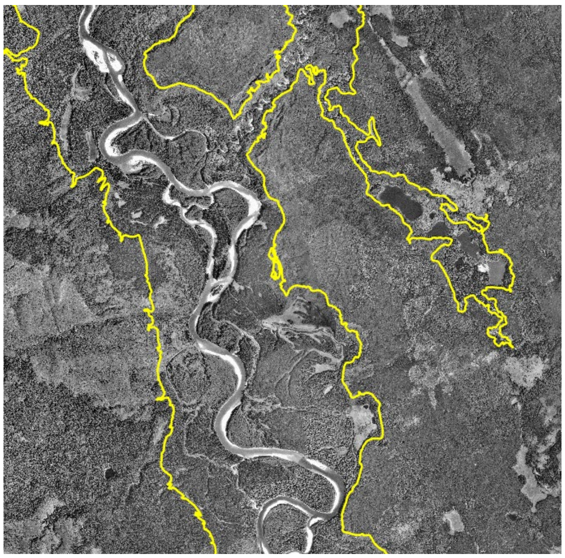
Williston Watershed Impact Assessment Mapping – Use of BEMVRI (Broad Ecosystem Mapping and Vegetation Resource Inventory) to Compare Current Conditions (2025) to Pre-flood (1968) Conditions



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Executive Summary

The following report describes the steps completed for the Williston Watershed Impact Assessment Mapping Project. Two standardized Broad Ecosystem Mapping (BEM) coverages based on Vegetation Resource Inventory (VRI) linework (1:20,000 scale) were created to represent current conditions (2025) and pre-flood conditions (1968) for the Williston Reservoir Watershed Area within the Peace Region of British Columbia (BC). The BEMVRI product contains data from multiple inputs including Biogeoclimatic Ecosystem Classification (BEC), VRI 2025, the Williston Wetland tool (WWET), and Digital Elevation Models (DEM) to assign slope, aspect and elevation to each VRI polygon. The inputs vary in their level of verification and accuracy. Technical methods used to create BEMVRI products, script documentation, example figures of product content, and a comparative analysis of pre-flood to current conditions are provided.

The BEMVRI mapping covers 7,286,165 hectares, encompassing the entire Williston Watershed. As per BC Hydro (2006), the reservoir covers approximately 177,300 ha. However, existing mapping incorporated into the BEMVRI to represent pre-flood conditions includes a high-water mark as well as a 200 m buffer; encompassing approximately 204,630 ha. The area up to the high-water mark (181,177 ha) and the adjacent 200 m buffer (23,453 ha) were tracked separately for analyses.

The BEMVRI mapping includes 5 BEC zones, represented by 22 BEC units (zone/subzone/variant). The most common BEC zone in the watershed is the Engelmann Spruce Subalpine Fir (ESSF) (2,874,221 ha), followed by the Sub-boreal Spruce (SBS) (1,755,119 ha), Sub-boreal Willow Spruce (SWB) (1,014,709 ha), Alpine (839,485 ha), and Boreal White and Black Spruce (BWBS) (782,697 ha). Five of the 22 BEC units were directly impacted by the reservoir. The Sub-Boreal Spruce moist cool subzone Williston variant (SBSmk2) lost a disproportionate amount of its former (pre-flooding) extent; reduced by 133,533 ha, representing a loss of 34% of the original extent of the SBSmk2.

A total of 62 unique ecosystem codes were applied to describe 24 forest types, 10 wetland types, 5 dedicated alpine codes, 7 disturbance codes, and others. Forested ecosystems are the most common land cover in the watershed representing 65% of the mapped area. Based on differences in land cover between 1968 and 2025, there was a loss of 115,876 ha of forest, representing 2% of the total forest cover. Following change in forest cover, riparian areas underwent the most change with a reduction of 40,500 ha, representing a loss of 19% of the area mapped as riparian in 1968. Wetlands experienced the next greatest proportionate loss and were reduced by 16,580 ha, representing 5% of their 1968 mapped extent.

Ecosystem types mapped within the 5 priority BEC units were examined for change in their extent and condition (structural stages) before and after flooding. Loss of terrestrial, riparian, and wetland ecosystems were highest within the SBSmk2 BEC unit. Other sources of disturbances (human-caused and natural) are presented.

Recommendations for future work include further testing and refinement of ecosystem assignments to the VRI polygons, deeper evaluation of conflicting data sources, improved delineation of subalpine and alpine areas, and use in habitat connectivity mapping or other interpretive analyses. Review of the products is encouraged along with recommendations for field verification programs, and product accessibility (e.g., use and understanding of the products).

This project aligns with the FWCP Peace Action Plan: “Develop approach to incorporate cumulative effects into actions - P1”. These BEMVRI products and the comparative analysis will support FWCP with understanding ecosystem impacts from the flooding of Williston reservoir, assisting the regional board with strategic planning and assessing appropriate compensation for BC Hydro dam impacts in the Peace region.

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List of Acronyms

Acronym	Description
BC	British Columbia
BCLCS	BC Land Classification System
BEC	Biogeoclimatic Ecosystem Classification
BEI	Broad Ecosystem Inventory (typically refers to product produced in 2000)
BEM	Broad Ecosystem Mapping (used to refer to product originating in 2016)
BEU	Broad Ecosystem Units
CCL	Consolidated Cutblock Layer
CE	Cumulative Effects
DEM	Digital Elevation Model
FWA	Fresh Water Atlas
FWCP	Fish and Wildlife Compensation Program
GIS	Geographic Information System
ha	Hectares
LUT	Look-up Table
QA	Quality Assurance
RIC	Resource Information Committee
RRM	Resource Ratings Model (a tool developed by MOE in 1999 for use with the WHR standards)
RSI	Resource Suitability Index
TB	Treed Broadleaf (used for broadleaf (deciduous)-leading forests)
TC	Treed Coniferous (used for coniferous-leading forests
VRI	Vegetation Resource Inventory
BEMVRI	Vegetation Resource Inventory polygons assigned Broad Ecosystem Map units
WHR	Wildlife Habitat Ratings
WWET	Williston Watershed Explorer Tool

1 Introduction

Completion of the WAC Bennett Dam in 1968 created the Williston Reservoir, with a footprint of 1,773 km^2 (177,300 hectares) (BC Hydro, 2007). Madrone Environmental Services Ltd. (Madrone) was engaged by the Fish and Wildlife Compensation Program (FWCP) for the Peace Region to undertake the Williston Watershed Impact Assessment Mapping Project. The project consisted of two components.

The first involved creating two standardized Broad Ecosystem Mapping and Vegetation Resource Inventory (BEMVRI) products. A BEMVRI coverage for the entire Williston Watershed Area (the project area) under current conditions (2025) was created. Next, a pre-flood (1968) conditions BEMVRI layer was developed using existing ecosystem mapping based on imagery from 1968 for the reservoir and high-water mark (Timberline 2006), and a VRI back cast product produced by Madrone to approximate age in 1968.

The second component consisted of a comparative assessment between BEMVRI 2025 and BEMVRI 1968 to quantify ecosystem losses resulting from reservoir flooding.

This project aligns with the FWCP Peace Action Plan: “Develop approach to incorporate cumulative effects into actions- P1”. These BEMVRI products and the comparative analysis will support FWCP with understanding the species and ecosystem impacts from the flooding of Williston reservoir, assisting the regional board with strategic planning.

1.1 Project Area

The project area for the BEMVRI ecosystem coverage was the entirety of the Williston Watershed Area in the Peace Region of British Columbia (**Error! Reference source not found.**). The watershed encompasses a wide range of latitudes consisting of boreal to sub-boreal ecosystems and includes five biogeoclimatic zones. The area contains habitat for a number of the FWCP’s Peace Region priority species. The region is located in the traditional territories of the Treaty 8 First Nations including: Blueberry River, Doig River, Fort Nelson, Halfway River, McLeod Lake, Prophet River, Saulteau, and West Moberly First Nations and the territories of Kwadacha, Tsay Keh Dene and Nak’azdli Whut’en First Nations.

The initial flooding of Williston Reservoir took place in 1968 with the construction of the WAC Bennett Dam by BC Hydro on the Peace River. The flooding affected the headwaters of the Peace River and the lower reaches of Finlay River and Parsnip River to create three reaches which have relatively homogenous limnology (Stockner et al. 2005). Williston Reservoir has a footprint which disproportionately impacted lowland ecosystems and displaced lowland wildlife habitat. Also, annual water level fluctuations are typically 12 vertical meters but can be up to 17, creating an unproductive drawdown zone at the reservoir’s margins (BC Hydro 2007). The lowest water levels occur in April or May, while the highest water levels are reached between late July and early October as the reservoir refills with meltwater runoff (d’Entremont et al. 2020). Discharge from the dam and reservoir drawdown are typically highest in the winter due to increased energy demand (Stockner et al. 2005).

The Williston Watershed region historically experienced and continues to experience both natural and human-caused disturbances including logging, mining, wildfires, insect outbreaks, and road construction.

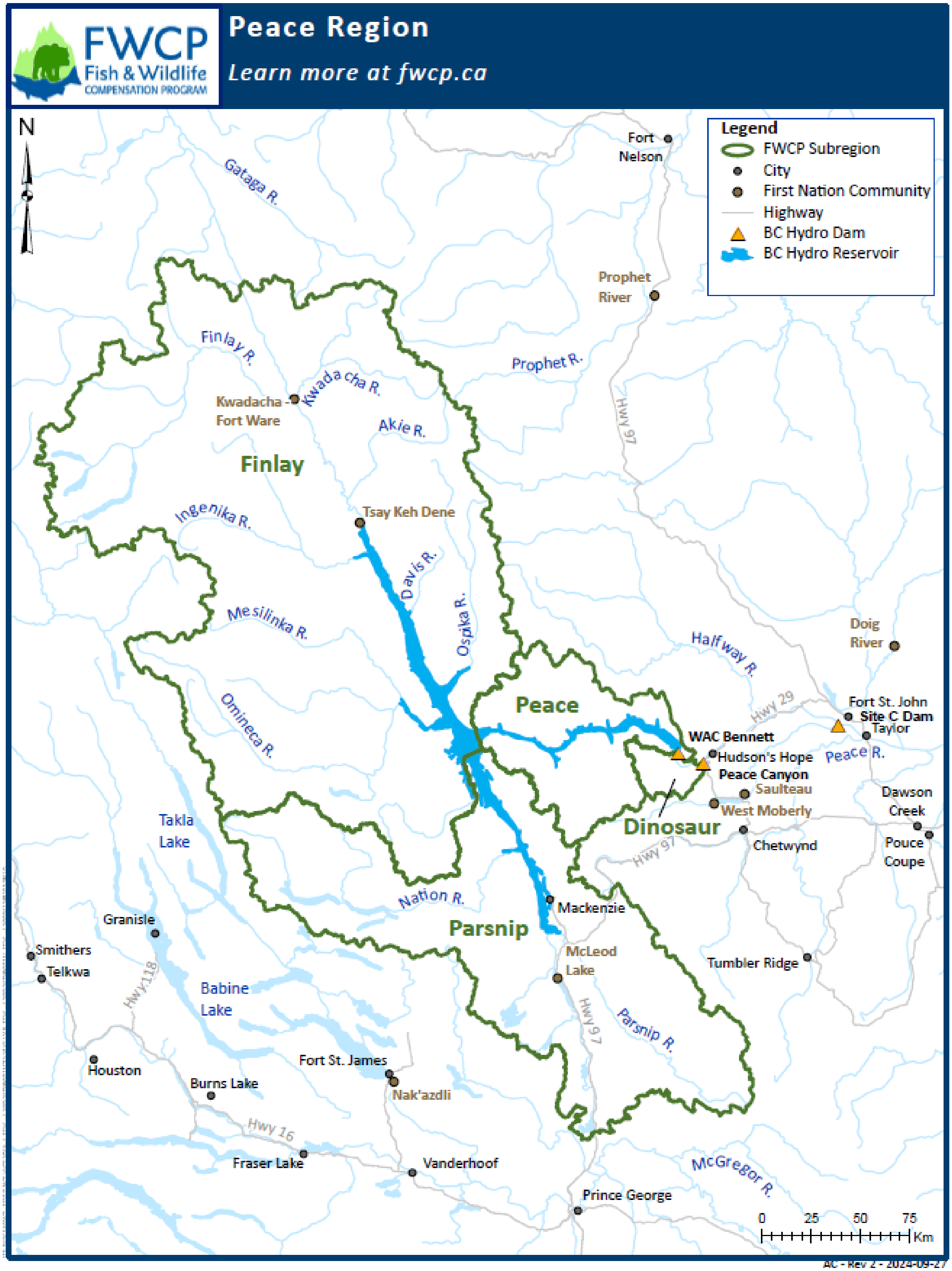

Figure 1. The extent of the BEMVRI map coverage is the Williston Watershed, consisting of the Finlay, Peace and Parsnip FWCP Subregions.

1.2 Objective

The primary project objective was to create two ecosystem coverages representing two points in time to assess impacts as a result of the creation of Williston Reservoir. This included creating current conditions (2025) and pre-flood (1968) standardized BEMVRI products for the project area, and subsequent quantification of ecosystem change.

2 Ecosystem Coverage of Current Conditions

This section describes the creation of the ecosystem map referred to as BEMVRI for current conditions (2025) of the Williston watershed area. Example figures are provided as a visual aid along with descriptions of data inputs.

2.1 Creation of the BEMVRI Map Coverage

BEMVRI is a polygon-based (vector) spatial product that assigns broad ecosystem units (BEUs) to Vegetation Resource Inventory (VRI) polygon outlines. The process starts with Broad Ecosystem Inventory polygons created in 2000 and associated provincial standards (RIC 1998). BEUs are transferred into a current provincial database standardized format for ecosystem map products, the TEIS format (TEL_Long_Tbl). This is the first step completed before the BEI polygon data is merged with the VRI polygons via a series of scripts. The result of this merge is a new feature class containing all of the VRI attributes with the addition of the BEI attribute fields included. The full set of attribute fields used are maintained through the creation of the BEMVRI.

Several updates or enhancements are made during the BEMVRI process to improve the original datasets representation of ecosystem units. The process brings the original BEI data up to current standards to later be referred to as a BEM. These improvements include, but are not limited to:

- reducing mapsheet polygon boundaries within large features such as large lakes or rivers;
- calculating mean slope, aspect, elevation, and populating slope modifiers from 25 m DEM rasters;
- assessing allowed BEC and BEU combinations and correcting for errors;
- incorporating wetland features;
- refining forested unit coding based on expert advice;
- assigning structural stage and stand composition information;
- quality assurance checks of the spatial data; and
- calculating crown closures from VRI attributes.

In 2021, BEMVRI became a recognized standardized Terrestrial Ecosystem Information (TEI) project type.

2.1.1 Data Inputs

The main data sources used to build the basemap for this project included Broad Ecosystem Inventory (BEI), VRI, consolidated cutblocks layer (CCL), Forest Cover Inventory (RESULTS) and a series of site data from a 25 m Digital Elevation Model (DEM). The Williston Wetlands Explorer Tool (WWET) was used to enhance wetland coverage. BC Fire history data was used to correct stand age for the current conditions layer. Inputs to the base data and resultant spatial outputs as well as all data sources used to build the BEMVRI product are summarized in Table 1. Further data resources that were assessed for this project but did not have sufficient coverage in the study area can be found in Appendix D.

Table 1. Data sources used to create the BEMVRI spatial coverage for the Williston Watershed.

Feature	Data Source	Uses in BEMVRI product	Scale	Public Data
2024 Vegetation Resource Inventory (VRI) [1] 2025 release date	DataBC	• Attain polygon linework • Assign forest cover attributes (e.g., crown closure, stand composition, forest age to structural stage, etc.) • Assign Biogeoclimatic Ecosystem Classifications (BEC) and nBEC • Correct BEM labels	1:20 000	Yes
Consolidated Cutblocks[2] (CCL) 2025	DataBC	• Delineate harvested areas	1:20 000	Yes
Reporting Silvicultural Updates and Land Tracking System[3] (RESULTS) 2025	DataBC	• Delineate harvested areas	1:20 000	Yes
Digital Elevation Model (DEM)	n/a	• Assign slope, aspect, elevation	25 m	No
Broad Ecosystem Inventory (BEI)	DataBC	• Assign ecosystem labels	1:250,000	Yes
BC Wildfire Perimeters - Historical	DataBC	• Stand age corrections in current conditions BEMVRI • Information layer in back-casting BEMVRI product	1:20 000	Yes
Williston Wetland Explorer Tool (WWET)	DataBC	• Identify wetland areas • Classify wetland areas into bog and fen classes where appropriate	25 m	Yes
BEC Data	VRI	• BEC Data from VRI for Zone/ Subzone/ Variant	1:20 000	Yes
Biogeoclimatic Ecosystem Classification (BEC) Zone/Subzone/Variant/Phase map (version 12)	DataBC	• BEC Data used to fill in VRI polygons where BEC Units are missing following enhancements (large VRI mapsheet polygons)	1:250,000	Yes

Figure 2 depicts some of these main GIS input steps (e.g., adding DEM data, adding disturbance reference data, assigning BEUs to each VRI polygon, etc.) applied to create the BEMVRI product. GIS processing methods are described in detail in Appendices A and B.

[1] https://catalogue.data.gov.bc.ca/dataset/vri-historical-vegetation-resource-inventory-2002-2022-/resource/a4e8da99-eabf-4ad1-979d-c121cb803b53

[2] https://catalogue.data.gov.bc.ca/dataset/harvested-areas-of-bc-consolidated-cutblocks-

[3] RESULTS - Forest Cover Inventory - Datasets - Data Catalogue (gov.bc.ca)

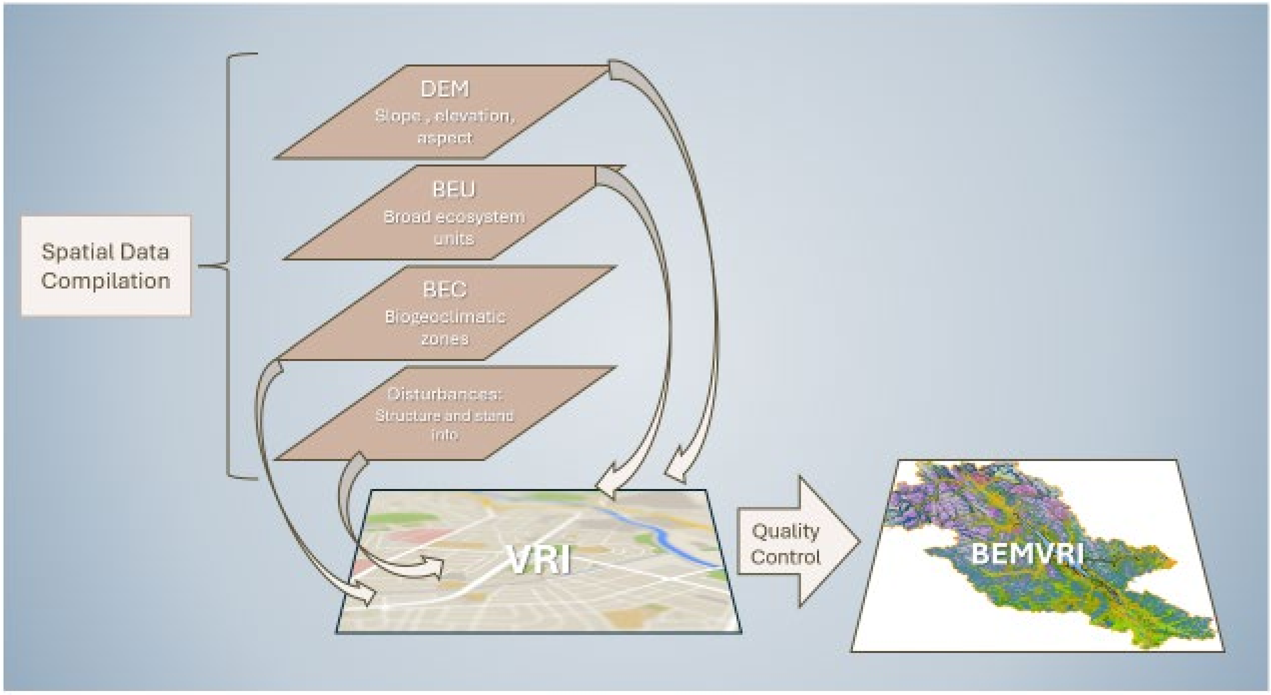

Figure 2. Overview of inputs and process of building the BEMVRI product.

2.2 Vegetation Resource Inventory (VRI)

One of the first steps in producing a BEMVRI project is to access the most up-to-date Vegetation Resource Inventory (VRI). VRI provides information on the status of BC's provincial forests and is publicly available online for download through DataBC. Data collection for VRI is overseen by the Forest Analysis Inventory Branch of the Ministry of Forests (MOF) and conducted in a two-phase process, comprising of 1) photo interpretation and 2) ground sampling. Due to the extremely large size of BC and the remoteness of many of BC's forests, aerial photography and photo interpretation are the main sources of forest inventory used to estimate forest attributes (MOFLNRO 2018). VRI is the only provincial coverage of forest type and age that is publicly accessible. Data quality, however, varies throughout the province based on quality and update frequency (i.e., age of the imagery interpretation and associated updates to the database to capture current VRI standards). As it is a forest inventory product, linework and data are limited above the tree line in the parkland and alpine areas.

Although linework updates were outside of the scope of this project, some edits were made where the Ecosystem Mapper found it necessary to do so. Linework adjustments were mainly applied in the parkland and alpine to improve delineation of ecosystem features such as splits between vegetated and unvegetated areas. Additionally, some large lakes required polygon line adjustment and linework edits were made to merge rivers into contiguous polygons. On-line imagery in ArcPro was used to interpret these edits.

2.3 Broad Ecosystem Data

The Broad Ecosystem Inventory Classification data layer is available from DataBC and covers the entire province. This layer provides broad regional information about ecosystems and their value to wildlife (RIC

1998). Broad Ecosystem Units (BEUs) are based on imagery of the provincial land base generally captured at a scale of 1:250,000 (DataBC 2022). BEUs describe the dominant cover of an area, which could be the dominant plant species or dominant non-vegetated terrain. Descriptions for the broad ecosystem units used with BEI can be found in the Broad Ecosystem Inventory standards (RIC 1998).

BEU attributes are initially assigned to VRI polygons based on majority area of overlap. This process results in numerous assignments of the same BEU to multiple VRI polygons due to the 1:250 000 scale BEM being assigned to the 1:20 000 scale VRI. Following this initial ecosystem information assignment to the VRI polygons, extensive corrections are necessary and require significant effort to develop the ecosystem basemap (refer to Appendix B).

Assignment of forested BEUs is based on VRI data such as tree species and site conditions. The logic applied to date is provided in Appendix B (refer to section that discusses “Step 2h” BEU update rules and methods). The Williston Wetland Explorer tool (WWET) was used to assist in the correction process for identification of wetland features. VRI polygons were also updated to reflect anthropogenic disturbance based on VRI labels and other disturbance inputs where available and appropriate.

Adjustments of BEU assignments to the appropriate scale were conducted to obtain as many correct assignments as possible with a high level of confidence within the scope of work and approved funding. Further edits should ideally incorporate field verification to improve the product’s accuracy.

2.4 Biogeoclimatic Ecosystem Classification (BEC)

VRI 2025 includes the biogeoclimatic ecosystem classification (BEC) data that was used in the BEMVRI product. The combination of zone, subzone, variants and phases are referred to as the BEC unit (BCMFLNRO 2017). BEC references for the Williston Watershed area are provided in “A field guide to site identification and interpretation for the North Central Portion of the Northern Interior Forest Region” (DeLong 2004), and “A field guide to ecosystem identification for the Boreal White and Black Spruce Zone of British Columbia” (DeLong et al. 2011). The best source of BEC information is the “BEC Web” (BEC WEB) and Biogeoclimatic zones - Province of British Columbia

A total of five BEC zones are represented within the Williston Watershed (Figure 3): the Boreal Altai Fescue Alpine (BAFA), Engelmann Spruce Subalpine Fir (ESSF), Spruce–Willow–Birch (SWB), Sub-boreal Spruce (SBS), and Boreal White and Black Spruce (BWBS). When further classified by subzone and variant, there are a total of 22 BEC units within the Williston Watershed (Table 2). The current most extensive BEC unit in the Williston Watershed project area is the Englemann Spruce - Subalpine Fir - Moist Very Cold, Omineca variant (ESSFmv3) (16.2% of the total area), followed by the alpine unit (BAFAun) (11.8% of the area) (Table 2).

The five BEC zones are sub-divided by subzone and variant that account for 22 BEC units (Table 2). BEC units overlapping with and immediately adjacent to the Williston reservoir include:

- Sub-Boreal Spruce - Moist Cool Mossvale variant (SBSmk1),
- Sub-Boreal Spruce - Moist Cool Williston variant (SBSmk2),
- Sub-Boreal Spruce - Wet Cool Finlay-Peace variant (SBSwk2),
- Boreal White and Black Spruce - Dry Cool Subzone (BWBSdk), and the
- Boreal White and Black Spruce - Moist Warm Subzone (BWBSmw).

Table 2. Biogeoclimatic Units of the Williston Watershed in 2025 (sorted by largest to smallest current extent) (bolded BEC units indicate the ones that overlap with or are immediately adjacent to the reservoir).

BEC Unit Code	BEC Unit Name (zone, subzone and variant where applicable)	Extent in Project Area (hectares)	% of Total Project Area
ESSFmv3	Englemann Spruce - Subalpine Fir - Moist Very Cold, Omineca variant	1,150,678.2	16.2
BAFAun	Boreal Altai Fescue Alpine - Undifferentiated	839,471.2	11.5
BWBSdk	**Boreal White and Black Spruce - Dry Cool Subzone**	**669,715.0**	**9.2**
SBSmk1	**Sub-Boreal Spruce - Moist Cool, Mossvale variant**	**638,436.0**	**8.8**
SWBmk	Spruce - Willow - Birch - Moist Cool	601,082.5	8.2
ESSFmv4	Englemann Spruce - Subalpine Fir - Moist Very Cold, Graham variant	565,145.1	8.0
SWBmks	Spruce - Willow - Birch - Moist Cool Scrub	413,573.5	5.7
SBSmk2	**Sub-Boreal Spruce - Moist Cool, Williston variant**	**388,730.2**	**5.3**
ESSFmvp	Englemann Spruce - Subalpine Fir - Moist Very Cold Parkland	359,898.8	5.1
SBSwk2	**Sub-Boreal Spruce - Wet Cool, Finlay-Peace variant**	**310,616.9**	**4.3**
ESSFwc3	Englemann Spruce - Subalpine Fir - Wet Cold, Cariboo variant	308,767.7	4.3
ESSFwk2	Englemann Spruce - Subalpine Fir - Wet Cool, Misinchinka variant	303,553.8	4.2
SBSwk1	Sub-Boreal Spruce - Wet Cool, Willow variant	269,821.4	3.7
SBSvk	Sub-Boreal Spruce - Very Wet Cool	142,356.9	2.0
ESSFwcp	Englemann Spruce - Subalpine Fir - Wet Cold Parkland	93,801.8	1.3
ESSFmv2	Englemann Spruce - Subalpine Fir - Moist Very Cold, Bullmoose variant	87,066.9	1.2
BWBSmw	**Boreal White and Black Spruce - Moist Warm Subzone**	**83,140.7**	**1.1**
BWBSwk2	Boreal White and Black Spruce - Wet Cool Subzone, Graham variant	28,844.5	0.4
SBSwk3	Sub-Boreal Spruce - Wet Cool, Takla variant	25,157.3	0.3
ESSFmcp	Englemann Spruce - Subalpine Fir - Moist Cold Parkland	3,021.5	<0.01
ESSFmc	Englemann Spruce - Subalpine Fir - Moist Cool	2,282.8	<0.01
BWBSwk1	Boreal White and Black Spruce - Wet Cool Subzone, Murray variant	1,001.7	<0.01
	Total BEC Area	**7,286,164.8**	**100.0**

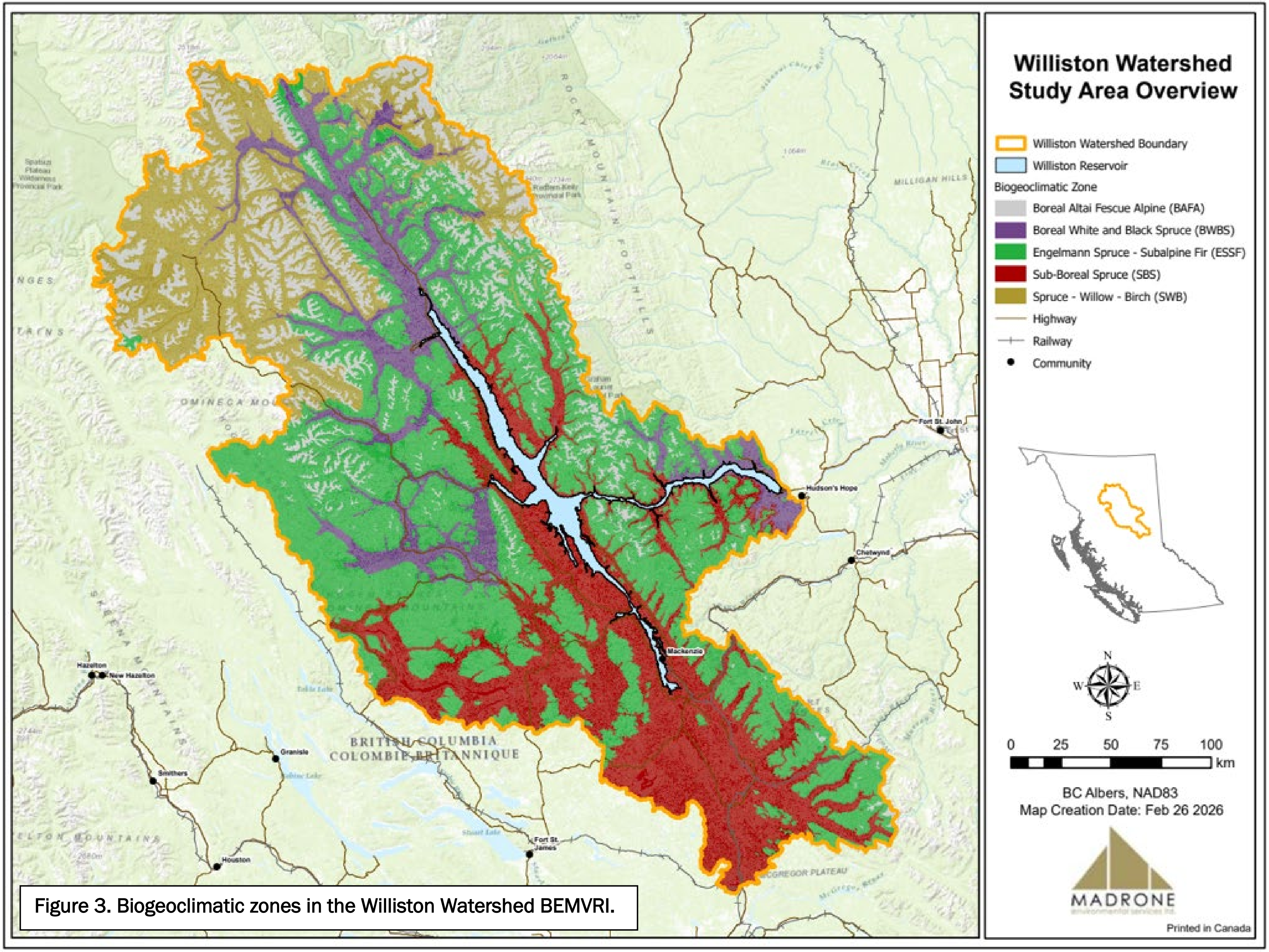

Figure 3. Biogeoclimatic zones in the Williston Watershed BEMVRI.

2.5 Wetland Features

Wetland and riparian associated ecosystems are important from an ecosystem services perspective as well as a wildlife habitat and overall associated with high biodiversity values. Many of these ecosystems were lost during flooding of the reservoir. Therefore, identifying and mapping these features received additional attention from the usual methods applied in the creation of a BEMVRI. Specifically, local wetland mapping was incorporated into the coverage.

2.5.1 Comparison of FWA and WWET

The Freshwater Atlas (FWA) is a standardized product with coverage of the entire province. It delineates watershed boundaries and freshwater bodies and some wetlands, although it does not distinguish between wetland types.

The Williston Wetland Explorer Tool (WWET) is the result of a multi-year program supported by FWCP to produce predictive mapping of wetlands based on field observations in the Williston drainage basin. WWET contains wetland classes in two resolutions, a three-class system and a ten-class system. To familiarize ourselves with potential trade-offs in use of a different wetland input than normal, a comparative analysis was performed to determine gains from use of WWET in the BEMVRI.

We were able to confirm that WWET captured more wetland areas than FWA, which provided further support for its use in identifying if a wetland was present or not. The next level of detail we hoped to obtain from WWET was wetland class. Based on the WWET report, identification of bogs, fens and open water wetland classes performed with reliable accuracy (Filatow et al. 2020). Therefore, it was determined that use of fen, bog and open water classes identified by WWET could be incorporated as BEUs (mapcode “FE” for fens, “BG” as a non-forested bog, and “OW” for open water) in the BEMVRI product. WWET was used to assign one of the following wetland classes to VRI polygons: fen, bog, open water, or generic “WL” (wetland). As with previous methods to incorporate FWA wetlands in BEMVRI, a minimum of 10% overlap with the VRI polygon was required to be incorporated into the label. When no clear wetland class could be assigned to a polygon due to the presence of competing deciles (i.e., WWET indicated overlap with the VRI polygon of multiple wetland classes; a mixed wetland site), the corresponding percentile was assigned as the generic wetland “WL” mapcode.

