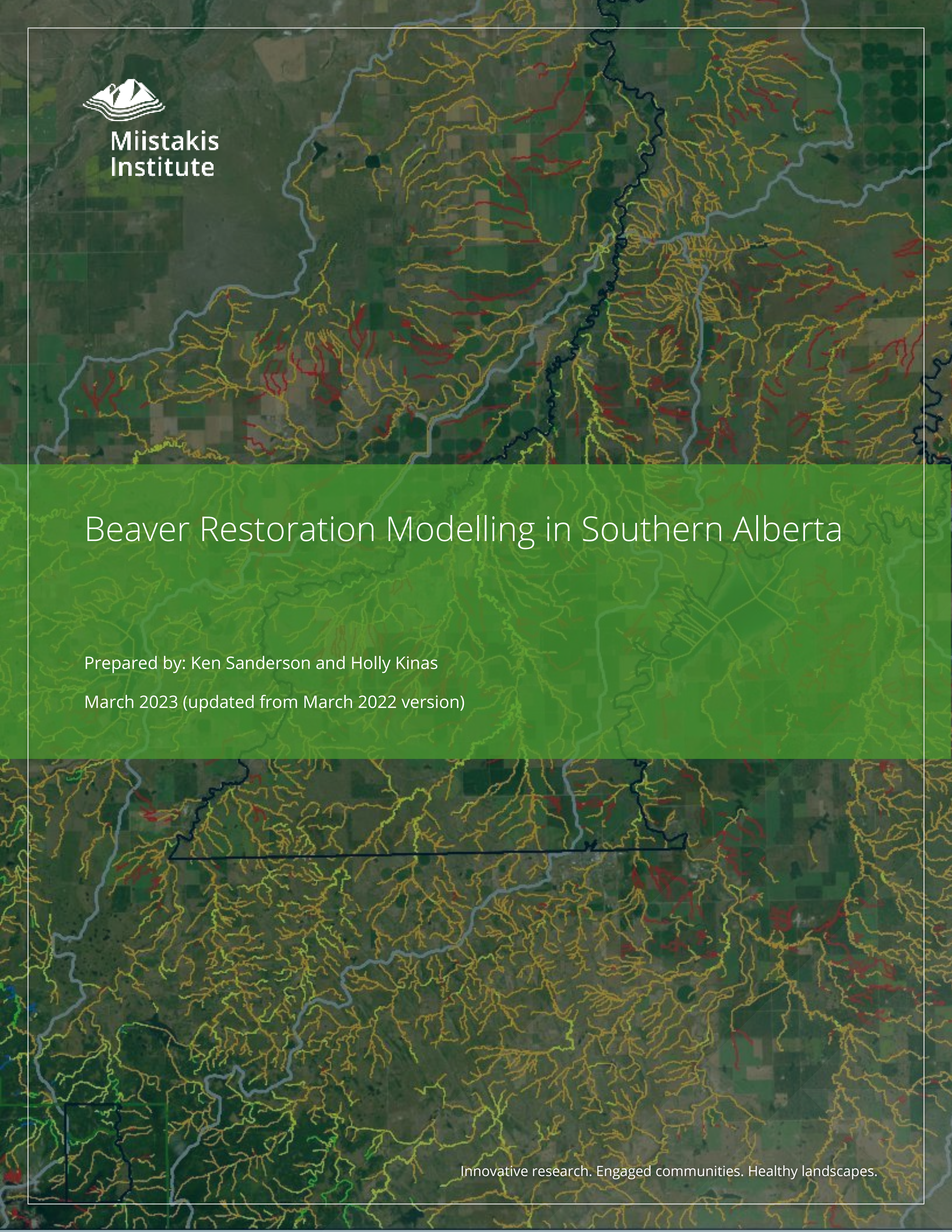

Miistakis Institute

Beaver Restoration Modelling in Southern Alberta

Prepared by: Ken Sanderson and Holly Kinas

March 2023 (updated from March 2022 version)

Innovative research. Engaged communities. Healthy landscapes.

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The purpose of this report is to document our methodology for running the BRAT model. It is a living document and will be updated as we refine and validate the model.

