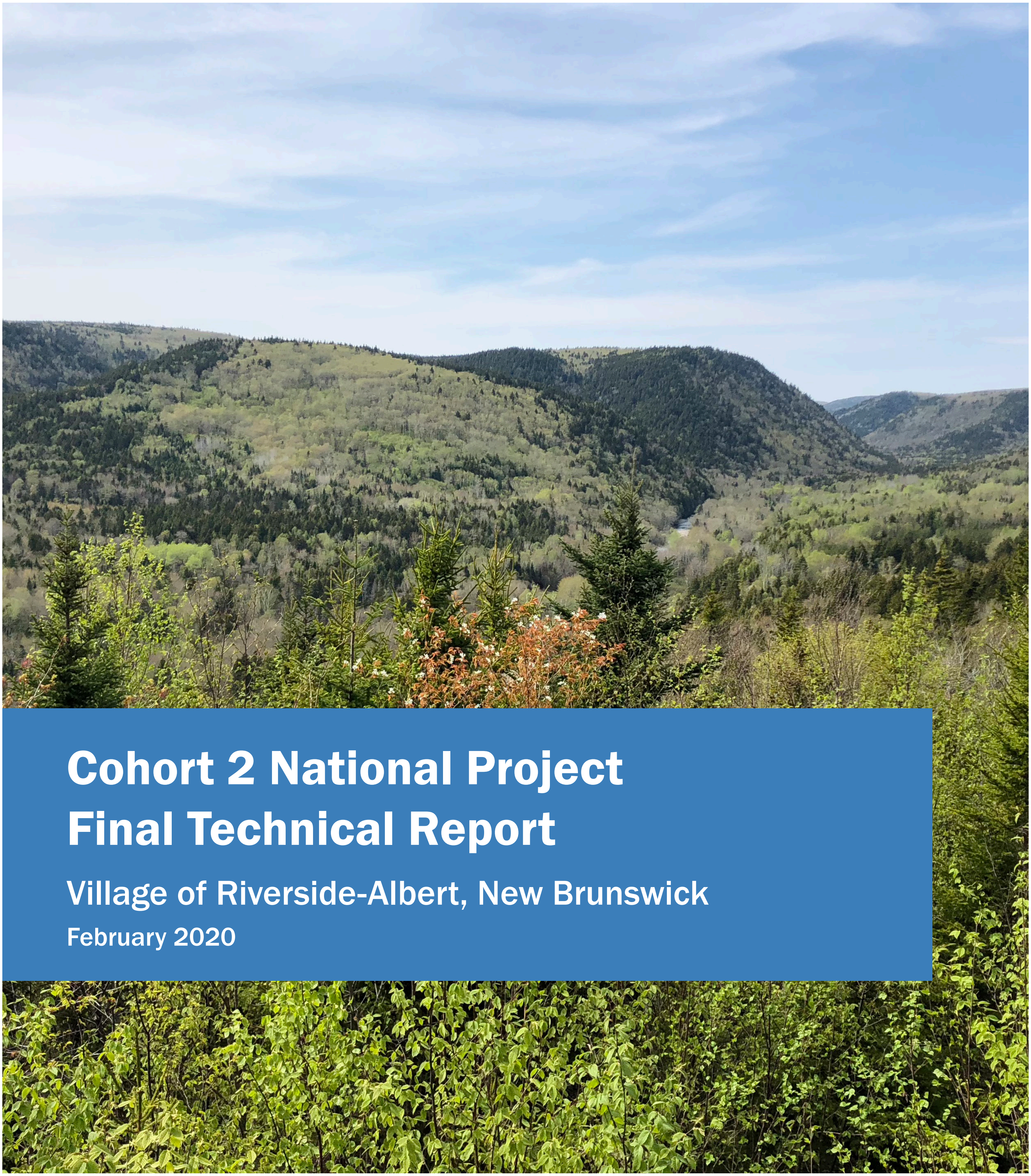

Cohort 2 National Project Final Technical Report

Village of Riverside-Albert, New Brunswick

February 2020

Municipal Natural Assets Initiative

Making Nature Count

INVEST IN NATURE

The Municipal Natural Assets Initiative (MNAI) is changing the way municipalities deliver everyday services, increasing the quality and resilience of infrastructure at lower costs and reduced risk. The MNAI team provides scientific, economic and municipal expertise to support and guide local governments in identifying, valuing and accounting for natural assets in their financial planning and asset management programs and developing leading-edge, sustainable and climate resilient infrastructure.

Acknowledgements

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Convening Organizations

Convening organizations: Smart Prosperity Institute, David Suzuki Foundation, Town of Gibsons, BC, and Roy Brooke and Associates were the original convening partners for the Municipal Natural Assets Initiative and the Cohort 2 project leading to this report was initiated by them.

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Summary

The term "municipal natural assets" refers to the stock of natural resources or ecosystems that is relied upon, managed, or could be managed by a municipality, regional district, or other form of local government for the sustainable provision of one or more local government services (MNAI, 2017). Communities like Riverside-Albert recognize that it is as important to understand, measure, manage and account for natural assets as it is for engineered ones. The Municipal Natural Asset Initiative (MNAI) project was initiated by Southeast Regional Service Commission (SERSC) in partnership with the Village of Riverside-Albert to increase their understanding of natural assets in their community and how they can be managed for a sustainable drinking water supply. Specifically, the goal of the Riverside-Albert MNAI project was to assess the watershed area known as the Arabian Vault that supplies drinking water to the Village and seek to understand key management actions to maintain and improve the area's long-term water supply.

The Arabian Vault Brook watershed area is comprised of 48.6% private land, 29.2% Crown land, 18.9% conserved land, and 3.4% municipal land. For this project, a continuous simulation model was created to estimate the runoff volumes over time based on different climate and land cover assumptions. The model was run between the years 1999 and 2018 to reflect a range of weather conditions and their impact on water supply. The modelling objective was to understand and quantify the potential water supply that is provided by the watershed.

