

Geology

Agb	Biotite +/- hornblende rich granitoids, mostly pre- to syn-kinematic (ca. 2625 - 2590 Ma); includes Unit Agbm
Agd	Diorite, quartz diorite, tonalite, granodiorite, gabbro (mostly 2630 - 2605 Ma)
Agk	Granitoids - 2 mica or K-feldspar megacrystic, pegmatite; mostly syn- to post-kinematic (ca. 2605 - 2580 Ma); includes Unit Agkm
Agn	Gneiss & granitoid complex - heterogeneous and unsubsided; massive to migmatitic and gneissic granitoids; various ages represented
Agx	Granitoids with abundant supracrustal/gabbro/gneiss xenoliths
Ams	Mafic intrusions (gabbro, anorthosite, diorite) associated with volcanic rocks; various ages represented but most assumed to be 'synvolcanic'
Ath	Turbiditic wacke to mudstone - high grade to migmatitic (sillimanite-grade +/- or anatectic melt phases)
Atm	Turbiditic wacke to mudstone - medium grade; knotted schists (andalusite +/- or cordierite porphyroblasts); includes areas of Unit Aam
Avf	Volcanic rocks - felsic to intermediate lavas, volcaniclastics, & related intrusions; local carbonate interbeds
Avm	Volcanic rocks - mafic to intermediate lavas, volcaniclastics, & related intrusions
Pm	Mafic and ultramafic intrusions (gabbro, pyroxenite, peridotite etc.); commonly enhanced magnetic signature

Geology Source:
 Stibley, MP (2005). Slave Craton: Interpretive Bedrock Correlation. NW-TNU; Northwest Territories Geoscience Office.
 NW-TNU Open File No. 2005-01. Retrieved Nov 30, 2012, from http://mgomap.nw.govscience.ca/reference_details_export.jsp?referenceD=11963

LEGEND

	Rivers		Quarries: <math>< 50,000m^3</math>		Road Section Overall Risk Rating: Very Low Risk
	Watersheds		Quarries: >50,000m ³		Moderate-Low Risk
	Borrow		Unknown Volume		Moderate-High Risk
	Rock Cuts				Variable Uncertain Risk
	Road Section Number				

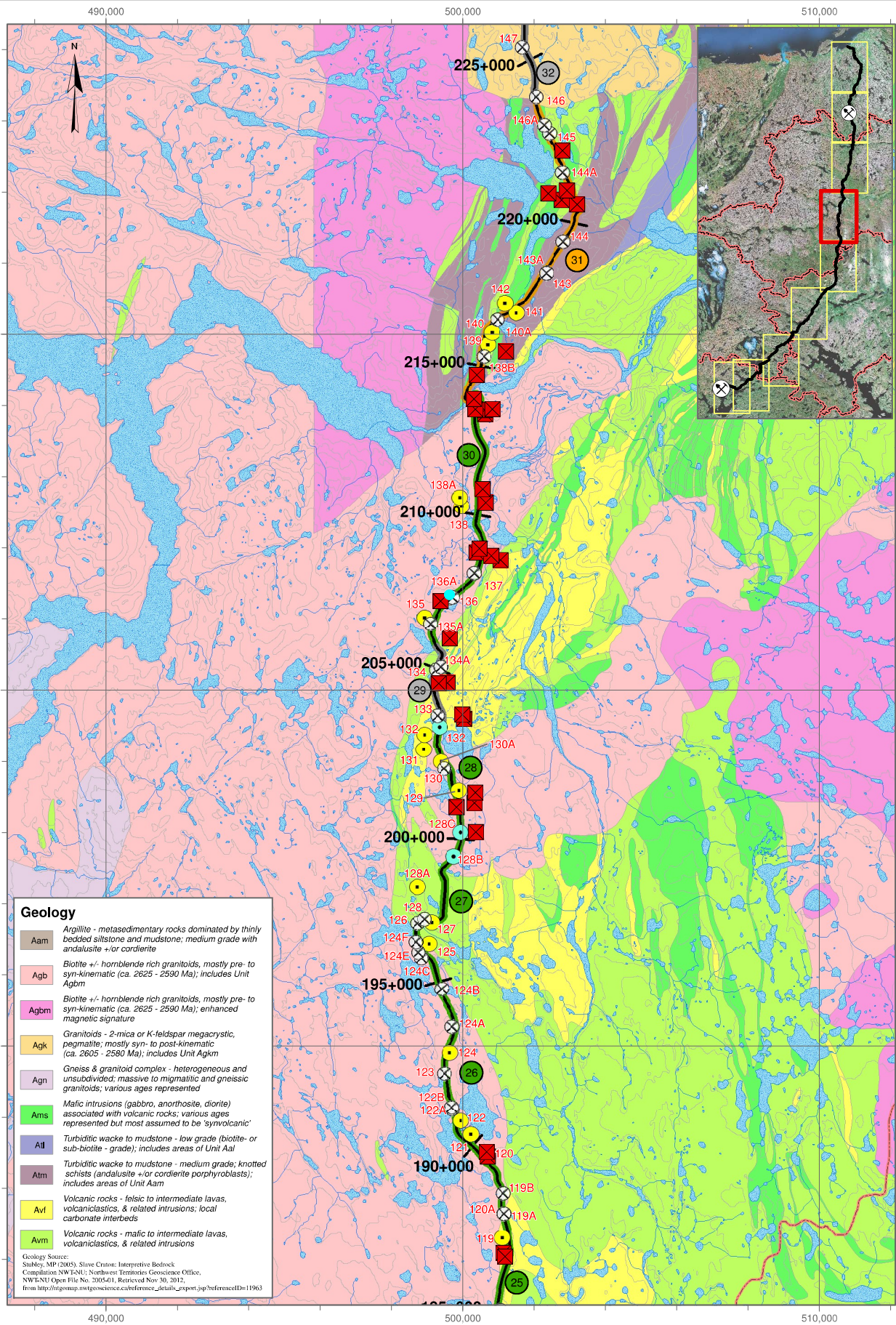
Road distance markers - 355-500
 These are not continuous, they have been divided into 6 segments by MMG

DATE SAVED:	Apr 18, 2013
DRAWN BY:	VV
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Scale:	1:100,000
Graphic Scale:	0 1 2 Km

CLIENT:




PROJECT:	Izok Road Geochemistry Program	
TITLE:	Izok Road Section Risk Part 5	
PROJECT #:	J995-3	FIGURE: 4-1



Geology

- Aam** Argillite - metasedimentary rocks dominated by thinly bedded siltstone and mudstone; medium grade with andalusite +/- cordierite
- Agb** Biotite +/- hornblende rich granitoids, mostly pre- to syn-kinematic (ca. 2625 - 2590 Ma); includes Unit Agbm
- Agbm** Biotite +/- hornblende rich granitoids, mostly pre- to syn-kinematic (ca. 2625 - 2590 Ma); enhanced magnetic signature
- Agk** Granitoids - 2-mica or K-feldspar megacrystic, pegmatite; mostly syn- to post-kinematic (ca. 2605 - 2580 Ma); includes Unit Agkm
- Agn** Gneiss & granitoid complex - heterogeneous and unsubsided; massive to migmatitic and gneissic granitoids; various ages represented
- Ams** Mafic intrusions (gabbro, anorthosite, diorite) associated with volcanic rocks; various ages represented but most assumed to be 'synvolcanic'
- Aal** Turbiditic wacke to mudstone - low grade (biotite- or sub-biotite - grade); includes areas of Unit Aal
- Atm** Turbiditic wacke to mudstone - medium grade; knotted schists (andalusite +/- cordierite porphyroblasts); includes areas of Unit Aam
- Avf** Volcanic rocks - felsic to intermediate lavas, volcaniclastics, & related intrusions; local carbonate interbeds
- Avm** Volcanic rocks - mafic to intermediate lavas, volcaniclastics, & related intrusions

Geology Source:
 Stuhley, MP (2005). Slave Craton: Interpretive Bedrock Compilation. NW 1242; Northwest Territories Geoscience Office. NWLENU Open File No. 2005-01, Retrieved Nov 30, 2012, from http://ntgsonp.nwtgscience.ca/reference_details_export.jsp?referenceid=11963

LEGEND

- Rivers
- Waterbodies
- Borrow
- Rock Cuts
- Road Section Number

Quarries:

- <math>< 50,000m^3</math>
- > $50,000m^3$
- Unknown Volume

Road Section Overall Risk Rating

- Very Low Risk
- Low Risk
- Moderate-Low Risk
- Moderate Risk
- Moderate-High Risk
- Variable Uncertain Risk

Road distance markers - 355-500. These are not continuous, they have been divided into 6 segments by MMG.

