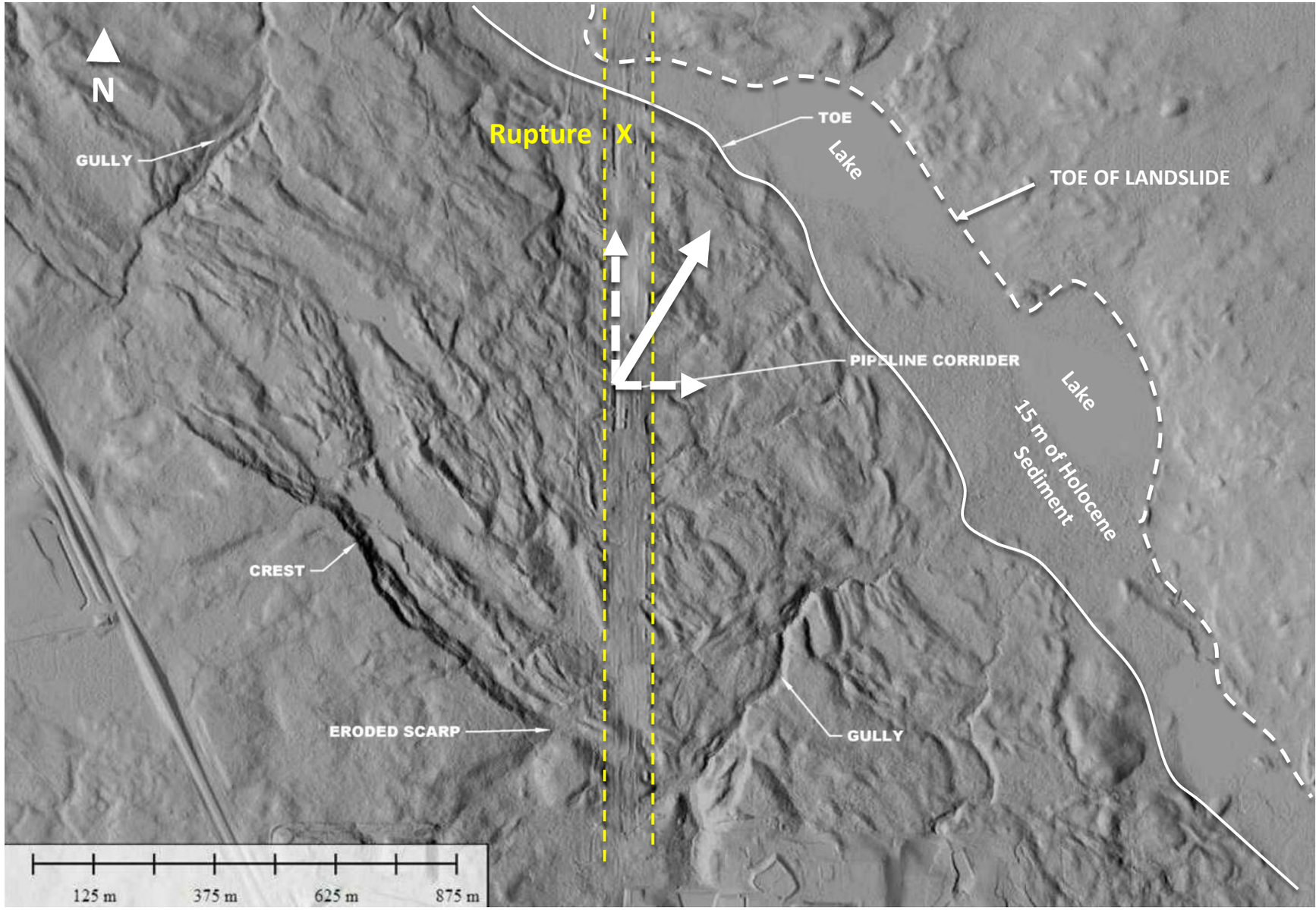
Geohazard risk assessment and asset management along railway corridors

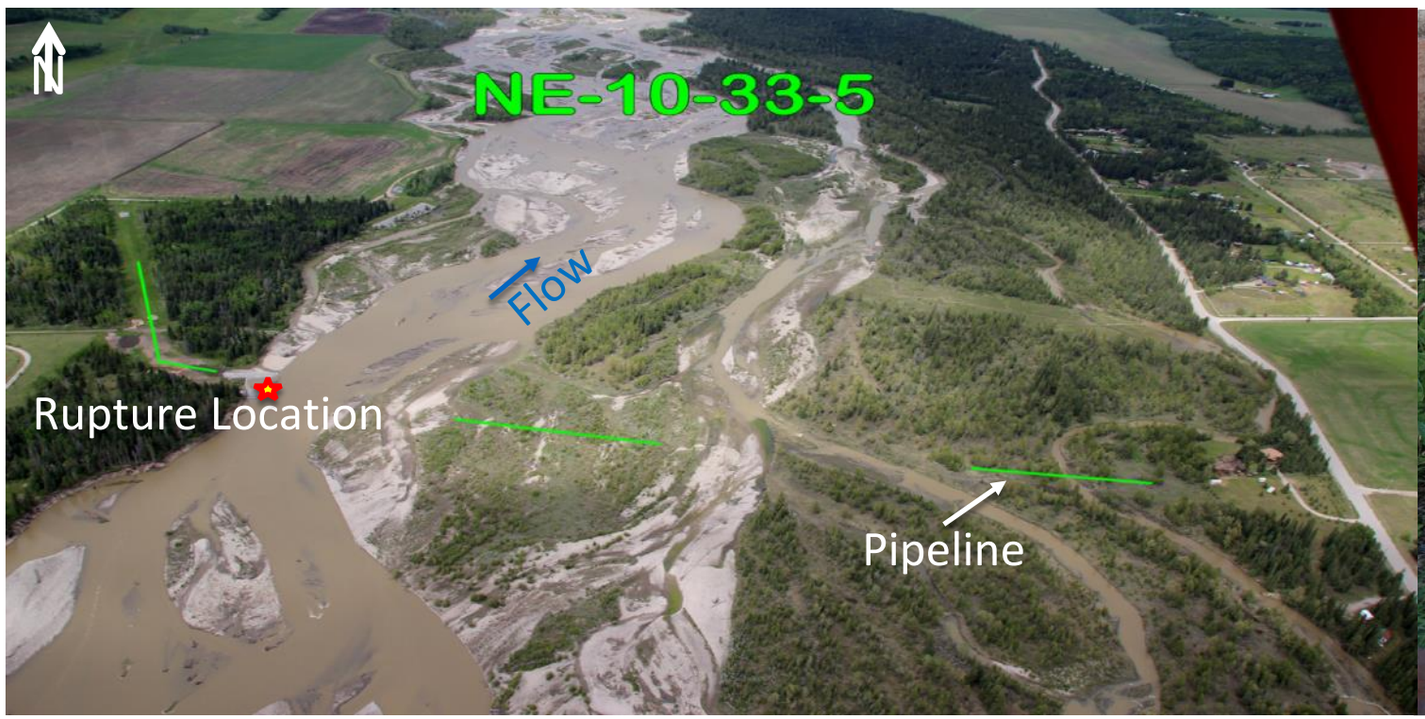
BGC: Matt Lato, Pete Quinn, Mark Pritchard, Mike Porter and Sarah Newton
IOC: Dominique Sirois

bgcengineering.com

BGC

BGC supports risk-based geohazard management for linear and distributed infrastructure, including: pipelines, highways, railways, communities and mines.


