RED DEER RIVER WATERSHED

Prioritizing Hydrologically Significant Natural Assets

Project Report

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Nature Conservancy of Canada
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Thanks to the enthusiasm and support from Josée Méthot and Rosemarie Ferjuc of the Red Deer Watershed Alliance (RDRWA), the initial project has now expanded to the Red Deer River watershed.

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The Red Deer River analysis, report and maps were prepared by Suzanne Marechal (NCC).

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Executive Summary

Effective conservation and watershed management efforts should be informed by clear, accessible and reliable baseline information about the landscapes they seek to influence. When working at a watershed scale, there is a need to identify areas with natural assets that provide important hydrologic services, like water provision, flow regulation and water purification. Understanding the location of these areas — or hydrologically significant areas (HSA) — can inform decision making on a variety of scales, whether it is a planner drafting a municipal plan or a land trust prioritizing potential project areas.

This report, led by the Nature Conservancy of Canada (NCC) in partnership with the Red Deer River Watershed Alliance, presents the results of a project to map hydrologically significant areas in the Red Deer River watershed, using a GIS-based approach and open-source data.

Initiated in 2019, the project engaged multiple stakeholders in the Red Deer River watershed, culminating in the publication of this report, alongside an online map portal for use by the public. Results indicate that approximately 30% of the area mapped in the Red Deer River watershed is of moderate to high hydrological significance.

The HSA conservation planning tool is a unique way to consider the importance of hydrology at a watershed or local scale. It uses a systematic approach that is transparent and repeatable, allowing for future updates or expansion. Partners from across sectors are encouraged to use the maps generated through this project as a decision-support tool to inform conservation, development and stewardship activities.

1. Overview

Watersheds, or regional drainage basins, are complex natural systems influenced by social, economic, cultural and ecological dimensions. When addressing land and water management, it is effective and logical to make decisions using a watershed perspective. The effect of development in one part of the system will impact the quality of the environment, both locally and downstream.

Partners in the Red Deer River watershed are interested in land-use planning and development that supports socio-economic prosperity and overall watershed health and resilience. Increasingly, partners from across sectors are working to conserve and steward areas that provide multiple benefits, helping to mitigate floods and droughts while enhancing water quality.

When working at a watershed scale, there is a need to identify areas with natural assets that provide important hydrologic services, like water provision, flow regulation and water purification. Understanding the location of these areas — or hydrologically significant areas — can inform decision making on a variety of scales, whether it is a planner drafting a municipal plan or a land trust prioritizing potential project areas.

In recent years, the Government of Alberta has invested in the ability of local landscapes to provide benefits like flood and drought mitigation, through programs like the Watershed Resiliency and Restoration Program (WRRP). In 2017, the WRRP helped fund a project to map hydrologically significant areas in the Oldman River watershed, and this approach has since expanded to the Bow River and Red Deer River watersheds.

In this report, we summarize the methodology and results of a project to map hydrologically significant areas across the Red Deer River watershed, recognizing the importance of these areas for watershed health and resilience. We also present a new online tool to support a variety of stakeholders — municipalities, stewardship groups, land trusts and more — to undertake planning and conservation efforts through a lens of water.

What is a hydrologically significant area?

This report defines hydrologically significant areas (HSAs) as areas with natural assets that, if preserved in a natural state, provide beneficial hydrologic services, like water provision, flow regulation and water purification. An HSA is not a formal designation; instead, it is a term to help understand the importance of landscapes through the lens of water and aligns with watershed resilience thinking.

Why did the Nature Conservancy of Canada undertake this project?

The key objectives of the project were to:

- Evaluate and map natural assets that support healthy hydrologic functions on lands that will potentially be developed.
- Facilitate conservation actions for multiple user groups by identifying priority landscapes in their focal areas.
- Support a shared understanding, participation and partnerships in long-term planning across the watershed.

The Nature Conservancy of Canada (NCC), in collaboration with the Red Deer River Watershed Alliance (RDRWA), produced this report and associated map products to support planning and decision making, and to inform conversations within the Red Deer River watershed at various scales. The partnership was initiated with the realization that both organizations were working toward similar objectives and as an opportunity to leverage expertise and funding.

There was a common understanding between NCC and the RDRWA that a publicly available map of HSAs would help facilitate current and future conservation efforts and improve access to information that can support land use planning and decision making. A web portal where HSA maps for the Red Deer, Bow and Oldman River watersheds can be viewed is now available online and can be accessed through the NCC's and RDRWA's websites.

The HSA web portal is an interactive interface that allows users to view hydrologically significant areas in combination with either data that a user wishes to upload, or geo-administrative, value-added or model input layers that are readily available in the platform. Looking at HSAs with other information will aid in regional or local assessments.

When to use hydrologically significant area information?

The principal intended use for the HSA map is as a decision-support tool to inform land use, watershed and conservation planning. The high-resolution map can be used as a reference, in conjunction with other management tools for land evaluation, development planning, stewardship decision support and landowner engagement. Identifying areas that are important hydrologically is a crucial first step in ensuring that a landscape's hydrologic value is considered in land use planning and development.

Examples of how the map output can be used to support decision making include:

- Identifying lands that land trusts may want to target for land conservation.
- Identifying lands that watershed or riparian stewardship groups may want to target for best management practices (for example, grazing and riparian health).
- Supporting municipal planning around watershed and headwaters health by identifying areas that need to be protected or may not be compatible with certain land uses.
- Supporting provincial planning around recreation and industrial activity on public lands.

- Identifying overlapping landscape values by comparing the maps to other datasets (e.g., important watershed features or wildlife habitats, range maps for species at risk, provincially designated Environmentally Significant Areas, Key Wildlife and Biodiversity Zones).

How were hydrologically significant areas created?

The HSA mapping tool was developed using a GIS spatial overlay model that incorporated relevant and representative landscape data. Six landscape inputs (layers) were created to identify areas that substantially contribute to hydrologic health. The inputs were derived from credible, open-source data that covered the extent of the watershed. A map output depicting HSAs was generated by overlaying the six inputs. By using a conservation-minded systematic approach, the intent was to create defensible, objective, repeatable and expandable results that can be modified as new inputs or updates become available.

The remainder of this report will detail the analytical methodology used to identify HSAs, and the results and limitations of the study.

2. Methodology

The approach used closely follows that developed for the Southern Alberta Land Trust (SALTS) Conservation Priority Mapping Project in the Oldman River watershed, which was generated by Associated Environmental (Associated Environmental, 2018). The method was based on work described in Barten and Earnest (2004) and the *Source Water Protection Handbook* published by the Trust for Public Land the American Water Works Association (2005).

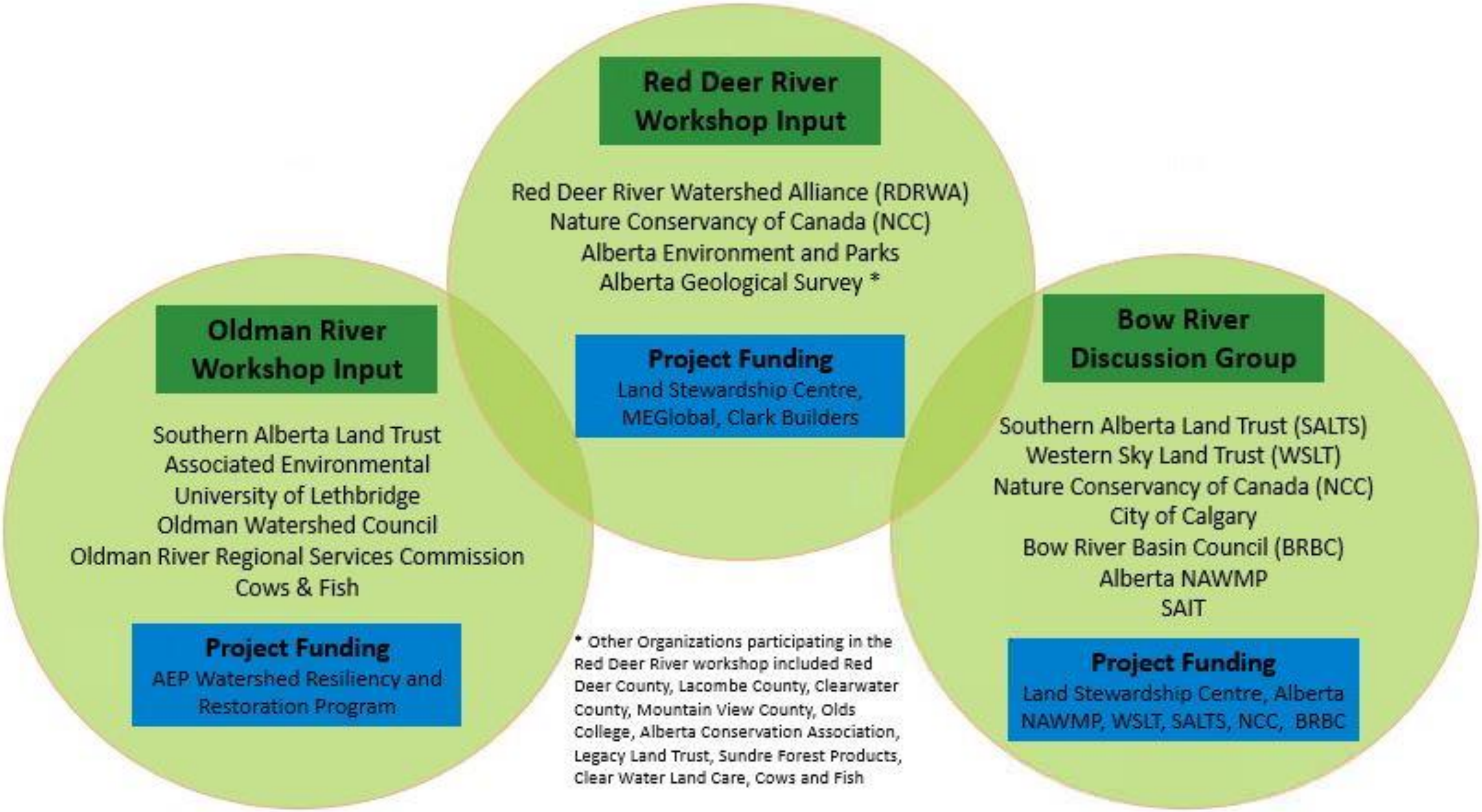
The priority mapping method followed these steps:

- data rationalization;
- data collection and verification;
- attribute classification, scoring and weighting;
- input overlay and final score calculation; and
- map product creation.

Collaborating with SALTS on the methods used for the Oldman River watershed, the Nature Conservancy of Canada adopted similar methods to create hydrologically significant areas in the Bow and Red Deer River watersheds. Sharing methodology ensures that mapping products developed are consistent and transferable across watersheds and will help inform land use planning at local, regional and watershed scales.