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Coordinate System: NAD 1983 UTM Zone 12N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

1:100,000

0 1 2 Km

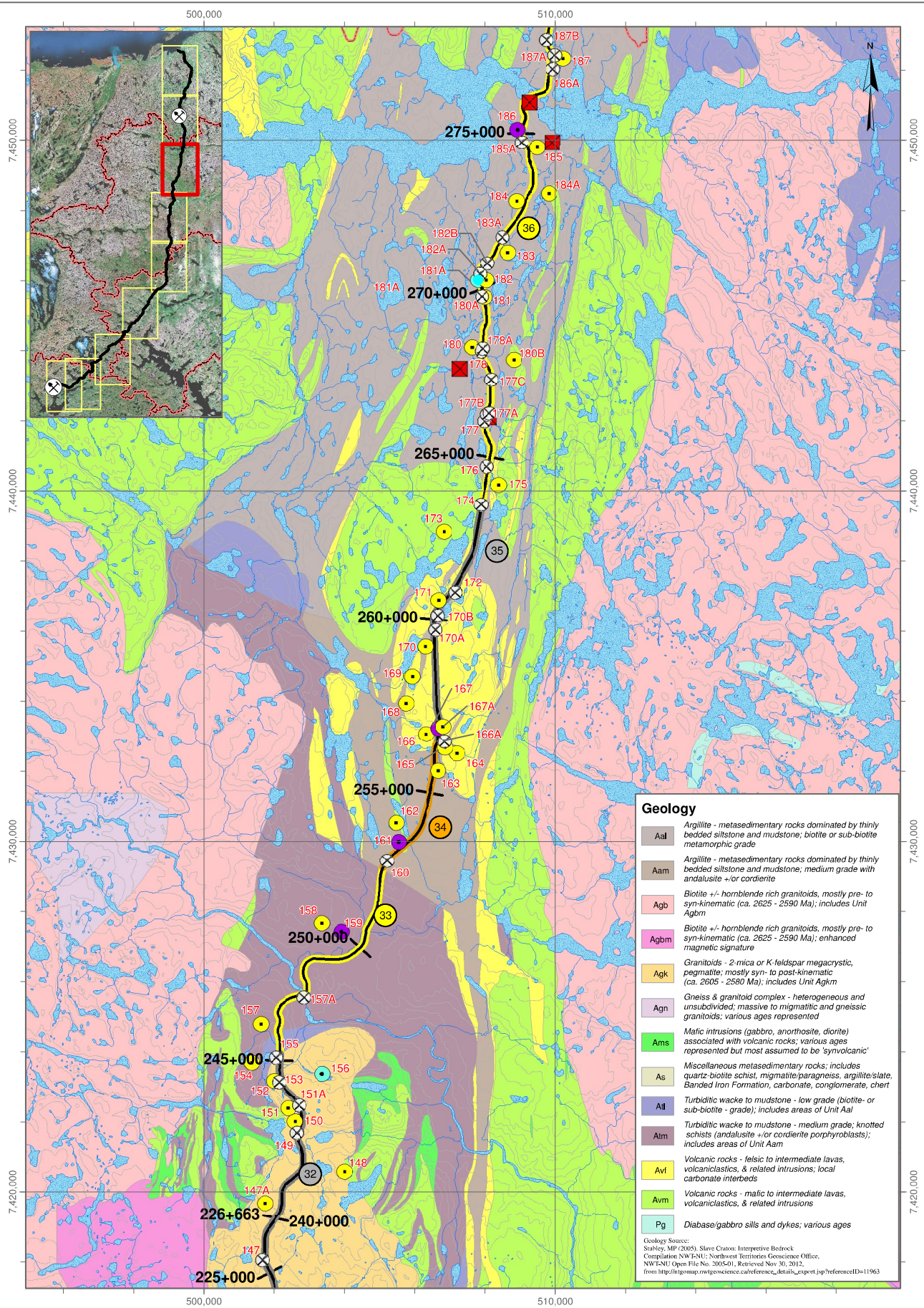
CLIENT:

PROJECT:

**Izok Road
 Geochemistry Program**

TITLE: Izok Road Section Risk Part 6

PROJECT #: J995-3 FIGURE: 4-1



Geology	
Aal	Argillite - metasedimentary rocks dominated by thinly bedded siltstone and mudstone; biotite or sub-biotite metamorphic grade
Aam	Argillite - metasedimentary rocks dominated by thinly bedded siltstone and mudstone; medium grade with andalusite +/- cordierite
Agb	Biotite +/- hornblende rich granitoids, mostly pre- to syn-kinematic (ca. 2625 - 2590 Ma); includes Unit Agbm
Agbm	Biotite +/- hornblende rich granitoids, mostly pre- to syn-kinematic (ca. 2625 - 2590 Ma); enhanced magnetic signature
Agk	Granitoids - 2-mica or K-feldspar megacrystic, pegmatite; mostly syn- to post-kinematic (ca. 2605 - 2580 Ma); includes Unit Agkm
Agn	Gneiss & granitoid complex - heterogeneous and unsubdivided; massive to migmatitic and gneissic granitoids; various ages represented
Ams	Mafic intrusions (gabbro, anorthosite, diorite) associated with volcanic rocks; various ages represented but most assumed to be 'synvolcanic'
As	Miscellaneous metasedimentary rocks; includes quartz-biotite schist, migmatite/paragneiss, argillite/slate, Banded Iron Formation, carbonate, conglomerate, chert
Ail	Turbiditic wacke to mudstone - low grade (biotite- or sub-biotite - grade); includes areas of Unit Aal
Atm	Turbiditic wacke to mudstone - medium grade; knotted schists (andalusite +/- cordierite porphyroblasts); includes areas of Unit Aam
Avf	Volcanic rocks - felsic to intermediate lavas, volcanoclastics, & related intrusions; local carbonate interbeds
Avm	Volcanic rocks - mafic to intermediate lavas, volcanoclastics, & related intrusions
Pg	Diabase/gabbro sills and dykes; various ages

