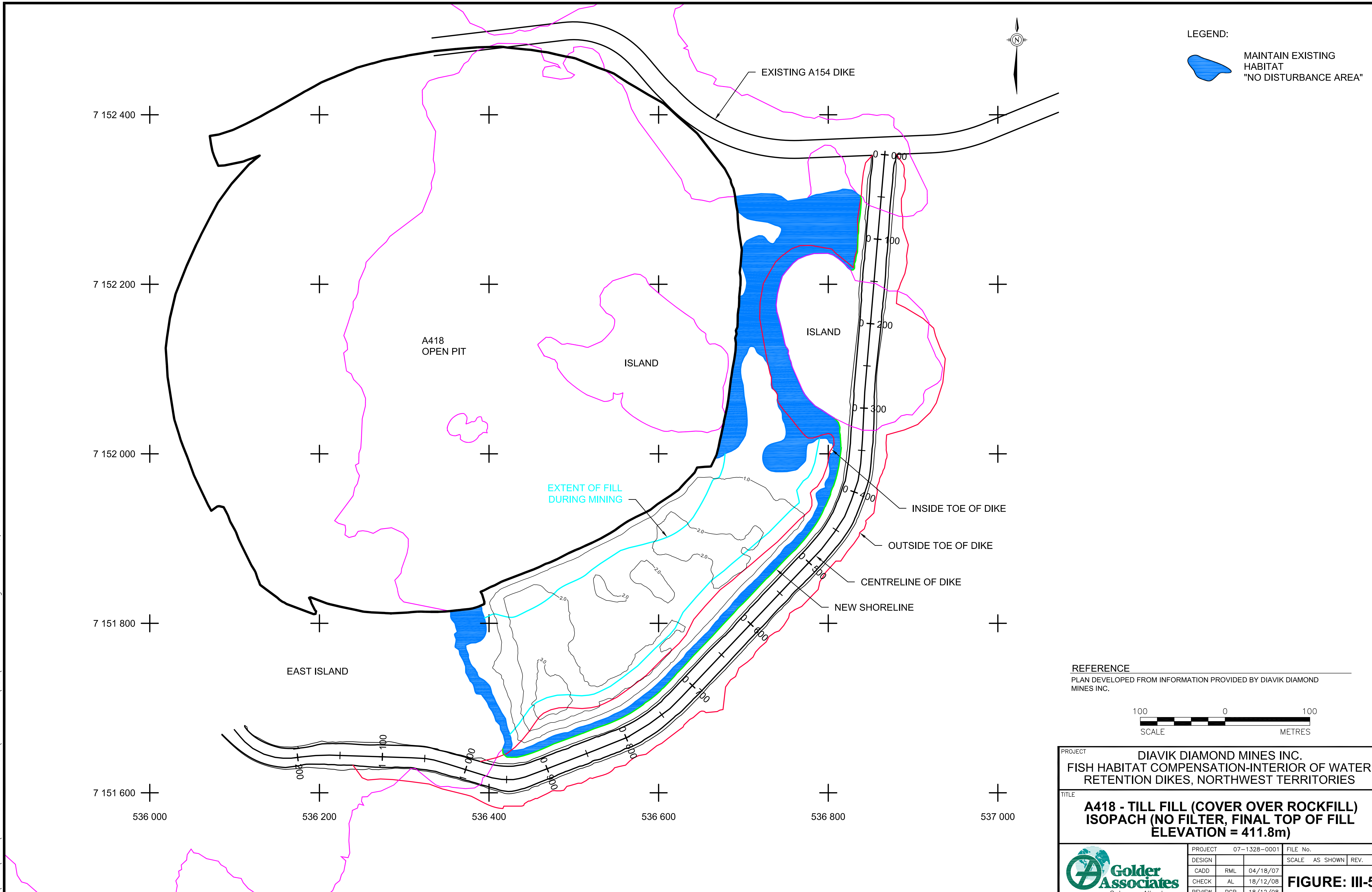

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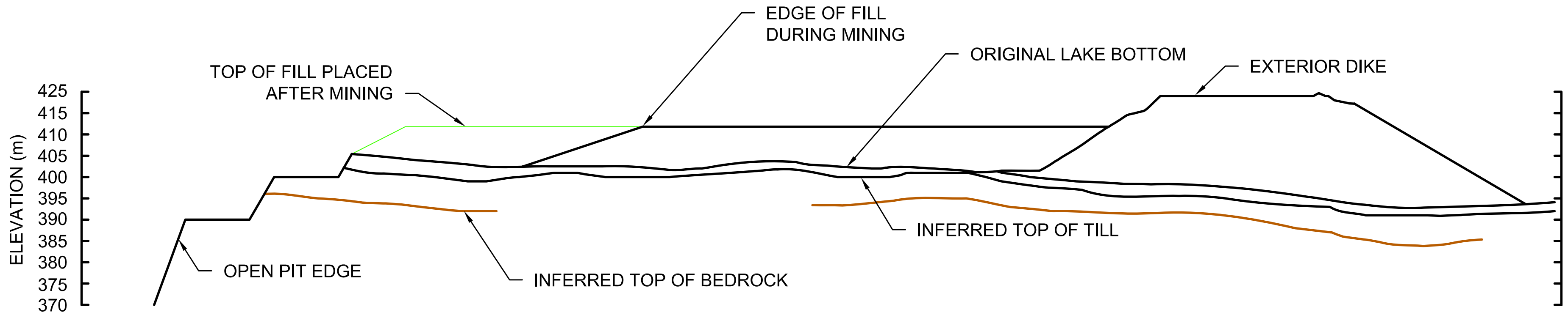
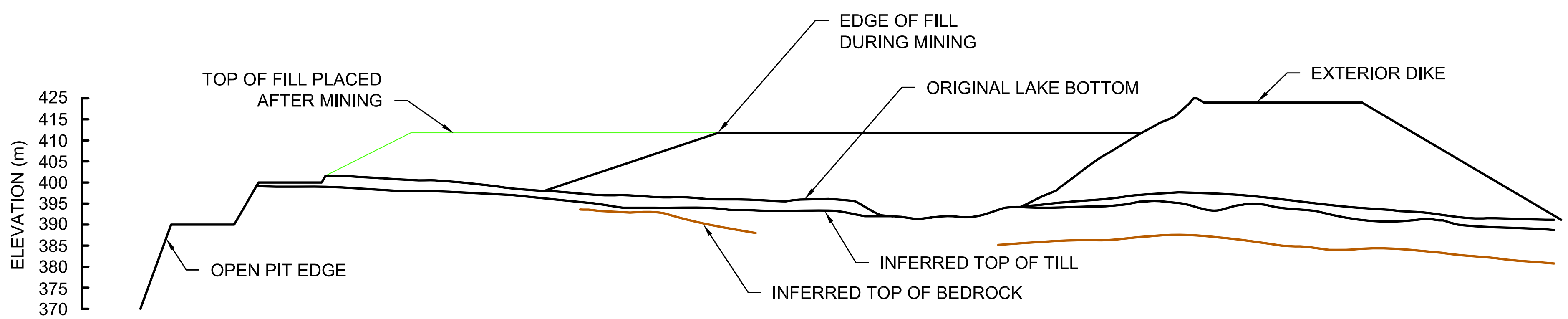


A
III-2
CROSS SECTION A-A'



B
III-2
CROSS SECTION B-B'

NOTE:

CROSS-SECTIONS MAY NOT BE PERPENDICULAR TO DIKE CENTRELINE.

30 0 30
SCALE METRES

PROJECT	DIAVIK DIAMOND MINES INC. FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES		
TITLE	A418 - CROSS SECTIONS OF FISH HABITAT FILL ON EXTERIOR DIKES		
PROJECT	07-1328-0001	FILE No.	
DESIGN		SCALE AS SHOWN	REV. 0
CADD	RML 04/18/07	FIGURE: III-6	
CHECK	AL 18/12/08		
REVIEW	PGB 18/12/08		

Golder Associates
Calgary, Alberta

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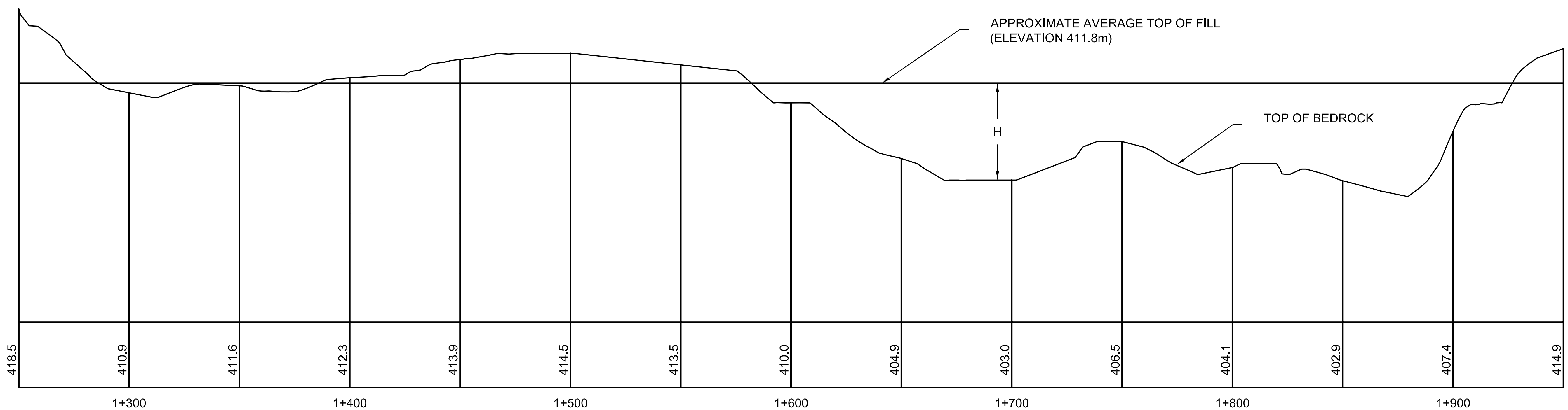

