ANNEX 1-D

EROSION POTENTIAL ASSESSMENT
OF
NORTHERN ONTARIO WATERPOWER SITES
FOR
XENECA POWER DEVELOPMENT INC.

Report

ORTECH Environmental
a division of ORTECH Consulting Inc.

EROSION POTENTIAL ASSESSMENT OF NORTHERN ONTARIO WATERPOWER SITES FOR XENECA POWER DEVELOPMENT INC.

A Report to:	Xeneca Power Development Inc. 5160 Yonge Street, Suite 520 Toronto, Ontario M2N 6L9
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Date:	June 2011

Xeneca Power Development Inc.

May 2011

ACKNOWLEDGEMENT

This Erosion Potential Assessment of Northern Ontario Waterpower Sites was prepared under the direction of Xeneca Power Development Inc. (Xeneca Power). Xeneca Power acknowledges the assistance and input from ORTECH Consulting Inc. (ORTECH), R.J. Burnside and AquaLogic Consulting.

AUTHENTICATION

This Erosion Potential Assessment document was prepared under the direction of Xeneca Power.

The main participants in the assessment were:

NAME	POSITION	RESPONSIBILITIES
Xeneca Power Development Inc.		
Nava Pokharel	Senior Project Manager	Project Management and Coordination
ORTECH Consulting Inc.		
Scott Manser	Senior Project Manager	Overall development and report summary.
R.J. Burnside		
Dan Miller, P.Eng. Tim Lozon	Project Manager, Senior Water Resources Engineer Water Resources Engineer	Preparation of HEC RAS related modelling, figures and tables.
AquaLogic		
Bill de Geus., CET, CPESC, EP	Project Manager	Development of erosion potential methodology and detailed report.

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Introduction

Background

Xeneca Power Development Inc. (Xeneca) is developing eighteen Waterpower Renewable energy Projects in Northern Ontario under contracts from the Ontario Feet in Tariff (FIT) program, regulated by the Ontario Power Authority (OPA). As part of the requirements of the FIT contract Xeneca is working towards the completion of the required Class Environmental Assessments (Class EA) for these projects. Xeneca contracted ORTECH Consulting Inc. (ORTECH) to conduct a desktop screening level assessment of the erosion potential for all eighteen projects in support of the overall Class EA process.

A screening level assessment tool was developed to compare conditions under different water depth scenarios, channel bank angle, channel velocity range and substrate type using available GIS, and topographic data.

Project Description

The waterpower projects are primarily run-of-river (ROR) type projects with varying storage capacity to allow for some degree of daily or weekly peaking operation. These projects are therefore referred to as "modified run-of-river" generating facilities having dominant properties of ROR projects with short term or limited peaking capabilities.

With "modified run-of-river" operations, a facility would operate at the same rate as the natural flow in the river (i.e. "run-of-river") with no variation in upstream water levels due to operation and no man-made variation in downstream flows from those experienced naturally. At other times, a facility would "modify" the natural flow in the river by storing some of the natural river flow during night time and/or weekend hours to be used during daytime hours (i.e. on business days from 11 am to 7 pm) when the need for electricity in the Province is greater.

Run-of-river operation would occur during two (2) types of natural flow conditions:

1) When natural river flows are greater than the maximum turbine capacity (Q_{Tmax}): Since the natural flow exceeds the amount of water that can be processed through the turbine, any excess water is bypassed through the spillway structure. The combined flow of the water used in the turbine to generate electricity and the water bypassed over the spillway equals the natural flow. This situation occurs primarily during spring thaw run-off conditions and during major storm events in the spring, summer and fall.

2) When natural flows are so low that any available water must be released to protect the downstream environment: The flow in this situation is typically too low to generate electricity. This situation occurs primarily in late summer and late winter when natural flows are typically very low. This situation may also occur during certain years when spring run-off flow is unusually low and the amount of water available is needed downstream.

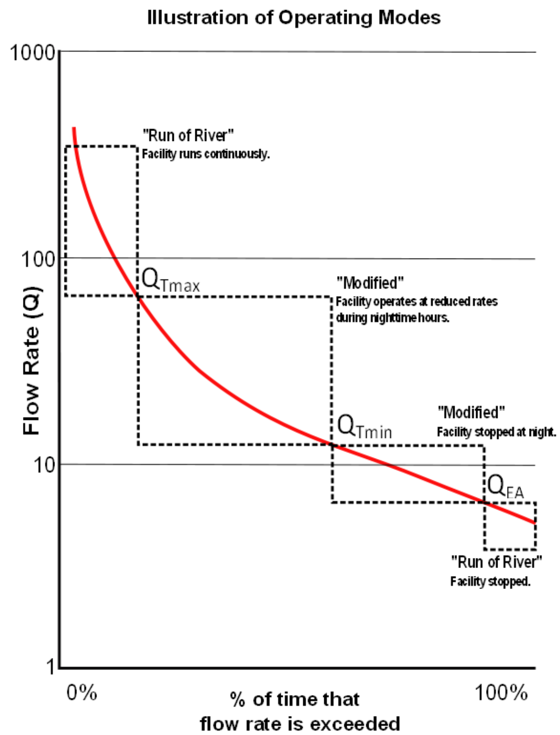
Modified run-of-river operation would occur during moderate and low flows when the natural flow in the river is below the maximum turbine flow capacity (Q_{Tmax}) but above the minimum flow required to protect the environment (Q_{EA}). During these flow conditions, some of the natural river flow during nighttime and/or weekend hours can be stored and used to produce electricity during daytime hours. There are two modes of modified operation as follows:

1) Facility runs at reduced rate at night: When natural river flows are moderate (i.e. between the minimum (Q_{Tmin}) and the maximum (Q_{Tmax}) rate of turbine capacity), the facility runs continuously, but some of the water is saved during nighttime and/or weekend hours. This operation results in downstream flows that are smaller than natural river flows during nighttime and/or weekend hours and larger than natural river flows during daytime hours when electricity use is higher. However, the minimum flow in this mode of operation is not less than the minimum turbine capacity (Q_{Tmin}).

2) Facility is stopped at night: When natural river flows are low (i.e. below the minimum turbine capacity (Q_{Tmin})), the facility will need to stop operation during some nighttime hours and save water until operation is again possible. The lower the natural river flow, the longer the period of stoppage will be. When the facility operates, it operates at a rate less than maximum turbine capacity (Q_{Tmax}). To ensure that the downstream river reach receives enough water flow to protect the environment (Q_{EA}), the appropriate amount of water is released through a bypass while the turbine operation is stopped.

Figure 1 below illustrates the mode of operation that occurs depending on the amount of natural flow in the river.

Figure 1: Mode of Operation



Note: Figure is for illustrative purposes only

An important factor in modified run-of-river operation is the availability of storage upstream of the facility. As described in the project description section of the environmental assessments, the amount of storage created as part of each project is very limited. To achieve the objective of building a project with limited environmental impact, the conceptual design of the facility limits the height of structure, the depth and the area of inundation upstream. Consequently, the amount of storage available for operation is inherently limited in relation the natural flow in the river, thereby limiting the storage to a few hours during moderate and low flows. The ability to use this storage is further constrained by environmental constraints outlined in other parts the environmental assessment document. It is the limited storage that differentiates modified run-of-river projects from hydroelectric projects that create large storage reservoirs with the ability to store water for weeks or seasons to “peak” when seasonal periods of hot or cold spells raise the need for extra electricity production. Typically, modified run-of-river projects have significantly less environmental impact than peaking hydroelectric projects.

For the purpose of these projects the range of headpond elevations is represented by the upstream normal operating level (U/S N.O.L.) and the N.O.L. minus 1 m. A summary of additional project features for the eighteen project sites is provided in Table 1 below.

Table 1: Key Project Features

	Project Name	**Installed Capacity @ FIT**	**Design Flow (Qd)**	**U/S N.O.L.**	**Tailwater Level**	**Project Type**
		(MW)	**(m^3/s)**	**(m)**	**(m)**	
1	Big Eddy	5.3	68	136	127	ROR
2	Half Mile Rapids	4.8	52	155	144.5	MROR
3	Marter Twp	2.1	16	196	183.5	MROR
4	Larder & Raven (Option 1)	1.25	7	286	268	Lake (MROR)
5	Allen and Struthers	2.8	57	187.5	182	MROR
6	Wabageshik Rapid	3.4	64	205	199	Lake (MROR)
7	At Soo Crossing	4.3	50	238	231.5	MROR
8	Cascade Fall	2.1	49	248.5	242	MROR
9	McPherson Fall	2	49	254	248.5	MROR
10	Four Slide Falls	7.3	23	284	255	MROR
11	McCarthy Chute	2	35.6	250	243	Lake (MROR)
12	Wanatango	4.67	50	259	250	MROR
13	The Chute	3.6	38	298	288.5	MROR
14	Ivanhoe: Third Falls (out side conservation area)	5.1	46	287	278	MROR
15	Lapinigam Rapids (Buchan Falls) - Option 1	8.2	49	294.5	274.5	MROR
16	Outlet Kapuskasing	2.5	48	312	305.5	Lake (MROR)
17	Middle Twp Buchan (Clouston Rapids)	5	50	274	260.5	MROR
18	Near North Boundary (Cedar Rapids)	3.75	60	259	250	MROR

Note:

ROR= Run of River
MROR= Modified Run of River
Lake (MROR)= Modified Run of River with Lake

Screening Level Methodology

The erosion potential screening assessment relies on a series of matrices covering a wide range of channel conditions and substrate combinations that represent the range of combinations at the eighteen waterpower sites. Substrate combinations are summarized in Table 2 with bolded values representing the dominant substrate type.

Table 2: Substrate Combinations

Scenario #	% Substrate Composition			
	Bedrock / Boulder / Cobble	**Gravel**	**Sand**	**Silt clay**
1	**100**			
2		**100**		
3			**100**	
4				**100**
5	**75**	8.3	8.3	8.3
6	8.3	**75**	8.3	8.3
7	8.3	8.3	**75**	8.3
8	8.3	8.3	8.3	**75**
9	**50**	16.6	16.6	16.6
10	16.6	**50**	16.6	16.6
11	16.6	16.6	**50**	16.6
12	16.6	16.6	16.6	**50**
13	**25**	**25**	**25**	**25**
14	**50**	**50**		
15		**50**	**50**	
16			**50**	**50**

Each substrate combination was modeled using hydraulic geometry and vegetative protection relationships indexed to rating scores, normalized on a 0 to 10 scale, as established in the bank erosion hazard index (BEHI) method. The overall rating represents conditions ranging from very low (0 – 1.9) to extreme (> 9.0) erosion potential based on how the noted physical and mechanical variables work together to provide natural erosion resistance and dynamic channel stability (AquaLogic, 2011).

The ranges of parameters considered in the assessment are provided in Table 3.

Table 3: Erosion Potential Data Inputs

Parameter	Value
Bank Height	equal to flow depth
Flow Depth	0.5 m - 6 m
Rooting Depth	2 m
Rooting Density	50%
Bank Angle	15 - 55 degrees
Vegetative Bank Face Protection	50%

A detailed analysis of a 40 km section of the Kapuskasing River was conducted and the range of conditions observed along this project was used to represent typical average site conditions. Rooting depth was assumed as an average of 2m, and rooting density and bank face protection as 50%, reflecting the range of scrub to treed conditions in shallow to medium depth soils for Boreal Forest on the Canadian Shield.

Bank angles representing conditions steeper than typical stable slope equilibrium and higher than 2m, under the noted average vegetative cover conditions, were excluded from analysis because they are considered erosion prone and unstable under all flow scenarios.

Applying the Screening Methodology

Erosion potential scenarios were assessed for each substrate type combination shown in Table 1 with incremental flow depth and bank angles applicable over a range of channel velocities. The resultant index scores are provided in Attachment 1. For each substrate combination velocities below the matrix value would represent "very low" erosion potential whereas velocities above the upper range of values provided would be deemed to trigger sustained erosion potential (AquaLogic, 2011).

Additionally, site areas that are relatively void of significant vegetation should be identified and referenced to the Hjulstrom Curve relationship for velocity as provided in Attachment 2. The Hjulstrom curve relationship is used by hydrologists to determine whether a river system will erode, transport or deposit particles of a given size at a specified channel velocity. This methodology agrees with the MNR guideline approach of identifying the point of incipient erosion as the threshold of channel stability (OMNR, 2002) for channel banks generally less than 2 m high.

The following steps were used in developing the erosion potential assessment for each project site:

1) A slope analysis map was produced for each project site based upon topographic information in the form of 0.5 m LIDAR contour data;
2) Slopes were categorized in ten degree intervals corresponding to the erosion sensitivity scoring system (15 to 55) degrees;
3) Surificial geology mapping was overlaid onto the slope analysis map;
4) Surfical geology for each project site was placed into one of the sixteen categories used in the erosion sensitivity scoring index as provided in Attachment 1, and
5) Areas deemed as having the potential for "moderate" erosion potential or areas requiring additional analysis were identified by blue circles.

Based upon the above approach the following project sites may have areas adjacent to the waterbody requiring additional analysis or "moderate" erosion potential:

- Big Eddy
- Half Mile Rapids
- Lapinigam Rapids

- Near North boundary

Erosion potential mapping for all project sites is provided in Attachment 3.

Conclusions

Erosion potential scenarios were assessed for each substrate type combination shown in Table 1 with incremental flow depth and bank angles. The resultant index scores are provided in Attachment 1. Modelling results indicate that:

- Good channel stability is generally found under all conditions for bedrock/boulder/cobble scenarios, as typical of most watercourses;
- Good stability conditions in aggregate and soil substrates is generally due to the positive influence of vegetative cover supplying additional reinforcement;
- Silt clay conditions are considered to have lower sensitivity to erosion than sand and gravel conditions which is an inherent result of cohesive properties;
- Any shift in velocity to above the identified stability range from one flow scenario to another would require a more detailed analysis;
- For flow depths of 1 m or less, which are proposed under the site operating plans, 100% sand and 75% sand + 25% "mixed" substrates have a potential for "moderate" erosion impacts under specific bank angle and flow velocity conditions, and
- All other substrate combinations, within the prescribed velocity ranges, for flow depths of 1 m or less are predicted to have either "low" or "very low" erosion potentials when bank angles are 45 degrees or less.

Comparative flow depth scenarios (existing and proposed) are possible using the screening methodology. This is typical of dynamic integrated stability under existing conditions representing decades and/or centuries of long term natural cycles and processes acting on a watercourse. Any identified shift from "very low" to "low" or from "low" to "moderate", under a manmade change in flow depth could be generally reflective of an equivalent natural peak flow event that the system is already adjusted to (AquaLogic, 2011).

The methodology presented in this report is a desk top screening level review tool so the assessment is by no means an exhaustive review of all physical, temporal and unknown factors.

References:

deGeus, B., 2011 Erosion Sensitivity Analysis Kapuskasing River Hydroelectric Candidate Sties Xeneca Power Development. AquaLogic Consulting

Ontario Ministry of Natural Resources. 2002. Natural Hazards Technical Guides; River and Steam Systems Erosion Hazard Limit Technical Guide.

Attachment 1

Erosion Sensitivity Scores

very low 0-1.9 | low 2.0-3.9 | moderate 4.0-5.9 | high 6.0-7.9 | very high 8.0-9.0 | extreme 10

100% Bedrock/Boulder/Cobble
velocity ranges - cobble = 1.5-2.5m s^{-1}, boulder = 2.5-3.5m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	1.46	1.68	1.78	1.88	1.97*
4.5	1.46	1.68	1.78	1.88	1.97*
4	1.05	1.28	1.38	1.47	1.58*
3.5	1.05	1.28	1.38	1.47	1.58*
3	1.05	1.28	1.38	1.47	1.58*
2.5	1.05	1.28	1.38	1.47	1.58*
2	0.65	0.87	0.97	1.07	1.16
1.5	0.65	0.87	0.97	1.07	1.16
1	0.65	0.87	0.97	1.07	1.16
0.5	0.65	0.87	0.97	1.07	1.16

*bedrock only

100% Gravel
velocity range = 1.1-1.5m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	4.21	4.43	4.53	4.63	n.a.
4.5	4.21	4.43	4.53	4.63	n.a.
4	3.81	4.03	4.13	4.23	n.a.
3.5	3.81	4.03	4.13	4.23	n.a.
3	3.81	4.03	4.13	4.23	n.a.
2.5	3.81	4.03	4.13	4.23	n.a.
2	3.40	3.62	3.72	3.82	n.a.
1.5	3.40	3.62	3.72	3.82	n.a.
1	3.40	3.62	3.72	3.82	n.a.
0.5	3.40	3.62	3.72	3.82	n.a.

100% Sand
velocity range = 0.5-1.1m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	4.46	4.69	4.78	n.a.	n.a.
4.5	4.46	4.69	4.78	n.a.	n.a.
4	4.06	4.28	4.38	n.a.	n.a.
3.5	4.06	4.28	4.38	n.a.	n.a.
3	4.06	4.28	4.38	n.a.	n.a.
2.5	4.06	4.28	4.38	n.a.	n.a.
2	3.65	3.87	3.97	4.07	n.a.
1.5	3.65	3.87	3.97	4.07	n.a.
1	3.65	3.87	3.97	4.07	n.a.
0.5	3.65	3.87	3.97	4.07	n.a.

100% Silt Clay
velocity range = 0.9-1.5m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	3.46	3.69	3.78	3.88	n.a.
4.5	3.46	3.69	3.78	3.88	n.a.
4	3.06	3.28	3.38	3.48	n.a.
3.5	3.06	3.28	3.38	3.48	n.a.
3	3.06	3.28	3.38	3.48	n.a.
2.5	3.06	3.28	3.38	3.48	n.a.
2	2.65	2.87	2.97	3.07	3.16
1.5	2.65	2.87	2.97	3.07	3.16
1	2.65	2.87	2.97	3.07	3.16
0.5	2.65	2.87	2.97	3.07	3.16

75% Bedrock/Boulder/Cobble + 25% Mixed
velocity ranges - cobble = 1.5-2.5m s^{-1}, boulder = 2.5-3.5m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	1.96	2.19	2.28	2.38	2.48*
4.5	1.96	2.19	2.28	2.38	2.48*
4	1.56	1.78	1.88	1.98	2.07*
3.5	1.56	1.78	1.88	1.98	2.07*
3	1.56	1.78	1.88	1.98	2.07*
2.5	1.56	1.78	1.88	1.98	2.07*
2	1.15	1.37	1.47	1.57	1.66
1.5	1.15	1.37	1.47	1.57	1.66
1	1.15	1.37	1.47	1.57	1.66
0.5	1.15	1.37	1.47	1.57	1.66

75% Gravel + 25% Mixed
velocity range = 1.1-1.5m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	4.21	4.43	4.53	4.63	n.a.
4.5	4.21	4.43	4.53	4.63	n.a.
4	3.81	4.03	4.13	4.23	n.a.
3.5	3.81	4.03	4.13	4.23	n.a.
3	3.81	4.03	4.13	4.23	n.a.
2.5	3.81	4.03	4.13	4.23	n.a.
2	3.40	3.62	3.72	3.82	n.a.
1.5	3.40	3.62	3.72	3.82	n.a.
1	3.40	3.62	3.72	3.82	n.a.
0.5	3.40	3.62	3.72	3.82	n.a.