As part of the process of incorporating these labels into the BEMVRI, quality assurance was conducted on the resultant spatial product. A limitation in our initial assumption was observed; in essence being broader in their assignment than the ecosystem codes available in BEM. Specifically, the generic fen class identified in WWET could represent three scenarios:

1) herbaceous sedge leading sites (typically assigned “FE” the BEU for Sedge Fen along with structural stage 2b),
2) short-shrub fens (assigned the BEU “SH” Shrub fen), and a corresponding structural stages 3a (shrubs under 2 m tall), and
3) tall-shrub fens (also assigned “SH”) but assigned structural stage “3b” (shrubs over 2 m but under 10 m tall).

After a number of attempts to apply a series of rules to all available data sources to apply “FE” and “SH” with high confidence, it was determined that it was not possible without visual or field verification. Where indicated as fen in WWET, the generic “FE” was applied along with structural stage “2b” as the default to capture these important fen sites. Due to the importance of these features, extensive photo verification was applied to improve incorporation of fens and bogs. A total of 1,865 wetland features were checked via desktop imagery.

2.6 Realm, Group, Class (nBEC)

In addition to BEC and BEU units, non-forested ecosystem coding is assigned to each BEMVRI polygon based on standardized coding for Realm, Group and Class as per provincial standards (BCMFR & BCMOE 2010; Mackenzie 2012). This classification system is referred to as nBEC. "The classification system assigns a hierarchical set of units into the BEC system and extends the system to all naturally occurring non-forested ecosystems in British Columbia, including alpine, subalpine krummholz and shrubland, grassland, rock outcrop and talus, and persistent disclimax ecosystem" (Mackenzie 2012). The nBEC system is meant to complement the forest site series guidebooks and the wetland classification system for BC (Mackenzie and Moran 2004).

2.7 Topographic Attributes

Topographic information from a 25 m resolution DEM was assigned to each VRI polygon; assigning the average value based on the overlapping 25 m by 25 m grid cells (pixels) of the DEM raster with each VRI polygon. The information provided by the DEM includes slope, aspect, and elevation.

A combination of slope and aspect is assigned to each polygon as per Terrestrial Ecosystem Mapping (TEM) standards for use of site modifiers[4]. The steps to assign DEM-related values are outlined in Appendix B and applied by a Python script[5,] that also creates a field ("SLOPE_MOD") and populates it with a slope /aspect modifier value. An example of topographic attributes based on these methods is provided in Figure 4.

2.8 Forest Age

Forest age is a key component of BEM that is provided from VRI data. Age Classes in VRI correspond to seral stages (i.e., Age Class 1 = 0 to 20 years capturing the primary regenerating forest early seral stage) and range from 1 to 9 with Age Class 9 the oldest age bin. The first VRI age class (0-20 yrs) is too broad to capture the transitions between early seral stages for the purpose of potential use of this map product for wildlife habitat suitability interpretations. Therefore, VRI Age Class 1 is split into three bins of 0-3 (roughly aligning with structural stage "2b" herbaceous and low shrub "3a"), 4-10 (representing "3b" tall shrub of high forage value for ungulates), and 11 to 20 years.

2.8.1 Correction for Disturbance

A number of steps and cross-references are conducted to capture as "correct" of an age input as possible. This process involves taking information from multiple sources to ensure that the stand age assigned in the BEM reflects current conditions. The VRI derived projected age attribute was corrected using the consolidated cutblocks layer (CCL), the Reporting Silviculture Updates and Land Status Tracking System (RESULTS) application, and the fire history layer (DataBC 2025).

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[4] TEMMAN.PDF (gov.bc.ca)

[5] DEM Script - 02a_ add_aspect_slope.py

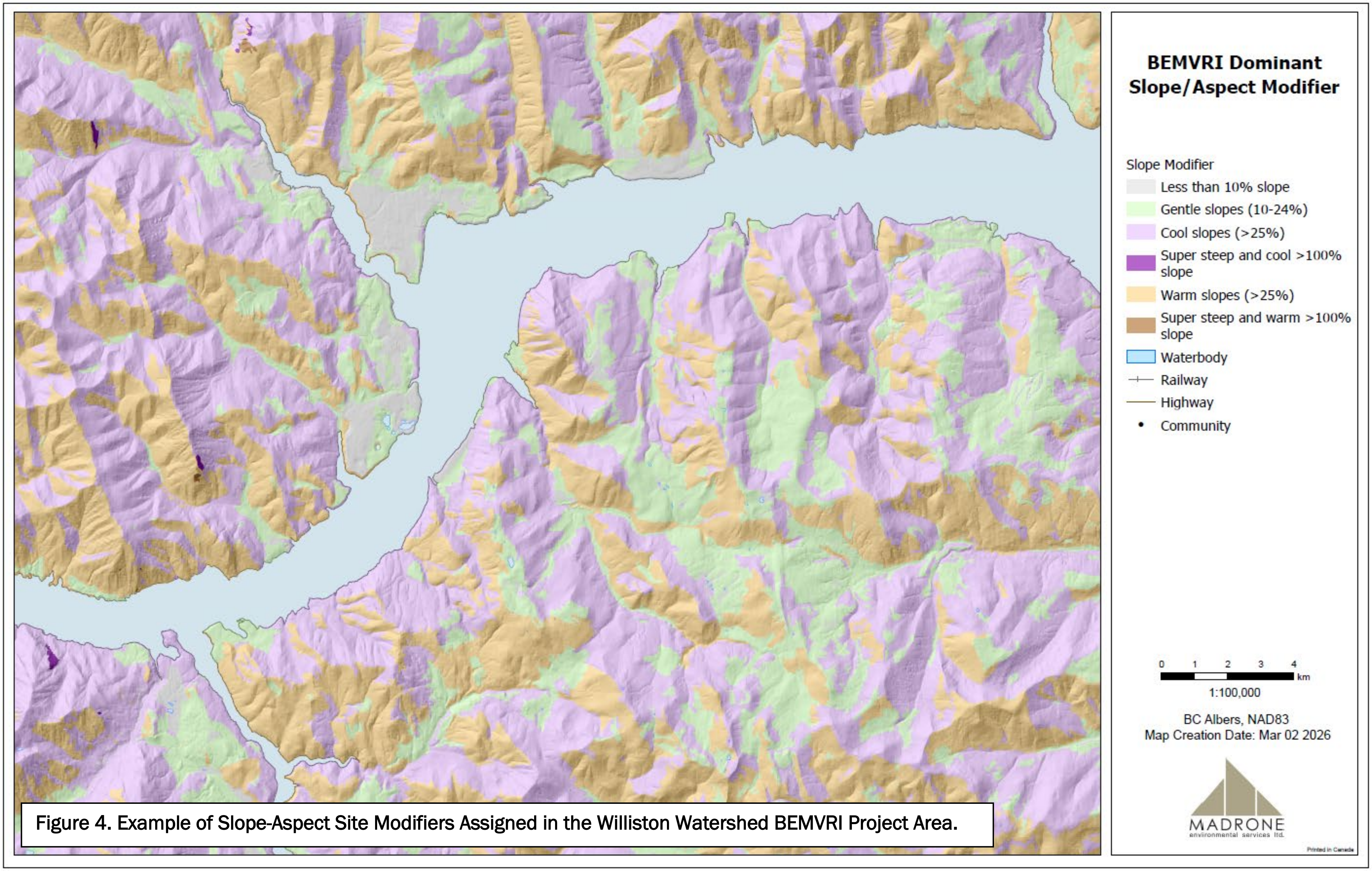

Figure 4. Example of Slope-Aspect Site Modifiers Assigned in the Williston Watershed BEMVRI Project Area.

RESULTS data were used to correct the VRI derived projected age attribute for forest harvesting activities conducted since the projected reference data (typically January 1st of the year prior to the release date) (Appendix B, Step 4). A script [6] to automate the process was developed to incorporate any changes in age class data based on the projected age and consolidated cut block information. In the script, the CCL harvest date took precedence over the VRI harvest date. For example, if VRI indicated a forest was old but the CCL indicated it had been harvested, the polygon age was updated to reflect the CCL data. Use of the CCL helped identify sites that had been harvested but were not indicated as such in the VRI.

A fire history layer with burn severity data was used to correct the VRI derived projected age attributes in the current conditions BEMVRI. In cases where VRI age class indicated old forest (Age Class 8 and 9), but the fire layer indicated extensive coverage of a high or moderate severity burn, age was updated to reflect the stand-replacing fire. In the current conditions version of the BEMVRI product, stand-replacing fires were defined as causing mortality of the majority of trees in the VRI polygon, in other words: coverage of ≥ 80% for a high severity burn, 100% for a moderate severity burn, or 100% for a combination of moderate and high severity burn.

2.8.2 Assignment of Structural Stage

Once the “best age” is determined, it is used to assign a corresponding structural stage code to describe the forest structure. Use of structural stages is the coding applied in provincial ecosystem mapping standards (RISC 1999). Structural stage codes are assigned to every ecosystem (BEU) in the BEMVRI product using a python script[7]. The script uses the corrected stand age attribute field in conjunction with a look-up-table (LUT) to populate a structural stage attribute field. Structural stage (STS) values ranging from 0 to 7d were assigned for a series of age ranges within the look-up table for each unique BEC-mapcode as per provincial, standardized definitions (MoFR and MoE 2010) and user-defined (for this project) non-standardized coding and associated definitions; specifically, “3u”, “7” and “7d” (Table 3).

High elevation, parkland forests, as well as lower elevation bog forests tend to have stunted structure regardless of how old they are; due to site factors such as shorter growing season, harsh winter conditions, and/or poor soil nutrients. The old growth state of these sites is very different from the classic, large, old forests that we tend to picture. From a wildlife habitat model perspective, this is an important consideration, especially for species that require large wildlife trees and large coarse woody debris that are typically associated with mature and old structural stages.

To differentiate the stunted forest types from other, more productive, forest types, a generic “7” was assigned to low elevation swamp and bog forests; with “productive” forest units assigned structural stages 7a. Low productivity but non-stunted forests, often found at higher elevations, were assigned to stage 7d. Stunted forests were assigned to 3c or 3d to represent krummholz communities acting as a shrub layer at high elevations.

Non-forested units typically defaulted (via the values assigned in the look-up table) to their structural stage condition at climax (structural stage 1, 2 or 3). Refer to the look-up table for the logic applied to “age” structure over time for each unique combination of BEC unit and BEU mapcode.

[6] 04b_update_sts_from_lut.py

Figure 5 depicts a high-level overview of assigned dominant structural stage to the first decile component in each BEMVRI polygon based on the LUT and VRI age data.

Table 3. Structural Stage Definitions (as per Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems, 2010) and Corresponding VRI Age Classes and Rules Applied in BEMVRI where Applicable.

Structural Stage	Description as per LMH 25	VRI Age Class	BEM Age Range
0 No Structure	Covers areas with no applicable structural stage such as rock, ice, and open water bodies.	Not applicable	Not applicable
1 Sparse/ cryptogam	Initial stages of primary and secondary succession; bryophytes and lichens often dominant, can be up to 100%; time since disturbance less than 20 years for normal forest succession, may be prolonged (50–100+ years) where there is little or no soil development (bedrock, boulder fields); total shrub and herb cover less than 20%; total tree layer cover less than 10%.	Not applicable	Not applicable
1a Sparse	Less than 10% vegetation cover;	Not applicable	Not applicable
1b Bryoid	Bryophyte-dominated communities (greater than ½ of total vegetation cover).	Not applicable	Not applicable
1c Lichen	Lichen-dominated communities (greater than ½ of total vegetation cover).	Not applicable	Not applicable
2 Herb	Early successional stage or herbaceous communities maintained by environmental conditions or disturbance (e.g., snow fields, avalanche tracks, wetlands, grasslands, flooding, intensive grazing, intense fire damage); dominated by herbs (forbs, graminoids, ferns); some invading or residual shrubs and trees may be present; tree layer cover less than 10%, shrubby layer cover less than or equal to 20% or less than 1/3 of total cover; time since disturbance less than 20 years for normal forest succession; many herbaceous communities are perpetually maintained in this stage.	Age Class 1	0 to 3 yrs since disturbance
2a Forb-dominated	Herbaceous communities dominated (greater than ½ of the total herb cover) by non-graminoid herbs, including ferns.	Not applicable	Not applicable
2b Graminoid-dominated	Herbaceous communities dominated (greater than ½ of the total herb cover) by grasses, sedges, reeds, and rushes.	Not applicable	Not applicable
2c Aquatic	Herbaceous communities dominated (greater than ½ of the total herb cover) by floating or submerged aquatic plants; does not include sedges growing in marshes with standing water (which are classed as 2b).	Not applicable	Not applicable
2d Dwarf shrub	Communities dominated (greater than ½ of the total herb cover) by dwarf woody species such as *Phyllodoce empetriformis, Cassiope mertensiana, Cassiope tetragona, Arctostaphylos arctica, Salix reticulata,* and *Rhododendron lapponicum*. (See list of dwarf shrubs assigned to the herb layer in the Field Manual for Describing Terrestrial Ecosystems).	Not applicable	Not applicable
3 Shrub/Herb	Early successional stage or shrub communities maintained by environmental conditions or disturbance (e.g., snow fields, avalanche tracks, wetlands, grasslands, flooding, intensive grazing, intense fire damage); dominated by shrubby vegetation; seedlings and advance regeneration may be abundant; tree layer cover less than 10%; shrub layer cover greater than 20% or greater than or equal to 1/3 of total cover.	Age Class 1	4 to 10 years
3a Low shrub	Communities dominated by shrub layer vegetation less than 2 m tall; may be perpetuated indefinitely to environmental conditions or repeated disturbance; seedlings and advance regeneration may be abundant; time since disturbance less than 20 years for normal forest succession.	Age Class 1	4 to 10 years
3b Tall shrub	Communities dominated by shrub layer vegetation that are 2–10 m tall; may be perpetuated indefinitely by environmental conditions or repeated disturbance; seedlings and advance regeneration may be abundant; time since disturbance less than 40 years for normal forest succession.	Age Class 1 & Age Class 2 (0 to 40 years)	11 to 30 years depending on BEC and BEU

Table 3 (cont'd). Structural Stage Definitions (as per Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems, 2010) and Corresponding VRI Age Classes and Rules Applied in BEMVRI where Applicable.

Structural Stage	Description as per LMH 25	VRI Age Class	BEM Age Range
3c Short stunted trees	Communities dominated by short stunted trees which may be perpetuated indefinitely by environmental conditions or repeated disturbance.	Not applicable	Not applicable
3d Krummholz	Parkland krummholz communities that are stunted trees functioning as a shrub layer vegetation that are 2–10 m tall; may be perpetuated indefinitely by environmental conditions or repeated disturbance; time since disturbance can be >100 years. Due to reduced growing season, deep snowpack, wind, poor nutrients, the trees remain stunted.	Not applicable	Not applicable
3u Declining Shrub	Communities which are dominated by shrubs 2-10 m tall but are beginning to be overshadowed by the regenerating forest (pole/sapling trees). Transitional between tall shrub and pole/sapling. At this stage, ungulate forage abundance and quality begins to decline due to shading.	Age Class 2 (21 to 40 years)	31 to 40 years depending on BEC and BEU
4 Pole/ Sapling	Trees greater than 10 m tall, typically dense stocked, have overtopped shrub and herb layers; younger stands are vigorous (usually greater than 10–15 years old); older stagnated stands (up to 100 years old) are also included; self-thinning and vertical structure not yet evident in the canopy – this often occurs by age 30 in vigorous broadleaf stands, which are generally younger than coniferous stand at the same structural stage; time since disturbance is usually less than 40 years for normal forest succession; up to 100+ years for dense (5,000 - 15,000+ stems per hectare) stagnant stands. - 15,000+ stems per hectare) stagnant stands.	Typically Age Class 3 (41 to 60)	31 to 60 years depending on BEC and BEU
5 Young Forest	Self-thinning has become evident, and the forest canopy has begun differentiation into distinct layers (dominant, main canopy, and overtopped); vigorous growth and a more open stand than in the pole/sapling sate; time since disturbance is generally 40–80 years but may begin as early as age 30, depending on tree species and ecological conditions.	Typically Age Class 4 (61 to 80 years)	41 to 80 years depending on BEC and BEU
6 Mature Forest	Trees established after the last disturbance have matured; a second cycle of shade tolerant trees may have become established; understories become well developed as the canopy opens up; time since disturbance is generally 80–140 years for stands within the Prince Rupert forest region.	Age Classes 5/6/7 (81 to 140)	81 to 140 years depending on BEC and BEU
7 Low Productivity/ Low Elevation Old Forest	Stands of old age with complex structure; patchy shrub and herb understories are typical; regeneration is usually of shade-tolerant species with composition similar to the overstorey; long-lived seral species may be present in some ecosystem types or edaphic sites. Old growth structural attributes will differ across biogeoclimatic units and ecosystems but typically begins 140 years after a succession-initiating disturbance.	Age Class 8 and 9 (>140 years)	(>140 years)
7a Productive Old Forest	Stands with moderately to well-developed structural complexity; stands composed mainly of shade-tolerant and regenerating tree species, although older seral and long-lived trees from a disturbance such as fire may still dominate the upper canopy; fire-maintained stands may have a 'single-storied' appearance; time since stand replacing disturbance generally greater than 140 years within the Prince George forest Region.	Age Class 8 and 9 (>140 years)	(>140 years)
7d Low-Productivity/ High elevation Old Forest	Old stands having complex structure, snags and coarse woody debris; snags and coarse woody debris in all stages of decomposition; stands are comprised entirely of shade-tolerant overstorey species with well-established canopy gaps; time since stand replacing disturbance generally greater than 140 years.	Age Class 8 and 9 (>140 years)	(>140 years)

2.8.3 Stand Composition

Stand composition is assigned by a script developed to apply the logic for reading all six tree species code fields in VRI to determine whether the forest is C (coniferous), B (broadleaf), or M (mixed) based on SPECIES_CD_# and amount in the SPECIES_PCT_# fields (Table 4). Stand composition that corresponds with the structural stage climax condition and age for the forested units was assigned according to the look-up table for some forested units when VRI tree species data was not available. A figure depicting distribution of current conditions for stand composition based on these methods is provided in Figure 6.

Table 4. Stand Composition Definitions as Available for Species-Habitat Models (modified from Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems, 2010).

Stand Composition	Description
	A description of the leaf-types of trees in a stand (only for structural stages 4-7)
C	Coniferous (>75% of total tree cover is coniferous)
B	Broadleaf (>75% of the total tree cover is broadleaf)
M	Mixed (neither coniferous or broadleaf account for >75% of the total tree cover)

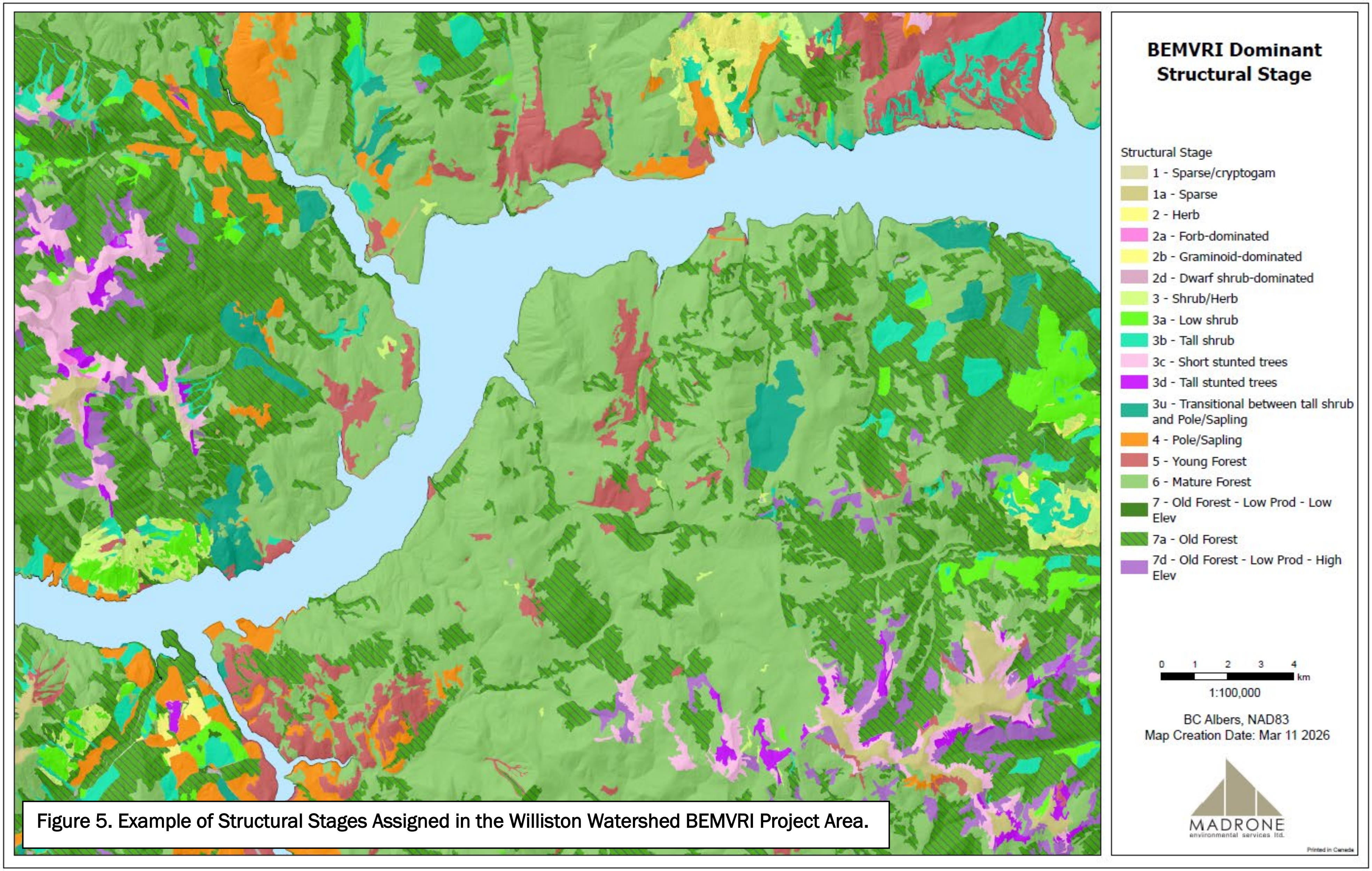

Figure 5. Example of Structural Stages Assigned in the Williston Watershed BEMVRI Project Area.

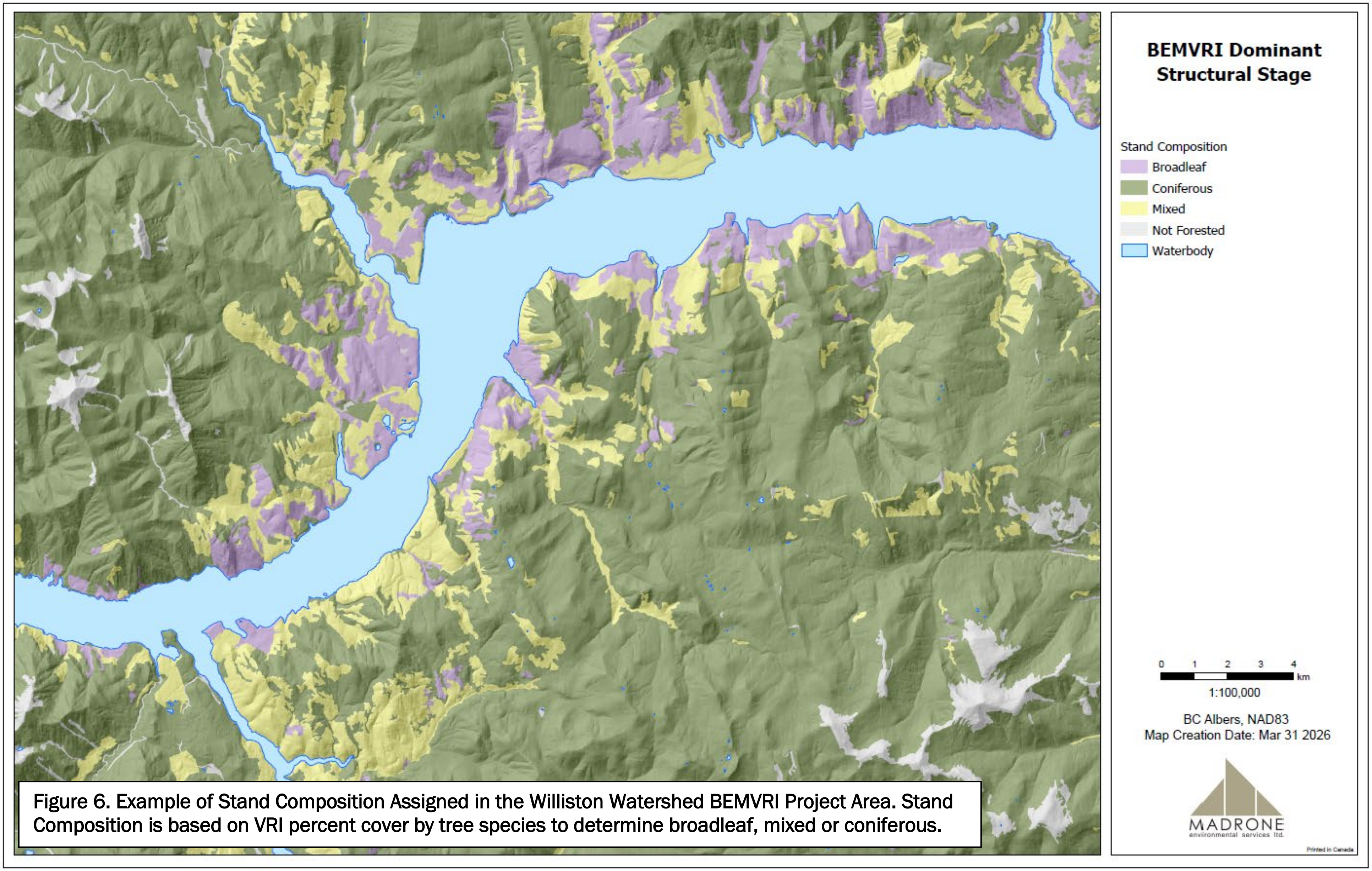

Figure 6. Example of Stand Composition Assigned in the Williston Watershed BEMVRI Project Area. Stand Composition is based on VRI percent cover by tree species to determine broadleaf, mixed or coniferous.

2.9 Tracking Updates to the BEMVRI 2025 Mapping

Future updates to the BEMVRI coverage could include incorporating a new age input, disturbance layer, or field verification of the ecosystems (BEU label). Polygon-specific updates need to be manually entered directly into the BEMVRI spatial product where features such as BEU labels and structural stages varied from the field compared to predictions. Where these edits are made, the field "SMPL_TYPE" needs to be filled in to indicate which type of field verification occurred. The SMPL_TYPE field can only contain one character. Verification types typically include air photo interpretation (P), visual (V), ground plots (G), and full plots (E). Coding for other plot or verification efforts can be added.

In the Williston Watershed BEMVRI, all desktop validation efforts are tracked in the SMPL_TYPE with the following coding: "P" was assigned in the 1968 coverage to indicate all polygons associated with the imagery based TEM product done by Timberline in 2006. The code "D" was used to indicate desktop verification efforts conducted by the Ecosystem Mapper for current conditions. Use of "D" indicates that the entire BEM label was checked. The code "F" was used where fire data or imagery indicated that a structural stage update was required. The code "W" was used to indicate review of wetland features.

The set of scripts created for this project that enable future updates with new data have been programmed to "skip" over any polygons indicated as field verified or desktop verified (i.e., SMPL_TYPE field is populated). In that the "hard coded" edits to the BEMVRI will not be over-written with scripted assumptions related to BEUs, stand composition, and structural stage.

3 Pre-flood Conditions (1968) BEMVRI Coverage

This section describes the creation of the BEMVRI product to represent pre-flood conditions (1968) of the Williston Watershed project area.

3.1 Incorporation of 2006 Ecosystem Mapping

Before flooding of the reservoir in 1968, aerial orthophoto imagery was captured over most of the reservoir's eventual extent (Figure 7). In 2006 ecosystem mapping of the 1968 imagery was funded by BC Hydro and completed by Timberline Forest Inventory Consultants (Timberline 2006). The mapping interpreted ecosystem conditions in the area below the current high-water line of the reservoir encompassing approximately 181,177 ha, as well as a 200 m buffer above the high-water mark (23,453 ha); for a combined mapped area of 204,223 ha.

The mapping (polygon delineation) was done at 1:20,000 scale on the air photos with subsequent digitization of the linework. The mapping approach applied modified from Terrestrial Ecosystem Mapping (TEM) RIC (1998), as bioterrain mapping, typically required by TEM, was not conducted. Each polygon was assigned at least one site series, structural stage, slope class, aspect class, forest type and cottonwood cover rating, as well as a wetland class where appropriate. A minimum polygon size of 2 ha was applied, unless it was a wetland, in which case the maximum size for a unique wetland polygon was 1 hectare.

Limitations associated with the mapping are detailed in Timberline (2006) and include:

> "This project has been unique and challenging. It differs from most modern digital spatial data capture and mapping processes because it lacks TRIM digital elevation

> data and TRIM water, as well as ground truth data for checking the reliability of reach break and ecosystem polygon attributes.
>
> The predominant issue around this mapping is the lack of field data describing the relationship between flood plain physical characteristics and site series classification. The ecosystems that were in place before the valley floors were inundated are rare in the present day landscape. The Peace River is an area which combines high relief with narrow valleys, consequently, level ground and flood plain local ecosystems were lost and may have been unique to the combination of climate and physiography historically present in the valley floors of the Peace, Parsnip and Finlay rivers.
>
> Site series classifications are not particularly elaborate in these areas. Not only are undisturbed flood plains rare in the post flooding era, but Ministry of Forests priorities for site series classification were with upland sites, suitable for forestry, during the development of the field guides available for use in this project (DeLong et al 1990, DeLong et al 1993, DeLong 2004). In the gentler landscapes that were flooded in the Finlay and Parsnip reaches, the network of wetlands and low ground and, likely, fine textured soils, is also probably unique for that area and not well reflected by the MOF classifications.
>
> The classification utilized in this project for wetlands lacks enough detail to differentiate between the vast number of diverse wetlands that likely existed in the project area pre-flooding. Most wetlands are classified as WE at the site series level, with graminoid versus shrub dominated wetlands recognized at the structural stage level. The wetland classification (MacKenzie et al 2004) is applied at the Site Class level, recognizing Fen (Fn), Marsh (Ms), Swamp (Sw), Shallow-waters (Ws), Flood Associations (Df) and Shrub-carr Transition Association (Tn).
>
> Interpretation of stand structure was complicated by the inconsistency of air photo quality. In some areas stands were being harvested to make way for the flooding, thus structural stage calls do not reflect pristine, pre-flood circumstances.
>
> Interpretation of stand composition and slope class was also complicated by photo quality and lack of field data.”

Original linework from this ecosystem map product was used as a foundational component for analysis of pre-flood conditions in the 1968 coverage for the Williston Watershed.

As noted above “In some areas stands were being harvested to make way for the flooding, thus structural stage calls do not reflect pristine, pre-flood circumstances.” As a result, the total amount of mature and old forest cleared in preparation for flooding prior to 1968 is unknown. Therefore, when comparing forest conditions before and after flooding, the loss of older forests is assumed to be under-represented. To attempt to address this lack of data, we quantified what was photo-interpreted based on 1968 imagery as recently harvested as reflected by mapped herbaceous “structural stage 2” and shrub “structural stage 3” forested site series. This area of the most recently harvested forests provides an indication of potential additional loss of old forest prior to 1968 for preparation of flooding.

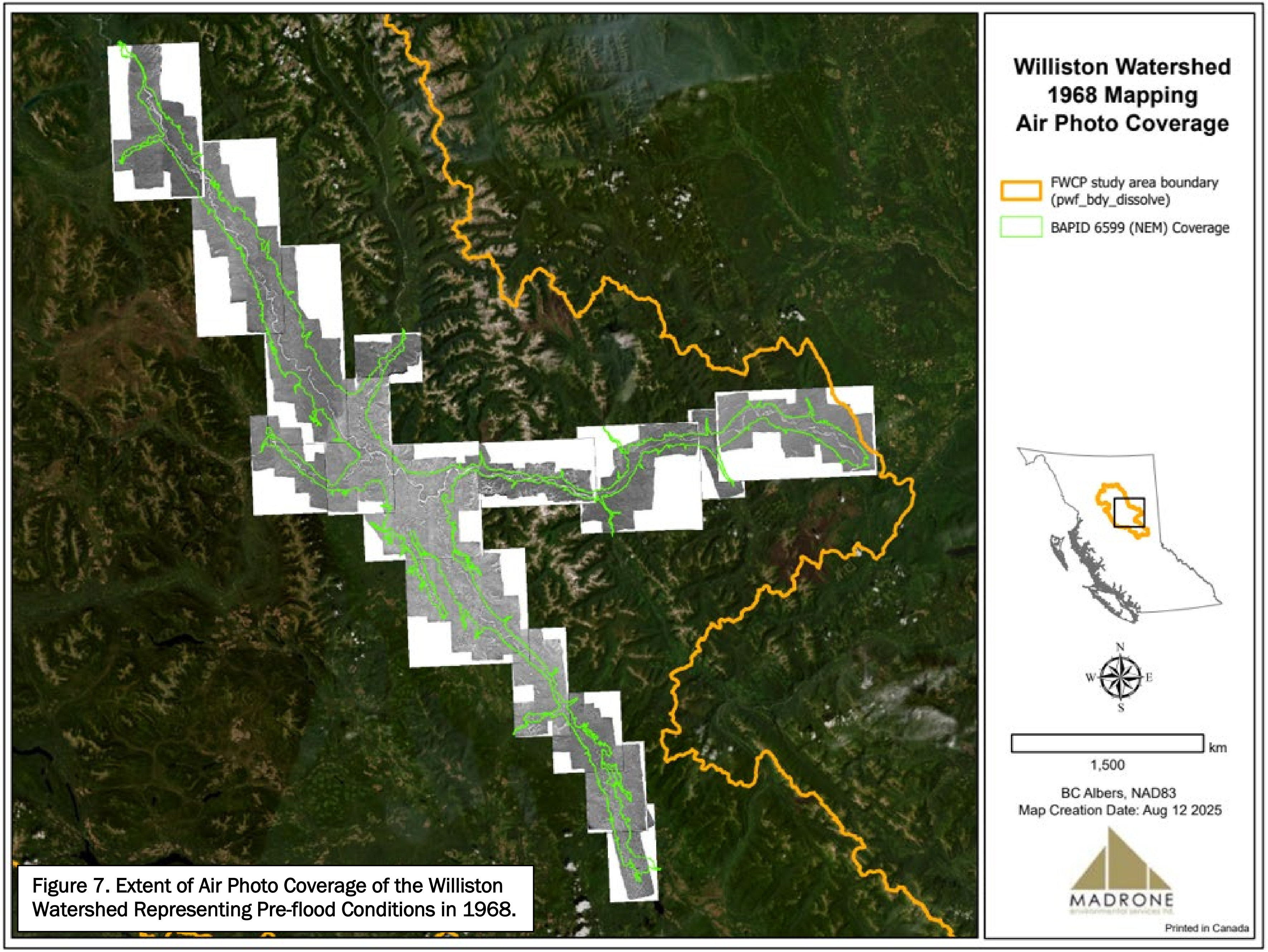

Figure 7. Extent of Air Photo Coverage of the Williston Watershed Representing Pre-flood Conditions in 1968.

