Miistakis Institute

Beaver Restoration Modelling for the CIPHER Project

Prepared by: Ken Sanderson and Holly Kinas

Prepared for: Trout Unlimited Canada (Alberta)

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Background

The Beaver Restoration Assessment Tool (BRAT) is a GIS-based modelling tool, developed by the Wheaton et al. lab, intended to help researchers, restoration practitioners and resource managers assess the potential for beaver as a stream conservation and restoration agent over large regions and watersheds (William W. Macfarlane et al., 2017; Utah State University, n.d.). The model demonstrates the potential beaver dam capacity of 1 km stream segments based on geography, vegetation, and hydrology of a defined study area. It has been applied in various regions across the USA (Riverscapes Consortium, n.d.-b) as well as Riding Mountain National Park in Manitoba, Canada (Stoll & Westbrook, 2020). In 2022, the Miistakis Institute ran the BRAT model for three HUC8 watersheds in southern Alberta (Belly River, Waterton River and St. Mary River) to determine potential sites for researching beaver dam analogue stream restoration. Building on this success, we have run the BRAT model for Trout Unlimited Canada's (TUC) CIPHER project to refine locations for stream restoration using beaver dam analogues (BDAs).

Methods

The Model

We used the most recent version of the Beaver Restoration Assessment Tool (BRAT) model, pyBRAT 3.1, for the CIPHER project (Utah State University, n.d.). The model was run in two HUC8 watersheds (upper Oldman River and Oldman below Oldman River reservoir), which TUC is exploring for stream restoration projects.

Study Area

Southwestern Alberta is considered a high priority area due to the intense focus on native trout recovery, on headwaters source water protection, and because it is the location of public and private land interface. The study area was delineated using the Hydrologic Unit Code Watersheds of Alberta. The model was run in two HUC8 watersheds, the upper Oldman River and the Oldman below Oldman River reservoir, which TUC is exploring for stream restoration projects.

Data Input

BRAT requires several specific datasets to run the model, all used are listed and described below.

- Digital Elevation Model (DEM)
- Vegetation (current and historical)
- Hydrology
- Hydrologic streamflow (high flow, base flow, maximum drainage area threshold)

Digital Elevation Model (DEM)

In the United States BRAT is run using a national DEM with a 10m spatial resolution. The Government of Alberta provided DEMs generated from LiDAR with spatial resolutions of 1m and 15m. As these DEMs only covered part of our study area, they were combined with Alberta Base Features DEM with a 25m spatial resolution, using the finest resolution possible based on overlap. The resulting 1m resolution DEM was resampled to 2m resolution to speed up processing times.

Vegetation

Vegetation is an important biological input for the BRAT model as it determines if beaver will have ample forage and building materials within the riparian area to be sustained and construct dams along the stream segment (William W. Macfarlane et al., 2017). Most of the study area is in the Alberta White Zone (human impacted landscape), therefore the 2020 AAFC Annual Crop Inventory database was used as the base vegetation layer.

Beavers have a preference in the vegetation they eat and then use as building material for dams, so the vegetation type that is available along a stream is an important input. A vegetation code was assigned to different classes of vegetation, representing the forage and dam-building material preferences of beaver with a value of 0 - 4, with 4 being the most preferred and 0 being least preferred (William W. Macfarlane et al., 2017). The BRAT vegetation code values were calculated based on the Annual Crop Inventory classifications (Table 1).