Technical experts and watershed stakeholders were consulted during the Oldman, Bow and Red Deer rivers projects to discuss design, rationalization, data layers, weighting and mapping products. Valuable input was obtained during workshops held in the Oldman River watershed (October 30, 2017), the Bow River watershed (2018) and the Red Deer River watershed (September 5, 2019). An overview of the organizations that have contributed expertise and funding is shown in Figure 1.

Figure 1 - Project collaboration, input and funding



* Other Organizations participating in the Red Deer River workshop included Red Deer County, Lacombe County, Clearwater County, Mountain View County, Olds College, Alberta Conservation Association, Legacy Land Trust, Sundre Forest Products, Clear Water Land Care, Cows and Fish

2.1 Data Rationalization

To identify hydrologically significant areas, six landscape inputs were selected as foundational layers in the model. Each input (layer) represents a hydrological service (natural asset) or influences the provision of a hydrological service. Table 1 identifies the data layers used in the analyses and the rationale behind choosing each input. In general, each input is associated with key water quantity and/or quality functions, which if protected in their natural state may attenuate flooding, mitigate drought conditions, prevent water quality degradation and contribute to overall watershed health.

Table 1 - Rationale behind the choice of landscape inputs

Input	Rationale: Hydrologic Benefits
Precipitation	Areas of higher precipitation increase source water input and replenish groundwater.
Proximity to water	These areas, if protected in their natural state, moderate flows (attenuating downstream floods and droughts) and promote water quality by filtering water, inhibiting eroded material from entering water systems and stabilizing stream banks.
Groundwater vulnerability	Regions with a higher groundwater vulnerability index have coarser textured soils and are more permeable, therefore absorbing water and reducing overland flow after rainfall events.
Land cover	Multiple processes and interactions between water and naturally vegetated zones (for example, interception, absorption, evapotranspiration and infiltration) have the effect of slowing surface flows, storing water and improving water quality.
Slope	Flat areas provide opportunities for pooling and promoting soil infiltration after rainfall events. Naturally vegetated moderate to steep slopes prevent runoff and erosion after rainfall events.
Surficial geology	If protected, areas with erodible surficial material are less vulnerable to erosion.

2.2 Dataset Collection and Model Input Creation

2.2.1 Precipitation

Mean annual precipitation (MAP) data for 30-year normals (1961–1990) were downloaded for Western North America from Dr. Andreas Hamann’s climate data website (Hamann, Climate Data, 2013). The data was developed using the parameter-elevation regressions on independent slopes model (PRISM), which uses physiographic information to better predict climate patterns in mountainous terrain (Hamann, Wang, Spittlehouse, & Murdock, 2013). The one-kilometre resolution point data was extracted for the Red Deer River watershed and interpolated using the natural neighbour method to create a continuous surface.

2.2.2 Proximity to Water

Multiple datasets were merged to create the proximity-to-water input layer. Below is a description of the data used and process followed to merge a) watercourse data with b) wetland and lakes data. Areas proximal to a) watercourses and b) waterbodies were merged to create the proximity-to-water input layer.

a) Watercourses

The following open datasets were used to represent the areas proximal to watercourses:

- *1:20,000 Base Feature Hydro Network* (AltaLIS, 2018)
- *Lotic Riparian Polygons (DEM derived)* collected 2011 (Alberta Government, 2017)
- *Digital Flood Hazard Mapping* collected 2015 (Alberta Government, 2015)

Aqueducts, canals, rivers, oxbows and streams were selected from the hydrology network and buffered by 250 metres. The buffered hydrological features were then merged with the digital elevation model (DEM)-derived riparian zones associated with streams and rivers and 100-year flood hazard areas (overland flow, floodway and flood fringe zones) to create a single layer representing all watercourses, to the best of our ability.

The prime purpose for creating a vegetated buffer zone, in this case, is to insulate both watercourses and waterbodies from potentially damaging external influences of nearby development or conversion. The fixed 250-metre buffer width used as a riparian setback in this study is a generous setback created to ensure that we considered the tremendous landscape variability that exists throughout the watershed along watercourses and the many localized factors that can influence the effectiveness of a buffer. It is recognized that buffer effectiveness can be affected by variety of factors, such as:

- land use and types of stressors associated with development;
- sensitivity of the features and/or functions of concern (that is, position in the landscape, area and shape of the feature); and
- biophysical factors (hydrologic dynamics, slope, vegetative composition of the buffer, soils) (Beacon Environmental Ltd., 2012).

Also, we wanted buffers to be “wide enough” to potentially include terrestrial protection zones (a riparian area buffer that can help control concentrated erosion flow) (Beacon Environmental Ltd., 2012). Finally, these larger buffers were selected because many watershed stakeholders are interested in both riparian and associated upland habitat, which support the healthy functions of watercourses.

The fixed buffer used was originally established by Associated Engineering for HSA procedures in the Oldman River watershed. Buffer assessment for the Oldman River was a conservation-orientated estimate based on expert opinion and guidance from the range of buffers suggested in the *Develop with Care Environmental Guidelines for Urban and Rural Land Development* (B.C.

Government, 2014). For the Red Deer River HSA assessment, we used the same buffer widths to keep methodology consistent across jurisdictions.

b) Wetlands and lakes

To represent the areas proximal to lakes and wetlands, the following datasets were collected:

- *Alberta Biodiversity Monitoring Institute (ABMI) Wetland Inventory* (ABMI, 2019)
- *Alberta Merged Wetland Inventory* (Alberta Government, 2019)
- *1:20,000 Base Feature Hydrology Polygons* (AltaLIS, 2018)

The ABMI and Alberta-merged wetland inventories were merged with the AltaLIS reservoir, lakes and wetland hydrology polygons. The merged data was then buffered by 50 metres to create areas proximal to water bodies. Buffering distances were determined based on *Stepping Back from the Water: A Beneficial Management Practices Guide for New Development near Water Bodies in Alberta's Settled Region* (Alberta Government, 2012).

2.2.3 Groundwater Vulnerability

The Alberta Government *Groundwater Vulnerability* dataset (2010) was used to represent soil infiltration potential. Groundwater vulnerability indices represent how efficiently surface contaminants may move into potential shallow aquifers, with vulnerability rankings of low, medium, high and very high. The depth to aquifers and types of geological materials above them are taken into consideration (Alberta Government, 2011). In this assessment, we used areas with high groundwater vulnerability to represent areas where the soil is more permeable and water will more easily infiltrate into the soil.

2.2.4 Land Cover

The Agriculture and Agri-Food Canada *2018 Annual Crop Inventory* dataset (Government of Canada, 2018) was used to characterize natural areas (forest, grassland and shrubland), croplands and other areas (developed, exposed, rock/rubble, snow/ice). Grasslands include both native and tame grasses. Tame grasses are composed of pasture and forage lands.

2.2.5 Slope

Slope surfaces were created using a 25 metre x 25 metre digital elevation model (DEM) supplied by AltaLIS (2018). Slope were classified as flat to gentle slopes (<10%), moderate slopes (10–15%), steep slopes (16–30%) and extremely steep slopes (>30%).

2.2.6 Surficial Geology

The 2013 *Surficial Geology* open dataset (Alberta Geological Survey, 2013) was included to describe the erosion potential of surface material. Erosional potential classes for the various surficial deposits were adopted from the *Mapping and Assessing Terrain Stability Guidebook* (British Columbia Government, 1999).

2.3 Dataset Publication Date and Resolution

Open source spatial data available across the Red Deer River watershed were used in the mapping model. Certain datasets were not available in Banff National Park, so final mapping did not include results for this region. A priority was to find the most current and highest resolution data available. Table 2 lists the publication date and map scale (or resolution) of each dataset used in the project.

Table 2 - Publication date and resolution of landscape inputs

Input	Dataset	Map Scale/Resolution	Publication Date
Precipitation	1961-1990 PRISM Interpolated	1 m x 1 m	2013
Proximity to watercourses	Lotic Riparian – DEM derived	1:20,000	2011
	Flood Hazard Mapping	Variable	2015
	Base Stream and Flow Representations	1:20,000	2018
Proximity to wetlands and lakes	ABMI Wetland Inventory	10 m	2019
	Hydrology Polygons	1:20,000	2018
	Alberta Merged Wetlands	Captured to a minimum mapping unit of 0.02 ha to 0.1 ha	2019
Groundwater vulnerability	Groundwater Vulnerability	1:250,000	2010
Land cover	Annual Crop Inventory	30 m x 30 m	2018
Slope	DEM (AltaLIS)	25 m x 25 m	2018
Surficial geology	Surficial Geology	1:500,000 to 1:1,000,000	2013

2.4 Landscape Input Scores

Scores were assigned to features within a landscape input based on the rationale established in Table 1. Scores range between 1 and 4, with 4 representing higher hydrological benefit. Not all inputs have all four score values assigned. In some instances, expert input recommended the removal of certain values (i.e.: proximity to watercourses, score 2 and 3) in order to simplify and assign more of a yes/no score, or to spread out the input values to accentuate the benefits of the highest category. Table 3 provides an overview of scores assigned to classifications in each landscape input.

Table 3 - Scoring and classification of landscape inputs

Input	Landscape Score				Hydrologic Benefits Provided by High Scoring Assets
	4	3	2	1	
Precipitation (mm)	> 707 mm	458–707 mm	375–457 mm	266-374 mm	Provides water yield for various uses (e.g., aquatic ecosystem health, drinking water, industries).
Proximity to watercourses (m)	≤ 250 m	n/a	n/a	> 250 m	Intact riparian areas and floodplains regulate water quantity and quality by filtering and storing water, buffering water systems, mitigating floods and droughts, and reducing runoff.
Proximity to wetlands and lakes	≤ 50 m	n/a	n/a	> 50 m	
Groundwater vulnerability	Very high	High	Moderate	Low	Regulates water quantity (i.e., overland flow and groundwater recharge) by retaining water through infiltration and regulates water quality by reducing overland flow after rainfall events.
Land cover	Forest, grassland (native/tame), shrubland, water	n/a	Cropland	Developed or exposed land	Regulates water quantity by retaining water through infiltration, absorption and evapotranspiration, and regulates water quality by minimizing runoff and stabilizing soil to prevent erosion.
Slope (%)	16–30%	10–15%	0–9%	> 30%	Regulates water quantity and quality by slowing down overland flow, retaining water through infiltration, and preventing runoff and erosion.
Surficial geology	Lacustrine, glacio-lacustrine, eolian, organic	Glaciofluvial, fluvial	Moraine	Colluvium, bedrock, glaciers	Regulates water quality by preventing exposure and erosion of erodible material.