N
GULLY
Rupture X
TOE
Lake
TOE OF LANDSLIDE
PIPELINE CORRIDER
Lake
15 m of Holocene Sediment
CREST
ERODED SCARP
GULLY
125 m
375 m
625 m
875 m

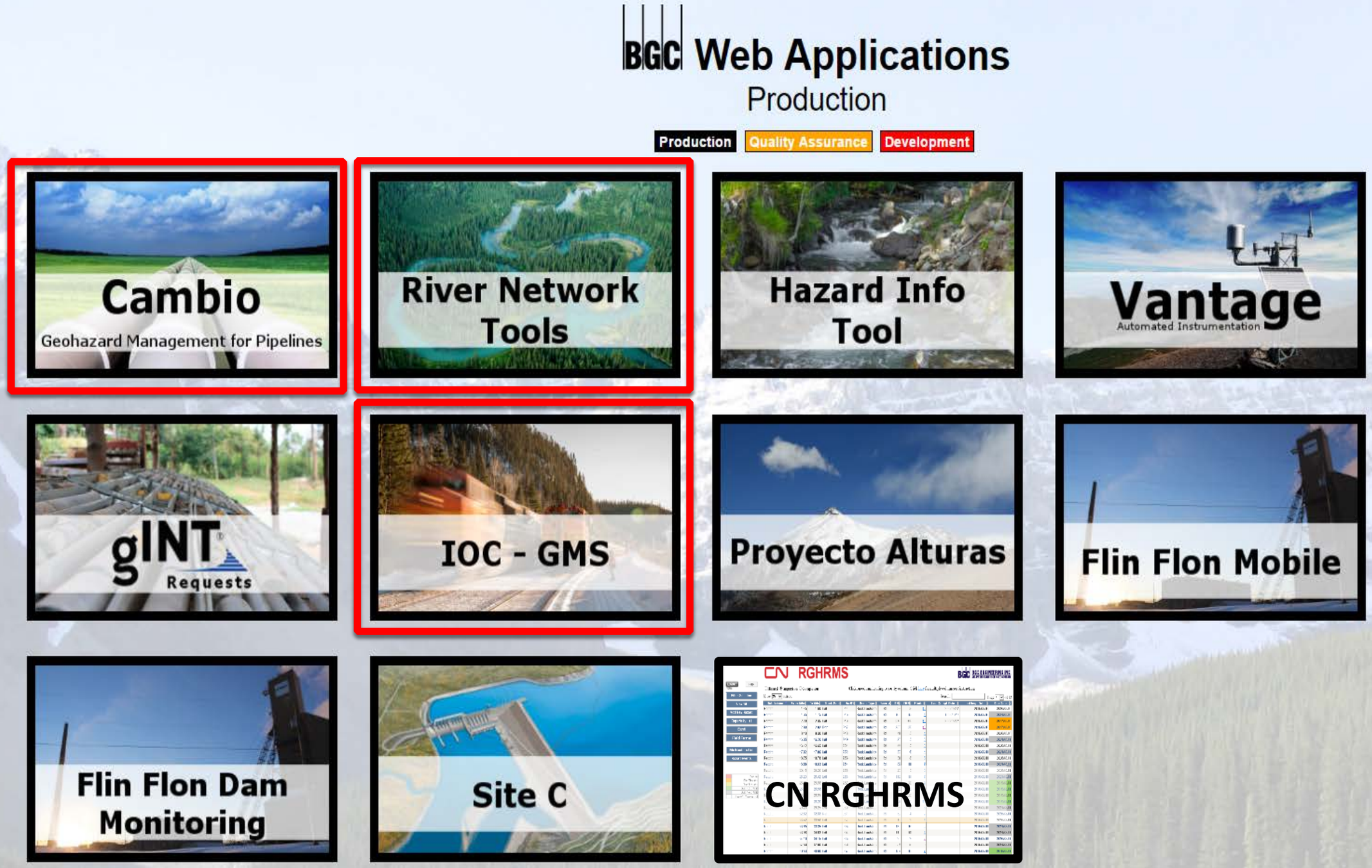

N
NE-10-33-5
Flow
Rupture Location
Pipeline


kink
6 o'clock orientation
Cut end

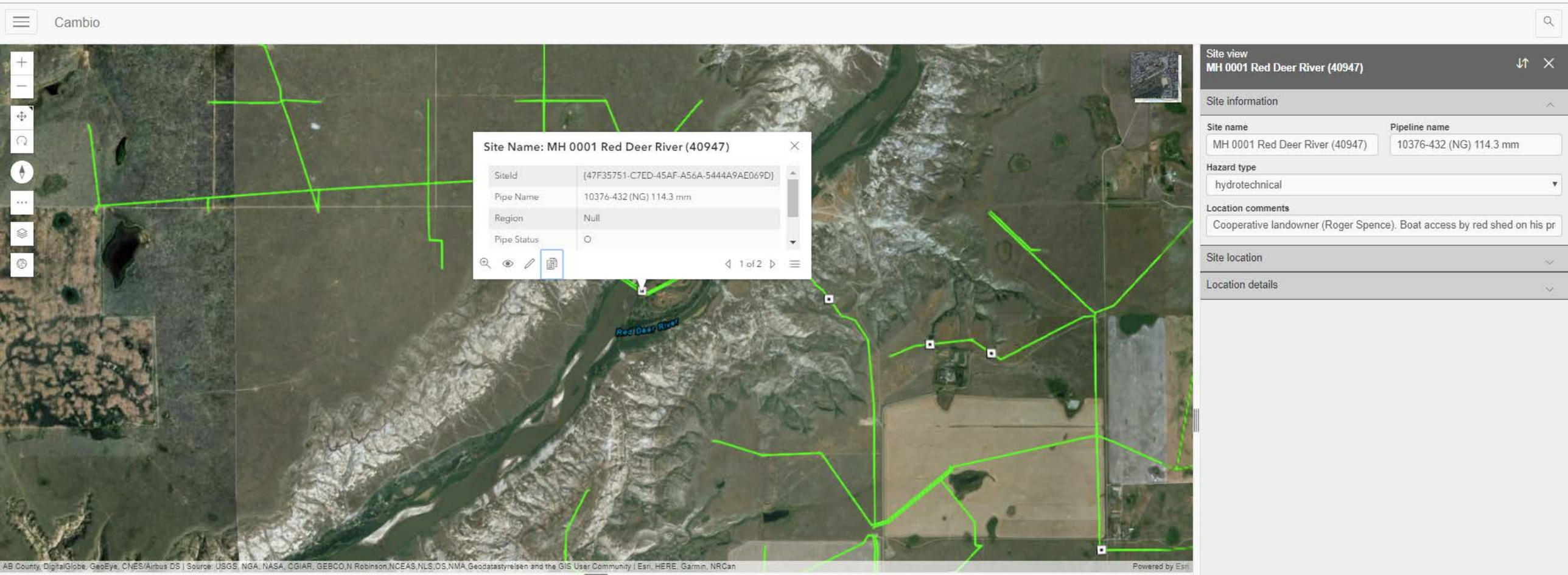
BGC

Cambio$_{Pipeline}$ contains >135,000 documented geohazards along 300,000 km of pipeline for 18 operators.