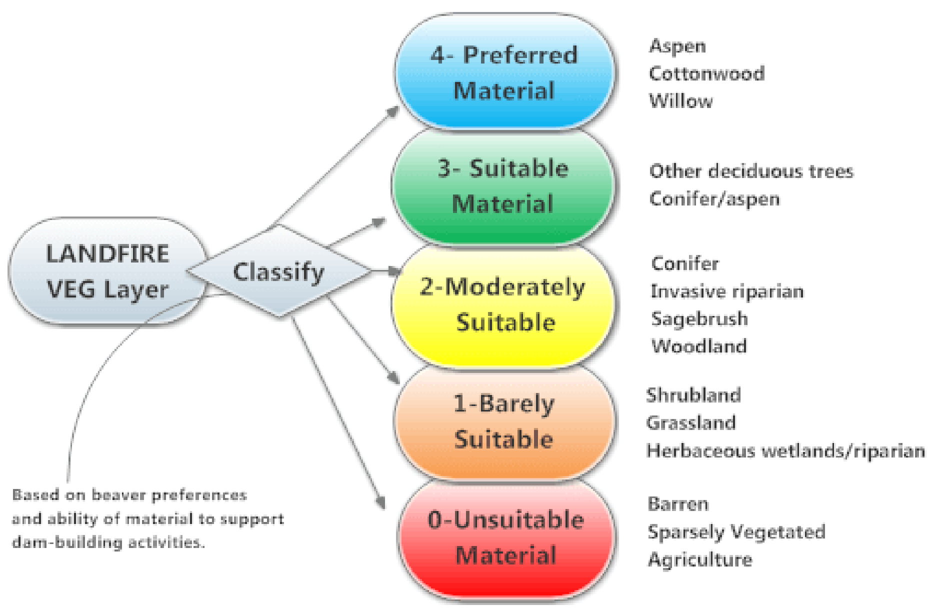

Figure 1: Diagram showing land cover data classification for the beaver dam capacity model (Riverscapes Consortium, n.d.-a)

The Annual Crop Inventory did not provide adequate classification for more desirable species such as aspen, cottonwood or willow (vegetation code of 4) therefore this data was approximated by comparing the annual crop inventory with a riparian layer. The riparian layer was created by merging and dissolving the Alberta Government Lotic Riparian Polygons DEM Derived and Alberta Government Lotic Riparian Polygons Strahler Order Derived datasets. This data provides an approximation of riparian areas. Vegetation classifications of 220 (Deciduous) and 230 (Mixedwood) that were within riparian areas were given a vegetation code value of 4.

Table 1: Vegetation code values used for BRAT

Annual Crop Inventory Classification	Name	Vegetation Code
20	Water vegetation	1
30	Barren	0
34	Urban	0
50	Shrubland	1

80	Wetland	1
110	Grassland	1
120-199	Agriculture	0
210	Conifers	2
220	Deciduous	3
230	Mixedwood	3
	Deciduous in riparian area	4
	Mixedwood in riparian area	4

Historic Vegetation

No pre-colonization vegetation datasets were found therefore we used the oldest available dataset, the 2000 ABMI Wall-to-Wall Land Cover. This was a reasonable approach because we were not interested in change of beaver dam capacity over time for this run of BRAT. The 2000 ABMI Wall-to-Wall Land Cover dataset has the same classifications as the Annual Crop Inventory and the same process was used to assign vegetation code values as used with the base vegetation dataset.

Hydrology

Hydrological features such as rivers, streams, and lakes were used to run the BRAT model. These features were derived from the Alberta Base Features, which is freely available from Altalis. The Base Stream and Flow Representation dataset were clipped to the study area. This dataset was broken into 300m segments using ArcGIS Point Along Line and Split Line at Point tools.

In order for the BRAT model to function it requires a StreamName field in the table, this was created and populated with the existing NAME field.

We do not want to encourage beaver-mediated or BDA restoration of manmade waterways as well as areas beavers would not typically be found (e.g., icefields) therefore the following feature types were removed from the dataset: AQUEDUCT, CANAL, CANAL-MAJ-REP-PRI, DITCH, ICEFIELD-REP-PRI, OXBOW-RECUR, SPILLWAY, STR-RECUR, RIV-MAJ-REP-SEC, LAKE-REP-PRI. Due to the removal of these feature types it is possible that hanging segments of streams are created, which are stream segments that are no longer connected to the stream network. For this run of the model these were included, but it may be beneficial to remove segments under a certain size in future BRAT runs.

HYDROLOGIC STREAMFLOW

The BRAT model requires the following hydrologic streamflow inputs: base flow equation, high flow equation, and maximum drainage area threshold.

Environment Canada Hydrometric stations were used to calculate the base flow and high flow equations (Government of Canada, 2016).

Hydrologist Matt Morrison created an R script that pulls all the stations in a specific area of interest and filters out stations without at least 30 years of data, with data gaps no larger than 2 years. The flow data from these stations are then evaluated in the script and an output formula is created for both base and high flow in a format ready to be inputted into BRAT.

The CIPHER project area unfortunately did not have enough viable hydrometric stations so the study area was expanded by combining the following HUC8 watersheds to create a more generalized formula for the area: Willow Creek, Waterton River, Upper Oldman River, St. Mary River, Pothole Creek, Pincher Creek, Oldman Below Waterton River, Oldman Below Oldman River Reservoir, Crowsnest River, Castle River, and Belly River.