Background

In 2012, the Miistakis Institute and Cows & Fish (Alberta Riparian Habitat Management Society) initiated the collaborative project; *Putting Beavers to Work for Watershed Resiliency and Restoration*. This project's primary goal is to foster human-beaver coexistence, promote the resilience of watersheds and restore the benefits that beavers provide. Beavers have been recognized as important for climate resiliency as they facilitate groundwater storage, increase stream permanence, enhance water quality, mitigate floods, create terrestrial and aquatic habitat, among myriad benefits. In an effort to capitalize on the watershed benefits that beavers and beaver mimicry provide, we conducted a GIS-based modelling exercise to determine the best location for beaver mimicry, or beaver dam analogues (BDA), to restore degraded streams. We have partnered with Blood Tribe Land Management to address watershed restoration and improve fish and wildlife habitat through the use of BDAs within the Blood Tribe Reservation and Timber Limit in southern Alberta. Along with running the GIS model described in this report, this project also includes several other research pieces: a citizen science component asking volunteers to look through satellite imagery for dams and lodges, ground-truthing of stream reaches, and local expert knowledge. Together, these research pieces will help to meet the project objectives:

- Determine beaver dam capacity for stream segments in southwestern Alberta
- Map and prioritize areas where beaver dam analogue (BDA) restoration is feasible and impactful. These are stream reaches that have high beaver dam capacity (as indicated by BRAT) but low beaver dam occurrence.
    - Beaver dam occurrence will be determined by using citizen science, ground-truthing, and local expert knowledge
- Estimate the study area's current water storage capacity and potential capacity if streams were to be restored by beaver to meet beaver dam capacity (i.e. beaver move into the area).

The three objectives will contribute to our overall beaver program goal of encouraging coexistence with beavers for the watershed and wildlife benefits they provide. The results of this research, paired with citizen science, ground-truthing, and local knowledge, will enable us to refine where we and other conservation partners can focus beaver coexistence and BDA stream restoration efforts; inversely, it also helps us determine sites where beaver restoration is not a good solution, and therefore we would focus our efforts elsewhere. An example of a good potential restoration site would be one that scores well in the BRAT tool (high dam capacity potential), currently does not have many dams (actual low dam capacity), and low conflict potential (low human population or infrastructure density). In a site like this, beaver can transform an area once devoid of habitat, into a complex, diverse habitat for a variety of species including large game, waterfowl, fish, amphibians, and insects, as it likely was historically before the fur trade era.

Methods

The Model

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 (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). A complication of using the BRAT tool is that the input data required is freely available in the US and differs from the data that is freely available in Canada so equivalencies need to be made, a step already accomplished by Stoll in Riding Mountain National Park in Canada (Stoll, 2019). Building on the successful application of this tool in Riding Mountain National Park, we applied BRAT to a region in southern Alberta in March 2022 which included our target study area of the Blood Tribe Reserve and Timber Limit to determine potential sites for researching beaver dam analogue stream restoration.

In Fall of 2022 we received higher resolution LIDAR data from the Government of Alberta which allowed us to rerun the model in our original study area. This report has been updated to reflect the rerun results.

For our study we used the most recent version of the BRAT model, pyBRAT 3.1 (Utah State University, n.d.). A new sqlBRAT is currently being built and could be explored in the future.

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. Our study focused on the Blood Tribe Reservation and Timber Limit but the study area is much boarder as it was delineated using the Hydrologic Unit Code Watersheds of Alberta. The Hydrologic Unit Code (HUC) Watersheds of Alberta represent a collection of five nested hierarchically structured drainage basin feature classes that have been created using the Hydrologic Unit Code system of classification developed by the United States Geological Survey (USGS) with accommodation to reflect the pre-existing Canadian classification system. For the purposes of this project the HUC8 watersheds that most overlapped with the Kainai Reserve and Timber Limit were selected, these were: Belly River, Waterton River and St. Mary River. There is a total of 7,139 km of streams within the study area.

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 4m 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 (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 (Macfarlane et al., 2017). The BRAT vegetation code values were calculated based on the Annual Crop Inventory classifications (Table 1).