3.2 Biogeoclimatic Ecosystem Classification (BEC) and BEUs

BEC from the current conditions BEMVRI product was used to represent BEC classification in 1968. This was the only approach to enable comparison of conditions before and after flooding. Within the flooded area, the BEC assigned by Timberline (2006) was applied.

BEU assignments were not altered between the BEMVRI 2025 and 1968 coverages; with the exception of pre-flood mapping described above. As with other provincial ecosystem map products, it was assumed that sites contain the same ecosystems over time; unless permanently disturbed via mining, roads, flooding, etc. The 1968 mapping relies on assumptions about vegetation distributions remaining similar between these two periods in time. Therefore, the pre-flood mapping does not account for changes in species distributions due to shifting climate, weather patterns, and most natural disturbances. A total of 62 unique BEU codes were mapped in the Williston Watershed BEMVRI (Table 5). Section 4.2.1, Table 9 summarizes the area of each BEU mapped by BEC zone for each BEMVRI coverage. Maintaining the same ecosystem types, provided a framework for a comparative analysis between products to account for change in structural stage conditions and loss of ecosystems.

3.2.1 Cross-walking TEM to BEM

The Timberline (2006) pre-flood ecosystem mapping linework and attribution (data) was loaded into the TEIS ecosystem mapping (i.e., TEM, PEM and BEM) table structure using *Append* and manually matching fields. Cross-walking TEM site series and mapcodes to BEU codes were completed using a combination of scripts and manual methods using logic summarized in Table 6. This process was assisted by creation of a crosswalk table to facilitate data transfer from the 2006 map product to current BC ecosystem classification codes by Jackie Churchill of BC's Ministry of Water, Land and Resource Stewardship.

As a result of the applied cross-walking of the TEM ecosystem codes to equivalent BEM codes (BEUs):

- In the BWBSdk 18 TEM codes were cross-walked to 11 corresponding BEUs, with four forested site series (01/03/05/06) represented by one BEU ("BP") (Table 6).
- In the BWBSmw, 20 TEM codes were cross-walked to 14 BEUs, again with four forested site series (01/03/05/06) represented by one BEU ("BP")
- In the SBSmk1, 17 TEM codes were cross-walked to 12 BEUs, with the 01 and 04 site series assigned to "SF".
- In the SBSmk2, 22 TEM codes were cross-walked to 18 BEUs.
- In the SBSwk2, 14 TEM codes were cross-walked to 11 BEUs.

Table 5. Broad Ecosystem Units (BEUs) Mapped in the BEMVRI for the Williston Watershed.

BEU Code	BEU Name	BEU Code	BEU Name	BEU Code	BEU Name
AG	Alpine Grassland	**FE**	Fen	**SF**	White Spruce - Subalpine Fir
AM	Alpine Meadow	**FP**	Engelmann Spruce - Subalpine Fir Parkland	**SG**	Subalpine Grassland
AS	Alpine Shrub	**GB**	Gravel Bar	**SH**	Shrub Fen
AT	Alpine Tundra	**GL**	Glacier	**SK**	Spruce - Swamp
AU	Alpine Unvegetated	**GP**	Gravel Pit	**SL**	Sub-boreal White Spruce - Lodgepole Pine
AV	Avalanche Track	**LL**	Large Lake	**SM**	Subalpine Meadow
BA	Boreal White Spruce - Trembling Aspen	**LP**	Lodgepole Pine	**SU**	Subalpine Shrub/Grassland
BB	Black Spruce Bog	**LS**	Small Lake	**SW**	Shrub Swamp
BG	Sphagnum Bog	**ME**	Meadow	**TA**	Talus
BK	Subalpine Fir - Scrub Birch Krummholz	**MI**	Mine	**TB**	Trembling Aspen - Balsam Poplar
BL	Black Spruce - Lodgepole Pine	**MR**	Marsh	**TC**	Transportation Corridor
BP	Boreal White Spruce - Lodgepole Pine	**NM**	Not Mapped	**TF**	Tamarack Wetland
BR*	Brush	**OW**	Shallow Open Water	**TR**	Transmission Corridor (after 1968)
CF	Cultivated Field	**PR**	White Spruce - Balsam Poplar Riparian	**UR**	Urban
CL	Cliff	**RE**	Reservoir	**UV**	Unvegetated
DF	Interior Douglas-fir	**RI***	River	**WB**	Whitebark Pine Subalpine
DL	Douglas-fir - Lodgepole Pine	**RO**	Rock	**WG**	Hybrid White Spruce Bog Forest
EF	Engelmann Spruce - Subalpine Fir (Dry)	**SA**	Sub-boreal White Spruce - Trembling Aspen	**WL**	Wetland
ER	Engelmann Spruce Riparian	**SB**	White Spruce - Paper Birch	**WP**	Subalpine Fir - Mountain Hemlock Wet Parkland
EW	Subalpine Fir - Mountain Hemlock Wet	**SC**	Shrub-Carr	**WR**	Hybrid White Spruce - Black Cottonwood Riparian
FB	Subalpine Fir - Scrub Birch Forested	**SD**	Spruce - Douglas-fir		

Table 6: Conversion logic of Timberline (2006) TEM codes to broad ecosystem units (BEUs) applied to the Williston BEMVRI for 1968.

BEC Unit	TEM Site Series/Mapcode*	BEU Code	BEC Unit	TEM Site Series/Mapcode*	BEU Code	BEC Unit	TEM Site Series/Mapcode*	BEU Code
BWBSdk	01/SM	BP	BWBSmw1	00/TA	TA	SBSmk2	00/GB	GB
BWBSdk	02/LL	LP	BWBSmw1	00/WH	SW	SBSmk2	00/LA	LL
BWBSdk	03/SW&05/SS&06/SR	BP				SBSmk2	00/OW	OW
BWBSdk	04/BL & 07/BC	BL	SBSmk1	01/SB	SF	SBSmk2	00/PD	LS
BWBSdk	08/SC	PR	SBSmk1	03/LC	LP	SBSmk2	00/RI	RI
BWBSdk	09/BH & 10/BS	BB	SBSmk1	04/DK	SF	SBSmk2	00/RO	RO
BWBSdk	11/SG	SK	SBSmk1	05/ST	SL	SBSmk2	00/RW	UR
BWBSdk	00/BB & 00/FB	SH	SBSmk1	06/BH	BL	SBSmk2	00/TA	TA
BWBSdk	00/CB	UV	SBSmk1	07/SO & 09/SH	WR	SBSmk2	00/WB	BB
BWBSdk	00/GB	GB	SBSmk1	10/BB	BB	SBSmk2	00/WF	SH
BWBSdk	00/HG	MR	SBSmk1	00/ES	UV	SBSmk2	00/WS	SK
BWBSdk	00/PW & 00/WF	PR	SBSmk1	00/FM	WR			
BWBSdk	00/RI	RI	SBSmk1	00/GB	GB	SBSwk2	01/SO	SF
			SBSmk1	00/OW	OW	SBSwk2	02/LH	LP
BWBSmw	01/AM	BP	SBSmk1	00/RI	RI	SBSwk2	03/SC & 05/SD	SF
BWBSmw	02/LL	LP	SBSmk1	00/WB	WR	SBSwk2	06/SH	SK
BWBSmw	03/SW&05/SO&06/SC	BP	SBSmk1	00/WF & 00/WH	SH	SBSwk2	00/CB	UV
BWBSmw	03-$/SW & 05-$/SO	BA	SBSmk1	00/WS	FE	SBSwk2	00/FL	WR
BWBSmw	07/SH &07-$/SH	PR				SBSwk2	00/GB	GB
BWBSmw	08/BT	BB	SBSmk2	01/SB & 05/SO	SF	SBSwk2	00/OW	OW
BWBSmw	00/CB	UV	SBSmk2	02/LC	LP	SBSwk2	00/RI	RI
BWBSmw	00/CF	CF	SBSmk2	03/SS	SL	SBSwk2	00/RO	RO
BWBSmw	00/ES	UV	SBSmk2	04/BH	BL	SBSwk2	00/TA	TA
BWBSmw	00/FL	PR	SBSmk2	06/SH	WR	SBSwk2	00/WF & 00/WS	SH
BWBSmw	00/GB	GB	SBSmk2	00/CB	UV			
BWBSmw1	00/RI	RI	SBSmk2	00/CF	CF			
BWBSmw1	00/RO	RO	SBSmk2	00/ES	UV			
BWBSmw1	00/RW	UR	SBSmk2	00/FL & 00/FM	WR			

*Refer to Timberline 2006 report and appendices for detailed descriptions of site series and mapcodes as applied to the 1968 ecosystem mapping.

3.2.2 Quality Assurance of Incorporation of 2006 Map Product

In addition to the transfer of attribute data, the original linework was assessed to ensure compatibility with current spatial data standards. Linework corrections applied included adjustment to remove overlapping polygons and closing gaps between polygons to create a fully contiguous layer. Slivers and topographic errors were fixed prior to transfer of the spatial data.

Once the 1968 mapping was incorporated into the correct ecosystem database format, the product was assessed for errors. A few typos were easily updated (i.e., SBSmK2 updated to SBSmk2). Polygon labels were checked to ensure that they were all populated. Because of incomplete imagery coverage of the entire reservoir there were 2,138 ha within the backcast map product which could not be classified into a BEU and were categorized as 'NM' for 'Not Mapped'. There were a number of polygons that went beyond the extent of the imagery that were blank. These polygons were removed to be replaced with BEMVRI 2025 polygon linework that was populated with digital elevation information (slope, aspect, elevation) and ecosystem(s) (BEUs). Although new mapping based on 1968 imagery was beyond the scope of the project, in a handful of cases there were polygons that encompassed obvious water bodies. Based on examination of the 1968 imagery these polygons were easily attributed to provide a more complete coverage.

As well, BEU coding was checked to ensure that it "fit" with the coding applied to the surrounding area. For example, codes for lakes were adjusted to reflect the correct size, for instance, if polygons were classified as large lakes (LL) but were less than 60 ha they were re-classified as small lakes for consistency with the BEM product. One small lake polygon less than 8 hectares was changed to the open water (OW) wetland class.

3.3 Back-casting Age to 1968

Following transfer of the 1968 ecosystem mapping by Timberline (2006) into a standardized TEIS "long table" database format, work began on an age input layer for the remainder of the Williston Watershed for back-casting the BEMVRI 2025 coverage. As VRI has been collected in the Williston area since 2002, older data can be used to estimate pre-flood vegetation conditions although there are challenges to its use such as lower accuracy and outdated data fields.

An initial attempt was made to create a back-cast version of BEMVRI based on VRI linework from 2002. Unfortunately, the linework was extensively different and would not have enabled a "true" comparison between time periods. Therefore, to capture likely conditions in 1968, an age layer was created to back-cast to that time. This age input was used with the same BEMVRI linework as used for current conditions. This approach enabled equivalent comparison of conditions between the two time periods.

To approximate conditions in 1968, linework and assigned ecosystems in the BEMVRI 2025 were used as the base polygon layer. Use of the same linework ensured a comparative analysis of "apples to apples". The main limitation to this approach was specific to linework in the current conditions coverage that captures anthropogenic disturbance features such as transmission lines that were not there pre-flooding. Disturbance features are discussed in the analysis section.

The following is an overly simplified summary of a complex, imperfect process to achieve an estimated stand age for 1968:

1) Assess difference in data coverage between VRI 2025 and VRI 2002 (Figure 8).

2) BEMVRI 2025 – non-forested (forested landbase = N): Assign “8888” to 1968 projected age field to indicate no age required; not forested – hold set of polygons to the side as “done”. Assumption is that water, rock, wetlands, etc. were the same ecosystem in 1968.
3) BEMVRI 2025 – forested units: Start by subtracting 57 years from projected age in current conditions product for any forests currently over 57 years old (2025-1968) – hold those polygons to the side as “done” (backcast to 1968).
4) VRI2002: Using VRI 2002 (the oldest available VRI spatial coverage), subtract 33 years (2002-1968) to all forests with projected age over 34 years in 2002 – hold those polygons to the side as “done”;
    a. Following steps 3 and 4, the majority of the forested landbase was populated with a 1968 backcast age. The remaining polygons were more challenging due to the following factors:
        i. Harvest took place between 1968 and 2002 and stand age at the time of first rotation harvest is undocumented.
        ii. Harvest took place between 1968 and 2002 and may reflect a second rotation in lower elevation, productive sites. Again, age at harvest is undocumented. Also, VRI does not track which rotation the harvest represents.
        iii. Difficulty in assigning age to sites with harvest dates and fire dates close together or sequences that don’t align with disturbance.
        iv. No age data provided in VRI2002 product; Projected Age was blank.
5) VRI2002: For polygons with no projected age information, use harvest date from VRI2025 to determine if an appropriate age can be assigned with this logic,
6) For remaining gaps in age, assess each BE. unit for the best approach to fill in the missing age data.
    a. As an example, to put the age data gaps in perspective, in the BWBSdk 36,051 polygons were assigned age via steps 3 through 5, and 4,535 (11% of BWBSdk forest polygons) remained un-assigned for “Age in 1968”.
7) Determine average age of stands in 1968 by BEC unit, and site index (<16, 16-20, and >20; <14, 14-18, and >18 used for higher elevation forests in the upper ESSF BEC units) based on data with highest confidence (the two layers identified above).
    a. Sticking with the BWBSdk example, 21,901 polygons with a site index <16 were available to calculate an average age of 186 years old in 1968. Corresponding polygons with <16 site index in the BWBSdk un-assigned age were populated with 186 years.
8) For high elevation BEC units where no harvest would have taken place prior to 1968 (i.e., ESSFmv4 and SWBmks), assign blank age with average known age data for corresponding site index bin;
    a. An example of the applied logic follows: for the ESSFmv4 age data backcast to 1968 was available based on steps 2 and 3 for 779 forested polygons with a site index over 14, and an age range of 52 to 176 years old (natural disturbance was the main source of younger aged forests), and an average age of 110 years. Therefore, for the 1968 age input, we applied 110 years to polygons without a clear pathway for age assignment.

   b. It was acknowledged that assigning averages may have resulted in "watering down" examples of old forest but was considered minimal due to high elevation nature of these sites and small number of polygons (~6,000 polygons).

9) After examining fire boundaries from 1968 and prior, it was determined that the historical fire layer was not very accurate when overlayed with on-line current imagery. Correction of fire boundaries using current imagery is possible but would require a high effort that was beyond the scope of this work. It was decided not to adjust age where it overlapped with the historical fire boundaries. However, the fire history layer is included in the BEMVRI product for future reference and use in queries.
   a. Some data for sequences of events aligned to enable age assignment (i.e., burned in 1920, 48 years in 1968, logged in 1998).

10) Compare two age layers (2025 and 1968) to check logic and assumptions;
   a. For example, old forest in 2025 shouldn't be indicated as logged in 1968 layer. Old forest in 2025 remained old forest in both products for assignment of structural stage if no source of disturbance was indicated.

11) Assign 1968 age input to 2025 BEMVRI polygons based on majority age overlap with current linework. This process also aids in assigning age to disturbance features that were forested prior to their creation after 1968.
   a. Age is binned into groups that correspond to structural stage assignments: 0-3, 4-10, 11-30, 31-40, 41-60, 61-80, 81-139, 140-249, and >249.

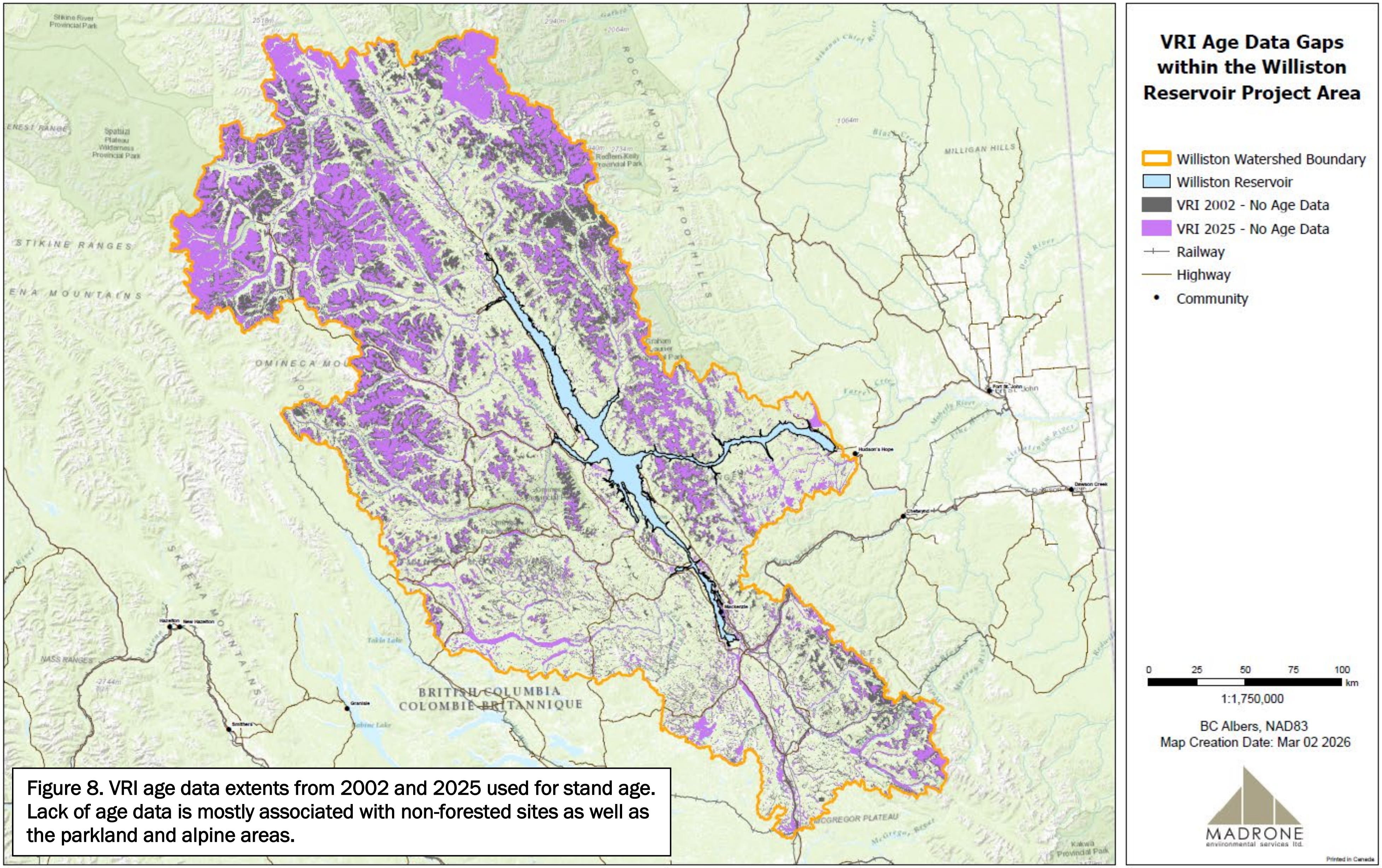

Figure 8. VRI age data extents from 2002 and 2025 used for stand age. Lack of age data is mostly associated with non-forested sites as well as the parkland and alpine areas.

3.3.1 Assignment of Structural Stage

As in the current conditions BEMVRI, structural stage class is assigned to every 1968 BEMVRI polygon using a python script[8]. The script uses the back dated stand age attribute field in conjunction with a look-up-table (LUT) to populate a structural stage attribute field. Structural stage (STS) values ranging from 0 to 7d were assigned for a series of age ranges within the look-up table for each unique BEC-mapcode as per provincial, standardized definitions (MoFR and MoE 2010) and proposed additions to the standardized definitions; specifically, “3d”, “3u”, “7” and “7d” (Table 3). Extensive QA of the output was conducted to provide for a stable product and confidence in the subsequent comparative analyses.

Appendix E provides a summary table by BEC unit of the differences in coverages in assignment of structural stage as well as change between the two time periods.

3.3.2 Stand Composition

Stand composition provided in the TEM product (Timberline 2006) based on interpretation of black and white imagery from 1968 were applied to the BEMVRI 1968 product in the corresponding field.

All forested polygons that were established stands in 1968 (young to old forest) and aged forward to 2025, the stand composition assigned in the 2025 was maintained based on VRI tree species composition. The assumption being that if the stand is presently an old mixed stand forest, it was likely a mixed stand 56 years ago. Due to the lack of VRI data from 1968 for the rest of the area, a set of rules were applied to each forested site based on BEC unit, ecosystem label (BEU), and age and assumed stand composition at that stage.

3.4 Topographic Attributes

A combination of slope and aspect is assigned to each polygon as per Terrestrial Ecosystem Mapping (TEM) standards for use of site modifiers[9]. The 2006 mapping by Timberline included interpretation of slope and aspect using historical imagery (pre-flood) from 1968. This data was used to populate the site modifier assigned to each of the 1968 polygons.

Outside of the reservoir footprint, the same DEM values were assigned to VRI polygons for the pre-flood and current conditions (BEMVRI 2025). The information provided by the DEM includes slope, aspect, and elevation. It was assumed that if a polygon presently has a warm aspect, those conditions would have been the same in 1968. The steps to assign DEM-related values are outlined in Appendix B and applied via Python scripts[10]

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8 04b_update_sts_from_lut.py

9 [TEMMAN.PDF (gov.bc.ca)]

10 DEM Script - 02a_ add_aspect_slope.py

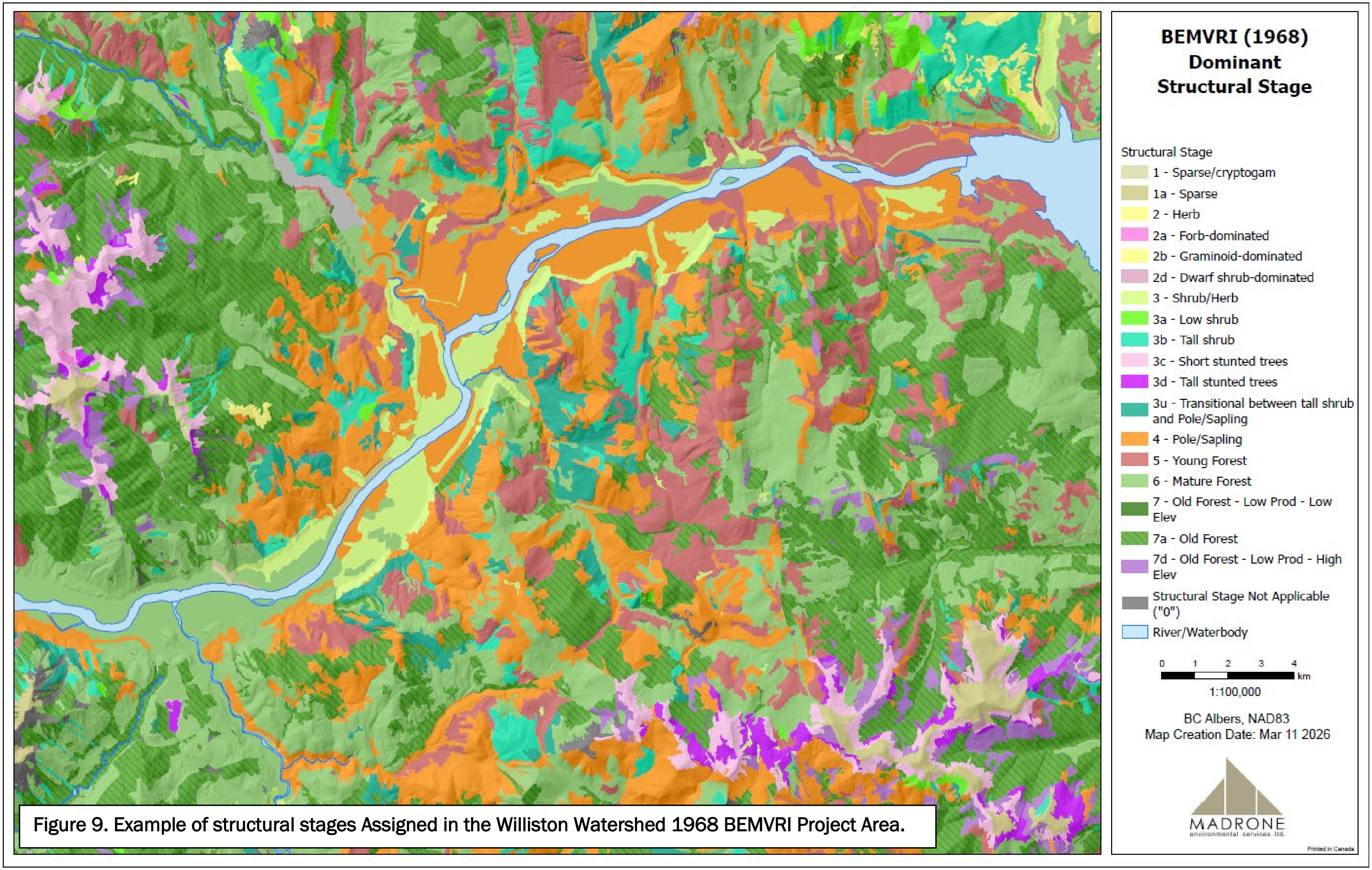

Figure 9. Example of structural stages Assigned in the Williston Watershed 1968 BEMVRI Project Area.

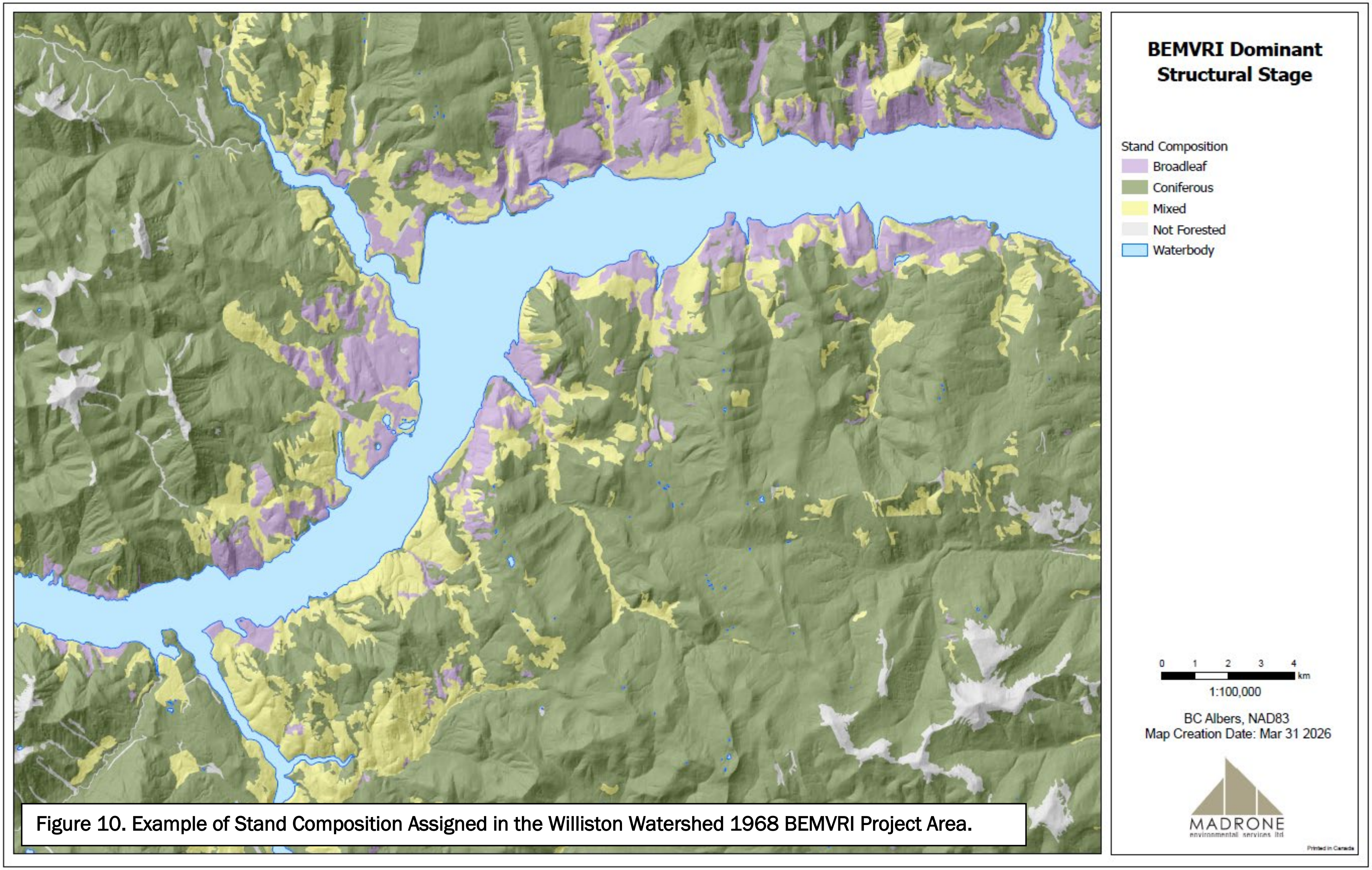

Figure 10. Example of Stand Composition Assigned in the Williston Watershed 1968 BEMVRI Project Area.

4 Comparison of Pre-flood to Current Conditions

Spatial data from the current conditions 2025 BEMVRI and the historical 1968 BEMVRI were exported from ArcGIS into Excel .csv format spreadsheets. Software from R (R Core Team, 2023) was used to compare the two datasets to examine change from 1968 to present. Missing data in the 1968 mapping, due to incomplete historical imagery and mapping coverage, was excluded from analysis (i.e., to compare equal total areas). Graphs were created either in R with the *ggplot2* package (Wickham, 2016) or in ArcPro unless otherwise specified.

4.1 Change in BEC Unit Representation

There are 22 BEC units in the Williston Watershed (Table 2), five of which were directly impacted by the reservoir: the SBSmk1, SBSmk2, SBSwk2, BWBSdk1 and BWBSmw.

The Sub-Boreal Spruce moist cool subzone Williston variant (SBSmk2) lost a disproportionate amount of its former (pre-flooding) extent; reduced by 133,533 ha representing a loss of 34% (Table 7). The BWBSmw lost 23% (19,765 ha) of its extent prior to the flooding, followed by the SBSwk2 (-4%, 13,128 ha), BWBSdk (1.6%, 10,751 ha), and the SBSmk1 (<1%, 3,999 ha) (Table 7). These lowland BEC units and their associated ecosystems were the most directly affected by the creation of the reservoir and are therefore the focus of Figures 11 and 12.

Table 7. Difference in extent within the Williston Watershed of the five BEC units directly impacted by the flooding of the Williston reservoir (1968 to 2025). Numbers reflect full extent of these five BEC units, not just within the high-water mark.