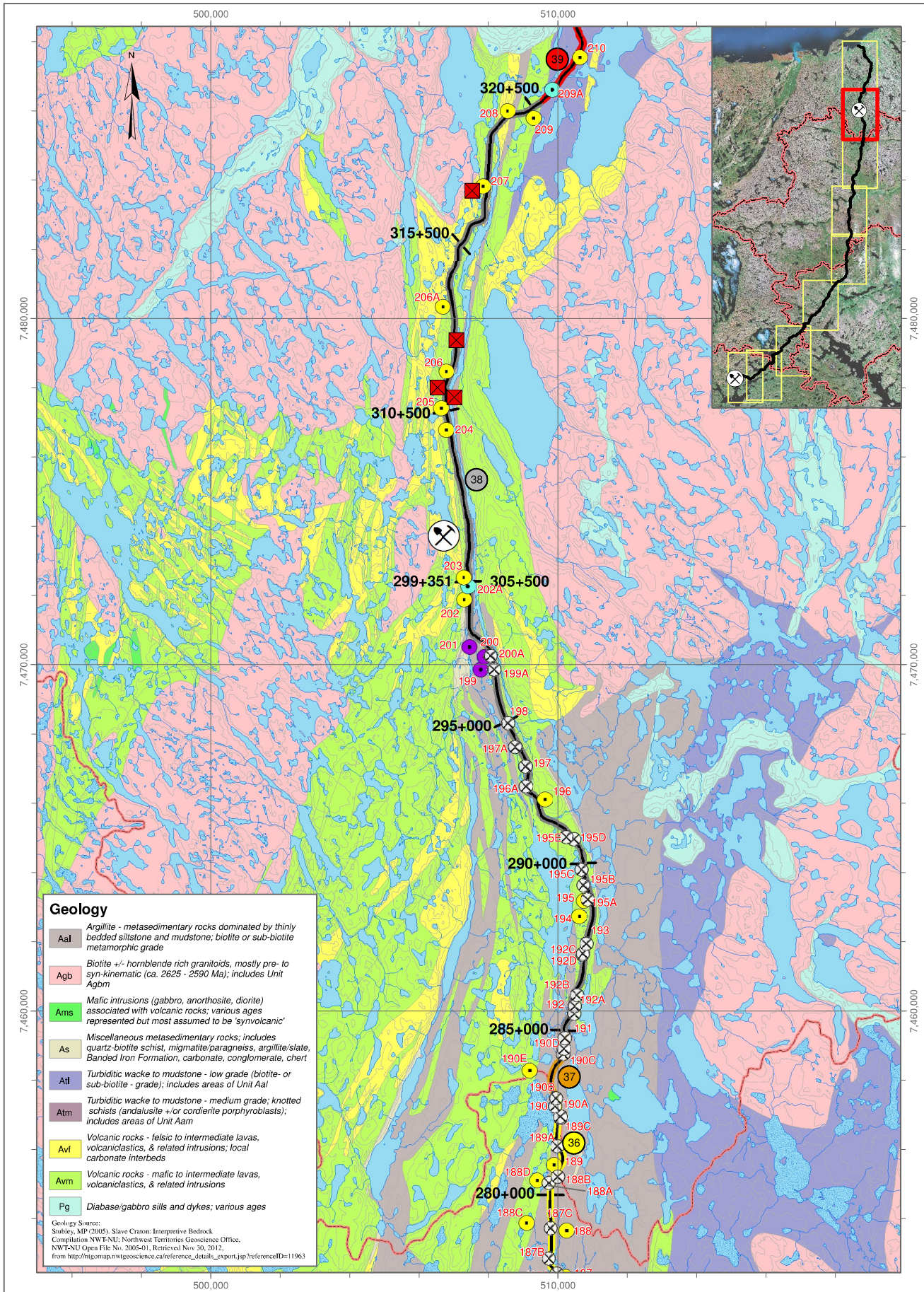
Geology Source:
 Staley, MP (2005). Slave Craton. Interpretive Bedrock Compilation. NWT/NTM; Northwest Territories Geoscience Office. NWT-NTU Open File No. 2005-01. Retrieved Nov 30, 2012, from http://imgomap.nwterritories.ca/reference_details_expert.jsp?referencedId=11963

LEGEND		
	Rivers	
	Waterbodies	
	Borrow	
	Rock Cuts	
	Road Section Number	
	Quarries: <math>< 50,000\text{m}^3</math>	
	>50,000m ³	
	Unknown Volume	
	Road distance markers - 355+500 (These are not continuous, they have been divided into 6 segments by MMG)	
	Road Section Overall Risk Rating	
	Very Low Risk	
	Moderate-Low Risk	
	Moderate Risk	
	Moderate-High Risk	
	Variable Uncertain Risk	

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Projection: Transverse Mercator	
Datum: North American 1983	
Units: Meter	
1:100,000	
0 1 2 Km	

CLIENT:

PROJECT:	
Izok Road Geochemistry Program	
TITLE:	
Izok Road Section Risk Part 7	
PROJECT #:	J995-3
FIGURE:	4-1



Geology

- Aal** Argillite - metasedimentary rocks dominated by thinly bedded siltstone and mudstone; biotite or sub-biotite metamorphic grade
- Agb** Biotite +/- hornblende rich granitoids, mostly pre- to syn-kinematic (ca. 2625 - 2590 Ma); includes Unit Agbm
- Ams** Mafic intrusions (gabbro, anorthosite, diorite) associated with volcanic rocks; various ages represented but most assumed to be 'synvolcanic'
- As** Miscellaneous metasedimentary rocks; includes quartz-biotite schist, migmatite/paragneiss, argillite/slate, Banded Iron Formation, carbonate, conglomerate, chert
- Atl** Turbiditic wacke to mudstone - low grade (biotite- or sub-biotite - grade); includes areas of Unit Aal
- Atm** Turbiditic wacke to mudstone - medium grade; knotted schists (andalusite +/- cordierite porphyroblasts); includes areas of Unit Aam
- Avf** Volcanic rocks - felsic to intermediate lavas, volcaniclastics, & related intrusions; local carbonate interbeds
- Avm** Volcanic rocks - mafic to intermediate lavas, volcaniclastics, & related intrusions
- Pg** Diabase/gabbro sills and dykes; various ages

Geology Source:
 Staley, MP (2005), Slave Craton, Interpretive Bedrock Compilation NW-TNU; Northwest Territories, Geoscience Office.
 NW-TNU Open File No. 2005-01, Retrieved Nov 30, 2012.
 from http://mtgomap.nwgtgeoscience.ca/reference_details_export.jsp?referenceID=11963

LEGEND

- Rivers
- Waterbodies
- Borrow
- Rock Cuts
- Road Section Number

Quarries:

- <math>< 50,000\text{m}^3</math>
- >=50,000m³
- Unknown Volume

Road Section Overall Risk Rating

- Very Low Risk
- Low Risk
- Moderate-Low Risk
- Moderate Risk
- Moderate-High Risk
- Variable/Uncertain Risk

Road distance markers - 355+500 These are not continuous, they have been divided into 6 segments by MMG

DATE SAVED: Apr 18, 2013

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VERSION: 1

Coordinate System: NAD 1983 UTM Zone 12N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