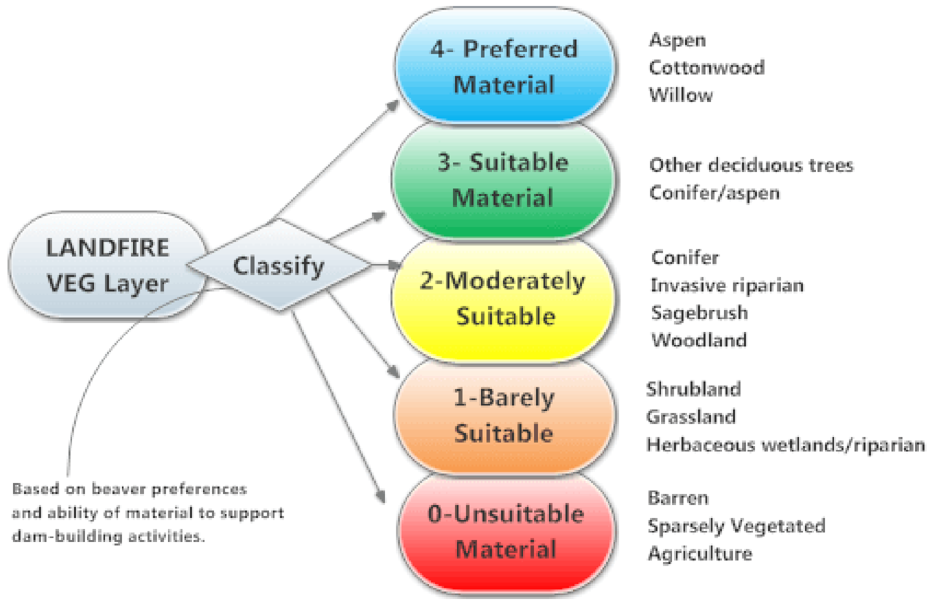

Figure 1: Diagram showing land cover data classification for the beaver dam capacity model (Riverscapes Consortium, n.d.-a)

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.

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.

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.

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 (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 (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 rare (0 – 1 dams/km) category (68%), followed by none (0 dams/km) (18%), occasional (1-5 dams/km) (12%), frequent (5-15 dams/km) (1%), and pervasive (15-40 dams/km) (<1%) (Table 2; Figure 2).