BEC unit Code	Area in 1968 (hectares)	Area in 2025 (hectares)	Change in Area (hectares)	% Change
SBSmk1	638,122.4	634,256.7	-3,865.7	-0.6
SBSmk2	390,046.3	256,388.2	-133,658.1	-34.3
SBSwk2	309,907.3	297,342.4	-12,564.8	-4.0
BWBSdk	668,238.8	657,313.3	-10,925.5	-1.6
BWBSmw	84,356.0	64,162.8	-20,193.2	-23.9

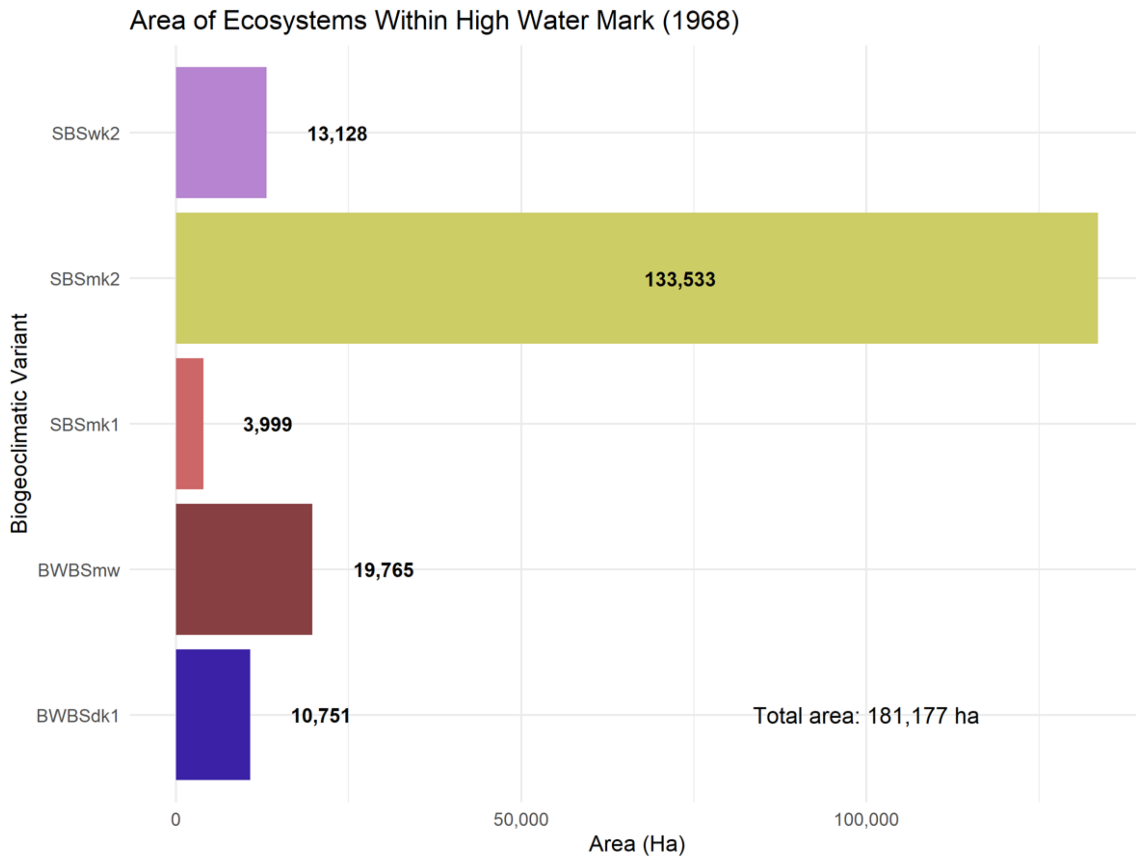

Figure 11. Biogeoclimatic Units (zone, subzone and variants) located in the high-water mark prior to flooding.

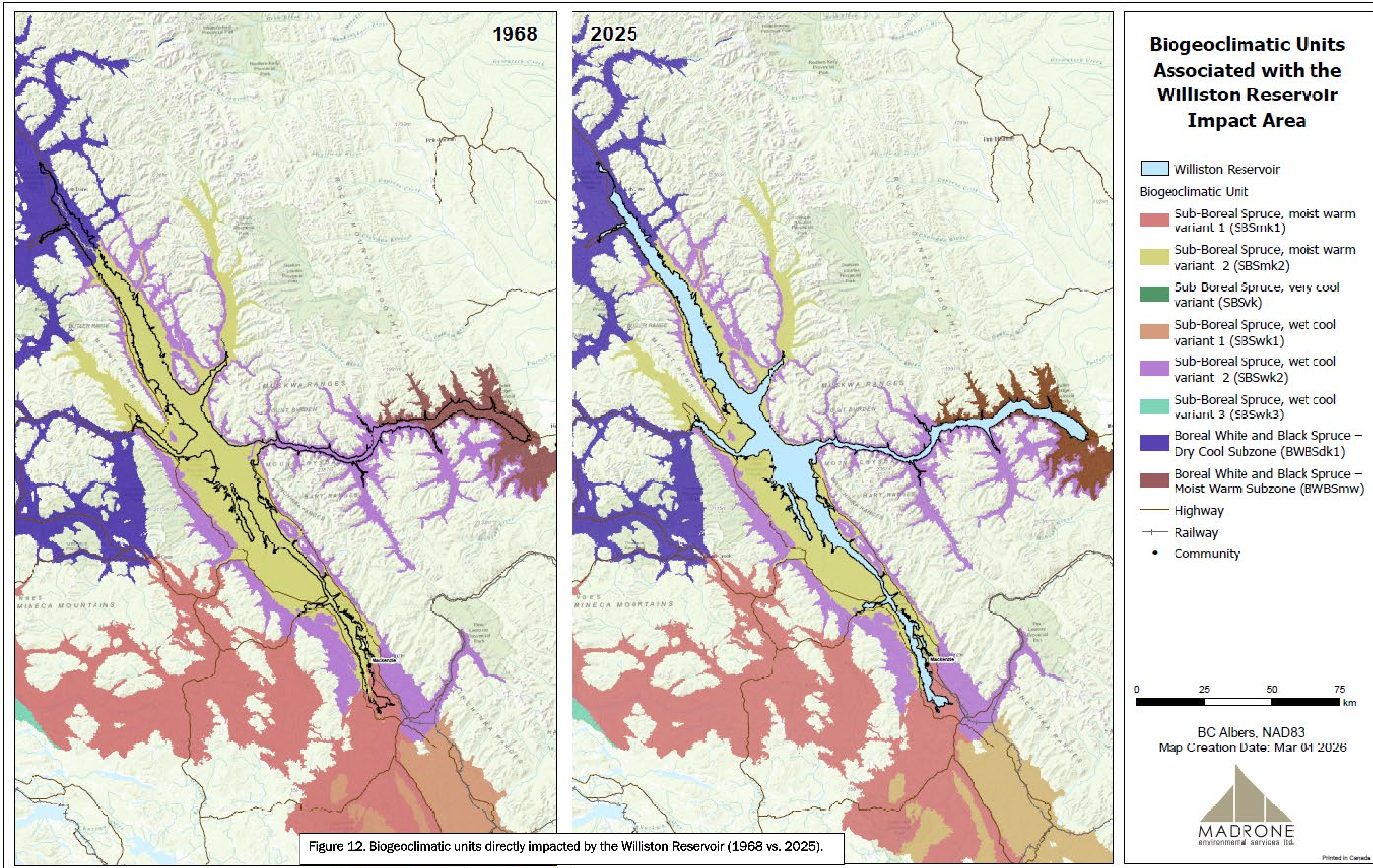

Figure 12. Biogeoclimatic units directly impacted by the Williston Reservoir (1968 vs. 2025).

4.2 Change in Ecosystem Representation

The below sub-sections examine the differences in BEMVRI coverages between 1968 and 2025 to provide insight into which ecosystems (broad ecosystem units "BEUs") underwent change.

4.2.1 Change by Broad Ecosystem Categories Across the Entire Watershed

Table 8 summarizes ecosystem change based on assigning all BEUs to one of the following categories: Forest, Alpine, Wetlands, Shrub sites, Riparian, Lakes, Disturbed, Rock/Cliff, Glacier, and Reservoir. Table 9 provides details for each of the 62 mapped BEUs within each BEC zone for the entire watershed between the two BEMVRI coverages.

Forests are the most common land cover in the watershed representing 65% of the mapped area (Tables 8 and 9). Based on differences in land cover between 1968 and 2025, there was a loss of 115,876 ha of forest, representing 2% of the total forest cover.

Following change in forest cover, riparian areas underwent the most change with a reduction of 40,500 ha, representing a loss of 19% of the area mapped as riparian in 1968 (Table 8). Wetlands experienced the next greatest proportionate loss and were reduced by 16,580 ha, representing 5% of their 1968 mapped extent.

Table 8. Change in Landcover Types for the Williston Watershed BEMVRI from 1968 – 2025.

	Total Broad Ecosystems within Williston Watershed (ha)		Ecosystem Area change from 1968 to 2025	
BEU groups	**1968**	**2025**	**Difference (ha)**	**Difference (%)**
Forest	4,711,584	4,595,708	-115,876	-2%
Alpine	1,538,542	1,538,545	4	0%
Wetlands	358,446	344,681	-13,765	-4%
Shrub	237,355	237,883	528	0%
Riparian	210,320	171,024	-39,295	-19%
Lakes	75,165	73,447	-1,718	-2%
Disturbed[11]	69,413	68,778	-634	-1%
Rock/cliff	59,603	59,475	-128	0%
Glacier	23,224	23,229	6	0%
Reservoir	370	173,394	173,024	468%
Total	**7,286,166**	**7,286,165**		

Alpine ecosystems represent 21% of the Williston Watershed mapping with essentially no change indicated between 1968 and 2025. VRI 2025 was the main data used for land classification, which does not update conditions above the tree line. Therefore, the extent of disturbance in the alpine is poorly captured in the BEMVRI products. There has certainly been change in the alpine since 1968 from mining and other industry-related activities. Also, the BEMVRI for this area overestimates glaciers; many of which are now bare ground.

[11] Not including forestry, insect, or fire disturbance

Table 9. Summary of Change in Broad Ecosystem Units (BEUs) in all BEC zones within the Entire Williston Watershed BEMVRI Coverages Representing 1968 and 2025 (excluding alpine).

BEU Code	BEU Name	Forested	Wetland	Riparian and Floodplains	BEU Code	BWBS 1968	BWBS 2025	Difference (ha)	ESSF 1968	ESSF 2025	Difference (ha)	SBS 1968	SBS 2025	Difference (ha)	SWB 1968	SWB 2025	Difference (ha)
AV	Avalanche Track				AV	379	379		18,883	18,882	-1	522	522	1	17,289	17,289	
BA	Boreal White Spruce - Trembling Aspen	Y			BA	147,549	149,735	2,187	-	-		-	-		-	-	
BB	Black Spruce Bog	Y	Y		BB	7,846	7,812	-34	1,589	1,589		23,245	21,769	-1,476	690	690	
BG	Sphagnum Bog		Y		BG	1,953	1,942	-11	983	983		7,609	7,496	-113	591	593	2
BK	Subalpine Fir - Scrub Birch Krummholz				BK	-	-		252,486	252,482	-3	-	-		317,139	317,137	-3
BL	Black Spruce - Lodgepole Pine	Y			BL	16,517	16,328	-190	-	-		41,110	18,608	-22,502	15,046	15,046	
BP	Boreal White Spruce - Lodgepole Pine	Y			BP	188,060	166,590	-21,470	-	-		170	-	-170	-	-	
BR*	Brush				BR	12,310	12,457	147	26,012	26,013		5,135	5,728	594	41,425	41,425	
CF	Cultivated Field				CF	356	18	-338	-	-		14	-	-14	-	-	
CL	Cliff				CL	5	5		1,210	1,210		67	80	14	243	243	
DF	Interior Douglas-fir	Y			DF	-	-		-	-		6,342	6,342		-	-	
DL	Douglas-fir - Lodgepole Pine	Y			DL	-	-		-	-		900	900		-	-	
EF	Engelmann Spruce - Subalpine Fir (Dry)	Y			EF	-	-		891,026	891,048	22	-	-		-	-	
ER	Engelmann Spruce Riparian	Y		Y	ER	-	-		4,917	4,917		-	-		-	-	
EW	Subalpine Fir - Mountain Hemlock Wet	Y			EW	-	-		986,945	986,951	6	-	-		-	-	
FB	Subalpine Fir - Scrub Birch Forested	Y			FB	43,953	43,953		-	-		-	-		322,907	322,918	11
FE	Fen		Y		FE	962	964	2	2,800	2,800		4,282	2,279	-2,003	2,632	2,632	
FP	Engelmann Spruce - Subalpine Fir Parkland	Y			FP	-	-		130,644	130,648	4	-	-		22,864	22,906	42
GB	Gravel Bar			Y	GB	625	-	-625	-	-		3,665	-	-3,665	-	-	
GP	Gravel Pit				GP	180	180		12	12		201	207	6	6	6	
LL	Large Lake			Y	LL	8,418	6,916	-1,502	1,556	1,556		35,550	35,323	-227	14,049	14,049	
LP	Lodgepole Pine	Y			LP	184,518	185,282	764	209,768	209,768		283,421	285,748	2,326	75,008	75,008	
LS	Small Lake			Y	LS	2,754	2,765	11	1,450	1,450		8,585	8,586		2,442	2,442	
ME	Meadow				ME	150	150		768	771	3	69	71	2	75	75	
MI	Mine				MI	36	36		932	932		568	568		1,066	1,066	
MR	Marsh		Y		MR	22	5	-17	-	-		5	5		5	5	
OW	Shallow Open Water		Y		OW	2,945	2,951	6	2,807	2,807		6,101	5,918	-183	2,230	2,230	
PR	White Spruce - Balsam Poplar Riparian	Y		Y	PR	74,645	69,820	-4,825	51	51		52	-	-52	13,822	13,822	
RE	Reservoir				RE	363	30,730	30,368	-	-		0	142,657	142,657	7	7	
RI*	River			Y	RI	14,502	12,430	-2,073	755	755		19,342	8,738	-10,604	3,092	3,091	-1
RO	Rock				RO	306	291	-15	13,676	13,676		408	280	-127	37,732	37,732	
SA	Sub-boreal White Spruce - Trembling Aspen	Y			SA	-	-		43,498	43,498		201,308	208,984	7,676	4,685	4,685	
SB	White Spruce - Paper Birch	Y			SB	-	-		-	-		82,988	84,916	1,928	879	879	
SC	Shrub-Carr				SC	2	2		-	-		-	-		359	359	
SD	Spruce - Douglas-fir	Y			SD	-	-		-	-		3,511	3,511		-	-	
SF	White Spruce - Subalpine Fir	Y			SF	-	-		4,721	4,721		461,864	377,265	-84,599	-	-	
SG	Subalpine Grassland				SG	-	-		886	886		-	-		602	604	2
SH	Shrub Fen		Y		SH	2,018	1,939	-79	3,653	3,653		9,108	5,794	-3,314	5,880	5,879	-1
SK	Spruce - Swamp	Y			SK	4,736	4,159	-577	-	-		11,661	3,203	-8,458	-	-	
SL	Sub-boreal White Spruce - Lodgepole Pine	Y			SL	-	-		-	-		375,639	373,462	-2,178	-	-	

Table 9 (continued). Summary of Change in Broad Ecosystem Units (BEUs) in all BEC zones within the Entire Williston Watershed BEMVRI Coverages Representing 1968 and 2025 (excluding alpine).

BEU Code	BEU Name	Forested	Wetland	Riparian and Floodplains	BEU Code	BWBS 1968	BWBS 2025	Difference (ha)	ESSF 1968	ESSF 2025	Difference (ha)	SBS 1968	SBS 2025	Difference (ha)	SWB 1968	SWB 2025	Difference (ha)
SM	Subalpine Meadow				SM	-	-		185	185		-	-		2,506	2,506	
SU	Subalpine Shrub/Grassland				SU	-	-		3,260	3,262	1	16	16		37,770	37,770	
SW	Shrub Swamp		Y		SW	7	-	- 7	-	-		33	-	- 33	-	-	
TA	Talus				TA	67	66	- 2	21,762	21,765	3	220	26	- 194	10,574	10,574	
TB	Trembling Aspen - Balsam Poplar	Y			TB	1,127	1,186	59	-	-		2,698	2,945	247	4,515	4,515	
TC	Transportation Corridor				TC	858	889	31	300	300		1,925	1,965	40	279	279	
TF	Tamarack Wetland		Y		TF	373	373		-	-		28	28		-	-	
TR	Transmission Corridor (after 1968)				Other	1,156	1,160	4	350	350		4,043	4,061	18	359	359	
UR	Urban				UR	188	205	17	-	-		1,313	1,427	114	-	-	
UV	Unvegetated				UV	1,481	654	- 827	39,432	39,430	- 2	836	1,157	322	13,838	13,838	
WB	Whitebark Pine Subalpine	Y			WB	-	-		1,180	1,180		-	-		-	-	
WG	Hybrid White Spruce Bog Forest	Y	Y		WG	47,506	47,273	- 233	-	-		47,112	47,053	- 59	2,688	2,688	
WL	Wetland		Y		WL	12,954	13,049	95	51,709	51,710	1	47,340	50,082	2,742	39,356	39,356	
WP	Subalpine Fir - Mountain Hemlock Wet Parkland	Y			WP	-	-		109,727	109,727		-	-		-	-	
WR	Hybrid White Spruce - Black Cottonwood Riparian	Y		Y	WR	-	-		-	-		74,852	57,400	- 17,452	-	-	
				Total Area (ha)		**781,829**	**782,697**		**2,829,933**	**2,829,968**		**1,773,857**	**1,775,119**		**1,014,652**	**1,014,706**	

* Indicates not a BEI standard code. Created for use in BEMVRI products to indicate rivers (RI) the same way they are mapped in TEM and PEM. "BR" used for brush (not satisfactorily stocked sites and shrub sites with no suitable BEU code)

4.2.2 Change by Broad Ecosystem Categories in Flooded BEC units

When inundated areas are examined in more detail, results indicate that certain lowland ecosystems were impacted disproportionally to others. Table 10 summarizes the top ten BEUs which had the greatest difference in area from 1968 to 2025; results are graphed in Figure 13.

The majority of the flooding occurred within the SBSmk2 BEC unit. Therefore, ecosystems mapped in the SBSmk2 area associated with the biggest chance (loss) between 1968 and 2025. A total of 72,653 ha of the White Spruce – Subalpine Fir ecosystem (BEU code “SF”) was impacted by flooding in the SBSmk2, representing 6.4% of the original extent of the SBSmk2, and 15.6% of the “SF” mapped in the entire watershed in 1968 (72,653 ha of 466,585 ha) (Tables 9 and 10). Within the SBSwk2 a further 10,854 ha of the “SF” ecosystem was lost due to flooding, far more than any other ecosystem type in the BEMVRI coverage (Table 10).

Table 10. The Broad Ecosystem Units (BEUs) with the most change in area from 1968 to 2025.

BEC Variant	BEU Code	BEU name	Area in 1968 (ha)	Percent of BEC Variant (1968)	Area in 2025 (ha)	Percent of BEC Variant (2025)	Area Difference (ha)
SBSmk2	SF	White Spruce - Subalpine Fir	88,974	22.8 %	16,321	6.4 %	-72,653
SBSmk2	BL	Black Spruce - Lodgepole Pine	28,468	7.3 %	6,640	2.6 %	-21,828
SBSmk2	WR	Hybrid White Spruce – Black Cottonwood Riparian	28,367	7.3 %	11,998	4.7 %	-16,368
SBSmk2	RI	River	10,756	2.8 %	2,228	0.9 %	-8,528
SBSmk2	SK	Spruce Swamp	8,402	2.2 %	859	0.3 %	-7,543
SBSmk2	SA	Sub-boreal White Spruce - Trembling Aspen	52,318	13.4 %	57,186	22.3 %	+4,868
SBSmk2	SL	Sub-boreal White Spruce - Lodgepole Pine	55,674	14.3 %	51,746	20.2 %	-3,928
SBSwk2	SF	White Spruce - Subalpine Fir	54,306	17.5 %	43,451	14.6 %	-10,854
BWBSmw	BP	Boreal White Spruce - Lodgepole Pine	29,493	35.0 %	15,243	23.8 %	-14,250
BWBSdk	BP	Boreal White Spruce - Lodgepole Pine	148,994	22.3 %	141,711	21.6 %	-7,283

Following the “SF” ecosystem type, the “BL” (Black Spruce – Lodgepole Pine) is indicated as having the next highest loss of area (-21,828 ha in the SBSmk2), followed by the “WR” (Hybrid White Spruce – Black Cottonwood Riparian) (-16,368 ha) (Table 10 and Figure 13).

Figure 14 depicts results within the five BEC units with the most change into broader ecosystem groups to visualize impacts of the reservoir on landcover by disturbed, forest, lakes, riparian and wetlands. Results indicate that forests make up the majority of the landcover lost from 1968 to present due to the flooding of Williston Reservoir. Riparian and wetland ecosystems were also heavily impacted.

Figure 15 provides an example from an area around the reservoir to highlight differences between 1968 and 2025.

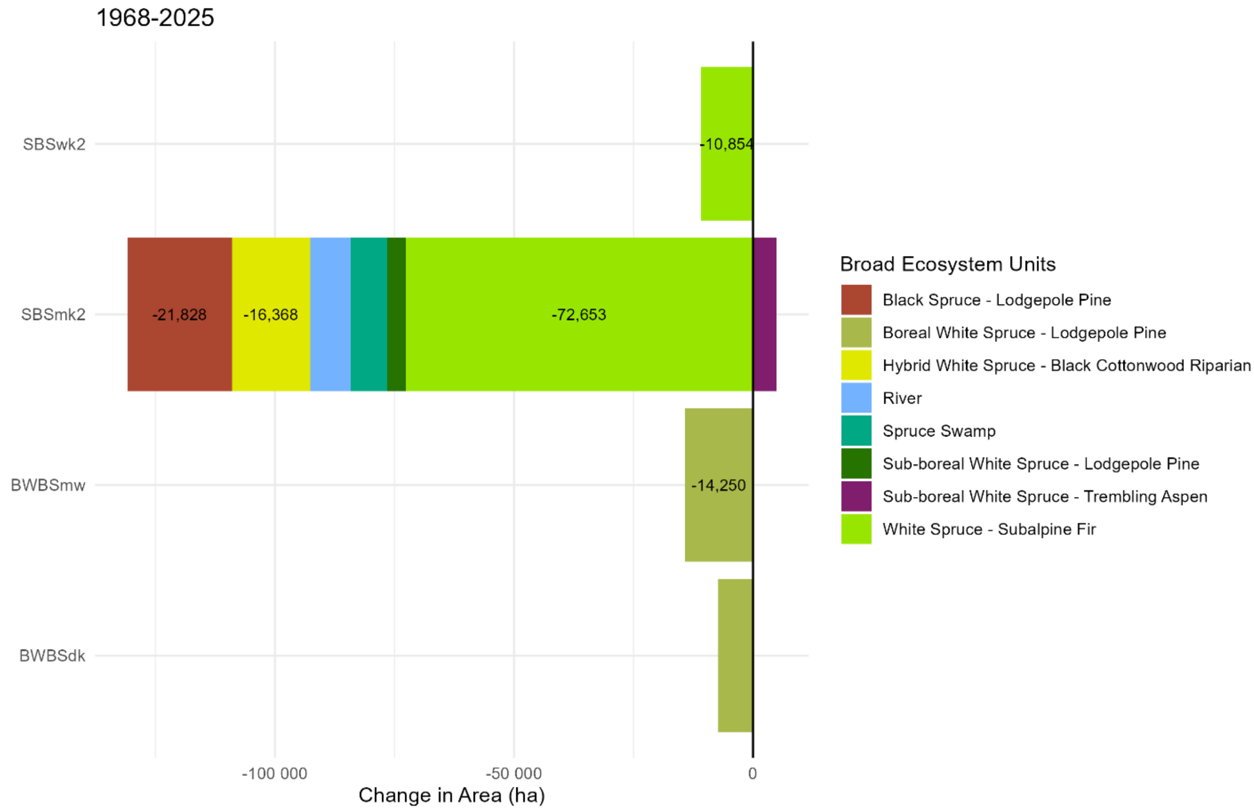

Figure 13. Top 10 Ecosystems with the most Change from 1968 to 2025.

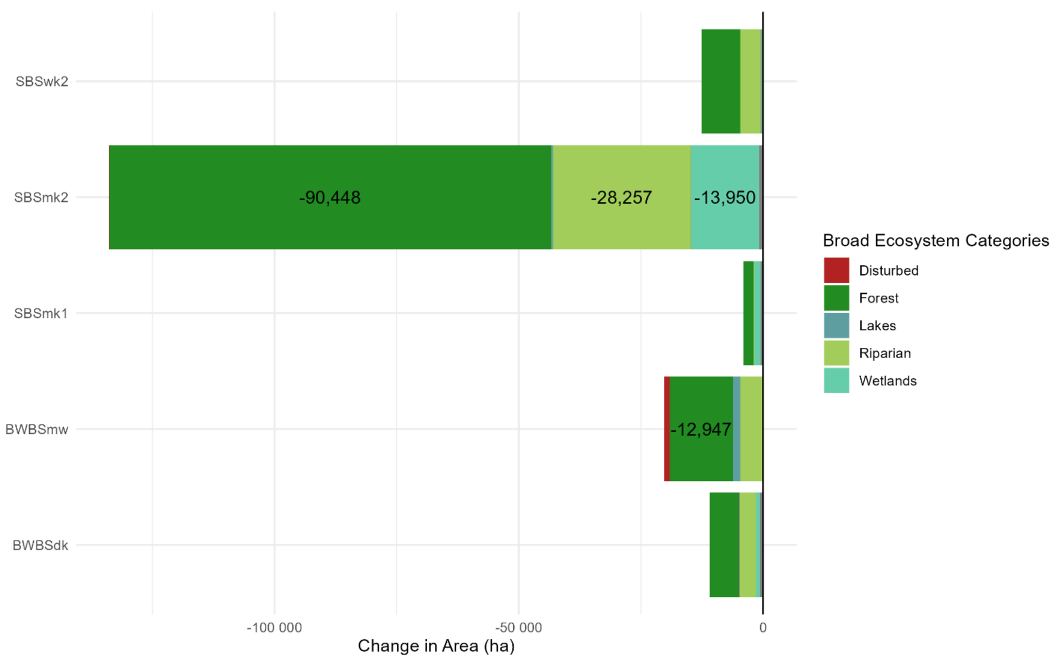

Figure 14. Change in Ecosystem Groupings within key lowland BEC units from 1968 to 2025.

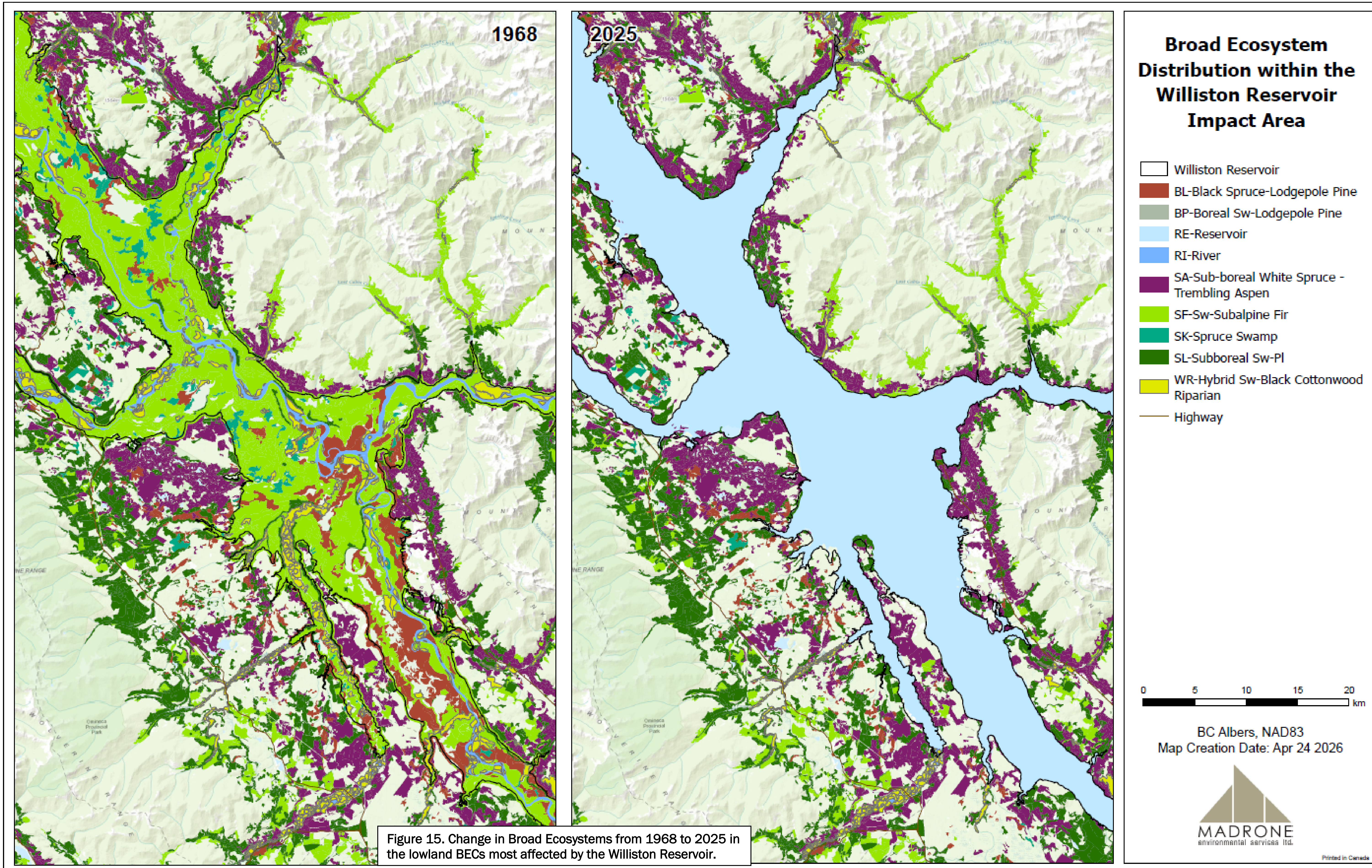

Figure 15. Change in Broad Ecosystems from 1968 to 2025 in the lowland BECs most affected by the Williston Reservoir.

4.2.3 Change within the 200 m buffer adjacent to the HWM

The ecosystem mapping from the 1968 interpretation of imagery was maintained for the backcast BEMVRI product for the 200 m buffer, while current conditions were mapped in the same area for comparison. When compared, the 200 m buffer adjacent to the HWM of the reservoir underwent significant changes. Table 8 provides a comparison of ecosystems mapped within the 200 m buffer in 1968 compared to the current conditions. Table 11 summarizes the top ten ecosystem units within the 200 m buffer adjacent to the HWM within in the SBSmk2 that indicates the most change between 1968 and 2025.

Table 11. Top 10 Broad Ecosystem Units (BEUs) in the SBSmk2 with the most change in area from 1968 to 2025 within the 200 m buffer of the high-water mark of the Williston reservoir.

BEC Variant	BEU Code	BEU name	Area in Buffer in 1968 (ha)	Area in Buffer in 2025 (ha)	Area Difference (ha)
SBSmk2	BL	Black Spruce - Lodgepole Pine	2,451.2	133.7	-2,317.5
SBSmk2	LP	Lodgepole Pine	801.4	3,827.0	+3,025.6
SBSmk2	SA	Sub-boreal White Spruce - Trembling Aspen	7.04	4,874.3	+4,867.3
SBSmk2	SB	White Spruce - Paper Birch	0.00	1,259.2	+1,259.2
SBSmk2	SF	White Spruce - Subalpine Fir	2,744.9	180.1	-2,564.9
SBSmk2	SF	White Spruce - Subalpine Fir	8,770.7	456.56	-8,314.1
SBSmk2	SH	Shrub fen	105.97	3.71	-102.3
SBSmk2	SK	Spruce-Swamp	312.3	17.5	-294.78
SBSmk2	SL	Sub-boreal White Spruce - Lodgepole Pine	1,863.6	2,401.8	+538.2
SBSmk2	UR	Urban	0	86.4	-86.4
SBSmk2	WL	Wetland (generic code)	20.23	750.8	+730.5

In contrast to the ecosystem types with loss in area, the BEU Sub-boreal White Spruce - Trembling Aspen (SA), gained area (+4,868 ha). The gain of “SA” all occurred within the 200 m buffer above the high-water mark; an area covering 23,453 hectares. The indicated change, increase in the ‘SA’ ecosystem type reflects VRI tree species composition in 2025. As aspens are relatively fast-growing and thrive on disturbed soils, this change from coniferous or mixed stands to aspen leading may reflect increased disturbance above the high-water line due to the creation of roads, transmission corridors, and natural disturbances such as fire.

Although an increase in wetlands ‘WL’ (the generic wetland code) is indicated as a gain in 730.5 hectares within the buffer, most of the gain is associated with loss of other wetland types as well as riparian. For example, the data indicates that in 1968, in the SBSmk2 there were 33.49 hectares of river (BEU mapcode “RI”) and only 0.03 hectares in 2025. Where riparian area used to drain into the valley, current water levels would prevent the same flow dynamic and may have converted to wetlands.

4.3 Change to Forest Age / Structural Stage

Structural stage was also compared between the two map coverages to estimate how the age/structure of forests has changed over these two periods due to disturbance factors including the flooding of the reservoir. Across the entire watershed, the greatest change that took place was the loss of old forest; structural stage "7a" forests over 140 years according to the back-casted age data. Old forest was reduced by 232,779 hectares with the greatest areas of change in the ESSFmv3 (-92,994 ha), followed by the SBSvk (-33,008 ha), SBSwk1 (-31,399 ha), SBSmk1 (-24,087 ha), and ESSFwk2 (-19,680 ha) (Table 12). One of these five BEC units is associated with the reservoir; SBSmk1. This change in "7a" represents a loss of 10% of old forest over 57 years. Additionally, there was a reduction from 1968 to 2025 in pole sapling ("4") (-140,220 ha; representing 38% loss of this structural stage over 57 years) and young forests ("5") (-183,155 ha; representing a 50% loss over 57 years). These three forested structural stages classes ("4", "5" and "7a") represent a loss of 556,154 ha.

The corresponding gains indicated in the 2025 mapping are represented mainly by increases in herbaceous ("2") (+122,045 ha) and shrub ("3", "3a" and "3b") (+304,120 ha); for a total gain in these younger structural stages of +555,476 ha (Table 12). Further examination of change in forest structure across the watershed can take place with the spatial data, Table 12, and the exported Excel file with this data for ease of queries.

4.3.1 Change to Forest Structure Associated with Flooding of the Reservoir

Between 1968 and 2025 key lowland BEC units in the Williston Watershed forests in general changed from mature and old to predominantly younger, reflected by the increase in the amount of early successional or shrub structural stages in 2025 (Figure 16). The increase in early successional stages between 1968 and 2025 reflects the cumulative impacts of the reservoir, wildfires, insect infestations, and forest harvesting.