PIT CREST PROFILE

40 0 40
SCALE METRES

5x VERTICAL EXAGGERATION

NOTES:

1. SEE FIGURE : III-2 FOR STATIONING

2. SETBACK FROM PIT CREST TO TOE OF FISH HABITAT FILL (DURING MINING) EQUAL TO 4H WITH A MINIMUM OF 15m.

PROJECT

DIAVIK DIAMOND MINES INC.
FISH HABITAT COMPENSATION-INTERIOR OF WATER RETENTION DIKES, NORTHWEST TERRITORIES

TITLE

A418 - PIT CREST PROFILE

Golder Associates
Calgary, Alberta

PROJECT	07-1328-0001		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
CADD	RML	04/18/07	**FIGURE: III-7**	
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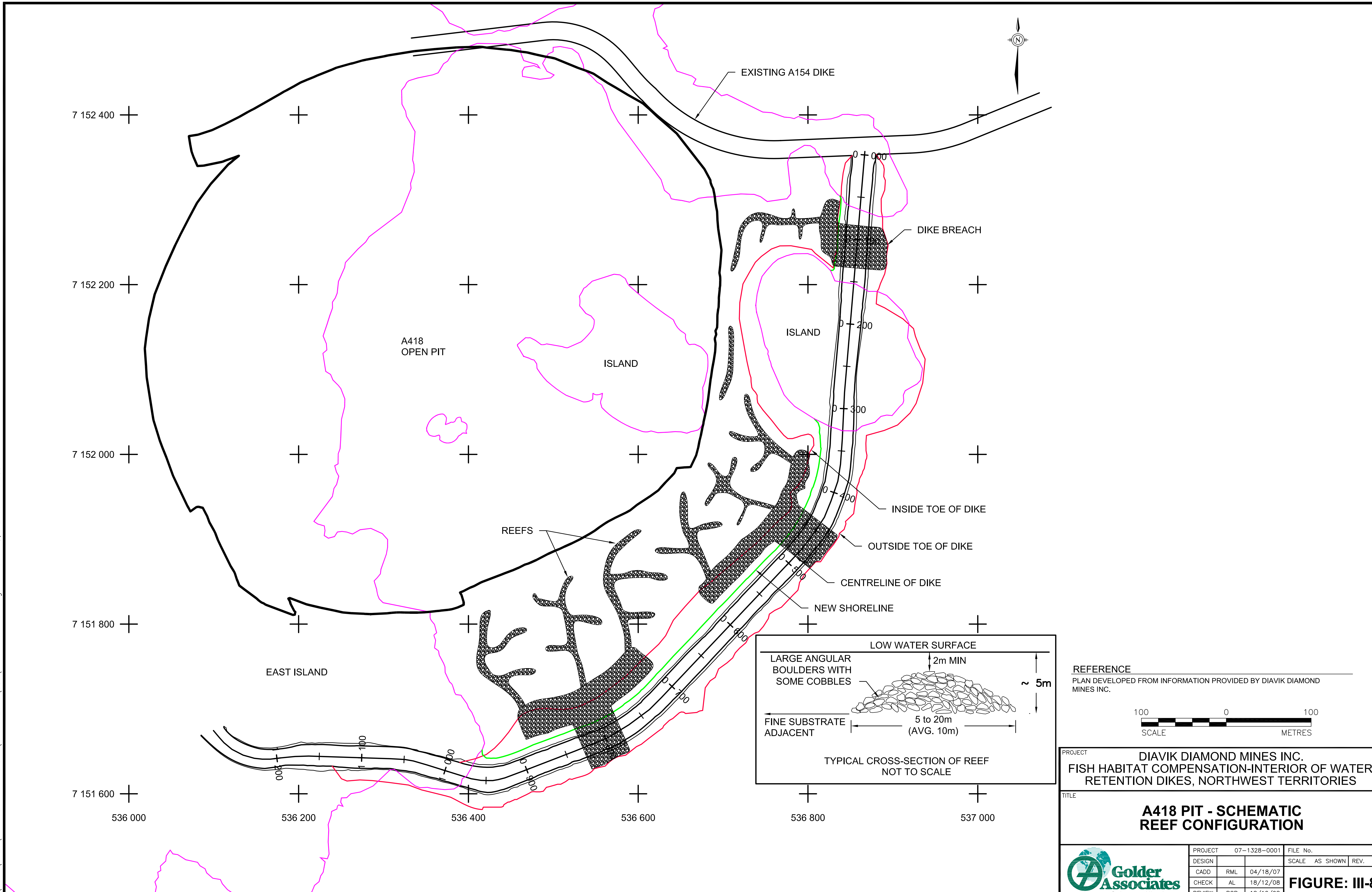

APPENDIX X-3

Fish Habitat Design – A21 Dike/Pit Area

22 March 2017

DIAVIK DIAMOND MINES (2012) INC.

A21 Dike Fish Habitat Design

Submitted to:
Diavik Diamond Mines (2012) Inc.
PO Box 2498
300 - 5201 50th Avenue
Yellowknife, NWT
X1A 2P8 Canada

Attention: Mr. Gord Macdonald

REPORT

Reference Number: 1648005-1568-R-Rev2-12000

Distribution:

1 Electronic Copy - Diavik Diamond Mines (2012) Inc.
1 Hard Copy - Golder Associates Ltd.

Golder Associates

Executive Summary

This report presents the design for post-closure fish habitat as part of the interior and exterior of the A21 Water Retention Dike for the Diavik Diamond Mines (2012) Inc. (DDMI) diamond mine located at Lac de Gras in the Northwest Territories, Canada. This design was prepared in accordance with the “No Net Loss” (NNL) Plan prepared by DDMI and the Geotechnical and Hydrogeological Feasibility Report, Case V-V1 A21 Open Pit, prepared by Golder Associates Ltd. (Golder 2012).

This design is applicable to the construction, operation, and decommissioning of the A21 pit and dike, and has been prepared by developing criteria for the end result, while allowing flexibility on the part of DDMI as to when (e.g., during pit mining or after decommissioning of the open pit), and how the end result is achieved. The objective of the fish habitat compensation measures is to provide spawning, nursery, rearing and foraging habitat for Lake Trout (*Salvelinus namaycush*), Cisco (*Coregonus artedi*), Round Whitefish (*Prosopium cylindraceum*), Lake Whitefish (*Coregonus clupeaformis*), Longnose Sucker (*Catostomus catostomus*), Burbot (*Lota lota*), Northern Pike (*Esox lucius*), and Slimy Sculpin (*Cottus cognatus*), in addition to rearing and foraging habitat for Arctic Grayling (*Thymallus arcticus*).

Shoreline, shoal and deep water habitat will be lost or altered in Lac de Gras after the construction of the A21 dike and pit and the causeway between the South Island and East Island. After decommissioning of the A21 pit and breaching of the dike and causeway, habitat will be created for fish through the flooding of the breach locations, the interior edge of the dike, the decommissioned pit, and the pit shelf (i.e., defined in this report and NNL Plan as the area between the edge of the pit crest and the toe of the dike). Shoreline areas within the diked area will be reclaimed, and where feasible, fish habitat structures (i.e., reefs) approximately 2 to 3 m high will be constructed on selected areas of the pit shelf.

Due to the sensitivity of the overall pit stability, operational requirements to access the toe of the A21 dike to assess seepage, the extensive instrumentation/depressurization system, and the relatively large fill volumes required to create fish habitat on the pit shelf (particularly in ‘Deep Blue’), the construction of fish habitat compensation fills on the pit shelf during mining operations is not recommended. Construction of the fish habitat compensation fills after completion of mining would avoid some of the challenges; however, the economics of this approach would be significantly different.

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TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

This report presents the design for the fish habitat compensation plan for the interior and exterior of the water retention dike (i.e., the pit shelf[1], interior and exterior edge of the dikes, and deep water) for the A21 pit and the causeway between the East Island and South Island at the Diavik Diamond Mines (2012) Inc. (DDMI) diamond mine in the Northwest Territories. The location of the mine, including two existing pits (i.e., A154 and A148) and the A21 pit, is shown in Figure 1. Mining of the A21 pit is scheduled to start in 2018 and to be complete by end of 2023 (Golder 2012).

