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GESPE'GEWA'GI
INSTITUTE OF NATURAL UNDERSTANDING

Forest Road Sedimentation Analysis of the Gaspe Peninsula

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Projet 1 (CEGS)

1. Modélisation de l'apport en sédiments aux points d'entrée
(i.e. les traverses)

2. Classer selon le potentiel à générer un transport de particules fines

3. Identifier les points d'entrées à haut risque selon le classement afin de créer et maintenir des fossés de diversion de l'écoulement (voirie)

Projet 2 (CENG)

1. À l'aide des données du Projet 1, classer selon le type de traverse, la pente, l'aire de drainage de la route de part et d'autre, type de dépôt de surface, sensibilité érosive

2. Identifier les traverses les plus problématiques (passage poissons x apports en sédiments)

3. Dresser une liste de projets priorisés pour la restauration

Aire d'étude

Divisée en 14 grands sous-bassin versants

Superficie (km^2)

32K

Cours d'eau (km)

62K

Routes (km)

54K

How do roads affect sedimentation?

- Impervious surfaces will create more runoff volume and at a faster delivery rate to watercourse.
- Non-impervious surfaces (forest roads) still facilitate the delivery and volume due to low absorption/percolation of the forest road.
- Non-maintained, poorly designed, or abandoned forest roads not only facilitate the above problems, the rate of erosion and sediment input into the watercourse drastically increases.

How can we identify areas of erosion risk/roadside runoff at a watershed scale?

- Using high resolution LiDAR DEM that is broadly available.
- Extracting landscape characteristics and drainage networks from a DEM.
- Creating models around the extracted terrain features and flow modelling to determine areas of concern.

GINU Stream Crossing Database
5,241 Culverts

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GINU Stream Crossing Database
5,241 Culverts

Crossing #	Culvert Length (m)	Elevation Difference	Slope	Elevation 1	Elevation 2	Upstream Km	X	Y	Watershed	River
0	10.00	1.99	19.89	286.76	284.77	0	-64.76875	48.862744	YORK	York, Rivière
425	13.43	0.08	0.59	168.78	168.86	0	-67.874812	48.675697	TARTIGOU	Tartigou, Rivière
465	8.13	0.40	4.92	64.35	64.75	2.03	-66.183709	48.144478	STEWART	Stewart, Rivière
493	8.51	0.65	7.67	57.92	58.57	10.49	-66.72221	49.0794	FOURNIER	Fournier, Ruisseau à
507	9.02	0.37	4.15	30.34	29.96	0.12	-66.614381	49.103138	GAGNON	Gagnon, Ruisseau

GINU Stream Crossing Database
1,134 Bridges

GINU Stream Crossing Database
1,134 Bridges

Crossing #	X	Y	Watershed	River
0	-64.967301	48.87419	YORK	York, Rivière
23	-67.787638	48.734119	TARTIGOU	Tartigou, Rivière
45	-64.898249	48.192019	ANSE À LA BARBE	Anse à la Barbe, Rivière de l'
74	-65.132301	48.063567	PASPÉBIAC	Paspébiac, Rivière
93	-64.967878	48.251475	PORT-DANIEL	Port-Daniel, Rivière

GINU Stream Crossing Database
1,010 Fords

GINU Stream Crossing Database
1,010 Fords

Crossing #	X	Y	Watershed	River
0	-65.157448	49.038434	YORK	York, Rivière
99	-65.2385	49.205136	GRAND RUISSEAU	Grand Ruisseau, Le
135	-65.68136	48.173802	CAPLAN	Caplan, Rivière
158	-65.813769	49.165186	MONT-SAINT-PIERRE	Mont-Saint-Pierre, Rivière de
181	-64.450104	48.541578	MURPHY	Murphy

GINU Stream Crossing Database
207 Impoundments

GINU Stream Crossing Database
207 Impoundments

Crossing #	X	Y	Watershed	River
0	-65.435106	48.914712	YORK	York, Rivière
9	-66.53132	48.962661	SAINTE-ANNE	Sainte-Anne, Rivière
34	-66.235045	48.251833	NOUVELLE	Nouvelle, Rivière
54	-67.290508	48.552639	MATANE	Matane, Rivière
81	-65.764132	48.643181	CASCAPÉDIA	Cascapédia, Petite rivière

GINU Stream Crossing Database Summary

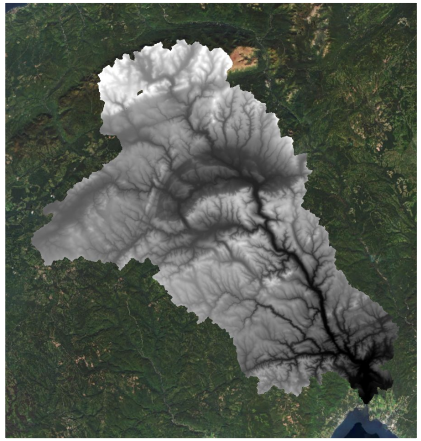
- 5,241 culverts
- 1,134 bridges
- 1,010 fords
- 207 impoundments

Total # of crossings

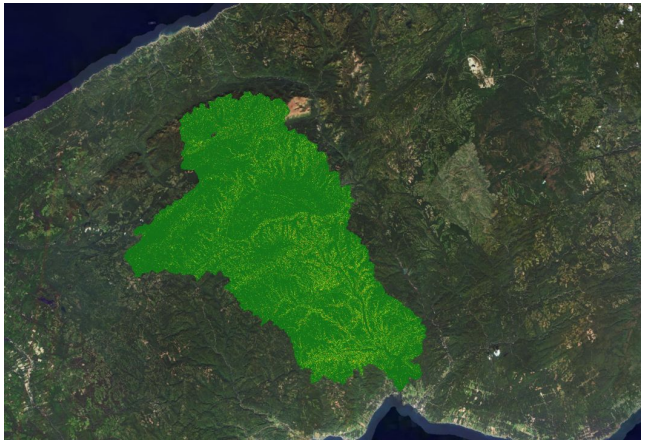
7,592

Sedimentation Study Area

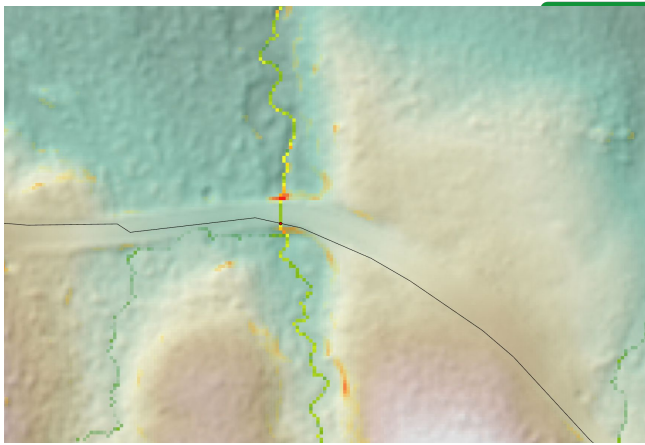
3 step methodology for identifying sedimentation at a watershed scale



Step 1: Use the Revised Universal Soil Loss Equation (RULSE) to identify areas that have are most vulnerable to erosion relative to the study area (watershed).