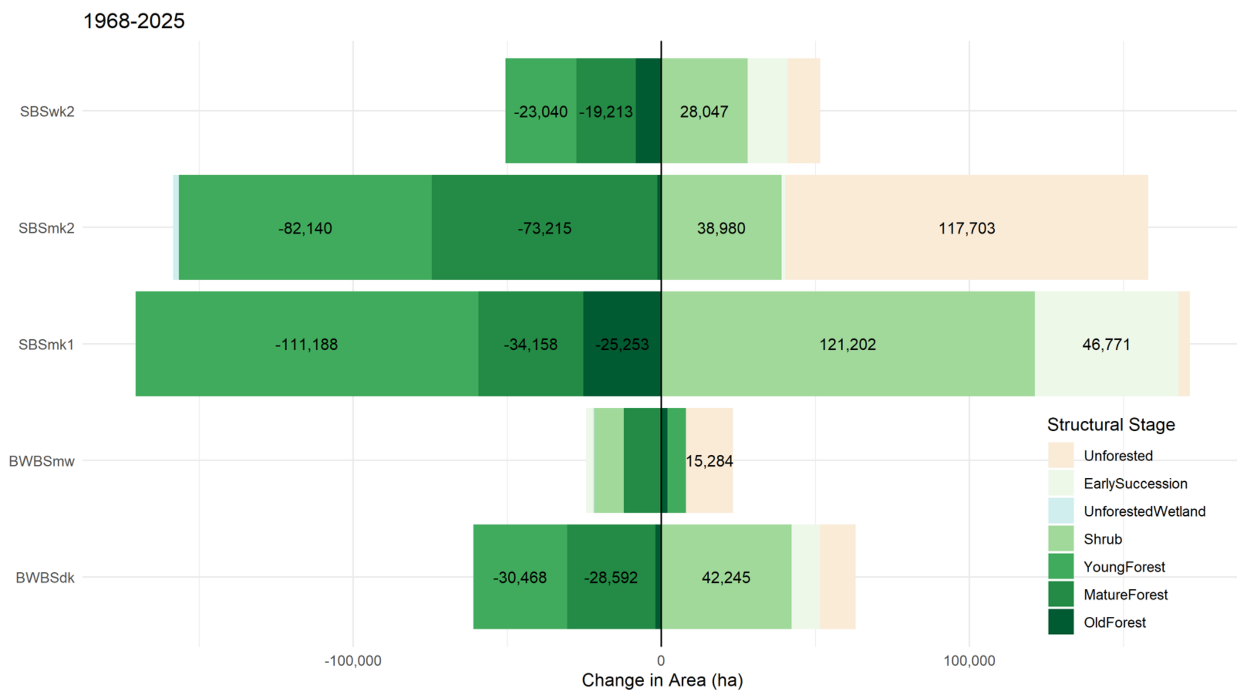

Figure 16. Change in forest structure between 1968 and 2025 with NA values excluded in the five lowland biogeoclimatic zones of the watershed. Structural stages to the left of the centerline have experienced a net loss in area, while those to the right have experienced a net gain.

The SBSmk2 and SBSmk1 ecosystems lost the most young/mature and old forest area (Figure 16). The SBSmk2 lost 85,140 hectares of pole sapling and young forest and 73,215 hectares of mature forest; largely attributed to the reservoir; reflected in the 117,703 hectares of unforested in 2025.

In SBSmk1, the loss of forest is likely not due to the reservoir as only 3,999 ha of this ecosystem was flooded. Most forest changes in this BEC unit correspond to multiple disturbances including fire, insect infestations, development of roads and transmission lines, and harvesting. In the SBSmk1 results indicate an increase of 121,202 hectares of shrub and 46,771 hectares of early succession vegetation, compared to the same area in 1968. An evident pattern of this analysis is the loss and conversion of young, mature and old forest from 1968 to 2025, with a distinct lack of mature and old forest present in 2025 within these five BEC units.

Figure 17 provides an example from the Williston reservoir for visual comparison of structural stages differences indicated in the 1968 and 2025 BEMVRI coverages. The overall increase in early succession stages (i.e., structural stages “2” herbaceous and “3” shrub) is evident when comparing the left to the right. The majority of dark green, indicated mature and old forests are predominately located in the higher elevation BEC units.

Prior to flooding (left pane), the dominant forest age in the SBSmk2 was young and mature interspersed with large areas of naturally created shrub conditions often associated with wetland units and floodplain units that underwent frequent flood events. The 1968 mapping delineating numerous rivers, gravel bars and floodplain units in the SBSmk2 (Table12).

4.3.1.1 Forest Clearing Prior to Flooding and Prior to 1968 Imagery Interpretation

It is important to note that as per Timberline (2006) “In some areas stands were being harvested to make way for the flooding, thus structural stage calls do not reflect pristine, pre-flood circumstances.” The Timberline report does not provide an estimate of the area that was harvested to make way for flooding (i.e., conditions as per imagery taken in 1968 would reflect any of the timber clearing up to that time). Therefore, the loss of mature and old forest as a result of inundation is likely under-represented in the comparison of forest structure between 1968 and 2025.

We can assume that in 1968 any forested site series mapped as structural stage 2 (herbaceous) or 3/3a (shrub) was the result of being harvested or crushed within 1 to 10 years of the imagery. It is probable that a significant part of the forest conversion 10 years prior to flooding was in preparation for the inundation.

A total of 138,051 ha of shrubs “3” and “3a”, and 7,965 ha of “2” (herbaceous) are mapped within the key lowland BEC unit associated with the reservoir (Table 12). These structural stages mainly represent conditions following forest harvesting 10 years prior to the 1968 imagery; indicating that preparation of the area for inundation may have impacted an additional 130,086 ha of mature and old forest. Tall shrub “3b” (over 2 m but under 10 m; 11 to 21 years since disturbance) covered 87,251 ha in the 1968 mapping. It is reasonable to assume that some of this forested area may also have been cleared in preparation for inundation.

Table 12. Change in Structural Stages Assigned in the BEMVRI Between 1968 and 2025 Coverages by BEC Unit for the Entire Williston Watershed. Shaded rows indicate BEC units associated with the Reservoir.

1968																					
BEC_Unit	**NA**	**0**	**1**	**1a**	**2**	**2a**	**2b**	**2d**	**3**	**3a**	**3b**	**3c**	**3d**	**3u**	**4**	**5**	**6**	**7**	**7a**	**7d**	**Total Area (ha)**
BAFAun	NA	24,425	5,958	496,158	NA	14,992	6,089	125,624	387	39,710	3,960	117,996	4,171	NA	NA	NA	NA	NA	NA	NA	839,471
BWBSdk	586	25,167	382	393	3,140	148	975	NA	14,222	29,653	30,172	1,292	6,402	10,457	31,604	61,452	184,425	65,090	202,678	NA	668,239
BWBSmw	25	4,763	730	1,128	2,781	1	380	NA	4,113	1,095	11,444	24	55	2,502	5,761	8,999	29,133	529	10,893	NA	84,356
BWBSwk1	NA	NA	NA	NA	NA	NA	NA	NA	NA	7	499	NA	NA	28	15	99	158	NA	196	NA	1,002
BWBSwk2	NA	135	4	28	1,659	NA	22	NA	130	574	4,096	15	58	1,018	2,567	6,823	4,086	954	6,675	NA	28,843
ESSFmc	NA	77	3	22	NA	18	68	NA	315	286	119	NA	NA	1	38	370	198	NA	697	70	2,283
ESSFmcp	NA	21	15	831	NA	17	NA	52	43	447	43	1,409	67	NA	NA	NA	19	NA	NA	57	3,022
ESSFmv2	NA	78	73	160	128	1	5	NA	635	289	2,467	52	113	769	5,376	5,369	21,581	NA	47,576	2,394	87,066
ESSFmv3	NA	5,351	374	3,577	5,501	178	1,698	NA	32,657	9,819	29,599	637	1,882	16,376	47,251	52,527	162,881	NA	773,064	7,308	1,150,678
ESSFmv4	NA	387	4,952	2,186	5,644	397	402	NA	2,921	24,880	32,158	563	171	5,877	32,383	38,690	66,789	NA	279,208	67,536	565,145
ESSFmvp	NA	783	5,725	38,421	NA	1,089	168	12,920	1,115	18,593	4,221	211,860	32,272	NA	NA	NA	542	NA	NA	32,189	359,899
ESSFwc3	NA	650	1,706	6,367	2,980	220	624	NA	8,431	4,993	25,189	365	1,032	4,297	13,045	15,197	25,049	NA	188,876	9,744	308,768
ESSFwcp	NA	276	1,962	13,091	NA	196	109	5,046	1,169	9,675	1,346	51,625	5,971	NA	NA	NA	54	NA	NA	3,282	93,802
ESSFwk2	NA	177	87	223	1,853	5	669	NA	4,797	7,590	12,203	12	129	3,803	9,603	7,086	20,999	NA	234,289	NA	303,524
SBSmk1	495	43,611	112	366	747	19	1,287	NA	25,089	9,214	18,024	2,138	6,544	32,293	73,969	65,942	209,554	17,469	131,220	28	638,122
SBSmk2	795	14,895	3,438	354	582	NA	2,768	NA	30,236	12,538	8,947	1,018	6,395	8,687	57,034	57,495	133,016	2,316	49,101	NA	389,615
SBSvk	NA	1,861	201	8	281	6	15	NA	3,329	2,121	4,151	551	1,163	4,192	3,231	2,226	11,574	1,422	106,026	NA	142,357
SBSwk1	NA	5,551	30	5	3,532	NA	153	NA	7,277	9,747	12,603	1,699	1,848	7,334	37,037	10,533	93,304	3,027	76,142	NA	269,821
SBSwk2	243	6,510	566	322	715	44	55	NA	6,577	5,294	18,664	392	1,297	17,851	38,491	19,133	98,857	1,740	93,157	NA	309,907
SBSwk3	NA	994	NA	1	12	NA	48	NA	742	192	342	22	163	1,524	1,052	1,216	4,367	550	13,932	NA	25,157
SWBmk	NA	20,769	13,214	7,303	2,228	1,427	2,093	NA	28,096	17,566	73,756	323	19,866	907	10,395	11,696	53,980	211,541	71,315	54,607	601,083
SWBmks	NA	2,396	24,767	17,109	69	1,158	1,358	NA	11,622	1,288	29,290	52,950	251,932	15	172	147	1,062	20	2,890	15,329	413,573
Total	**2,145**	**158,876**	**64,298**	**588,053**	**31,852**	**19,917**	**18,988**	**143,642**	**183,906**	**205,573**	**323,292**	**444,945**	**341,531**	**117,930**	**369,025**	**364,999**	**1,121,626**	**304,657**	**2,287,937**	**192,543**	**7,285,734**
2025																					
BEC_Unit	**NA**	**0**	**1**	**1a**	**2**	**2a**	**2b**	**2d**	**3**	**3a**	**3b**	**3c**	**3d**	**3u**	**4**	**5**	**6**	**7**	**7a**	**7d**	**Total Area (ha)**
BAFAun	-	24,425	5,958	496,159	NA	14,992	6,089	125,627	380	41,674	2,004	117,955	4,209	NA	NA	NA	NA	NA	NA	NA	839,471
BWBSdk	53	36,739	271	384	12,516	148	936	NA	30,919	27,180	49,889	1,633	6,052	18,771	30,860	31,728	155,833	63,720	202,083	NA	669,715
BWBSmw	-	20,047	201	307	1,887	1	34	NA	1,553	1,081	4,602	24	31	2,195	8,284	12,431	17,014	529	12,917	NA	83,141
BWBSwk1	-	NA	NA	NA	NA	NA	NA	NA	NA	6	8	NA	NA	NA	77	441	386	NA	84	NA	1,002
BWBSwk2	-	136	4	28	337	NA	18	NA	685	797	1,408	15	58	1,539	1,242	4,828	10,824	921	6,004	NA	28,845
ESSFmc	-	77	3	22	NA	18	68	NA	315	216	189	NA	NA	NA	NA	23	410	NA	860	82	2,283
ESSFmcp	-	21	15	831	NA	17	NA	52	43	485	5	1,319	151	NA	NA	NA	6	NA	NA	76	3,022
ESSFmv2	-	78	73	160	6,099	1	5	NA	3,660	6,512	5,282	100	65	1,132	1,138	807	14,412	NA	45,115	2,426	87,067
ESSFmv3	-	5,351	374	3,577	18,624	178	1,698	NA	47,169	50,975	53,533	874	1,758	13,129	21,876	18,218	225,897	NA	680,070	7,378	1,150,678
ESSFmv4	-	388	4,952	2,186	1,201	397	401	NA	7,110	6,041	18,811	416	351	7,103	24,185	33,874	140,000	NA	274,535	43,193	565,145
ESSFmvp	-	783	5,725	38,421	NA	1,091	168	12,920	1,275	15,938	8,966	198,794	24,583	NA	1,100	1,224	16,644	NA	NA	32,266	359,899
ESSFwc3	-	650	1,706	6,369	77	220	624	NA	8,597	2,701	8,655	1,046	469	1,325	6,323	12,578	64,187	NA	188,839	4,403	308,768
ESSFwcp	-	276	1,962	13,091	NA	196	109	5,046	1,169	8,266	3,314	48,270	5,438	NA	307	510	2,511	NA	NA	3,336	93,802
ESSFwk2	-	177	87	223	2,292	5	669	NA	5,030	4,433	9,291	95	47	1,895	7,050	7,155	50,498	NA	214,609	NA	303,554
SBSmk1	-	47,183	109	454	47,433	19	1,149	NA	25,823	73,663	84,664	2,676	5,935	21,745	17,087	11,635	175,397	16,331	107,133	NA	638,436
SBSmk2	-	132,598	39	554	5,111	NA	868	NA	17,061	25,419	39,286	1,700	4,320	19,048	24,694	8,059	59,828	2,276	47,869	NA	388,730
SBSvk	-	1,861	201	8	13,503	6	15	NA	3,326	10,707	10,492	806	907	1,580	8,052	2,864	13,664	1,348	73,018	NA	142,357
SBSwk1	-	5,551	30	5	28,173	NA	153	NA	8,111	26,067	32,467	2,023	1,525	9,010	35,661	12,519	61,212	2,571	44,743	NA	269,821
SBSwk2	-	17,039	189	162	14,221	46	52	NA	8,602	19,246	32,157	529	1,161	16,428	24,328	10,256	79,644	1,665	84,894	NA	310,617
SBSwk3	-	994	NA	1	2,032	NA	48	NA	825	2,489	4,007	41	145	774	598	197	4,759	536	7,712	NA	25,157
SWBmk	-	20,768	13,214	7,303	385	1,427	1,883	NA	29,266	18,592	60,805	465	19,724	2,835	15,563	11,623	65,867	268,278	63,085	NA	601,083
SWBmks	-	2,396	24,767	17,109	3	1,158	1,357	NA	12,338	18,385	12,927	29,825	275,009	NA	378	873	1,488	27	1,587	13,945	413,573
Total	**53**	**317,537**	**59,880**	**587,354**	**153,897**	**19,921**	**16,346**	**143,644**	**213,255**	**360,873**	**442,762**	**408,605**	**351,936**	**118,509**	**228,805**	**181,844**	**1,160,479**	**358,200**	**2,055,158**	**107,106**	**7,286,165**
Difference	- 2,092	158,661	- 4,418	- 699	122,045	4	- 2,642	2	29,350	155,300	119,470	- 36,339	10,405	579	- 140,220	- 183,155	38,853	53,543	- 232,779	- 85,437	431

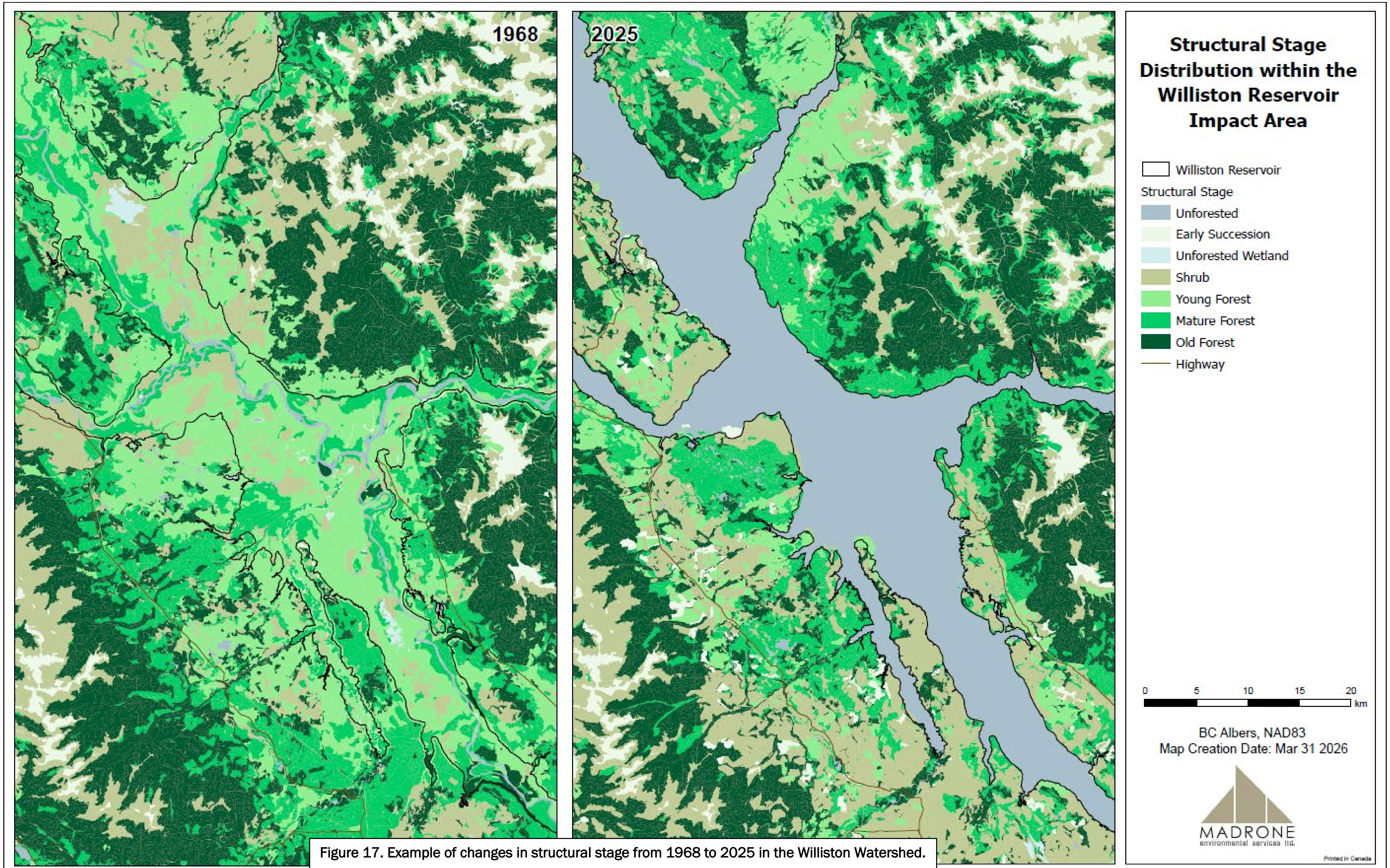

Figure 17. Example of changes in structural stage from 1968 to 2025 in the Williston Watershed.

4.3.2 Wetlands and Riparian Ecosystems

As the reservoir primarily affected lowland ecosystems, wetlands and riparian ecosystems were disproportionally impacted. Across the entire watershed, 8% (50,494 ha) of all mapped wetlands were lost directly due to inundation. Direct wetland loss was calculated by removing all wetland areas within the high-water mark (Table 13, Figure 18). A gain of 2,818 ha of unclassified wetland area is also indicated (Figure 18). These gained wetlands are all located within the high-water mark of the reservoir. Many of these wetlands are predominately the result of fluctuating water levels experienced within the draw-down zone; often associated with non-forested riparian areas and low relief topography.

Table 13. Wetland BEU area changes across the entire Williston Watershed area between 1968 - 2025 and immediately post-inundation.

	Total Wetland Areas in Williston Watershed (ha)		Wetland Area change from 1968 -2025	
Wetland BEU groups	**1968**	**2025**	**Difference (ha)**	**Difference (%)**
Lakes, Shallow Water, and Rivers	128,095	113,523	-14,572	-11%
Hybrid White Spruce - Black Cottonwood Riparian	74,852	57,400	-17,452	-23%
Englemann Spruce Riparian	4,917	4,917	0	0%
White Spruce - Balsam Poplar Riparian	88,570	83,693	-4,878	-6%
Marsh	33	16	-17	-52%
Swamp	16,436	7,362	-9,074	-55%
Fen	31,335	25,940	-5,395	-17%
Bog	141,812	139,887	-1,925	-1%
Wetland - Unclassified	151,766	154,584	2,818	2%
Total	**637,817**	**587,323**	**-50,494**	**-8%**

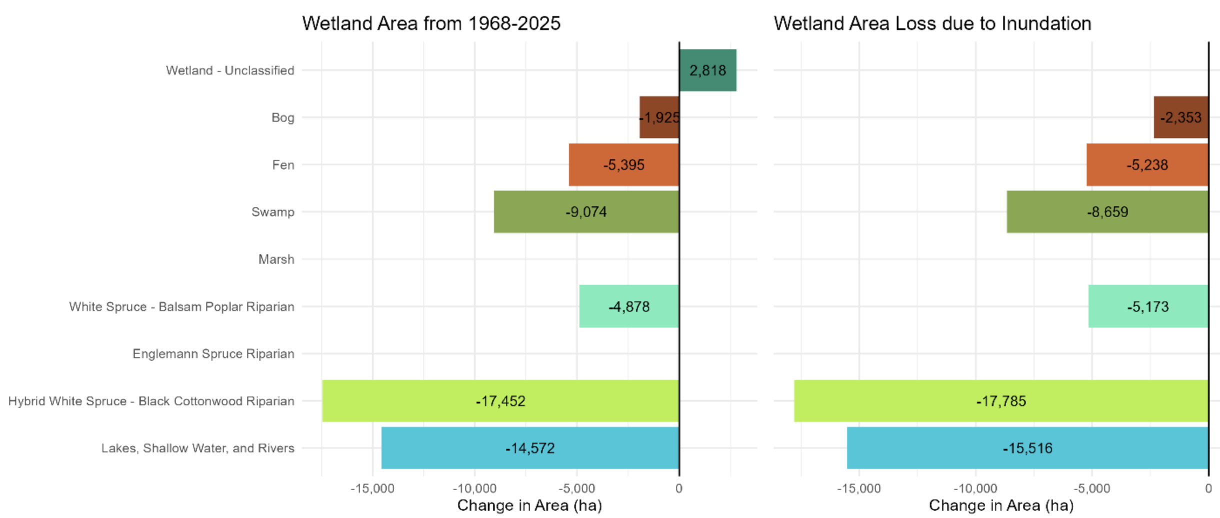

Figure 18. Change in wetland and riparian associated ecosystems through the entire Williston Watershed compared to change due to inundation between 1968 and 2025.

4.3.2.1 Change in the SBSmk2

The sub-boreal spruce – moist ecosystem variant (SBSmk2), which has a large proportion of wetlands, made up most of the area flooded and therefore had the greatest area of wetlands lost due to flooding.

In 1968 wetlands in the SBSmk2 made up 21% of the ecosystems and covered 83,623 hectares of the area (Table 14). In 2025 wetlands in the SBSmk2 were collectively reduced by 38,927 ha, representing a 56% loss of wetlands in the SBSmk2 (Figure 19). Figure 20 provides an example of an area before and after flooding that highlights wetland and riparian ecosystems in the SBSmk2.

Table 14. The wetland Broad Ecosystem Units (BEUs) in the SBSmk2 ecosystem of the Williston Watershed based on 1968 and 2025 BEMVRI coverages.

BEC Unit	BEU Code	BEU Name	Area in 1968 (ha)	Percent of SBSmk2 (1968)	Area in 2025 (ha)	Area Difference (ha)
SBSmk2	WR	Hybrid White Spruce - Black Cottonwood Riparian	28,366	7.3 %	12,256	-16,109
SBSmk2	RI	River	10,756	2.8 %	2,502	-8,253
SBSmk2	SK	Spruce - Swamp	8,402	2.2 %	859	-7,542
SBSmk2	SH	Shrub Fen	5,413	1.4 %	2,323	-3,090
SBSmk2	FE	Sedge Fen	2,725	0.7 %	863	-1,861
SBSmk2	BB	Black Spruce Bog	7,426	1.9 %	6,021	-1,405
SBSmk2	LL	Large Lake	824	0.2 %	597	-227
SBSmk2	BG	Sphagnum Bog	2,240	0.6 %	2,055	-184
SBSmk2	OW	Shallow Open water	1,323	0.3 %	1,171	-152
SBSmk2	LS	Small Lake	1,197	0.3 %	1,156	-40
SBSmk2	SW	Shrub Swamp	33	0.0 %	-	-33
SBSmk2	WG	Hybrid White Spruce Bog Forest	3,203	0.8 %	3,175	-27
SBSmk2	MR	Marsh	4.4	0.0 %	4.4	0
SBSmk2	WL	Wetland	11,710	3.0 %	13,987	2,277
		Totals	**83,623**	**21.4 %**	**46,972**	**- 38,927**
		SBSmk2 Total Area	**389,606**			

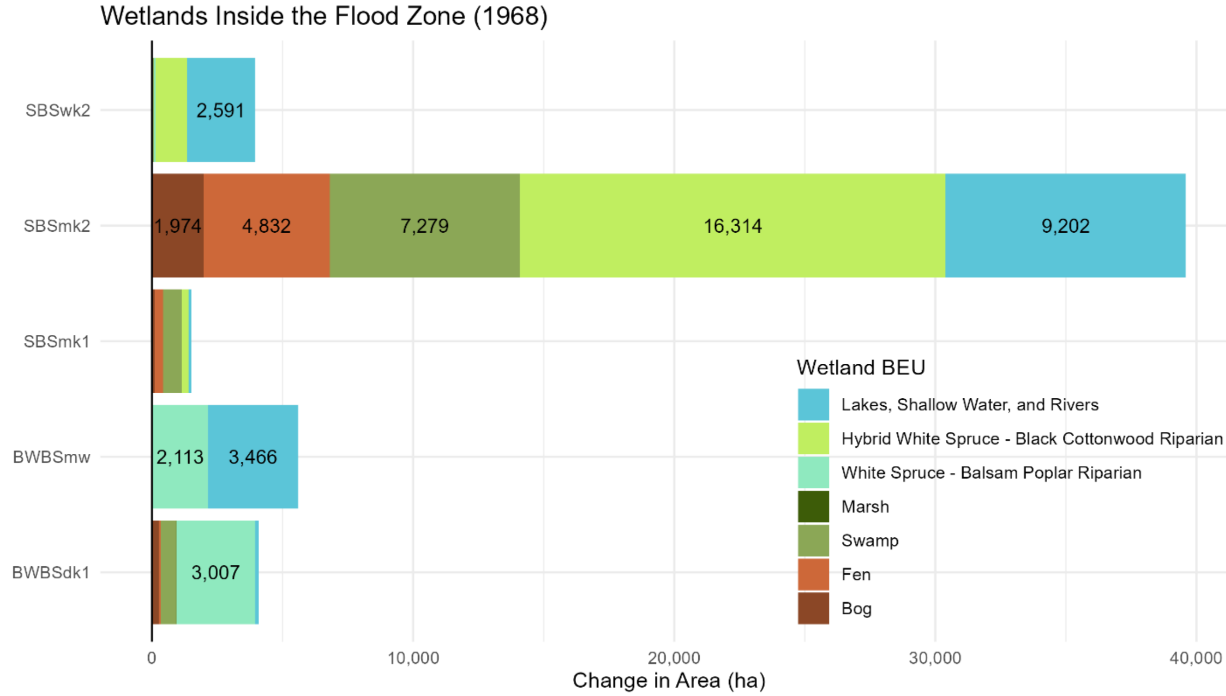

Figure 19. Wetlands inside the high-water mark in 1968 which were lost in the flooding.

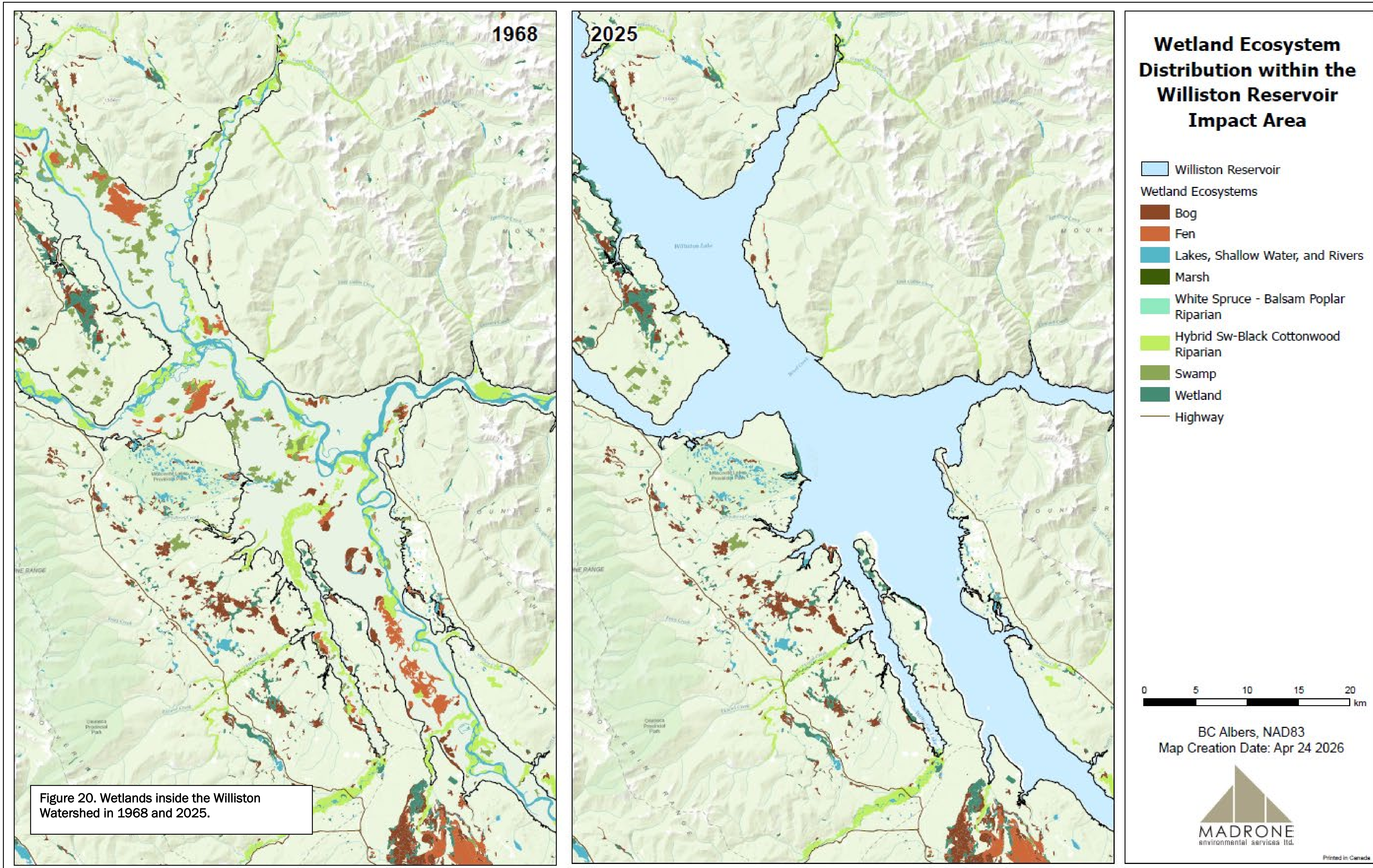

Figure 20. Wetlands inside the Williston Watershed in 1968 and 2025.

4.4 Other Change due to Disturbance

Although impacts are most obvious for the flooded area of the reservoir (i.e., within the high-water mark), other related impacts within the Williston Watershed are provided below for consideration. Also refer to 4.2.3 regarding change indicated in the 200 m buffer zone adjacent to the HWM of the reservoir.

4.4.1 Anthropogenic Disturbances

When the reservoir is excluded, the primary anthropogenic disturbance types in the Williston Watershed are roads and transmission lines (Figure 21). Fire, insect, and forestry disturbances, which cover significantly more area than these disturbance types, are discussed in the following section. According to data representing land change, the SBSmk1 ecosystem has the greatest area of non-reservoir disturbance at 3,076 hectares (Table 15 and Figure 21).

As transmission lines are hydroelectric infrastructure directly associated with the dam, they were not present before the flooding of the reservoir and are assumed to be a direct result of the infrastructure associated with the reservoir and hydro station. The BEMVRI 2025 mapping indicates at least 3,903 hectares of transmission line right-of-way within the five BEC units associated with the reservoir. The full extent of transmission line right-of-way disturbance is far greater throughout the entire watershed with the BEMVRI 2025 providing an estimate of 5,930 hectares).