The modelling results demonstrate that while there is generally ample water flows available to meet the community's current water demand needs, there are annual low flow periods that could result in future water supply shortages, especially in the context of climate change and economic development (i.e. increased tourism). Results demonstrate that climate change could impose significant changes to the flow patterns as a result of greater precipitation in winter and earlier snow melt.

The value of the water supply benefits provided by the Arabian Vault Brook watershed were estimated to range from $0.8 to $1.2 million based on the cost of establishing a groundwater source system to replace the current surface water source system. The value of the system was also estimated based on the cost of trucking water to the community from outside sources. This approach resulted in an estimated value of $0.8 million per year based on current average water demand or $1.1 million per year assuming the maximum daily demand occurred. These perpetual annual costs were converted to present values demonstrating a value of the watershed's water supply in the range of $27 to $37 million. These estimated values do not include co-benefits associated with the watershed, including benefits related to wildlife habitat, hydraulic detention and human health improvements.

Natural asset management plans articulate strategies and tasks for conservation, land use, interpretation, operations and maintenance of natural assets. Such a plan for the Arabian Vault Brook watershed would specify actions to protect and conserve the watershed to ensure sufficient water quantity and quality for the Village of Riverside-Albert for years to come. In the case of the Arabian Vault Brook watershed, while long term water quantity may be less of a concern (on an average, annual basis), water quality has been a concern in the past (between November 2014 and September 2018 high turbidity resulted in 10 boil water advisories that totalled 79 days) and may be more of a concern in the future. Taking into consideration expected increases in precipitation due to climate change, it was found that the number of boil water advisories could increase from an average of 3.7 per year to 4.18 per year by 2050. Forest harvesting in the watershed would exacerbate this result and highlight the importance of the forest as a natural asset to retain soil in the watershed. Negative impacts resulting from forest harvesting and climate change could result in increased cost to treat the drinking water supply, increased reservoir sedimentation leading to more frequent maintenance, and a degradation in aquatic habitats due to increased total suspended solids in waterbodies.