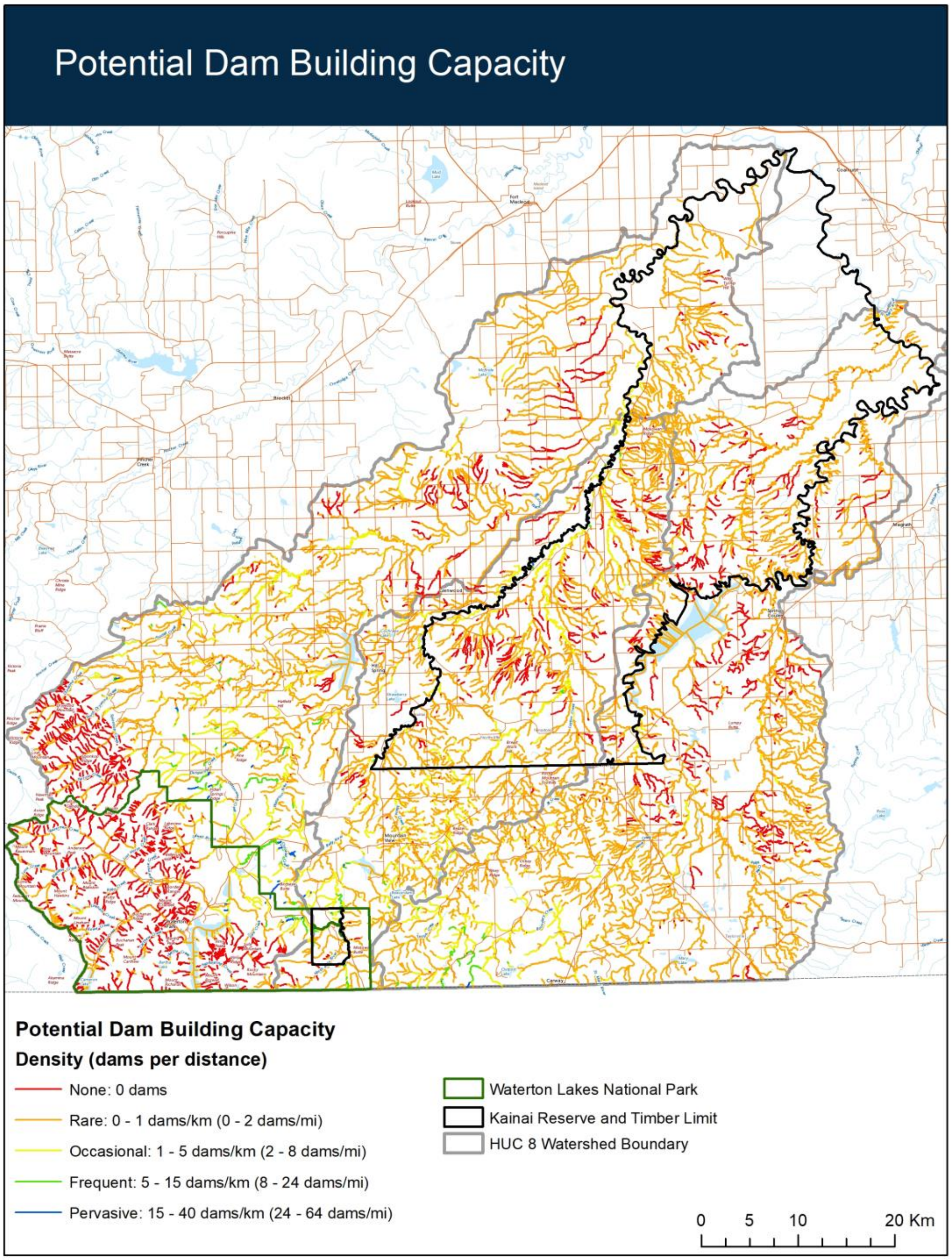

Figure 2: Potential dam building capacity in study area

Table 2: Beaver dam capacity in study area (Belly River, Waterton River and St. Mary River HUC8 watersheds)

Category	Beaver dam density (dams/km)	Beaver dam density (dams/mi)	% of streams in study area in category	Length of streams in study area in category (km)
None	0 dams	0 dams	18.25%	1,303
Rare	0 – 1	0 – 2	68.49%	4,889
Occasional	1 – 5	2 – 8	11.72%	836
Frequent	5 – 15	8 – 24	1.29%	92
Pervasive	15 – 40	24 – 64	0.25%	18

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 (Macfarlane et al., 2017; Utah State University, n.d.). We have partnered with Blood Tribe (Kainai) Land Management to restore streams by harnessing the power and cunning of beavers to enhance the resiliency of the watershed. By completing BRAT, we have accomplished the first objective, to determine beaver dam capacity for stream segments in southwestern Alberta.

The results of BRAT will be paired with several other datasets (citizen science, ground-truthing, and local expert knowledge) used to validate the model and ultimately allow us to map and prioritize areas where beaver dam analogue (BDA) restoration is feasible and impactful.

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 the citizen science component, ground-truthing of stream reaches, and local expert knowledge.

BRAT shows that in our study area, the majority of the streams (68%) are in the rare category, which is 0-1 dam/km. Although this looks like a low number, in reality, 1 dam in every kilometer of stream could provide a substantial contribution to stream and watershed restoration. 12% of the stream reaches in our study area are considered to have dams occasionally (5-15 dams/km). We will focus on ground-truthing these areas first as they have a fairly high capacity for beaver so could indicate ideal locations for restoration, and they are approximately 10 times more common across the study area than the higher capacity categories (frequent and pervasive). Also, the higher the capacity for beavers, the more likely a beaver has already moved into the stream segment, therefore BDAs are not required at that site, so focusing our ground-truthing efforts in "occasional" stream segments increases our chances of finding potential restoration sites.

Our next step is to build additional datasets from citizen science, ground-truthing, and local expert knowledge. All of these components launched in spring 2023.

We have taken steps to refine the model by working with a hydrological consultant for review and refinement of the hydrological curves and have received higher resolution LIDAR data from the government of Alberta. This report presents results after the rerun of this model with enhanced hydrologic and LIDAR data inputs. We will continue to document the evolving BRAT methods as we refine the model.