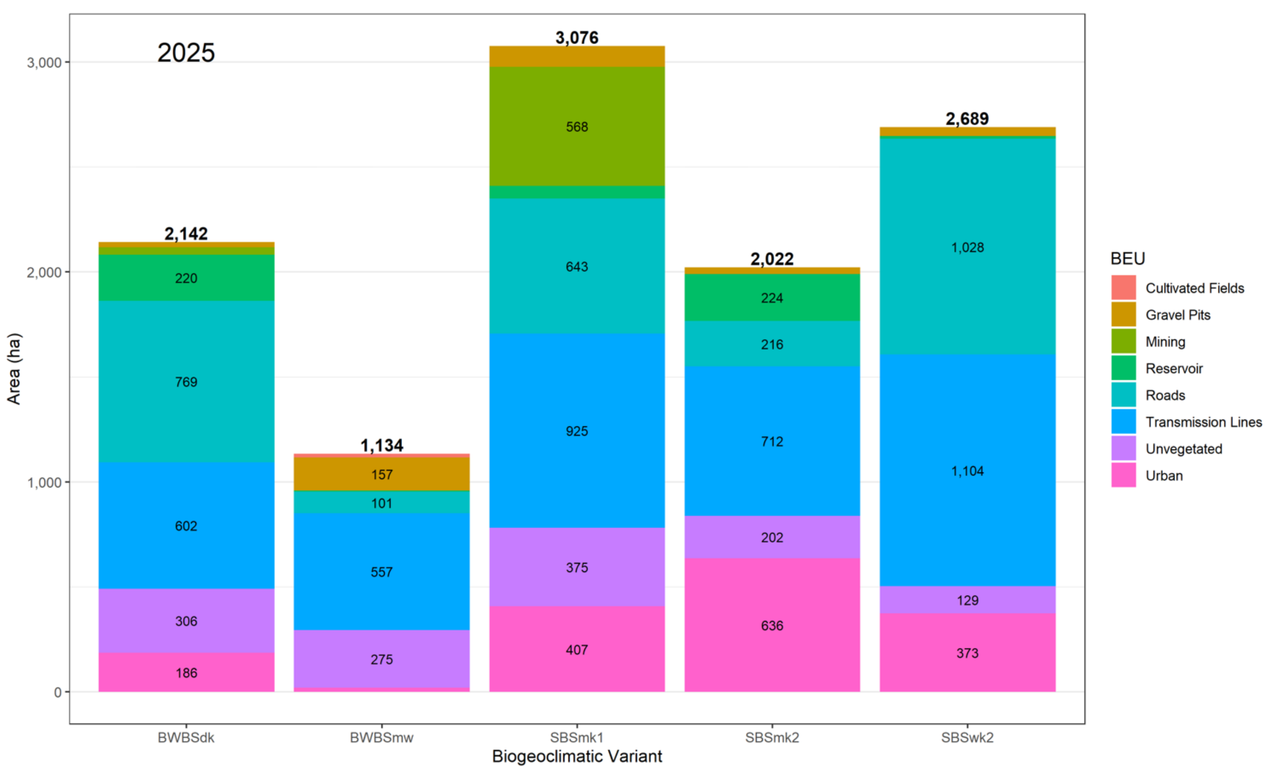

Figure 21. Non-Williston Reservoir disturbances recorded in Broad Ecosystem Units (BEUs) in lowland BEC units within the Williston Watershed.

Table 15. Disturbances in the lowland Biogeoclimatic variants of the Williston watershed – Current Conditions (BEMVRI 2025).

BEC Variant	BEU Name	Area in 2025 (ha)	Percent of BEC Variant
BWBSdk	Gravel Pits	24	0.0
BWBSdk	Mining	36	0.0
BWBSdk	Reservoir	11,984	1.8
BWBSdk	Roads	769	0.1
BWBSdk	Transmission Lines	602	0.1
BWBSdk	Unvegetated	324	<0.1
BWBSdk	Urban	186	<0.1
BWBSmw	Cultivated Fields	18	<0.1
BWBSmw	Gravel Pits	157	0.2
BWBSmw	Reservoir	18,746	22.5
BWBSmw	Roads	102	0.1
BWBSmw	Transmission Lines	558	0.7
BWBSmw	Unvegetated	304	0.4
BWBSmw	Urban	19	<0.1
SBSmk1	Gravel Pits	104	<0.1
SBSmk1	Mining	568	0.1
SBSmk1	Reservoir	3,300	0.5
SBSmk1	Roads	647	0.1
SBSmk1	Transmission Lines	925	0.1
SBSmk1	Unvegetated	454	0.1
SBSmk1	Urban	408	0.1
SBSmk2	Gravel Pits	31	<0.1
SBSmk2	Reservoir	126,269	32.5
SBSmk2	Roads	219	0.1
SBSmk2	Transmission Lines	714	0.2
SBSmk2	Unvegetated	555	0.1
SBSmk2	Urban	646	0.2
SBSwk2	Gravel Pits	42	<0.1
SBSwk2	Reservoir	13,088	4.2
SBSwk2	Roads	1,028	0.3
SBSwk2	Transmission Lines	1,104	0.4
SBSwk2	Unvegetated	140	<0.1
SBSwk2	Urban	373	0.1

A literature review was conducted to assess potential impacts of the reservoir beyond the water line. The zone above the annual high water line experiences flooding from interannual high water levels, and consists of perennial, flood-tolerant vegetation such as Salix spp. (May, 2021). Moreover, the reservoir likely has a hydrological influence on vegetation above the maximum high-water line (May, 2021).

In addition to direct hydrological influences on vegetation, Williston reservoir has climatological effects on the temperature and precipitation regime within the broader (10-13 km) surroundings (Onwukwe et al., 2024). The influence of the large body of water increased mean annual air temperature by 0.2-0.5 C within 10 km of the reservoir (Onwukwe et al., 2024). The influence of the reservoir led to increased autumn precipitation and decreased summer precipitation. Overall, there was a 15% annual decrease in precipitation on the eastern ridges of the watershed (Onwukwe et al., 2024). There are implications of reduced precipitation in this boreal system, as research suggests that drought reduces carbon storage in western boreal forests (Ma et al., 2012).

The reservoir's disproportionate removal of lowland habitat also likely led to wildlife habitat fragmentation. Traditional knowledge from Treaty 8 First Nations groups asserts that the loss of lowland habitat and interruption of traditional caribou herd migration paths likely contributed to the decline of the local Scott caribou herd (West Moberly First Nation, 2009). Many caribou populations today are non-migratory and the loss of this behaviour due to disturbance and habitat fragmentation, such as the Williston Reservoir, likely contributes to reduced caribou persistence (Lamb et al., 2022).

It should be noted that, although it was beyond the scope of this project to evaluate, there are potentially additional indirect disturbance impacts of the reservoir such as increased forest harvesting and road construction.

Although they both lead to a successional reset, there are differences between naturally occurring disturbances and human-caused disturbances. Figure 22 depicts change in the same area with imagery from 1968 and 2025. In 1968 disturbances in the area shown in the imagery were primarily caused by the changing course of the river which reset the forest to early successional stages but also created complex habitats and structural complexity.

In 2025 most disturbances visible in the imagery are cutblocks and roads, which also reset the forest to early successional stages but instead of increasing complexity at the site level, they create large areas with a homogenous structural stage, decreasing structural complexity at the site level. Therefore, comparing forest structural stages between the past and the present may underestimate habitat degradation for species which rely on a mosaic of habitat types or high structural complexity at the site level.

The ecosystem classification within the reservoir footprint was not field validated and may not reflect actual conditions pre-flood. The classification covered a large area and lacks detail on fine scale ecosystem structure. As the mapping relied solely on imagery, it is possible that the site richness, and therefore the forest productivity, was underestimated in valley bottoms.

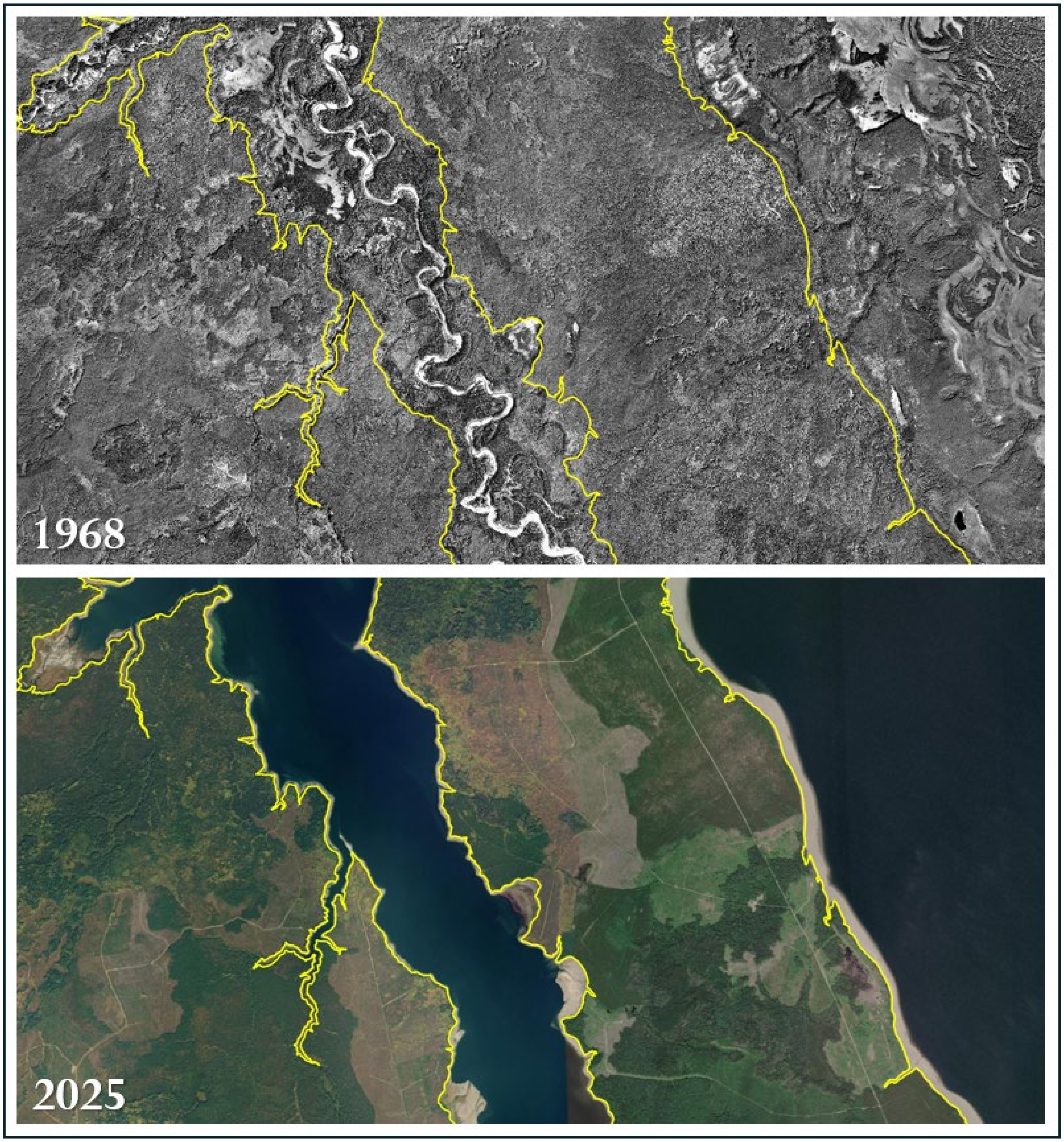

Figure 22. There has been a change in the nature of disturbances from 1968 and 2025. The top image (1968) displays natural forest disturbance caused by river movement while the bottom image (2025) shows human-cause disturbance in the form of roads and forest harvesting.

4.4.2 Natural Disturbances

Fire can be influenced by human activities both directly, through forest management, and indirectly through climate change, but for the purpose of this analysis are included as a natural disturbance. The pattern of fire disturbance in the watershed from the start of the data collection (roughly 1920) until 2010 consisted of smaller but numerous footprints (Figures 23 and 24). Fires that burned prior to fire suppression (which began in the 1970's) are thought to have burned at lower severity that resulted in increased tree survival post-fire. Over a much shorter period between 2010 and 2025, a greater amount of forest area burned.

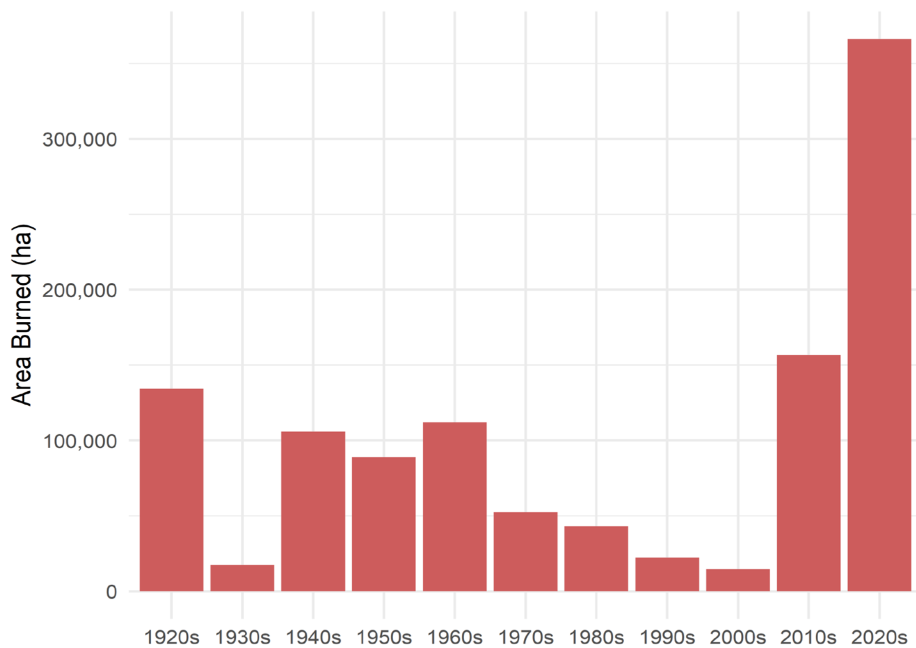

Figure 23. The cumulative area burned in hectares (ha) per decade in the Williston watershed region figure created in R (R Core Team, 2023) using the ggplot2 package (Wickham, 2016).

Insect outbreaks also have a extensive impact on the forests in the Williston Watershed, and have been widespread throughout the watershed (Figure 24). Although both wildfires and insect outbreaks are a natural forest process in the Williston watershed, they can be exacerbated by warmer winters and changing precipitation regimes, both of which may be influenced by the reservoir (Onwukwe et al., 2024).

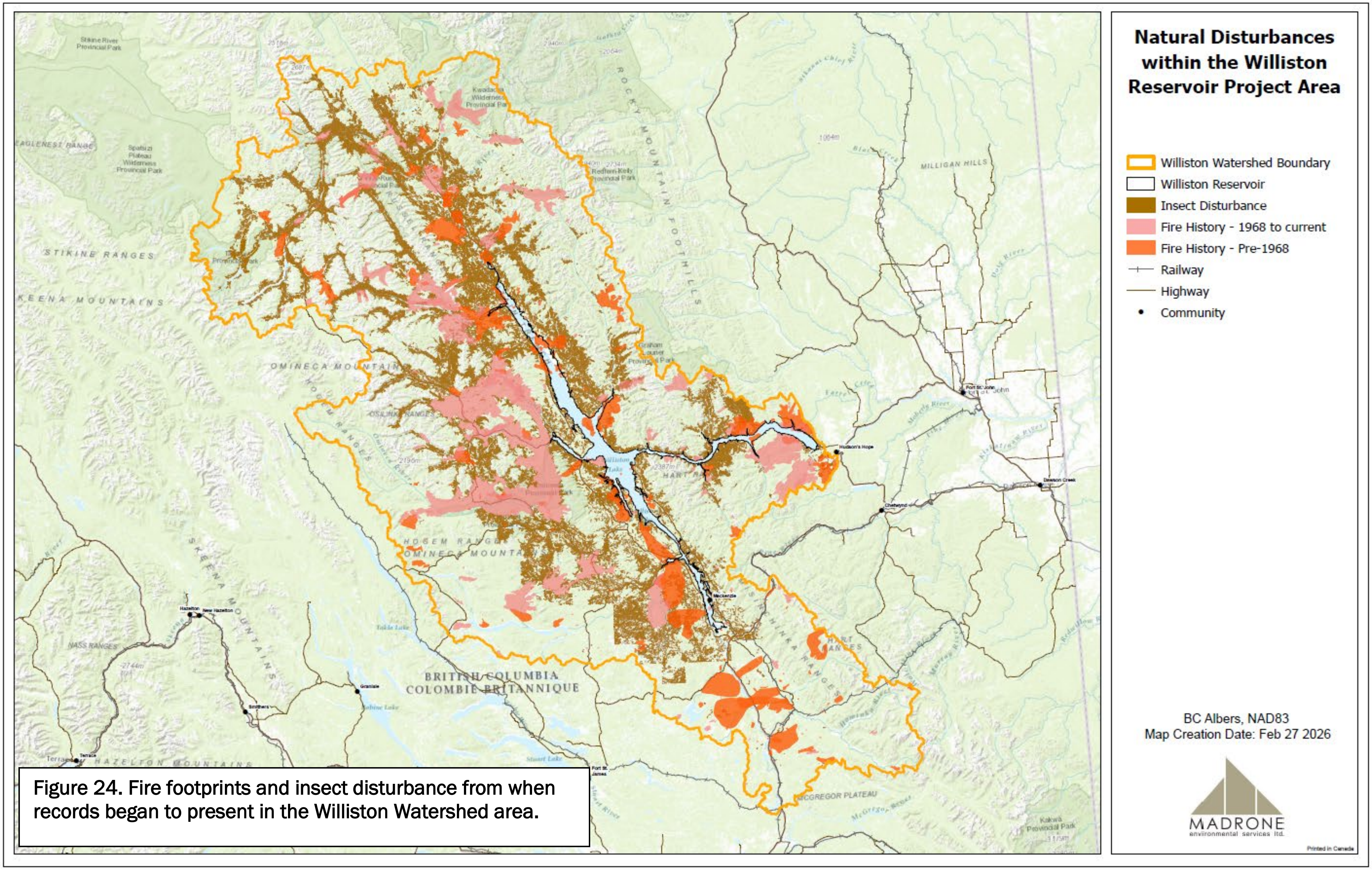

Figure 24. Fire footprints and insect disturbance from when records began to present in the Williston Watershed area.

5 BEMVRI Strengths and Limitations

BEMVRI is a spatially explicit ecosystem model attributed with BEUs, structural stage, stand composition, slope, aspect, and elevation data. As a result of also maintaining the VRI attribution, many additional user defined fields can be added to inform further analyses and applications such as habitat models. The following is a summary of key strengths and limitations, and potential applications of the product identified at this time.

5.1 Strengths

The following is a summary of some of the strengths of BEMVRIs and the documented methodology for creating it:

- BEMVRI provides a single, standardized ecosystem spatial coverage at 1:20,000 scale that incorporates modelled current conditions of a project area, and in this case was also used to apply age data backcast to 1968 to examine a pre-flood scenario for the Williston Watershed.
- BEMVRI uses broad scale ecosystem mapping (BEM) in combination with finer scale modelling of current conditions and dominant ecosystem types from VRI. This combination provides systematic estimates of ecosystem abundance and distribution.
- BEMVRI provides useful site-specific information that can be used for planners and resource managers, recognizing the limitations of the input data.
- The BEMVRI spatial coverage has the potential to inform habitat models for many different wildlife species.
- Scripts and supporting tools have been developed for use with the BEMVRI to enable efficient updating of BEMVRI over time for the current conditions (2025) coverage.

5.2 Limitations

Although a number of strengths are listed, caution should be applied by recognizing the scale of use for interpretation of the BEMVRI product. Reliability of several aspects of the assessment are limited by the accuracy of forest inventory data.

The main limitation in use of VRI data for ecosystem interpretations is in reliance on the BC Land Classification System (BCLCS) and other attributes related to non-forested sites. VRI was not developed or designed to track non-forested sites, but in general does a decent job at identifying non-forested units below tree line. VRI quality and detail varies throughout the province depending on when it was last updated.

Despite best efforts to apply automated rules for corrections to ecosystem labels, this product has not been field verified, and limited desktop validation was conducted. As such, the ecosystem labels should be treated with caution for site-specific (stand level) queries. The product is best applied at this time at a broad scale of analysis such as current conditions within the extent of a specific BEC unit or for a landscape unit.

6 Conclusions

Through the Williston Watershed Impact Assessment Mapping Project, two map coverages were produced representing conditions in 1968 and 2025. The standardized BEMVRI products were completed for the entire Williston Watershed Area and cover 7,286,165 hectares. The mapping includes a high-water mark (181,176 hectares) as well as a 200 m buffer (23,453 hectares); encompassing approximately 204,630 ha of valley floor landscapes in the BEMVRI 1968 coverage.

A total of 62 unique ecosystem codes were applied in the two BEMVRI map products. Ecosystem types mapped within the 5 priority BEC units were examined for change in their extent and condition (structural stages) before and after flooding. Loss of terrestrial, riparian, and wetland ecosystems were highest within the SBSmk2 BEC unit. Other sources of disturbances (human-caused and natural) are presented.

Recommendations for future work include further testing and refinement of ecosystem assignments to the VRI polygons, deeper evaluation of conflicting data sources, improved delineation of subalpine and alpine areas, and use in habitat connectivity mapping or other interpretive analyses. Review of the products is encouraged along with recommendations for field verification programs, and product accessibility (e.g., use and understanding of the products).

This project aligns with the FWCP Peace Action Plan: “Develop approach to incorporate cumulative effects into actions- P1”. These BEMVRI products and the comparative analysis will support FWCP with understanding ecosystem impacts from the flooding of Williston reservoir and assisting the regional board with strategic planning in the Peace region.

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Appendix A: Methods Applied to Create the BEMVRI Coverage

Step 1a: Create Initial Spatial Product

Name	Data Type	Description
VRI	Input	All VRI 2021 polygons that intersect the study area are selected and exported to a new feature class.
CC & Results	Input	Consolidated cutblock layer (CC) and Results were used to enhance the representation of recent harvesting in VRI (i.e., where VRI indicated a forest was old, but the CC or Results Layer indicated it had been harvested the polygon age was updated to reflect the newer age).
	Script	Script "vri_union_cc_and_results_in_aoi.py" was run to create a combined layer, VRI+CC+Results. Script "vri_cc_res_calc_age.py" then incorporates any changes in age class data based on the projected age, consolidated cut block, and results information.
DEM	Input	Topographic information from a 25 m resolution Digital Elevation Model (DEM) was applied to each VRI polygon. The information provided included: Mean Slope, Aspect, and Elevation of the polygon.
	Script	Scripts 02a and 02b were run using a 25 m DEM raster to populate the mean slope, mean aspect, and mean elevation for each polygon. This also resulted in the addition of the slope /aspect modifier (k, w, etc.) field. QA was done at this stage to ensure that the slope modifiers were assigned in the SLOPE_MOD field correctly.
BEM	Input	The BEI 2000 product ecosystem label was assigned to each VRI polygon based on majority area of overlap. This resulted in numerous rows of the same data assigned to multiple (sometimes 100's) of VRI polygons due to the 1:250,000 scale BEM being assigned to the 1:20,000 VRI.

Step 1b: GIS Clean-up of Initial Spatial Product

Name	Description
Topo	Multipart exploded to single-part features. Can result in slivers and gaps to correct in the next step.
Slivers	The process of intersecting the VRI , CC, and Results datasets created many slivers where the line work was cut between polygon boundaries. These topology errors were alleviated using the Elimination, Integrate, and Topology tools. Any sliver with an area of less than 0.3ha was merged with the next adjacent polygon.
TEIS ID	Unique TEIS_ID [12]values were applied to all polygons in preparation of running existing scripts in later steps that require a unique TEIS_ID.

[12] TEIS_ID is the unique polygon identifier as specified in Terrestrial Ecosystem Information System (TEIS) data standards.

Appendix B: BEMVRI Script Descriptions

Initial Project Setup:

There is no required or recommended folder structure for running the scripts or processing the data. The scripts may reside in any folder. The BEMVRI feature class must be stored in an ArcGIS file geodatabase (FGDB), preferably located on a local hard drive.

Some scripts automatically create and use a scratch file geodatabase for intermediate data. This scratch FGDB is typically created in the same folder as the FGDB containing the input BEMVRI feature class.

The workflows described below do not depend on a specific folder structure. Outputs are generally saved in the same folder or FGDB as the input dataset. The script will display the full paths and names of output files in the console for reference.

In some cases, a Scratch folder will be created at the same directory level as the input data, along with a Scratch.gdb file geodatabase inside that folder. This geodatabase stores intermediate outputs and may be reviewed as part of your quality assurance process.

Most scripts modify the input feature class rather than creating a new output feature class. Therefore, it is strongly recommended that you create a copy of the feature class before running each script and rename it using the project name, script ID, and processing date. For example, before running script 01a, create a copy named Project_01a_02032026. Before running script 01b, create a new copy of the previous version and name it Project_01b_02032026.

This naming convention clearly identifies which script was applied, preserves previous processing stages, provides a processing date for traceability, and supports quality assurance and reproducibility throughout the workflow.

Step 1: BEMVRI Geometry and Attributes

Note: Scripts may not run sequentially. Some were skipped due to good overall data quality, because related steps were completed under other project work, or because manual effort provided a higher-quality outcome.

Step 1a: Incorporate CC linework and attributes into VRI	
Script Name:	01a_vri_union_cc.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Advanced License (for Eliminate tool)
Inputs (Arguments):	1) VRI feature class polygons that intersect study area 2) CC feature class polygons that intersect study area
Description: This script uses the Union geoprocessing tool to combine the linework of the selected VRI polygons[13] and the selected Consolidated Cutblocks[14] (CC) polygons. The output contains many small "sliver" polygons which the script dissolves into their larger neighbouring polygons using multiple iterations of the Eliminate tool. The final output should have no polygons smaller than 1,250 m^2 and an attribute table consisting of all VRI and CC attributes. This VRI+CC feature class is the basis of what will become our final BEMVRI feature class.	

Step 1c: Format BEI polygon attributes to BEM table schema	
Script Name:	None
Requirements:	ArcGIS Pro 3.x
Inputs (Arguments):	1) BEI 2000 feature class polygons that intersect all BEMVRI polygons 2) Empty polygon feature class template with BEM table schema
Description: Use the Append tool or the Load Data tool available in ArcCatalog to copy the selected BEI 2000 polygons into the empty BEM feature class template. Ensure that the BEI 2000 fields are mapped to the BEM fields as follows: • FCODE → FCODE • ECO_SEC → ECO_SEC • DEC1 → SDEC_1 • HAB1 → BEUMC_S1 • DEC2 → SDEC_2 • HAB2 → BEUMC_S2	

[13] VRI - https://catalogue.data.gov.bc.ca/dataset/vri-2024-forest-vegetation-composite-layers-all-layers-

[14] Harvested Areas of BC - https://catalogue.data.gov.bc.ca/dataset/harvested-areas-of-bc-consolidated-cutblocks-

Step 1d: Extract large VRI polygons	
Script Name:	01d_extract_large_vri.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher
Inputs (Arguments):	BEMVRI feature class (the output of Step 1b)
Description: This script selects all BEMVRI polygons that are larger than 35,000,000 m^2. It then adds to this selection all polygons that are neighbours of these large polygons. It then uses the Dissolve tool, retaining the following seven attribute fields: • INVENTORY_STANDARD_CD • BCLCS_LEVEL_1 • BCLCS_LEVEL_2 • BCLCS_LEVEL_3 • BCLCS_LEVEL_4 • BCLCS_LEVEL_5 • SPECIES_CD_1 From the output of this Dissolve process, the polygons that remain larger than 35,000,000 m^2 are selected and exported to a new feature class, which are referred to as the Large VRI Polygons.	

Step 1e: Cut large VRI polygons and attribute BEUs	
Script Name:	None – Manual geoprocess
Requirements:	ArcGIS Pro 3.x
Inputs (Arguments):	Large VRI Polygons (the output of Step 1d)
Description: • Use the "Identity" tool to overlay the Large VRI Polygons (the output of Step 1d) with the BEI polygons in the BEM table schema (the output of Step 1c). The result should be the large VRI polygons cut up by the BEI linework and with all of the BEM attributes. ○ If you do not have the Advanced license for ArcGIS Desktop and cannot use the "Identity" tool, use the "Union" tool, but then delete any polygons in the output that did not overlap with the original VRI Large Polygons. • An ecologist or biologist should use the geometry editing tools and the satellite imagery basemap layers available in ArcGIS Pro to further split these large VRI polygons into smaller ones that have distinct BEUs. The ecologist or biologist should reassign more appropriate BEU codes and decile values to the attributes SDEC_1, BEUMC_S1, SDEC_2 and BEUMC_S2 (and modifiers to SITE_M1A and SITE_M2A where applicable) as they deem necessary based on their expertise. For the polygons that they update the BEU codes for, they should also add any string, typically their initials, to the POLY_COMM field, which will ensure that their BEU codes will not be overwritten by subsequent scripts that perform automated corrections.	

Step 1f: Attach BEM attributes to BEMVRI polygons	
Script Name:	01f_attach_bei_attr_to_vri.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher
Inputs (Arguments):	1) VRI+CC feature class with single part polygons and cleaned topology (the output of Step 1b) 2) BEM feature class (the output of Step 1c)
Description: This script will overlay the VRI+CC feature class with the BEM feature class to determine for each VRI+CC polygon, which is the area-dominant BEM polygon. It will then add all of the fields of the BEM table schema to the VRI+CC attribute table and assign the appropriate BEM attributes to each VRI+CC polygon. The output is the "BEMVRI" feature class moving forward.	

Step 1h: Clean up the BEMVRI attributes	
Script Name:	01h_bemvri_attribute_cleanup.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher
Inputs (Arguments):	BEMVRI feature class (the output of Step 1g)
Description: This script will update the BEMVRI attributes in the following ways: • In string fields, it replaces all Null values and single space values with an empty string • In SDEC_1, SDEC_2 and SDEC_3, it replaces all 0 values with Null • It creates a new field named DEC_Total and populates it with the expression SDEC_1 + SDEC_2 + SDEC_3	

Step 1i: QA the BEMVRI attributes	
Script Name:	None
Requirements:	ArcGIS Pro 3.x
Inputs (Arguments):	BEMVRI feature class (the output of Step 1h)

Description:

- QA the attributes, especially the values that the ecologist/biologist assigned to the large polygons in Step 1e. Particularly, the values in SDEC_1 and SDEC_2 should always add up to 10, which you can more easily check using the DEC_Total field that was created and populated in Step 1h. Also, the codes in BEUMC_S1 and BEUMC_S2 should always be two uppercase letters.
- Check any polygons where PROJ_AGE_1 is 0, which would indicate that the polygon has been logged in the current year. Replace the 0's with Null in this field if there is no other evidence that the polygon was logged in the current year.
- Repeat the previous step for the HARVESTYR_CC field.

Step 1j: Calculate BEC units	
Script Name:	01j_calc_bec_units.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 1i) 2) Provincial BEC Unit polygons v12 or newer if available

Description: This script will copy the Biogeoclimatic Ecosystem Unit (BEC) attribute values from the VRI BEC fields to the BEM BEC fields, as follows:

- BEC_ZONE_CODE → BGC_ZONE
- BEC_SUBZONE → BGC_SUBZON
- BEC_VARIANT → BGC_VRT
- BEC_PHASE → BGC_PHASE

For polygons where there are Null values in the VRI BEC fields, the script will overlay the BEMVRI polygons with the Provincial BEC v12 (or newer) polygons, and assign values to the BEM BEC fields based on the BEC v12 unit that occupies the majority of each BEMVRI polygon.

Step 1k: Calculate Age, Stand and Crown attributes	
Script Name:	01k_calc_age_std_crown.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher Python module "openpyxl"
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 1i) 2) The year that the VRI data was released (e.g. 2021) 3) The BEMVRI Metadata Excel file

Description: This script requires a BEMVRI Metadata Excel file. The Excel file must contain a worksheet named "Age_Class_Bins", which must contain the columns seen here:

	A	B	C	D	E	F	G	H	I
1	STS_LUT_Field	Type	Min	Max	Label				
2	Structural Stage at_VRI Age_0-3	STS	0	3	3				
3	Structural Stage at_VRI Age_4-10	STS	4	10	10				
4	Structural Stage at_VRI Age_11-30	STS	11	30	30				
5	Structural Stage at_VRI Age_31-40	STS	31	40	40				
6	Structural Stage at_VRI Age_41-60	STS	41	60	60				
7	Structural Stage at_VRI Age_61-80	STS	61	80	80				
8	Structural Stage at_VRI Age_81-139	STS	81	139	139				
9	Structural Stage at_VRI Age_140-179	STS	140	179	179				
10	Structural Stage at_VRI Age_180-249	STS	180	249	249				
11	Structural Stage at_VRI Age_250+	STS	250	9999	9999				
12	Stand Comp at_Age_1-15	STD	0	15	15				
13	Stand Comp at_Age_16-30	STD	16	30	30				
14	Stand Comp at_Age_31-50	STD	31	50	50				
15	Stand Comp at_Age_51-80	STD	51	80	80				
16	Stand Comp at_Age_>80	STD	81	9999	9999				
17									
18									
19	Notes:								
20	Ensure that bins for STS cover every age value from 0 to 9999 without overlapping each other.								
21	Ensure that bins for STD cover every age value from 1 to 9999 without overlapping each other.								
22	STS LUT Field names must exactly match the field names found in column A of the STS_LUT_Fields worksheet.								

In this metadata table, two sets of age class bins are defined: one for Structural Stage (STS), and one for Stand Composition (STD). The Structural Stage Lookup Table (STS LUT) will allow us to assign Structural Stage and Stand Composition codes to each polygon in the BEMVRI feature class based on the age class fields which will be calculated by this script.

First, this script creates a new field named VRI_CC_AGE and populates it for each polygon with an actual age value, i.e. the number of years since the most recent logging. The value is assigned according to the following logic:

- If the CC field HARVESTYR_CC contains a year, then assign the value of the user-specified "current" year (the second argument given when running this script) minus that year.