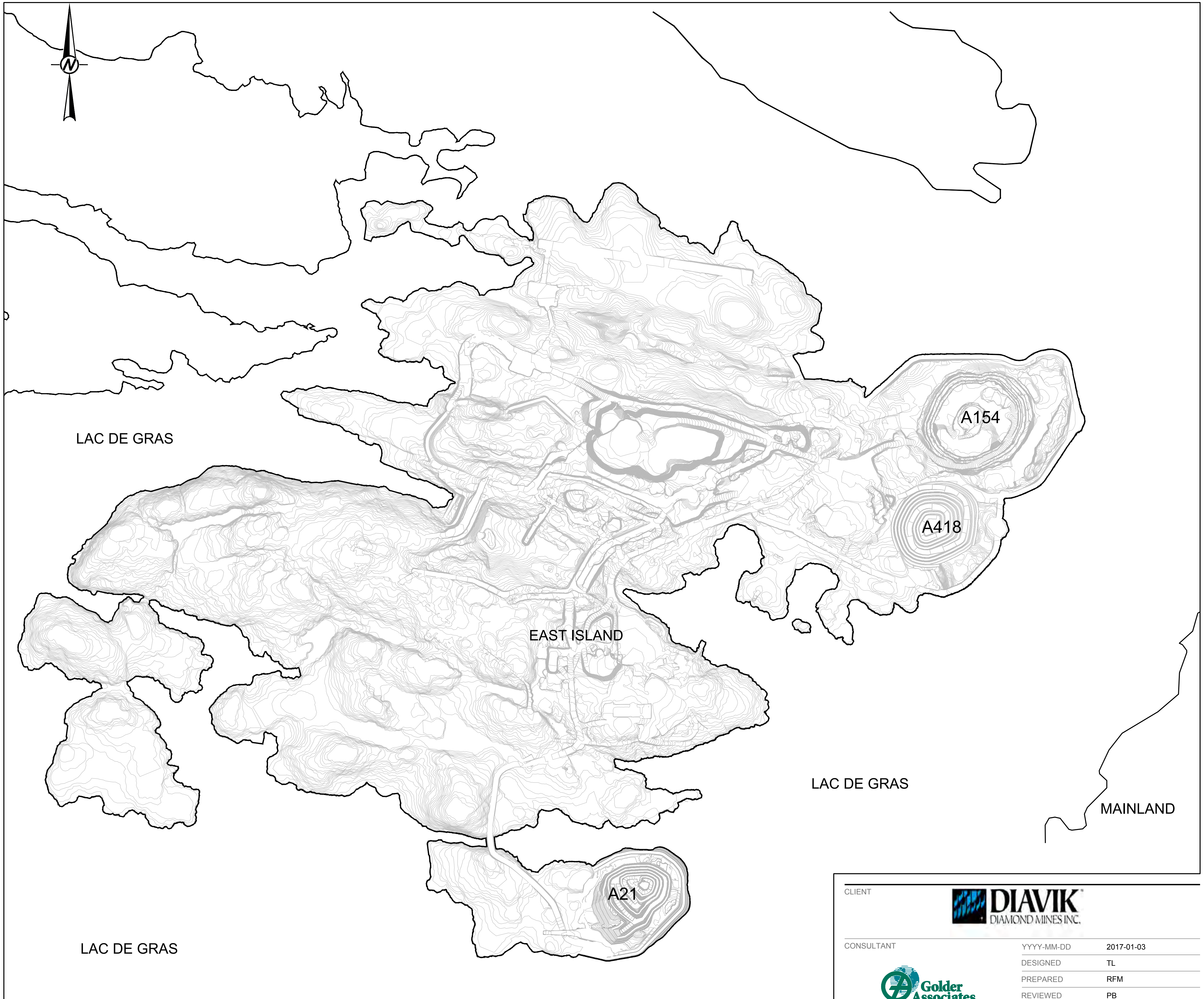
The original (1999) concept for the A21 dike alignment was revised and adjusted in 2007 (AMEC 2007), and again in 2012 (AMEC 2012). A further update to the A21 feasibility study undertaken in 2014 incorporated design and construction methodology changes for the A21 dike (BCG 2014). Changes to the alignment of the A21 dike since 1999 have resulted in a decrease in the footprint area under the current alignment.

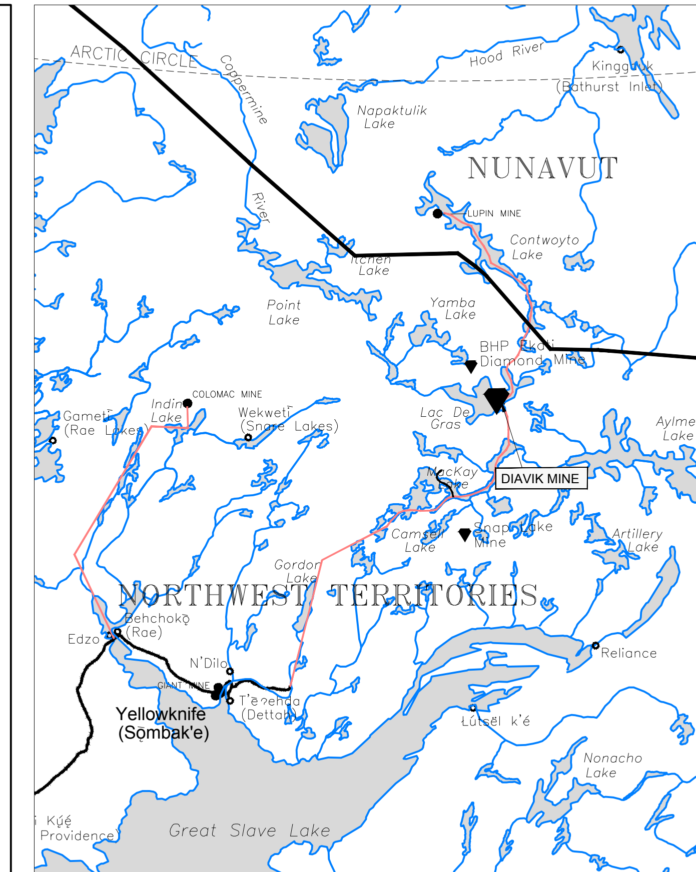
The fish habitat compensation design is based on the “No Net Loss” (NNL) Plan (DDMI 1999), the conceptual fish habitat plan prepared by Golder Associates Ltd. (Golder 2001), and the Geotechnical and Hydrogeological Feasibility Report, Case V-V1 A21 Open Pit (Golder 2012). The conceptual fish habitat compensation plan for the pit shelf is to fill in the deeper areas (i.e., greater than 5 m depth) on the pit shelf with material excavated from the open pit to provide habitat with a water depth of approximately 5 m, and to construct fish habitat structures (i.e., reefs) approximatively 2 to 3 m high on the re-contoured areas of the pit shelf. However, geotechnical conditions and operational requirements may restrict the feasibility of constructing the fills on the pit shelf.

This document provides the design for the fish habitat compensation for the A21 dike without the specifications for implementation of the design. The document focuses on the details of the plan for achieving the desired end result by considering fish habitat requirements, surface water runoff and geotechnical issues, and also provides flexibility in how the end result is achieved. The flexibility reflects unknowns with respect to material parameters (e.g., type, proportions), mine operations (i.e., blasting details, availability of various materials), and construction timing. Design details with respect to surface water handling, material selection, construction, and other issues would be addressed by DDMI, to achieve the desired habitat compensation prior to reflooding of the diked area.

Although the A21 fish habitat design applies specifically to the A21 pit, it is similar in concept to plans developed for the A154 and A148 pits. A154 and A418 dikes were completed in 2002 and 2006, respectively (Yip and Thompson 2015). Initial open pit mining at A154 and A418 pits commenced in November 2002 and 2008, respectively, after dewatering of the diked area, and removal of lake-bottom sediments and till overburden. Open pit mining concluded in 2010 for A154 and in 2012 for A418; the Diavik Diamond Mine is currently a fully underground mine (Yip and Thompson 2015). Construction of the A21 dike and pit is ongoing since 2015, and the dike enclosure was completed in 2016. It is intended that the A21 dike fish habitat design be reviewed prior to construction of any compensation structures to incorporate knowledge gained from the construction and performance of those implemented at the A154 and A148 dikes. It will also be important to consider mine operations, seepage control measures for the A21 dike, overall pit stability and instrumentation/monitoring requirements prior to implementing the A21 habitat compensation design.

[1] Defined in this report and NNL Plan (DDMI 1999) as the area between the edge of the pit crest and the toe of the dike; in mining, this is often the definition of the pit crest which includes both the area of the top of the pit and the edge of the first bench.





INSET MAP - NOT TO SCALE

0 500 1,000
1:30,000 METRES

CLIENT
DIAVIK DIAMOND MINES INC.

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-01-03
DESIGNED	TL
PREPARED	RFM
REVIEWED	PB
APPROVED	PB

PROJECT
DDMI 2016 ENVIRONMENTAL PROJECTS

TITLE
SITE LOCATION

PROJECT NO.	CONTROL	REV.	FIGURE
1648005	12000-RF-0002	0	1

2.0 BACKGROUND

The objective of the fish habitat compensation measures for the A21 dike is to provide spawning, nursery, rearing and foraging habitat for Lake Trout (*Salvelinus namaycush*), Cisco (*Coregonus artedi*), Round Whitefish (*Prosopium cylindraceum*), Lake Whitefish (*Coregonus clupeaformis*), Longnose Sucker (*Catostomus catostomus*), Burbot (*Lota lota*), Northern Pike (*Esox lucius*), and Slimy Sculpin (*Cottus cognatus*), in addition to rearing and foraging habitat for Arctic Grayling (*Thymallus arcticus*).

The conceptual design for the fish habitat compensation is outlined in Golder's report entitled "Conceptual Design and Compensation Workplan for the Fish Habitat Compensation Program, Diavik Diamond Mines Inc., Lac de Gras" (Golder 2001). The conceptual design consists of:

- Re-contouring the pit shelf (i.e., area between the interior toe of the dike and the crest of the pit slope) to provide habitat with a water depth of approximately 5 m after the dike is breached; habitat will only be constructed where the pre-mining water depth exceeds 5 m; the shallower areas of the shelf will not be excavated, and will be left "as is", as these areas already provide shallow water habitat.
- If fill is placed in the pit shelf area during mine operations, a setback will be required between the edge of pit crest and the toe of the dike slope to maintain the safety of the operation; although the setback area could be filled near the end of operations or during closure.
- Constructing long, narrow, rocky reefs (i.e., rearing shoals) approximatively 2 to 3 m in height, extending from the interior slope of the dike on the pit shelf to a specified setback distance from the crest edge of the open pit. These reefs would be constructed on disturbed areas of the pit shelf (i.e., areas filled to a minimum of 5 m depth). The depths on the pit shelf would vary from 2 to 3 m where the reefs are constructed and would be a maximum of 5 m deep at the remaining areas (i.e., undisturbed areas or areas filled with material excavated from the pit). The composition of granular and soft substrates between the reefs would be consistent with the baseline conditions for the North Inlet.
- Modification of disturbed shoreline areas to establish conditions similar to pre-development. This may include placement of boulders in water depths up to about 5 m.
- Reflooding of the diked area through multiple breach locations of the dike to a minimum 2 m depth from the low water mark, which is expected to maintain passage between the main body of Lac de Gras and the reflooded area while deterring the movement of larger fish into rearing habitats.