75% Sand + 25% Mixed
velocity range = 0.5-1.1m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	4.46	4.69	4.78	n.a.	n.a.
4.5	4.46	4.69	4.78	n.a.	n.a.
4	4.06	4.28	4.38	n.a.	n.a.
3.5	4.06	4.28	4.38	n.a.	n.a.
3	4.06	4.28	4.38	n.a.	n.a.
2.5	4.06	4.28	4.38	n.a.	n.a.
2	3.65	3.87	3.97	4.07	n.a.
1.5	3.65	3.87	3.97	4.07	n.a.
1	3.65	3.87	3.97	4.07	n.a.
0.5	3.65	3.87	3.97	4.07	n.a.

75% Silt Clay + 25% Mixed
velocity range = 0.9-1.5m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	3.30	3.52	3.62	3.72	n.a.
4.5	3.30	3.52	3.62	3.72	n.a.
4	2.89	3.11	3.22	3.31	n.a.
3.5	2.89	3.11	3.22	3.31	n.a.
3	2.89	3.11	3.22	3.31	n.a.
2.5	2.89	3.11	3.22	3.31	n.a.
2	2.49	2.71	2.81	2.91	3.00
1.5	2.49	2.71	2.81	2.91	3.00
1	2.49	2.71	2.81	2.91	3.00
0.5	2.49	2.71	2.81	2.91	3.00

Prepared by: AquaLogic, 2011

very low 0-1.9 | low 2.0-3.9 | moderate 4.0-5.9 | high 6.0-7.9 | very high 8.0-9.0 | extreme 10

50% Bedrock/Boulder/Cobble + 50% Mixed
velocity ranges - cobble = 1.4-1.8m s^{-1}, boulder = 1.8-2.5m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	2.46	2.68	2.78	2.88	n.a.
4.5	2.46	2.68	2.78	2.88	n.a.
4	2.06	2.28	2.38	2.48	n.a.
3.5	2.06	2.28	2.38	2.48	n.a.
3	2.06	2.28	2.38	2.48	n.a.
2.5	2.06	2.28	2.38	2.48	n.a.
2	1.65	1.87	1.97	2.07	2.16
1.5	1.65	1.87	1.97	2.07	2.16
1	1.65	1.87	1.97	2.07	2.16
0.5	1.65	1.87	1.97	2.07	2.16

50% Gravel + 50% Mixed
velocity range = 1.3-1.7m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	3.46	3.68	3.78	3.88	n.a.
4.5	3.46	3.68	3.78	3.88	n.a.
4	3.06	3.28	3.38	3.48	n.a.
3.5	3.06	3.28	3.38	3.48	n.a.
3	3.06	3.28	3.38	3.48	n.a.
2.5	3.06	3.28	3.38	3.48	n.a.
2	2.65	2.87	2.97	3.07	n.a.
1.5	2.65	2.87	2.97	3.07	n.a.
1	2.65	2.87	2.97	3.07	n.a.
0.5	2.65	2.87	2.97	3.07	n.a.

50% Sand + 50% Mixed
velocity range = 0.7-1.2m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	3.46	3.68	3.78	n.a.	n.a.
4.5	3.46	3.68	3.78	n.a.	n.a.
4	3.06	3.28	3.38	n.a.	n.a.
3.5	3.06	3.28	3.38	n.a.	n.a.
3	3.06	3.28	3.38	n.a.	n.a.
2.5	3.06	3.28	3.38	n.a.	n.a.
2	2.65	2.87	2.97	3.07	n.a.
1.5	2.65	2.87	2.97	3.07	n.a.
1	2.65	2.87	2.97	3.07	n.a.
0.5	2.65	2.87	2.97	3.07	n.a.

50% Silt Clay + 50% Mixed
velocity range = 0.9-1.5m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	3.14	3.36	3.46	3.56	n.a.
4.5	3.14	3.36	3.46	3.56	n.a.
4	2.74	2.96	3.06	3.16	n.a.
3.5	2.74	2.96	3.06	3.16	n.a.
3	2.74	2.96	3.06	3.16	n.a.
2.5	2.74	2.96	3.06	3.16	n.a.
2	2.33	2.55	2.65	2.75	2.84
1.5	2.33	2.55	2.65	2.75	2.84
1	2.33	2.55	2.65	2.75	2.84
0.5	2.33	2.55	2.65	2.75	2.84

25% Each Type
velocity range = 1.3-1.7m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	2.96	3.18	3.28	n.a.	n.a.
4.5	2.96	3.18	3.28	n.a.	n.a.
4	2.56	2.78	2.88	n.a.	n.a.
3.5	2.56	2.78	2.88	n.a.	n.a.
3	2.56	2.78	2.88	n.a.	n.a.
2.5	2.56	2.78	2.88	n.a.	n.a.
2	2.15	2.37	2.47	2.57	n.a.
1.5	2.15	2.37	2.47	2.57	n.a.
1	2.15	2.37	2.47	2.57	n.a.
0.5	2.15	2.37	2.47	2.57	n.a.

50% Bedrock/Boulder/Cobble + 50% Gravel
velocity range = 1.5-2.0m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	2.46	2.68	2.78	2.88	n.a.
4.5	2.46	2.68	2.78	2.88	n.a.
4	2.06	2.28	2.38	2.48	n.a.
3.5	2.06	2.28	2.38	2.48	n.a.
3	2.06	2.28	2.38	2.48	n.a.
2.5	2.06	2.28	2.38	2.48	n.a.
2	1.65	1.87	1.97	2.07	2.16
1.5	1.65	1.87	1.97	2.07	2.16
1	1.65	1.87	1.97	2.07	2.16
0.5	1.65	1.87	1.97	2.07	2.16

50% Gravel + 50% Sand
velocity range = 0.9-1.2m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	3.46	3.68	3.78	n.a.	n.a.
4.5	3.46	3.68	3.78	n.a.	n.a.
4	3.06	3.28	3.38	n.a.	n.a.
3.5	3.06	3.28	3.38	n.a.	n.a.
3	3.06	3.28	3.38	n.a.	n.a.
2.5	3.06	3.28	3.38	n.a.	n.a.
2	2.65	2.87	2.97	3.07	n.a.
1.5	2.65	2.87	2.97	3.07	n.a.
1	2.65	2.87	2.97	3.07	n.a.
0.5	2.65	2.87	2.97	3.07	n.a.

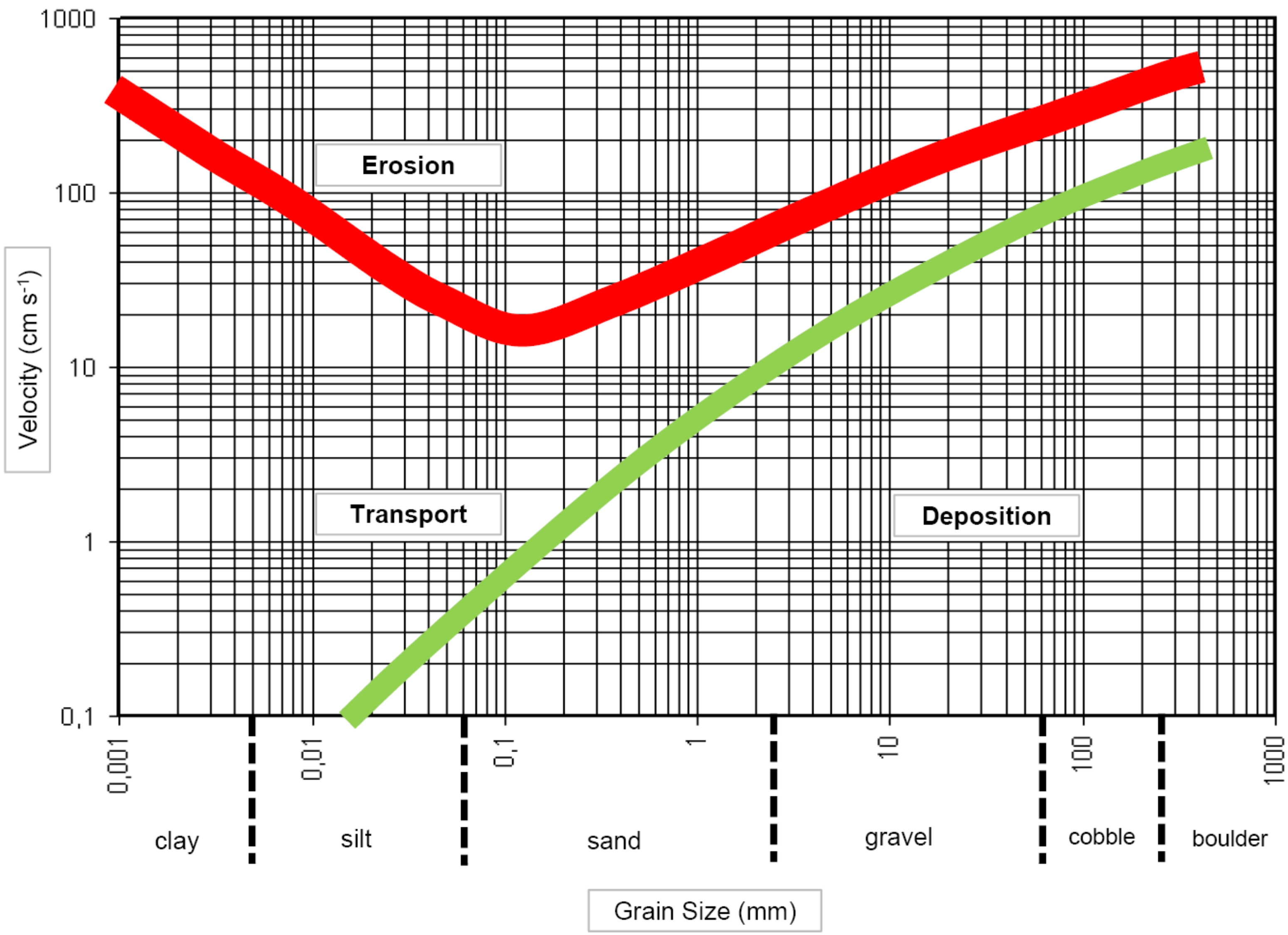
50% Sand + 50% Silt Clay
velocity range = 0.7-1.2m s^{-1}

flow depth (m) \ bank angle (°)	15	25	35	45	55
5-6	3.46	3.68	3.78	3.88	n.a.
4.5	3.46	3.68	3.78	3.88	n.a.
4	3.06	3.28	3.38	3.48	n.a.
3.5	3.06	3.28	3.38	3.48	n.a.
3	3.06	3.28	3.38	3.48	n.a.
2.5	3.06	3.28	3.38	3.48	n.a.
2	2.65	2.87	2.97	3.07	3.16
1.5	2.65	2.87	2.97	3.07	3.16
1	2.65	2.87	2.97	3.07	3.16
0.5	2.65	2.87	2.97	3.07	3.16

Prepared by: AquaLogic, 2011

Attachment 2

Erosion Sensitivity – Hjulstrom Curve


1000
100
10
1
0,1
Velocity (cm s-1)
Erosion
Transport
Deposition
0,001
0,01
0,1
1
10
100
1000
clay
silt
sand
gravel
cobble
boulder
Grain Size (mm)

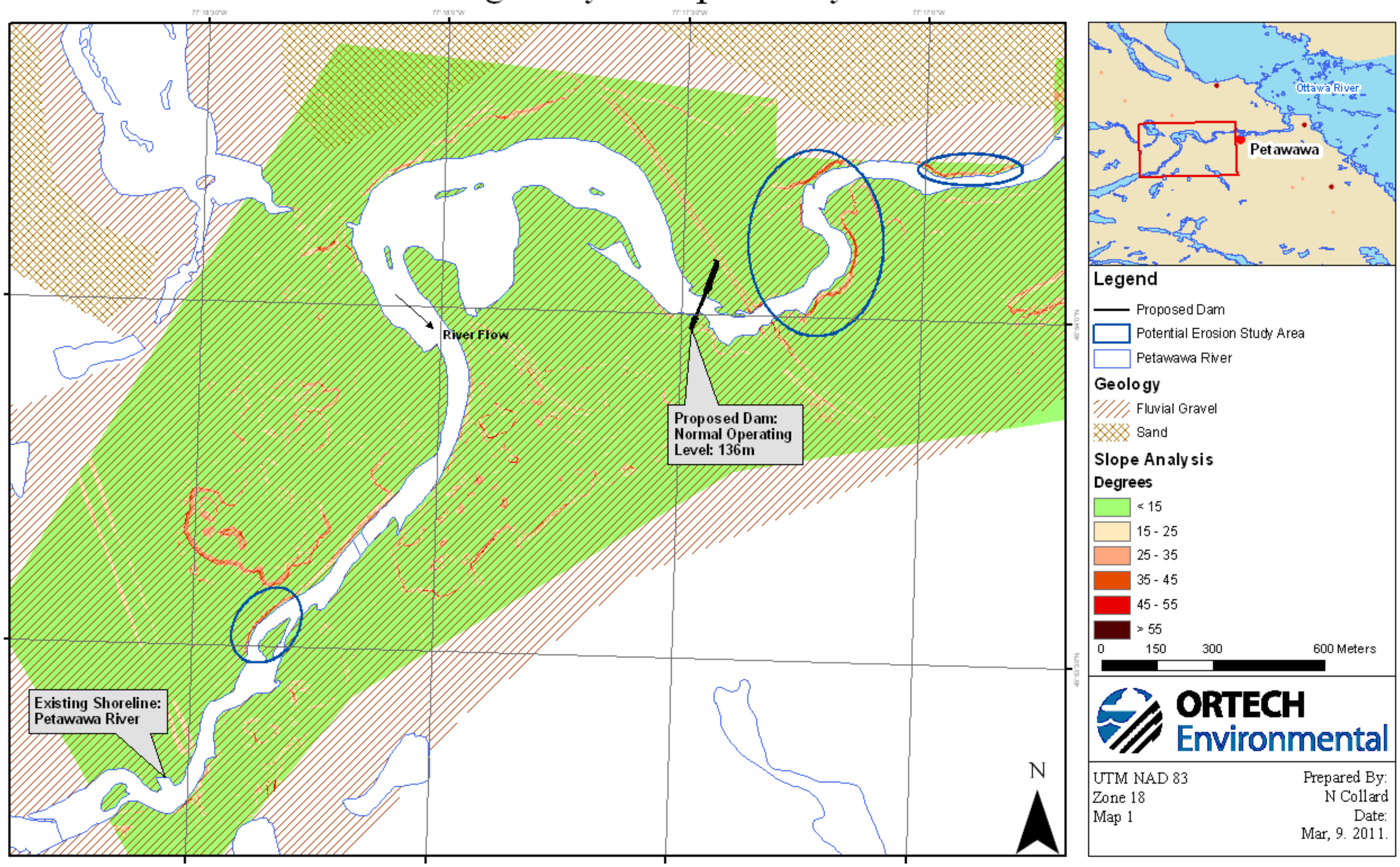
Attachment 3

Erosion Potential Mapping

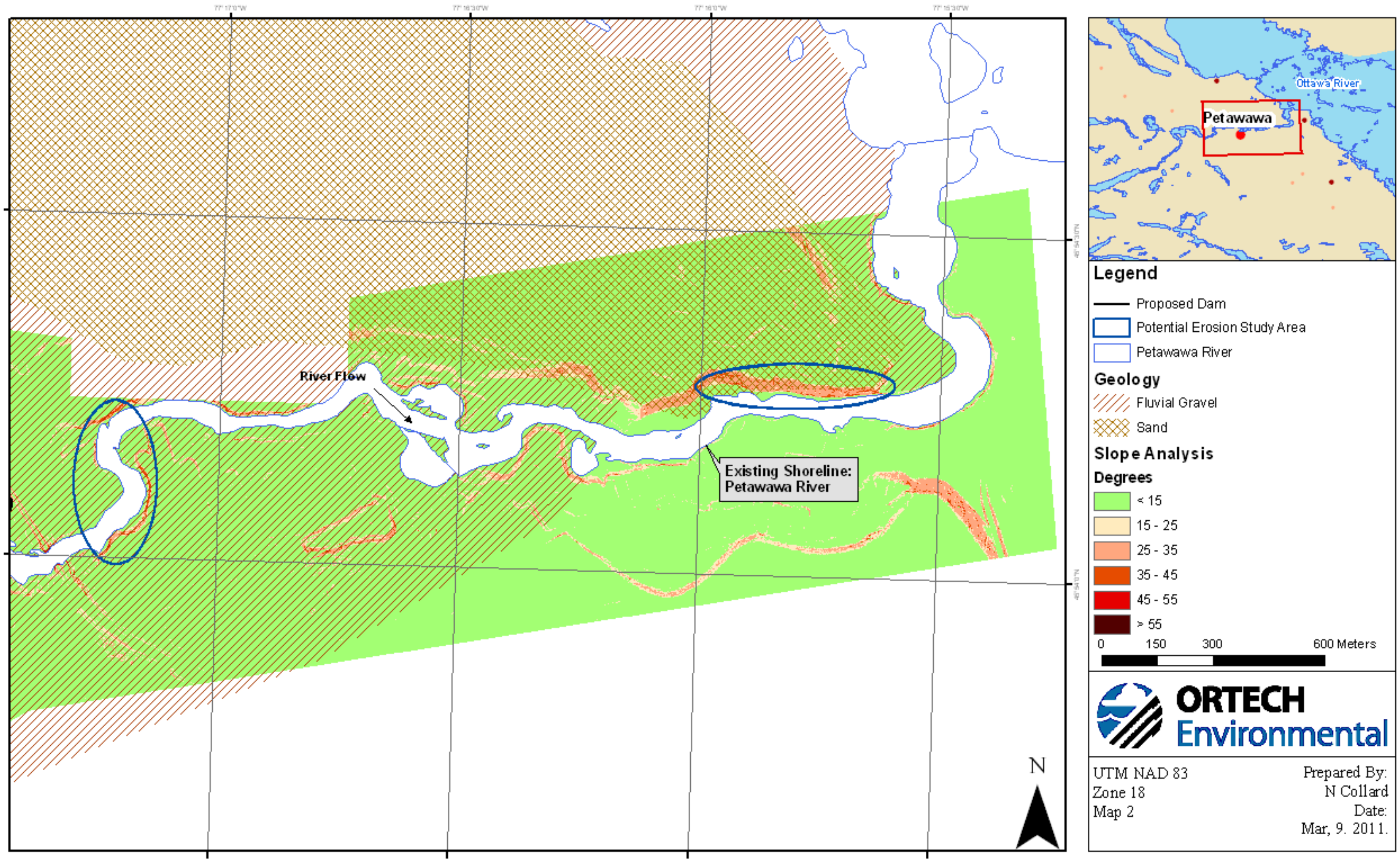
Table A3: Project Site Surficial Geology and Erosion Potential