BGC's geohazard management platforms

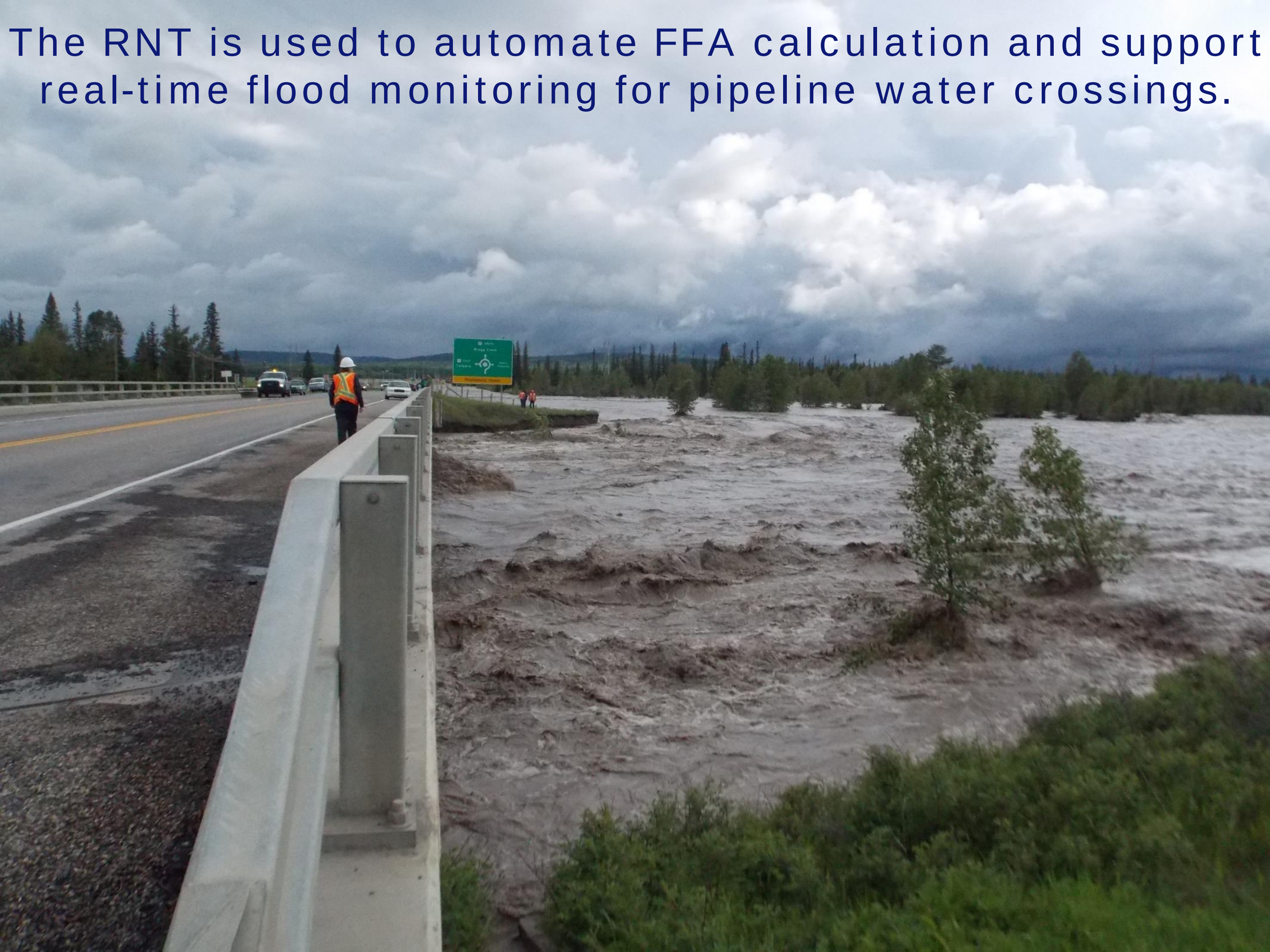


Cambio$_{Pipelines}$ combines real-time monitoring, inspection and historical data with risk-based algorithms to help operators make decisions to prevent failures and reduce consequences.



bgcengineering.com

The RNT is used to automate FFA calculation and support real-time flood monitoring for pipeline water crossings.



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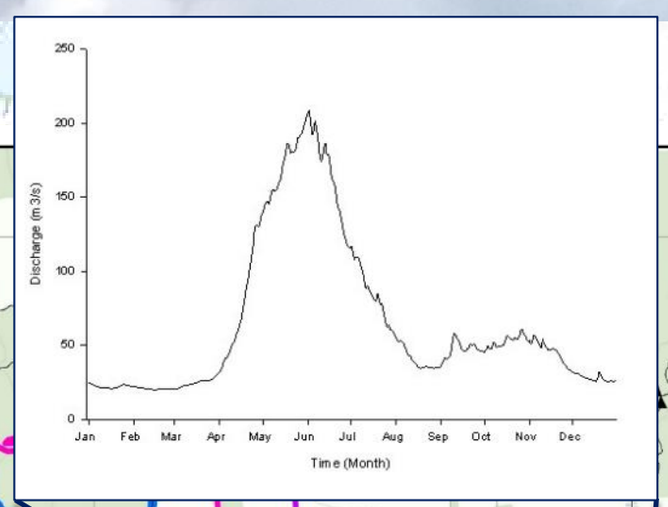


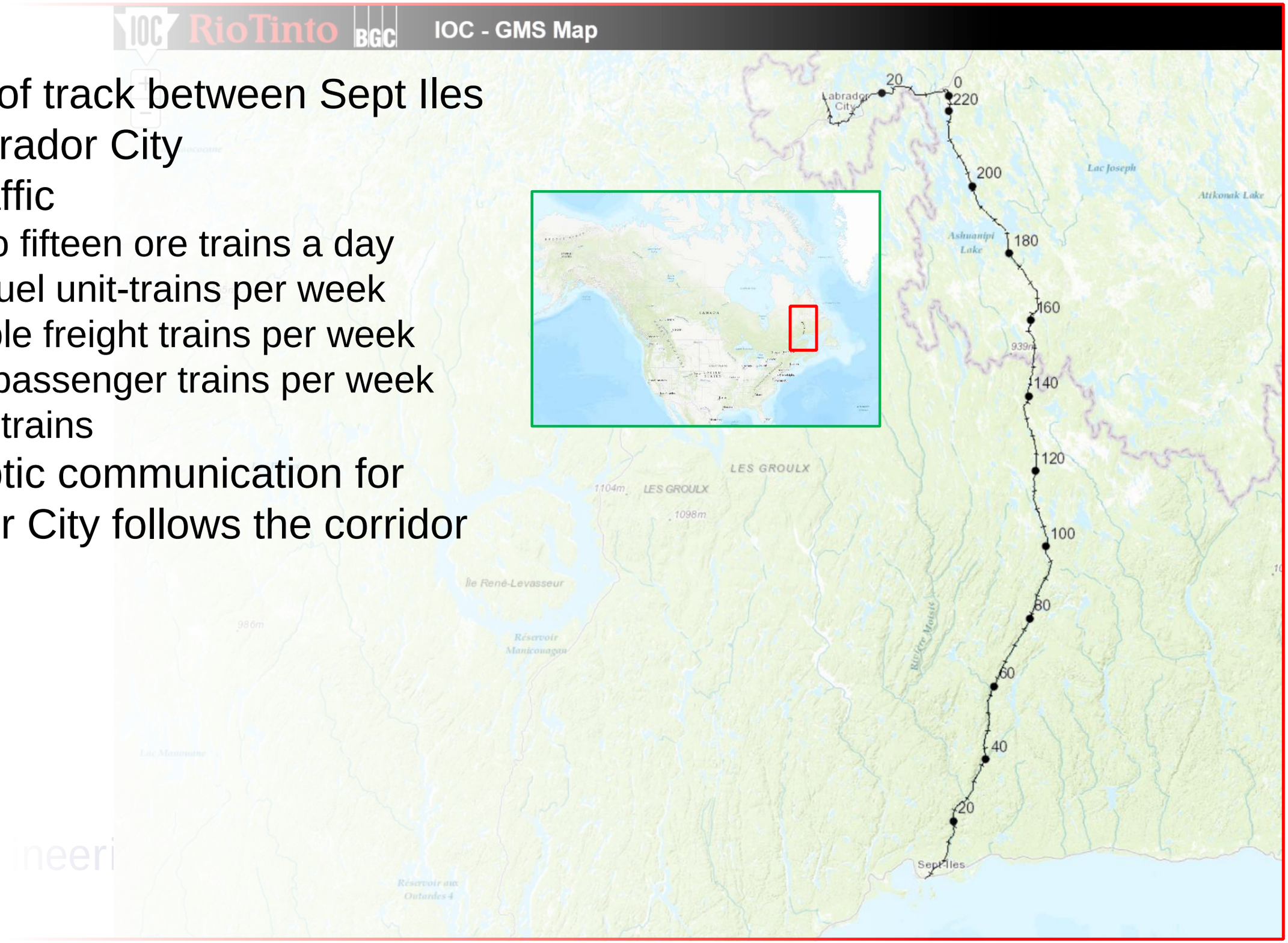
HAZARD: 68034
SEGMENTID: 2001528609
TOTAL CATCHMENT AREA: 41.48 km²