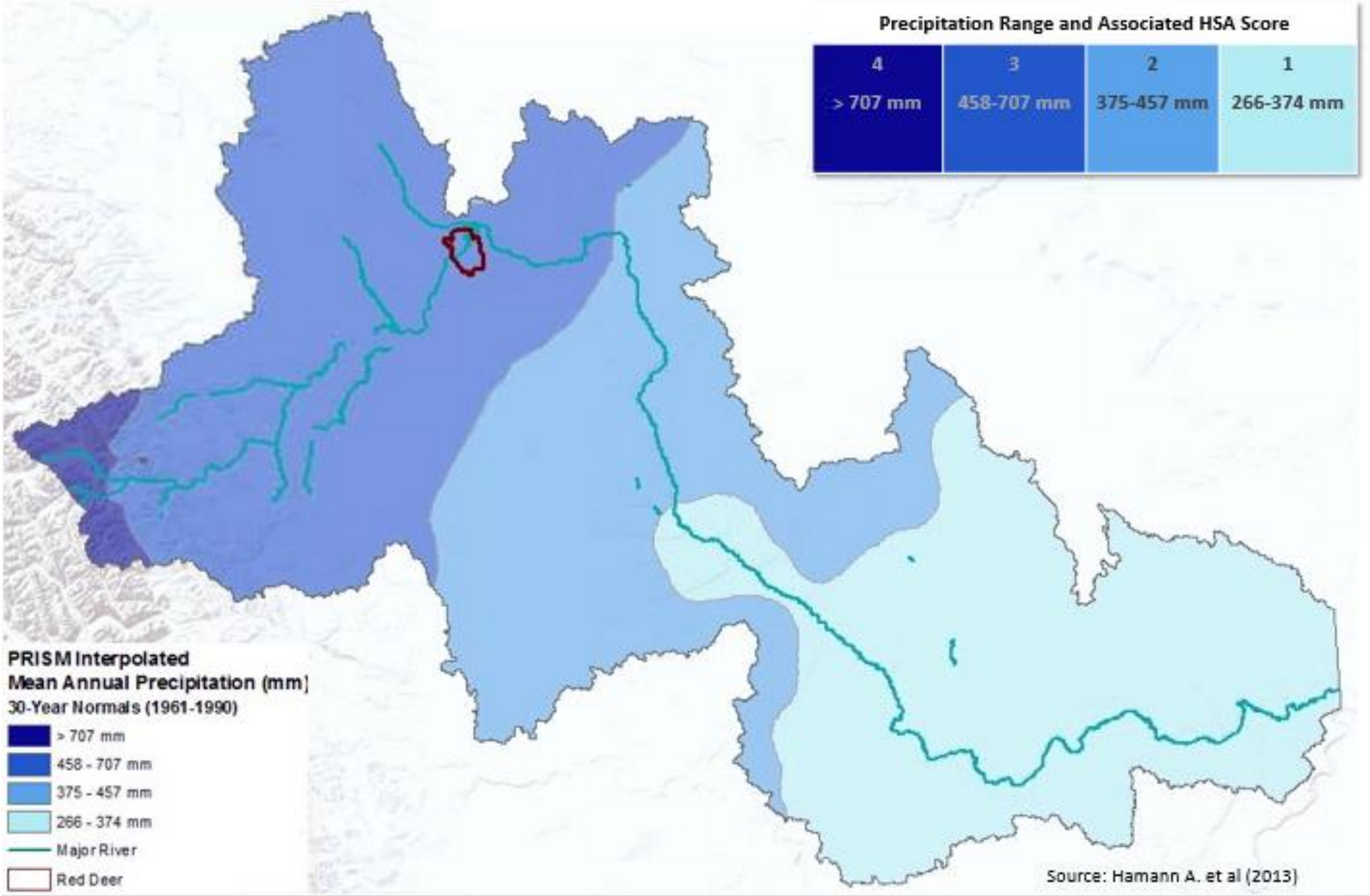
2.5 Landscape Classification and Score Distributions

The following figures show both classification and scoring distribution for the six landscape inputs (layers) used to map hydrologically significant areas within the Red Deer River watershed.

2.5.1 Precipitation

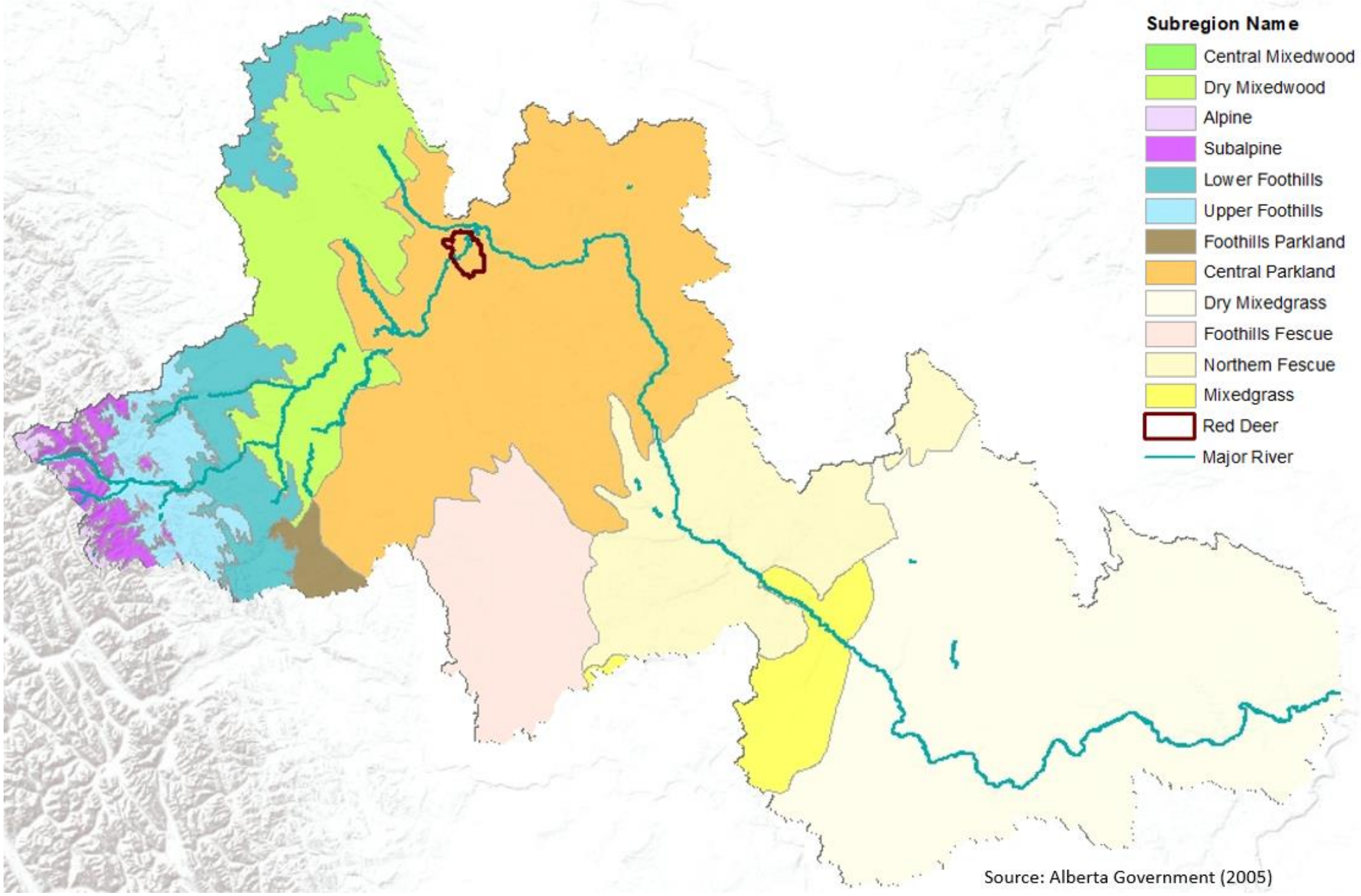
Precipitation classifications (Figure 2) were delineated by first finding the mean annual precipitation (MAP) of different natural sub-regions (Figure 3), and then creating four precipitation classes (Figure 2). The MAP scores of different regions were assigned as 1 (low) to 4 (high).

Figure 2 - Mean annual precipitation distribution within the Red Deer River watershed



Source: Hamann A. et al (2013)

Figure 3 - Natural sub-regions of Alberta within the Red Deer River watershed

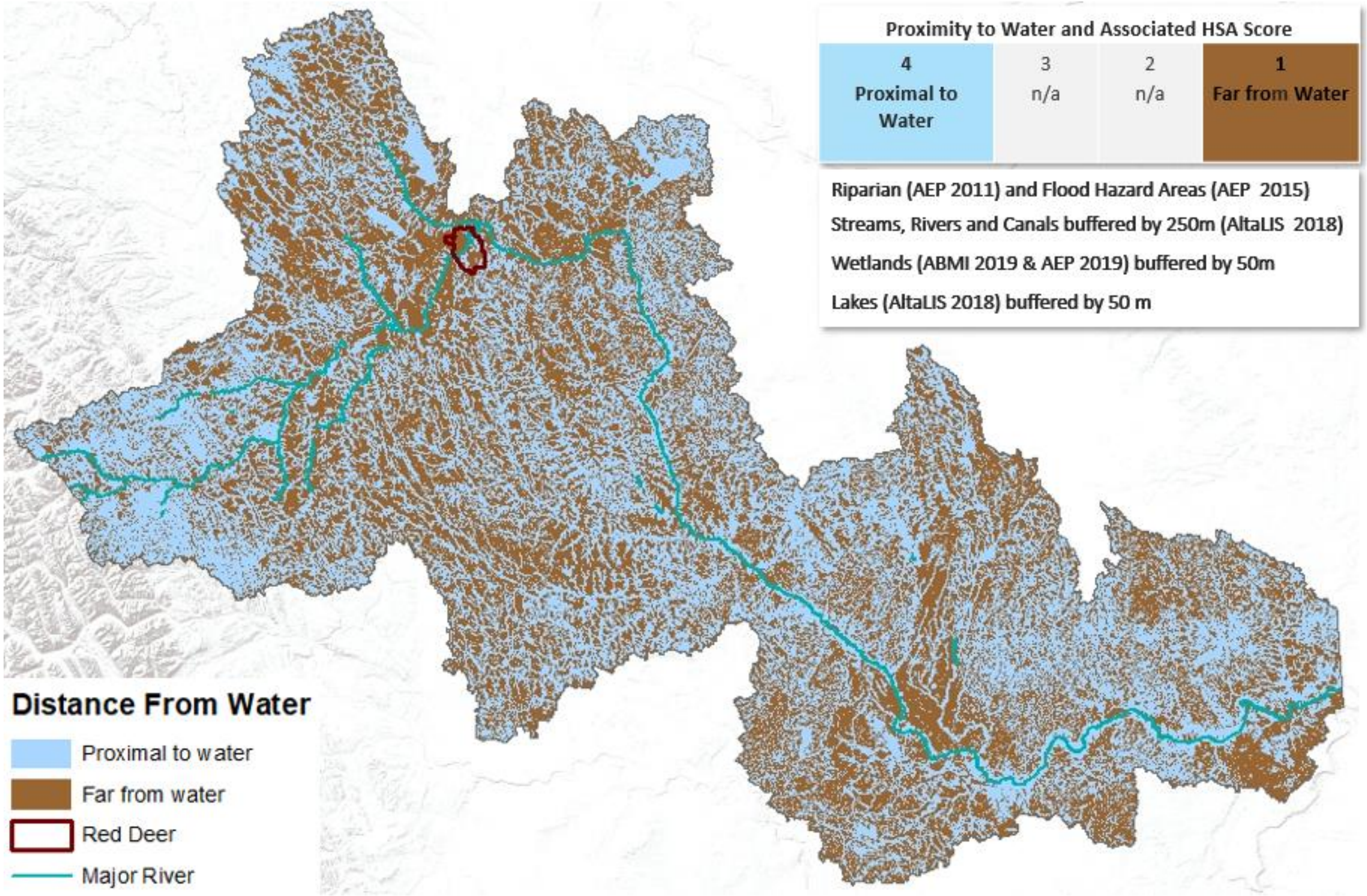


Source: Alberta Government (2005)

2.5.2 Proximity to Water

Areas proximal to water (Figure 4) consist of riparian zones, flood hazard areas, streams, rivers and canals buffered by 250 metres, and wetlands, reservoirs and lakes buffered by 50 metres. These areas were given the highest score (4) in the model.