High flow Equation

High flow for each station was determined as being the 2-year flood high. This was calculated using the annual peak flow data of all available hydrometric stations within the defined study area using Station Selection and Flow Methodology scripts developed by Matt Morison to determine the sensitivity of total length of record and data continuity on station availability. Stations were removed if they did not include at least 30 years of data and with data gaps no longer than 2 consecutive missing years, for years with a no more than 10% of missing daily data for each year.

For each station, daily flow data was obtained via the tidyhydat package (v 0.5.7) in R, and annual daily peak flows were sorted by in descending order and assigned a rank starting at 1, a Weibull probability value was then calculated for each annual data point using a formula: rank / {(# of data points) + 1}, i.e., rank / 41 (Stoll, 2019).

Using data analysis via R, a regression was performed with between annual peak flow and Weibull probability to determine the 2-year flood high by setting Weibull = 2 years in the regression formula, returning a high flow value in m^3/s for that specific station, which was converted to cubic feet per second.

At this point our methods differed from Stoll's thesis (Stoll, 2019) in that Stoll used a single station and adapted a formula to match the high flow value of that station. Our approach was to complete a power regression between the 2-year flood values of all stations and drainage area for each station (in square miles), and use the resulting equation as our high flow equation for the BRAT model.

Base flow Equation

Base flow was determined by calculating the mean annual minimum 7-day flows with a recurrence interval of 10 years for all available hydrometric stations within the defined study area using Station Selection and Flow Methodology scripts developed by Matt Morison to determine the sensitivity of total length of record and data continuity on station availability. Stations were removed if they did not include at least 30 years of data and with data gaps no longer than 2 consecutive missing years, for years with a no more than 10% of missing daily data for each year.

For each station, daily flow data was obtained via the tidyhydat package (v 0.5.7) in R, and 7-day rolling mean daily flow data were sorted by in descending order and assigned a rank starting at 1, a Weibull probability value was then calculated for each annual data point using a formula: rank / {(# of data points) + 1}, i.e., rank / 41 (Stoll, 2019).

Using data analysis via R, a Pearson Type III fit (Environmental Protection Agency, 1986) was performed with between annual minimum 7-day flow and recurrence interval to determine the 2-year flood high by setting recurrence interval to 10 years, returning a low flow value in m^3/s for that specific station, which was converted to cubic feet per second.

At this point our methods differed from Stoll's thesis (Stoll, 2019) in that Stoll used a single station and adapted a formula to match the base flow value of that station. Our approach was to complete a power regression in Excel on the base flow values of all 7 stations as the Y-axis and drainage area for each station (in square miles) as the X-axis and use the resulting equation as our base flow equation for the BRAT model.

Maximum Drainage Area Threshold

To run the BRAT model over a large area, a threshold needs to be set for the maximum drainage area in which a beaver could not build a dam (W.W. Macfarlane et al., 2014). The stream data calculated by the BRAT model was explored to find a relationship with drainage area and stream power, but no correlation was found therefore we could not calculate a threshold specific to our study area. Unable to find a better approach for our region we used a threshold of 4661.979 km^2 as is identified by Macfarlane et al. who base this value on the USGS Geohyrdologic Region thresholds (W.W. Macfarlane et al., 2014). Using this number for our region may or may not be applicable. Stoll (2019) indicated she used the area of her study area, which would thus be the maximum size available.

Results

The majority of the streams in the study area fall into the occasional (1-5 dams/km) (45%) category, followed by rare (0 – 1 dams/km) (33%), none (0 dams/km) (17%), frequent (5-15 dams/km) (6%), and pervasive (15-40 dams/km) (<1%) (Table 2; Figure 2).