Water Survey of Canada Gauge Station

SCALE 1:50000
2000 1000 0 2000
METRES

The QNS&L railway line

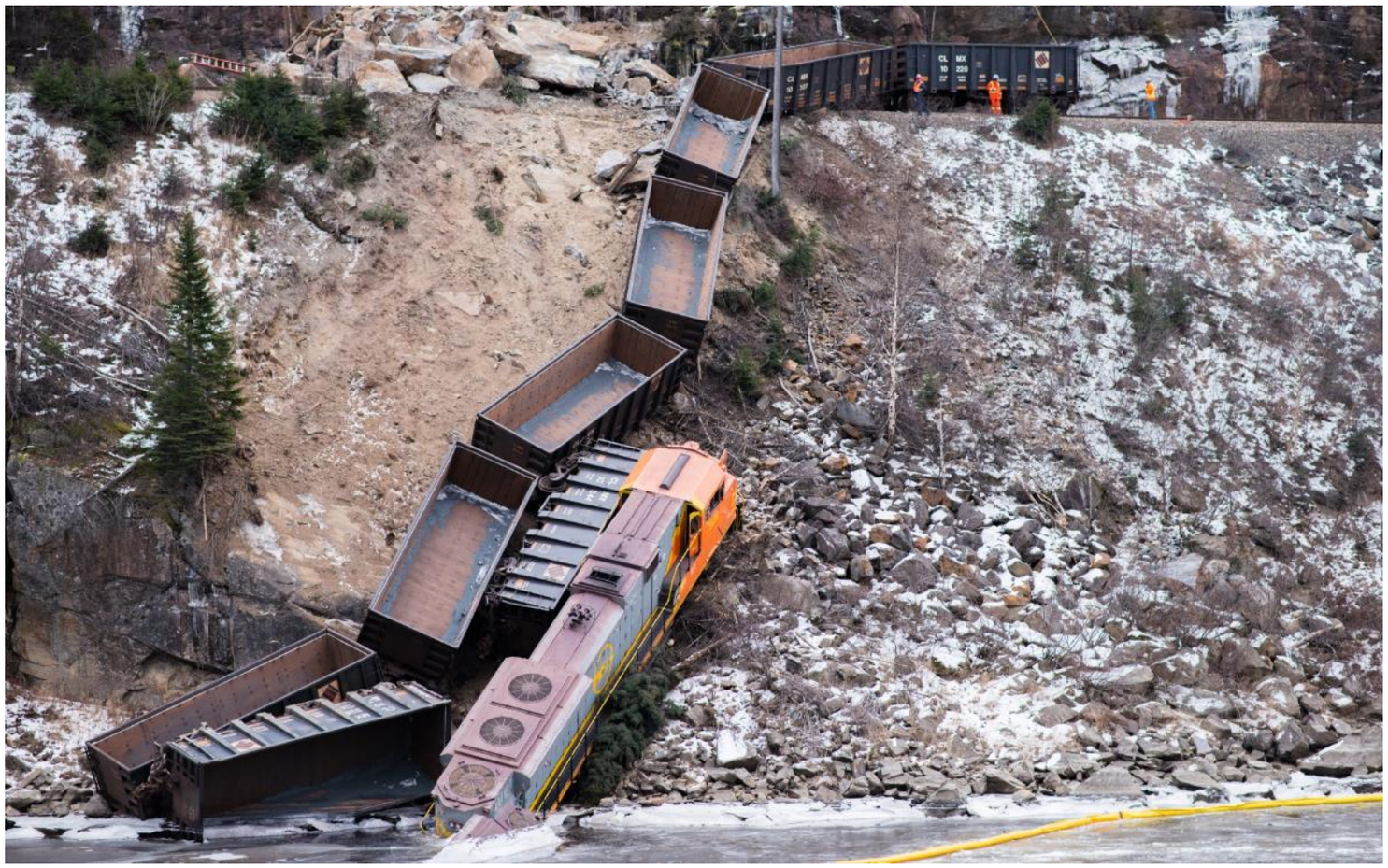
- 420 km of track between Sept Iles and Labrador City
- Daily traffic
  - Ten to fifteen ore trains a day
  - Two fuel unit-trains per week
  - Multiple freight trains per week
  - Four passenger trains per week
  - Work trains
- Fibre-optic communication for Labrador City follows the corridor



Origins of Cambio$_{Rail}$

(IOC Geohazard Management System)

- At approximately 05:30 on November 6, 2014 a northbound (empty) ore train derailed into the Moisie River
  - One locomotive was completely submerged
  - One locomotive derailed onto the embankment
  - Nine empty ore cars derailed onto the embankment



Geohazard risk management framework

Assessment Type

- Geohazard Assessment
- Geohazard Risk Identification
- Geohazard Risk Analysis
- Geohazard Risk Assessment
- Geoazard Risk Management

Risk Communication and Consultation
Informing stakeholders about the risk management process

1. Scope Definition
- a. Recognize the potential hazard
- b. Define the study area and level of effort
- c. Define roles of the client, regulator, stakeholders, and Qualified Registered Professional (QRP)
- d. Identify 'key' consequences to be considered for risk estimation

2. Geohazard Analysis
- a. Identify the geohazard process, characterize the geohazard in terms of factors such as mechanism, causal factors, and trigger factors; estimate frequency and magnitude; develop geohazard scenarios; and estimate extent and intensity of geohazard scenarios.

3. Elements at Risk Analysis
- a. Identify elements at risk
- b. Characterize elements at risk with parameters that can be used to estimate vulnerability to geohazard impact.

4. Geohazard Risk Estimation
- a. Develop geohazard risk scenarios
- b. Determine geohazard risk parameters
- c. Estimate geohazard risk

5. Geohazard Risk Evaluation
- a. Compare the estimated risk against tolerance criteria
- b. Prioritize risks for risk control and monitoring

6. Geohazard Risk Control
- a. Identify options to reduce risks to levels considered tolerable by the client or governing jurisdiction
- b. Select option(s) with the greatest risk reduction at least cost
- c. Estimate residual risk for preferred option(s)

7. Action
- a. Implement chosen risk control options
- b. Define and document ongoing monitoring and maintenance requirements

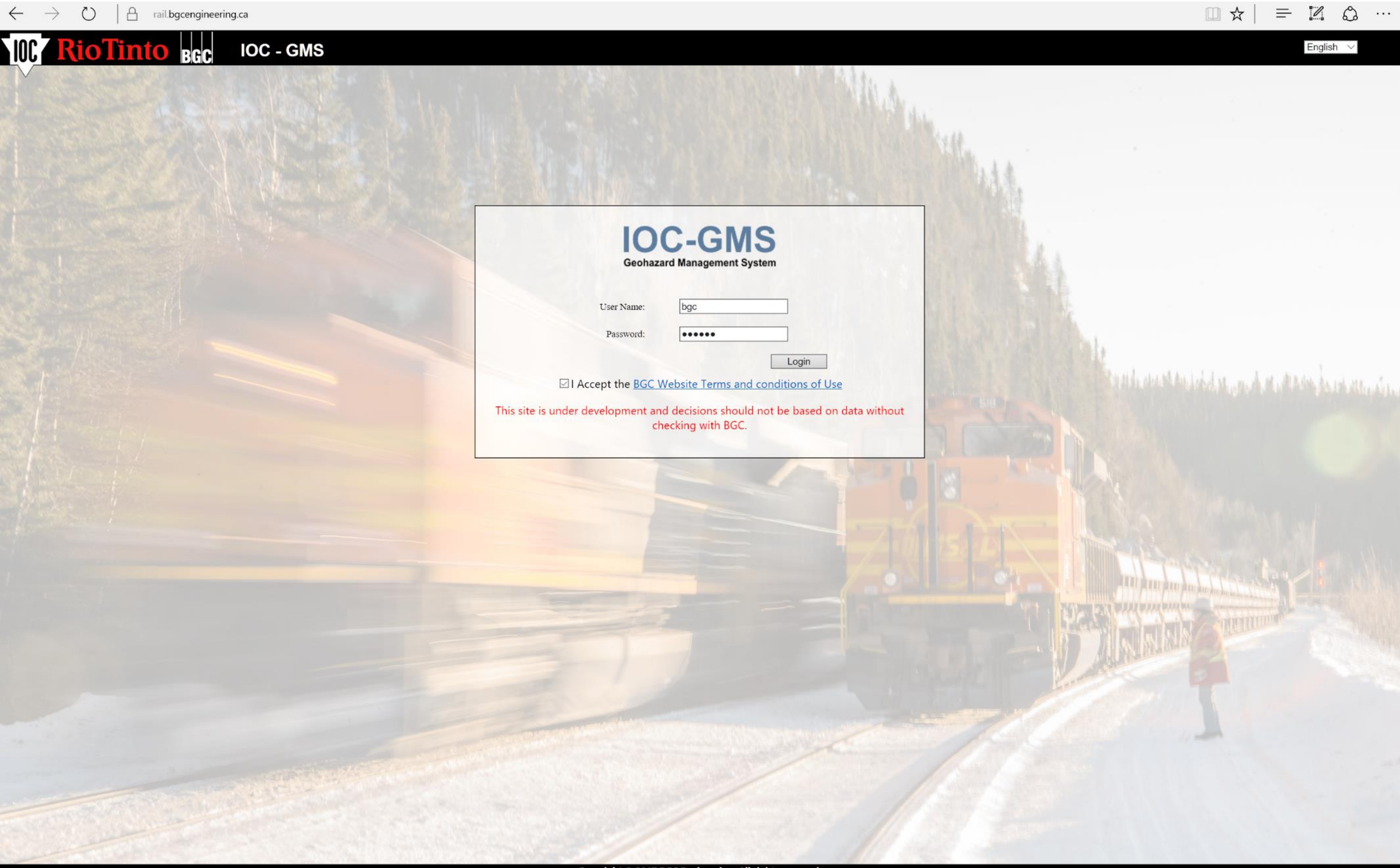
Monitoring and Review
Ongoing review of risk scenarios and risk management process

Key assumptions

- Geohazards conform to a frequency-magnitude relationship, where larger events occur more rarely.
- Large events may be lower risk than a small event if the likelihood of unwanted outcome is sufficiently lower.
- Mitigation priorities depend on risk tolerance for specific consequences, not only event magnitude or frequency

Cambio$_{Rail}$

(IOC Geohazard Management System)