    - If the PROJ_AGE_1 field also contains a value, and it indicates a more recent harvest than HARVESTYR_CC does, then assign the PROJ_AGE_1 value instead.
    - If PROJ_AGE_1 is Null but the VRI field HARVEST_DATE contains a year that indicates a more recent harvest than HARVESTYR_CC does, then assign the value of the user-specified “current” year minus the HARVEST_DATE year.
- If not, then if the VRI field PROJ_AGE_1 contains a value, then assign that value.
- If not, then if the VRI field HARVEST_DATE contains a year, then assign the value of the user-specified “current” year minus that year.
- If not, then assign the value of -1, which will indicate that no age value is available for this polygon.

The script also calculates values for the AGE_CL_STS and AGE_CL_STD fields according to the value that was assigned to VRI_CC_AGE and which of bins in the metadata table that value belongs in. The value assigned will be the value in the “Label” column of the metadata table, which is simply a name for the age class bin, which in this case happens to be the same as the highest value of the range for each bin.

HARVEST_DATE	PROJ_AGE_1	HARVESTYR_CC	VRI_CC_AGE	AGE_CL_STS	AGE_CL_STD
1989-01-01	32	1989	32	40	50
1981-01-01	34	1981	40	40	50
<Null>	<Null>	0	-1	-1	-1
<Null>	<Null>	0	-1	-1	-1
1960-01-01	<Null>	0	61	80	80
<Null>	62	0	62	80	80
1966-01-01	52	1966	55	60	80
1988-01-01	31	1988	33	40	50

The script will also calculate values for a field named STD_VRI, which will contain a Stand Composition code derived from VRI attributes. It considers all of the tree species listed in the VRI fields SPECIES_CD_1 through SPECIES_CD_6, and their percentages given in the fields SPECIES_PCT_1 through SPECIES_PCT_6, and adds up the total percentage occupied by broadleaf tree species, represented by codes D, DR, U, UP, A, AC, ACB, ACT, AX, AT, R, RA, E, EA, EXP, EP, EW, GP, MB, MB, MV, Q, QG, V, VB, VP, W, WS, WA, WB, WD, WP, WT, or XH. Stand Composition codes are assigned to STD_VRI field according to the following table:

Stand Composition Definitions

C (Coniferous)	<25% broadleaf
M (Mixed)	<75% broadleaf
B (Broadleaf)	>=75% broadleaf

A sample of results is seen in the image of the BEMVRI attribute table below:

SPECIE	SPECI	SPECI	SPECI	SPECI	SPECIE	SPECI	SPECIE	SPECI	SPECIE	SPECI	SPECIE	STD_VRI
DR	70	HW	20	BA	10		<Null>		<Null>		<Null>	M
DR	40	MB	20	FD	15	CW	15	HW	10		<Null>	M
DR	40	MB	20	FD	15	CW	15	HW	10		<Null>	M
DR	60	MB	15	CW	10	HW	10	FD	5		<Null>	B
HW	40	CW	30	SE	15	BA	10	FD	5		<Null>	C
CW	40	HW	30	BA	15	DR	10	FD	5		<Null>	C
DR	80	CW	10	HW	10		<Null>		<Null>		<Null>	B
DR	60	MB	15	CW	10	HW	10	FD	5		<Null>	B

Step 2: Derive and Assign BEMVRI Attributes from Spatial Overlays and Reference Tables

Step 2a: Calculate Slope, Aspect and Slope Modifier

Script Name:	02a_add_aspect_slope.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher Spatial Analyst extension
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 1k) 2) Slope raster (representing percent gradient) 3) Aspect raster (must have integer value type)

Description: This script will use the “Zonal Statistics As Table” tool in the Spatial Analyst toolbox to overlay the slope raster with the BEMVRI polygons and then assign a mean slope value to each polygon in the MEAN_SLOPE field.

It then uses the “Tabulate Area” tool in the Spatial Analyst toolbox to overlay the aspect raster with the BEMVRI polygons, and then assign a circular mean aspect value to each polygon in the MEAN_ASP field.

It then calculates the Slope Modifier in the SLOPE_MOD field, using the following logic:

- If the mean slope is greater than or equal to 10% and less than 25% (but 35% for polygons in BEC zones CWH, MH, CDF or CMA), assign a “j”.
- If the mean slope is greater than or equal to 25% (but 35% for polygons in BEC zones CWH, MH, CDF or CMA) and less than or equal to 100%:
  - If the mean aspect is 0 to 134 or 285 to 360, assign a “k”.
  - Otherwise, assign a “w”
- If the mean slope is greater than 100%:
  - If the mean aspect is 0 to 134 or 285 to 360, assign a “q”.
  - Otherwise, assign a “z”

Only the slope modifier is used in subsequent processes. However, keeping the source values also allows end users to change the thresholds if using the VRI/BEM dataset for other wildlife species in the future, or to compare changes in the current thresholds on WHR results.

MEAN_ASP	MEAN_SLOPE	SLOPE_MOD
180	3	
199	9	
271	18	j
334	4	
165	108	z
238	33	j
206	57	w
255	48	w
215	12	j
252	6	

Step 2b: Calculate Mean Elevation and Above Elevation Threshold

Script Name:	02b_add_elev.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher Spatial Analyst extension
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 2a) 2) DEM raster (representing elevation in meters above sea level) 3) Elevation threshold value (in meters above sea level, e.g. 1200) If not needed, set the threshold to 0. There must be a value entered.

Description: This script will use the “Zonal Statistics as Table” tool in the Spatial Analyst toolbox to overlay the DEM raster with the BEMVRI polygons and then assign a mean elevation value to each polygon in the ELEV field. It then assigns a “Y” or “N” value to the ABOVE_ELEV_THOLD field based on the threshold value that the user specified as the third argument when running the script.

ELEV	ABOVE_ELEV_THOLD
239	N
323	N
216	N
597	N
1275	Y
578	N
241	N

Step 2d: Update the BEC/BEU Combos Table

Script Name:	02d_update_bec_beu_combo_table.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher Python module “openpyxl”
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 2c) 2) BEC/BEU Combos Table Excel file

Description: The BEC/BEU Combos table is a list of combination of BEC zone, BEC subzone and BEU mapcode that have been encountered in BEMVRI projects, with each combination designated as “Approved” or “Error”; for those that are designated an “Error”, a corrected mapcode is provided. A sample is shown in the image below:

	A	B	C	D	E
1	BGC Subzone	BEU_#	Name	Script rule	Change to BEU =
479	CWHvh	YB	Yellow-cedar Bog Forest	Allowed	
480	CWHvh	YM	Yellow-cedar - Mountain Hemlock Forest	Allowed	
481	CWHvh	YS	Yellow-cedar Skunk Cabbage Swamp Forest	Allowed	
482	CWHvm	AM	Alpine Meadow	Error	ME
483	CWHvm	AT	Alpine Tundra	Error	UV
484	CWHvm	AU	Alpine Unvegetated	Error	UV
485	CWHvm	AV	Avalanche Track	Allowed	
486	CWHvm	BG	Sphagnum Bog	Allowed	
487	CWHvm	CB	Cedars - Shore Pine Bog	Allowed	
488	CWHvm	CD	Coastal Douglas-fir	Error	FR

This script will read the Excel file, then read the BEMVRI feature class. For any combination of BEC zone, BEC subzone and BEU mapcode that doesn’t exist in the Excel file, the script will add a new row to the Excel file.

The script will first check for errors in the Excel file, such as a combination designated as an error but with no corrected mapcode specified. If any such errors are found, the user will be informed of them, and the script will finish without any updates to the Excel file. The user must first fix the errors and then run this script again.

If the script adds any new rows to the table, the script will inform the user of this, and the user must perform Step 2e which is to manually edit the table in Excel to designate each newly added combination as Approved or Error, with the corrected mapcode.

If the script did not find any errors in the table and did not need to add any new rows to the table, the user can move on to Step 2f.

Step 2e: Manually Update the BEC/BEU Combos Table

Script Name:	None
Requirements:	Microsoft Excel
Inputs (Arguments):	BEC/BEU Combos Table Excel file (the output of Step 2d)

Description: Open the BEC/BEU Combos table in Excel. The script in Step 2d will have added new combinations at the bottom of the table, with columns A and B shaded in red. The user must fill in columns C, D and (if applicable) E for each new row, as seen in the image below.

	A	B	C	D	E
1	BGC Subzone	BEU_#	Name	Script rule	Change to BEU =
2655	CMAunp	CW	Coastal Western Hemlock - Douglas Fir	Error	HP
2656	ESSFmw	GL	Glacier	Error	UV
2657	CDFmm	BR	Brush - specific to NSR sites, NCBR and BCLCS leve	Allowed	
2658	CDFmm	WL	Wetland	Allowed	
2659	CMAunp	BR	Brush - specific to NSR sites, NCBR and BCLCS leve	Error	AS
2660	CWHdm	BR			
2661	CWHds	BR			
2662	CWHmm	BR			
2663	CWHms	BR			
2664	CWHvm	BR			
2665	CWHxm	BR			
2666	CWHxm	ME			
2667	CWHxm	WL			
2668	ESSFmw	BR			
2669	MHmm	BR			

When this has been completed and the Excel file has been saved, the user can move on to Step 2f.

Step 2f: Make Corrections to BEMVRI BEU Attributes	
Script Name:	02f_bem_corrections.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher Python module "openpyxl"
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 2c) 2) BEC/BEU Combos Table Excel file (the output of Step 2d or 2e)

Description: This script will first check BEC/BEU Combos Table Excel file for errors. If it finds any, it will report them to the user, and terminate the script. The user must then address the errors in the Excel table and save it before running this script again.

If there are no errors in the Excel table, the script will then apply a series of checks of the BEMVRI attributes and apply corrected values to the BEMVRI feature class attributes as needed. See following section, **BEM Corrections Applied During Step 2f Scripted Process,** for more details.

The script will write the appropriate updated values to the BEU attributes, and it will also create a new field named BEM_Correction_Comment, containing a description of what was modified. This is a helpful for the QA process. A sample of these descriptions is seen in the image below:

BEM_Correction_Comment
CWHxm CW in decile 1 combination is allowed
CWHxm CW in decile 1 combination is allowed; CWHxm CD in decile 2 combination is allowed
CWHxm CW in decile 1 combination is allowed; CWHxm CD in decile 2 combination is allowed
Combined components 1 and 2 with same BEUMC_S# code into single component 1; CWHdm CD in decile 1 combination is allowed
Updated to 10 WL because BCLCS_LEVEL_1/2/3 = 'V'/'N'/'W' and AGE_CL_STS = -1; CWHdm WL in decile 1 combination is allowed
Updated to 10 OW because BCLCS_LEVEL_1 = 'N', BCLCS_LEVEL_5 = 'LA', Area <= 10 ha; MHmm OW in decile 1 combination is allowed
CWHdm CW in decile 1 combination is allowed
Updated to 10 LS because BCLCS_LEVEL_1 = 'N', BCLCS_LEVEL_5 = 'LA', Area <= 60 ha; CWHxm LS in decile 1 combination is allowed
Updated to 10 BR because BCLCS_1/2/3/4 = V, N, U, SL/ST; CWHdm BR in decile 1 combination is allowed
Updated to 10 BR because BCLCS_1/2/3/4 = V, N, U, SL/ST; CWHdm BR in decile 1 combination is allowed
Updated to 10 LS because BCLCS_LEVEL_1 = 'N', BCLCS_LEVEL_5 = 'LA', Area <= 60 ha; CWHdm LS in decile 1 combination is allowed
CWHvm FR in decile 1 combination is allowed
Updated to 10 BR because BCLCS_1/2/3/4 = V, N, U, SL/ST; CWHdm BR in decile 1 combination is allowed
Updated to 10 BR because BCLCS_1/2/3/4 = V, N, U, SL/ST; CWHvm BR in decile 1 combination is allowed
CWHdm WL in decile 1 combination is allowed
Updated to 10 WL because BCLCS_LEVEL_1/2/3 = 'V'/'N'/'W' and AGE_CL_STS = -1; CWHdm WL in decile 1 combination is allowed
CWHdm LL in decile 1 combination is allowed; Updated SITE_M3A from '' to 'a' because polygon is adjacent to river

If a polygon's POLY_COMM field contains a non-null value, indicating that an ecologist/biologist has assigned the current BEU mapcodes to this polygon in Step 1e, then the script will only implement corrections based on the Approved BEC/BEU Combos table to this polygon. The other corrections indicated in the following section, **BEM Corrections Applied During Step 2f Scripted Process,** will not be applied to this polygon.

BEM Corrections Applied During Step 2f Scripted Process

The following steps were applied to update and QA the BEM labels to reflect the 1:20,000 scale prior to running the habitat ratings (WHR moose winter habitat model). Broad Ecosystem labels were adjusted for errors due to finer scale of VRI polygons. The quality assurance (QA) and resulting updates were conducted using VRI BCLCS Levels 1-5.

Name	Description of Update
BEC/BEM Combo Check	Checks for allowable BEC Unit and BEM Mapcode combinations based on a CSV of approved combinations and applies the corrected codes. The script also exports a list of BEC/BEM combinations that require direction from the user to indicate what is allowed or should be corrected as a CSV output.
BEM Correction Comment	Updates and QA efforts are tracked through a field added to the product called "BEM_Correction_Comment" with descriptions of edits made to the BEM labels. **BEM_Correction_Comment** CWHxm CW in decile 1 combination is allowed CWHxm CW in decile 1 combination is allowed; CWHxm CD in decile 2 combination is allowed CWHxm CW in decile 1 combination is allowed; CWHxm CD in decile 2 combination is allowed Combined components 1 and 2 with same BEUMC_S# code into single component 1; CWHdm CD in decile 1 combination is allowed Updated to 10 WL because BCLCS_LEVEL_1/2/3 = 'V'/'N'/'W' and AGE_CL_STS = -1; CWHdm WL in decile 1 combination is allowed Updated to 10 OW because BCLCS_LEVEL_1 = 'N', BCLCS_LEVEL_5 = 'LA', Area <= 10 ha; MHmm OW in decile 1 combination is allowed CWHdm CW in decile 1 combination is allowed Updated to 10 LS because BCLCS_LEVEL_1 = 'N', BCLCS_LEVEL_5 = 'LA', Area <= 60 ha; CWHxm LS in decile 1 combination is allowed Updated to 10 BR because BCLCS_1/2/3/4 = V, N, U, SL/ST; CWHdm BR in decile 1 combination is allowed Updated to 10 BR because BCLCS_1/2/3/4 = V, N, U, SL/ST; CWHdm BR in decile 1 combination is allowed Updated to 10 LS because BCLCS_LEVEL_1 = 'N', BCLCS_LEVEL_5 = 'LA', Area <= 60 ha; CWHdm LS in decile 1 combination is allowed CWHvm FR in decile 1 combination is allowed Updated to 10 BR because BCLCS_1/2/3/4 = V, N, U, SL/ST; CWHdm BR in decile 1 combination is allowed Updated to 10 BR because BCLCS_1/2/3/4 = V, N, U, SL/ST; CWHvm BR in decile 1 combination is allowed CWHdm WL in decile 1 combination is allowed Updated to 10 WL because BCLCS_LEVEL_1/2/3 = 'V'/'N'/'W' and AGE_CL_STS = -1; CWHdm WL in decile 1 combination is allowed CWHdm LL in decile 1 combination is allowed; Updated SITE_M3A from '' to 'a' because polygon is adjacent to river

Broad Ecosystem Unit Updates	
Combine duplicate BEUs in same polygon	Where BEUMC_S1 = BEUMC_S2, combine into one decile Remove forest duplicate labels (in BEM may have had two of the same forested unit; one associated with one set of site conditions and the other representing different conditions). Site modifiers are NOT updated in this product. Therefore, duplicate forested unit labels were removed where BEUMC_S1 = BEUMC_S2.
Open Water	Where BCLCS_LEVEL_1 = 'N' AND BCLCS_LEVEL_5 = 'LA' AND Area_Ha <=10, assign SDEC_1 = 10 and BEUMC_S1 = 'OW' - shallow open water typically associated with floating vegetation - For Living in the Winter (LIW) for moose, LS is rated 0.05, and OW is rated 0.25 because of its common association with a shrub fringe
Small Lake	Where BCLCS_LEVEL_1 = 'N' AND BCLCS_LEVEL_5 = 'LA' AND Area_Ha >10 ha AND Area_Ha <=60, assign SDEC_1 = 10 and BEUMC_S1 = LS - LA (>10 ha and < or equal to 60 ha) = LS - small lake
Large Lake	Where BCLCS_LEVEL_1 = 'N' AND BCLCS_LEVEL_5 = 'LA' AND Area_Ha >60 ha, assign SDEC_1 = 10 and BEUMC_S1 = 'LL' - LA (>60 ha) = BEM code LL (large lake)
Reservoir	Where BCLCS_LEVEL_1 = 'N' AND BCLCS_LEVEL_5 = 'RE', assign SDEC_1 = 10 and BEUMC_S1 = 'RE'
River	Where BCLCS_LEVEL_1 = 'N' AND (BCLCS_LEVEL_5 = 'RI' OR BCLCS_LEVEL_5 = 'RS'), assign SDEC_1 = 10 and BEUMC_S1 = 'RI' There are two VRI codes (labels) that apply to rivers; river and river sediments: - RI = River - RS = River Sediments Previously, the default applied was to assign 'FS' (Fast Perennial Stream) or 'SP' (Slow Perennial Stream) to BEUMC_S1 where rivers were identified by this query.
Black Spruce Bog	Where SPECIES_CD_1 = 'SB' AND SPECIES_PCT_1 >= 90, assign SDEC_1 = 10 and BEUMC_S1 = 'SB' Query of other wetland forage identified assigned "WL" a generic BEM and PEM wetland code.
Wetland	where BCLCS_LEVEL_4 = 'ST' OR BCLCS_LEVEL_4 = 'SL' OR BCLCS_LEVEL_4 = 'HE' OR BCLCS_LEVEL_4 = 'HF' OR BCLCS_LEVEL_4 = 'HG' o 3b for ST, 3a for SL, 2b for HE
	Where BCLCS_LEVEL_1 = 'V' AND BCLCS_LEVEL_2 ='N' AND BCLCS_LEVEL_3 = 'W' AND AGE_CL_STS =-1, assign SDEC_1 = 10 and BEUMC_S1 = 'WL' Other BEM wetland codes that could be applied following photo or field confirmation include: BG = Sphagnum bog; FE = Sedge fen; SC = Shrub-carr; SW = shrub swamp; ME = meadow; MR = marsh; MS = montane shrub/grassland; SH = Shrub fen; SK = spruce-swamp
Note:	Many of the wetland sites are assigned an age and tree species in the VRI, but the VRI land classification indicates wetland. The age and tree information often refers to tree patches or peripheries of tree.
Forested – NOT Wetland	Where (BCLCS_LEVEL_4 = 'TB' OR BCLCS_LEVEL_4 = 'TC' OR BCLCS_LEVEL_4 = 'TM') AND BEUMC_S1 = WL Records matching this query should not contain a wetland (WL) label component. Remove WL decile component and update values in SDEC_1, SDEC_2 and SDEC_3.
Cultivated Field	Identify Cultivated Field (CF) labels for BEM via VRI. Cultivated field (CF) is a label assigned to many areas that may actually be forested broadleaf/hardwood. Query = Tree species 1 % >98% and BCLCS level 4 – TB (treed-broadleaf). If VRI indicates a leading tree species and projected age, the site is kept as a forested site. (BEUMC_S1 ='CF' AND VRI_AGE_CL_STS >-1) OR (BEUMC_S2 ='CF' AND VRI_AGE_CL_STS >-1) VRI_AGE_CL_STS = -1 AND (LINE_5_VEGETATION_COVER ='C' OR LINE_5_VEGETATION_COVER = 'OR') BEUMC_S2 ='CF' AND BCLCS_LEVEL_2 ='T' AND VRI_AGE_CL_STS >=2 BEUMC_S2 ='CF' AND BCLCS_LEVEL_2 ='N' AND VRI_AGE_CL_STS >=2
Transportation Corridor	Roads in VRI Veg 'rz' component (leading factor is road in the below cases) For polygons that are indicated as "NOT Treed" (N), the following cases had their BEM labels updated to "TC" (transportation corridor). A number of these sites were identified as Static Upland shrub forage potential. They will be removed from the effective habitat model when the road buffers/layer is applied.

	LINE_5_VEGETATION_COVER LIKE 'rz%' (this query selects all records where the value begins with 'rz') Where the above applies and VRI BCLCS_LEVEL_2 = 'T' (Treed), a second decile of 20% 'TC' has been added to the BEM label. Several images were checked to gauge the level of road disturbance within these polygons and ranged from 10-30%.

Anthropogenic and Non-vegetated	The VRI land classification was queried to identify anthropogenic and non-vegetated units, specifically where BCLCS_Level_5 =
	- AP (airport)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = UR
	- BU (burned area)
	  o Assign DISTCLS_1 = 'F'
	- CL (cliff) (could ID with DEM slopes >160%; check TEM definition)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = CL
	- GB (gravel bar)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = GB
	- GL (glacier) or PN (snow cover)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = GL
	- GP (gravel pit)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = GP
	- LL (landing)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = LL
	- MI (mine) or TZ (tailings) or MZ (rubbly mine spoils)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = MI
	- RO (rock) or BR (bedrock) or BI (block field)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = RO
	- TA (talus)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = TA
	- TC (transportation corridor) or RN (rail) or RZ (roads)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = TC
	- TR (transmission corridor)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = TR
	- UV (un-vegetated) to apply to VRI codes indicating exposed soil and other cleared features; RS (river sediment), MU (mudflat), ES (exposed soil), CB (cutbank), MN (moraine), RM (reservoir margin)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = UV
	- UR (urban)
	  o Assign SDEC_1 = 10 and BEUMC_S1 = UR
	
	Also, where SLOPE_MOD = 'q' or 'z', assign SDEC_1 = 10 and BEUMC_S1 = 'CL' (cliff)
	
	In this model, in the VRI queries for static forage, urban areas are considered to provide no winter forage values. However, numerous urban areas are not indicated as such in the VRI data. The level of confidence in the label "UR" based on VRI alone is considered Low to Moderate. Urban development and associated activities such as farming and cultivated fields are not the focus of VRI updates and are therefore not as reliable as other VRI data. The only way to obtain a high confidence in identification of disturbed areas is via air photo interpretation and field verification.

Active Floodplain	"a" = Active floodplain modifier populated in the site modifier field of decile 3, SITE_M3A. This value is assigned to VRI polygons that were adjacent to large river polygon features in the Fresh Water Atlas Rivers polygon layer (guaranteed to have a large floodplain component). Fresh Water Atlas Stream linear features are not used.

Other corrections applied and QA conducted

Water Features	**Large Lakes "LL", Small Lakes "LS" (BEM):** Large Lakes as over 60 hectares, Small Lakes as 10-60 hectares; Open Water "OW" (<10 ha) maintained because of high association with adjacent shrub forage – static forage BCLCS_LEVEL_5 = 'LA' (this is another query that can be applied but does not distinguish between size; use area calculation to determine rules for size) BCLCS_LEVEL_1 = 'N' AND BCLCS_LEVEL_5 = 'LA' AND Area_Ha >60 ha BEU_MC = LL
Deciduous	On completion of Script 4 conduct QA to assign sites identified as persistent deciduous with Stand Composition "B". If VRI indicates other sites as "TB" then assign "B" and if "TM" then assign "M" for stand composition. where BCLCS_LEVEL_4 = 'TB' change Stand_A1 to "B"; OR BCLCS_LEVEL_4 = 'TC' OR BCLCS_LEVEL_4 = 'TM') change Stand_A1 to "M"

	Expectations: AC = Trembling Aspen Copse in the SBPS and SBS BA = Sub-boreal White Spruce - Trembling Aspen SB = Spruce - paper birch (for mixed sites with spruce and Ep in the SBS) TB = Trembling aspen – Balsam Poplar (At/Ac) for deciduous sites in the SWB **Riparian forests** (occur on floodplains and riparian areas): ER (in the ESSF) (Engelmann Spruce Riparian; typically a dense coniferous forest with shrub and forb understories) PR (BWBS and SWB) (White Spruce - Balsam Poplar Riparian; typically a dense deciduous, mixed or coniferous forest with thick shrub understories found on or in association with fluvial sites) WR (SBS and SBPS) (Hybrid White Spruce - Black Cottonwood Riparian; typically a dense deciduous, mixed or coniferous forest with shrub-dominated understories, found on or in association with fluvial sites) SW is the unit for shrub-swamp. This code can be applied along slow meandering streams with wide swamp areas with sparse trees, dense shrubs, willows – often associated with riparian areas.
STS / STD	Check for cases of structural stage and stand composition mis-matches that will result in fewer "B" or "M" assignments. AGE_CL_STS and AGE_CL_STD (i.e., "2" and "-1") Match VRI STS and STD for young sites. Select by attribute: AGE_CL_STS = 3 (represents 0-3 years) Where these cases were assigned "15" for stand age = should default to "-1" AGE_CL_STS = 7 (mid-range 5 to 10 years) Where these cases were assigned "15" for stand age = should default to "-1" AGE_CL_STS = 20 (11 to 30 years) Where these cases were assigned "15" for stand age = should default to "30" to receive a stand comp of B or M. Majority are likely already assigned "30"
STD	Stand composition (Broadleaf/Mixed/Coniferous) values were re-assigned once the BEM labels were updated. QA of the stand composition via use of VRI - default to "B" if VRI is "TB", default to mixed stand composition if VRI indicates it is a mixed stand. This step will help to identify where the same broad forest types can vary in how much of the broadleaf is present.
Tree Species	The number of pure polygons could be increased further through a series of rules for splitting out and assigning one forest type (most likely broad ecosystem unit) where there are presently two broad ecosystem forest types assigned (as a carryover from the BEM). The VRI leading tree species would be the best option for this approach, but requires further thought and an assessment of the value gained through conducting that step.
LUT	A number of new BEM codes were added to the look-up table that resulted from the BEM label update (i.e., the labels were not applied at the 1:250,000 product scale; such as Open Water, specific wetland types, etc.). This step was necessary in order to ensure that all possible combinations were contained in the BEM Lookup Table for running the wildlife habitat ratings model (the moose winter range model developed for the BEM product).

Step 2g: Update Wetland and Riparian Attributes in BEMVRI	
Script Name:	02g_update_wetland_riparian.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 2f) 2) BC Fresh Water Atlas Wetlands polygon feature class
Description: This script will overlay the BEMVRI feature class with the BC Fresh Water Atlas Wetlands polygon feature class. The script will calculate the proportion of each BEMVRI polygon that is overlapping with wetland polygons. It will then recalculate the BEM decile and mapcode values so that the wetland mapcode is appropriately represented. For example, if a BEMVRI polygon currently has two non-wetland BEU components, one with decile value 6 and mapcode CD, and the other with decile value 4 and mapcode CW, but it finds that a wetland overlaps 41% of the polygon, then the polygon attributes will be modified to have three components: 4 CD, 4 WL and 2 CW. See the following section, **Wetland overlap attribute allocation**. The script will not modify a polygon that overlaps a wetland if: • The POLY_COMM field contains any non-null value, indicating that the current BEU mapcodes were assigned by an ecologist/biologist in Step 1e; • the value in BCLCS_LEVEL_4 is "TB", "TC" or "TM" indicating a treed area; • the overlap with wetland is less than 8%; or	

- the first component has the BEU mapcode BA, BB, BG, CB, CR, ER, FE, LL, LS, MR, OW, PB, PR, RI, RR, RS, SH, SK, SR, SW, TF, WG, WR, YB, or YS, indicating that 50% or more of the polygon is water. (See the following section, **Mapcodes that Capture Water Features**.)

The script will create and populate a field named Wetland_Update_Comment with a description of what was modified. A sample of results is seen in the image below:

Wetland_Update_Comment
No wetland. Current BEU: 10 BR (10000); No update needed
80% of polygon occupied by wetland. Current BEU: 10 WL (10001); No update needed
8% of polygon occupied by wetland. Current BEU: 10 BR (10000); Updated BEU: 9 BR, 1 WL (9102)
No wetland. Current BEU: 10 FR (10000); No update needed
No wetland. Current BEU: 10 BR (10000); No update needed
40% of polygon occupied by wetland. Current BEU: 10 BR (10000); Updated BEU: 6 BR, 4 WL (6402)
70% of polygon occupied by wetland. Current BEU: 10 BR (10000); Updated BEU: 7 WL, 3 BR (7301)
No wetland. Current BEU: 10 LS (10000); No update needed
100% of polygon occupied by wetland. Current BEU: 10 BR (10000); Updated BEU: 10 WL (10001)
No wetland. Current BEU: 10 BR (10000); No update needed
No wetland. Current BEU: 10 MF (10000); No update needed
No wetland. Current BEU: 10 CW (10000); No update needed

The script will also check if each polygon has been assigned the value "a" in the SITE_M3A field, which was applied in Step 2f, indicating that the polygon is adjacent to a river and is thus considered to be in a riparian area. If so, and the value in MEAN_SLOPE is less than 10%, and the first BEU component mapcode is currently a non-vegetated unit, then the script updates the attributes to assign a first and only component with a decile value of 10 and a BEU mapcode according to the BEC zone as follows:

- For zone BWBS, the mapcode is PR;
- in zone CDF, the mapcode is CR;
- in zone CWH, the mapcode is SR;
- in zone ESSF, the mapcode is ER;
- in zone ICH, the mapcode is RR;
- in zones SBPS and SBS, the mapcode is WR;
- in zone SWB, the mapcode is PR.
- In other BEC zones, the mapcodes will remain unchanged.

Mapcodes that Capture Wetland, Riparian and Water Features

BB	black spruce bog	**WR**	hybrid white spruce black cottonwood riparian
CB	cedars shore pine bog	**YB**	yellow cedar bog forest
CR	black cottonwood riparian habitat class	**YS**	yellow cedar skunk cabbage swamp forest
ER	Engelmann spruce riparian	**BG**	sphagnum bog
PB	lodgepole/shore pine bog	**FE**	sedge fen
PR	white spruce balsam popular riparian	**MR**	Marsh
RR	western red cedar black cottonwood riparian	**OW**	Shallow open water
RS	western red cedar swamp	**SH**	shrub fen
SK	spruce swamp	**SW**	shrub swamp
SR	Sitka spruce black cottonwood riparian	**WL**	Wetland
TF	tamarack wetland	**LS**	small Lake
WG	hybrid white spruce bog forest	**LL**	large Lake

Wetland overlap attribute allocation

Percent overlap by FWA Wetlands	**WL% 0-7**	**WL% 8-14**	**WL% 15-24**	**WL% 25-34**	**WL% 35-44**	**WL% 45-54**	**WL% 55-64**	**WL% 65-74**	**WL% 75-79**	**WL% 80-100**
Decile Value of Wetland Component added to BEMVRI polygon	None	1	2	3	4	5	6	7	8	10

Step 2h: Improve Forested BEUs in BEMVRI	
Script Name:	02h_improve_forested_beu.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher Python module “openpyxl”
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 2g) 2) Rules for Improved Forested BEUs Excel file

Description: This script will read a table of rules for replacing BEU mapcodes based on VRI and other attributes. An excerpt of the Excel table is shown in the image below.

	I	J	K	L	M	N	O	P	Q	R	U	V	W	X
1	INPUTS	BGC_ZONE	BGC_SUBZON	BGC_VRT	TREE_RL_SP_CD_1	TREE_RL_SP_PCT_1	TREE_RL_SP_CD_2	TREE_RL_SP_PCT_2	TREE_RL_SP_CD_3	TREE_RL_SP_PCT_3	SOIL_MOISTURE_REGIME_1	SLOPE_MOD	OUTPUTS	BEUMC
23		CWH			PLC,PL	25-100	CW,YC,C	25-75						CB
24		CWH			CW,C	25-100					5,6,7,8	BLANK		RS
25		CWH			CW,C	50-100								CH
26		CWH			EP,EXP,EA	20-100								HB
27		CWH			FD,FDC,F	25-80	PLC, PL	10-100						CP
28		CWH			FD,FDC,F	60-100								CD
29		ESSF			SE	30-100	BL, BA, B	5-100	ACT,ACB,AC	5-100				ER
30		ESSF			SB	90-100								BB
31		ESSF	DOES NOT CONTAIN p		PA	5-100								WB
32		ESSF			PL, PLI, PLC	60-100								LP
33		ESSF	mv	3	SW, SX, SE, S, SWX	25-100	BL, B, BA	0.1-100						SF
34		ESSF	DOES NOT CONTAIN p		BL, B, BA	5-95	HM, HW, H	5-100						EW
35		ESSF	DOES NOT CONTAIN p		BL, B, BA	0.1-100	SW, SXW, SX, SE, S	0.1-100						EF
36		ESSF	CONTAINS p		PA	25-100								WB

The table consists of rules, one rule per row. Each value to the right of the INPUTS columns is a value for which a “match” is sought. The first row can be translated to the logical statement: If BGC_ZONE is CWH and the total percentage of PLC and PL is 25 to 100 and the total percentage of CW, YC and C is 25 to 75, then assign BEU mapcode CB. The rules listed in this table were developed by ecologists, and the table can be changed in the future. A full list of rules is found in the section **Table of BEU forest assignment rule updates applied in BEMVRI version 6 (October 2025)**.

The script reads in the Excel file, and then checks every polygon to see if it matches any of the rules. For the first rule that a polygon matches, it modifies its BEU components to be decile value 10 and the BEU mapcode as the rule dictates. The other two components, if they existed, are dropped.

The script will report how many matches occurred in the BEMVRI feature class for each row of the rules table. This can be used for further development of the rules table.

If a polygon’s POLY_COMM field contains a non-null value, indicating that an ecologist/biologist has assigned the current BEU mapcodes to this polygon in Step 1e, then the corrections indicated by these rules will not be applied.