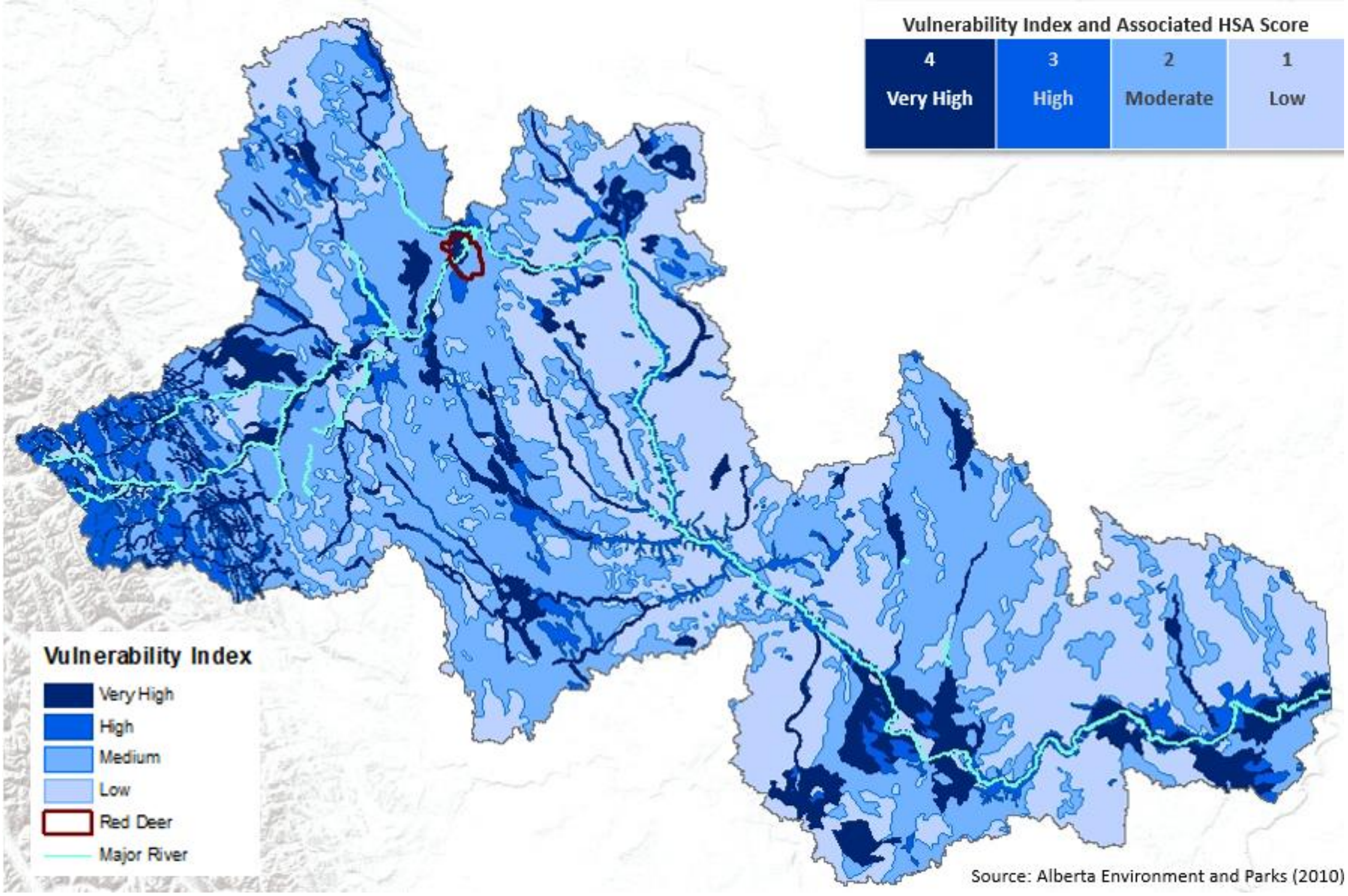
Figure 4 - Distribution of areas proximal to water within the Red Deer River watershed



2.5.3 Groundwater Vulnerability

The groundwater vulnerability map in Figure 5 provides a high-level overview of the sensitivity of shallow groundwater to potential surficial impacts (Alberta Government, 2011). Areas with a very high vulnerability index have the highest sensitivity to surface activities due, in part, to the coarse-textured deposits at the ground surface. Regions with coarser materials facilitate soil infiltration (vertical movement of surface water) and were given a higher score.

Figure 5 - Groundwater vulnerability index distribution within the Red Deer River watershed

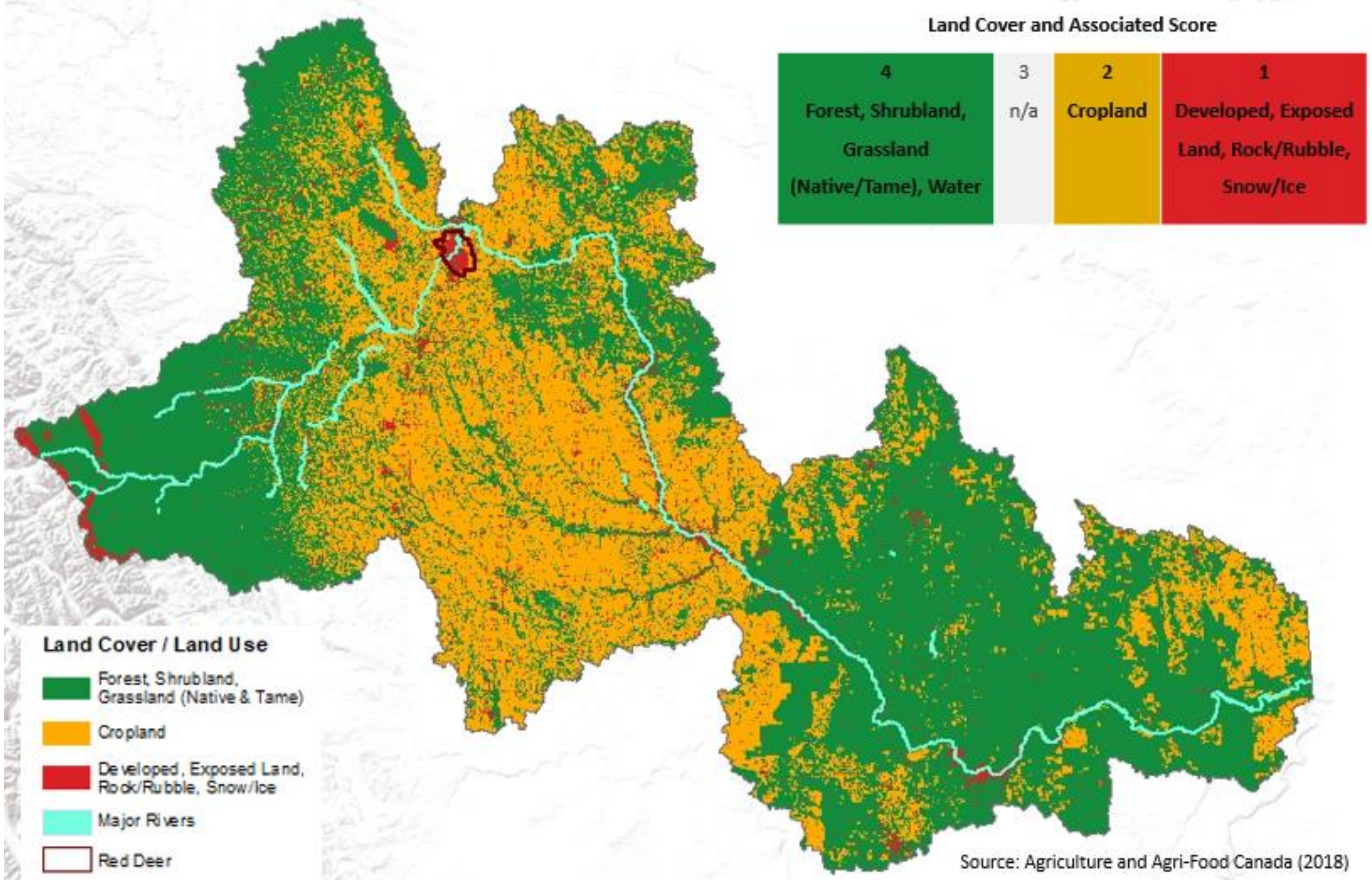


Source: Alberta Environment and Parks (2010)

2.5.4 Land Cover

The ground cover, organic litter and complex root systems integral to perennial natural vegetation play an important role in capturing and slowly releasing water. Natural land cover, such as forest, shrubland and grassland, is therefore given the highest score in this model. The distribution of land cover scores within the Red Deer River watershed can be seen in Figure 6.

Figure 6 - Land cover score distribution within the Red Deer River watershed



Land Cover and Associated Score

4	3	2	1
Forest, Shrubland, Grassland (Native/Tame), Water	n/a	Cropland	Developed, Exposed Land, Rock/Rubble, Snow/Ice

Source: Agriculture and Agri-Food Canada (2018)

2.5.5 Slope

Assigning slope classes and scoring based on potential hydrological benefit was one of the more challenging parts of this project, as slope can influence hydrological function and services in various ways.