Geological Formation	Substrate Category	Upper Velocity Range (m/s)	Project Site #	Erosion Sensitivity at Flow Depth of 1m: Very Low	Low	Moderate	Additional Analysis Required
Fluvial Gravel	2, 6	1.5	1, 2		<45		**>45**
Sand	3	1.1	1, 2		<25	**25 - 45**	**>45**
Bedrock	1	2.5	2, 13	<55			
Bog Deposits	7	1.1	2		<25	**25-45**	**>45**
Glacial Gravel	2, 6	1.5	2		<45		**>45**
Glacial Till	7	1.1	2		<25		
Ice Contract Drift	7	1.1	2		<25	**25-45**	**>45**
Granite	1	2.5	3	<55			
Gneiss	1	2.5	5	<55			
Ultramafic Rock	1	2.5	6	<55			
Volcanic, Sedimentary Material	1	2.5	7	<55			
Batholithic Intrusives	1	2.5	7, 8, 10	<55			
McKim Formation	1	2.5	7	<55			
Mississaji Quarizite	1	2.5	7	<55			
Ramsay Lake Conglomerate	1	2.5	7	<55			
Schistified Volcanics, Clastic Sediments	1	2.5	7, 8	<55			
Basic Intrusives	1	2.5	8, 10	<55			
Noritic "Basic Edge" Differentiate	1	2.5	8, 9	<55			
Nickel Bearing Irruptive	1	2.5	9	<55			
Onaping Tuff	1	2.5	9	<55			
Transition Zone (Tuff / Irruptive)	1	2.5	9	<55			
Schist Complex	1	2.5	10	<55			
Transition Material (Schist / Intrusives)	1	2.5	10	<55			
Glasiolacustrine Deposits	4, 16	1.5	12, 14		<55		
Glaciofluvial Outwash Deposits	4, 16	1.2	13		<55		
Glaciofluvial Ice	4, 16	1.2	14		<55		
Fluvial Deposits	4, 16	1.2	14		<55		
Beach	3, 7	1.1	15, 18		<25	**25-45**	**>45**
Cloustan Silt	4	1.5	15, 17, 18		<55		
Wadsworth Rock Upland	1	2.5	15	<55			
Drumlins	13	1.7	16		<45		**>45**
Hanging Cliff	1	2.5	16	<55			
Lisgar Silt	4	1.5	16		<55		
The Flutes	1	2.5	17, 18	<55			
Ablation	13	1.7	18		<45		**>45**
Allenby Lake Clay	4	1.5	18		<55		