3.0 DESIGN DEVELOPMENT

The design of the fish habitat compensation plan considered a suite of parameters, including the A21 footprint estimate, geotechnical parameters, and baseline conditions near the A21 dike and pit in Lac de Gras. The design also follows the Fisheries Authorization (DFO File No.SC98001) where requirements for achieving NNL of habitat for the DDMI Diamond Project are described.

3.1 A21 Footprint Summary

Calculations for estimating habitat area (i.e., habitat quantity) lost or altered due to construction of the dike and pit were quantified by habitat type as per the NNL Plan (DDMI 1999, Table 1). AutoDesk Civil 3D 2016 software was used to produce closed polygons of each of the habitat areas on a current drawing of the assessment area, including available elevations pre-construction (i.e., water depths). The A21 footprint containing elevations at construction and post-closure (i.e., dike, causeway and open pit elevations) was then added to the baseline map to calculate available habitat at post-closure (see Section 6.0).

Determination of fisheries habitat value was based on the Habitat Evaluation Procedure, which included the development of a Habitat Suitability Index (HSI) for each habitat class (spawning, nursery, rearing, foraging, overwintering and migration corridor) for each fish species potentially affected by the construction of A21 dike and pit. The HSI value, which is a measure of habitat quality, was multiplied by the habitat quantity of each type of habitat under examination. The calculations yielded a weighted measure, in Habitat Units (HUs), of the relative value of habitat under the Project footprint and of compensation habitat for a post-closure scenario (see Section 6.0). Additional details are provided in DDMI (1999).

It is important to note that the original (1999) concept for the A21 dike alignment was revised and adjusted in 2007 (AMEC 2007), and again in 2012 (AMEC 2012). A further update to the A21 feasibility study undertaken in 2014 incorporated design and construction methodology changes for the A21 dike (BCG 2014). Changes to the alignment of the A21 dike since 1999 have resulted in a decrease in the area of habitat that will be lost (or altered) due to dike construction (Table 1).

The NNL Plan predicted that a total of 79.7 ha of habitat would be lost or altered from the construction of the A21 dike (DDMI 1999). In 2007, it was predicted that a total of 44.7 ha of habitat would be lost or altered. Current predictions indicate that a total of 57.1 ha of habitat will be affected, representing 17.7 weighted habitat units (Table 1; Figure 2).

Of note is that a causeway is now included in the design and was not part of the original A21 dike configuration in 1998. As such, related fish habitat changes were not specifically accounted for in the original NNL Plan. As part of the final design, it has been determined that 0.5 ha of Type R shoreline habitat and 0.3 ha of deep habitat will be lost as a result of construction of the causeway (Table 1).

Table 1: Summary of Habitat Areas and Units Affected by the Construction of the A21 Dike

Habitat Type	Depth (m)	Habitat Category	Habitat Description[(a)]	Original Footprint (ha)[(b)]	Current Footprint (ha)[(c)]
Shoreline Q (Diked Area)	0–6	1	Boulder ledge at shoreline; composed of boulders leading to sand and boulder patches.	23.1	9.7
Shoreline R (Diked Area)	0–6	3	Bedrock outcrops surrounded by boulder and cobble leading to a mixture of large boulder and sand substrates.	3.9	2.1
Shoreline R (Causeway)	0–6	3		n/a	0.5
Shoreline Subtotal				*27.0*	*12.3*
Shoal C150	0–6	2	Clean (silt-free) boulder, not adjacent to deep water, interstitial spaces of optimum size, 45° slope.	3.2	3.3
Shoal C151	0–6	2			2.4
Shoals Subtotal				*3.2*	*5.8*
Deep Water 6 to 10 m (Diked Area)	6–10	-	Sand/silt substrate.	5.5	8.1
Deep Water 6 to 10 m (Causeway)				n/a	0.3
Deep Water >10 m	>10	-		44.0	30.5
Deep Water Subtotal				*49.5*	*39.0*
TOTAL				**79.7**	**57.1**

Notes:

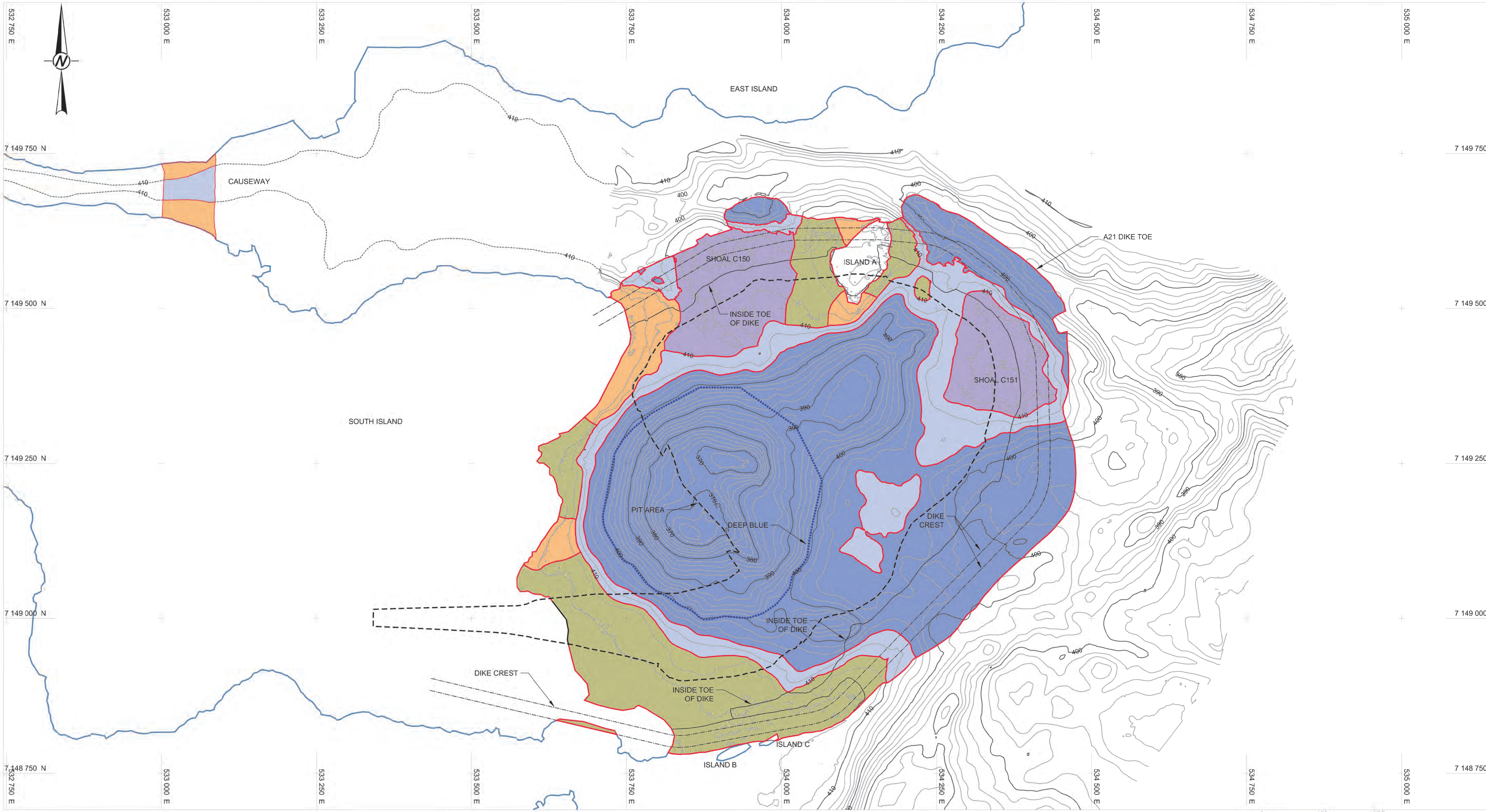
A total of 17.7 habitat units will be lost after applying weighting related to life history functions.

a) No Net Loss Plan (DDMI 1999); habitat descriptions were summarized from multiple Technical Memorandums prepared by Golder for the 1996 Diavik Baseline Study (Golder 1997a, 1997b, 1997c).

b) From No Net Loss Plan (DDMI 1999).

c) As per BGC Drawing 14300-41D2-1003.1 Rev 2 provided by DDMI, updated May 2016.

m = metre; ha = hectare; >more than; - = not applicable, n/a = not available; ° = degree.



LEGEND

- BATHYMETRY CONTOUR (2 m INTERVAL)
- BATHYMETRY CONTOUR (10 m INTERVAL)
- SHORELINE HABITAT TYPE 1 (Q) TO 6 m DEPTH
- SHORELINE HABITAT TYPE 3 (R) TO 6 m DEPTH
- SHOAL HABITAT LOST TO 6 m DEPTH
- DEEP WATER 6-10 m DEPTH
- DEEP WATER > 10 m DEPTH

NOTE(S)

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. BATHYMETRY DATA SHOWN ARE FROM DDMI COMPOSITE SURFACE DATED NOVEMBER 14, 2015, AND INCLUDES PARTIALLY COMPLETED FOUNDATION DREDGING EXTENT. BASE TOPOGRAPHIC DATA BASED ON CHALLENGER SURVEY OPERATIONS 1997. CONTOUR INTERVAL IS 1.0 M. APPROXIMATE PRE-CONSTRUCTION SHORELINE IS BASED ON SURVEYS CONDUCTED PRIOR TO CONSTRUCTION AND MAY NOT MATCH CURRENT CONTOURS.
3. PROJECTION IS DIAVIK MINE GRID.
4. DASHED CONTOUR LINE IS APPROXIMATE 6 m BATHYMETRY CONTOUR DIGITIZED FROM GOOGLE EARTH IMAGE (CONTOURS WERE NOT AVAILABLE FOR THIS AREA)

REFERENCE(S)

ORIGINAL DRAWING AND REFERENCE DRAWINGS OBTAINED OCTOBER 2016 FROM BGC ENGINEERING FOR THE PURPOSE OF CALCULATING AREAS AND SHORELINE AFFECTED BY THE CONSTRUCTION OF DIKE A21 AND ACCESS. (14300-41D2-1003.1-REV-2 DATED MAY 16, 2016)

CLIENT

DIAVIK DIAMOND MINES INC.