Slope classes and scoring (Figure 7) were determined by considering:

- The impact that *undeveloped* moderate and steeper slope gradients have on decreasing runoff and erosion in comparison to developed slopes with similar gradients. If left undeveloped, vegetation on these sloped areas works to protect water quality and reduce runoff by protecting and stabilizing the soil and minimizing the erosive power of runoff.
- The influence that *undeveloped* gentle-sloped areas have on supporting infiltration and slowing overland flow in comparison to developed areas with gentle slopes. If left undeveloped, vegetation on these gentle-sloped areas slow overland flow and promote water absorption and infiltration.

Scores were assigned from high (4) to low (1) as follows:

- **(4):** For scoring purposes, *undeveloped* steep slopes with a 16–30% slope range were classified as being most important hydrologically because these are areas with the highest runoff coefficients (highest volumes of runoff per volume of precipitation). According to Nassif & Wilson (1975), runoff amounts peak between slopes of 16% and 24%, depending on soil and cover. Increase in runoff amounts on steeper slopes is related to increased surface flow and decreased soil infiltration rates and runoff lag time (Mu, et al., 2015). Protecting these areas and keeping them intact in their natural state will minimize the damage and degradation that high volumes of runoff cause to soils and the quality and quantity of waterways. Development on these slopes would pose the highest risk to hydrological function and health.

- **(3):** In comparison, *undeveloped* moderate slopes (10–15%) were classified as being important hydrologically because these are areas with significant potential for runoff (runoff increases significantly beyond slopes of 8% (Nassif & Wilson, 1975)). The runoff coefficient will more than likely be less than steep slopes but still important enough to highlight and protect from development to help minimize the negative effects of runoff.

- **(2):** Undeveloped gentle slopes (0–9%) were classified as being less important hydrologically because the effects of runoff on these slopes is significantly reduced. However, the infiltration capacity of these regions is noteworthy, so it is still important to protect these regions to help maintain water absorption and retention and decrease overland flow.

- **(1):** Undeveloped extremely steep slopes (31–60%) were classified as least significant. Naturally, these are areas where there would be considerable runoff; however, they are also spaces that do not need to be highlighted for protection because they are typically not developable (City of Nanaimo, 2005) and therefore are at minimal risk of alteration.

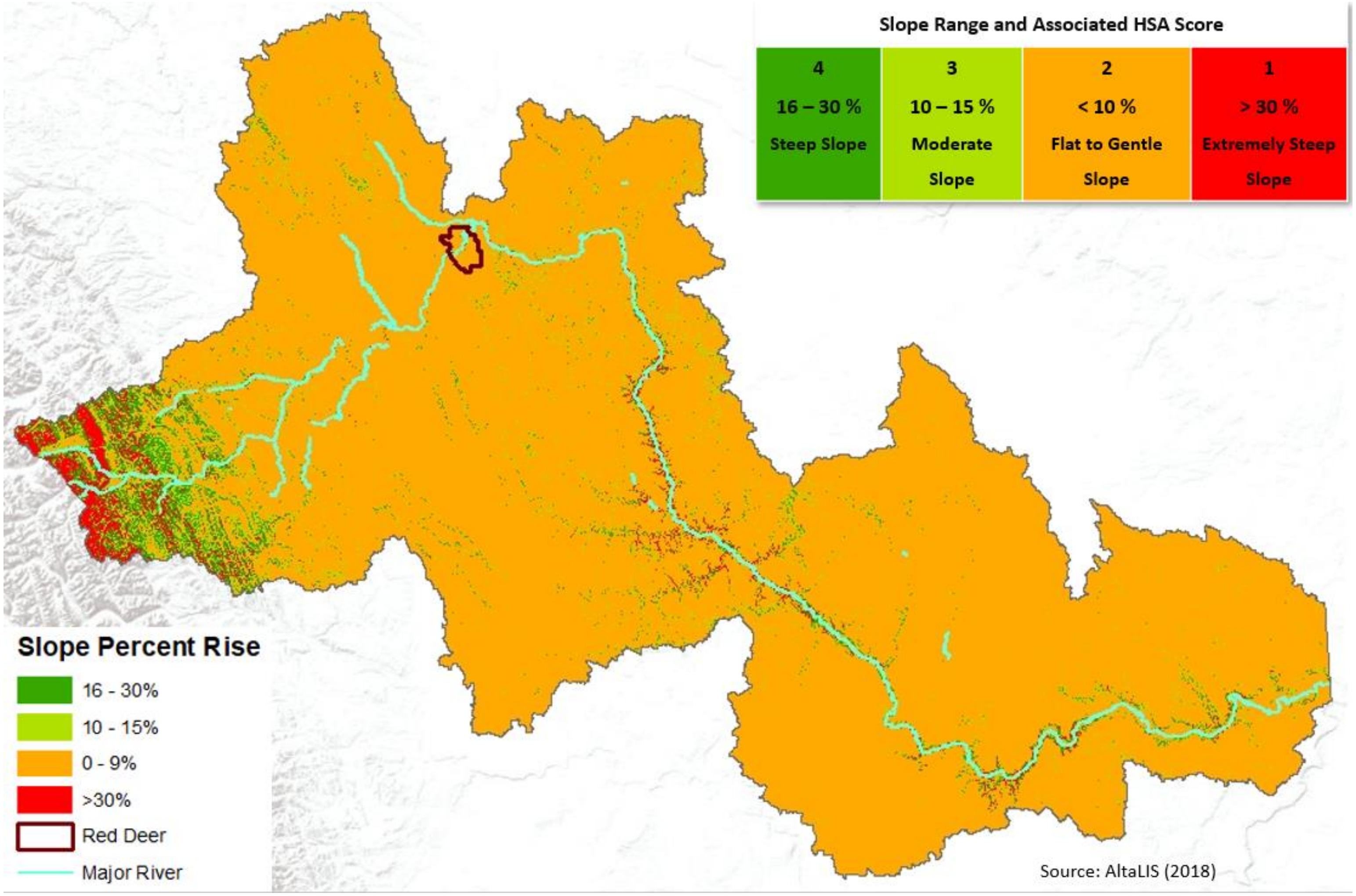
A summary of how slopes were scored and a generalized justification for slope divisions can be seen in the table below.

Table 4 - Justification for slope gradient divisions used in project analysis

Class and Description*	Slope Range	Score	Effect (if Slope Left Undisturbed)**
Little or no slope: 0–3% gradient	0–9%	2	Moderate beneficial hydrologic effects — maximum infiltration capacity
Gentle slope: 4–9% gradient			
Moderate slope: 10–15% gradient	10–15%	3	High beneficial hydrologic effects — potential to reduce runoff volume
Steep slope: 16–30% gradient	16–30%	4	Very high beneficial hydrologic effects — potential to reduce peak runoff volumes
Extremely steep slope: 31–60% gradient	> 30%	1	Considered not developable (City of Nanaimo, 2005) — not an area of interest
Excessively steep slope: > 60% gradient			

* Slope classes defined by Agriculture and Agri-Food Canada (Government of Canada, 2013)
** Effects described based on Nassif & Wilson (1975)

Figure 7 - Slope score distribution within the Red Deer River watershed



Slope Range and Associated HSA Score

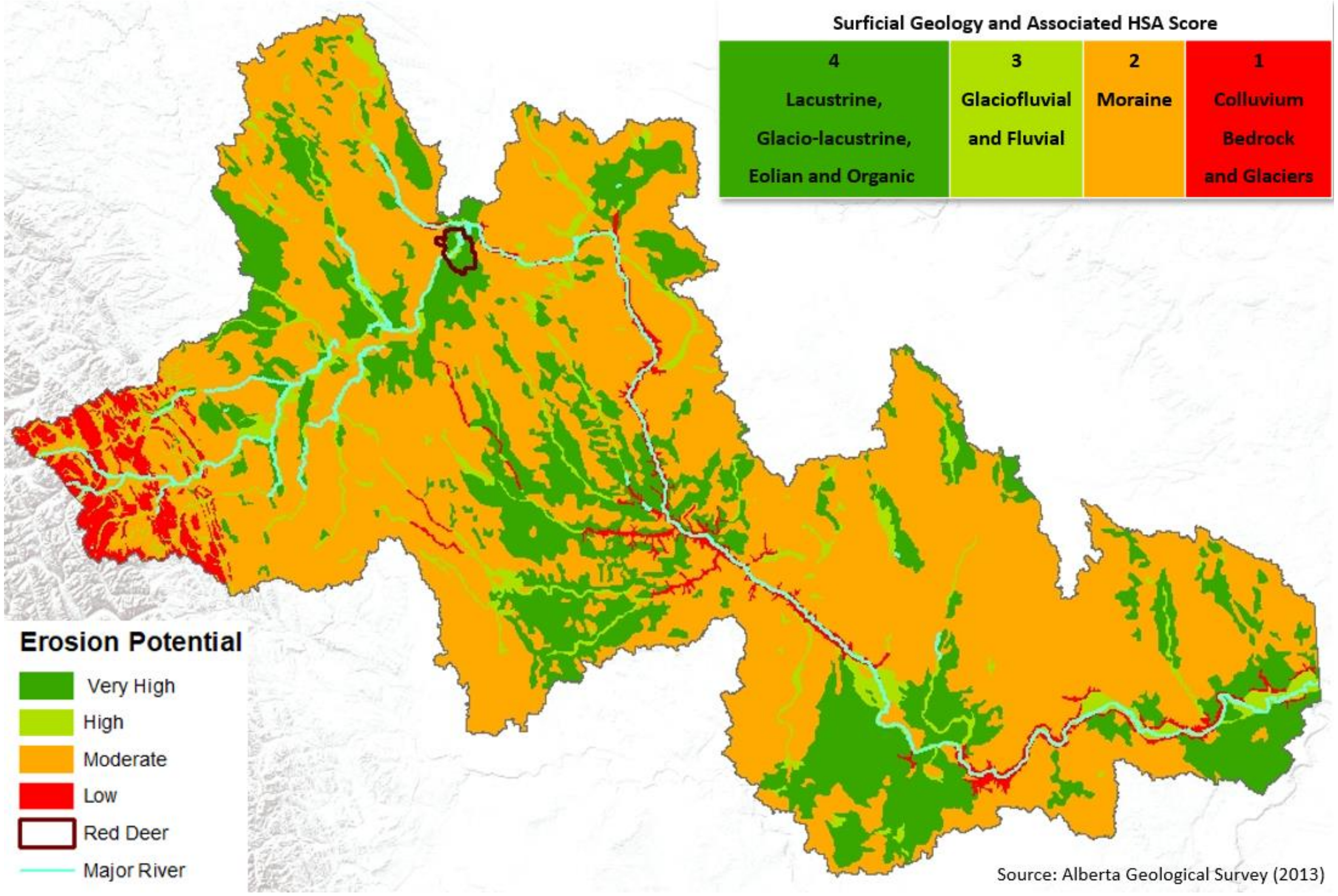
4	3	2	1
16 – 30 %	10 – 15 %	< 10 %	> 30 %
Steep Slope	Moderate Slope	Flat to Gentle Slope	Extremely Steep Slope

Source: AltaLIS (2018)

2.5.6 Surficial Geology

Soil erosion potential is ranked from low to very high based on surficial geology criteria used by the B.C. Ministry of Forests (British Columbia Government, 1999). Figure 8 shows the distribution of regions of very high to low erosion potential based on geological characteristics. Areas of high erosion potential scored high (4); they are areas that if left intact would prevent the largest amount of sediment runoff. Conversely, areas with low soil erosion potential scored low (1), as they present less of an erosional threat.