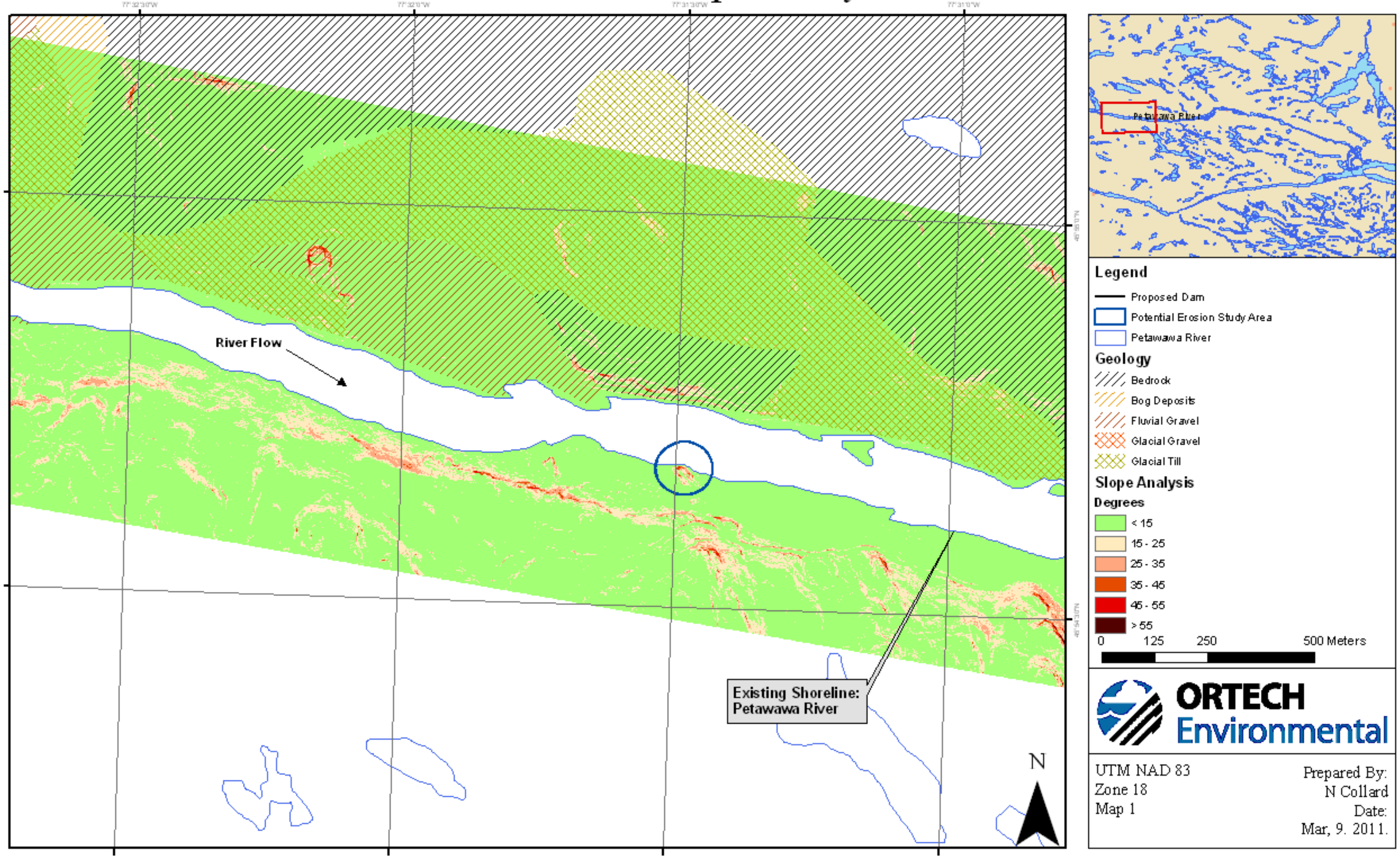
Big Eddy - Slope Analysis



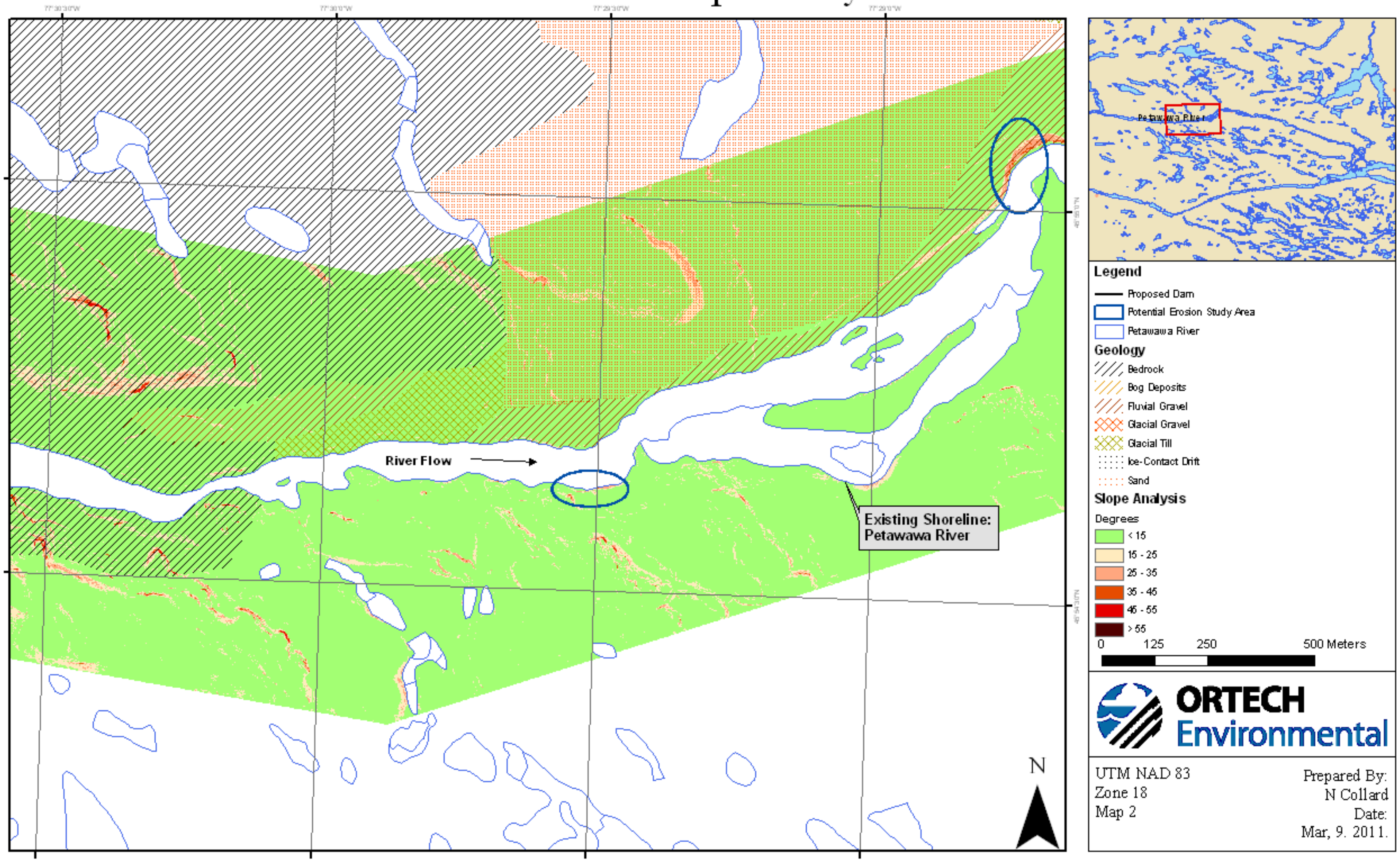
Big Eddy - Slope Analysis



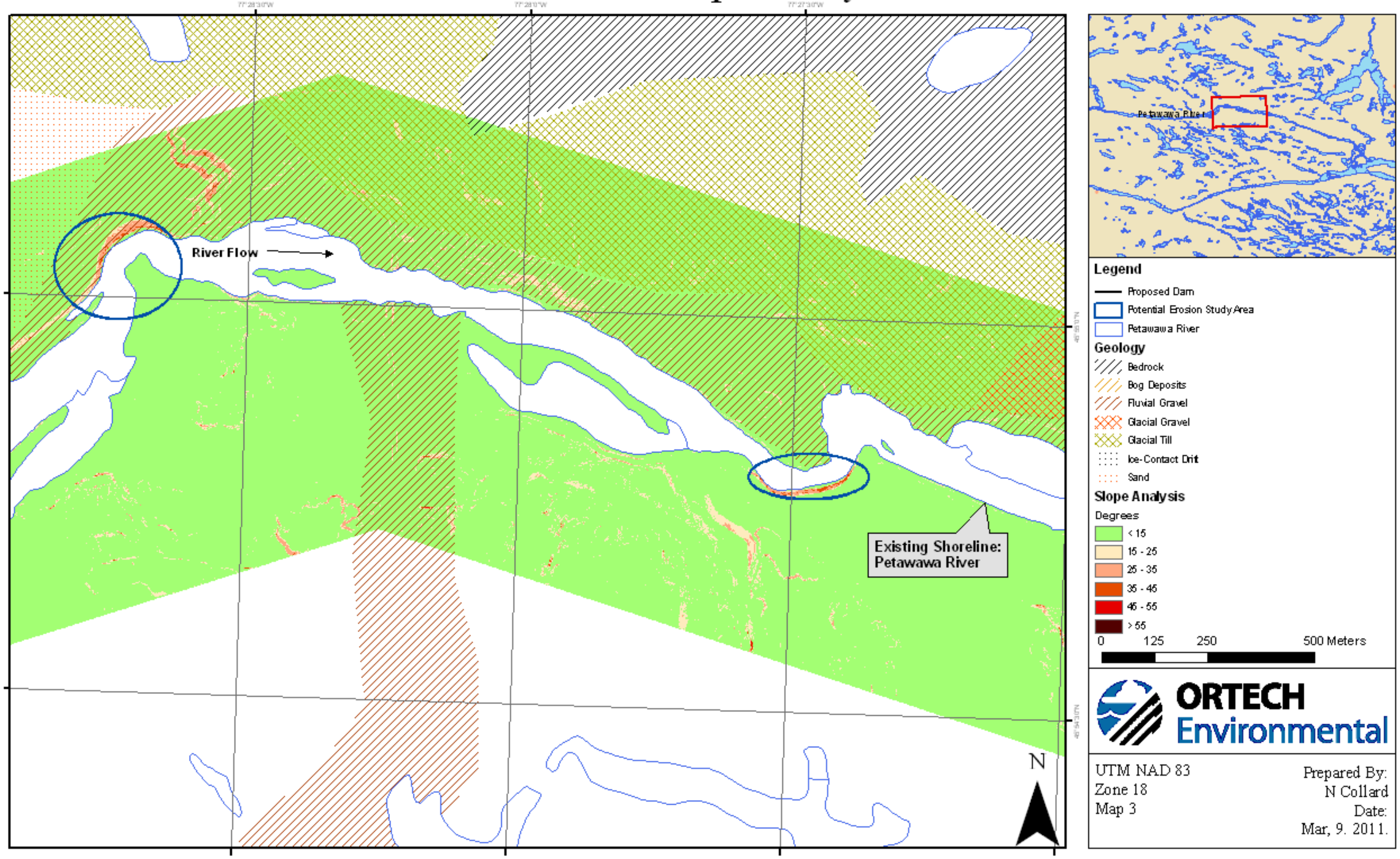
Half Mile - Slope Analysis



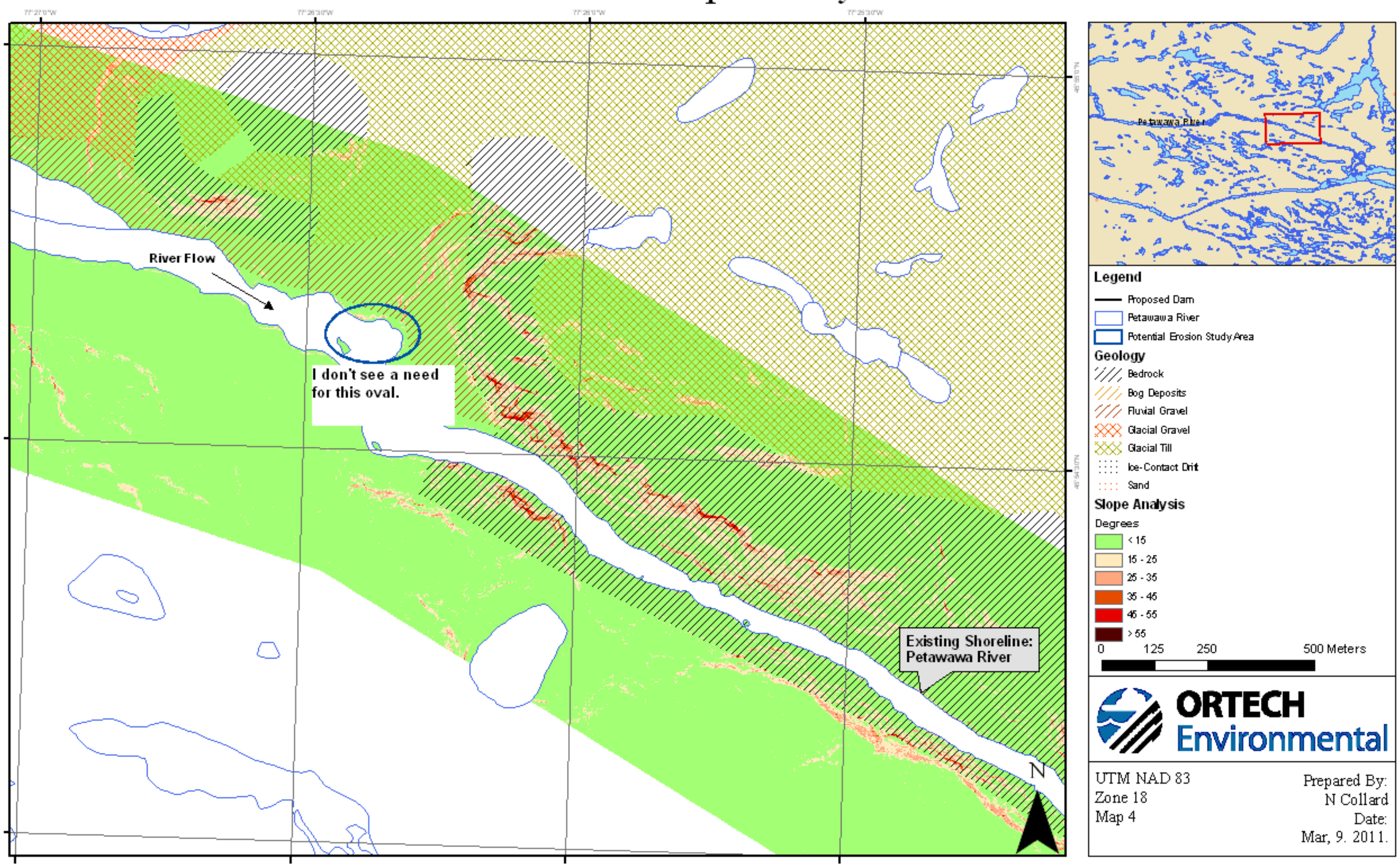
Half Mile - Slope Analysis

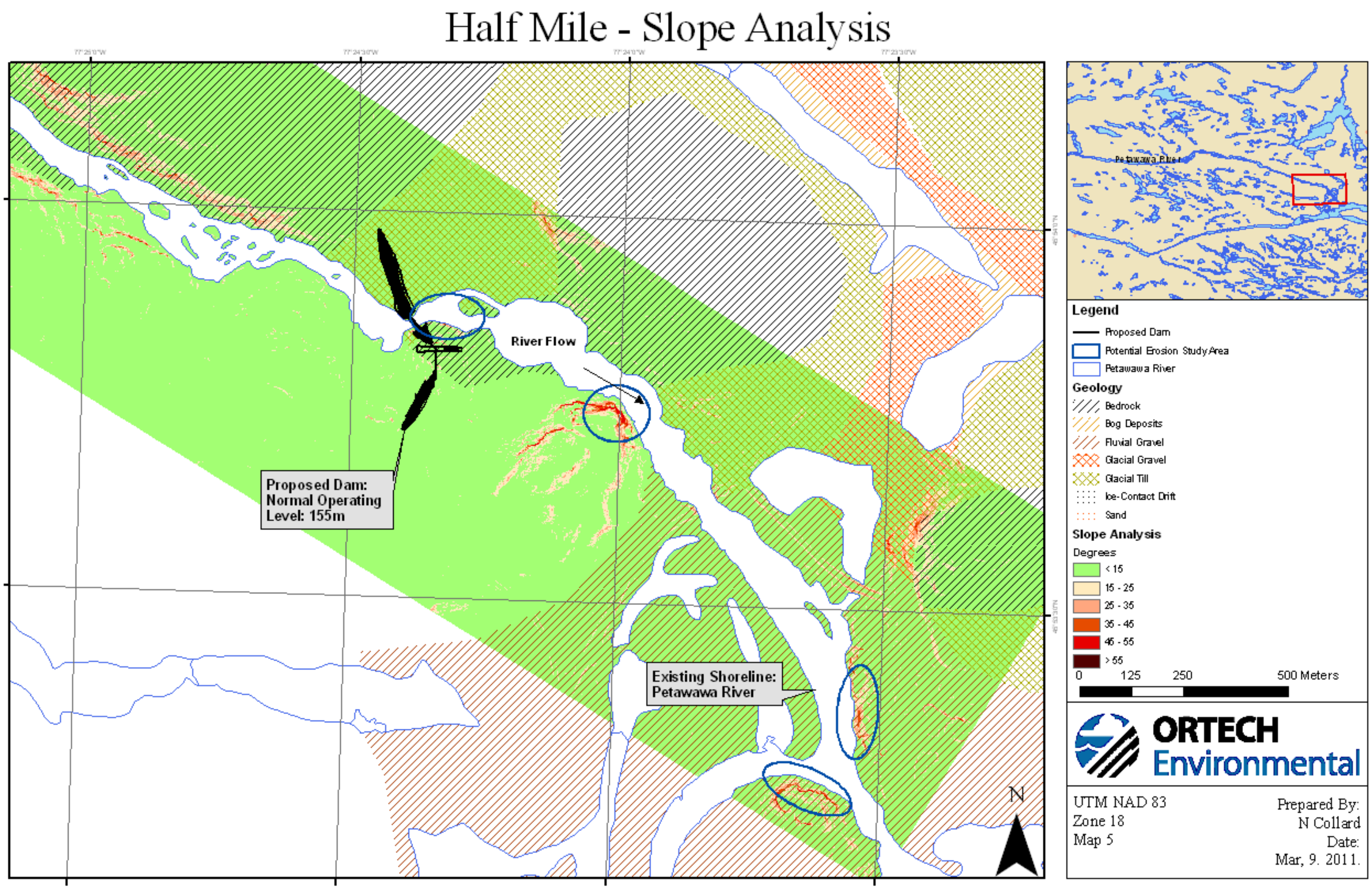


Half Mile - Slope Analysis

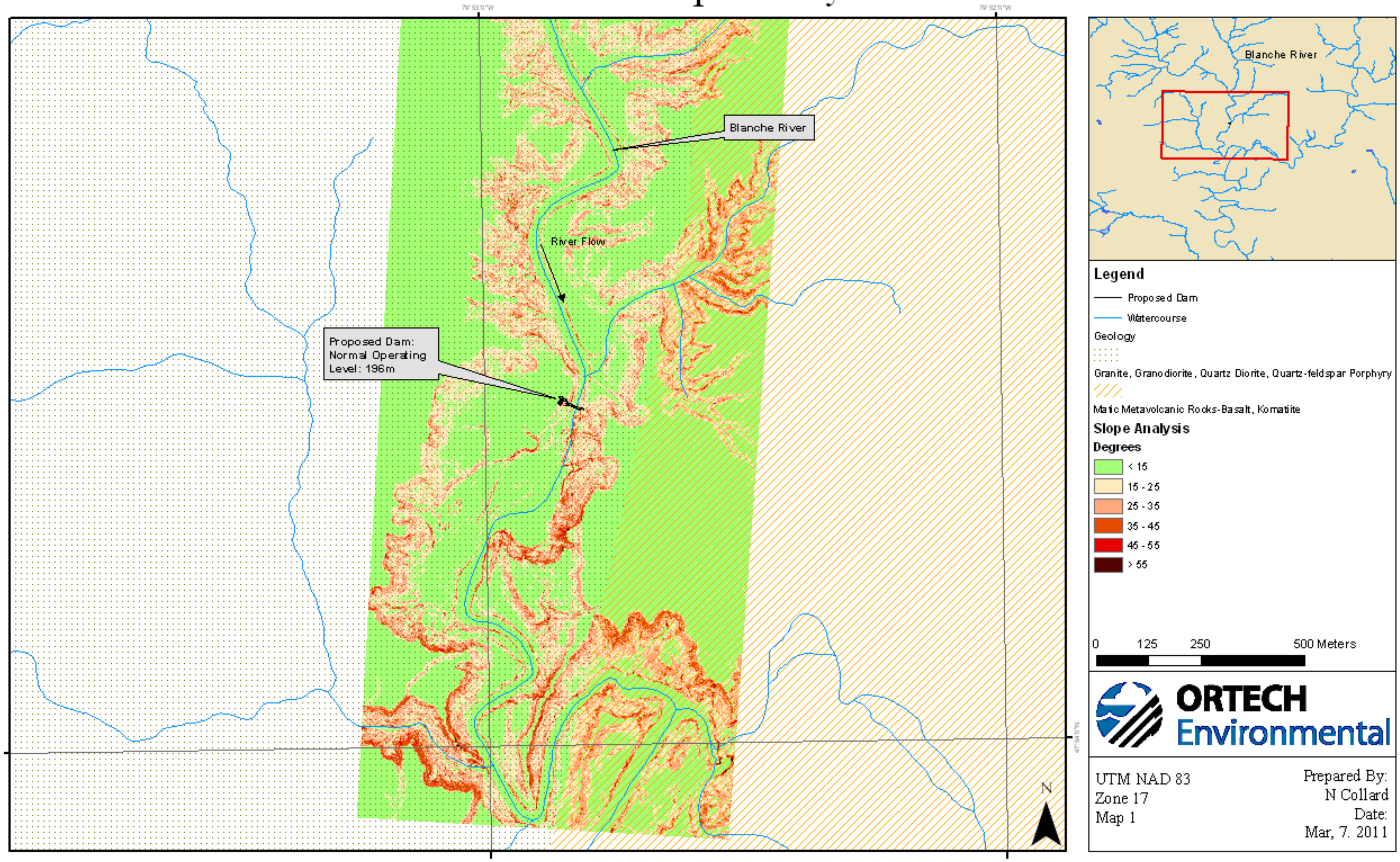


Half Mile - Slope Analysis

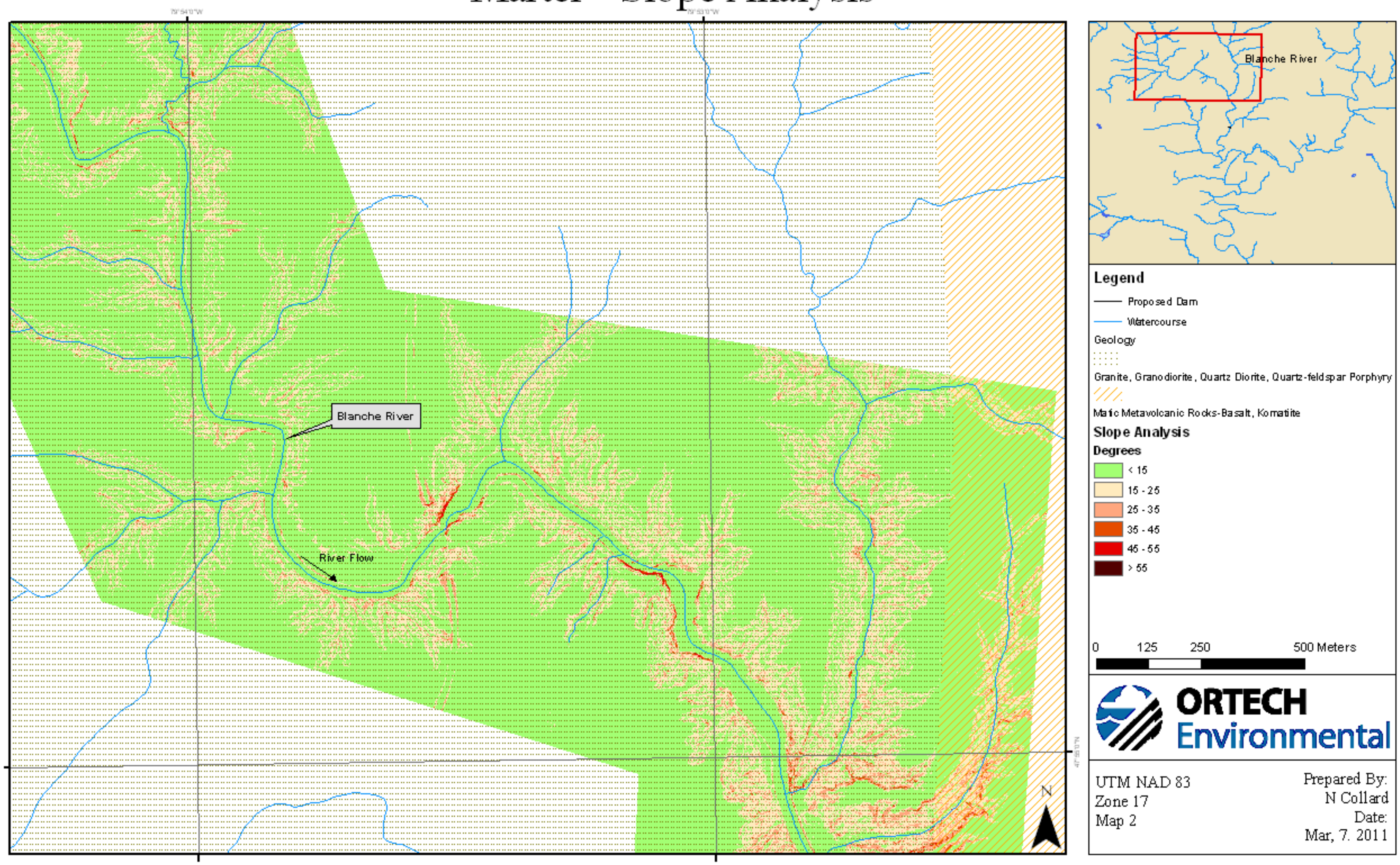



Half Mile - Slope Analysis
River Flow
Proposed Dam:
Normal Operating
Level: 155m
Existing Shoreline:
Petawawa River
N
Legend
Proposed Dam
Potential Erosion Study Area
Petawawa River
Geology
Bedrock
Bog Deposits
Fluvial Gravel
Glacial Gravel
Glacial Till
Ice-Contact Drift
Sand
Slope Analysis
Degrees
< 15
15 - 25
25 - 35
35 - 45
45 - 55
> 55
0 125 250 500 Meters
ORTECH
Environmental
UTM NAD 83
Zone 18
Map 5
Prepared By:
N Collard
Date:
Mar, 9. 2011.

Marter - Slope Analysis

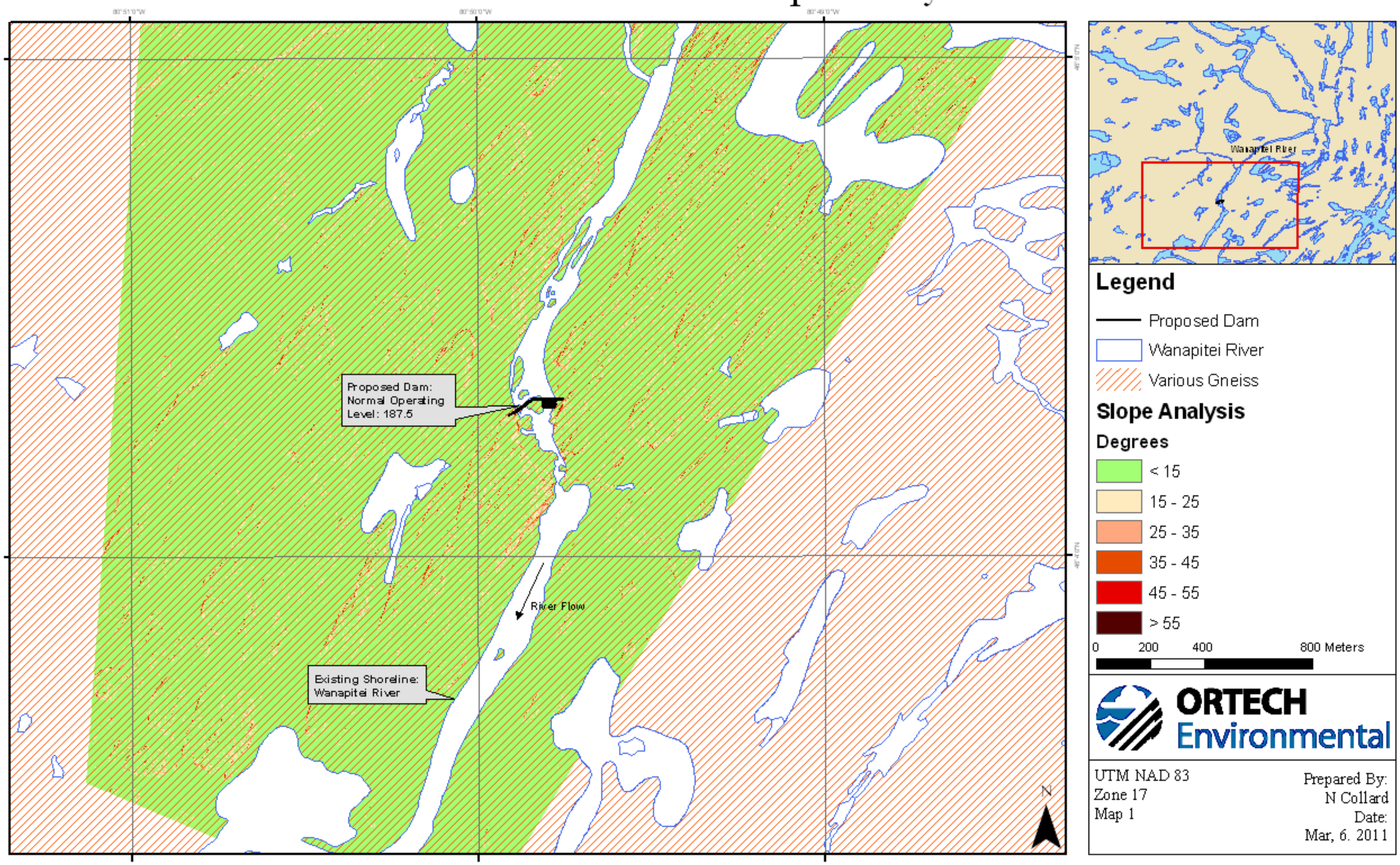


Marter - Slope Analysis

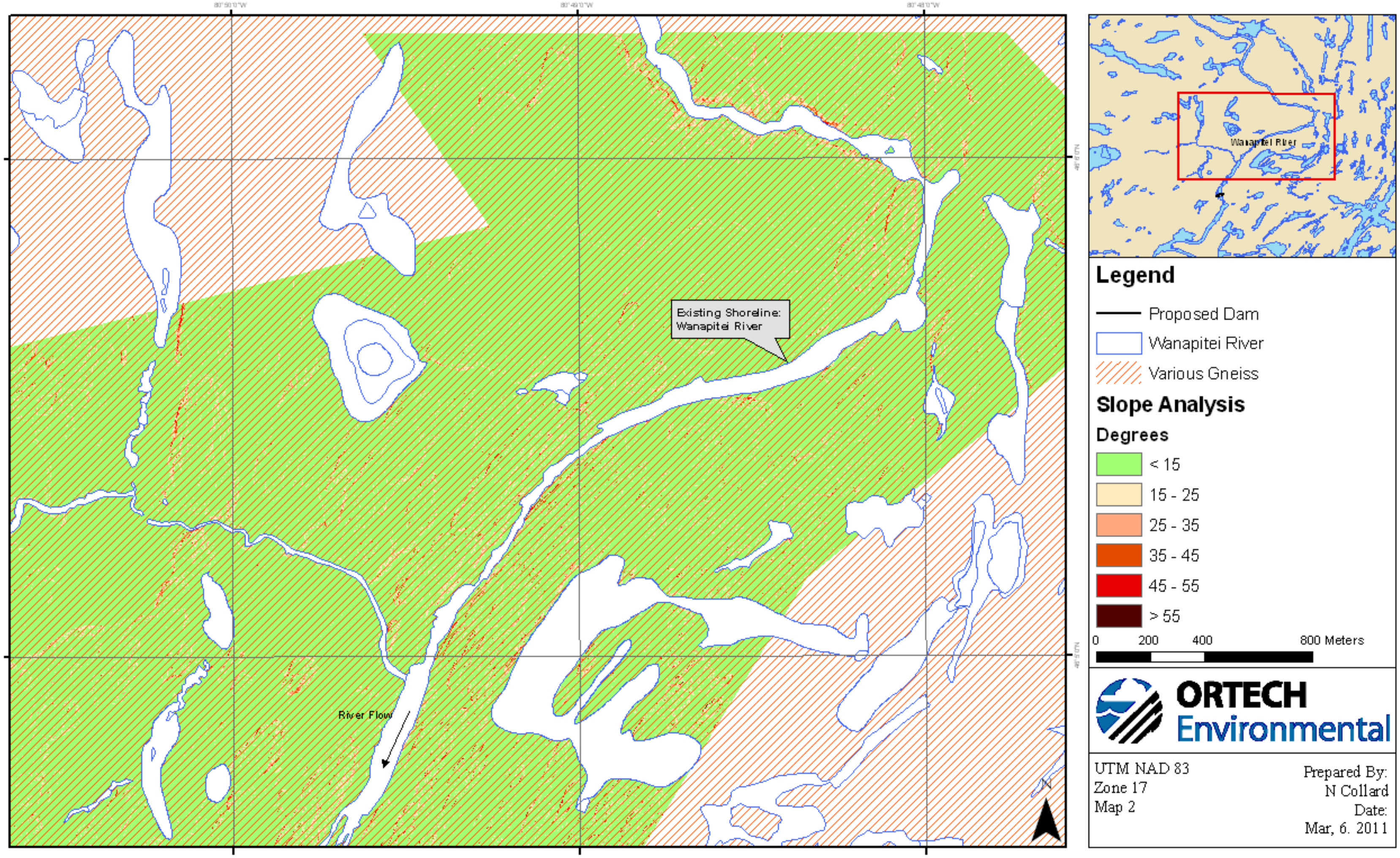


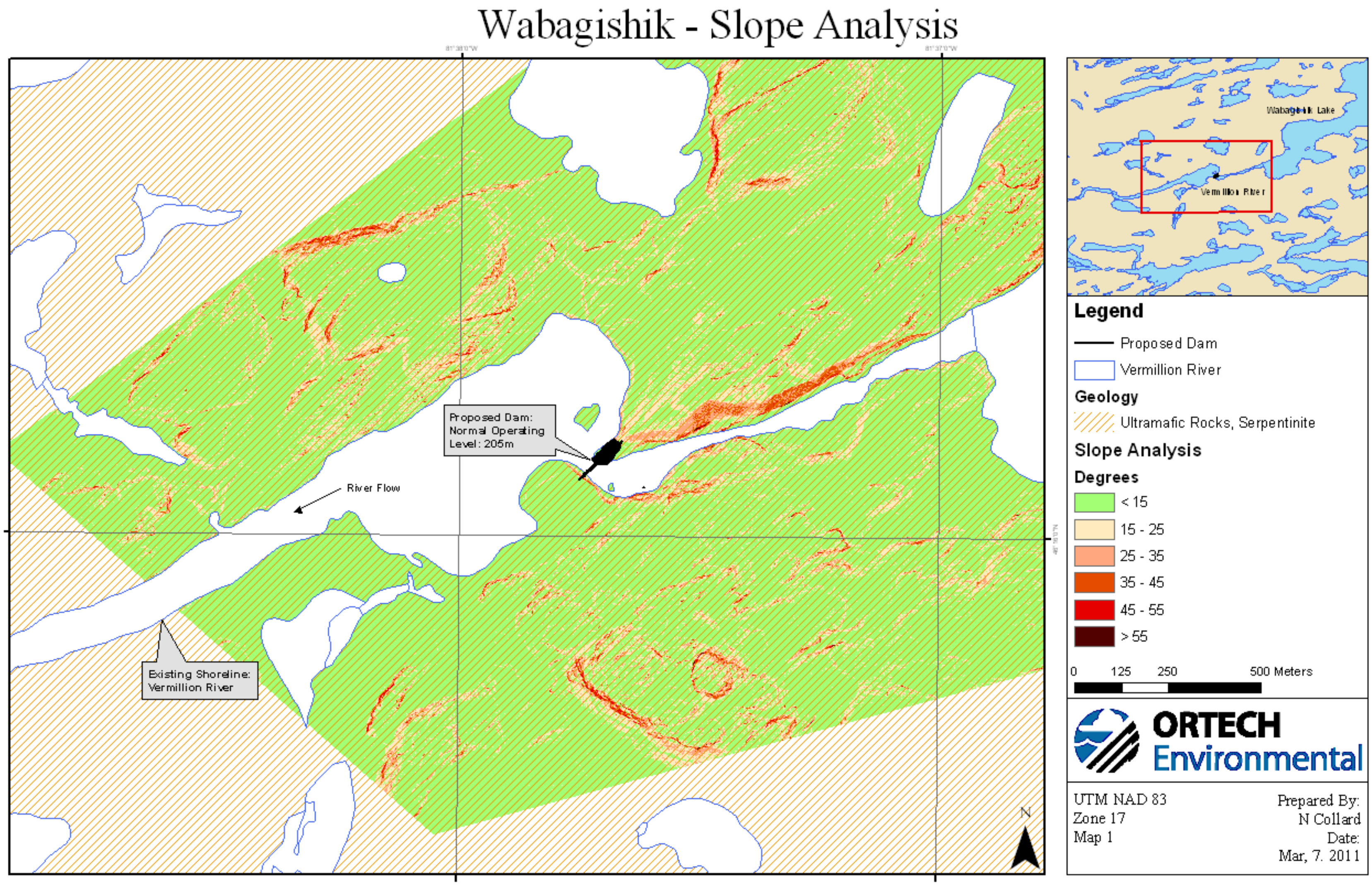
Larder & Raven – LIDAR Data not Available