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-10
DESIGNED	TL
PREPARED	RFM/JDS
REVIEWED	PB
APPROVED	PB

PROJECT

DDMI 2016 ENVIRONMENTAL PROJECTS

TITLE

EXPECTED HABITAT TYPES LOST OR ALTERED FROM A21 DIKE AND PIT CONSTRUCTION

PROJECT NO.	CONTROL	REV.	FIGURE
1648005	12000-RF-0001	0	2

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

3.2 Geotechnical Assessment

Geotechnical parameters (as well as bathymetric information) were considered in the fish habitat compensation measures. Geotechnical parameters are summarized in detail in the Geotechnical and Hydrogeological Feasibility Report, Case V-V1 A21 Open Pit (Golder 2012). The report includes a summary of historical studies relating to the A21 pit design that included the following activities:

- geotechnical drilling
- oriented coring
- downhole geophysical surveys
- geotechnical mapping of the A21 decline
- laboratory testing
- thermistor installations
- hydraulic conductivity testing of bedrock and soils
- bathymetry surveys of lake systems
- bedrock and soil laboratory testing and materials characterization

Historical investigations for the A21 dike have also included geological bedrock mapping and exploration drilling. Oriented geotechnical drilling was conducted in 1998, 2004, 2006, 2007, and 2010 (Golder 2012). Underground geotechnical line and cell mapping took place in 2006 and 2007, during the development of an access ramp constructed to facilitate kimberlite bulk sampling.

The fish habitat compensation plan, including ‘fills’, considered the stratigraphy (i.e., thickness and vertical sequence of materials), as well as the strength parameters for each material. As described in Golder (2012), the main surficial deposits in the project area consist of lakebed sediments and glacial till. Where present, lakebed sediments range in thickness from 0.4 m to 4.6 m, with an average thickness of approximately 2.0 m. The sediments generally consist of very soft to soft sandy silt, and in some areas contain traces of gravel. The project site is covered by laterally extensive glacial till deposits consisting mainly of silty sand with some gravel. The till is well graded in some areas, with grain sizes ranging from fine silt to coarse gravel. The till layer ranges in thickness from 0.1 m to 16.3 m, with an average thickness of approximately 4.5 m. Based on sonic drill-hole data, the average till thickness along the dike alignment has been estimated to be approximately 1.5 m.

Most of the soft lake bottom sediments are removed or displaced during construction of the dike and preparation of the pit shelf; therefore, for geotechnical modelling, all of the overburden has been considered as glacial till, with a total unit weight of 18.5 kN/m^3, and an effective angle of internal friction of 30^o, and 5 kPa cohesion.

3.3 Habitat Compensation Design

The Fisheries Authorization (DFO File No.SC98001) identified the requirements for achieving NNL of habitat for the DDMI Diamond Project. Specific requirements for the A21 diked area included the following:

- the development of shallow rearing habitat and shoreline habitat
- ensuring that the habitat features within the diked area are modeled after those features found in other productive areas of Lac de Gras, with consideration of depth, and substrate type and size

Four key habitat features within the diked area are identified in the NNL Plan (DDMI 1999, Golder 2003), these included the following:

- **Inside Edge of the Dike:** the area of water depths from 0 to 2 m along constructed sections of the dike representing new shoreline habitat.
- **Reclaimed Shorelines:** areas of pre-existing shorelines of water depths ranging from 0 to 6 m, which will be maintained as is, or reclaimed after being disturbed.
- **Pit Shelf:** the area between the inside edge of the dike, the shorelines and the edge of the pit crest; includes a portion of a natural bathymetric depression (currently referred to as “Deep Blue” in this report). Lake bottom areas on the pit shelf currently less than 5 m depth will be left undisturbed to the extent possible. Areas deeper than 5 m would be filled to a depth of approximatively 5 m, where feasible.
- **Deep Water:** includes the pit, extending to a depth of approximately 185 m and areas of the pit shelf that would remain deeper than 5 m after completion of habitat compensation modifications (e.g., because of a setback, and deep water areas on the pit shelf).

In addition to the above-listed zones, the areas of water depths from 0 to 2 m and from 2 to 6 m around the dike (i.e., herein referred as “exterior edge of the dike”) and causeway are expected to provide habitat for fish immediately upon completion of the structure (DDMI 1999), and additional habitat areas are expected to be created within the breach locations of the dike and causeway upon flooding.

3.4 Criteria for Habitat Compensation Design

The following sections outline the general principles and criteria used in developing the final layout of fish habitat compensation measures for the A21 diked area. The feasibility of modifications to the pit shelf are discussed in Section 4.

As discussed in the NNL, the primary focus for habitat creation inside the diked area is based on maximizing rearing habitat value; the exterior edge of the dike, the causeway and the breach channels would be configured to maximize the potential habitat value for spawning and rearing habitat. Target species include Lake Trout, Arctic Grayling, Burbot, Longnose Sucker, Round Whitefish, Cisco, Lake Whitefish, and Slimy Sculpin.

Several overall governing criteria are to be applied to the habitat creation activities inside and outside the dike:

- Existing shoreline features (from 0 to 6 m deep) are to be maintained to the extent feasible.
- Areas inside the dike on the pit shelf that are already at a depth of 5 m or less are not to be disturbed where possible. Construction crews are to avoid driving on these areas to the extent feasible. Leaving these areas intact would decrease the amount of work required to remediate habitat at closure and speed the recovery process of the altered areas inside the dike upon flooding.
- The storage and handling of materials, particularly hydrocarbons or other types of contaminants, are to be closely monitored on the shorelines, pit shelf, and inside edges of the dike. Heavy equipment in the area are to be maintained and fuelled in a manner that avoids the possibility of spills occurring in areas to be reclaimed as fish habitat.
- The exterior edge of the dike, causeway and the breach channels are to be configured to maximize their potential value as fish habitat. Any applicable monitoring data on the effectiveness of habitat created on the exterior edge of the A154 and A418 dikes are to be used to improve the exterior surface of A21 for fish habitat (DDMI 1999).
- Breach channels are to be constructed to depths of approximately 2 m from the expected low water level in Lac de Gras.
- As per the *Navigable Waters Protection Act* Permit for the project, no dike breach or constructed reef features will be less than 2 m from the expected low water level in Lac de Gras.

3.4.1 Inside Edge of Dike

The inside edge of the dike will provide new shoreline features for foraging and rearing habitat for most of the target species. The dike itself will resemble existing shoreline and shoal habitat, providing a rocky (boulder/cobble) substrate, with a moderate slope and low to moderate wind and wave action. The habitat calculation for the inside edge the dike considered this area as shoreline habitat (see Section 6).

Suitable materials for this habitat feature are to be a mix of boulder with some smaller cobble. Slopes are designed to ensure a stable profile, ranging from a gentle to moderate slope.

3.4.2 Reclaimed Shorelines

The objectives for the existing shoreline along the edge of the diked area, at the start of the pit access ramp, and around any islands within diked areas, include the following:

- minimize change to existing lake substrates and riparian features
- remediate disturbed areas during closure, as needed

Any areas of disturbed shoreline are to be remediated to enhance habitat for fish, which may include the placement of boulder and cobble substrates in affected shallow water.

3.4.3 Pit Shelf

The A21 pit shelf area extends from the lower inside edge of the dike to the edge of the pit. Lake bottom disturbance would be minimized in areas of the pit shelf that are 5 m or less in depth. Material excavated from the pit would be used to fill deep portions (i.e., deeper than 5 m) of the pit shelf area, where feasible. After filling, these areas of the pit shelf would be at depths of approximately 5 m. Reefs ranging from 2 to 3 m in height would be constructed on areas of the pit shelf that have been filled in with materials from the pit.

As indicated in the NNL Plan (DDMI 1999) and the Fisheries Authorization (DFO File No.SC98001), the objectives for the selection of substrate type and pit shelf configuration are based on physical characteristics of other high-quality foraging and rearing habitats in Lac de Gras. In order to address these objectives, substrate information from baseline data collections were used and a basic configuration evaluation of the North Arm and two other nearby inlets identified as rearing areas within Lac de Gras was completed. The configuration evaluation was completed through air photo interpretation. Key features identified by assessing other rearing areas included:

- **Shoal Configuration:** rocky shoals are often somewhat irregular in size and shape and relatively long and narrow. Some shoals may also be a series of submerged rocky humps similar to links in a chain. Longer and narrower shoals have more “edge” habitat, where edges are expected to be important to fish that forage in one habitat type but rest or seek refuge in another.
- **Isolated Pond-like Areas:** observed isolated pond-like areas may be beneficial to small fish in that they form a disjointed “ring” to provide pond-like conditions where circulation is limited and water temperatures are warmer.
- **Hard to Soft Substrate Ratio:** the hard substrate (shoals areas) to soft substrate (depositional areas) ratio in other nearby rearing areas ranged from 25% to 40% hard with the remainder as soft substrate.
- **Access to Refuge Habitat:** observed rocky substrates are expected to provide refuge or cover for small fish, and maintain connectivity between locations through the provision of cover during foraging movements. Distances of less than 30 to 40 m between rocky shoals may allow fish reasonable access to refuge.
- **Littoral Habitat:** shallow water (e.g., less than 2 m deep) in existing rearing habitats in Lac de Gras warms up at quicker rate in spring compared to deep water. Warmer water is expected to increase biological productivity inside these areas.