Figure 8 - Surficial geology erosion potential distribution in the Red Deer River watershed



Source: Alberta Geological Survey (2013)

2.6 Weighting Inputs

Relative weighting was assigned to each landscape input based on data quality and hydrologic function (Table 5). For each input, data quality was scored on a scale of 1 to 3, with 3 given to higher spatial resolution data. Hydrologic function was scored on a scale from 1 to 5, with 5 representing landscapes with natural assets that are most important for watershed health and resilience.

The value of the hydrologic function of a landscape is not easily measured or quantified. Hydrologic services can have ecological, social or economic values, and these are not absolute (what is important to one person may not be important to another). The values assigned for the hydrologic function in this study were determined during the October 31, 2018, Oldman Watershed Conservation Priority Technical Workshop and were based on expert opinion. Key to the valuation process was establishing the number and type of hydrologic services each input provided. As well, it was important to qualify the negative effects that could result to both water quality and quantity if a landscape feature (input layer) was disturbed and unable to provide its hydrologic services.

The relative weights for each layer were determined by summing the data quality and hydrologic function scores and dividing them by the total sum of scores (e.g. 41). Finally, the weighting for each input layer was calculated by assigning a relative weight of 15% to a neutral weight of 1 (Table 6) to simplify the weighting process.

Landscape input scores were then multiplied by the weighting factor to arrive at a weighted score.

Table 5 - Weighting the data quality and hydrologic function of each landscape layer

Input	Data Quality	Hydrologic Function	Sum	Relative Weight	Weighting
Precipitation	3	3	6	15%	1
Proximity to watercourses	3	5	8	20%	1.33
Proximity to wetlands and lakes	3	5	8	20%	1.33
Groundwater vulnerability	2	2	4	10%	0.67
Land cover	3	3	6	15%	1
Slope	3	3	6	15%	1
Surficial geology	1	2	3	7%	0.5
Total			41	≈ 100%	

Weighting reduced the importance of the surficial geology and groundwater vulnerability inputs and increased the importance of the proximity to water input.

2.7 Weighted Overlays and Final Scores

All six inputs were overlaid and consolidated into one final map. Approximately two million discrete polygons were created during this overlay process. Table 6 illustrates a sample of the results for four different polygons in the Red Deer River watershed.

Table 6 - Example of final overlay results

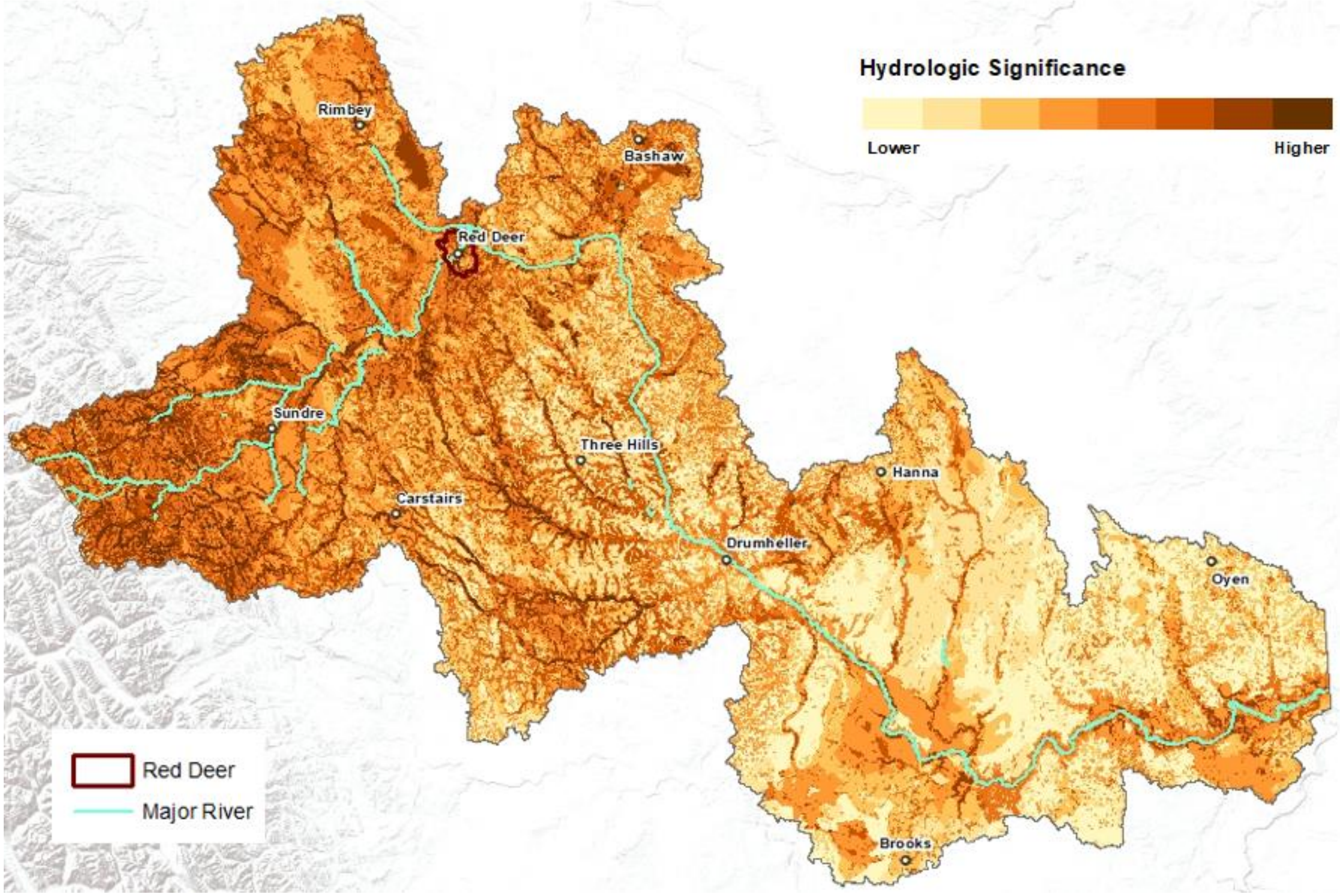
Sub-basin Name	Precipitation Score	Precipitation Weighted Score	Land Score	Land Weighted Score	Slope Score	Slope Weighted Score	Surficial Geology Score	Surficial Geology Weighted Score
Rosebud River	**2**	**2**	**1**	**1**	**2**	**2**	**2**	**1**
Lower Red Deer River	**1**	**1**	**4**	**4**	**3**	**3**	**2**	**1**
Panther River	**4**	**4**	**4**	**4**	**3**	**3**	**3**	**1.5**
Service Berry Creek	**2**	**2**	**1**	**1**	**2**	**2**	**2**	**1**

Sub-basin Name	Groundwater Vulnerability Score	Groundwater Vulnerability Weighted Score	Water Proximity Score	Water Proximity Weighted Score	Final Score (Added)	Final Weighted Score (Added)	Final Score (Multiplied)	Final Weighted Score (Multiplied)
Rosebud River	**2**	**1.34**	**4**	**5.32**	**13**	**12.66**	**64**	**28.5152**
Lower Red Deer River	**1**	**0.67**	**1**	**1.33**	**12**	**11**	**24**	**10.6932**
Panther River	**4**	**2.68**	**4**	**5.32**	**22**	**20.5**	**2304**	**1026.5472**
Service Berry Creek	**1**	**0.67**	**4**	**5.32**	**12**	**11.99**	**32**	**14.2576**

To create the final map, weighted scores were multiplied and categorized into eight classes using the Jenks Natural Breaks Classification (or Optimization) system, a data classification method designed to optimize the arrangement of a set of values into "natural" classes. A “natural” class is the most optimal class range found "naturally" in a data set (Wiki GIS, 2018).

A multiplicative methodology for combining the scores for all the layers was chosen over additive methodology, as it provides a greater score range (0.67–1368.73) and a more balanced distribution of scores. The natural breaks classification used to group the scores into eight categories was chosen for similar reasons. The final scores were mapped for the Red Deer River watershed and appear in Figure 9.

Figure 9 - Hydrologically significant areas within the Red Deer River watershed

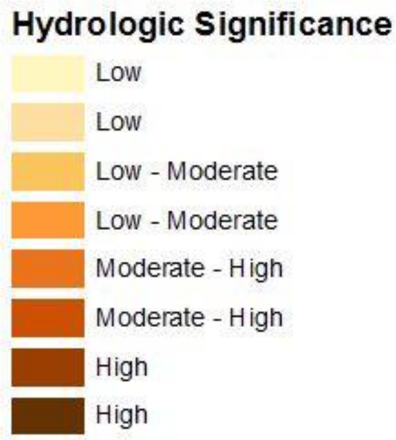


3. Results

3.1 HSA Mapping Results

A total of 1,999,759 polygons over an area of 4,606,768 hectares were created during the Red Deer River watershed HSA assessment. Of these polygons, 1,390,066 hectares or 30% of the area assessed was identified as having moderate - high hydrologic significance. 288,786 hectares or 6% of the area assessed was identified as having high hydrologic significance. Moderate - high and high hydrologic significance ratings have higher weighted final scores and include the areas that were classified into the top four hydrologic significance categories as seen in Figure 10 below.

Figure 10 - Hydrologic significance classification within the Red Deer River watershed



Areas of higher significance (high and moderate - high) are not evenly distributed across the watershed. The regions within the Rocky Mountains and foothills (headwaters) have a significantly higher proportion classified as having moderate - high or high hydrologic significance. The variation is driven by the fact that these regions generally have higher volumes of precipitation and larger areal extents of natural land cover. In contrast, the proportion of area classified with moderate - high or high hydrologic significance are generally found less in the grassland regions where there is quite often lower mean annual precipitation and natural land cover is more fragmented by agricultural activities.

Uneven distribution of HSAs can be seen if we compare five distinct zones within the Red Deer River watershed. The five zones — Upper Headwaters, Lower Headwaters, Central Urbanizing, Central Agricultural and Dry Grasslands — contain sub-watersheds, which are outlined in Table 7.