To manage risks to water quality in the future, it is recommended that the Village and SERSC engage the province to discuss conservation of the Crown land and participate in a watershed management planning process to ensure any forest activity on the land protects water supply quality. Improving water storage capacity will also be important to increase storage during boil water advisories and to increase the volume of water than can be stored in the system (i.e. through additional retention ponds and other water storage infrastructure), especially during summer months when water flows are lower and tourism potential is greatest. Opportunities to reduce lost water from the spillways in the north and south ponds should also be considered. This could include consideration of naturalized/green infrastructure options.

1 Introduction

The term "municipal natural assets" refers to the stock of natural resources or ecosystems that is relied upon, managed, or could be managed by a municipality, regional district, or other form of local government for the sustainable provision of one or more local government services (MNAI, 2017). By conceptualizing nature as an asset, we can codify, measure, and track the ways in which we depend on and impact the environment. Business and economic activity depends on natural assets to provide important inputs into production such as clean water, minerals, and timber. Natural assets are also important to human physical and social well-being. Benefits in terms of better air quality, water quality and climate stability as well as protection from flood and erosion impacts of extreme weather events are well established. Urban greenspaces, parks, wetlands and protected areas provide important recreation spaces and buffer the effect of extreme heat in urban settings reducing the prevalence of respiratory infections and heat related illnesses. If natural assets are not managed responsibly, their value depreciates as does their ability to provide services from which humans benefit. Indeed, like any asset, natural assets need to be carefully managed to ensure a sustainable supply of services.

Communities like Riverside-Albert recognize that it is as important to understand, measure, manage and account for natural assets as it is for engineered ones. The Municipal Natural Asset Initiative (MNAI) project was initiated by Southeast Regional Service Commission (SERSC) in partnership with the Village of Riverside-Albert to increase their understanding of natural assets in their community and how they can be managed for a sustainable drinking water supply (see Box 1). In their role of supporting municipalities within their regional jurisdiction, SERSC conducted the work on behalf of the Village of Riverside-Albert. The Village of Riverside-Albert was regularly consulted on key aspects of the project and provided essential input and data. This report summarizes the results of the Riverside-Albert project. It is organized as follows:

- This **Introduction** chapter describes the project objectives, the project area and provides a brief overview of the relevant natural assets.
- The **Approach** chapter describes the modelling approach that was employed to assess the contribution of the assets to water supply as well as key data sources that informed the analysis.
- The **Natural Assets Assessment** chapter describes the quantity and condition of natural assets in the project area.
- The **Planning for Natural Assets** chapter provides direction on how to manage the natural assets for improved water supply.
- The **Implementation of Natural Assets Plan** chapter describes specific actions that should be considered as a natural asset plan to protect the natural assets of interest.
- The **Conclusion** chapter summarizes the approach and findings of the project and articulates next steps and key priorities for the Village of Riverside-Albert.
- **Appendices** at the end of the report contain additional information of relevance to the project and associated outcomes.

1.1 Objective

The goal of the Riverside-Albert MNAI project was to assess the watershed that supplies drinking water to the Riverside-Albert community and seek to understand key management actions to maintain and improve the area's long-term water supply, taking into consideration potential economic development such as tourism. The key objectives of the project were to:

- Assess the potential water quantity supply from the watershed in light of future climate and potential forest harvesting.
- Assess the current and potential future water demand.
- Assess the economic value of the watershed's provision of drinking water to the community of Riverside-Albert.
- Assess the operations and maintenance costs of a water filtration plant.