Allen & Struthers - Slope Analysis

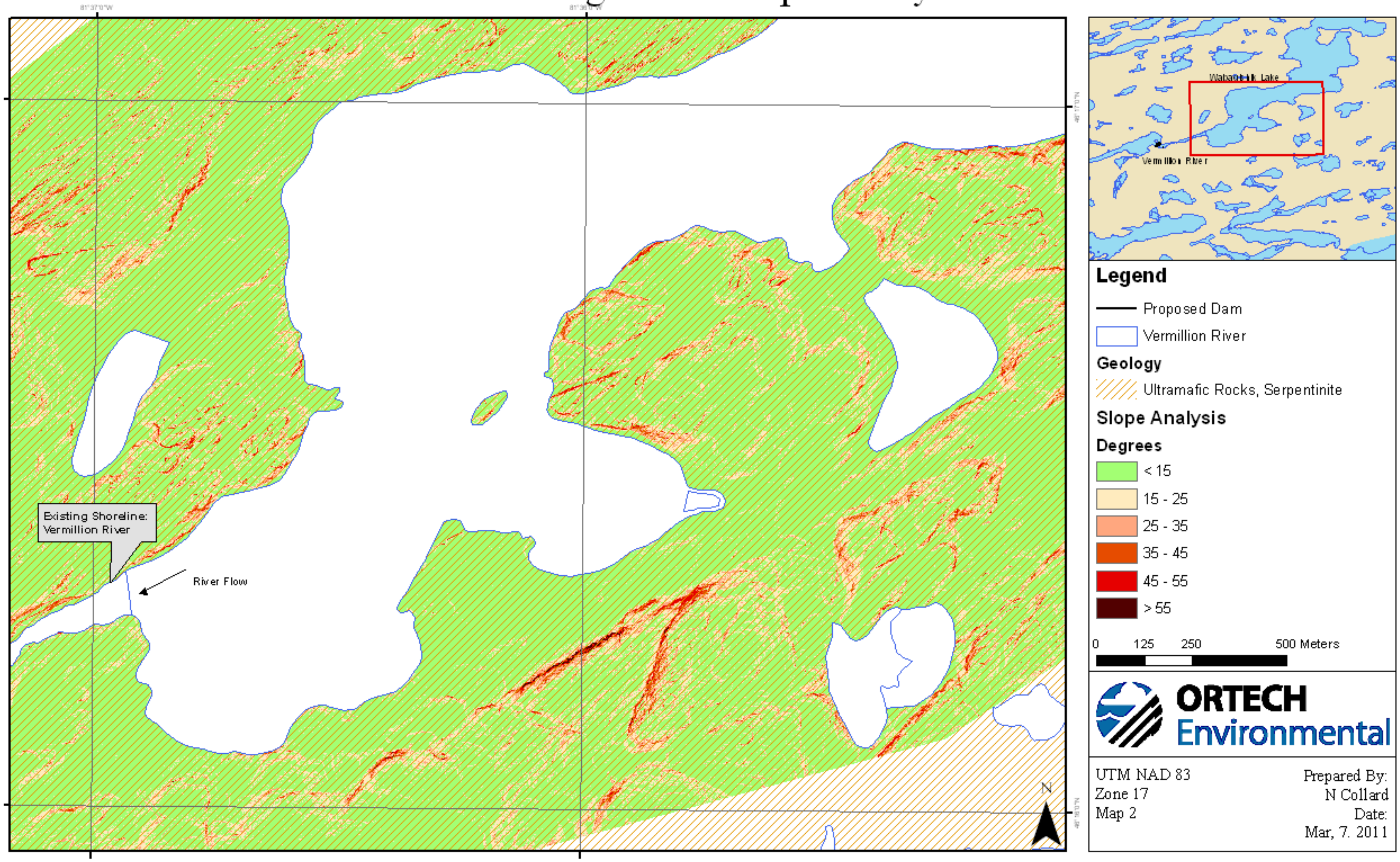


Allen & Struthers - Slope Analysis

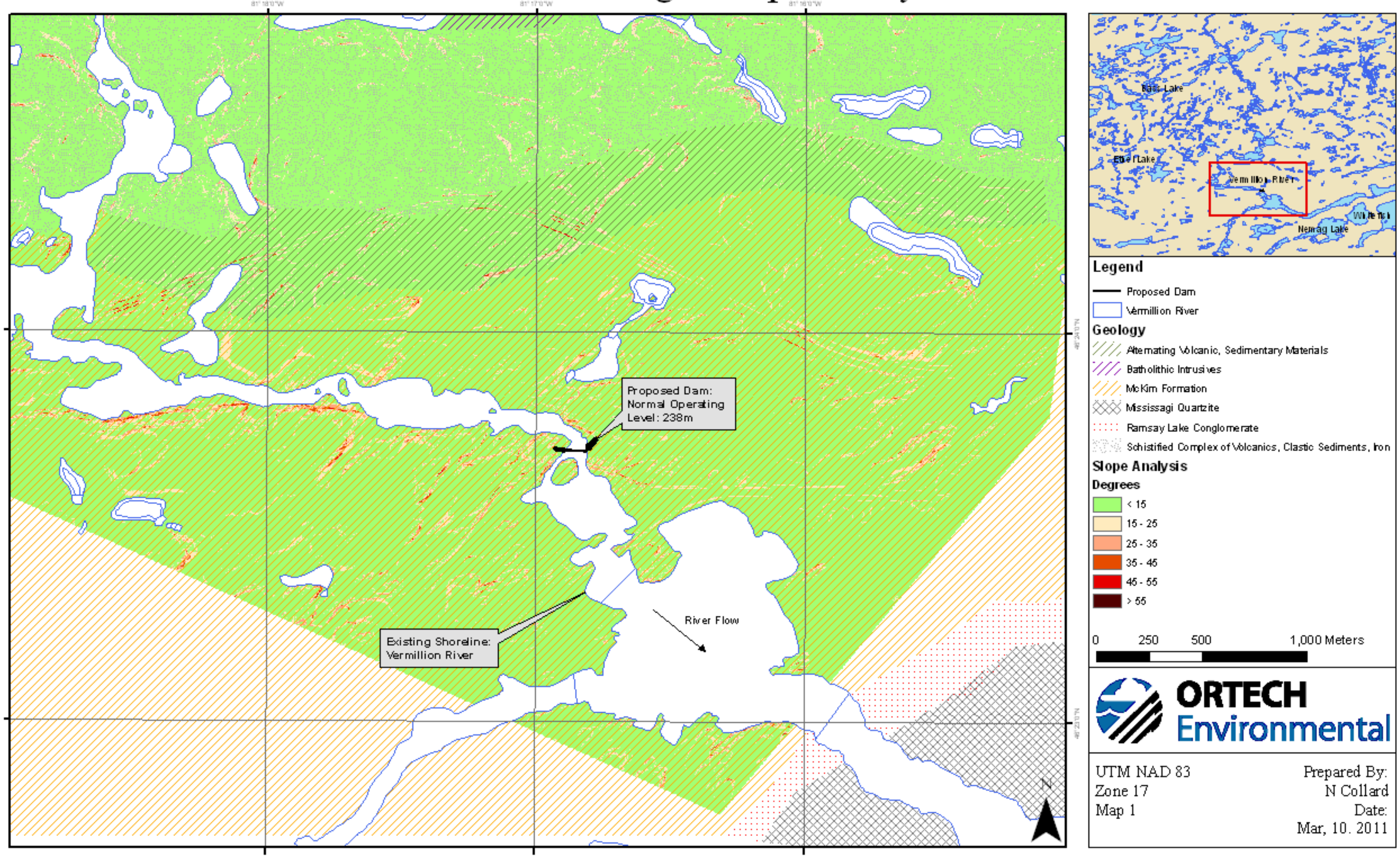



Wabagishik - Slope Analysis
Proposed Dam: Normal Operating Level: 205m
River Flow
Existing Shoreline: Vermillion River
Wabagishik Lake
Vermillion River
Legend
Proposed Dam
Vermillion River
Geology
Ultramafic Rocks, Serpentinite
Slope Analysis
Degrees
< 15
15 - 25
25 - 35
35 - 45
45 - 55
> 55
0 125 250 500 Meters
ORTECH Environmental
UTM NAD 83
Zone 17
Map 1
Prepared By:
N Collard
Date:
Mar, 7. 2011
N