Cambio$_{Rail}$: dashboard

rail.bgcengineering.ca/dashboard.aspx

RioTinto IOC BGC **IOC - GMS Dashboard**

English

Current Weather Conditions

Refresh

Location	MilePoint	Elevation (m)	Air Temp (C)	Ground Temp (C)	24 hour precip (mm)	Landslide TARP *	Rock Fall TARP *	Washout TARP *	Reading Time (EDT)
Gagnon Sud	WAC 15.5	44	11.9	12.9	0	Level 1: 1 h < 7 mm	Level 1	Level 1: 0.5 h < 9.2 mm	2017-09-25 15:44:00
Nicman Nord	WAC 36.2	62	11.4	12	2.4	Level 1: 1 h < 7 mm	Level 1	Level 1: 0.5 h < 9.2 mm	2017-09-25 15:44:00
Tika Nord	WAC 57.8	109	11.7	14	0.3	Level 1: 1 h < 7 mm	Level 1	Level 1: 0.5 h < 9.2 mm	2017-09-25 15:45:00
Premio Sud	WAC 78.9	472	8.1	10.2	1.8	Level 1: 1 h < 7 mm	Level 1	Level 1: 0.5 h < 9.2 mm	2017-09-25 15:44:00
Waco Sud	WAC 100.4	580	7.3	10.7	1.8	Level 1: 1 h < 7 mm	Level 1	Level 1: 0.5 h < 9.2 mm	2017-09-25 15:44:00
Mai Terminal	WAC 128.1	606	6.8	9.7	0	Level 1: 1 h < 7 mm	Level 1	Level 1: 0.5 h < 9.2 mm	2017-09-25 15:44:00
Oreway Camp	WAC 186.6	534	5.5	null	3.5	Level 1: 1 h < 7 mm	Level 1	Level 1: 0.5 h < 9.2 mm	2017-09-25 15:44:00
Menistouc Ouest	NL 11.2	549	4.4	14.2	7.4	Level 1: 1 h < 7 mm	Level 1	Level 1: 0.5 h < 9.2 mm	2017-09-25 15:44:00

Current Stream Flow Conditions

Location	MilePoint	Elevation (m)	Discharge (m^3/s)	Bank Erosion TARP *	Reading Time (EDT)
Moisie River	WAC 14.9	20	435.7	Level 1	2017-09-25 16:00:00

Geohazards | Culverts | Map | Events | Graphs | Weather Links

* TARP levels are presently under testing and development decisions should not be based on data without checking with BGC

Draft Website in Preparation

Cambio$_{Rail}$: tabular database

rail.bgcengineering.ca/HazardListing.aspx

IOC RioTinto BGC IOC - GMS

English

Click Record to View: ○ Hazard ◉ Inspection ○ Completion

Search:

Actions

Filter Selection
View All

Add New Hazard
Export to Excel

Legend

Overdue
Due This Year
Due Next Year
Due in 2-3 Years
Due in 4-5 Years
Due 6-10 Years or null

Subdivision	From Mile	To Mile	Track Side	HazID	Scenario Type	Photos	Haz Rating	Consequence Rating	Risk Rating	Last Insp. Date	Due Date
Wacouna	10.04	10.06	Right Side	563	Earth and Debris Landslide	9	Moderate	Moderate	Level 3	16 Jun 2016	16 Jun 2021
Wacouna	10.15	10.15	Left Side	832	Washout	9	Low	Moderate	Level 2	16 Jun 2016	16 Jun 2021
Wacouna	10.19	10.29	Both Sides	564	Earth and Debris Landslide	4	Non-Credible	Unknown	Unknown	18 Aug 2015	
Wacouna	10.45	10.45	Right Side	844	Washout	8	Low	Moderate	Level 2	16 Jun 2016	16 Jun 2021
Wacouna	10.60	10.60	Both Sides	797	Washout	9	High	Moderate	Level 4	16 Jun 2016	16 Jun 2019
Wacouna	10.74	10.74	Left Side	847	Washout	14	High	High	Level 5	16 Jun 2016	16 Jun 2019
Wacouna	10.85	10.92	Left Side	566	Earth and Debris Landslide	5	Low	Moderate	Level 2	16 Jun 2016	16 Jun 2021
Wacouna	10.94	10.94	Left Side	833	Washout	0	Non-Credible	Moderate	Non-Credible	18 Aug 2015	18 Aug 2025
Wacouna	10.95	11.00	Right Side	500	Earth and Debris Landslide	2	Non-Credible	Unknown	Unknown	18 Aug 2015	
Wacouna	100.17	100.20	Right Side	582	Earth and Debris Landslide	6	Low	High	Level 3	27 Aug 2015	27 Aug 2020
Wacouna	100.54	100.54	Right Side	804	Washout	1	Low	Very High	Level 4	27 Aug 2015	27 Aug 2018
Wacouna	101.45	101.45	Right Side	896	Washout	4	Non-Credible	Very High	Non-Credible	27 Aug 2015	27 Aug 2025
Wacouna	101.75	101.75	Right Side	781	Washout	4	Low	High	Level 3	27 Aug 2015	27 Aug 2020
Wacouna	102.11	102.11	Right Side	861	Washout	2	Low	Very High	Level 4	27 Aug 2015	27 Aug 2018
Wacouna	103.48	103.50	Right Side	583	Earth and Debris Landslide	4	Non-Credible	Unknown	Unknown	27 Aug 2015	
Wacouna	103.53	103.56	Right Side	584	Earth and Debris Landslide	5	Non-Credible	Unknown	Unknown	27 Aug 2015	
Wacouna	103.94	104.00	Right Side	585	Earth and Debris Landslide	6	Low	Very High	Level 4	27 Aug 2015	27 Aug 2018
Wacouna	106.33	106.39	Left Side	586	Earth and Debris Landslide	7	Non-Credible	Unknown	Unknown	27 Aug 2015	
Wacouna	11.06	11.06	Left Side	871	Washout	5	Moderate	High	Level 4	16 Jun 2016	16 Jun 2019
Wacouna	11.10	11.15	Right Side	570	Earth and Debris Landslide	2	Non-Credible	Unknown	Unknown	18 Aug 2015	
Wacouna	11.22	11.24	Right Side	565	Earth and Debris Landslide	10	High	High	Level 5	16 Jun 2016	16 Jun 2019
Wacouna	11.23	11.25	Right Side	1	Rock Fall	4	Moderate	Very High	Level 5	16 Jun 2016	16 Jun 2019
Wacouna	11.23	11.25	Left Side	2	Rock Fall	6	Moderate	Very High	Level 5	16 Jun 2016	16 Jun 2019
Wacouna	11.25	11.63	Unlined Tunnel	3	Rock Fall	28	Very High	High	Level 6	18 May 2017	18 May 2018
Wacouna	11.63	11.64	Right Side	4	Rock Fall	5	High	High	Level 5	18 May 2017	18 May 2020
Wacouna	11.63	11.64	Left Side	5	Rock Fall	2	Moderate	High	Level 4	18 May 2017	18 May 2020
Wacouna	11.65	11.66	Right Side	2277	Below Track Rock Fall	35	Moderate	High	Level 4	26 Oct 2016	26 Oct 2019
Wacouna	11.66	11.68	Both Sides	1076	Below Track Rock Fall	18	High	High	Level 5	18 Jun 2016	18 Jun 2019
Wacouna	11.86	12.04	Right Side	965	Earth and Debris Landslide	4	Low	High	Level 3	18 Jun 2016	18 Jun 2021
Wacouna	11.90	11.92	Right Side	567	Earth and Debris Landslide	6	Non-Credible	Unknown	Unknown	18 Aug 2015	

Showing 1 to 30 of 724 entries

Show 30 entries Page 1 of 25

Shift-click Header to order by multiple columns

Selection Criteria:
Subdivisions | Wacouna

- Sortable and searchable table with filters for documented geohazards
- Links to photos, rating and inspection history, and planned mitigation
- Automatic assignment date of next inspection based on risk level
- Exportable data and reports

Cambio$_{Rail}$: documentation forms

IOC-GMS
Earth and Debris Landslide Site Characterization Form

BGC ENGINEERING INC. AN APPLIED EARTH SCIENCES COMPANY

Location Information
Date: 16-Jun-2016 **Inspector:** Marc-Andre Brideau
Subdivision: Wacouna
Mileage: 10.04 - 10.06
Track side: Right

Risk Matrix (field estimate)

Annual Probability of Impassable Track	Consequence, given Impassable Track	Risk (expected loss)
P_{gh}: Likely	L_d: Likely	R: Level 3

Required Information

Slope Type:
Embankment or Slope Ar
Embankment or Slope He
Rail to Embankment Cres (below track hazard):
Warning time: Hours
Topographical setting: >