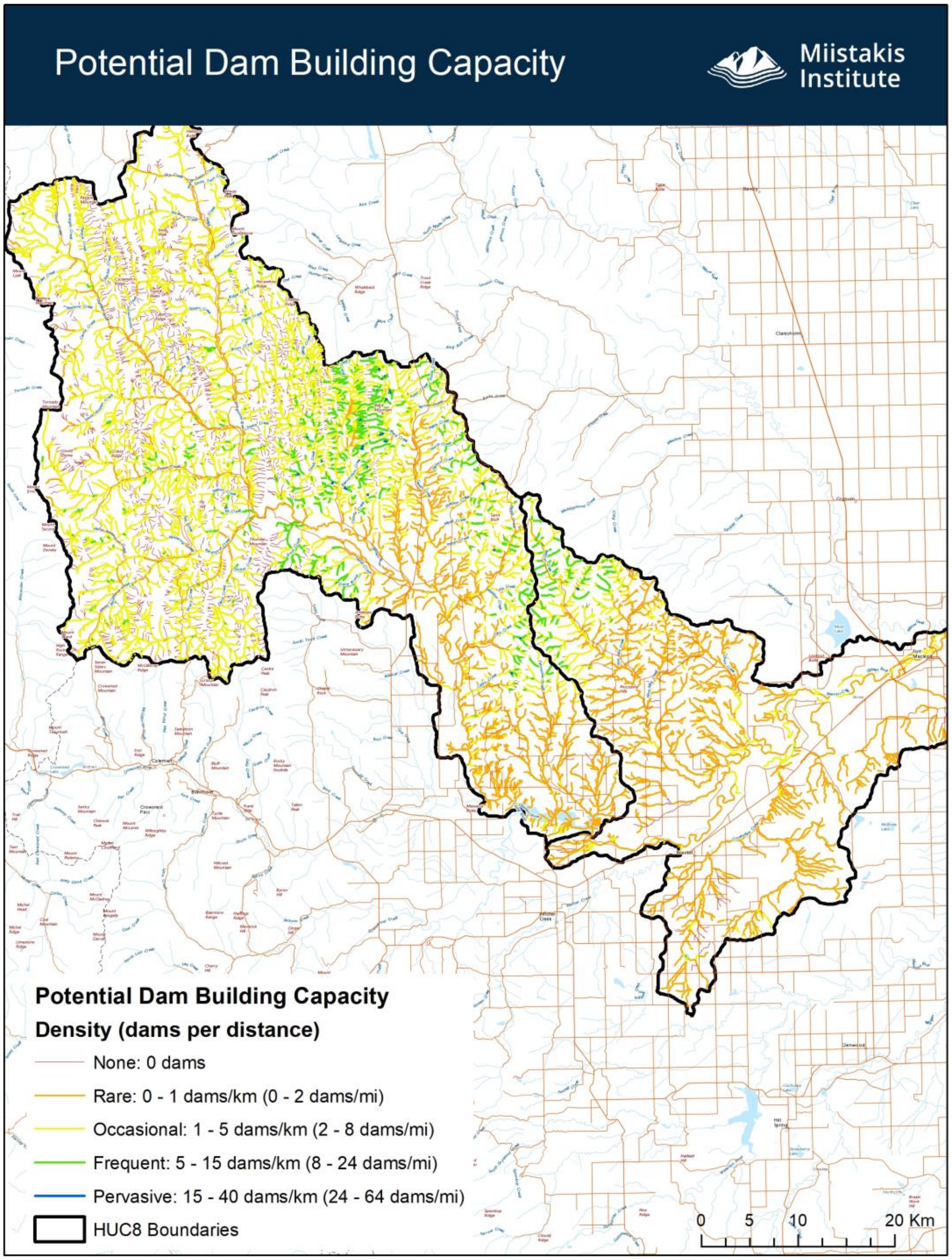

Figure 2: Potential dam building capacity in study area

Table 2: Beaver dam capacity in study area (upper Oldman River and the Oldman below Oldman River reservoir HUC8 watersheds)

Category	Beaver dam density (dams/km)	Beaver dam density (dams/mi)	% of streams in study area in category
None	0 dams	0 dams	16.70
Rare	0 – 1	0 – 2	32.62
Occasional	1 – 5	2 – 8	44.87
Frequent	5 – 15	8 – 24	5.70
Pervasive	15 – 40	24 – 64	0.10

Discussion and Next Steps

BRAT was developed by the Wheaton et al. lab to help researchers, restoration practitioners and resource managers assess the potential for beaver as a stream conservation and restoration agent over large regions and watersheds (William W. Macfarlane et al., 2017; Utah State University, n.d.). The preferred sites for BDA restoration are stream reaches that have high beaver dam capacity, as indicated by BRAT, but low beaver dam occurrence, indicated by ground-truthing of stream reaches and local expert knowledge. We recommend that ground-truthing of restoration sites be conducted to refine and prioritize areas where beaver dam analogue (BDA) restoration is feasible and impactful.