Step 2: Use the RULSE output and isolate them to stream-road crossings that have increased erosion chance.



Step 3: Identify the sediment sources (ditch, road/stream embankment, culvert, road, etc.…) at each individual stream crossing.

Watershed-scale → All stream crossings → SPI Individual crossing

The Universal Soil Loss Equation (USLE)

A= RKLSCP

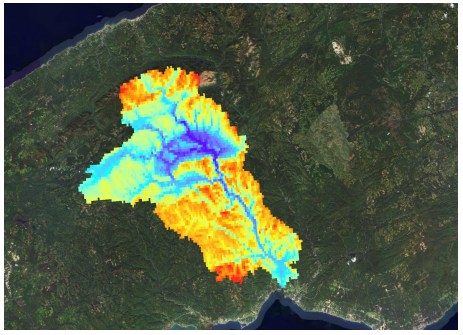
- Where:

- A= mean annual soil loss
- R= Rainfall Erosivity Factor
- K= Soil Erodibility Factor
- L= Slope Length Factor
- S= Slope Steepness Factor
- C= Crop Management Factor
- P= Erosion Control Practice Factor

Methodology: RULSE Inputs

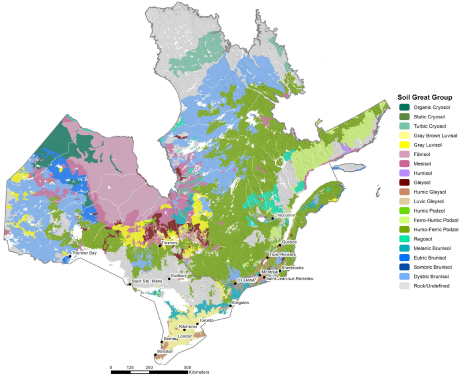
Annual Soil Loss (tons/hectare/year) =

Rainfall Erosivity

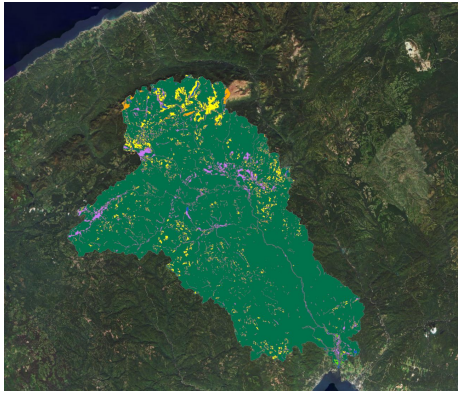


Rain Erosivity (R) = 732 – 1066 MJ mm ha^{-1} h^{-1} yr^{-1}

Soil Erodibility Factor



Land Use Index



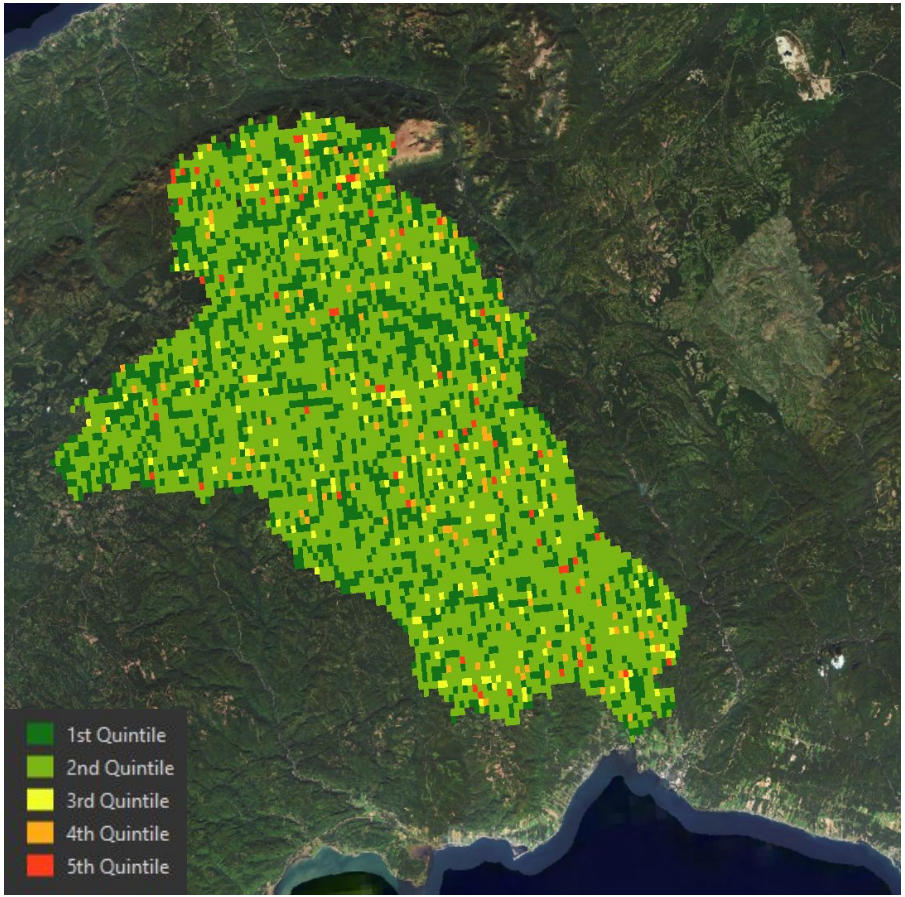
Length and steepness of slope factor

$$LS = \left(flow\ accumulation \times \frac{Cell\ Size}{22.13} \right)^{0.5} \times \frac{Sin\ (Slope)}{0.0896}^{1.3}$$

The Universal Soil Loss Equation (USLE)