Notes
New material was a metres worth of ma value increased fr

Information/experience fr

IOC-GMS
Washout Site Characterization Form

BGC ENGINEERING INC. AN APPLIED EARTH SCIENCES COMPANY

Location Information
Date: 18-May-2017 **Inspector:** Rebecca Lee
Subdivision: Wacouna
Mileage: 9.78 - 9.78
Track side: Right Side

Risk Matrix (field estimate)

Annual Probability of Impassable Track	Consequence, given Impassable Track	Risk (expected loss)
P_{gh}: Very Unlikely	L_d: Likely	R: Level 3

Required Information

Slope Protection:
Erosion at the Shoulders:
Erosion of the Top of the Em
Evidence of Embankment Slo
Channel Obstructions:
Ponded Water Upstream of
Sediments Retained Upstrea
Embankment material:
Culvert Cross-sectional area

Warning time: A few months
Topographical setting: >25

Notes
This site (IOC-GMS Ha

IOC-GMS
Bank Erosion Site Characterization Form

BGC ENGINEERING INC. AN APPLIED EARTH SCIENCES COMPANY

Location Information
Date: 22-Aug-2015 **Inspector:** Melissa Hairabedian
Subdivision: Wacouna
Mileage: 57.14 - 57.23
Track side: Left Sid

Risk Matrix (field estimate)

Annual Probability of Impassable Track	Consequence, given Impassable Track	Risk (expected loss)
P_{gh}: Unlikely	L_d: Likely	R: Level 5

Required Information

Minimum Perpendicular D
Evidence of Erosion on Er
Evidence of Erosion at the
Regional Channel Pattern
Left bank Vegetation:
Right Bank Vegetation:
Primary Natural Right Ban
Secondary Natural Right

Bank Protection

Right Bank Toe Protectio
Left Bank Toe Protection:
Right Bank Slope Protect
Left Bank Slope Protectio

Warning time: A few wee
Topographical setting: W

IOC-GMS
Rock Slope Site Characterization Form

BGC ENGINEERING INC. AN APPLIED EARTH SCIENCES COMPANY

Location Information
Date: 19-May-2017 **Inspector:** Marc-Andre Brideau
Subdivision: Wacouna
Mileage: 12.20 - 12.27 **8**
Track side: Right Side **Track speed (mph):** 25

Risk Matrix (field estimate)

Annual Probability of Impassable Track	Consequence, given Impassable Track	Risk (expected loss)
P_{gh}: Unlikely	L_d: Likely	R: Level 5
L_{it}: Variable	V: Very Likely	
H: High	C: High	

Required Information

Slope Attributes:
Estimated ○
Measured ◉
(*Pierson et. al 2001, Rockfall catchment area design guide)

Slope Height (m): 15
Slope Angle (°): 90
Ditch width / depth (m): 2.7 / 1.5
Ditch effectiveness* (%): 0.52

Source Zone:
Volume class breakdown (%):
V_1 (< 1 m^3): 0.35
V_2 (1 to 3 m^3): 0.25
V_3 (> 3 m^3): 0.4

Rockfall Frequency
Monthly ○
Yearly ○
1/10 years ◉
> 1/10 years ○

Evidence of Previous Rock Slope Failure
1. Rock fall currently detaching from the slope, tension cracks ☑
2. Presence of detachment scars on the slope ☑
3. Impact marks in the track ballast, ties, or rails ☐
4. Presence of rock fall debris Rock ☑ Soil ☐
5. Damaged vegetation above or adjacent to track ☐
6. Mitigative structure such as mesh nets, lockblock walls, etc. ☑
7. Information/experience from track personnel and train operators ☐

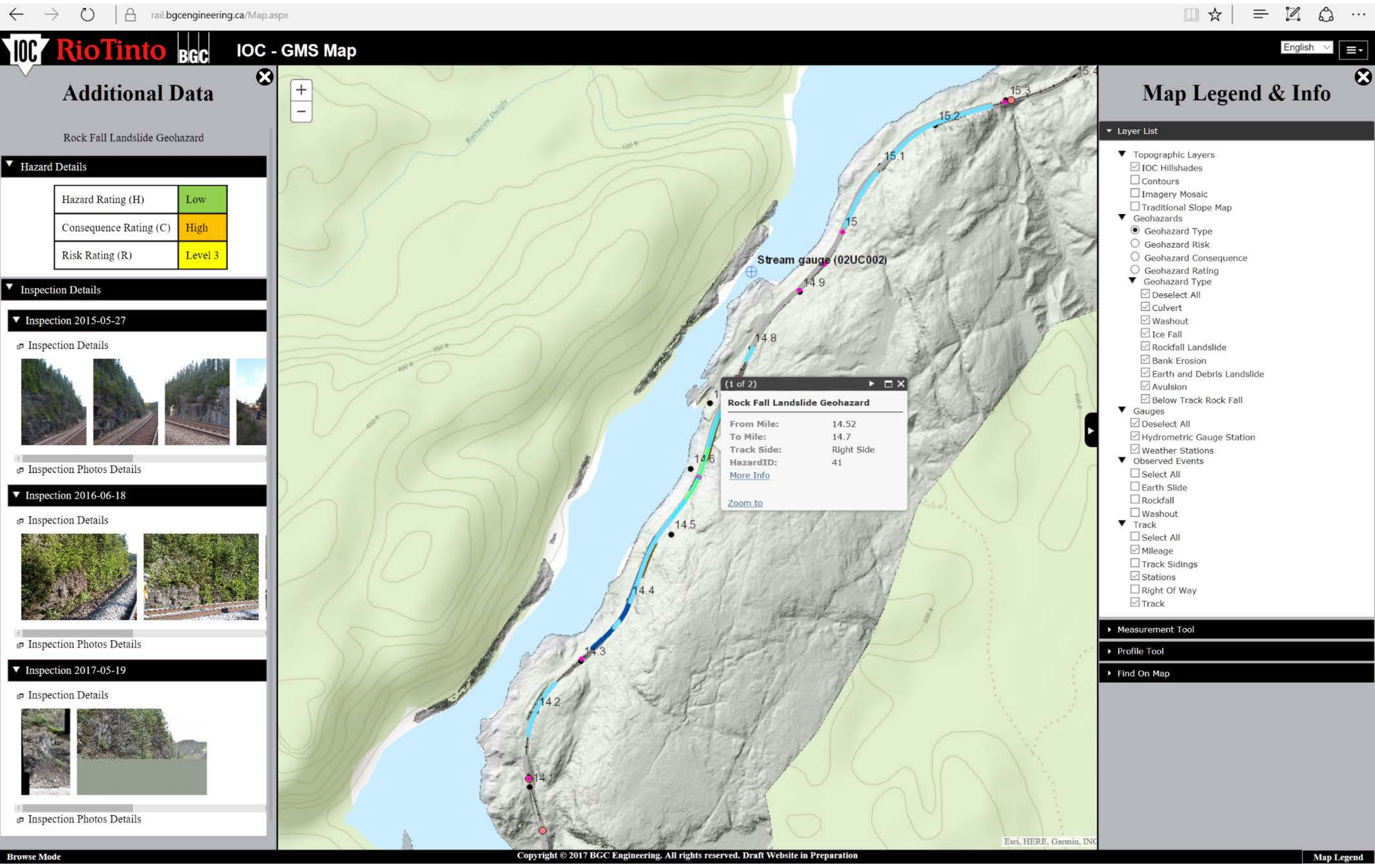
Debris / evidence present
Uphill of track ☑
At grade ☐
Downhill of track ☐

Slope Maintenance: Scaling ☐ Bolts ☑ Mesh ☑

Effectiveness of Slope Mitigation with respect to rock fall reaching the railway

bgcengineering.com

Cambio$_{Rail}$: spatial access to information



Cambio$_{Rail}$: individual site risk estimation

rail.bgcengineering.ca/Inspections.aspx?IID=786

Rating | **Inspection** | **Planning** | **Observations** | Docs | Photos

Wacouna (14.52 - 14.70) - Right Side
Rock Fall Hazard

Inspection 2 of 5
Select Inspection: 22-Oct-2015

Hazard Id: 41
Inspection Id: 786

Geohazard Rating

Annual probability of impassable track from the geohazard (H)					
Classification	**Annual Probability**				
Low	< 0.001	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Moderate	0.001 to < 0.009	**Level 2**	**Level 3**	**Level 4**	**Level 5**
High	0.009 to < 0.09	**Level 3**	**Level 4**	**Level 5**	**Level 6**
Very High	≥ 0.09	**Level 4**	**Level 5**	**Level 6**	**Level 7**
Expected consequence of impassable track (C)	**Indices**	Low	Moderate	High	Very High
	Conditional probability of loss of one or more lives given impassable track occurs	< 0.009	0.009 to < 0.09	0.09 to < 0.081	≥ 0.81

	Previous Rating	Selected Rating
Date	27-May-2015	22-Oct-2015
Hazard Rating (H)	Very High	Moderate
Consequence Rating (C)	High	High
Risk Rating (R)	Level 6	Level 4
Status	Completed	Completed
Status Changed By		
Site Characterization Sheet	View	View

○ Rating Unchanged ◉ Rating Changed

Reason for rating change:
Updated rock fall occurrence frequency based on completion of 2015 stabilization work.