1.2 Project Area

Riverside-Albert is a small community with a population of approximately 350. The community has limited access to human resources and could greatly benefit from natural approaches to reduce infrastructure costs, including to:

- reduce operating and maintenance costs of water filtration,
- maintain a supply of clean drinking water as the climate changes, and
- meet increased demand for water that may result from tourism, which could provide the village with a vital source of sustainable income.

The Village relies on a consistent flow of surface water provided by the forested Arabian Vault Brook watershed (Figure 1) to service the community's municipal water supply needs.

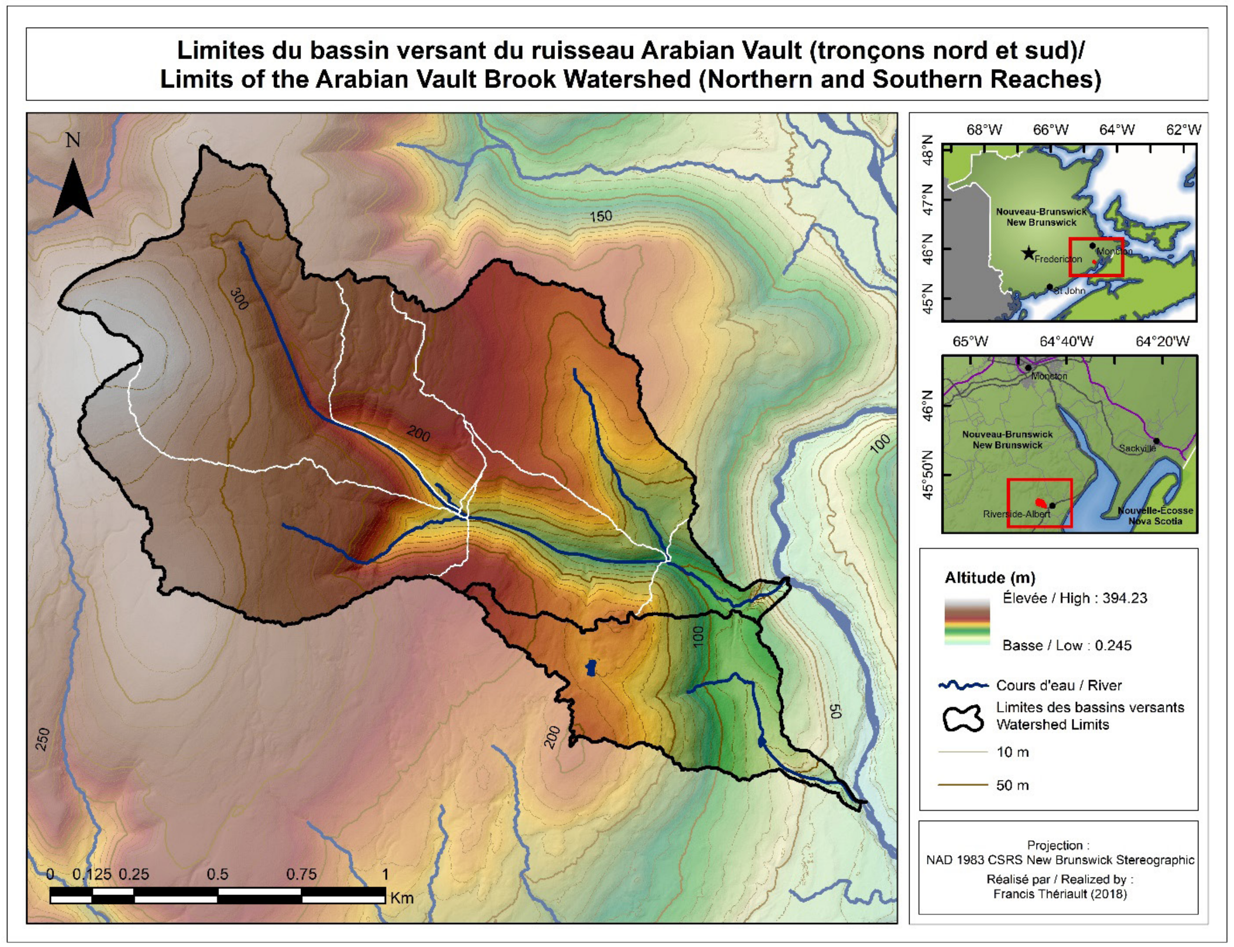

Figure 1. Overview of the Arabian Vault Brook watershed. Source: SERSC

1.3 Natural Asset Focus

MNAI defines natural assets as ecosystem features that are nature-based and provide services that would otherwise require equivalent engineered infrastructure (MNAI 2017). For local governments, natural assets can include forests that convey stormwater and recharge aquifers, wetlands that reduce flooding risk, and coastal areas that protect against storm surges and sea level rise, among others. By identifying natural assets at the community level and prioritizing such assets in municipal asset management portfolios, local governments can often secure budget savings while delivering vital municipal services and other co-benefits. Local governments will also be better prepared to deal with the effects of climate change (MNAI 2017).

For this project, the natural assets of interest were defined as the two interconnected watersheds (shown in Figure 1). The watersheds are known as the Arabian Vault, and has provided the Village of Riverside-Albert with a public water system since the 1920's. The Arabian Vault is located outside of the municipal boundaries on the other side of Crooked Creek, which forms the Village's western boundary (Figure 2) and consists of North and South watersheds.