Symbol	Description	Data Source	Spatial Resolution	Source
R	Rainfall Erosivity	GloReda (Panagos et al., 2017-2023)	-	https://www.sciencedirect.com/science/article/pii/S2352340923005826
K	Soil Erodibility	Donnees Quebec	100 meter	https://www.donneesquebec.ca/recherche/dataset/siigsol-100m-carte-des-proprietes-du-sol
L	Slope Length	User Generated	1 meter	-
S	Slope Steepness	User Generated	1 meter	-
C	Vegetation Cover	Donnees Quebec	30 meters	https://www.donneesquebec.ca/recherche/dataset/carte-ecoforestiere-avec-perturbations
P	Support Practice	Donnees Quebec	30 meters	https://www.donneesquebec.ca/recherche/fr/dataset/utilisation-du-territoire

The Universal Soil Loss Equation (USLE)



A= mean annual soil loss

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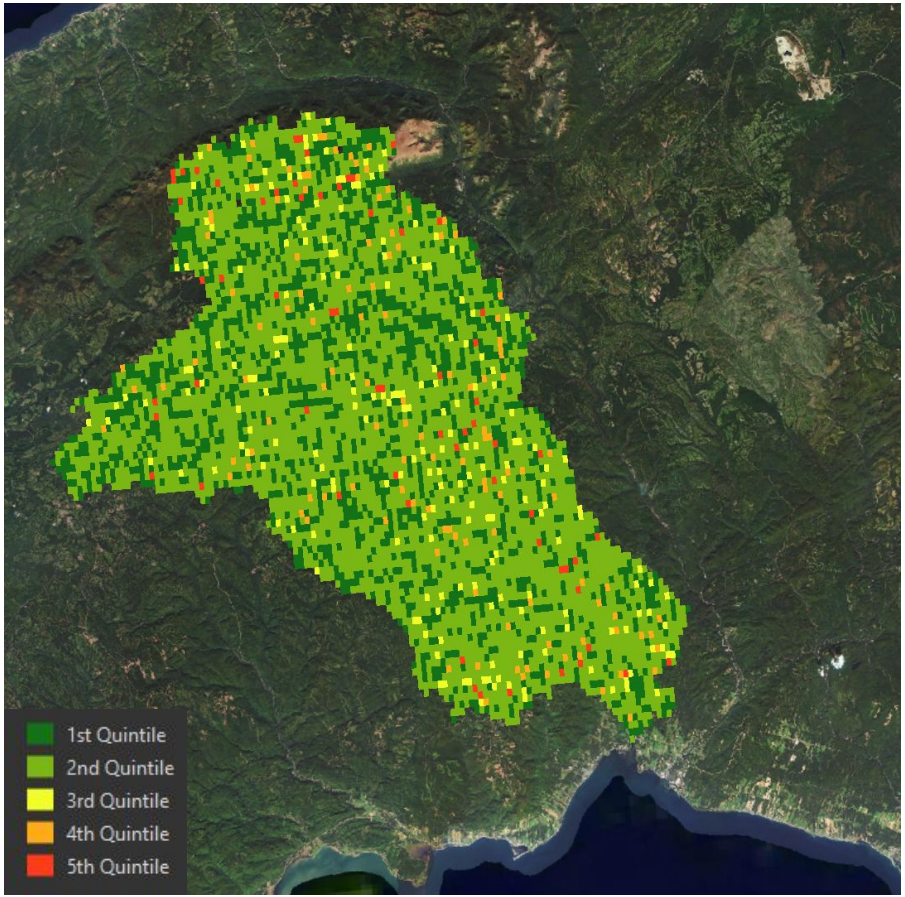
Why use Quintiles instead of estimating tonnes/hectare/year

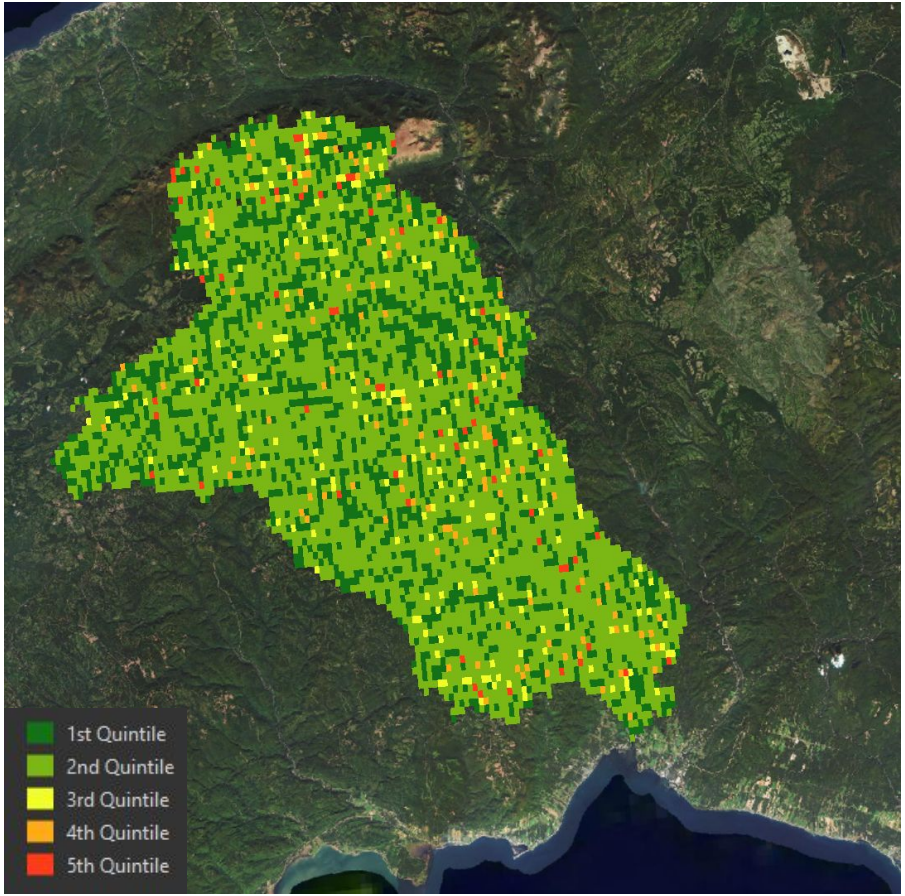


The Government of Canada (GoC) in their "RUSLECAF: Revised Universal Soil Loss Equation for Application in Canada (2015)"

Soil Erosion Class	Potential Soil Loss tonnes/hectare/year
Very Low	< 6
Low	6-11
Moderate	11-22
High	22-33
Severe	> 33

The GoC created these categories by separating the results by soil loss tolerance. The underlying research the GoC used was conducted by Shelton et al., 1985. The study sites were located in Ontario.