Edit | Save | Delete | New

Photograph - Microsoft Edge

rail.bgcengineering.ca/Photograph.aspx?M=I&IID=786&photoID=13560

View Photo | **Add/Change Photo**

Wacouna (14.52 - 14.70) - Right Side
Inspection Date: 22-Oct-2015

Hazard Id: 41
Inspection ID: 786

Click on image to view photo in full size.

DSCN4379.JPG
DSCN4380.JPG

Set As Hazard Photo

Photo Date: 22-Oct-2015 **File Name:** 20151022-41-DSCN4379.JPG **RPT Photo #:** DSCN4379.JPG

Comment: ------ Select a comment to add to caption description belc | Add Comment To Caption

Caption: View looking track-north from the track-south end of the interval.

Edit | Save | Delete

Cambio$_{Rail}$: TARP warning systems

RioTinto

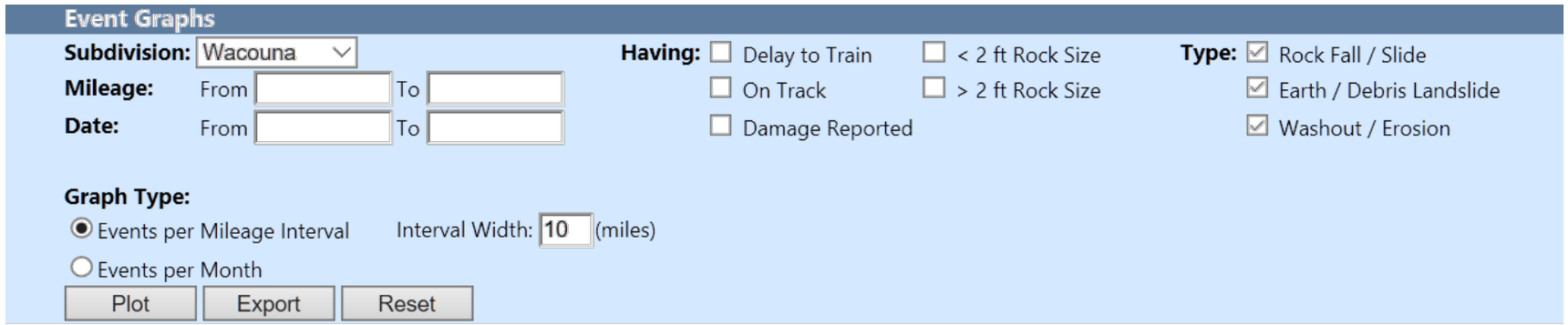
TARP for weather triggered shallow landslides

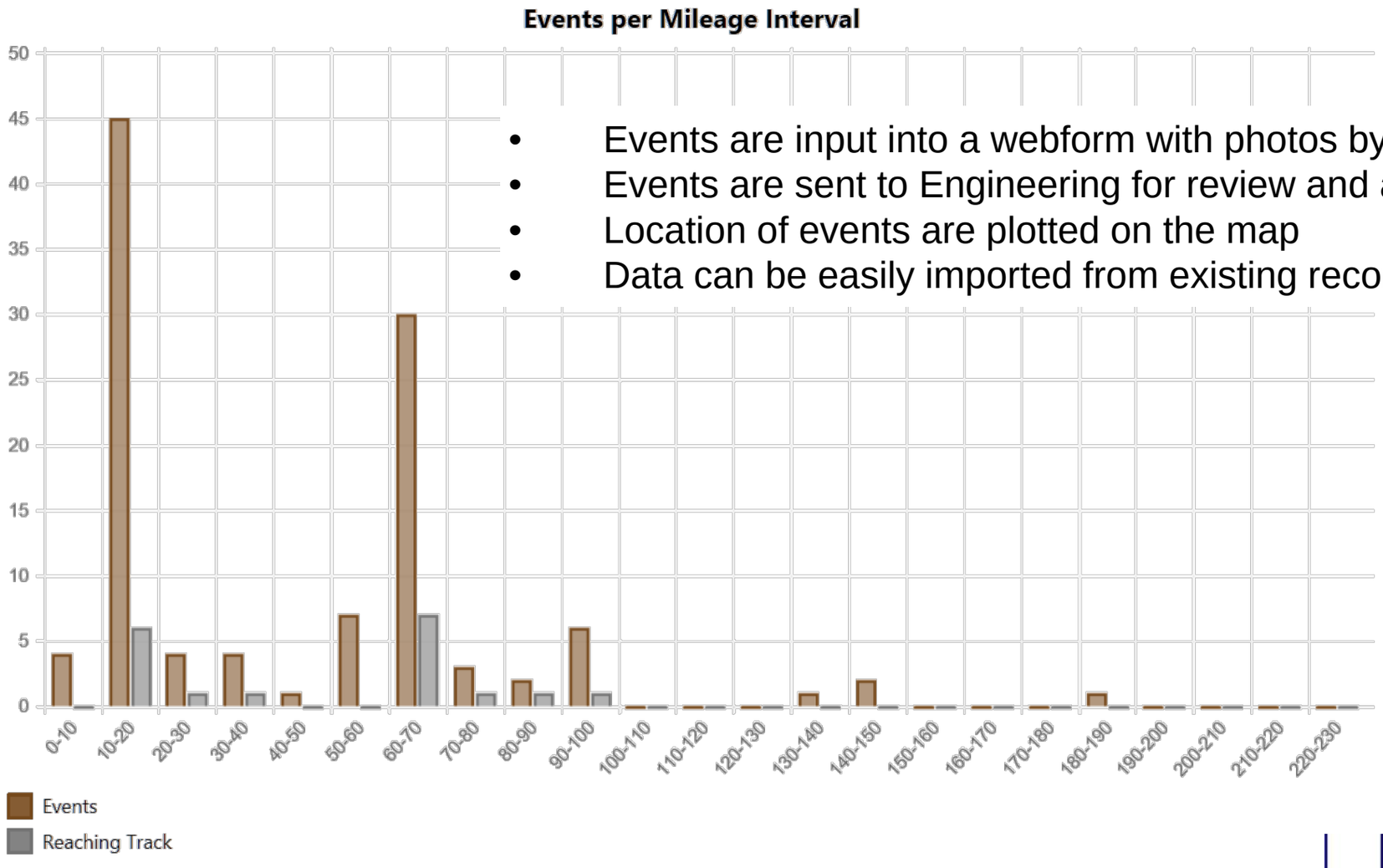
IOC may escalate the TARP levels on any observed monitoring data, beyond that explicitly described in the TARP.

Response Level	Weather Characteristics	Geohazard Activity	Operational Response	Management Response
1	**Rainfall below Threshold 1-2** 1-hr < 7 mm 24-hr < 19 mm 2-hr < 9 mm 48-hr < 23 mm 6-hr < 12 mm 72-hr < 25 mm 12-hr < 15 mm 96-hr < 27 mm	Shallow landslides very unlikely	TBD by IOC	TBD by IOC
2	**Rainfall below Threshold 2-3** 1-hr < 17 mm 24-hr < 44 mm 2-hr < 21 mm 48-hr < 54 mm 6-hr < 29 mm 72-hr < 61 mm 12-hr < 36 mm 96-hr < 67 mm	Sporadic shallow landslides unlikely	TBD by IOC	TBD by IOC
3	**Rainfall below Threshold 3-4** 1-hr < 27 mm 24-hr < 70 mm 2-hr < 33 mm 48-hr < 86 mm 6-hr < 46 mm 72-hr < 97 mm 12-hr < 57 mm 96-hr < 106mm	Sporadic shallow landslides possible	TBD by IOC	TBD by IOC
4	**Rainfall above Threshold 3-4** 1-hr > 27 mm 24-hr > 70 mm 2-hr > 33 mm 48-hr > 86 mm 6-hr > 46 mm 72-hr > 97 mm 12-hr > 57 mm 96-hr > 106mm	Abundant shallow landslides likely	TBD by IOC	TBD by IOC