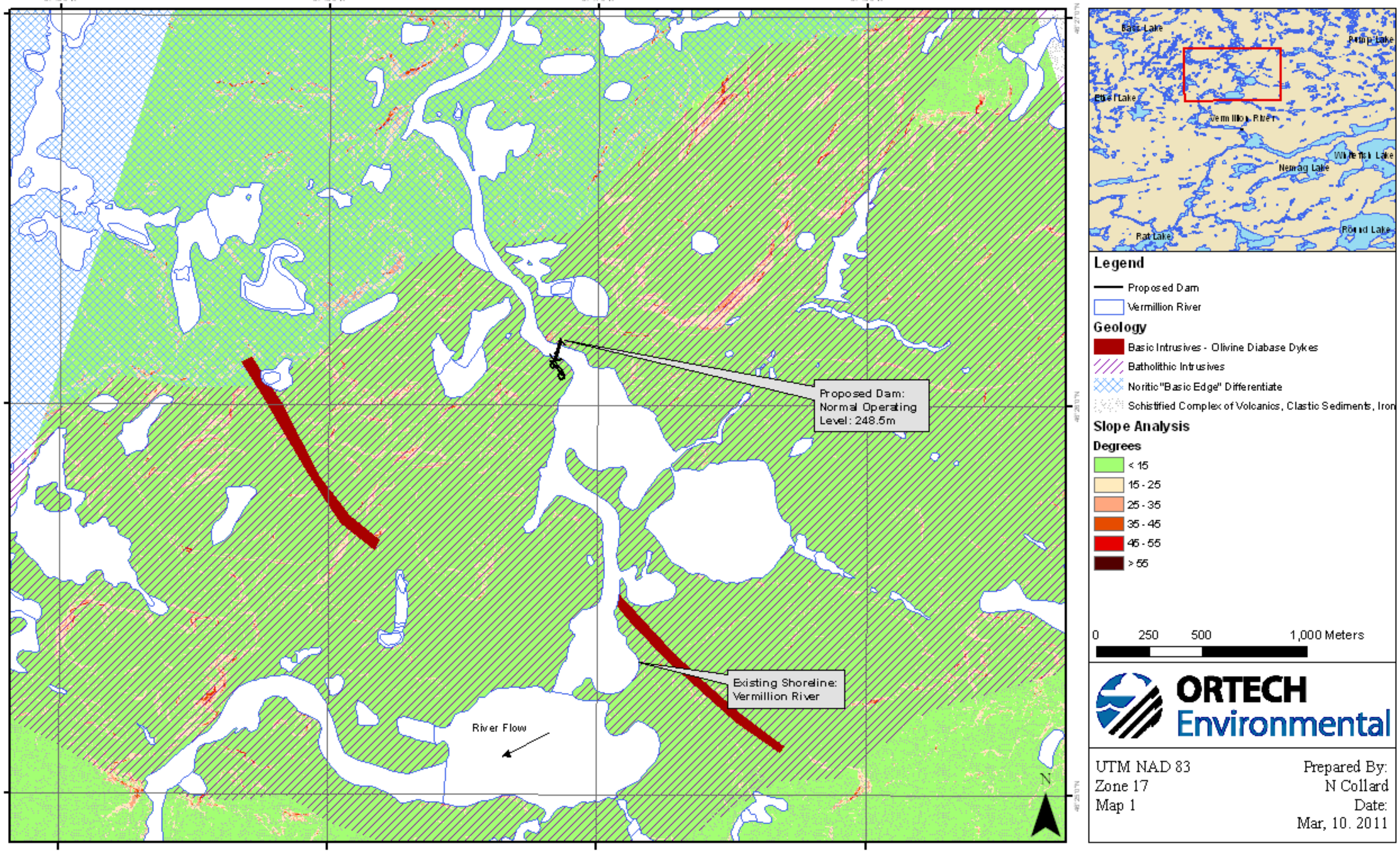
Wabagishik - Slope Analysis



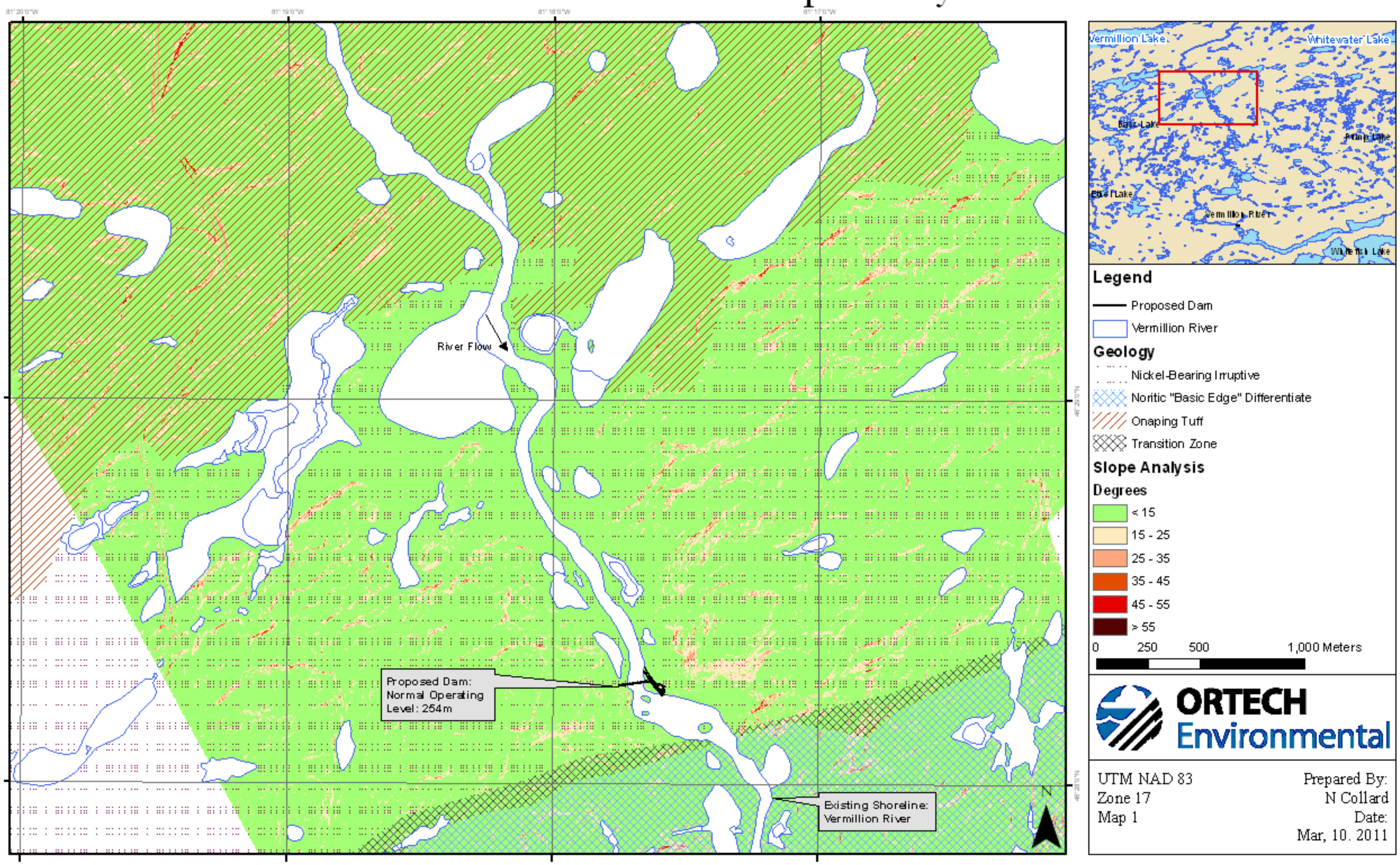
At Soo Crossing - Slope Analysis



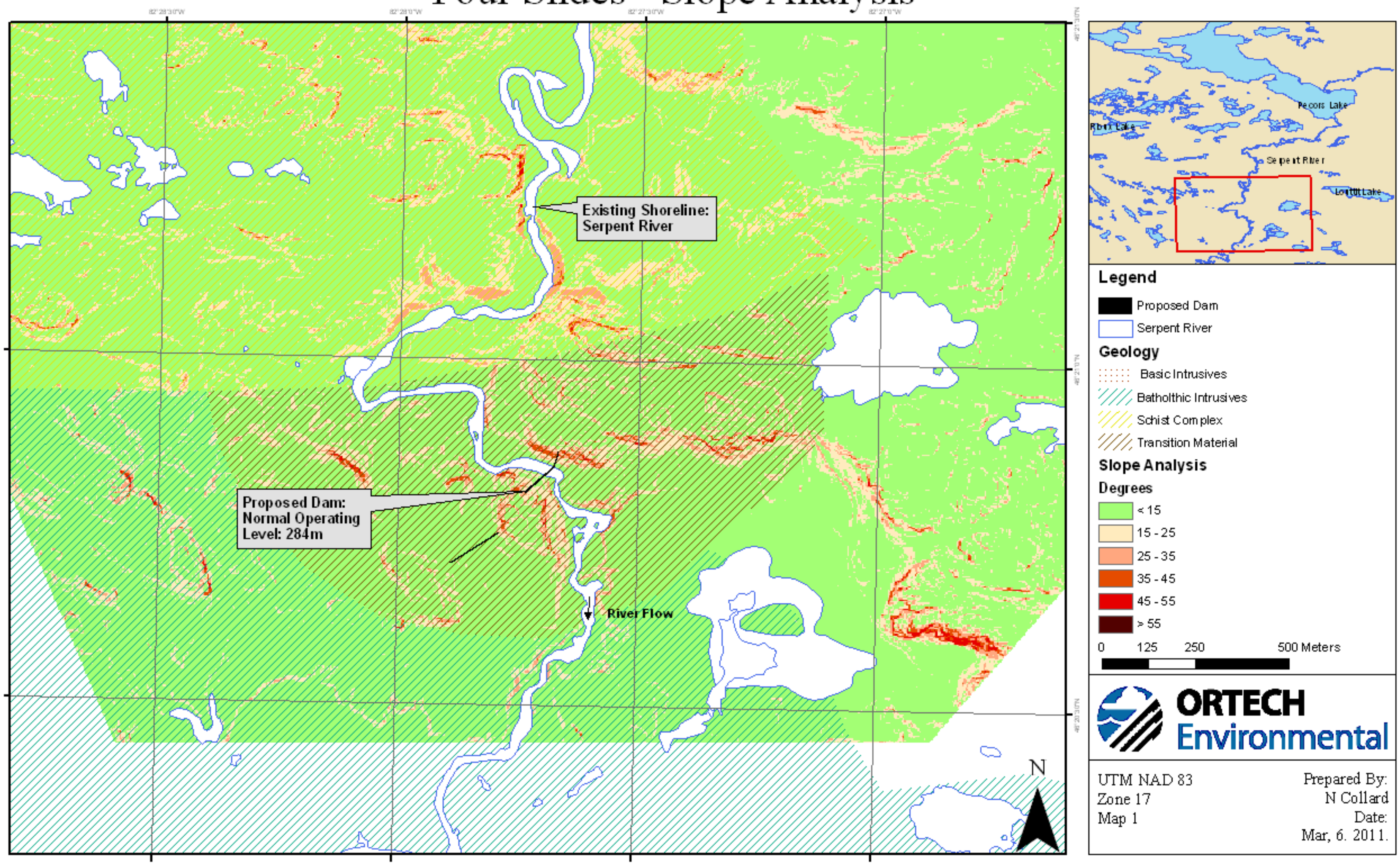
Cascade Falls - Slope Analysis



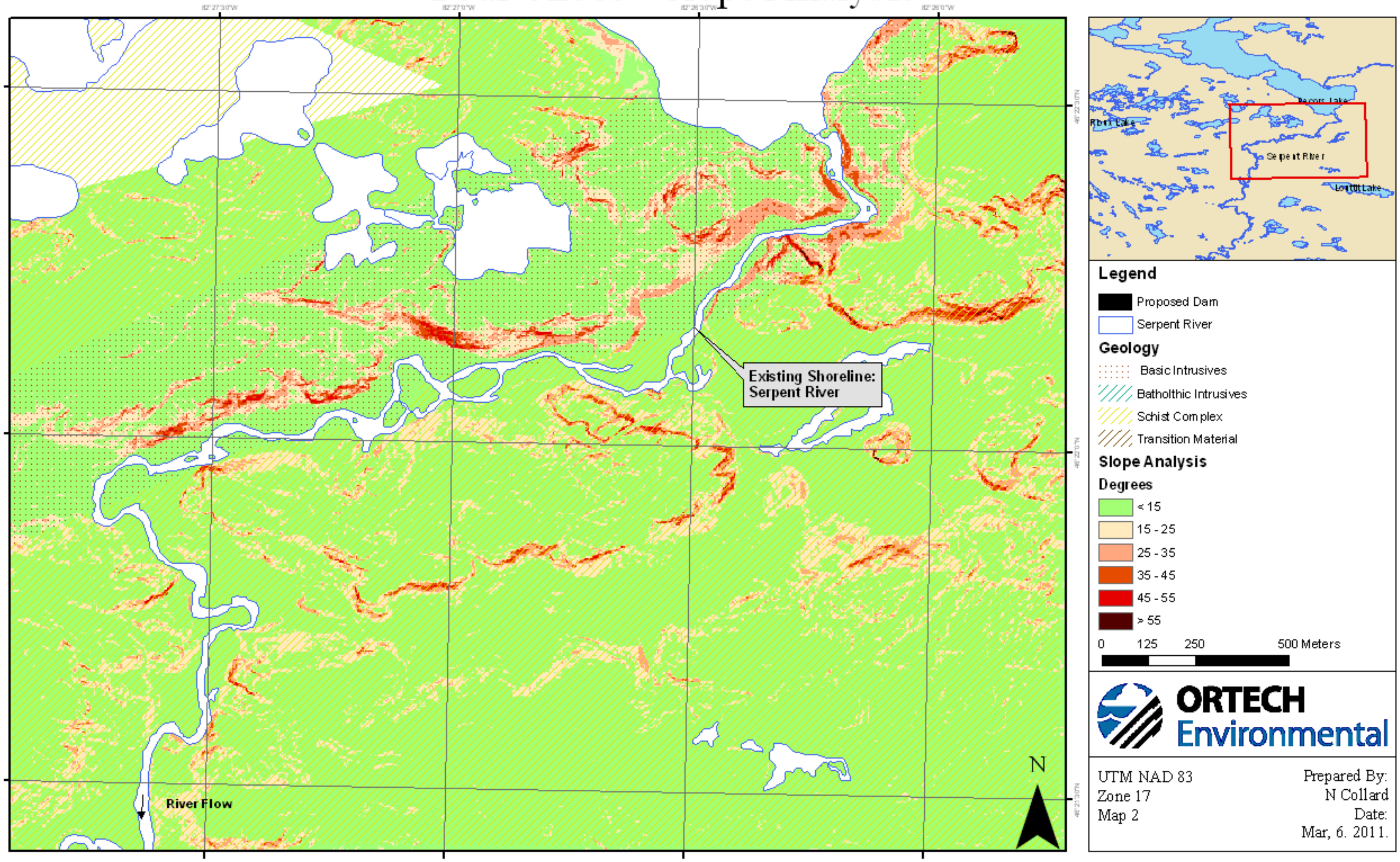
MacPherson Falls - Slope Analysis



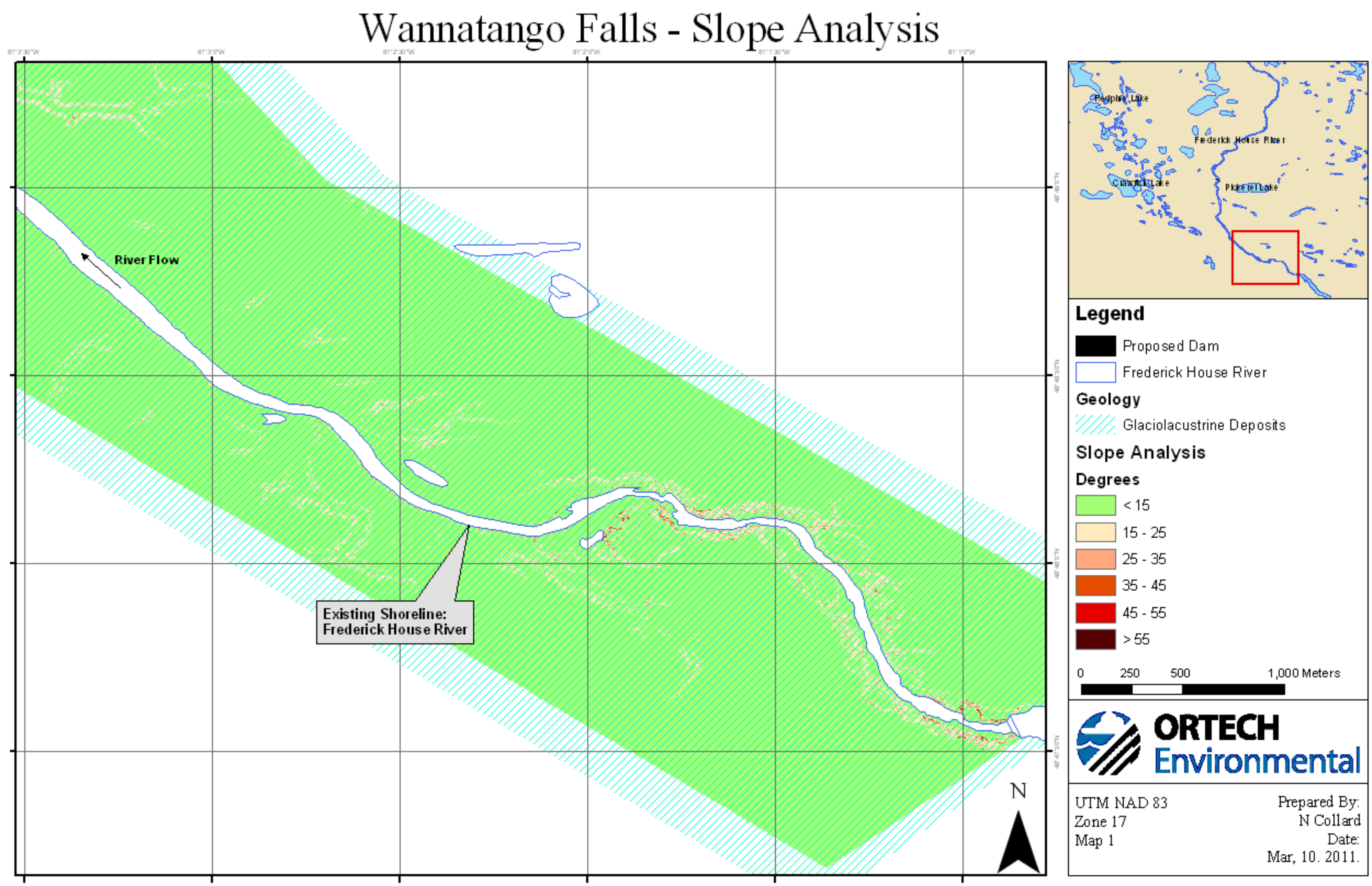
Four Slides - Slope Analysis

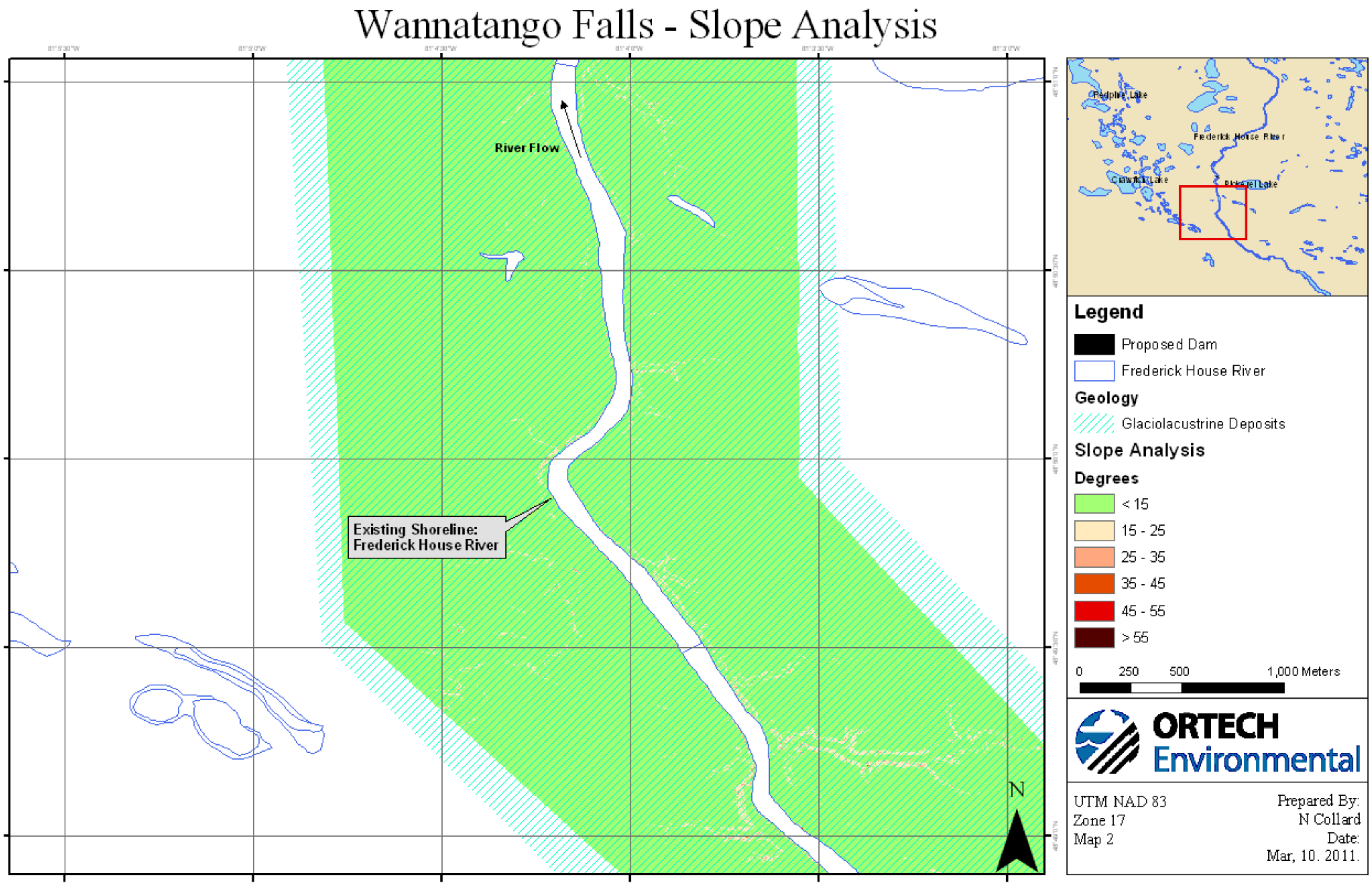


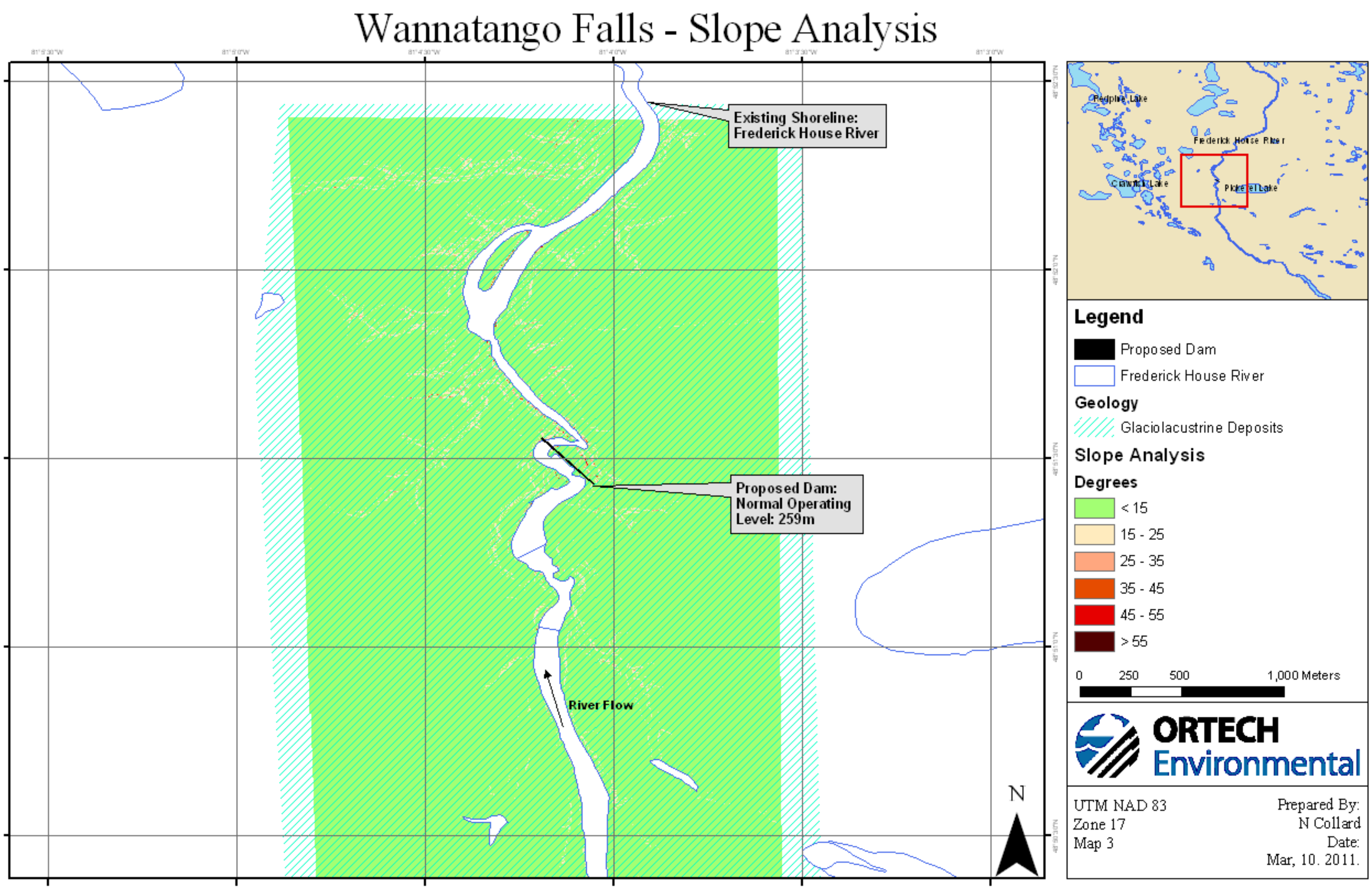
Four Slides - Slope Analysis



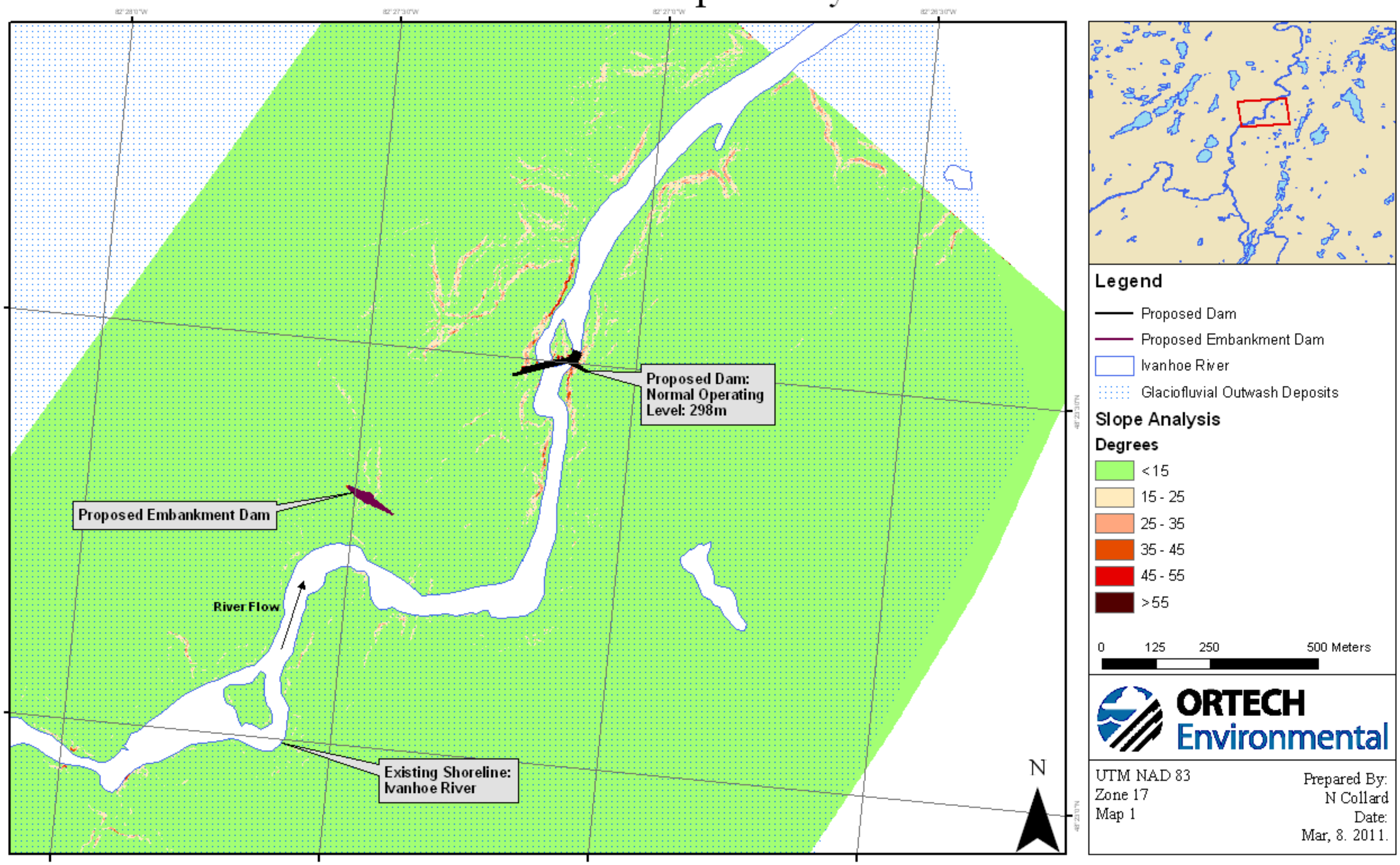
McCarthy Chute – no LIDAR Data available


Wannatango Falls - Slope Analysis
River Flow
Existing Shoreline:
Frederick House River
N
Redpine Lake
Frederick House River
Clawfish Lake
Pickerel Lake
Legend
Proposed Dam
Frederick House River
Geology
Glaciolacustrine Deposits
Slope Analysis
Degrees
< 15
15 - 25
25 - 35
35 - 45
45 - 55
> 55
0 250 500 1,000 Meters
ORTECH Environmental
UTM NAD 83
Zone 17
Map 1
Prepared By:
N Collard
Date:
Mar, 10. 2011.