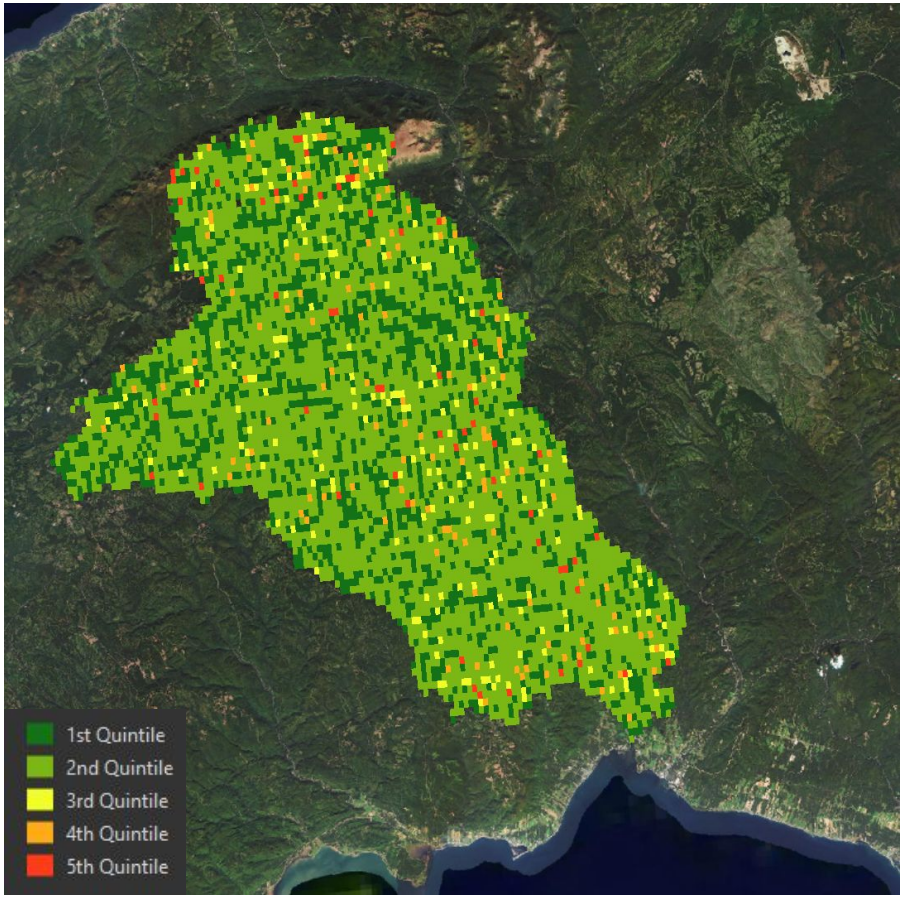
Why use Quintiles instead of estimating tonnes/hectare/year



Drawbacks of using GoC categorization in Gaspésie:

- Different landscape characteristics, topsoil depths, soil group type, annual rainfall, organic matter composition.
- Using “local” measurements to extrapolate national guidelines.
- Quantifying erosion potential through indices. Shelton et al., (1985) and the GoC Erosion handbook warned against taking the RULSE results as fact/

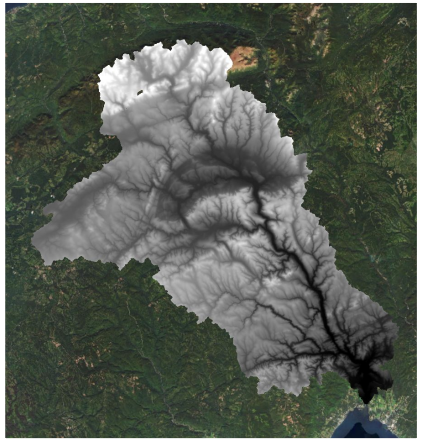
Why use Quintiles instead of estimating tonnes/hectare/year



Relative percentile classification

Soil Erosion Class	Quintile Ranges
Very Low	0 - 19.99%
Low	20 - 39.99%
Moderate	40 – 59.99%
High	60 – 79.99%
Severe	80 – 100%

3 step methodology for identifying sedimentation at a watershed scale



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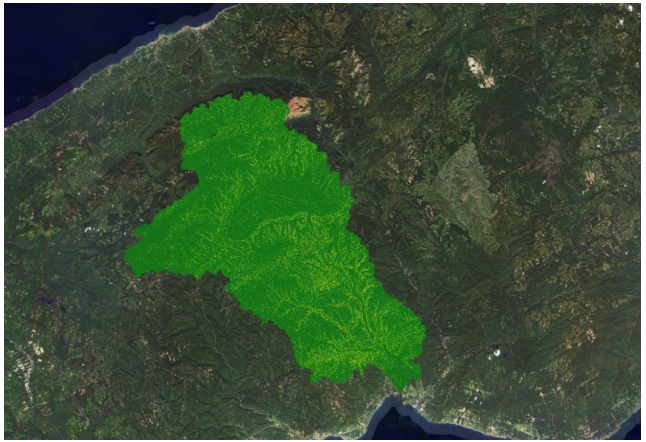

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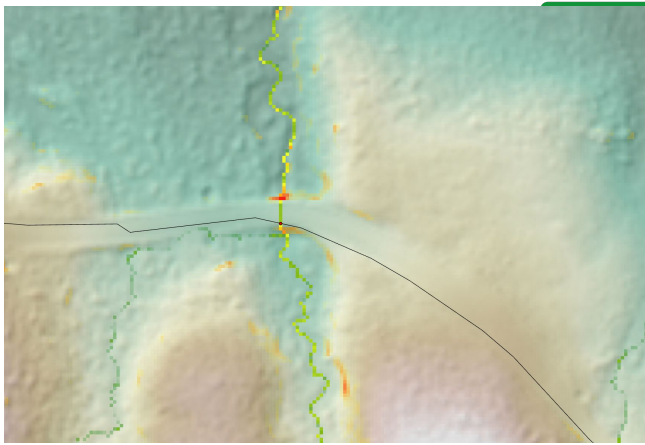

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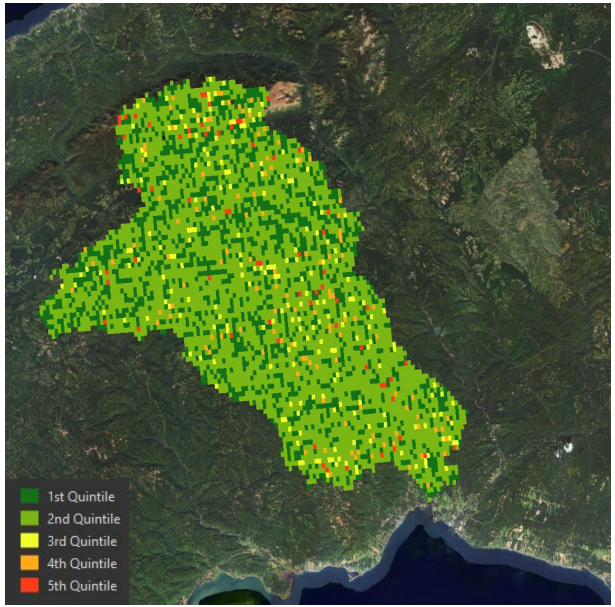
Overlaying RULSE output with stream crossings