BGC

Cambio$_{Rail}$: geohazard event database





- Events are input into a webform with photos by track forces
- Events are sent to Engineering for review and approval
- Location of events are plotted on the map
- Data can be easily imported from existing records

bgcengineering.com

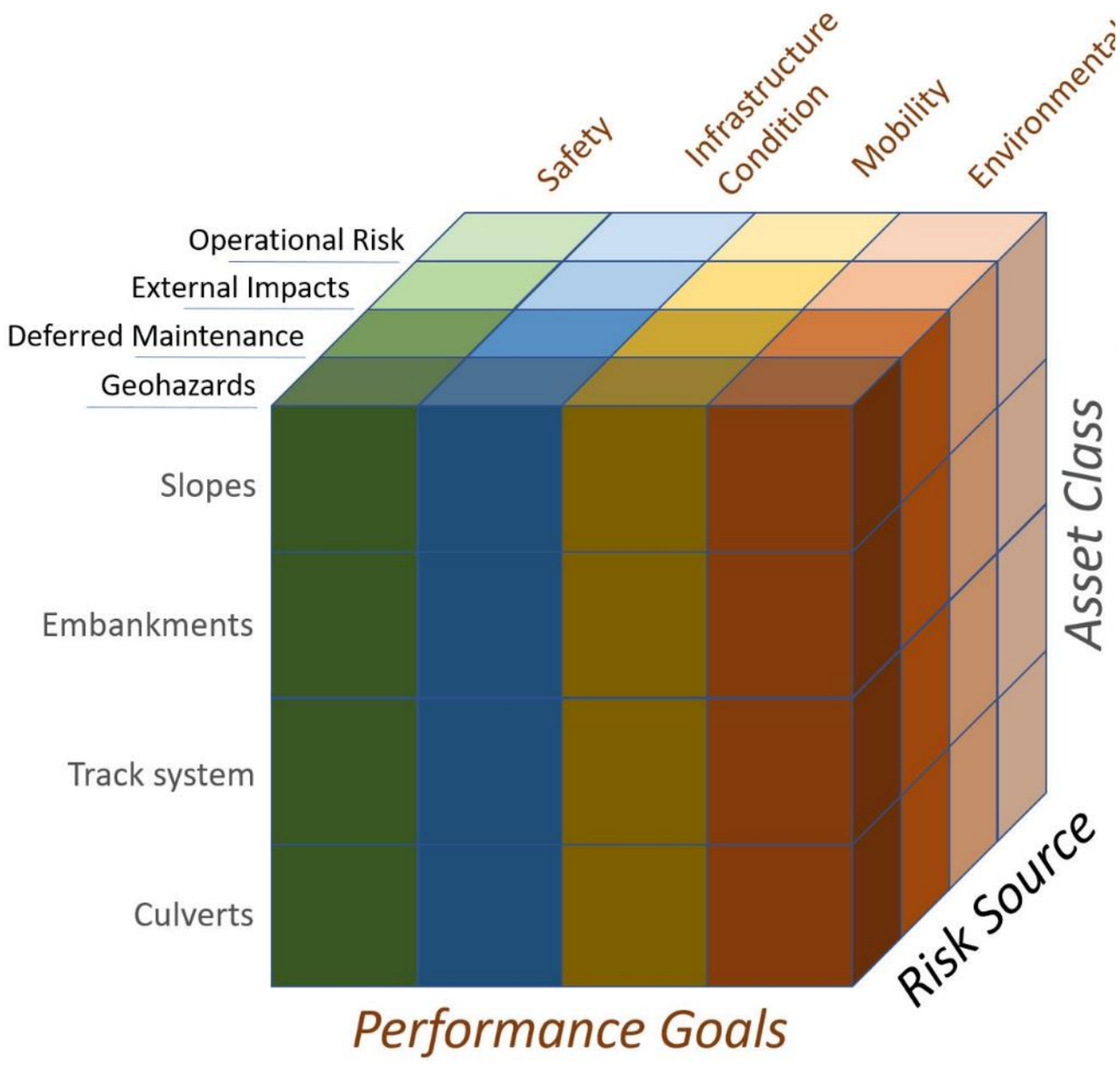
Cambio$_{Rail}$ strengths

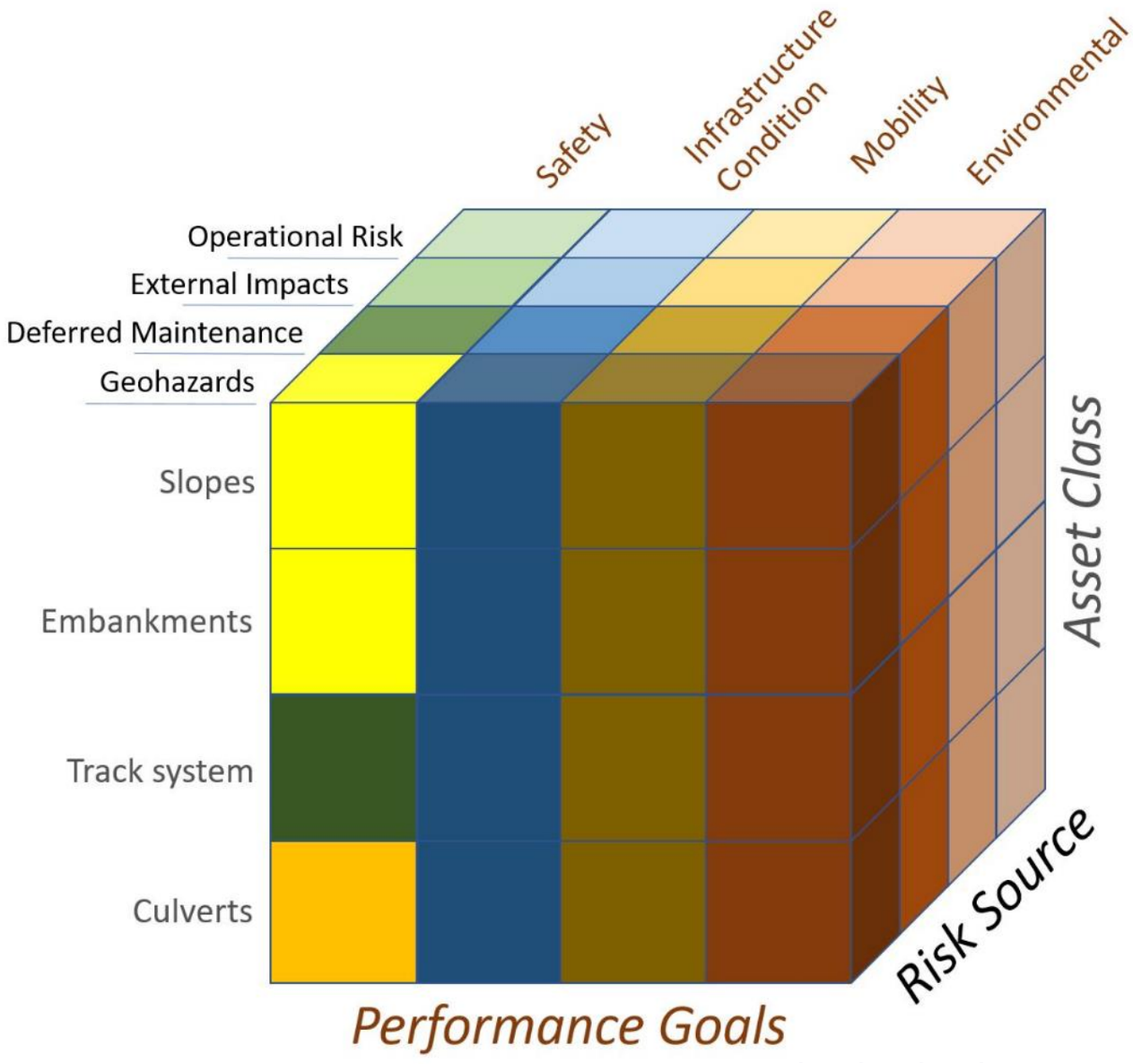
- All geohazards and risk scenarios are assessed using a consistent framework to allow direct comparison between different asset and hazard types
- The IOC-GMS is used by maintenance workers, engineers, planners, and executives
- Information is easily accessible with minimal learning required
- Risk levels reflect corporate standards
- Real-time warning based on live weather data along the railway
- Ability to measure risk reduction versus dollar invested

Cambio$_{Rail}$ outlook

- Expanding the capabilities to include culvert rating and management
- Integrating performance objectives and maintenance scheduling
- Working with Rio Tinto Iron Ore in Australia to implement Cambio$_{Rail}$ for a 1,600 km rail network that connections 16 mines and two port facilities

Cambio$_{Rail}$ outlook: beyond geohazards





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BGC