Table of BEU forest assignment rule updates applied in BEMVRI version 6 (October 2025)

BGC Zone	BGC Subzone	Tree Species/Percent Cover	Slope Modifier	Assigned BEU Mapcode
BAFA		BL 95-100		BK
BAFA		PA 10-100		WB
BAFA		SE,SX,SXE 5-100 BL,B 5-100		FP
BAFA		BL 5-95.9		WP
BWBS		ACT,ACB,AC,AX,E,EP 20-100		PR
BWBS		AT 25-100		BA
BWBS		LT,L 10-100	BLANK	TF
BWBS		BL 40-100		FB
BWBS		SB 95-100		BB
BWBS		P,PL,PLI,PLC 50-100		LP
BWBS		SW 45-100	BLANK,j	PR
BWBS		SX,SXW 40-100	BLANK,j	WG
BWBS		SX,SXW 5-39.9 B 5-94.9		WG
BWBS		SB 5-94.9 PL,PLI,PL C5-49.9		BL
BWBS		SB 5-94.9		BL
BWBS		SW,SXW,SX,SE,S 30-100	BLANK	SK
BWBS		SW,SXW,S30-100PL,PLI,PLC 1-49.9		BP
BWBS		SW,SXW,S 30-100		BP
ESSF		ACT,ACB,AC,E,EP 10-100		ER
ESSF		W,WD 20-100		ER
ESSF		SW,SWX 20-100 ACT,ACB,AC,E,EP 1-9.999	BLANK,j	ER
ESSF		SB 95-100		BB
ESSF		AT 25-100		SA
ESSF	CONTAINS p	PA 10-100		WB
ESSF		PA 5-100		WB
ESSF		P,PL,PLI,PLC 50-100		LP
ESSF		SW,SWX2 5-100		SF
ESSF	CONTAINS p	BL 100		BK
ESSF		B,BL 60-100		EW
ESSF		SX,SE 50-100	BLANK,j	EW
ESSF		SX,SE 90-100		EF
ESSF		B,BL 5-100 SX,SXE,SXL,SE,S,SXS 1-95		EF
ESSF	CONTAINS p	B,BL 20-100		FP
SBS		ACT,ACB,AC,AX 10-100		WR
SBS		AT 25-100		SA
SBS		SB 95-100		BB
SBS		EP,E 15-100		SB
SBS		P,PL,PLI,PLC 50-100		LP
SBS		SW 45-100	BLANK,j	WR
SBS		SX,SXW 40-100	BLANK,j	WG
SBS		FD,FDI 30-100		DF
SBS		FD,FDI 5-100 PL,PLI,PLC 5-59.9		DL
SBS		FD,FDI 5-60 SW,SXW,SX,SE,S 20-60		SD
SBS		SW,SXW,SX,SE,S 45.9-100	BLANK	SK
SBS		SW,SXW,S 5-100 BL,B 5-100		SF
SBS		SXW,SX,S 20-100 PL,PLI,PLC 1-49.9		SL

SBS		SXW,SX,S 30-100		SL
SBS		SB 5-94.9 PL,PLI,PLC 5-59.9		BL
SBS		SB 5-94.99		BL
SWB		ACT,ACB,AC,AX,E,EP 20-100		PR
SWB		SW 45-100	BLANK,j	PR
SWB		SB 95-100		BB
SWB		AT 40-100		TB
SWB		P,PL,PLI,PLC 50-100		LP
SWB		AT 25-100		SA
SWB	mks	BL 20-100		BK
SWB		BL 40-100	BLANK,j	FB
SWB		SB 5-94.9PL,PLI,PLC 5-59.9		BL
SWB		SB 5-94.99		BL
SWB		SX,SXW 30-100	BLANK,j	WG

Step 2i: QA the Improved Forested BEUs	
Script Name:	None
Requirements:	ArcGIS Pro 3.x
Inputs (Arguments):	BEMVRI feature class (the output of Step 2h)

Description: Open the attribute table of the BEMVRI feature class in ArcGIS Pro. The improved forested mapcodes that were applied in Step 2h were written to a new field named BEUMC, and a description of the matching rule has been written to a new field named BEUMC_Comments. Allow the developer of the rules table to review the contents of these fields to ensure that the rules were applied as they had intended.

BEUMC	BEUMC_Comment
	No match: BGC_ZONE CDF, BGC_SUBZON mm, BGC_VRT null, Species DR 60.0%, FD 30.0%, CW 10.0%, SOIL_MOISTURE_REGIME_1
	No match: BGC_ZONE CWH, BGC_SUBZON dm, BGC_VRT null, No species, SOIL_MOISTURE_REGIME_1 blank, SLOPE_MOD w
CW	Matched with rule on row 14 of Excel table: BGC_ZONE CWH, BGC_SUBZON xm, BGC_VRT 1, Species DR 65.0%, CW 20.0%, FD 10.0
	No match: BGC_ZONE CDF, BGC_SUBZON mm, BGC_VRT null, No species, SOIL_MOISTURE_REGIME_1 blank, SLOPE_MOD blank
CW	Matched with rule on row 14 of Excel table: BGC_ZONE CWH, BGC_SUBZON xm, BGC_VRT 1, Species DR 80.0%, H 20.0%, SOIL_MOI
CW	Matched with rule on row 14 of Excel table: BGC_ZONE CWH, BGC_SUBZON xm, BGC_VRT 1, Species DR 80.0%, H 20.0%, SOIL_MOI
CP	Matched with rule on row 27 of Excel table: BGC_ZONE CWH, BGC_SUBZON xm, BGC_VRT 1, Species FD 60.0%, PL 30.0%, H 10.0%,
	No match: BGC_ZONE CWH, BGC_SUBZON vm, BGC_VRT 2, Species FD 50.0%, HW 30.0%, CW 20.0%, SOIL_MOISTURE_REGIME_1 b
CD	Matched with rule on row 28 of Excel table: BGC_ZONE CWH, BGC_SUBZON xm, BGC_VRT 1, Species FD 70.0%, CW 20.0%, HW 10.
	No match: BGC_ZONE CWH, BGC_SUBZON xm, BGC_VRT 1, Species H 50.0%, FD 30.0%, CW 20.0%, SOIL_MOISTURE_REGIME_1 bla
CD	Matched with rule on row 12 of Excel table: BGC_ZONE CDF, BGC_SUBZON mm, BGC_VRT null, Species FD 100.0%, SOIL_MOISTURE
FR	Matched with rule on row 17 of Excel table: BGC_ZONE CWH, BGC_SUBZON vm, BGC_VRT 2, Species H 50.0%, BA 30.0%, CW 10.0
CD	Matched with rule on row 28 of Excel table: BGC_ZONE CWH, BGC_SUBZON dm, BGC_VRT null, Species FD 70.0%, DR 30.0%, SOIL_
CD	Matched with rule on row 12 of Excel table: BGC_ZONE CDF, BGC_SUBZON mm, BGC_VRT null, Species FD 60.0%, DR 20.0%, MB 10.
CW	Matched with rule on row 14 of Excel table: BGC_ZONE CWH, BGC_SUBZON dm, BGC_VRT null, Species DR 90.0%, FD 10.0%, SOIL_

Step 2j: Apply the Improved Forested BEUs to BEMVRI	
Script Name:	02j_copy_improved_beu.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher
Inputs (Arguments):	BEMVRI feature class (the output of Step 2h)

Description: This script should be run after the correct application of the Improved Forested BEU rules has been verified in Step 2i. For each polygon that has had a value written to the BEUMC field in Step 2h, this script will overwrite the value in the BEUMC_S1 field with the value in the BEUMC field, set the SDEC_1 field to 10, and remove the other two BEU components if they existed.

Step 3: Develop the Structural Stage Lookup Table

Step 3a: Update the Master Structural Stage Look-up Table	
Script Name:	03a_update_master_sts_lut.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher Python module "openpyxl"
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 2h) 2) BEMVRI Metadata Excel file 3) Master Structural Stage Look-up Table Excel file

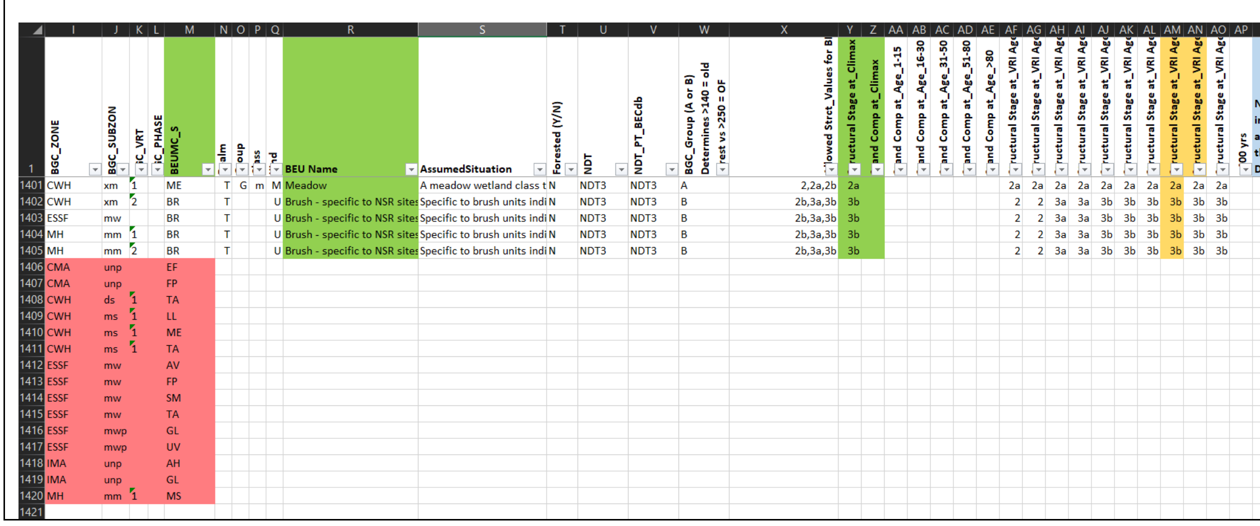
Description: The Master Structural Stage Look-up Table (LUT) contains all of the BEC and BEU mapcode combinations that have been encountered in previous BEMVRI projects. This script will read in the BEC and BEU mapcode combinations from the current BEMVRI feature class and add any missing combinations to the Master LUT.

The BEMVRI Metadata Excel file contains a worksheet named "STS_LUT_Fields", which must contain the following columns as shown in the image below:

Field_Name	Value_Source	Interpretation
FREQ	TEM:Freq	
BGC_ZONE	TEM:BGC_ZONE:Zone	
BGC_SUBZON	TEM:BGC_SUBZON:Subzone	
BGC_VRT	TEM:BGC_VRT:Variant	
BGC_PHASE	TEM:BGC_PHASE:Phase	
BGC_Label	TEM:Concatenate:BGC_ZONE,BGC_SUBZON,BGC_VRT,BGC_PHASE	
BEUMC_S	TEM:BEUMC_S#:Mapcode	
BEU Name		
Realm		TEM:REALM_#:Existing
Group		TEM:GROUP_#:Existing
Class		TEM:CLASS_#:Existing
Kind		TEM:KIND_#:Existing
Forested (Y/N)		TEM:FORESTED_#:Add:TEXT_1
Allowed Strct_Values for BEM3.0		STS_Range
Structural Stage at_Climax Conditions		STS_Climax
Stand Comp at_Climax		SComp_Climax
Stand Comp at_Age_1-15		Age:STD:15
Stand Comp at_Age_16-30		Age:STD:30
Stand Comp at_Age_31-50		Age:STD:50
Stand Comp at_Age_51-80		Age:STD:80
Stand Comp at_Age_>80		Age:STD:9999
Structural Stage at_VRI Age_0-3		Age:STS:3
Structural Stage at_VRI Age_4-10		Age:STS:10
Structural Stage at_VRI Age_11-30		Age:STS:30
Structural Stage at_VRI Age_31-40		Age:STS:40
Structural Stage at_VRI Age_41-60		Age:STS:60
Structural Stage at_VRI Age_61-80		Age:STS:80
Structural Stage at_VRI Age_81-139		Age:STS:139
Structural Stage at_VRI Age_140-179		Age:STS:179
Structural Stage at_VRI Age_180-249		Age:STS:249
Structural Stage at_VRI Age_250+		Age:STS:9999

These fields listed in column A must be present as headers in row 1 of the Master LUT. The data in columns B and C provide guides to this script and subsequent scripts as to what data appears in these columns of the Master LUT.

This script will read all of the BEC and BEU combos from the BEMVRI feature class. It will then add any combinations that are not already listed in the Master LUT to the bottom of the LUT, and then save the Excel file. The newly added rows will have a red colour fill, as seen in the image below.



Step 3b: Fill In the Master Structural Stage Look-up Table	
Script Name:	None
Requirements:	Microsoft Excel
Inputs (Arguments):	Master Structural Stage Look-up Table Excel file (the output of Step 3a)

Description: An ecologist must update the Master LUT with information about the newly added BEC/BEU combinations. This table contains Structural Stage and Stand Composition codes through the age classes for all BEUs. The table after adding the information to the new rows would look like the image below.

	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
1	BGC_ZONE	BGC_SUBZON	iC_VRT	iC_PHASE	BEUMC_S	alm	oup	ass	nd	BEU Name	AssumedSituation	Forested (Y/N)	NDT	NDT_PT_BECdb	BGC_Group (A or B) Determines >140 = old rest vs >250 = OF	lowed Strct_Values for B	ructural Stage at_Climax	and Comp at_Climax	and Comp at_Age_1-15	and Comp at_Age_16-30	and Comp at_Age_31-50	and Comp at_Age_51-80	and Comp at_Age_>80	ructural Stage at_VRI Age	ructural Stage at_VRI Age	ructural Stage at_VRI Age	ructural Stage at_VRI Age	ructural Stage at_VRI Age	ructural Stage at_VRI Age	ructural Stage at_VRI Age	ructural Stage at_VRI Age	ructural Stage at_VRI Age	ructural Stage at_VRI Age	00 yrs
1401	CWH	xm	1		ME	T	G	m	M	Meadow	A meadow wetland class t	N	NDT3	NDT3	A	2,2a,2b	2a							2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	
1402	CWH	xm	2		BR	T			U	Brush - specific to NSR sites	Specific to brush units indi	N	NDT3	NDT3	B	2b,3a,3b	3b							2	2	3a	3a	3b	3b	3b	3b	3b	3b	
1403	ESSF	mw			BR	T			U	Brush - specific to NSR sites	Specific to brush units indi	N	NDT3	NDT3	B	2b,3a,3b	3b							2	2	3a	3a	3b	3b	3b	3b	3b	3b	
1404	MH	mm	1		BR	T			U	Brush - specific to NSR sites	Specific to brush units indi	N	NDT3	NDT3	B	2b,3a,3b	3b							2	2	3a	3a	3b	3b	3b	3b	3b	3b	
1405	MH	mm	2		BR	T			U	Brush - specific to NSR sites	Specific to brush units indi	N	NDT3	NDT3	B	2b,3a,3b	3b							2	2	3a	3a	3b	3b	3b	3b	3b	3b	
1406	CMA	unp			EF	T	T		M	Engelmann Spruce - Subalpi	BEI describes this unit as t	Y	NDT2	NDT2	B	2,3a,3b,4,5,6,7	7	C			C	C	C	2	3a	3a	3b	4	5	6	6	7	7	7
1407	CMA	unp			FP	T	T		M	Engelmann Spruce - Subalpi	Typically a high elevation	Y	NDT5	NDT5	B	2,3a,3b,4,5,6,7	7	C			C	C	C	2	2	3a	3b	4	5	6	7	7	7	7
1408	CWH	ds	1		TA	T	R	t	N	Talus	Typically sparsely vegetat	N	NDT2	NDT2	B	1	1							1	1	1	1	1	1	1	1	1	1	
1409	CWH	ms	1		LL	O			N	Large Lake	Large lakes over 60 hectar	N	NDT2	NDT2	B	not applicable																		
1410	CWH	ms	1		ME	T	G	m	M	Meadow	A meadow wetland class t	N	NDT3	NDT3	A	2,2a,2b	2a							2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	
1411	CWH	ms	1		TA	T	R	t	N	Talus	Typically sparsely vegetat	N	NDT2	NDT2	B	1	1							1	1	1	1	1	1	1	1	1	1	
1412	ESSF	mw			AV	T	V	s	M	Avalanche Track	BEI describes this unit as t	N	NDT1	NDT1	B	2,3a,3b	3b							2b	3a	3a	3a	3b	3b	3b	3b	3b	3b	
1413	ESSF	mw			FP	T	T		M	Engelmann Spruce - Subalpi	Typically a high elevation	Y	NDT5	NDT5	B	2,3a,3b,4,5,6,7	7	C			C	C	C	2	2	3a	3b	4	5	6	7	7	7	7
1414	ESSF	mw			SM	T	A	m	M	Subalpine Meadow	BEI desribes this unit as ty	N	NDT2	NDT2		2,2a,2b	2a							2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	
1415	ESSF	mw			TA	T	R	t	N	Talus	Typically sparsely vegetat	N	NDT2	NDT2	B	1	1							1	1	1	1	1	1	1	1	1	1	
1416	ESSF	mwp			GL	T			N	Glacier	A mass of perennial snow	N	NDT2	NDT2	B	not applicable																		
1417	ESSF	mwp			UV	T			U	Unvegetated	BEI describes this unit as t	N	NDT2	NDT2	B	1	1							1	1	1	1	1	1	1	1	1	1	
1418	IMA	unp			AH	T	A	h	M	Alpine Heath	Typically a high elevation	N	NDT5	NDT5	B	2d	2d							2d	2d	2d	2d	2d	2d	2d	2d	2d	2d	
1419	IMA	unp			GL	T			N	Glacier	A mass of perennial snow	N	NDT2	NDT2	B	not applicable																		
1420	MH	mm	1		MS	T	G	b	M	Montane Shrub/Grassland	BEI describes this unit as t	N	NDT3	NDT3	A	2b,3a,3b	3b							2b	2b	3a	3b	3b	3b	3b	3b	3b	3b	

Step 3c: Create or Update a Project-Specific Look-up Table for Current BEMVRI	
Script Name:	03c_create_or_update_project_sts_lut
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher Python module "openpyxl"
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 2g) 2) BEMVRI Metadata Excel file 3) Existing project-specific LUT Excel file (optional) 4) Master LUT Excel file (optional)

Description: This script creates or updates a stripped-down version of the Master LUT that was updated in Steps 3a and 3b. This project-specific LUT will contain only the BEC/BEU combinations that exist in the current BEMVRI, and only the fields needed to update the BEMVRI attributes listed in the Metadata Excel file.

First the script reads the BEMVRI Metadata Excel file, in particular the Age_Class_Bins worksheet (described in Step 1k and the "STS_LUT_Fields" worksheet (described in Step 3a). Using the information found here, and after reading the contents of the BEMVRI attribute table, the script will either create a new project-specific LUT Excel file, or append new rows as needed to an existing project-specific LUT Excel file. It will pull the structural stage, stand composition and other information from the Master LUT if one was specified.

The resulting project-specific LUT Excel file will look like the excerpt in the image below.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1	FREQ	BGC_ZONE	BGC_SUBZON	BGC_VRT	BGC_PHASE	BGC_Label	BEUMC_S	BEU Name	Realm	Group	Class	Kind	Forested (Y/N)	Allowed Strct_Values for BEM3.0	Structural Stage at_Climax Conditions	Stand Comp at_Climax	Stand Comp at_Age_1-15	Stand Comp at_Age_16-30	Stand Comp at_Age_31-50	Stand Comp at_Age_51-80	Stand Comp at_Age_>80	Structural Stage at_VRI Age_0-3	Structural Stage at_VRI Age_4-10	Structural Stage at_VRI Age_11-30	Structural Stage at_VRI Age_31-40	Structural Stage at_VRI Age_41-60	Structural Stage at_VRI Age_61-80	Structural Stage at_VRI Age_81-139	Structural Stage at_VRI Age_140-179	Structural Stage at_VRI Age_180-249	Structural Stage at_VRI Age_250+
2	69	CDF	mm			CDFmm	BR	Brush - specific to NSR sites and NCBR in VRI	T			U	N	2b,3a,3b	3b							2	2	3a	3a	3b	3b	3b	3b	3b	3b
3	1339	CDF	mm			CDFmm	CD	Coastal Douglas-fir	T	T		M	Y	2,3a,3b,3c,4,5,6,7a,7b	7b	C			C	C	C	2	3a	3b	3c	4	5	6	6	7a	7a
4	330	CDF	mm			CDFmm	CG	Coastal Western Redcedar - Grand Fir	T	T		M	Y	2,3a,3b,3c,4,5,6,7a,7b	7b	C			C	C	C	2	3a	3b	3c	4	5	6	6	7a	7a
5	4	CDF	mm			CDFmm	CR	Black Cottonwood Riparian	T	F	h	M	Y	2,3a,3b,3c,4,5,6,7a,7b	7b	M			M	M	M	2	3a	3b	3c	4	5	6	6	7a	7a
6	1	CDF	mm			CDFmm	GP	Gravel Pit	T	X	a	N	N	1, 1a	1							1	1	1	1	1	1	1	1	1	1
7	15	CDF	mm			CDFmm	LS	Small Lake	O			N	N	not applicable																	
8	4	CDF	mm			CDFmm	MI	Mine	T	X		U	N	not applicable																	
9	7	CDF	mm			CDFmm	OW	Shallow open water	O			N	N	not applicable																	
10	5	CDF	mm			CDFmm	PB	Lodgepole / Shore Pine Bog	W	P	b	O	Y	2,3a,3b,4,5,6,7	7	C			C	C	C	2	3a	3a	3b	4	5	6	6	6	7
11	54	CDF	mm			CDFmm	RO	Rock	T	R	o	N	N	1, 1a	1							1	1	1	1	1	1	1	1	1	1
12	19	CDF	mm			CDFmm	ST	Subtidal Marine	O			N	N	not applicable																	
13	101	CDF	mm			CDFmm	UR	Urban	T	X		U	N	not applicable																	
14	18	CDF	mm			CDFmm	UV	Unvegetated	T			U	N	1	1							1	1	1	1	1	1	1	1	1	1

Step 4: Update BEMVRI Attributes from LUT

Step 4a: Update the Realm, Group, Class and Kind BEMVRI Attributes	
Script Name:	04a_update_rgck_from_lut.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher Python module "openpyxl"
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 2g) 2) Project-specific LUT Excel file 3) BEMVRI Metadata Excel file

Description: This script requires the BEMVRI Metadata Excel file, particularly the "STS_LUT_Fields" worksheet (described in Step 3a) which defines the names of the Realm, Group, Class and Kind fields in both the BEMVRI attributes and in the Project-specific LUT Excel file. The latter contains a list of all BEC/BEU combinations and the values that belong in the Realm, Group, Class and Kind fields for each combination.

The script will read in both the Metadata and LUT Excel files, and then loop through each polygon in the BEMVRI feature class, and write the Realm, Group, Kind and Class attribute values for each BEU component of each polygon to the appropriate attribute fields.

Step 4b: Update the Structural Stage, Stand Composition and Forested BEMVRI Attributes	
Script Name:	04b_update_sts_from_lut.py
Requirements:	ArcGIS Pro 3.x with 64-bit Geoprocessing and Python 3 Basic License or higher Python module "openpyxl"
Inputs (Arguments):	1) BEMVRI feature class (the output of Step 4a) 2) The name of the BEMVRI attribute field containing Age Class for Structural Stage values 3) Project-specific LUT Excel file 4) BEMVRI Metadata Excel file

Description: This script requires the BEMVRI Metadata Excel file, particularly the "STS_LUT_Fields" worksheet (described in Step 3a) which defines the names of the Structural Stage, Stand Composition, Forested, Age Class for Structural Stage and Age Class for Stand Composition fields in both the BEMVRI attributes and in the Project-specific LUT Excel file. The latter contains a list of all BEC/BEU combinations and the values that belong in Structural Stage, Stand Composition and Forested fields for each combination and in each age class.

The script will read in both the Metadata and LUT Excel files, and then loop through each polygon in the BEMVRI feature class, and write the Structural Stage, Stand Composition, and Forested attribute values for each BEU component of each polygon to the appropriate attribute fields.

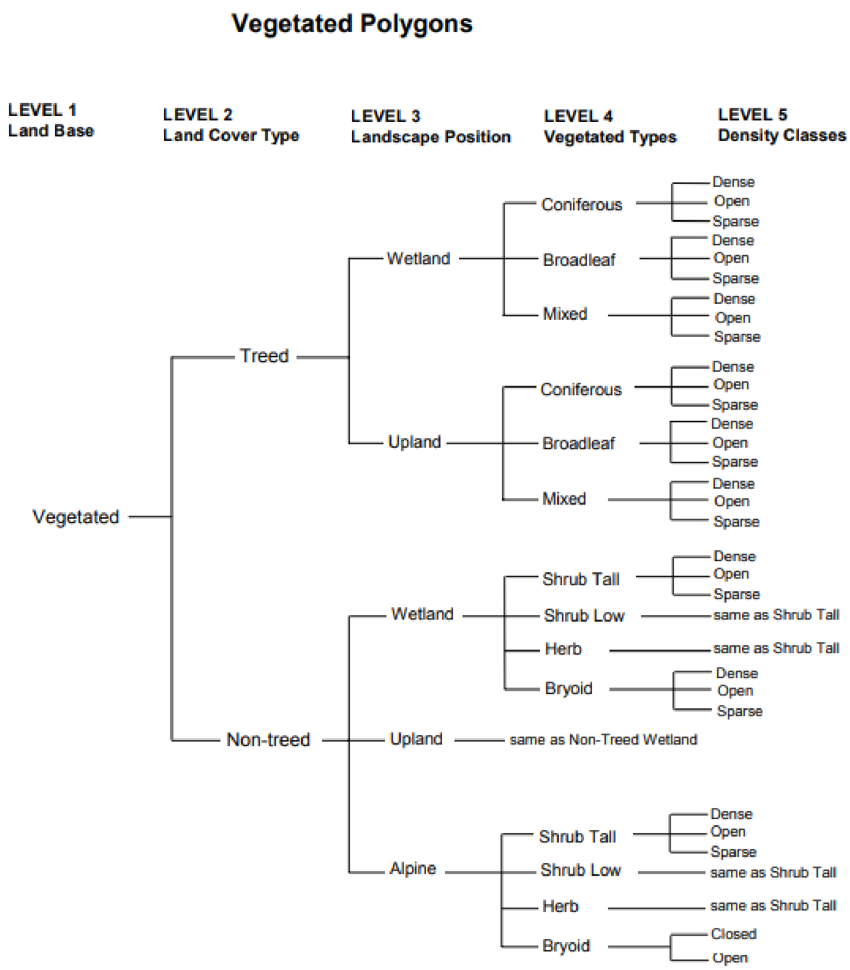
The script will create and populate a new field named STS_Comment with a description of what was modified. A sample of the results is seen in the image below:

STS_Comment
Eco Unit (MC) 1: CWHvm1 CW, For='Y' Age=179 STD_VRI='C' STRCT_S1 was '', now '6' (from LUT), STAND_A1 was '', now 'C' (from STD_VRI)
Eco Unit (MC) 1: CWHvm1 FR, For='Y' Age=9999 STD_VRI='C' STRCT_S1 was '', now '7a' (from LUT), STAND_A1 was '', now 'C' (from STD_VRI)
Eco Unit (MC) 1: CWHxm1 BR, For='N' Age=249 STD_VRI='C' STRCT_S1 was '', now '3b' (from LUT), STAND_A1 was '', now '' (from LUT)
Eco Unit (MC) 1: CWHvm1 CD, For='Y' Age=139 STD_VRI='C' STRCT_S1 was '', now '6' (from LUT), STAND_A1 was '', now 'C' (from STD_VRI)
Eco Unit (MC) 1: CWHvm1 FR, For='Y' Age=9999 STD_VRI='C' STRCT_S1 was '', now '7a' (from LUT), STAND_A1 was '', now 'C' (from STD_VRI)
Eco Unit (MC) 1: CWHvm2 CH, For='Y' Age=9999 STD_VRI='C' STRCT_S1 was '', now '7a' (from LUT), STAND_A1 was '', now 'C' (from STD_VRI)
Eco Unit (MC) 1: MHmm1 MF, For='Y' Age=9999 STD_VRI='C' STRCT_S1 was '', now '7a' (from LUT), STAND_A1 was '', now 'C' (from STD_VRI)
Eco Unit (MC) 1: CWHdm CD, For='Y' Age=249 STD_VRI='C' STRCT_S1 was '', now '7a' (from LUT), STAND_A1 was '', now 'C' (from STD_VRI)
Eco Unit (MC) 1: CWHvm1 BR, For='N' Age=-1 STD_VRI='' STRCT_S1 was '', and STAND_A1 was '', now both blank (no age)
Eco Unit (MC) 1: MHmm1 MF, For='Y' Age=-1 STD_VRI='' STRCT_S1 was '', and STAND_A1 was '', now both blank (no age)
Eco Unit (MC) 1: CWHvm2 BR, For='N' Age=-1 STD_VRI='' STRCT_S1 was '', and STAND_A1 was '', now both blank (no age)
Eco Unit (MC) 1: MHmm1 MF, For='Y' Age=9999 STD_VRI='C' STRCT_S1 was '', now '7a' (from LUT), STAND_A1 was '', now 'C' (from STD_VRI)

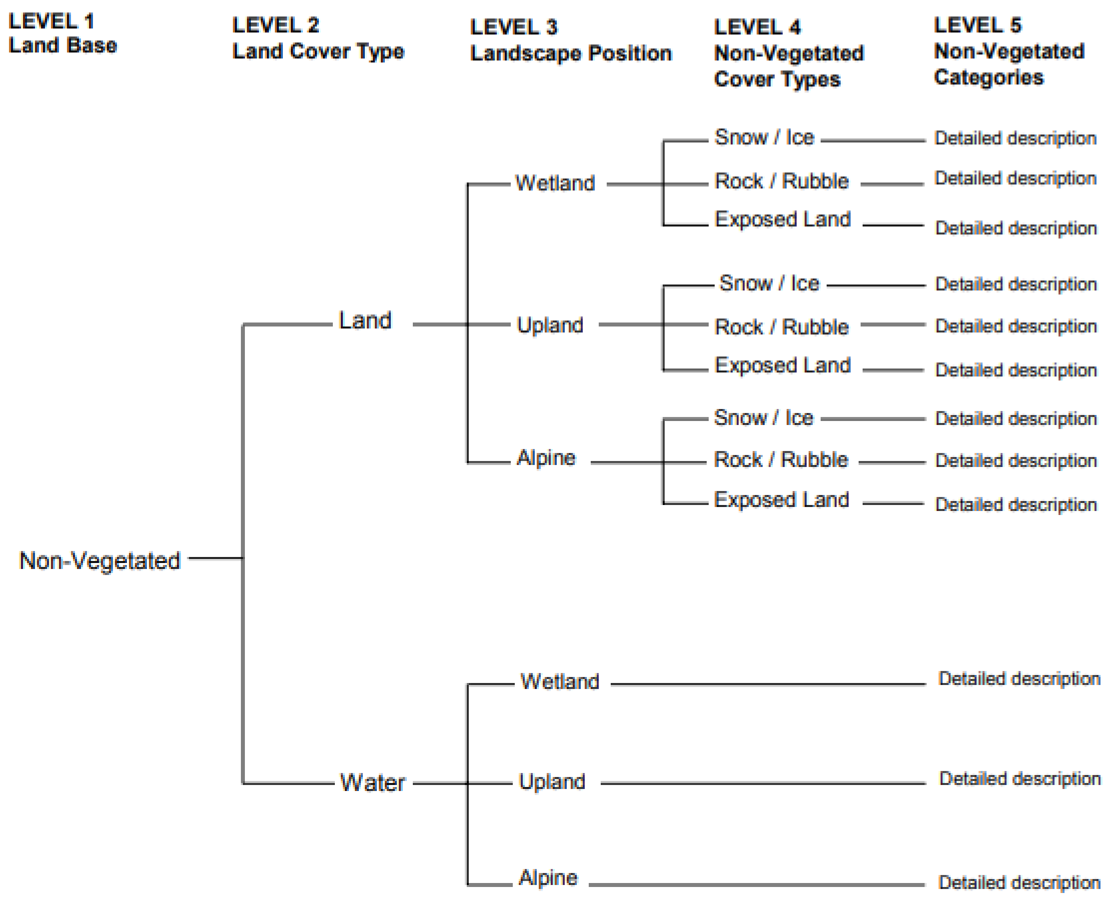
Appendix C: Structure of the B.C. Land Cover Classification Scheme

Vegetated polygons

Source: https://www.for.gov.bc.ca/hfd/library/documents/bib107006_2002.pdf (page 4)



Non-Vegetated Polygons



Appendix D: Data Sources Assessed for the Project

Layer	Source	Notes
BC Cumulative Effects Framework - Human Disturbance	DataBC	2023 version obtained
Forest Biodiversity - BC Cumulative Effects Framework - 2019 Assessment	DataBC	Does not cover project area at present time
Old Growth - BC Cumulative Effects Framework - 2019 Assessment - Kamloops - Datasets - Data Catalogue	DataBC	Does not cover project area at present time
Grizzly Bear - BC Cumulative Effects Framework - 2019 Assessment	DataBC	Suitable reference for GB habitat ratings – out of scope for this round
Aquatic Ecosystems - BC Cumulative Effects Framework - 2020 Assessment	DataBC	Minimal coverage with Project Area
Omineca Watershed Hazard Assessment - BC Cumulative Effects Framework - 2019 Assessment	DataBC	Not suitable for inclusion into the current process
Freshwater Atlas (FWA)	DataBC	Assessed for usage in BEMVRI wetland updates; found to have lower confidence than WWET
BC Forest Disturbance Layer	-	Coverage not available during project timeframe
Historic forested land base	-	Considerations for inclusion within back casting model; not available during project timeframe