1:100,000

0 1 2 Km

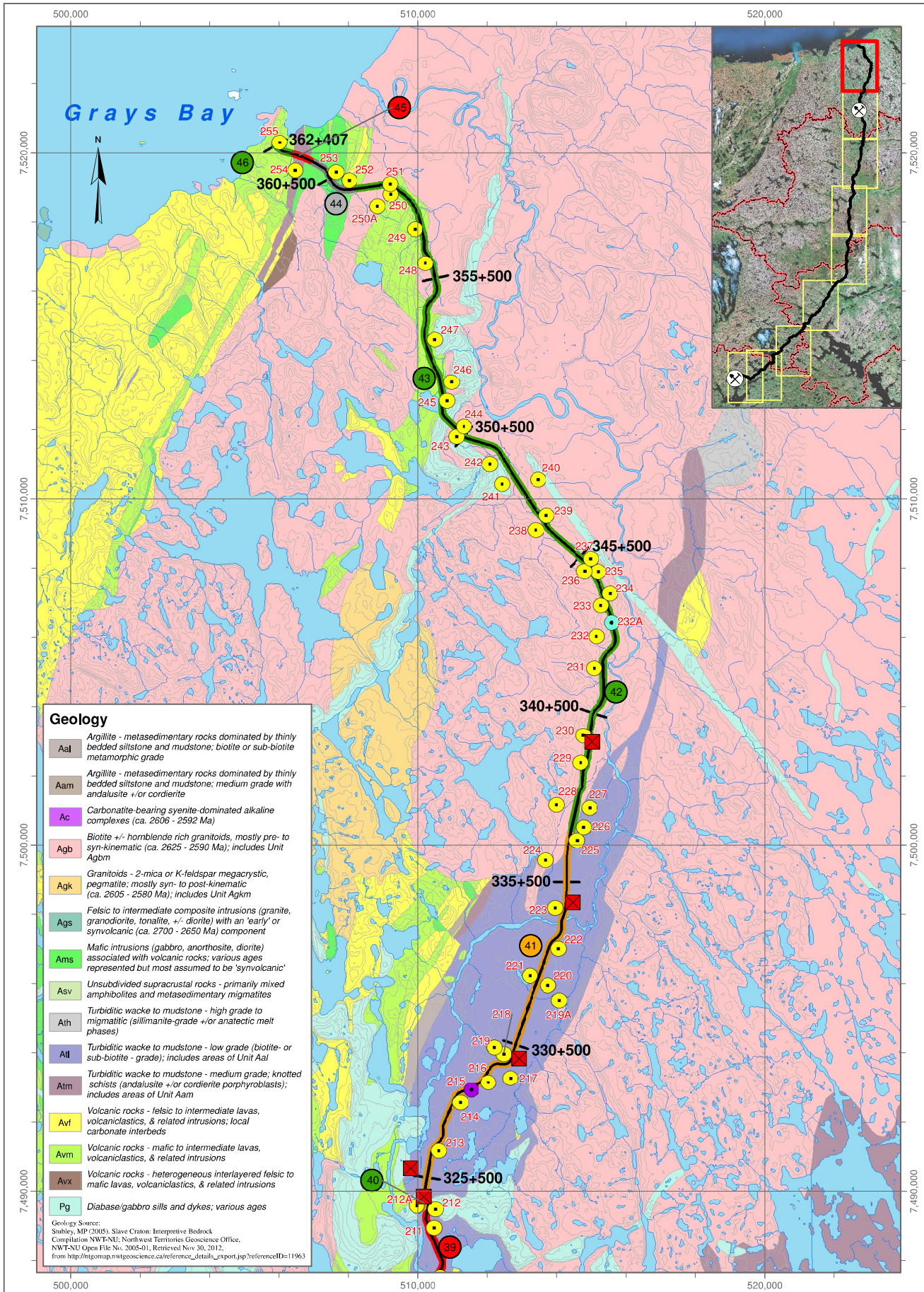
CLIENT:

PROJECT:

**Izok Road
 Geochemistry Program**

TITLE: Izok Road Section Risk Part 8

PROJECT #: J995-3 FIGURE: 4-1



Geology

- Aal** Argillite - metasedimentary rocks dominated by thinly bedded siltstone and mudstone; biotite or sub-biotite metamorphic grade
- Aam** Argillite - metasedimentary rocks dominated by thinly bedded siltstone and mudstone; medium grade with andalusite +/- cordierite
- Ac** Carbonatite-bearing syenite-dominated alkaline complexes (ca. 2606 - 2592 Ma)
- Agb** Biotite +/- hornblende rich granitoids, mostly pre- to syn-kinematic (ca. 2625 - 2590 Ma); includes Unit Agbm
- Agk** Granitoids - 2-mica or K-feldspar megacrystic, pegmatite; mostly syn- to post-kinematic (ca. 2605 - 2580 Ma); includes Unit Agkm
- Ags** Felsic to intermediate composite intrusions (granite, granodiorite, tonalite, +/- diorite) with an 'early' or synvolcanic (ca. 2700 - 2650 Ma) component
- Ams** Mafic intrusions (gabbro, anorthosite, diorite) associated with volcanic rocks; various ages represented but most assumed to be 'synvolcanic'
- Asv** Unsubdivided supracrustal rocks - primarily mixed amphibolites and metasedimentary migmatites
- Ath** Turbiditic wacke to mudstone - high grade to migmatitic (sillimanite-grade +/- anatexitic melt phases)
- All** Turbiditic wacke to mudstone - low grade (biotite- or sub-biotite - grade); includes areas of Unit Aal
- Atm** Turbiditic wacke to mudstone - medium grade; knotted schists (andalusite +/- cordierite porphyroblasts); includes areas of Unit Aam
- Avf** Volcanic rocks - felsic to intermediate lavas, volcanoclastics, & related intrusions; local carbonate interbeds
- Avm** Volcanic rocks - mafic to intermediate lavas, volcanoclastics, & related intrusions
- Avx** Volcanic rocks - heterogeneous interlayered felsic to mafic lavas, volcanoclastics, & related intrusions
- Pg** Diabase/gabbro sills and dykes; various ages

Geology Source:
 Shibley, MP (2005). Slave Craton. Interpretive Bedrock
 Compilation NW-TNLI, Northwest Territories Geoscience Office.
 Compilation NWT-NLI, Northwest Territories Geoscience Office.
 NWT-NLI Open File No. 2005-01, Retrieved Nov 30, 2012.
 from http://mtgomap.nwtgscience.ca/reference_details_expport.jsp?referenceID=13963

LEGEND

Rivers	Quizzes: <math><=50,000\text{m}^3</math>	Very Low Risk
Waterbodies	>50,000m ³	Moderate-Low Risk
Borrow	Unknown Volume	Moderate Risk
Rock Cuts	Road Section Number	Moderate-High Risk
Road Section Number		Variable Uncertain Risk

Road distance markers - 355+500
 These are not continuous, they have been divided into 6 segments by MMG

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 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

1:100,000

0 1 2 Km

CLIENT:

PROJECT:

**Izok Road
 Geochemistry Program**

TITLE: Izok Road Section Risk Part 9

PROJECT #: J995-3 FIGURE: 4-1

4.1 Higher Risk Road (15) Sections

This section summarizes the results for a total of 15 road sections that are rated as having:

- Moderate-High Risk (2 Sections);
- Moderate Risk (9 sections); and
- Moderate-Low Risk (4 sections).

These ratings are driven primarily by higher risk associated with the geologic units that occur. Bedrock disturbance should be avoided in these sections, unless further work is undertaken and supports a reduction in the risk ratings. These sections are summarized in Table 4-3 and discussed in further detail below.