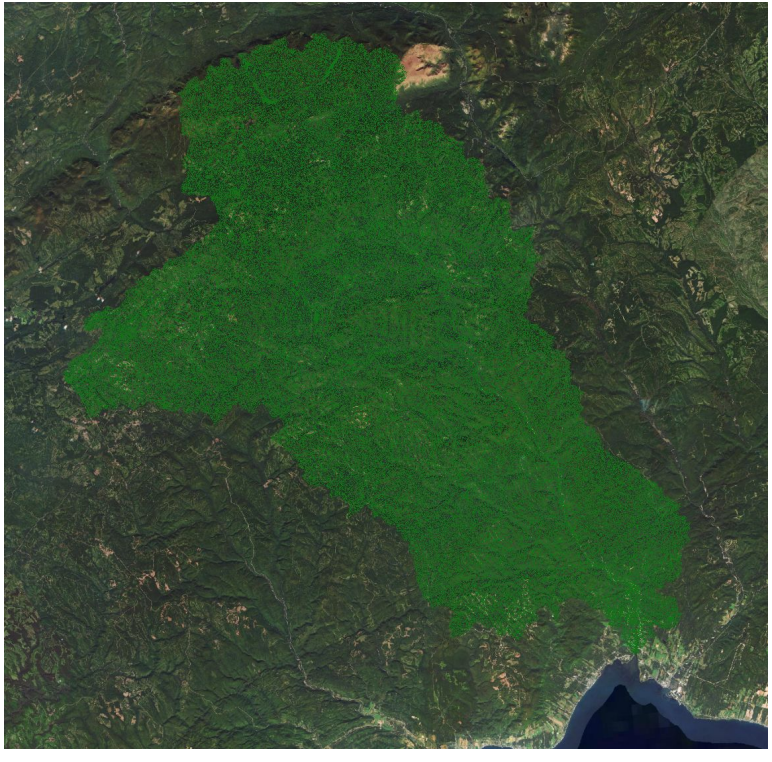
7,592 Stream Road Crossings

RULSE Output



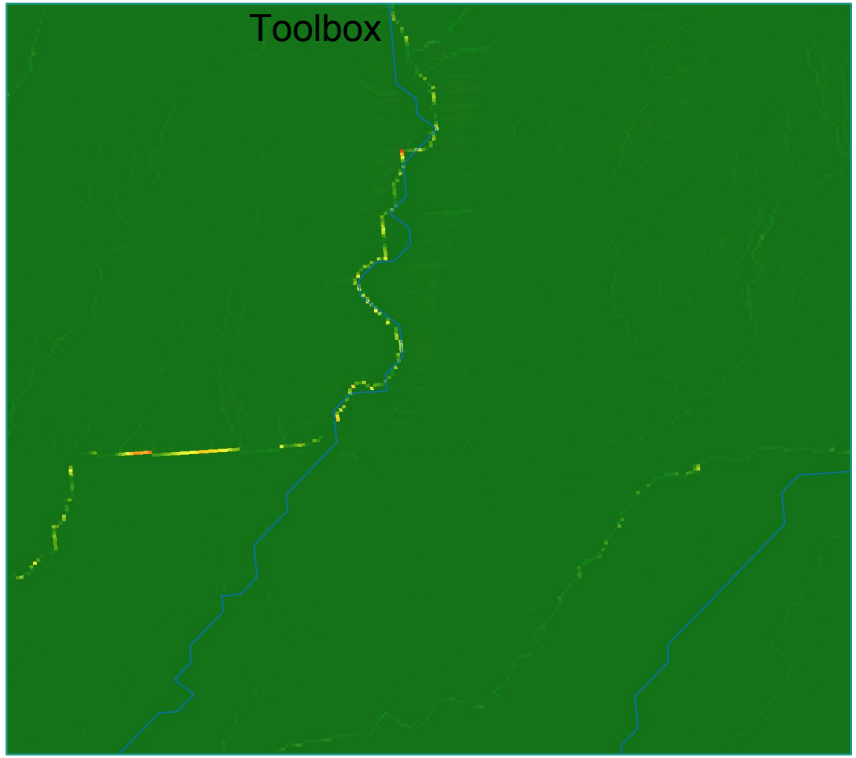
Sediment Transport Index

$$Power\ (\text{“}SCA\text{”}/22.13\ \ 0.16) * Power\ (Sin(\text{“}Slope.tif\text{”})\ /\ 0.0896,1.3)$$

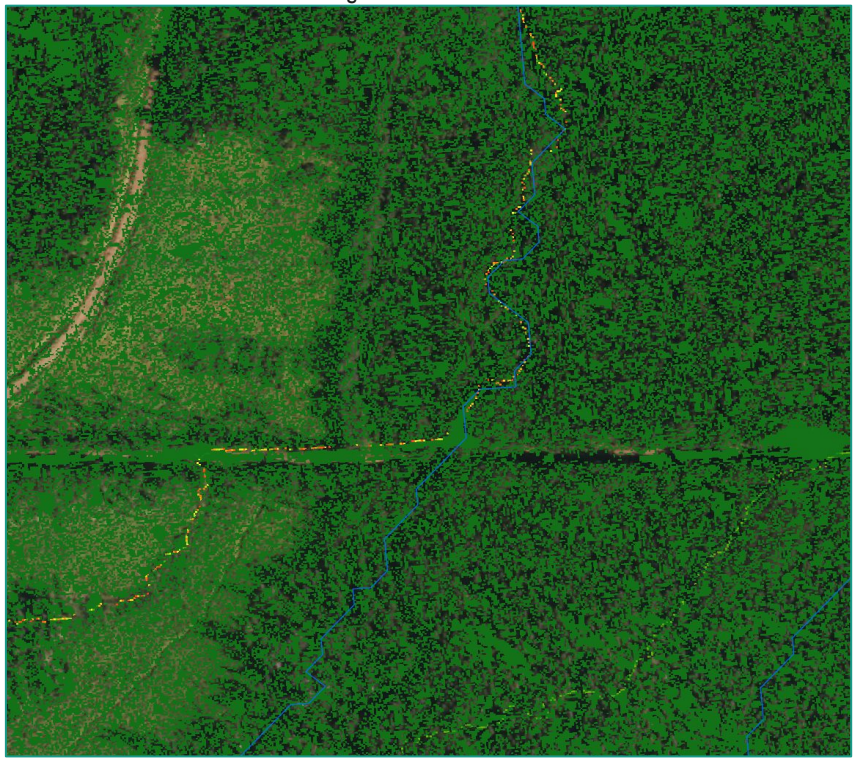


Sediment Transport Index

Whitebox ArcGIS Toolbox



$STI = (m + 1)(A_s / 22.13)^m * (\sin(\beta) / 0.0896)^m$



Sedimentation Study Area

Results: Stream road crossings within 4th and 5th Quintiles

- 557 stream road crossings were within the 4th and 5th quintile
  - 328 in the 4th quintile
  - 229 in the 5th quintile