BRAT shows that in the CIPHER study area, the majority of the streams (45%) are in the occasional category, which is 1-5 dam/km. Although this looks like a low number, in reality, 1-5 dams in every kilometer of stream could provide a substantial contribution to stream and watershed restoration. Six percent of the stream reaches in the study area are considered to have dams frequently (5-15 dams/km). We recommend a focus on ground-truthing the “frequent” and “occasional” areas first as they have a relatively high capacity for beaver so could indicate ideal locations for restoration, and they are more common across the study area than the higher capacity, “pervasive” category. Also, the higher the capacity for beavers, the more likely a beaver has already moved into the stream segment, therefore BDAs would not be recommended at that site.

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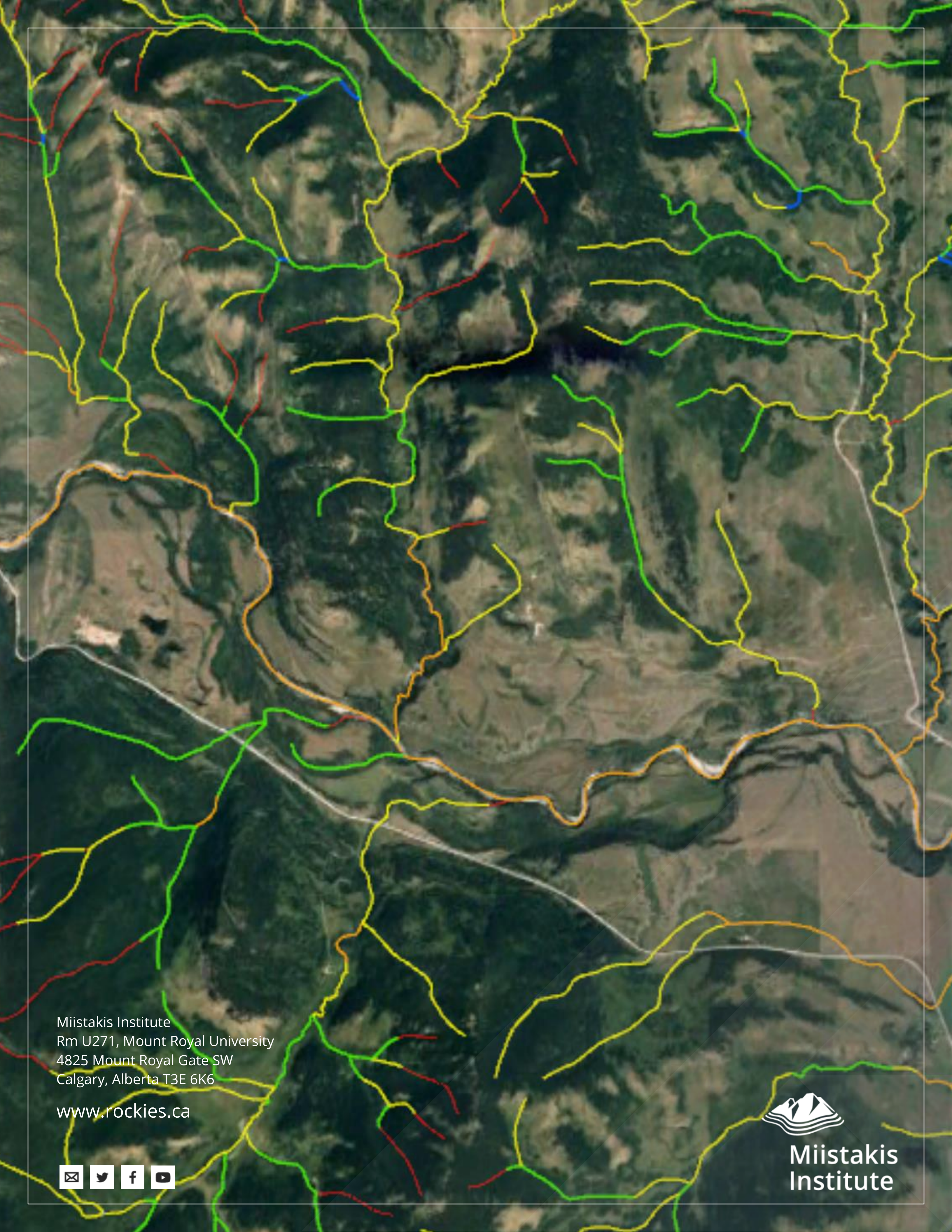

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