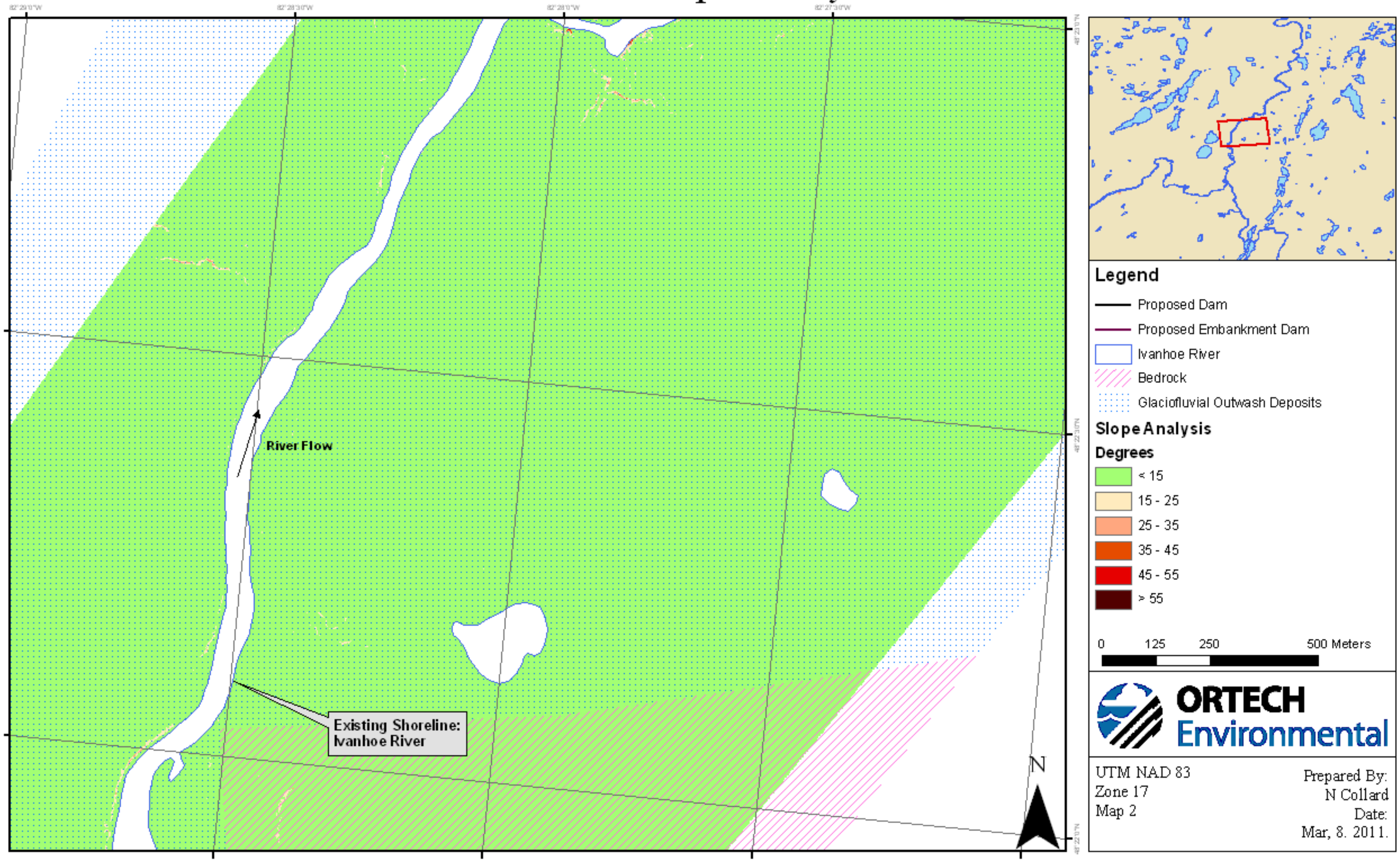

Wannatango Falls - Slope Analysis
River Flow
Existing Shoreline: Frederick House River
Pedpine Lake
Frederick House River
Pickerel Lake
Legend
Proposed Dam
Frederick House River
Geology
Glaciolacustrine Deposits
Slope Analysis
Degrees
< 15
15 - 25
25 - 35
35 - 45
45 - 55
> 55
0 250 500 1,000 Meters
ORTECH Environmental
UTM NAD 83
Zone 17
Map 2
Prepared By: N Collard
Date: Mar, 10. 2011.
N


Wannatango Falls - Slope Analysis
Existing Shoreline: Frederick House River
Proposed Dam: Normal Operating Level: 259m
River Flow
N
Legend
Proposed Dam
Frederick House River
Geology
Glaciolacustrine Deposits
Slope Analysis
Degrees
< 15
15 - 25
25 - 35
35 - 45
45 - 55
> 55
0 250 500 1,000 Meters
ORTECH Environmental
UTM NAD 83
Zone 17
Map 3
Prepared By:
N Collard
Date:
Mar, 10. 2011.