Further Analysis

An additional objective we plan on completing with the BRAT model and results of the citizen science component, is to estimate the study area's current water storage capacity and potential capacity if streams were to be restored by beaver to meet beaver dam capacity (i.e. beaver move into the area). We could also explore human conflict areas by overlaying ABMI Human Footprint layer with BRAT results. All further analysis will be documented as completed.

We were not able to compare historic data to current in the BRAT model as data was not useable past 2000 therefore changes would be minimal.

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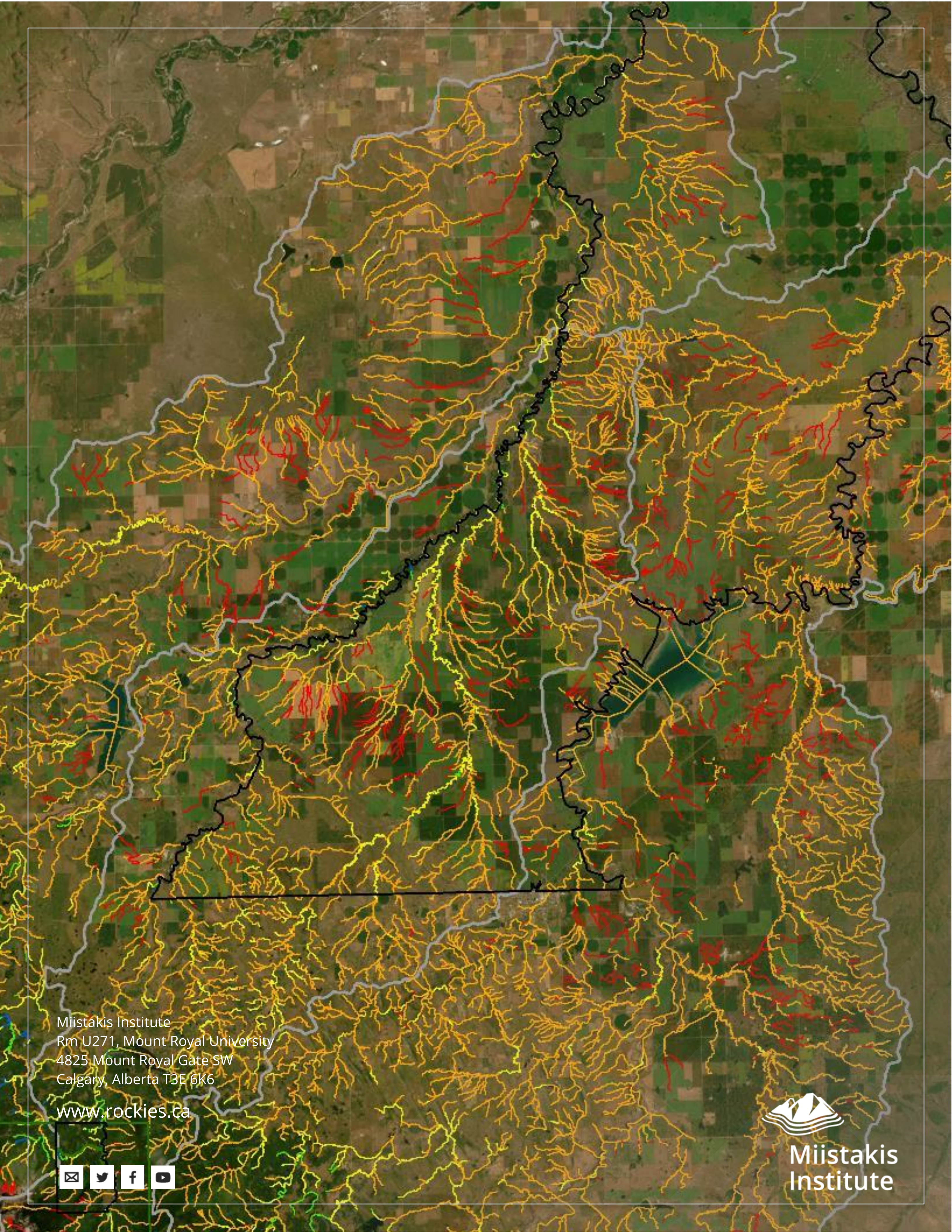

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