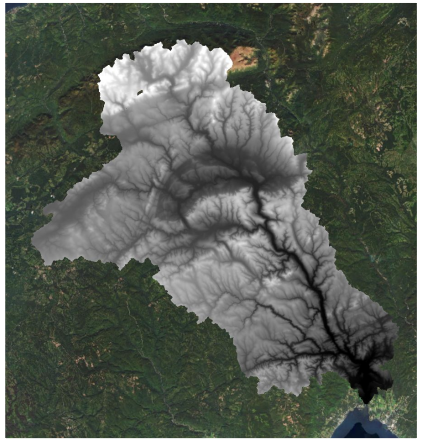
- 533 crossings were located on dirt roads, 24 on paved roads

Stream crossing type within the 4th and 5th quintiles

Culvert	Bridge	Ford	Impoundment
557	4	84	0

Watershed	#
Dartmouth	81
York	66
Madeleine	51
Matane	46
Blanche	35
Saint-Jean	35
Grand Riviere	28
Little Cascapedia	27
Mount-Louis	26
Bonaventure	24
Cap Chat	24
Sainte-Anne	18
Nouvelle	17
Port-Daniel Petite	17
Grand Pabos	12
Cascapedia	11
Grand Pabos Quest	10
Malbaie	8
Port Daniel	8
Port-Daniel du Milieu	6
Stewart	4
Petit Pabos	3

3 step methodology for identifying sedimentation at a watershed scale



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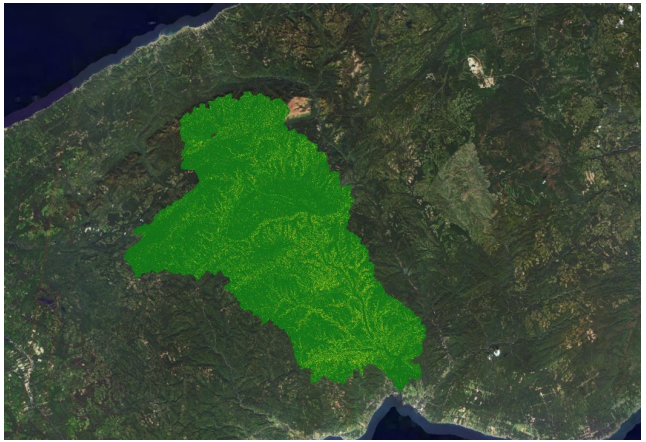

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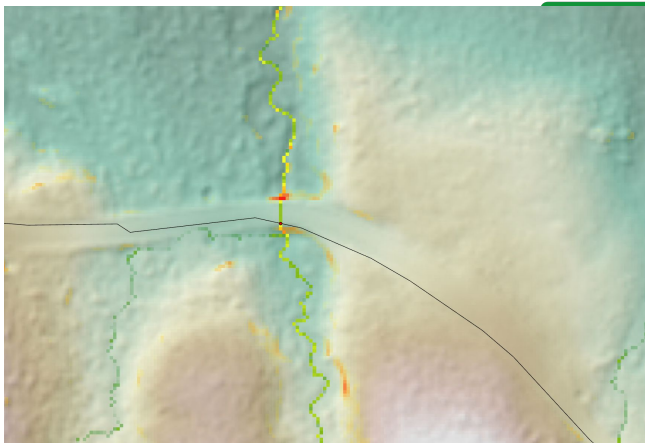


Step 3: Identify the sediment sources (ditch, road/stream embankment, culvert, road, etc.…) at each individual stream crossing.

Watershed-scale → All stream crossings → SPI Individual crossing

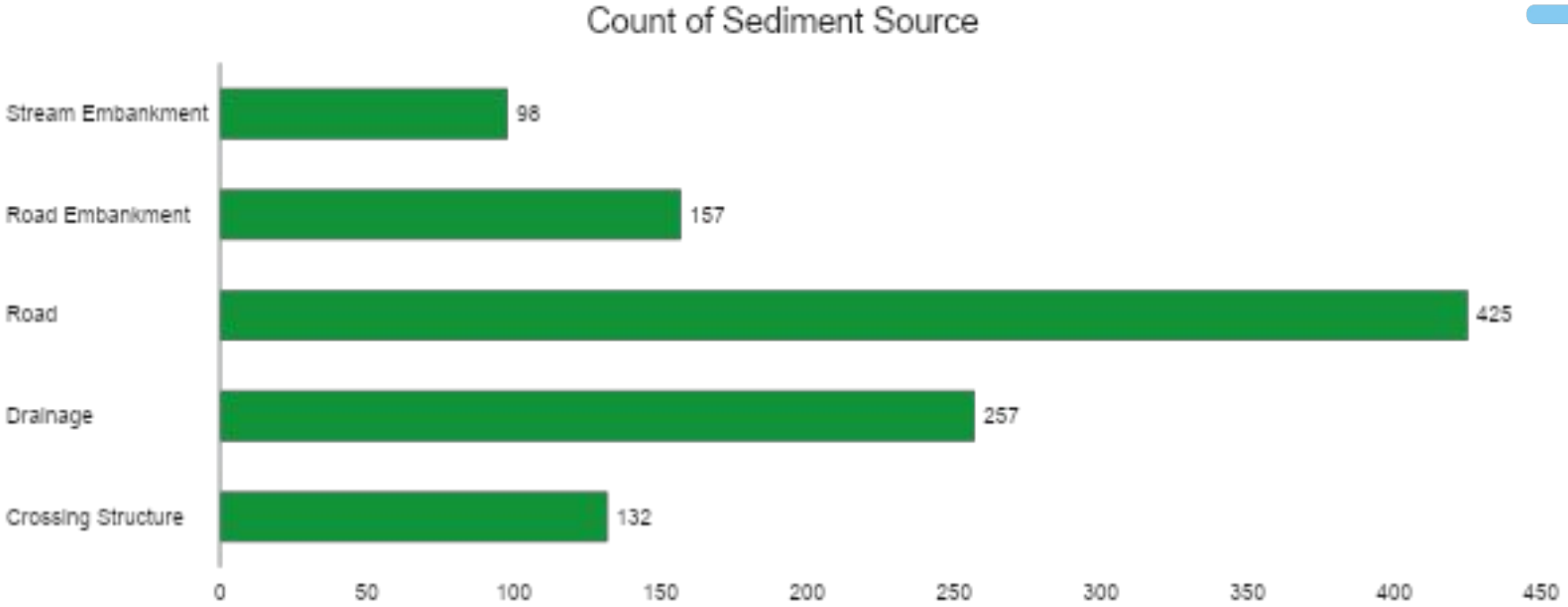
1,069 Sediment Sources over the 557 stream crossings