Table 7 - Sub-watersheds within the HUC-4 watershed boundaries assessed in this report

	Upper Headwaters	Lower Headwaters	Central Urbanizing	Central Agricultural	Dry Grasslands
Sub-watersheds	Panther, James	Raven, Little Red Deer, Medicine	Blindman, Waskasoo	Buffalo, Threehills, Kneehills, Michichi, Rosebud	Berry, Matzhiwin

Zones are delineated in Figure 11. It is important to note that in this report, areas within Banff National Park were not assessed for hydrologic significance due to data gaps.

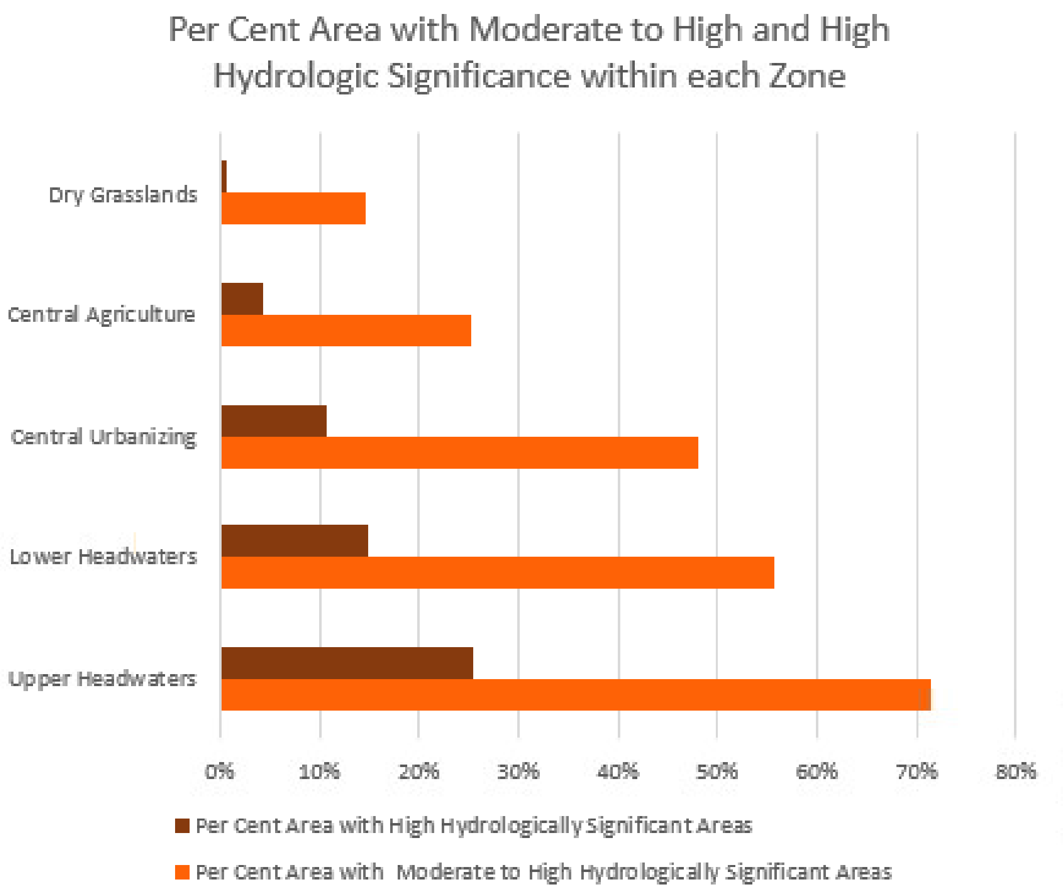
Figure 11 - Zones within the Red Deer River watershed assessed for hydrologic significance

The per cent area with high hydrologic significance ranges from 1% in the Dry Grasslands to 25% in the Upper Headwaters. The percent area with moderate - high hydrologic significance ranges from 25% in the Dry Grasslands to 71% in the Upper Headwaters.

Even though the Dry Grasslands have a lower portion of high hydrologic significance, a range of values (viewed as a range of colours) still exists. When assessing an area of interest in the Dry Grasslands, the highest hydrologic values (darkest colours) present should be considered as the

HSAs in the region. This is a valuable consideration when using the maps and web portal, as project scale and HSA distribution will vary from one focus area to the next.

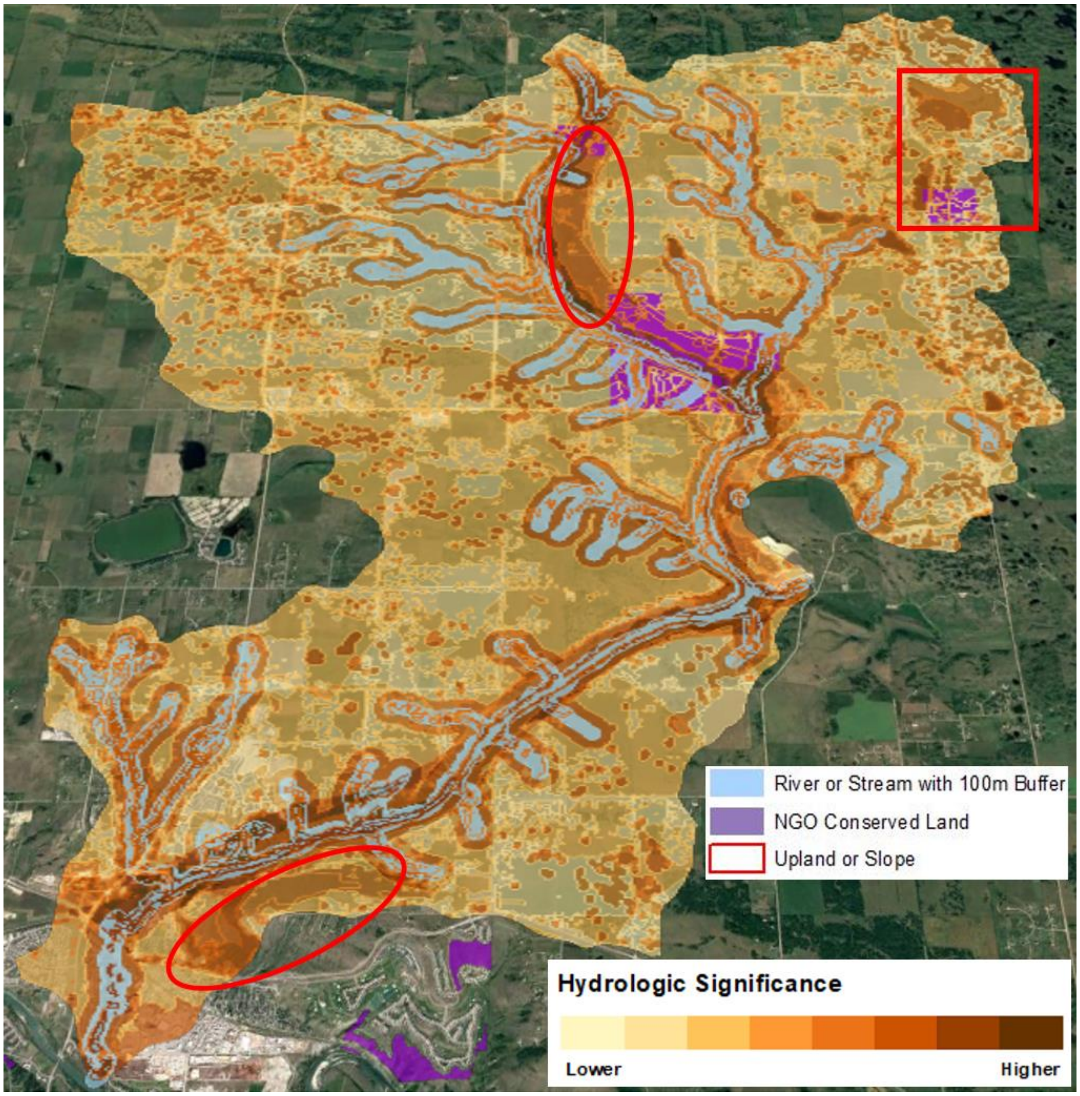
Figure 12 - Per cent area with moderate - high and high hydrologic significance



Interestingly, the HSA map can also help to identify uplands and slopes that may be of hydrological significance. It may be thought that the areas that have been high graded as hydrologically significant will likely fall within riparian areas. That is true, as noticeable in Figure 13 below where the buffered rivers and streams (areas in light blue) align with the darkest areas (higher HSAs).

But in addition to those very important riparian areas, there are many examples where slopes and upland areas have been identified as hydrologically significant. Figure 13 provides an example of a sub-watershed where three additional areas (outlined in red) that are outside of the buffered lotic systems have higher hydrologic significance.

Figure 13 - Example of higher hydrologically significant uplands and slopes



3.2 HSA Map Portal

NCC created a map portal where HSA maps for the Red Deer, Bow and Oldman River watersheds can be viewed on the web. It was designed as a tool to help users better understand landscapes from a hydrological perspective, and to support decisions related to land use planning, development and conservation in a user-friendly format.

3.2.1 Optional Layers

Geo-administrative, value-added and model input map layers are also available to be used as a reference or aid in regional or local assessments. All layers have been grouped as boundaries, value-add layers and landscape inputs. All layers can be turned on and off, as needed.

The following geo-administrative boundaries are included in the portal:

- First Nations Communities Reserves
- protected areas
- cities, towns and villages
- rural municipalities
- treaty territories
- land-use framework regions
- Red Deer River Watershed Alliance sub-watersheds
- Hydrological Unit Code (HUC) boundaries: HUC2 to HUC10 sub-basins
- legal land descriptions for townships and sections
- Alberta green zones

The following value-added layers are included in the portal:

- Environmentally significant areas
- Annual recharge per acre (quantified for southern Alberta)
- Alberta natural sub-regions

Landscape inputs used in the development of the HSA GIS model were also included for the Bow and Red Deer River watersheds; however, NCC does not have access to the input layers from the Oldman River watershed project. The landscape inputs include:

- precipitation
- land cover
- slope
- surficial geology
- groundwater vulnerability
- water proximity

3.2.2 Navigating within the Mapping Portal

a) Widgets are available to:

🔍 Facilitate searches by sub-basin, legal land description, park, reservation or municipal district.

☰ View symbology of visible layers.

≋ View a list of layers available to turn on or off.

▦ Change base maps.

🖨 Print map layouts in various formats.

ℹ Read more about the portal.

Add your own data (Shape Files, CSV, KML, GPX, Geo JSON) or ArcGIS online maps.

b) Pop-ups containing specific information about a feature appear when a visible feature is clicked on the interactive map.

3.3 GIS Data

Requests for HSA GIS data (in a layer package format) can be made by contacting NCC's Alberta Region GIS team (alberta@natureconservancy.ca).