**Table 4-3:
 Road Sections with Moderate-High to Moderate-Low Risk**

Road Section	Chainage		Length (km)	Overall Risk	Description
	From	To			
5	43+800	46+600	2.8	Moderate-High Risk	
39	320+900	324+400	3.5		
45	361+300	361+800	0.5		
1	0+000	3+900	3.9	Moderate Risk	
4	42+400	43+800	1.4		
7	48+400	53+400	5		
8	53+400	58+400	5		
23	174+100	177+900	3.8		
31	213+800	223+800	10		
34	252+400	256+400	4		
37	283+000	285+000	3.1		
41	324+500	336+900	12.4		
10	77+200	79+900	2.7	Moderate-Low Risk	
33	245+200	252+400	7.2		
36	263+600	283+000	19.4		

4.1.1 Moderate-High Risk Road Sections

Sections 5, 39 and 45 have an overall risk rating of moderate-high. One is located in the Takijuq Lake Watershed and the other two within the Kennarctic River Watershed, near Grays Bay Port (Table 4-3, Figure 4-1). All three consist only of proposed quarry locations and do not include road cuts. The extents of these moderate-high risk road

sections are short, measuring <3.5 km each in length. The high risk rating is primarily a response to the geology (ratings of 3 or 4), but is also influenced by the proposed large cut volumes, relatively small drainage areas and generally high receptor ratings (Table 4-2). Fish presence and habitat resiliency data was generally available for these sections, so the receptor ratings are believed to be reliable and accurate.

The 2.8 km section from 43+800 to 45+600 (road section 5) is through granitoid rocks (Agk) with a rating of 3, verified by test samples within 500 m proximity. Road section 5 is primarily influenced by the high receptor rating of 6, which is based on reliable investigations along this stretch of road.

The 3.5 km section from 320+900 to 324+400 (road section 39) and 0.5 km section from 361+300 to 361+800 (road section 45), which are both within the Kennarctic River Watershed, are through turbiditic wackes to mudstones (Ath), with geology ratings of 4. The overall risks for these sections are predominantly based on the geology and high proposed cut volumes (ratings of 4 and 5) that resulted in stressor ratings of 17 and 20, respectively. The pathway ratings are also high (4), due to the high cut volumes in the context of the relatively small catchment areas. For these two road sections, the receptor ratings have little influence in the overall risk.

4.1.2 Moderate Risk Road (9) Sections

There are nine moderate risk sections along the Izok Road (Table 4-3, Figure 4-1). Sections of the road assessed to be moderate risk generally contain both proposed quarry and rock cut locations.

The moderate risk sections are through a variety of geology with ratings of 3 or 4, including turbiditic wackes to mudstones (Atl, Atm and Ath), volcanic rocks (Avm and Avx), granitoid rocks (Agk and Ag), argillites (Aal and Aam) and a mafic intrusive unit (Ams).

Six of the moderate risk sections have reliable fisheries data on which the receptor ratings are based. The other three road sections, 0+000 to 3+900 (road section 1), 213+800 to 223+800 (road section 31) and 324+500 to 336+900 (road section 41), have several receptor ratings that have been conservatively assumed at the highest ratings due to lack of fisheries data. This has a notable influence on the overall risk for the road section as a whole and may be reduced based on results from further fieldwork.

4.1.2.1 Short Road Sections (section reference 1, 4, 23, 34 and 37)

Road sections 1, 4, 23, 34 and 37 are each <4 km in length and have geology ratings of 3 and 4. One quarry is proposed for the 3.8 km road stretch from 174+100 to 177+900

(section reference 23) through turbiditic wackes to mudstones (Ath). The moderate risk rating for this section is primarily based on the high geology risk rating of 4 and pathway rating of 4. The pathway rating is based on a relatively small drainage area (126.5 ha) with respect to estimated cut volume (600,392 em³).

The three quarries and one rock cut proposed for road section 34 from 252+400 to 256+400 is a 4 km stretch through argillite (Aam) with a rating of 4. This rating is supported by static test samples within the 500 m radius. The overall stressor rating for this section is 15. Furthermore, available fisheries data for this section generally indicates fish presence within small and large permanent streams, resulting in an overall receptor rating of 5. Overall, this section is best avoided if possible.

4.1.2.2 Road Section 48+400 to 58+400 (section references 7 and 8)

The 10 km stretch from 48+400 to 58+400 (road sections 7 and 8) are through volcanic (Avx) and granitoid (Ag) rocks with a geology rating of 3. No static test samples were obtained within the 500 m radius of the quarries and rock cuts along this stretch of road; however, a couple of samples within the same Ag unit along a 1.8 km stretch from 46+600 to 48+400 (road section 6) have low risk geology ratings of 1. Additional static test sampling along this road section may reduce the geology and overall risk rating.

4.1.2.3 Road Section 213+800 to 223+800 (section reference 31)

The 10 km stretch from 213+800 to 223+800 (road section 31) consists of four proposed quarries and eight proposed rock cuts within turbiditic wackes to mudstones (Atm) and volcanic rocks (Avm). Both units have ratings of 4 that are supported by static test samples in the vicinity. A couple of rock cuts are located within the mafic intrusive unit Ams (rating of 3) that alternates with the Avm unit in lengthwise sections measuring 250 m to 500 m in width parallel to the road. This section is largely made up of individual quarries and rock cuts with moderate-high risk and variable/uncertain risk. The uncertainty is largely due to the large drainage area applied to the pathway rating, while the moderate-high risk is largely due to the conservative receptor rating due to lack of fisheries data in the area.

4.1.2.4 Road Section 324+500 to 336+900 (section reference 41)

The road section from 324+500 to 336+900 (section reference 41), in particular, contains 16 proposed quarries along the 12.4 km stretch through dominantly turbiditic wackes to mudstones (Atl). Few static test samples are available along this section; however, where samples are within 500 m of a proposed quarry, the geology rating was decreased to 3 based on the ABA results rather than the overall unit rating of 4 (see quarries 119A, 120

and 121 in Table 4-2). This road section does have lower risk areas from which material can be drawn. For example, quarry 224, for which a large cut volume was estimated (1,418,567 em³), is located within low risk granitoid rock (Agb).

4.1.3 Moderate-Low Risk Road (4) Sections

There are three moderate-low risk sections along the Izok Road (Table 4-3, Figure 4-1). Sections of the road assessed to be moderate-low risk generally contain both proposed quarry and rock cut locations.

4.1.3.1 Short Road Sections (10 and 33)

Two smaller stretches of road are also indicated to be moderate-low risk. One from 77+200 to 79+900 (road section 10) which traverses mafic intrusives (Ams) with a rating of 3 (confirmed by a sample within 500 m) and the other from 245+200 to 252+400 (road section 33) within turbiditic wackes to mudstones (Atm) which have a rating of 4. Both have receptor ratings based on fisheries data within these sections. As a result of the high stressor, pathway and receptor ratings, both sections should be avoided if possible. However, if deemed necessary to develop within these stretches, it is recommended that additional information be collected to confirm the total sulphur concentrations of the rock type and the size of the catchment with respect to overall dilution potential.

4.1.3.2 Road Section 263+600 to 285+000 (Sections 36 and 37)

The 19.4 km stretch from 263+600 to 283+000 (road section 36), in particular, contains 16 proposed quarries and 25 proposed rock cuts in predominantly argillitic metasedimentary rocks (Aal), with a rating of 4. Of note are the relatively large volcanoclastic intrusions (Avm), with a lower risk rating of 3, located along both sides of the road. In addition to the 4 km by nearly 6 km intrusion in which quarry 175 is located, is a 10 km long intrusion approximately 2 km east of the road. Considerably smaller pockets measuring 300 m to <700 m in width, and in which a few quarries are proposed (180B, 184, 188C and 188D), are in closer proximity to the road. However, additional sampling may be required to delineate the extent of the small pockets and ensure development remains within the low risk unit. Furthermore, 8 of the proposed quarries/rock cuts along section 36 were assigned the most conservative receptor ratings due to a lack of fisheries data. As was discussed under the moderate risk road sections, the receptor rating does have a notable influence on the overall risk of a road section as a whole and may be reduced based on results from additional fieldwork.