Types of Sediment Sources

Sources of sediment input

- Crossing Structure (culvert, ford, bridge)
- Drainage
- Road
- Road embankment
- Stream embankment

Types of Sediment Sources



Types of Sediment Sources

Crossing #	X	Y	Source
18	-67.720564	48.727483	Crossing Structure
47	-67.821507	48.634405	Drainage
28	-67.664438	48.719555	Road
165	-64.833627	48.84133	Road embankment
638	-64.707513	48.488207	Stream embankment

Field Validation

Sources of sediment input

- Crossing Structure (culvert, ford, bridge)
- Drainage
- Road
- Road embankment
- Stream embankment

Double Steel Corrugated Culvert

Hanging Culvert

Concrete Box Culvert

Double Plastic Culvert

Field Validation

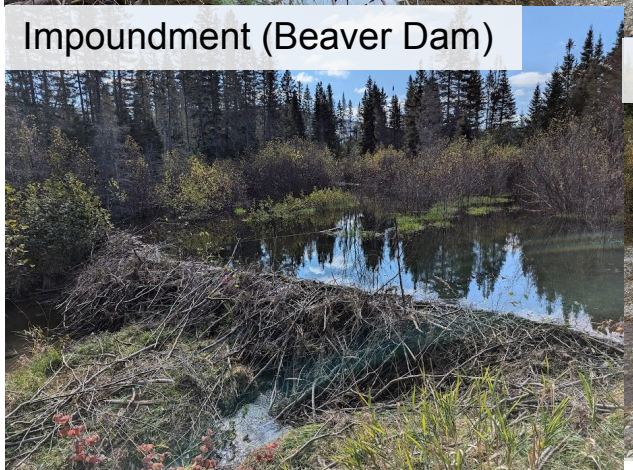
Sources of sediment input

- Crossing Structure (culvert, ford, bridge)
- Drainage
- Road
- Road embankment
- Stream embankment

Impoundment (Weir)

Ford

Impoundment (Beaver Dam)



Bridge

Field Validation

Sources of sediment input

- Crossing Structure (culvert, ford, bridge)
- Drainage
- Road
- Road embankment
- Stream embankment

Field Validation

Sources of sediment input

- Crossing Structure (culvert, ford, bridge)
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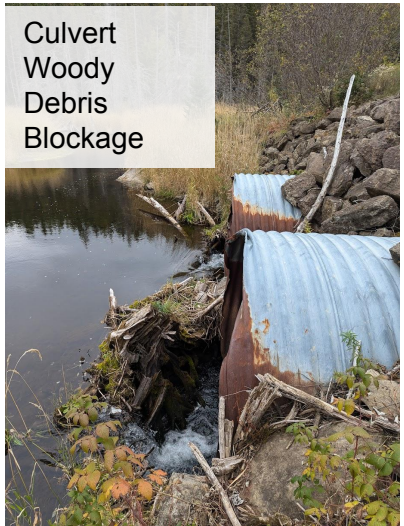
Culvert Woody Debris Blockage



Culvert Scouring & Structural Damage

Road Failure

Culvert Scouring & Undersized Culvert

Field Validation: Presence/Absence Comparison

Watershed	# of Sediment Sources
YORK	139
DARTMOUTH	129
MADELEINE	105
MATANE	100
BLANCHE	83
SAINT-JEAN	75
CASCAPÉDIA	66
GRANDE RIVIÈRE	59
PORT-DANIEL	47
BONAVENTURE	43
SAINTE-ANNE	43
MONT-LOUIS	42
CAP-CHAT	34
NOUVELLE	32
GRAND PABOS OUEST	17
GRAND PABOS	16
MALBAIE	14
PORT-DANIEL DU MILIEU	9
STEWART	9
PETIT PABOS	7

Field Validation: Presence/Absence Comparison

Sediment Source	Field Sediment Sources Identified over n=281 sites	GIS	GIS Compared to Field Accuracy (%)
Crossing Structure	62	36	58%
Drainage	43	47	90%
Road	312	290	93%
Road embankment	81	65	80%
Stream embankment	103	87	84%

What do these results mean?

Sediment Source	Field Sediment Sources Identified over n=281 sites	GIS	GIS Compared to Field Accuracy (%)
Crossing Structure	62	36	58%
Drainage	43	47	90%
Road	312	290	93%
Road embankment	81	65	80%
Stream embankment	103	87	84%

- Lidar resolution and age of the LiDAR resulted in underestimating the number of sediment sources per site
- Crossing structures with woody blockages were never detected and cannot be detected (5 culverts)
- Sediment sources identified in the field were overwhelmingly more severe than observed from the sediment transport index and LiDAR

Field Validation: Presence/Absence Comparison

Stream Order	Field Sediment Sources Identified over n=281 sites	GIS	GIS Compared to Field Accuracy (%)
1st	123	96	64
2nd	93	101	71
3rd	377	395	88
4th	5	6	83
5th	3	3	100