3.4.3.1 Reef Configuration

Determining the locations of the constructed reefs considers several factors. Constructed reefs should have some connectivity to the dikes and other reefs to allow fish to travel throughout the area without being fully exposed to predators for long distances. If the reefs are long, winding, and finger-like, a large amount of “edge” habitat will be created to allow fish to feed in the fine substrate while maintaining close proximity to the cover provided by the rocky reefs. The reefs would be placed in areas where the final water depth will be 2 to 3 m deep and the tops of the reefs would remain under 2 m of water at all times. This will allow the reef habitat to remain functional even in winter.

Widths of the reefs would vary between 5 and 30 m, averaging from 10 to 20 m in width. Distance between the constructed reefs would range from 10 to 40 m, averaging from 20 to 30 m apart. Habitat diversity is important and varying the size and shape of the reefs throughout the pit shelf area is expected to improve its value as fish habitat.

The reefs would be configured to reduce water circulation and warm temperatures within partially isolated areas of the pit shelf. The remnant dike sections, combined with the shallow nature of the breach channels, the shallow nature of the pit shelf, and the creation of reefs on the pit shelf is expected to reduce circulation and wind and wave action. The shallow water would warm up quickly in the spring, relative to the main body of Lac du Gras, in part, because of the limited water circulation within the enclosed area. The warmer water created by the pit shelf and reef configuration should, therefore, increase biological productivity inside the dike, particularly during spring conditions.

3.4.3.2 Substrate Material

The composition of substrates on the pit shelf would include fine material, primarily sand and silt interspersed with rocky reefs for habitat diversity. The till (existing lake substrate) is primarily sand and silt with some gravel, and therefore, is expected to be an appropriate substrate for providing a biological zone within any added substrates on the pit shelf (i.e., approximately top 10 cm layer represents the biological zone for macroinvertebrates). The fine substrate areas between reefs that will not be disturbed are expected to support a variety of benthic organisms as forage for small-bodied fish.

Reefs would be constructed of granular material of a range of sizes, with the primary material being large boulders with some smaller cobble material. The objective is to create refuge habitat, or hiding areas, among the rocks. Angular, unconsolidated material would provide the required interstitial spaces for cover. Run of mine blast rock is expected to be acceptable for this purpose.

3.4.4 Deep Water (Pit Area)

Any area of the A21 pit shelf that will not be filled for reef or shallow water habitat would continue to provide deep water habitat for fish. Deep water habitat would also be located in the mine pit, near the center of the diked area and at the center and end of the access ramp. The deep water provides a cooler environment for fish (i.e., thermal refuge during summer) and a pelagic zone, as described in the NNL Plan. This area can provide habitat for pelagic feeding fish such as Cisco and may provide other functions for fish (e.g., overwintering habitat). The maximum depth of the pit areas is anticipated to be 185 m.

3.4.5 Exterior Edge of Dike and Causeway, and Breach Channels

Fish habitat on the exterior slope of the water retention dikes will primarily consist of spawning and rearing habitat (Golder 2001). The quality of the habitat created by the exterior of the dikes will vary with depth and substrate size. The portion of the slopes from 0 to 2 m depths is expected to provide good rearing and foraging habitat, but possibly poor spawning habitat for Lake Trout and other fall spawning salmonids. The best spawning habitats are expected to be found at depths from 2 m to 6 m. At depths greater than 6 m, spawning and nursery habitat are expected to be poor for all species, except for species such as Slimy Sculpin. This portion of the dike is not expected to be kept free of silt by wave action. Gradual accumulations of silt are expected on the rocky exterior of the dike over time. Due to the potential presence of silt, this area of the dike was categorized as being unsuitable for all fish species in Lac de Gras (DDMI 1999) and not included in the habitat losses or gains calculations.

The modified causeway, exterior edge of dike, and breach locations would provide new shoreline features for foraging and rearing habitat (at 0 to 2 and 2 to 6 m depths, respectively) and spawning and nursery (2 to 6 m depths) for most species. The causeway itself will resemble existing shoreline and shoal habitat, providing a rocky (boulder/cobble), moderate slope area with low wind and wave action. The interstitial spaces provided by rocky substrates would provide refuge for small fish.

It is important to note that the 2 to 6 m depth contour around the causeway was given the same Habitat Suitability Index (HSI) value as the 0 to 2 m depth contour (as part of the calculations in Section 6) because the area was considered limited for wind or wave exposure. The habitat units created by the sides and bed of the breach channels at 0 to 2 m and 2 to 6 m depths were given the same HSI values as the external edge of the dike at depths 0 to 2 m and 2 to 6 m, respectively. Suitable construction materials for these habitat features would be a mix of large boulder with some smaller cobble. Slopes would be designed under a stable profile with a gentle to moderate slope.

3.5 Construction Considerations

There are a number of construction considerations that arise due to the variabilities in the material parameters, pore-pressure conditions, blasting effects and construction timing. The following construction considerations were evaluated with respect to the design of the fish habitat compensation measures for the pit shelf areas:

- The relatively steep slopes and the narrow dike setback proposed for A21 Case V-v1 pit causes the pit slope stability to be very sensitive to water pressures and hence a depressurization system is required in some areas for the factors of safety to meet the design criteria. In addition, greater continuity of low-angle joints is expected in the A21 pit compared to the other Diavik pits, which increase the likelihood that potential basal sliding planes will be encountered. For these reasons an emphasis must be placed on detailed planning, design and implementation of sophisticated monitoring and instrumentation systems as a means to mitigate the risks and consequences associated with the mining of the proposed pit. The construction of fish habitat compensation fills on the pit shelf during mining operations is not recommended.

- The fine-grained lake-bottom sediments are expected to provide poor trafficability, particularly when the materials are thawing. Portions of the A21 dike are expected to encounter permafrost, which would also present poor trafficability conditions if it thaws.

- Should fill be placed during operations, a berm (or other measures, such as rockfall fencing) would be required between the edge of the pit crest and the toe of the fish habitat fill to provide safety with respect to equipment travelling too close to the pit crest edge and to reduce the potential for fill materials spilling into the pit during placement. The berm could also be used as a construction access road prior to pit development adjacent to the berm. A formal run-out assessment will have to be conducted as part of the final pit design to assess the risks, and develop specific measures to prevent materials from the fish habitat compensation fills from entering the pit.

- It has been assumed that the fill used to create the fish habitat will consist of rock fill derived from development of the pit. Rock fill has relatively high shear strength and is not expected to develop high internal pore-water pressures. Rock fill would also provide a stable trafficking surface for the initial lifts.

4.0 STABILITY ASSESSMENT

4.1 Stability of Fish Habitat Fills

Based on direction from DDMI, it has been assumed that the fish habitat compensation fills on the pit shelf will be constructed of rock fill. The stability of the downstream slope of the fish habitat compensation fills may be simply evaluated using an "infinite slope analysis"; where the factor of safety (FS) of the slope is defined by:

$$FS = \tan \Phi' / \tan \alpha$$

Where Φ' is the effective angle of internal friction for the fill and α is the slope angle of the downstream toe of the fill, measured from the horizontal, both in degrees. The typical FS considered for an embankment similar to the proposed fish habitat compensation fill is 1.5, which is consistent with the values used for the A154 and A418 pipes. The fish habitat compensation fills have been designed with a downstream slope of 2H:1V (26.6 degrees); in order to achieve a FS = 1.5, the effective angle of internal friction for the fill must be at least 37 degrees; which is considered reasonable for run of mine blast rock. The strength of the material used for the construction of the fish habitat compensation fills should be confirmed, and the slope angle adjusted, if required.

It was understood that during construction of the A21 dike, lake bottom sediments removed from the dike footprint were placed in the Deep Blue depression. This represents a potential zone of weakness, both with respect to slope stability and settlement; therefore, construction of fish habitat compensation fills in Deep Blue would require additional investigation and design. In addition, preliminary calculations show that due to the existing water depth, large fill volumes would be required to create fish habitat in Deep Blue, resulting in a very high ratio of construction cost to fish habitat gains.

The setback from the pit crest edge to the toe of the fish habitat compensation fills should be based on a detailed assessment of the overall pit stability, as well as operational requirements for access to the toe of the dike and requirements for instrumentation and dewatering wells on the pit shelf.

4.2 Overall Pit Stability

The overall pit stability was assessed in Golder's report "Geotechnical and Hydrogeological Feasibility Report, Case V-V1 A21 Open Pit" (Golder 2012). The information provided in this section is excerpted and/or summarized from Golder 2012. It is understood that the pit design may be modified from that presented in Golder 2012 (Case V-v1); it is possible that changes to the pit will impact the conclusions of this report.

The pit slope design was based on kinematic, limit equilibrium and distinct element analyses. In addition to these methods of assessing factors of safety and expected deformations of the pit slopes, reliability methods based on probability theory were used to assess the potential risk of unsatisfactory performances of certain pit walls. The A21 pipe has lower value than the A154 and A418 pipes, consequently, the viability of A21 project comes with greater commercial and geotechnical risk. As indicated before, the relatively steep slopes and the narrow dike setback proposed for A21 Case V-v1 pit causes the pit slope stability to be very sensitive to water pressures and hence a depressurization system is required in some areas for the factors of safety to meet the design criteria. Preliminary economic evaluation has indicated the viability of implementing a pit slope depressurization system to meet the design criteria at the design pit depth rather than increasing the footprint of the surrounding dike.