Note that the geology discussed for sections 36 and 37 continues into road stretch 38, a 35.9 km stretch from 285+000 to 320+900. Section 38, however, is predominantly

composed of mafic intrusions (Ams) with a lower risk rating of 3. As with sections 36 and 37, the geology will constrain the development unless further field work indicates otherwise. Road section 38 is discussed in more detail in Section 4.6.1 of this report.

4.2 Variable/Uncertain Road (7) Sections

Seven road sections, covering 100.2 km (30%) of the Izok Road, have been assigned a Variable/Uncertain Risk due to low sample density and intricate geology along these stretches of the road alignment. These road sections have been divided into three groups:

- 1) Variable Geology - Moderate Risk with pockets of low risk; and
- 2) Variable Geology - Low Risk with pockets of higher risk;
- 3) Uncertain Geology.

These are presented in Table 4-4 and discussed in more detail below. In particular, the 26.2 km section from 15+400 to 42+400 (road section 3), the 18.8 km section from 58+400 to 77+200 (road section 9) and the 35.9 km road section from 285+000 to 320+900 (road section 38) warrant further examination given their extent.

**Table 4-4:
 Road Sections with a Variable/Uncertain Rating**

Road Section	Chainage		Length (km)	Description
	From	To		
3	15+400	42+400	26.16	Variable Geology - Moderate Risk with pockets of low risk
9	58+400	77+200	18.8	
35	256+400	263+600	7.2	
44	359+600	361+300	1.7	
32	223+800	245+200	8.06	Variable Geology - Low Risk with pockets of moderate risk
38	285+000	320+900	35.9	
29	203+300	205+700	2.4	Uncertain Geology Ratings

4.2.1 Variable Geology - Moderate Risk with Pockets of Low Risk

Four sections of road are considered to be variable with a predominantly moderate risk. However, each section contains a large number of low risk areas, which are highlighted and discussed. These are a 26.2 km section from 15+400 to 42+400 (section reference 3), an 18.8 km section from 58+400 to 77+200 (reference 9), a 7.2 km section from 256+400 to 263+600 (reference 35) and a 1.7 km section from 359+600 to 361+300 (reference 44).

Road sections 3 and 9 are predominantly through turbiditic wackes and mudstones (Atm and Atl, respectively) which have an overall unit rating of 4. Nineteen quarries/rock cuts

are proposed for unit Atm along section 3. Both road sections also consist of the granitoid unit Agk, which has an overall unit rating of 2, and in which several quarries are proposed in each section. While it is obviously recommended that development remain within the granitoid unit if possible, it is likely, particularly for such large stretches of road (26 and 19 km) that additional material will be required from quarries/cuts within the Atm and Atl unit. It should be noted that static test samples in the areas decreased the geologic rating of Atm samples to 3 and Atl to 1 based on the lower total sulphur values in the samples. Therefore, further static testwork along the sections of road may decrease the unit rating on a quarry by quarry basis. Additional field work to delineate the catchment sizes within the 27,393 ha basin may also be required prior to development along this stretch of road.

Road sections 35 and 44 alternate between low risk and higher risk units and will require further delineation by a site geologist to ensure development remains within the low risk units.

4.2.2 Variable Geology - Low Risk with Pockets of Higher Risk

Two sections along the Izok Road are considered to be predominantly low risk with pockets of higher risk areas. These are an 8 km section from 223+800 to 245+200 (road section 32) and a 35.9 km section from 285+000 to 320+900 (road section 38).

Road section 32 is predominantly Agk with a geology rating of 1; however, three proposed quarries/rock cuts (148, 154 and 155) are located within higher risk geologic units of volcanic (Avm) and turbiditic wackes to mudstones (Atm and Atl). This section is included here to highlight the zones that should be avoided if possible. It is recommended that every effort be made to remain within the Agk unit.

Section 38 extends into the predominantly Ams (volcanic intrusions) zone along the Izok Road and based on the current proposed quarry and rock cut sites, at least 75% of this stretch of road is therefore low risk (rating of 1 and 2). Similar to section 32, several quarries/rock cuts, including 192, 192A, 199, 200, 201 and 202 are within the higher risk argillic unit (Aal) that has a rating of 4. Additionally, the Ams zone along the road is narrow, ranging from 0.5 km up to 1 km in width across the road and is bordered by the argillites (Aal). Therefore, the 36 km stretch is considered to be low risk where development is proposed within the volcanic intrusive unit (Ams).

4.2.3 Uncertain Geology Rating

Only road section 203+300 to 205+700 (section reference 29) has an uncertain geology. This section of the road is through volcanic rocks (Avf), which generally have an overall unit rating of 2. However, two samples near rock cuts 134 and 134A indicate a higher

risk potential of 3 based on an NPR value of <2 and total sulphur values of >0.05%. It is recommended that a static test sample be collected at each quarry and or rock cut site along this section of road prior to development to confirm the total sulphur values. Note that if a higher risk rating of 3 is determined from the static test work, the pathway and receptor ratings will need to be delineated to determine the overall risk for this section. Furthermore, the geology along this section of road is complex. The area comprises alternating narrow lengths of volcanic intrusive units Avf and Avm within the granitoid Agb unit. Both volcanic units have demonstrated a variable geochemistry and a range in the geologic rating from 1 to 3.

4.3 Low Risk / No Risk Road (24) Sections

There are a total of 21 road sections that are deemed low risk, and 3 sections (12, 16, and 20) that are considered to have no risk, because there are no rock cuts or quarries proposed within the section. These are described in more detail below.

4.3.1 Proposed Quarries and Rock Cuts

There are 21 low risk sections along the Izok Road (Table 4-1, Figure 4-1). The low risk sections cover 151.7 km (45%) of the proposed road alignment. In general, these sections are located predominantly within the Burnside River and Hood River watersheds, along an approximately 113 km stretch from 79+900 to 203+300 (with the exception of a 3.8 km section that is of moderate risk).

The stressor rating is generally fairly low through these sections, traversing low risk geological units with ratings of 1 or 2, including granitoid rocks (Ag, Agb, Agk and Agx), volcanic rocks (Avf and Avm) and mafic sills/dykes (Pg). For road sections dominated by granitoid rocks and/or have samples within 500 m to confirm rating, no further work is recommended, as the overall risk is low enough to determine that ML/ARD will not be an issue during or following road construction. These road sections include: 2, 6, 11, 13, 17, 18, 21, 22, 24, 26, 28, 30, 40 and 43.

For road sections 14, 15, 19, 25, 27 and 46, which traverse volcanic rocks of Avf and Avm, and for which there are no static test samples within 500 m of proposed quarries/rock cuts, it is recommended that a sample be collected at each site prior to development to ensure total sulphur concentration is <0.05%. Unit Avf and Avm have demonstrated variable total sulphur values ranging from <0.01% to 0.17% and from <0.01% to 0.47%, respectively, and therefore a range in geology ratings from 1 to 3.

Similarly, section reference 42, which is through the granitoid Agb unit, demonstrates a range of geologic ratings across the unit. Static test samples within 500 m of proposed quarries/rock cuts along this section indicate a range of total sulphur values ranging from <0.01% to 0.25% and therefore geology risk ratings of 1 to 3.

4.3.2 Unconsolidated Surficial Material (Soil Samples)

Unconsolidated surficial material along the Izok Road is found in layers of > 50 cm depth in lower lying areas between ridges of bedrock. Twenty-one soil samples were collected from the north end of the Izok Road near the Grays Bay Port. The soil samples have been given a low risk rating of 1 and are not expected to have a high ML/ARD potential. This is considered an appropriate rating given that the soil forms relatively thin layers, is weathered and does not appear to be regolith derived from the underlying sulphide-bearing rock but rather glaciofluvial or marine sediments transported to the area. Overall, the soil samples have sulphide sulphur levels and inorganic carbon levels at or near detection (<0.01% and 0.8%, respectively). Low paste pH values ranging from 4.8 to 6.2 for some of the samples are associated with the high organic carbon content of the soil.