Field Validation: Presence/Absence Comparison

Stream Order	Field Sediment Sources Identified over n=281 sites	GIS	GIS Compared to Field Accuracy (%)
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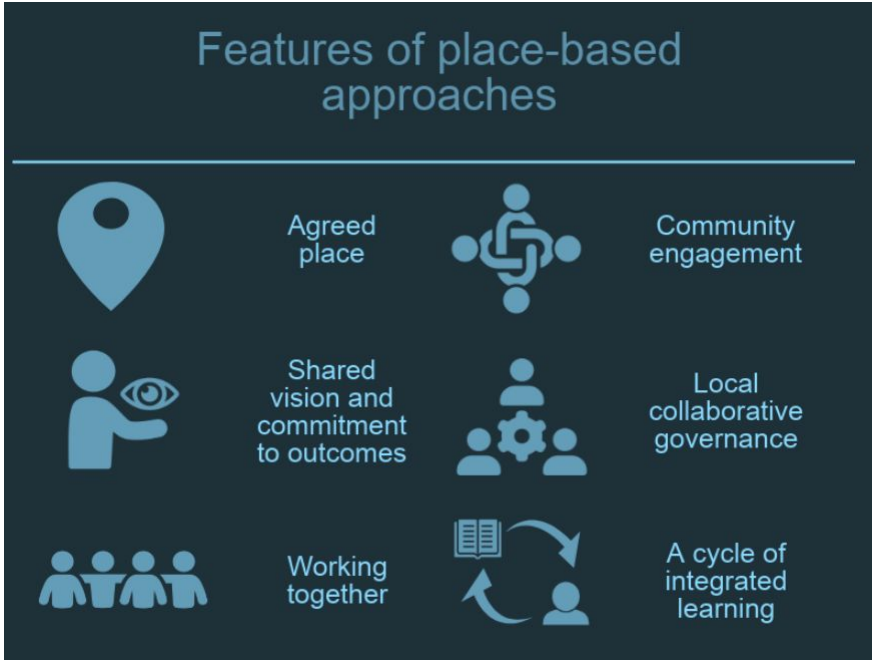
4th	5	6	83
5th	3	3	100

- The GIS accuracy decreases as stream order decreases
- As average road width decreases our ability to detect certain sediment sources
- Low resolution and outdated LiDAR with thick canopy cover could influence the detection ability at lower stream orders

Stratégie de priorisation régionale/locale

- Besoins spécifiques selon secteur d'activité
- De plus en plus interpelés
- Autres parties prenantes
- Approche méthodologique
- Consensus
- Co-développement
- Couches géomatiques et filtres
- Outil de priorisation dynamique (CGQ)



Data Prioritization

Layer	Link	Priority 1-5
Equity Index for Living Environments	https://www.donneesquebec.ca/recherche/dataset/vmtl-indice-equite-milieux-vie	
Indicators of food deserts and accessibility to food shops	https://www.donneesquebec.ca/recherche/dataset/indices-de-desert-alimentaire-et-d-accessibilite-aux-commerces-d-alimentation	
Public land use plans (PATP)	https://www.donneesquebec.ca/recherche/dataset/plans-d-affectation-du-territoire-public	
Forest Territorial Subdivisions (STF)	https://www.donneesquebec.ca/recherche/dataset/stf	
Delimitation of industrial and port zones	https://www.donneesquebec.ca/recherche/dataset/delimitation-des-zones-ip-industrialo-portuaires	
Forest pricing zone	https://www.donneesquebec.ca/recherche/dataset/zone-de-tarification	
Industrial zones	https://www.donneesquebec.ca/recherche/dataset/zones-industrielles	
Public places	https://www.donneesquebec.ca/recherche/dataset/vqat_1267315911	
Land cover mapping of Quebec	https://www.donneesquebec.ca/recherche/dataset/cartographie-de-l-occupation-des-terres-du-quebec	
Portrait of Quebec's forest cover	https://www.donneesquebec.ca/recherche/dataset/portrait_du_couvert_forestier_du_quebec	
Structured Wildlife Territories (SWT)	https://www.donneesquebec.ca/recherche/dataset/territoires-fauniques-structures	
Land cover in matrix format generated by artificial intelligence CMQuébec	https://www.donneesquebec.ca/recherche/dataset/couverture-matricielle-des-sols-generee-par-intelligence-artificielle-cmquebec	
High-resolution geodatabase of the Quebec hydrographic network (GRHQ-HR)	https://www.donneesquebec.ca/recherche/dataset/geobase-du-reseau-hydrographique-du-quebec-a-haute-resolution-grhq-hr	
Distribution areas of plant species at risk in Quebec	https://www.donneesquebec.ca/recherche/dataset/aires-de-repartition-des-especes-floristiques-en-situation-precaire	
List of threats to species in precarious situations	https://www.donneesquebec.ca/recherche/dataset/listemenacesespecesituationprecaire	
Quebec Lake Bathymetry Geobase (GBLQ)	https://www.donneesquebec.ca/recherche/dataset/bathymetries-lacs	
Distribution areas of plant species at risk in Quebec	https://www.donneesquebec.ca/recherche/dataset/aires-de-repartition-des-especes-floristiques-en-situation-precaire	
Integrated water management zones by watershed	https://www.donneesquebec.ca/recherche/dataset/zgiebv	
Sentinel - Invasive Alien Species	https://www.donneesquebec.ca/recherche/dataset/especes-exotiques-envahissantes	
Territorial boundaries of wildlife protection districts in Quebec	https://www.donneesquebec.ca/recherche/dataset/limites-districts-protection-de-la-faune	
Inventory of contaminated sites (GTC)	https://www.donneesquebec.ca/recherche/dataset/repertoire-des-terrains-contamines-gtc	
Land cover mapping of the St. Lawrence Lowlands	https://www.donneesquebec.ca/recherche/dataset/cartographie-de-l-occupation-du-sol-des-basses-terres-du-saint-laurent	
Potential wetlands	https://www.donneesquebec.ca/recherche/dataset/milieux-humides-potentiels	
Monitoring of metals in the waters of Quebec rivers and the St. Lawrence River	https://www.donneesquebec.ca/recherche/dataset/suivi-des-metaux-dans-les-eaux-des-rivieres-du-quebec-et-du-fleuve-staint-laurent	
Median surface water hardness	https://www.donneesquebec.ca/recherche/dataset/duretes-medianes-des-eaux-de-surface	
Floral habitats	https://www.donneesquebec.ca/recherche/dataset/habitats-floristiques	
Monitoring of pesticides in surface waters	https://www.donneesquebec.ca/recherche/dataset/suivi-des-pesticides-en-rivieres	
Benthos monitoring	https://www.donneesquebec.ca/recherche/dataset/suivi-du-benthos	
Land use	https://www.donneesquebec.ca/recherche/dataset/utilisation-du-territoire	
Register of protected areas in Quebec	https://www.donneesquebec.ca/recherche/dataset/aires-protegees-au-quebec	
Ecological reference framework	https://www.donneesquebec.ca/recherche/dataset/cadre-ecologique-de-reference	
Wildlife habitats	https://www.donneesquebec.ca/recherche/dataset/habitats-fauniques	
Hydrogeological Information System (HIS)	https://www.donneesquebec.ca/recherche/dataset/eau-souterraines-sih-index	
Industrial pressures - Wastewater discharges	https://www.donneesquebec.ca/recherche/dataset/pressions-industrielles-rejets-d-eaux-usees	

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Thank you.

Merci.