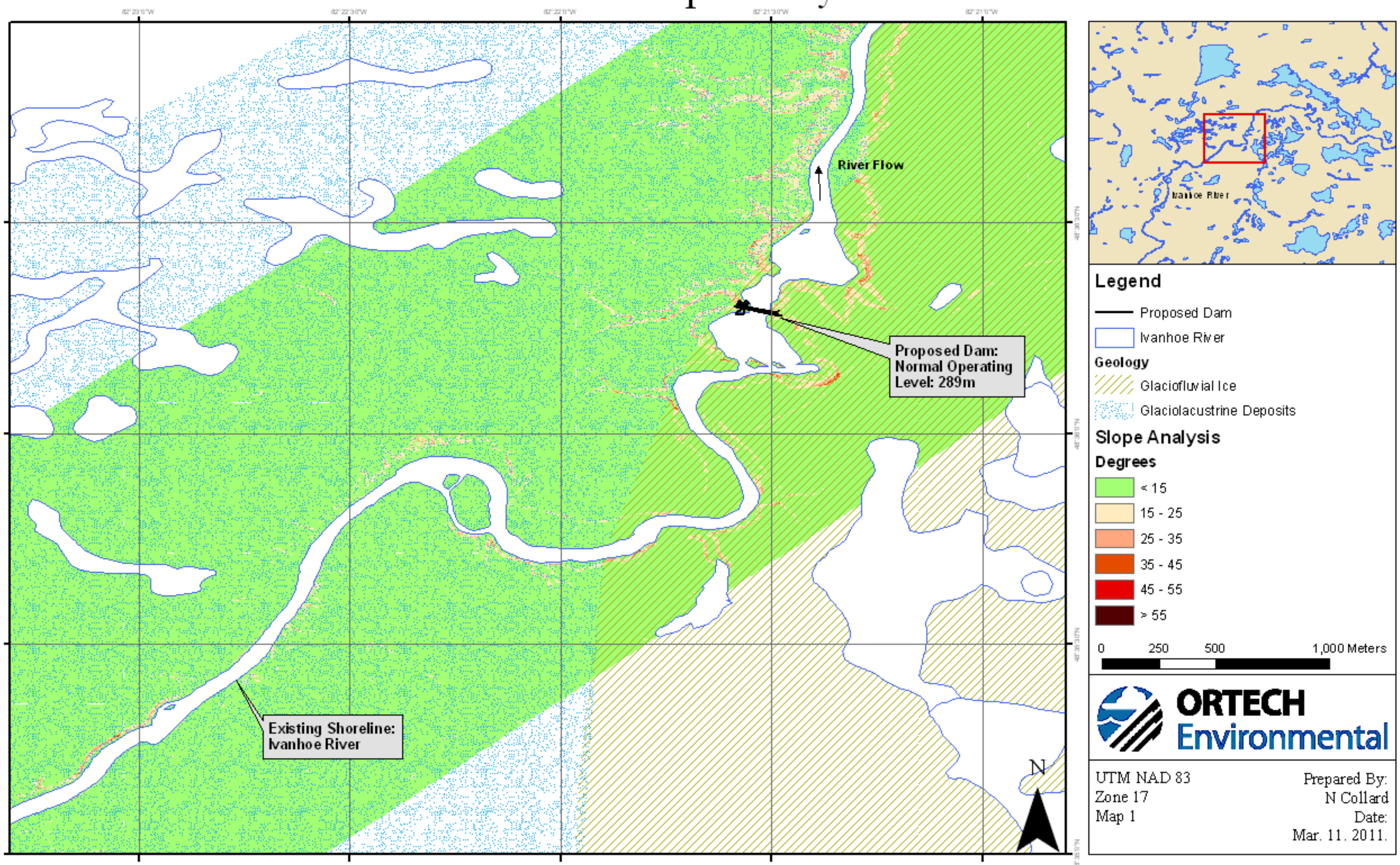
The Chute - Slope Analysis

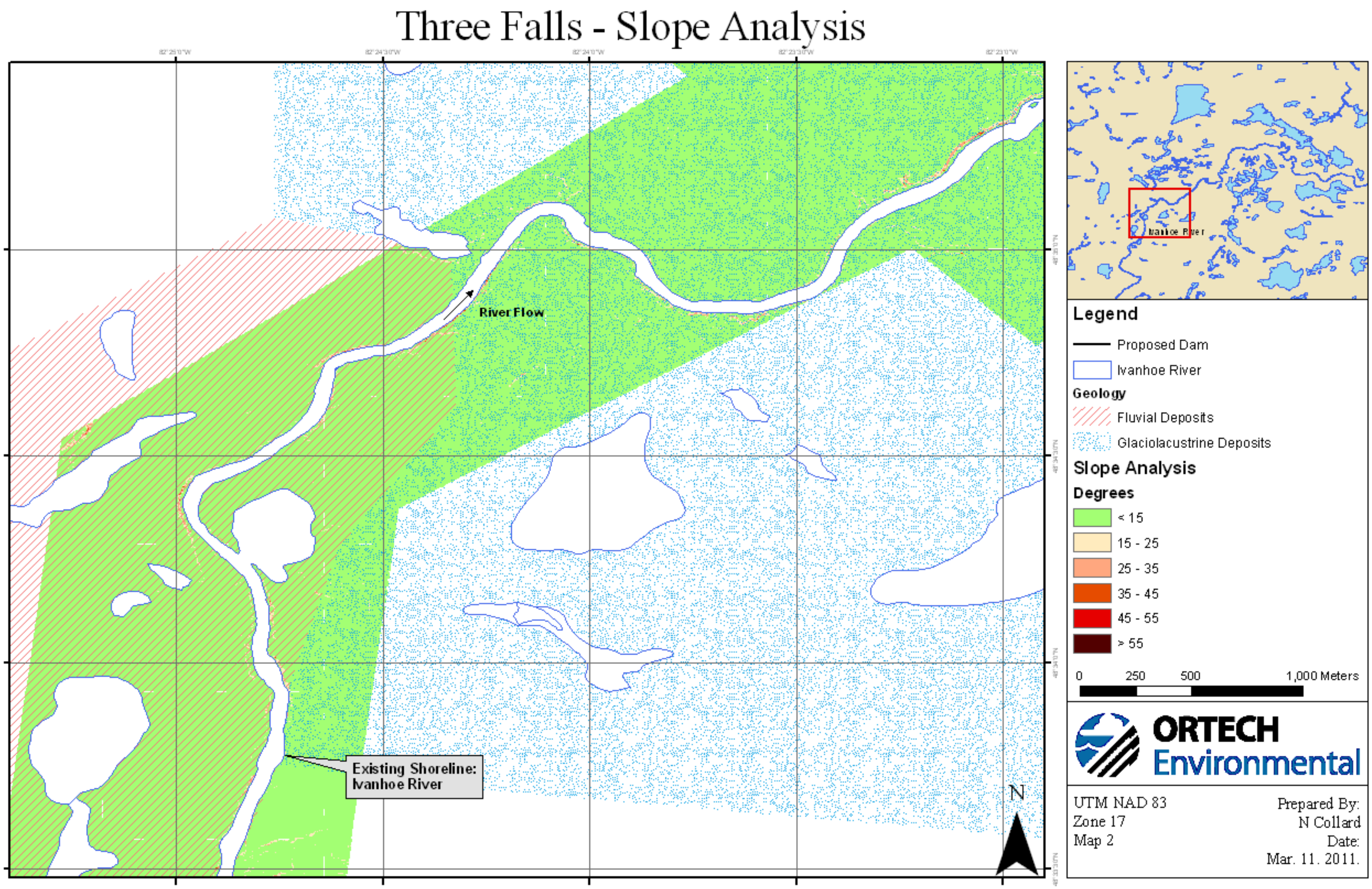


The Chute - Slope Analysis

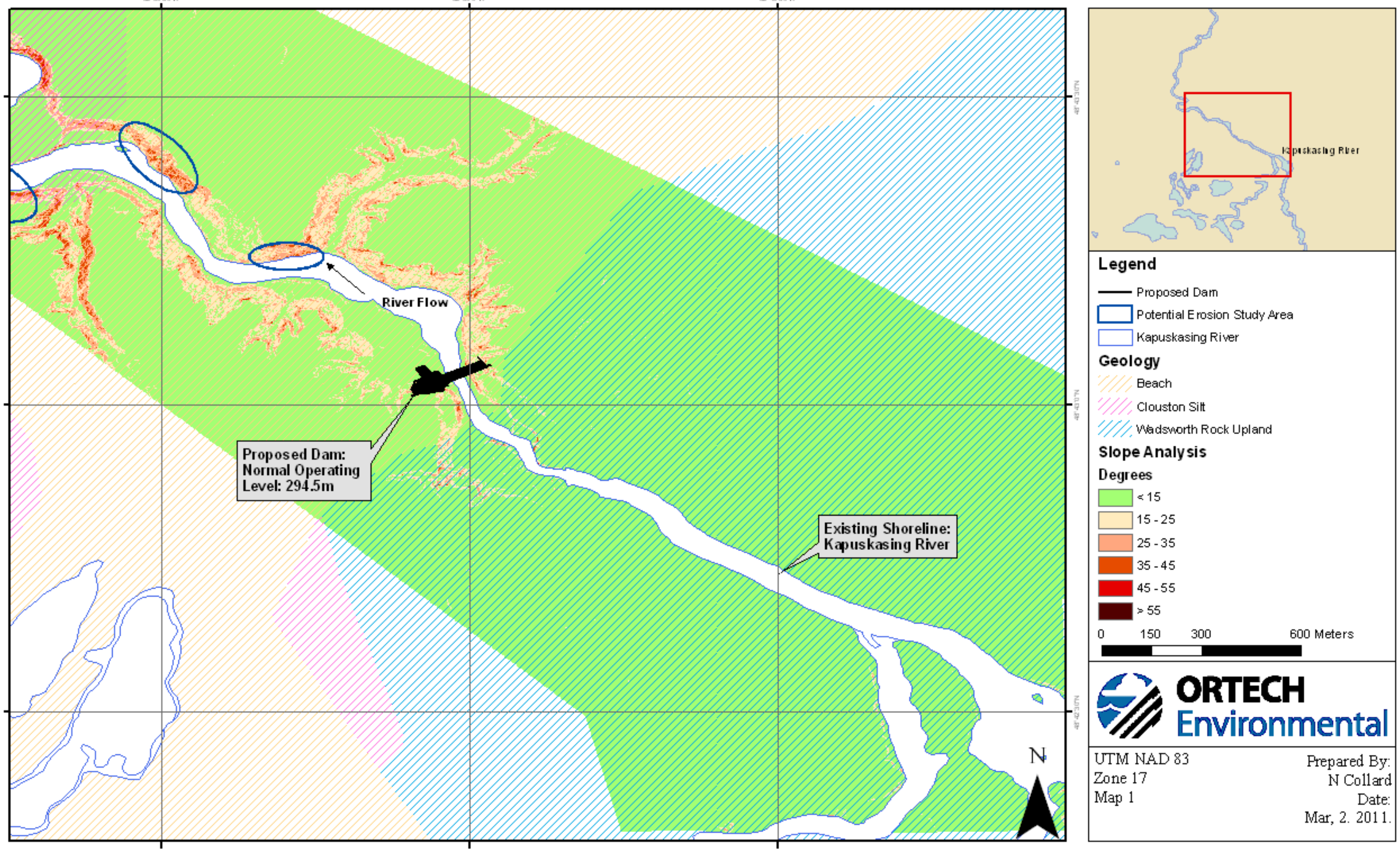


Three Falls - Slope Analysis

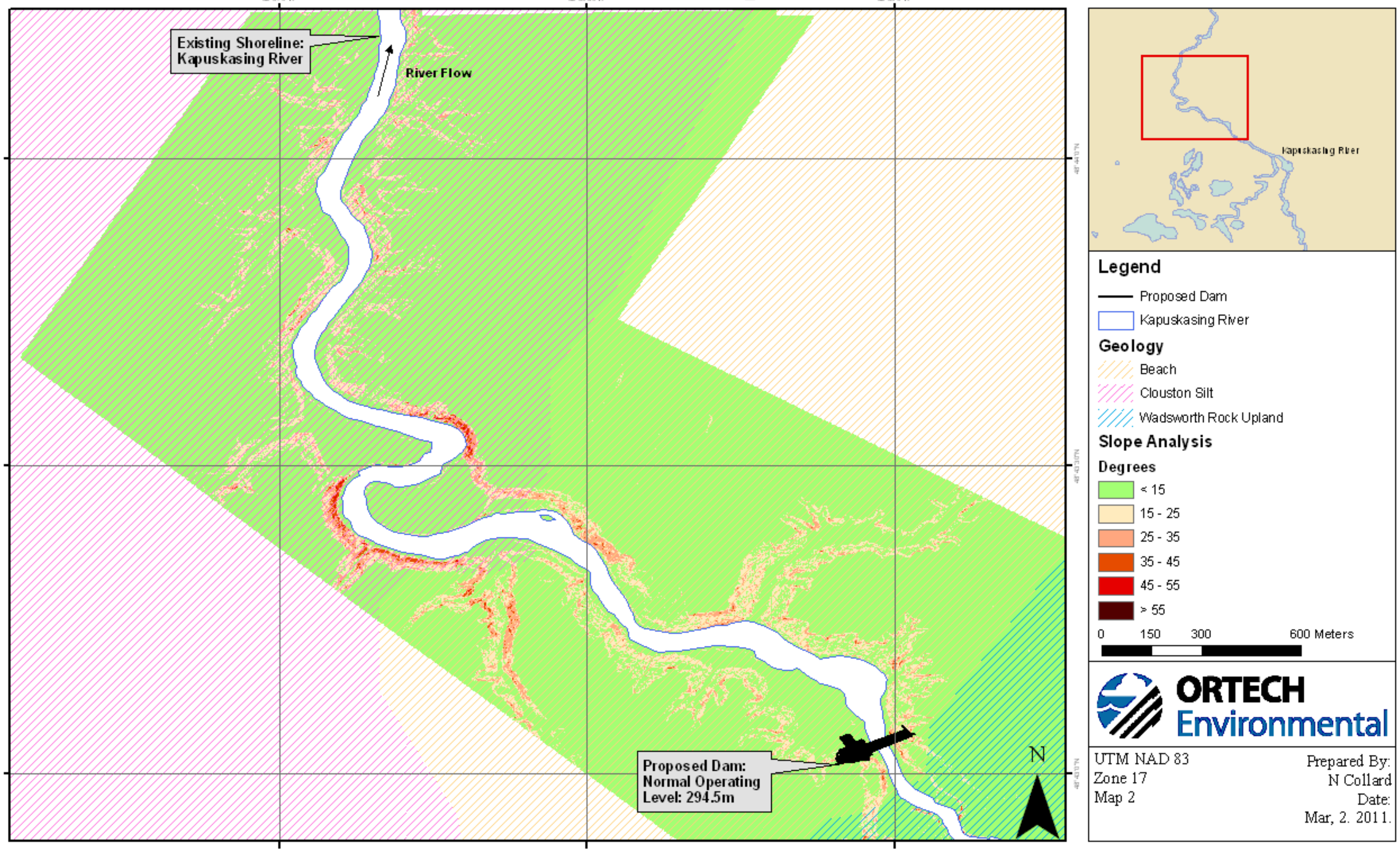



Three Falls - Slope Analysis
River Flow
Existing Shoreline:
Ivanhoe River
N
Legend
Proposed Dam
Ivanhoe River
Geology
Fluvial Deposits
Glaciolacustrine Deposits
Slope Analysis
Degrees
< 15
15 - 25
25 - 35
35 - 45
45 - 55
> 55
0
250
500
1,000 Meters
ORTECH
Environmental
UTM NAD 83
Zone 17
Map 2
Prepared By:
N Collard
Date:
Mar. 11. 2011.

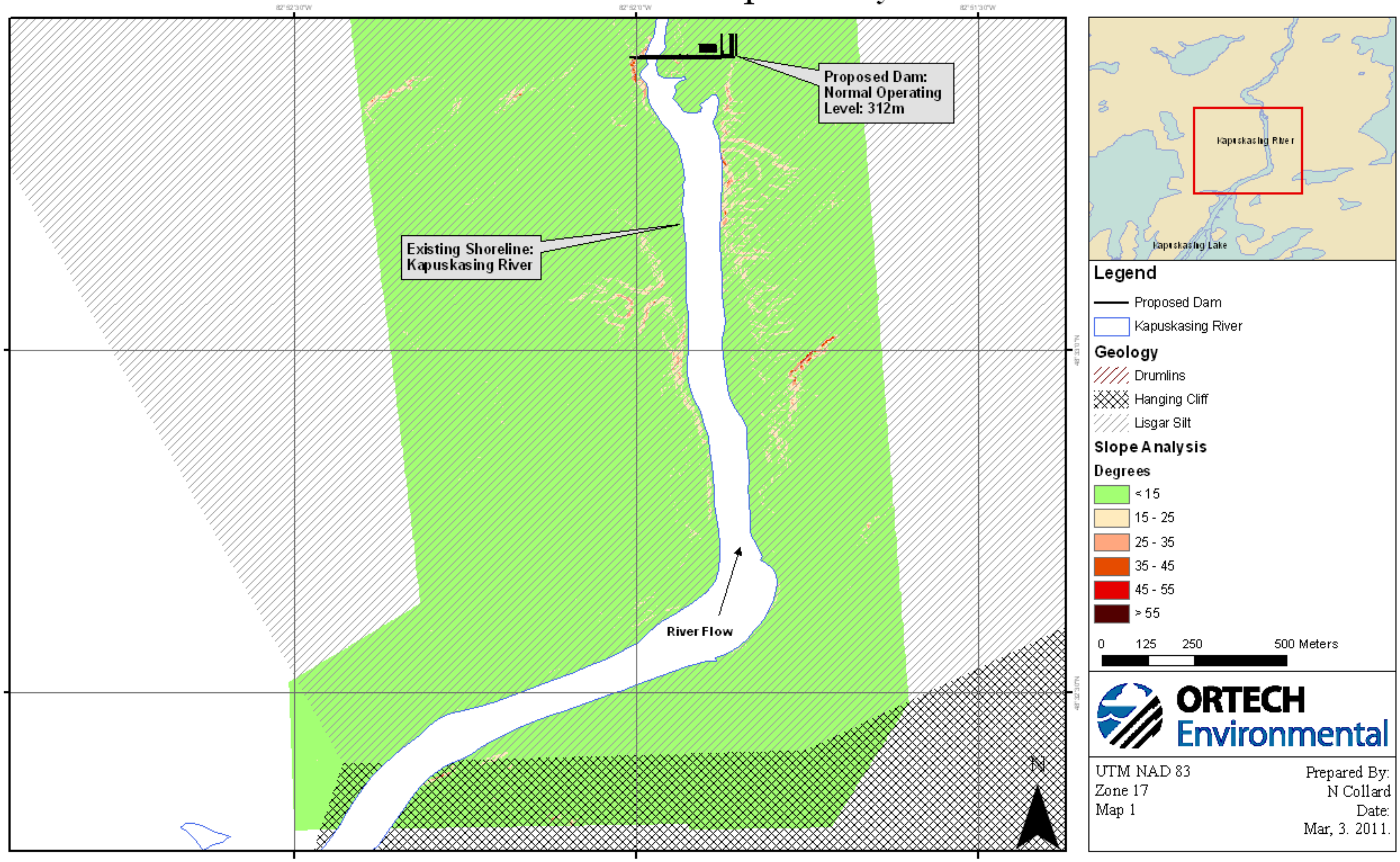
Buchan Falls - Slope Analysis



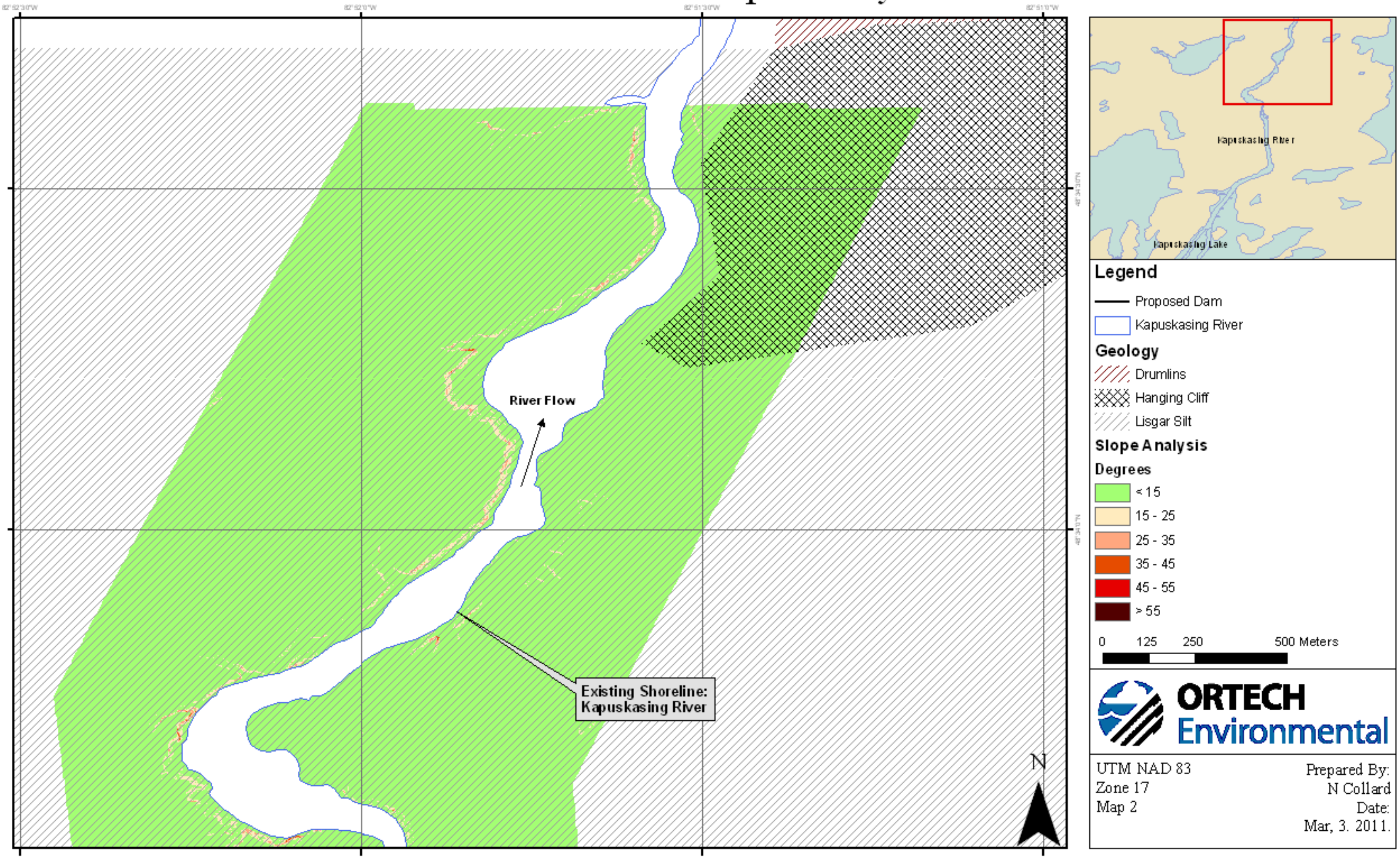
Buchan Falls - Slope Analysis



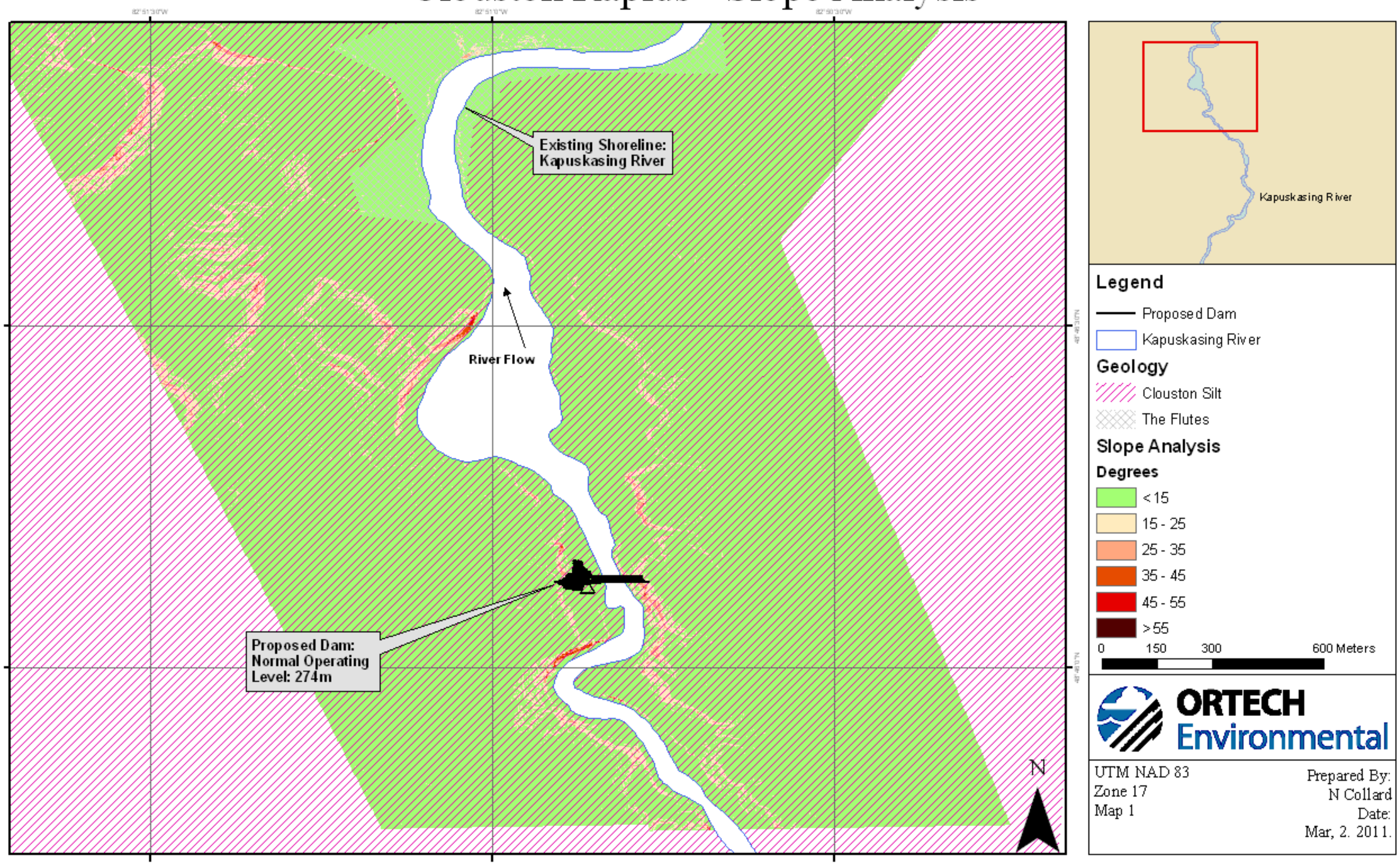
Outlet Lake - Slope Analysis



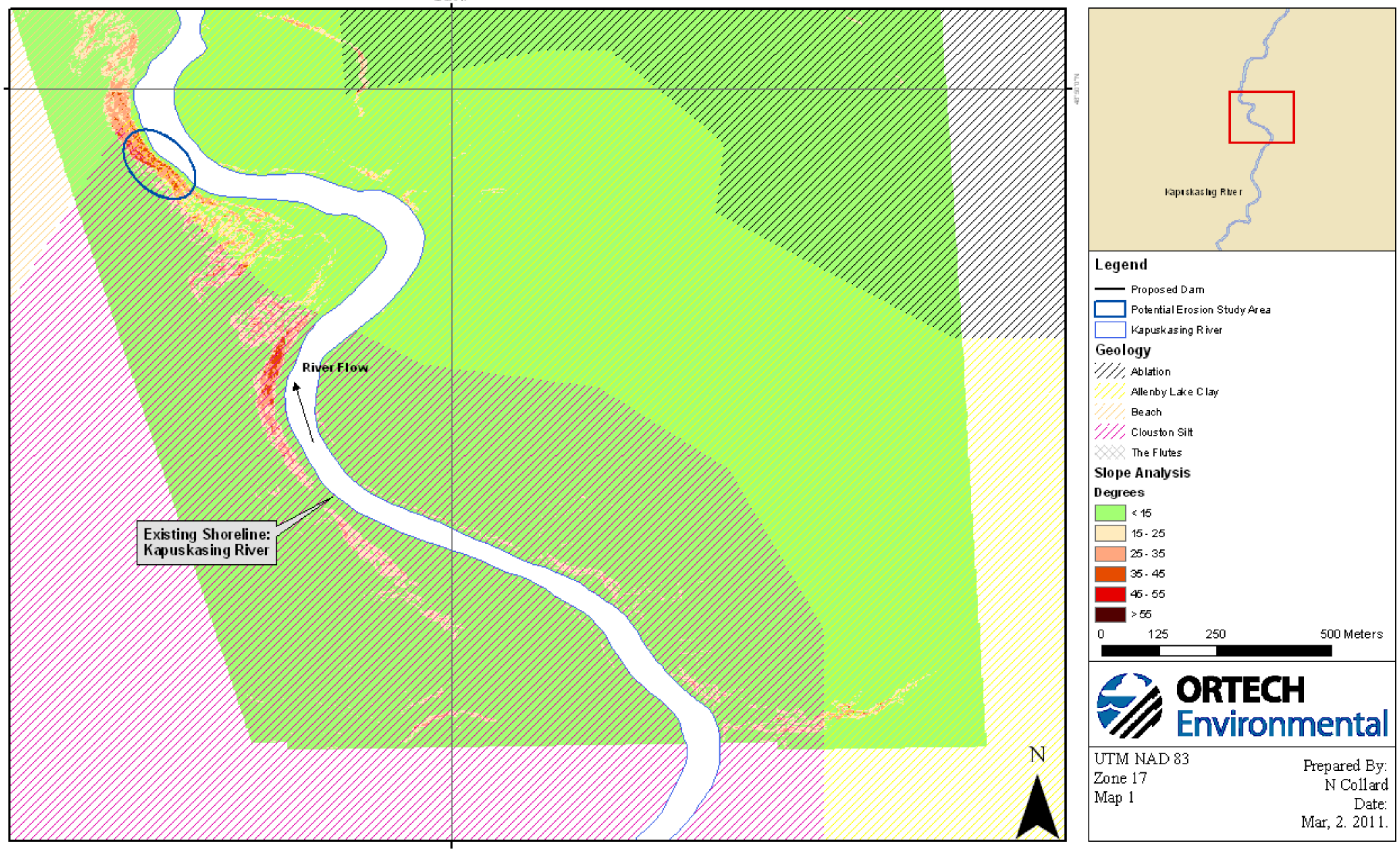
Outlet Lake - Slope Analysis



Clouston Rapids - Slope Analysis



Cedar Rapids - Slope Analysis



Cedar Rapids - Slope Analysis