Only one soil sample (LX-HL-45) collected near the Grays Bay Port demonstrated a similar signature to the underlying bedrock. Therefore, any disturbance in quarries or road in the vicinity of this sample should be assessed through additional static testwork prior to development. Visual examination of sediments and soil should be undertaken to ensure no visible signs of ARD.

4.4 Potential for Metal Leaching and Mobility

This section summarizes the metals which are elevated in geologic units with ratings of 3 and 4 and which may be mobilized if acidic drainage were to be produced from a quarry site or road section.

Solid-phase metals data are used to identify which metals are enriched in the various waste materials. Establishing the solid phase elemental content of geologic units is an important first step in evaluating the elements that may become problematic in drainage from excavated rock and quarry walls. Although not conclusive, the degree of enrichment of an element over the average continental crustal abundance can be used as a general indicator of the metals of potential concern. Of course, solid-phase elemental concentrations well above crustal abundance do not necessarily indicate that a metal will be elevated in drainage waters. The rate at which a metal (metalloid) leaches is dependent on the mineralogical associations, geochemical stability of the minerals, and aqueous geochemistry of the infiltrating waters. Furthermore, while certain metals leach in response to low pH conditions, such as silver (Ag), cadmium (Cd), lead (Pb) and zinc (Zn); metalloids such as arsenic (As), molybdenum (Mo) and antimony (Sb) can become mobile under neutral pH conditions.

Table 4-5 presents a statistical summary of the solid phase metal concentrations for geological units that received a rating of 4, which includes the argillites and turbiditic

wackes and mudstones. An indicator of significant solid-phase enrichment is assigned arbitrarily in the table to be values that are greater than or equal to three times the average continental crustal abundance. These values are indicated as light grey shaded cells in the tables. The complete aqua regia metal results are provided in Appendix A.2.

**Table 4-5:
Solid Phase Metals in Argillite and Turbiditic Wacke and Mudstone Samples along
Moderate-Low and Higher Risk Sections of Izok Road**

Rock Unit	Ag	As	Bi	Cd	Mo	Pb	S	Sb	Th	Zn
	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
<i>Argillite - Metasediments (rating of 4)</i>										
Aal (n = 9)										
Max	0.16	63	0.47	0.48	2.36	8.2	0.58	0.68	6.9	218
Median	0.06	19	0.07	0.09	1.91	5.2	0.19	0.26	4.7	99
Min	0.01	5	0.02	0.03	0.53	3.1	0.02	0.09	1.9	65
Aam (n = 4)										
Max	0.08	207	0.39	0.23	2.81	8.5	0.44	0.93	6.3	115
Median	0.065	91	0.14	0.05	2.39	4.7	0.15	0.28	3.6	82.5
Min	0.03	60	0.11	0.03	1.08	3.4	0.05	0.14	3.1	32
<i>Turbiditic wacke to mudstone (rating of 4)</i>										
Ath (n = 11)										
Max	0.38	7	1.08	0.08	33	9.6	0.91	0.12	14.9	101
Median	0.05	6	0.22	0.02	1.75	3.4	0.08	0.095	4.9	39
Min	0.01	1	0.03	0.01	0.21	0.8	0.02	0.07	0.5	18
Atl (n = 6)										
Max	0.3	67	0.41	0.79	14.2	64.1	0.33	0.12	7.4	135
Median	0.12	17	0.235	0.22	2.955	25.05	0.105	0.11	6.7	109.5
Min	0.07	2	0.12	0.07	2.09	7.7	0.06	0.08	5.5	59
Atm (n = 15)										
Max	0.16	198	0.47	0.18	3.82	9.8	0.38	ND	8.6	101
Median	0.08	32.5	0.245	0.03	3.1	4.1	0.08	ND	6.7	58
Min	0.02	3	0.14	0.01	1.35	1	0.01	ND	1.2	17
<i>Granitoid (rating of 3)</i>										
Ag (n = 4)										
Max	0.13	ND	0.57	0.05	2.87	11.3	0.03	ND	8.1	84
Median	0.08	ND	0.18	0.04	2.05	6.4	0.03	ND	5.45	38
Min	0.02	ND	0.03	0.03	0.87	1.8	0.03	ND	1.4	25
Average Crustal Abundance	0.075	1.8	0.009	0.15	1.2	14	0.035	0.2	1.2	70

Notes: n = number of samples analyzed; ND = no data; no samples were analyzed for units Ams and Avx for which a rating of 3 was assigned.

Solid phase arsenic (As), bismuth (Bi) and thallium (Tl) are elevated with respect to average crustal abundance in nearly 50% of samples from each of the argillite and turbiditic wacke and mudstone units (Table 4-4). To a lesser extent, Ag, Cd, Mo and Pb are also elevated in the turbiditic samples and Cd, Sb and Zn are also elevated in the argillites. The granitoid unit (Ag) is only elevated in Bi and Th with respect to crustal concentrations.

5. Recommendations



5. Recommendations

The ML/ARD risk assessment for the proposed 339.3 km Izok Road identified 46 sections based on major lithological divides and watershed boundaries. Of the 46 sections, 15 sections (84.7 km, 25%) are moderate-low risk or higher (>100) with potential for ML/ARD issues; 7 sections are variable or uncertain risk (100.2 km, 30%); and 24 sections (154.4 km, 46%) are considered low to no risk.

Moderate-Low and Higher Risk

The greatest lengths of road with moderate-low risk or greater are located in five main sections of road:

- 1) a 10 km section from 48+400 to 58+400 (reference sections 7 and 8),
- 2) a 10 km section from 213+800 to 223+800 (reference section 31),
- 3) a 12.2 km section from 245+200 to 256+400 (reference section 33 and 34),
- 4) a 22.5 km section from 263+600 to 285+000 (reference sections 36 and 37), and
- 5) a 12.4 km section from 324+500 to 336+900 (reference section 41).

These sections are in areas where both quarries and rock cuts will be required and are predominantly located in the northern 40% of the alignment. The other sections are distributed along the road alignment, and include sections 1, 4, 5, 10, 23, 39 and 45.

Further work is recommended for all of these road sections in order to fully assess the level of ML/ARD risk to aquatic ecosystems during and following road construction. In addition, the ML/ARD potential of the quarry locations must be assessed.

Further work should include:

- In several cases, the major watershed is applied as the drainage area, resulting in a low pathway rating. It is important that the drainage area, and overall dilution potential, for certain sections of the road be delineated with greater certainty where major development is proposed within geologic units with ratings of 3 or 4.
- Characterization of the streams where no fisheries data is available. Further work for sites for which there is no data and the most conservative ratings have been applied may reduce the receptor rating, and the overall risk, if it is determined that the streams in this area are not fish-bearing and/or do not have permanent flow. This may reduce the overall risk in some sections to less than 100 and decrease the area of further sampling along the proposed road.

- Collecting additional bedrock samples from along the sections indicated to be moderate-low or higher risk. In areas where there will be rock cut, the ideal sampling method would be by drilling, in order to fully characterize the weathering at different depths and to obtain “fresh” rock samples. The number of samples collected should be based on the excavated volume of material, as per the MEND (2009) guidelines. The samples should be collected under the supervision of a geologist and submitted for total sulphur analysis.