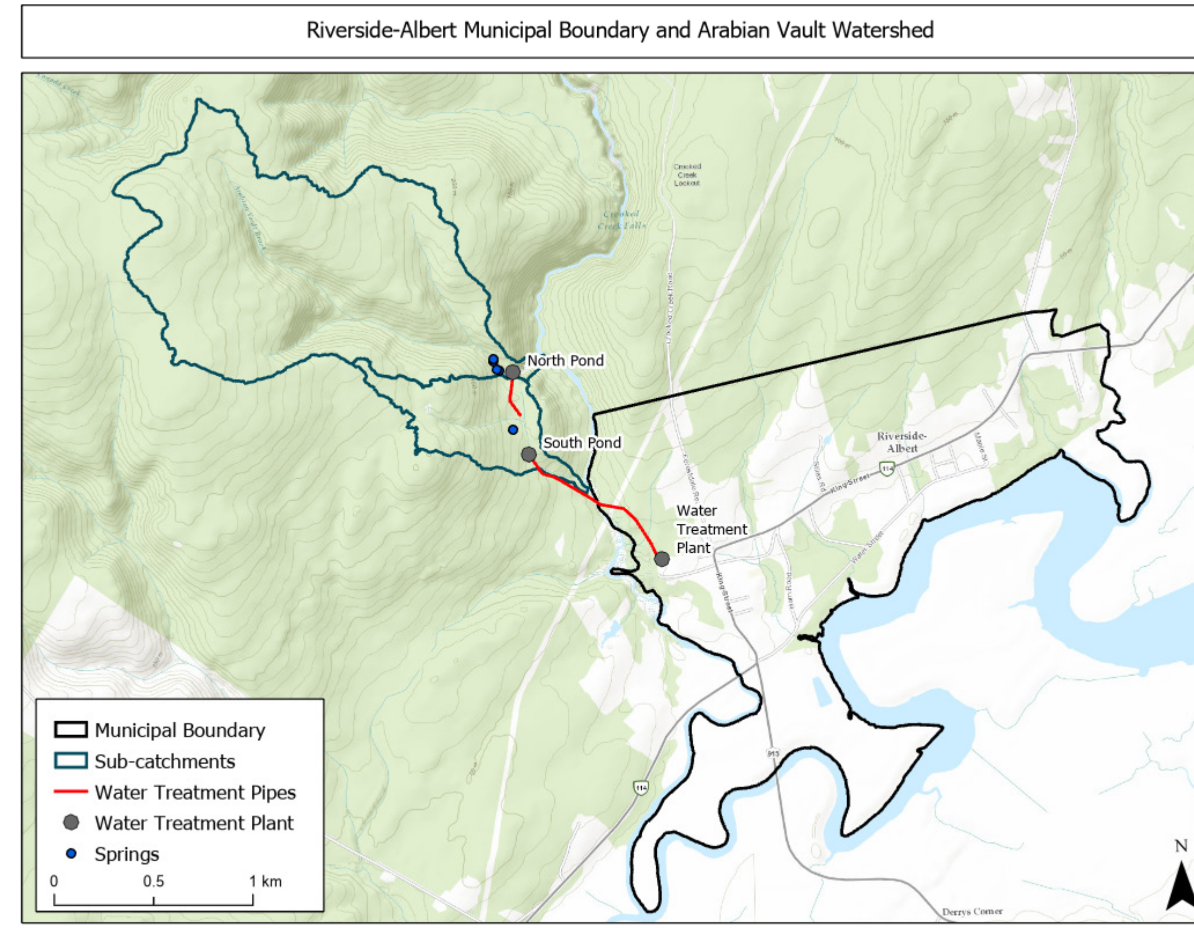

Figure 2. Riverside-Albert municipal boundary in relation to the Arabian Vault watershed. Source: SERSC

Flow from the north watershed is diverted to the south watershed via pipe. A reservoir in the south watershed has historically provided storage capacity in the event of low flows. In the 1980's, a settlement pond and small reservoir in the north watershed were added to the water distribution system to improve water quality (settlement of sediments) and to provide additional storage. The system is gravity fed, and water is transported from the larger South reservoir to a water treatment facility located within the village on the east side of Crooked Creek (Figure 2).

The Arabian Vault is provincially designated as both a protected watershed and protected wellfield. These designations limit activities within the watershed to reduce risks to water quality. A large portion of the Arabian Vault watershed is within a protected wellfield – Zone A – which only permits the removal of trees in forested areas to prevent the spread of pests and disease or to remove dead or fallen trees. By contrast, protected watershed Zones B and C, permit some forestry activities.

The Arabian Vault watershed has a number of land uses and has designations to limit potential negative impacts to water quality under the federal *Clean Water Act*. A large portion of both watersheds is owned by the Nature Conservancy of Canada following a land purchase in May 2018. The Nature Conservancy of Canada completed the purchase in recognition of the importance of the watershed in providing clean drinking water and the presence of rare, old-growth Acadian forest. As of May 2019, 29.2% of the Arabian Vault watershed was Crown land, that has been periodically harvested, 48.6% is private land, and Riverside-Albert owns 22 acres of land surrounding the reservoirs for the purposes of perpetual conservation and the management of drinking water (Figure 3 and Table 1).

Land Ownership within the Arabian Vault Watershed (Northern and Southern Sub-catchments)