The development of the A21 pit will require a carefully integrated system or array of instrumentation to monitor very subtle physical changes within the rock mass, the overburden soils at the slope crests, and the groundwater regime. This slope monitoring system will need to be fully integrated with the dike monitoring instrumentation system. DDMI gained strong experience in management of dike-pit instrumentation systems at their A154 and A418 pit. However, the monitoring and instrumentation system required for the A21 pit is significantly more intensive than those implemented for A154 and A418 pits. The primary justification for this is the higher sensitivity of slope stability to water pressures, caused by the narrow dike setback proposed for A21 pit. An additional reason is the expected greater continuity of low-angle joints in the A21 pit compared to the other pits, which increase the likelihood that potential basal sliding planes will be encountered.

The Hydrogeological and Geotechnical Feasibility Report (Golder 2012) also included a number of considerations regarding the slope management requirements:

- The primary trigger of slope instability is expected to be water pressure.
- Because the rock mass is relatively brittle, little measurable deformation prior to a failure can be expected.
- The ability to install instrumentation will be limited by the comparatively narrow in-field between the crest of the pit wall, and the toe of the dewatering dike.
- It will be necessary to incorporate dilation monitoring behind the pit crest in conjunction with the dike instrumentation program. The pit and dike monitoring systems must be fully integrated.
- Geotechnical mapping beginning early in the pit development will be critical to confirming the rock mass quality and joint orientations on which the current analyses have been based.
- Effective depressurization of the slopes is essential to the stability of the slopes. The performance of the depressurization system needs extensive monitoring.
- The use of controlled blasting methods during mining activities is necessary. Planning activities must include the provision for anchoring of potentially unstable blocks.
- The planning, design, development, installation, and implementation of a sophisticated slope management strategy (SMS), including monitoring and instrumentation, is paramount in the development of the A21 pit. The adopted overall SMS should consist of a combination of the following items:
  - training of mine personnel in basic slope stability and hazard assessment
  - systematic, regularly scheduled visual monitoring of the crests and slopes
  - systematic, regularly scheduled evacuation drills
  - surface and boring extensometers, inclinometers and TDR cables
  - vibrating wire piezometers
  - fracture shear displacement meters
  - GeoMoS automated prism monitoring system
  - prismless laser scanners (Riegl LPM-2K) or LIDAR with reflectors
  - slope stability radar (SSR)

A Trigger-Action-Response Plan (TARP) must be developed as a result of a detailed risk assessment during the final planning phase of pit design. It is crucial that the fish habitat compensation fills be constructed with due consideration of operational mine requirements, as well as accommodating the slope depressurization and instrumentation systems. As previously noted, a formal run-out assessment should be conducted as part of the final pit design to assess the risks, and develop specific measures to prevent materials from the fish habitat compensation fills on the pit shelf from entering the pit.

4.3 Geotechnical Conclusions

Due to the sensitivity of the overall pit stability, operational requirements to access the toe of the A21 dike to assess seepage, the need for an extensive instrumentation/depressurization system, and the relatively large fill volumes required to create fish habitat on the pit shelf (particularly in Deep Blue), the construction of fish habitat compensation fills on the pit shelf during mining operations is not recommended. Construction of the fish habitat compensation fills on the pit shelf after completion of mining would avoid some of the challenges; however, the economics of this approach would be significantly different.

5.0 CONSTRUCTION GUIDELINES

Based on the geotechnical assessment (Section 4), it has been assumed that fish habitat compensation fills on the pit shelf will not be implemented for the A21 dike. In the event that the fills can be safely constructed, the following construction guidelines are presented:

- Construct fills composed of rock fill (run of mine blast rock) with face slopes of 2H:1V.
- Setback from the pit crest edge to the toe of the fill should be should be based on detailed stability analysis. The extent of the fills may be limited by the requirements for depressurization wells and instrumentation on the pit shelf area, as well as operational considerations.
- To the extent feasible, areas of existing shallow habitat (i.e., water depth less than 5 m below mean normal water level) should remain untouched.
- A berm should be constructed between the toe of the fish habitat fill and the crest of the pit, if fills are to be placed on the pit shelf during in-pit activities. This berm will help retain material that erodes from the slope away from the pit, and will reduce the potential for any material rolling down the slope and into the pit. The setback from the crest of the pit to the toe of the berm should be based on detailed stability analyses, and observations of performance at the pit crest. As a minimum, the berm should be approximately 2 m high, with a 2 m crest width and 2H:1V side slopes. The geometry of this berm may be modified on the basis of construction techniques. A formal run-out assessment must be conducted as part of the final pit design to assess the risks, and develop specific measures to prevent materials from the fish habitat compensation fills from entering the pit.
- Construction in one lift is acceptable.
- Grading of the surface of the fill at a nominal grade of 1% is recommended, to direct surface water towards the water collection system at the toe of the dike.
- Final contouring of the surface will be required to establish some relief to provide fish habitat (i.e., some hummocks and hollows, rather than an evenly graded surface).
- Any rock ridges or reefs should be constructed of non-acid generating country rock, and conform to the parameters discussed in Section 3.4.3.1.For excavation of the causeway, the final slopes should be 2H:1V or flatter.

6.0 POST-CLOSURE HABITAT SUMMARY

The NNL Plan provided habitat unit calculations based on the available design information for the dikes and pits at the time. Some modifications to the design dike and pit dimensions were made subsequent to the submission of the NNL Plan, and the new habitat unit calculations reflect these changes. The habitat units calculated as part of the NNL Plan (DDMI 1999), along with re-calculated values based on this updated information are presented in Appendix A. The quantity of habitat available post-closure has changed from 87.9 ha in the NNL Plan (DDMI 1999) to 47.6 ha in 2007. Current predictions indicate that the following quantities of habitat will be available post-closure:

- 4.3 ha at the exterior edge of the dike and breaches at depths ranging from 0 to 6 m
- 0.4 ha around the breached causeway at depths ranging from 0 to 6 m
- 1.3 ha on the pit shelf at depths less than 5 m
- 7.8 ha of undisturbed areas of the shoreline and the reclaimed shoreline
- 35.0 ha of areas deeper than 5 m (i.e., flooded pit area and the majority of the pit shelf)

In total, the 49.9 ha of habitat available at post-closure represents 14.0 weighted habitat units (Table 2; Figure 3). The new alignment of the A21 dike will result in an overall net loss of 7.2 ha of habitat, or a loss of 3.6 habitat units after weighting (Figure 3).

Table 2: Summary of Compensation Habitat Areas and Units at the A21 Dike Post-Closure

Habitat Type	Depth (m)	Habitat Type	Habitat Description[a]	Original Estimate (ha)[a]	Current Estimate (ha)
External Edge of Dike and Breach Channels	0–2	Shoreline 1	Boulder ledge at shoreline; drop-off composed of boulders leading to sand and boulder patches.	2.6	1.8
	2–6				2.6
A21 Causeway	0–2[b]	Shoreline 1	Rocky (boulder/cobble), moderate slope area with low wind and wave action; boulders provide refuge from predators for small fish.	n/a	0.1
	2–6			n/a	0.3
Pit Shelf	2–5	-	Area at depths less than 5 m between dike interior and edge of open pit; deep areas of the pit shelf are not considered for this habitat type.	54.1	1.3
Internal Edge of Dike	0–2	Shoreline 1	Boulder ledge at shoreline; drop-off composed of boulders leading into sand and boulder patches.	1.1	1.0
Reclaimed Shoreline	0–6	Shoreline 1	Areas of lake shorelines, which will be maintained as is, or reclaimed if disturbed. Area of boulder ledge at shoreline with a drop-off composed of boulders leading to sand and boulder.	0.8	7.8
Pit and Deep Water Areas	>5	Deep Water	A deep water area on the pit shelf will remain post-closure; the pit area will be a steeply sided large hole descending to a depth of 185 m.	29.3	35.0
TOTAL				**87.9**	**49.9**

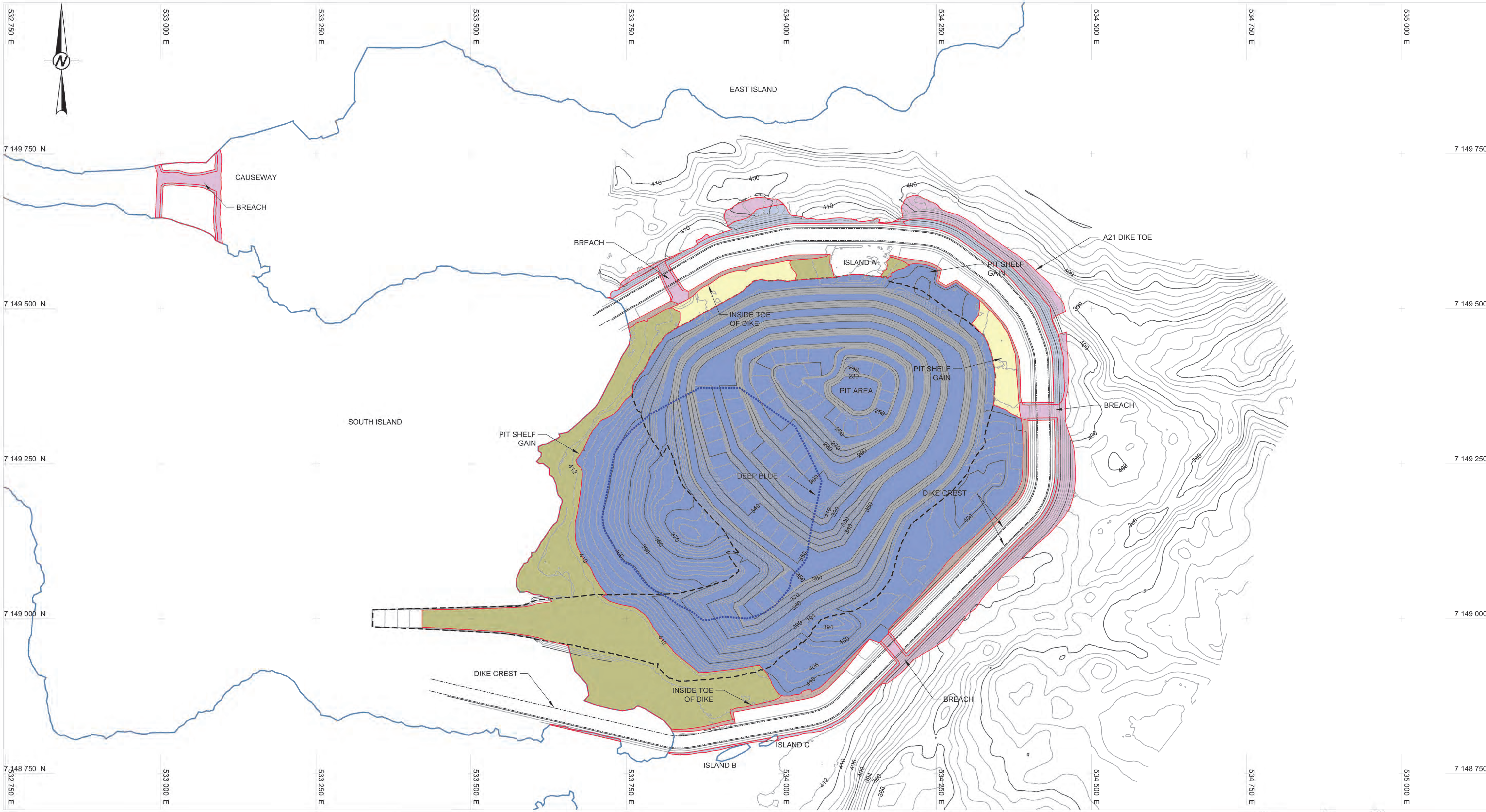
Notes:

A total of 14.0 habitat units are predicted post-closure after applying weighting, resulting in a net loss of 3.6 weighted habitat units.

a) No Net Loss Plan Addendum (DDMI 1999).

b) The 2–6 m depth contour around the causeway was given the same Habitat Suitability Index value as the 0–2 m depth contour because the area was considered limited for wind or wave exposure.

m = metre; ha = hectare; >more than; - = not applicable; n/a = not available.



LEGEND

- BATHYMETRY CONTOUR (2 m INTERVAL)
- BATHYMETRY CONTOUR (10 m INTERVAL)
- INTERIOR EDGE OF DIKE 0 TO 2 m DEPTH
- EXTERIOR EDGE OF DIKE 0 TO 2 m DEPTH
- EXTERIOR EDGE OF DIKE 2 TO 6 m DEPTH
- PIT SHELF < 5 m DEPTH
- RECLAIMED SHORELINE
- DEEP WATER > 5 m DEPTH

NOTE(S)

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. BATHYMETRY DATA SHOWN ARE FROM DDMI COMPOSITE SURFACE DATED NOVEMBER 14, 2015, AND INCLUDES PARTIALLY COMPLETED FOUNDATION DREDGING EXTENT. BASE TOPOGRAPHIC DATA BASED ON CHALLENGER SURVEY OPERATIONS 1997. CONTOUR INTERVAL IS 1.0 M. APPROXIMATE PRE-CONSTRUCTION SHORELINE IS BASED ON SURVEYS CONDUCTED PRIOR TO CONSTRUCTION AND MAY NOT MATCH CURRENT CONTOURS.
3. PROJECTION IS DIAVIK MINE GRID.

REFERENCE(S)

ORIGINAL DRAWING AND REFERENCE DRAWINGS OBTAINED OCTOBER 2016 FROM BGC ENGINEERING FOR THE PURPOSE OF CALCULATING AREAS AND SHORELINE AFFECTED BY THE CONSTRUCTIO OF DIKE A21 AND ACCESS. (14300-41D2-1003.1-REV-2 DATED MAY 16, 2016)

CLIENT

DIAVIK™ DIAMOND MINES INC.

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-10
DESIGNED	TL
PREPARED	RFM/JDS
REVIEWED	PB
APPROVED	PB

PROJECT

DDMI 2016 ENVIRONMENTAL PROJECTS

TITLE

POST-CLOSURE HABITAT TYPES AFTER A21 DIKE BREACH

PROJECT NO.	CONTROL	REV.	FIGURE
1648005	12000-RF-0001	0	3

7.0 CLOSURE

We trust this report presents the information that you require. Please feel free to call at any time if you have any questions or concerns.

GOLDER ASSOCIATES LTD.

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APPENDIX A

Summary of Habitat Unit Accounting for A21

Summary of Habitat Unit Accounting for A21

Weighted Habitat Units, and Net Change at A21 Dike from No Net Loss Addendum, 1999, and Recalculated with Current A21 Dike Alignment and Pit Dimensions

Life Stage	Species	No Net Loss Plan A21[a]			Current A21 Alignment[b]		
		Construction to Closure Habitat Loss[c]	Post-Closure Compensation Habitat[d]	Net Change	Construction to Closure Habitat Loss[c]	Post-Closure Compensation Habitat[d]	Net Change
Spawning	LKTR	0.79	0.14	-0.64	0.42	0.39	-0.03
	ARGR	0.00	0.00	0.00	0.00	0.00	0.00
	CISC	0.80	0.11	-0.69	0.48	0.34	-0.13
	RNWH	0.14	0.26	0.12	0.10	0.08	-0.03
	LKWH	0.30	0.04	-0.26	0.16	0.13	-0.03
	LNSC	0.17	0.02	-0.15	0.07	0.03	-0.05
	BURB	0.12	0.01	-0.12	0.09	0.04	-0.05
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00
	SLSC	0.27	0.66	0.39	0.15	0.23	0.08
Rearing	LKTR	3.46	8.31	4.85	2.72	2.90	0.18
	ARGR	0.44	0.60	0.16	0.42	0.22	-0.20
	CISC	3.83	8.02	4.19	2.97	2.58	-0.39
	RNWH	0.72	1.69	0.96	0.56	0.46	-0.09
	LKWH	1.00	1.93	0.93	0.64	0.54	-0.10
	LNSC	0.80	1.34	0.53	0.62	0.41	-0.21
	BURB	0.65	0.74	0.09	0.48	0.28	-0.19
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00
	SLSC	0.87	1.32	0.45	0.64	0.47	-0.17
Foraging	LKTR	2.44	2.19	-0.25	1.89	1.02	-0.87
	ARGR	0.27	0.31	0.04	0.23	0.14	-0.09
	CISC	2.37	3.31	0.94	1.83	1.50	-0.32
	RNWH	0.51	0.63	0.12	0.40	0.30	-0.11
	LKWH	0.44	0.77	0.33	0.34	0.27	-0.07
	LNSC	0.55	0.67	0.11	0.41	0.20	-0.21
	BURB	0.31	0.27	-0.04	0.24	0.12	-0.12
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00
	SLSC	0.40	0.64	0.24	0.30	0.17	-0.13
Nursery	LKTR	0.79	0.12	-0.67	0.42	0.36	-0.06
	ARGR	0.00	0.00	0.00	0.00	0.00	0.00
	CISC	0.80	0.11	-0.69	0.48	0.34	-0.13
	RNWH	0.14	0.26	0.12	0.10	0.08	-0.03
	LKWH	0.30	0.04	-0.26	0.16	0.13	-0.03
	LNSC	0.17	0.02	-0.15	0.07	0.03	-0.05
	BURB	0.12	0.01	-0.12	0.09	0.04	-0.05
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00
	SLSC	0.27	0.66	0.39	0.15	0.23	0.08
Total		24.27	35.19	10.93	17.65	14.02	-3.63
Total by life stage	Spawning	2.59	1.24	-1.35	1.48	1.24	-0.24
	Rearing	11.78	23.94	12.16	9.05	7.87	-1.18
	Foraging	7.30	8.80	1.50	5.64	3.72	-1.92
	Nursery	2.59	1.22	-1.38	1.48	1.20	-0.28
Total by species	LKTR	7.48	10.76	3.29	5.45	4.67	-0.78
	ARGR	0.71	0.91	0.20	0.65	0.35	-0.29
	CISC	7.80	11.55	3.76	5.75	4.78	-0.98
	RNWH	1.52	2.84	1.33	1.16	0.91	-0.26
	LKWH	2.05	2.79	0.74	1.31	1.07	-0.24
	LNSC	1.69	2.03	0.34	1.18	0.67	-0.51
	BURB	1.21	1.03	-0.18	0.89	0.47	-0.42
	NRPK	0.00	0.00	0.00	0.00	0.00	0.00
	SLSC	1.82	3.28	1.46	1.25	1.11	-0.14

Note:

Species and lifestage weightings include modifications suggested by K. Minns (DFO) (17 December 1998) on Diavik proposal (14 December 1998).

(a) Data summarized in No Net Loss Plan Addendum (DDMI1999).

(b) Recalculated in December 2016 based on new A21 Dike Alignment and Pit dimensions (BGC 2014).

(c) Habitat Units lost due to construction of the A21 dike and pit and the causeway include shoreline, shoal, and deep water habitats (see report Table 1 and Figure 2)

(d) Habitat Units after construction of the A21 dike and decommissioning of the A21 dike and pit represent enhanced habitat at the exterior edge of dike, causeway and breaches, the interior edge of dike, reclaimed shorelines, pit shelf and deep water (Report Table 2 and Figure 3)

LKTR = Lake Trout; ARGR = Arctic Grayling; CISC = Cisco; RNWH = Round Whitefish; LKWH = Lake Whitefish; LNSC = Longnose Sucker; BURB = Burbot; NRPK = Northern Pike; SLSC = Slimy Sculpin.

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