In the event that further testing determines that certain areas are potentially acid producing, there are several possible mitigation measures that may be employed to minimize the development of ML/ARD along the proposed road alignment. Ideally, material with high acid generating potential will be avoided during road construction, in favour of selecting an alignment and construction materials that have a low acid generating potential. In cases where this is not possible, the PAG material will require re-handling for placement away from important aquatic ecosystems. It is recommended that a knowledgeable expert be consulted at that time to develop a suitable mitigation strategy.

ML/ARD monitoring should continue during the construction phase for any areas which are determined to be potentially acid generating. This should include additional sampling and static testing of geotechnical drill core or blasted rock from these sections of road. Prior to receiving the test results, any material which may have acid generating potential should be placed in a location away from streams, to minimize impact to aquatic ecosystems. The results of this secondary testing will determine how the material must ultimately be handled.

Variable/Uncertain Risk

The greatest lengths of road with a variable or uncertain risk include:

- a 26.2 km section from 15+400 to 42+400 (reference 3),
- a 18.8 km section from 58+400 to 77+200 (reference 9), and
- a 35.9 km road section from 285+000 to 320+900 (reference 38).

Other sections with a variable or uncertain risk include section 29, 32, 35 and 44. In general, these sections comprise either a mix of low and moderate risk geology and/or the geology is complex and requires careful delineation by a site geologist prior to and during development. Each of these sections comprises low risk portions from which material can be drawn. It is recommended that an additional static test sample be collected under the supervision of a geologist and that the sample be analyzed for total sulphur to confirm the risk rating prior to development.

Low Risk

Due to the low density of samples (206 samples along the 339.3 km road) and the inherent range in total sulphur values for many of the geologic units, it is recommended that for each quarry and rock cut site with a geologic rating of 2, a sample be collected within 500 m of the proposed site prior to development. It is recommended that the sample be collected under the supervision of a geologist and that the sample be analyzed for total sulphur to confirm the risk rating prior to development.

All quarries and rock cuts with a rating of 1 are considered low risk and available for development. No further work is required for these sites.

Visual examination of sediments and soil should be undertaken to ensure no visible signs of ARD. Any disturbance in quarries or road in the vicinity of soil sample LX-HL-45 near Grays Bay Port should be assessed through additional static test work prior to development. For surficial material samples, sampling from below the organic layer would be sufficient.

6. Closure



6. Closure

We trust that this report meets your present requirements. Please contact us should you have any questions.

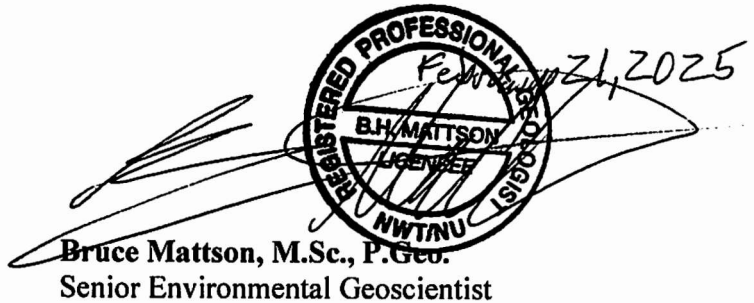
Yours sincerely,

LORAX ENVIRONMENTAL SERVICES LTD.


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PERMIT TO PRACTICE	
LORAX ENVIRONMENTAL SERVICES LTD.	
Signature	
Date	<u>February 21, 2025</u>
PERMIT NUMBER: P 1487	
NT/NU Association of Professional Engineers and Geoscientists	

References



References

- AMEC (2009) Identification and Mitigation of Acid Rock Drainage and Metal Leaching During Construction, Enbridge Northern Gateway Project. Submitted to Northern Gateway Pipelines Inc. by AMEC Earth & Environmental, October 2009, revised February 16, 2010.
- BGC (2012) Documents provided by BGC to Lorax concerning the “Revision A” road alignment and observations made at stream crossings.
- Edumine (n.d.) Average Specific Gravity of Various Rock Types from Edumine – Professional Development and Training for Mining and the Geosciences. <<http://www.edumine.com/xtoolkit/tables/satables.htm>>
- Canadian Council of Ministers of the Environment (CCME) (1996) A Framework for Ecological Risk Assessment: General Guidance. Canadian Council of Ministers of the Environment (CCME) and the National Contaminated Sites Remediation Program.
- Department of Fisheries and Oceans Canada (DFO) (n.d.) Practitioners Guide to the Risk Management Framework for DFO Habitat Management Staff, Version 1.0. Prepared by the Department of Fisheries and Oceans Canada.
- GeoBase (2012) National Hydrometric mapping <<http://www.geobase.ca/geobase/en/data/nhn/index.html>>
- Gusek, J., H. Moore, V. Bateman, J. Ozment, L. Oliver, D. Kathman, J. Waples, T. Rutkowski, W. Bowden and A. Reither (2008) A New Guidance Document for Mitigating Impacts from Acid-Producing Rock Formations in Tennessee Road Construction Projects. For presentation at the 59th Highway Geology Symposium, May 6-9, 2008.
- MMG (2012) Izok Corridor Project – Project Proposal Volume 1. Submitted by MMG (Minerals and Metals Group), August 2012.
- Ministry of Energy and Mines (MEM) & Ministry of Environment, Lands and Parks (MOE) (1998) Policy for Metal Leaching and Acid Rock Drainage at Minesites in British Columbia. July 1998.
- Mine Environment Neutral Drainage (MEND) (2009) Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials, MEND Report 1.20.1. Prepared for MEND Program. Prepared by William A. Price, CANMET – Mining and Mineral Sciences Laboratories, December 2009.

- MOT (2004) ARD Testing at Quarry and Rock Cut Sites – Technical Circular T-10/04. Prepared by the BC Ministry of Transportation and Infrastructure, November 4, 2004.
- Northwest Hydraulic Consultants (2012) Memorandum Re: Izok Lake Corridor Project – Annual Precipitation for Hydrotechnical Design DRAFT, December 10, 2012.
- NWT (2012) Northwest Territories Geoscience Office <<http://www.nwtgeoscience.ca/>>
- RC BioSolutions Ltd. (2012) Izok Corridor – Fisheries Field Report for the Road Corridor and High Lake Mine Site for 2012. Submitted to Minerals and Metals Group (MMG) November 23, 2012
- Pollard, S.J., D.O. Harrop, P. Crowcroft, S.H. Mallett, S.R. Jeffries and P.J. Young (1995) Risk Assessment for Environmental Management: Approaches and Applications. Water and Environment Journal, Vol 9 (6), 621-628.
- Price, W.A. and J.C. Errington (1998) Guidelines for Metal Leaching and Acid Rock Drainage at Minesites in British Columbia. Prepared for Ministry of Energy and Mines, August 1998.
- Stubley, MP (2005) Slave Craton: Interpretive Bedrock Compilation NWT-NU; Northwest Territories Geosciences Office, NWT-NU Open File No. 2005-01, Retrieved Nov. 30, 2012, from http://ntgomap.nwtgeoscience.ca/reference_details_export.jsp?referenceID=11963
- Yu, C., C. Loureiro, J.-J. Cheng, L.G. Jones, Y.Y. Wang, Y.P. Chia and E. Faillace (1993) Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil. Prepared for U.S. Department of Energy Assistant Secretary for Environment, Safety and Health, Office of Environmental Guidance, Assistant Secretary for Environmental Restoration and Waste Management, Office of Environmental Restoration.

***Appendix A:
Geochemical Sampling
and Results***