GIS data provides final scores calculated by adding weighted and non-weighted input scores or multiplying weighted and non-weighted input scores (Table 7). This allows users to remap results using unweighted inputs, if desired, or to apply additive instead of multiplicative methodology. Users could also work with a subset of the data, dig deeper into specific areas, exclude less relevant inputs or include additional information pertinent to a specific area that is required for planning purposes.

4. Discussion and Conclusion

Hydrologically significant areas across the Red Deer River watershed were identified based on well-defined inputs. These inputs were selected to represent natural assets that, if preserved in a natural state, provide beneficial hydrologic services, like water provision, flow regulation and water purification.

The HSA conservation planning tool is a unique way to consider the importance of hydrology at a watershed or local scale. It uses a transparent, repeatable systematic approach, allowing for future updates or expansion. Finally, it can and should be used as a decision support tool to complement other land use and conservation planning tools and to increase the probability that hydrologic value is considered in multifunctional landscape decisions. Overall, identifying hydrologically significant areas is a crucial step in creating and maintaining healthy and resilient watersheds.

There are several limitations and assumptions inherent in this model that should be considered when using this product.

1. The HSA map contains finely detailed results but is developed from a variety of coarsely scaled inputs. With that in mind, this should be considered a coarse-scale assessment. HSA boundaries are rough estimates and may need to be ground-truthed and further refined at local scales. Its value is to outline patterns that may not be visible at the surface and should make a user consider the impact of their decision to the local or regional hydrological network.

2. The analysis of HSAs considers the potential hydrologic value of undisturbed natural assets. It considers whether an area has natural vegetation or is developed. It does not consider, however, how nearby disturbances can impact and potentially downgrade the effectiveness of a local hydrologic service. For example, a disturbance such as a road can negatively affect the value a vegetated slope plays in reducing runoff. We did consider including disturbance layers into the project, but recognized the complexity that this would bring to the analysis. Disturbances in a region that potentially compromise hydrologic services should be considered in a planning and decision-making process and can be included as a separate layer if need be.

3. The assessment does not include important wildlife habitats, species locations, landforms, or infrastructure sites such as drinking water intakes. These could also be considered as additional layers in a planning process for a specific project.

4. While it would be valuable to understand which main river stems and tributaries provide clean water and what is driving water quality patterns, the data is not available at this time. In these cases, we used buffered areas surrounding streams, rivers and water bodies as a surrogate measure to identify key areas that contribute to water quality in general. A similar method was used by Fiera Biological Consulting (2010) to identify and define Aquatic Environmentally Significant Areas in Alberta. For simplicity, a similar buffer was used for both streams and rivers rather than using stream classifications or other classification systems to stratify the value of different-sized watercourses.

5. Mean annual precipitation was used as a proxy for where water enters the hydrologic system. This was the best representation we could find. It is important to point out that:

    - Precipitation computations always have a certain level of uncertainty due to the interpolation of precipitation point measurements, which were themselves generated through the PRISM model.
    - A base period of 1961–1990 was used, as this was the only period for which we could find PRISM interpolated data. By using this, we are assuming that 30-year normal mean annual precipitation has not significantly changed in the last 30 years.
    - Precipitation ranges for scoring purposes were developed by aligning precipitation to Alberta's natural sub-regions as closely as possible. This method was chosen because climate is a key factor in land classification (Alberta Government, 2005). There is room for subjective interpretation in the process.

6. The important interconnectivity between landscapes, groundwater and river systems should not be overlooked; however, understanding all potential ground and surface interactions is very complex. Areas of regional recharge, groundwater springs, alluvial aquifers and prairie potholes are all zones that should be targeted for conservation.

    Unfortunately, we were unable to source watershed-scale regional recharge and local groundwater discharge data. However, by combining annual precipitation amounts with soil infiltration (groundwater vulnerability), we were able to high grade areas where surface-groundwater interactions may take place. As part of the value-added layers in the portal, we did incorporate area-weighted average annual recharge for southern Alberta, scaled up to a HUC8 sub-watershed scale (Klassen, Liggett, Pavlovskii, & Abdrakhimova, 2018).

7. When looking at inputs for the model, we explored the option of incorporating either runoff curve numbers (United States Department of Agriculture - Soil Conservation Service, 1989) or runoff coefficients (Kienzle & Mueller, 2013). In the end, we chose to use neither of these based on feedback from hydrology experts who pointed out various assumptions and generalizations that were made during their computation. Instead, as part of the HSA determination, we identified slope grades that maximized runoff potential (Nassif & Wilson, 1975) as areas that need to be kept intact. There was extended discussion around assignment of scores to slope grades. Ultimately, we decided to look at slope from a land conservation versus development perspective. We gave the lowest score to areas that were not at risk of being developed and applied higher scores to those areas that would cause the most damage to water quality/quantity if they were developed.

8. As new data is continuously being produced and updated, it would be valuable to incorporate these into future iterations of an HSA map. Specifically, the model would benefit from improved wetland inventories, LIDAR-created wet-area mapping, flood hazard areas that extend beyond populated areas, soil permeability data and groundwater recharge and discharge information.

References

ABMI. (2019). *ABMI Data and Analytics Portal*. Retrieved from Predictive Landcover 3.0 and ABMI Wetland Inventory: https://abmi.ca/home/data-analytics/da-top/da-product-overview/Advanced-Landcover-Prediction-and-Habitat-Assessment--ALPHA--Products.html

Alberta Geological Survey. (2013). *Surficial Geology of Alberta*. Retrieved from Open Data: http://geology-ags-aer.opendata.arcgis.com/datasets/surficial-geology-of-alberta-generalized-digital-mosaic-dig-2013-0002?geometry=-166.812%2C45.024%2C-63.101%2C62.793

Alberta Government. (2005). *Natural Regions and Subregions of Alberta*. Retrieved from GeoDiscover Alberta: https://geodiscover.alberta.ca/geoportal/catalog/search/resource/fullMetadata.page?uuid=%7B130A9885-D79E-4964-B31F-8331506B76D5%7D

Alberta Government. (2011). *South Saskatchewan Regional Plan - Groundwater Vulnerability*. Retrieved from GeoDiscover Alberta: https://geodiscover.alberta.ca/geoportal/catalog/search/resource/fullMetadata.page?uuid=%7B835844A6-7576-48C1-A674-E602B2A54BE1%7D

Alberta Government. (2012). *Stepping Back from the Water: A Beneficial Management Practices Guide for New Development Near Water Bodies in Alberta's Settled Region.* Edmonton: Alberta Government.

Alberta Government. (2015). *Digital Flood Hazard Mapping*. Retrieved from GeoDiscover Alberta: https://geodiscover.alberta.ca/geoportal/catalog/search/resource/fullMetadata.page?uuid=%7B41C92445-1244-4985-99F8-CEE0C090B839%7D

Alberta Government. (2017). *Lotic Riparian - Digital Elevation Model (DEM) Derived*. Retrieved from GeoDiscover Alberta: https://geodiscover.alberta.ca/geoportal/catalog/search/resource/fullMetadata.page?uuid=%7B14E2B4A7-ACA7-4BA9-B9ED-FBE8B0FFE5B9%7D

Alberta Government. (2019). *Alberta Merged Wetland Inventory*. Retrieved from GeoDiscover Alberta: https://geodiscover.alberta.ca/geoportal/catalog/search/resource/details.page?uuid=%7BA73F5AE1-4677-4731-B3F6-700743A96C97%7D

AltaLIS. (2018). *20K Base Features*. Retrieved from AltaLIS Products - Base Features: http://www.altalis.com/products/base/20k_base_features.html

AltaLIS. (2018). *DEM*. Retrieved from Products - Terrain: http://www.altalis.com/products/terrain/dem.html

Associated Environmental. (2018, April). *Oldman Watershed Priority Mapping.* Retrieved from Southern Alberta Land Trust Society: https://salts.land/wp-content/uploads/2018/05/Oldman-WS-Priority-Technical-Report.pdf

B.C. Government. (2014). *Develop with Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia.* Victoria: B.C. Government.

Barten, P. K., & Ernst, C. (2004). Land Conservation and Watershed Management for Source Protection. *American Water Works Association Journal*, 98: 4.

Beacon Environmental Ltd. (2012). *Ecological Buffer Guideline Review.* Markham, Ontario: Credit Valley Conservation.

British Columbia Government. (1999). *Forest Practices Code Mapping and Assessing Terrain Stability Guidebook.* British Columbia Ministry of Forests.

City of Nanaimo. (2005). *Steep Slope Development Permit Area Guidelines.* Nanaimo: City of Nanaimo.

Fiera Biological Consulting. (2010). *Aquatic Environmentally Significant Areas in Alberta.* Edmonton: Alberta Environment.

Government of Canada. (2013). *Slope Gradient*. Retrieved from Agriculture and Agri-Food Canada: http://sis.agr.gc.ca/cansis/nsdb/slc/v3.2/cmp/slope.html

Government of Canada. (2018). *Annual Crop Inventory*. Retrieved from Open Government: https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9

Hamann, A. (2013). *Climate Data*. Retrieved from University of Alberta: https://sites.ualberta.ca/~ahamann/data.html

Hamann, A., Wang, T., Spittlehouse, D. L., & Murdock, T. Q. (2013). A Comprehensive High-Resolution database of Historical and Projected Climate Surfaces For Western North America. *American Meteorological Society*, 307-309.

Kienzle, S. W., & Mueller, M. (2013). Mapping Alberta's Surface Water Resources for the Period: 1971 - 2000. *The Canadian Geographer*, 57(4): 506-518.

Klassen, J., Liggett, J. E., Pavlovskii, I., & Abdrakhimova, P. (2018). *First-order groundwater availability assessment for southern Alberta.* Edmonton: Alberta Energy Regulator / Alberta Geological Survey.

Mu, W., Yu, F., Li, C., Xie, Y., Tian, J., Liu, J., & Zhao, N. (2015). Effects of Rainfall Intensity and Slope Gradient on Runoff and Soil Moisture on Different Growing Phases of Spring Maize. *Water*, 2990-3008.

Nassif, S. H., & Wilson, E. M. (1975). The Influence of Slope and Rain Intensity on Runoff and Infiltration. *Hydrological Sciences, XX, 4 12*, 539-553.

Trust for Public Land and the American Water Works Association. (2005). *Source Protection Handbook: Using Land Conservation to Protect Drinking Water Supplies.* Washington D.C.: U.S. Environmental Protection Agency.

United States Department of Agriculture - Soil Conservation Service. (1989). *Runoff Curve Number Computations.* United States Department of Agriculture.

Wiki GIS. (2018, November 2). *Jenks Natural Breaks Classification*. Retrieved from Wiki.GIS.com: http://wiki.gis.com/wiki/index.php/Jenks_Natural_Breaks_Classification#:~:text=The%20Jenks%20Natural%20Breaks%20Classification,naturally%22%20in%20a%20data%20set.