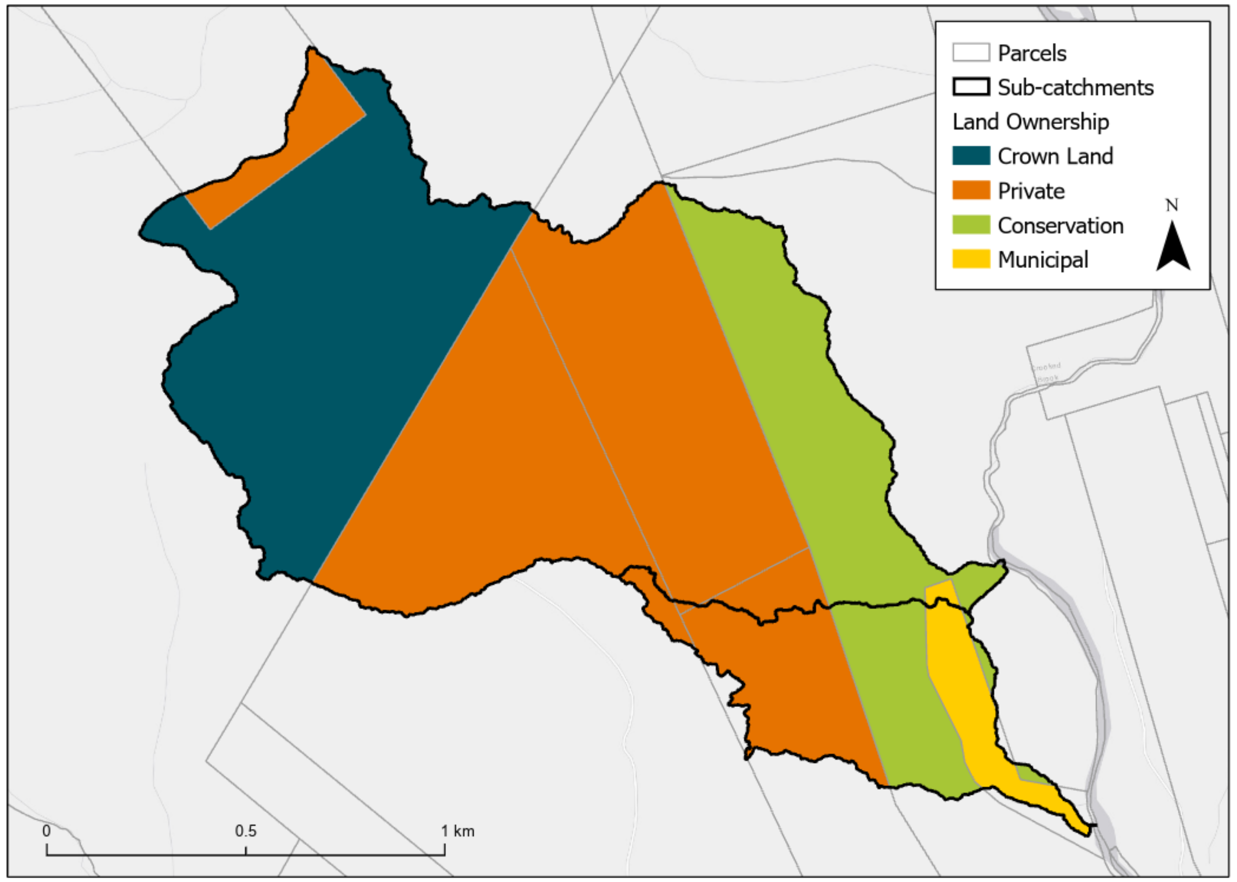

Figure 3. Overview of land ownership within the Arabian Vault watershed (May 2019). Source: SERSC

TABLE 1 - LAND OWNERSHIP IN THE ARABIAN VAULT BROOK WATERSHED (MAY 2019)	
Ownership	**Percent area (%)**
Private	48.6
Crown Land	29.2
Conservation	18.9
Municipal	3.4

To date, the watersheds have been able to provide a reasonably consistent supply of drinking water to the Village of Riverside-Albert, with the exception of an occasional drought year that has impacted supply. However, this may change in the future.

Increased tourism represents a major opportunity for the Riverview-Albert area. The increase in tourism is due to the completion of the Fundy Parkway, a scenic drive from St. Martins to Alma National Park. This project will increase road traffic along Route 114, which passes through Riverside-Albert and connects Fundy Park/Fundy Parkway to Moncton and the trans-Canada Highway. A regional trail is also in development that will connect Fundy National Park to Moncton and will pass through Riverside-Albert.

Additional tourism could increase demand for potable water during summer months, when low water flow events take place. Potential impacts from climate change and increased demand from tourism could also put pressure on the local water supply.

Box 1: About the Southeast Regional Service Commission (SERSC)

In 2013, the province of New Brunswick adopted a new governance model and created 12 Regional Service Commissions to provide mandated and optional services through cost sharing agreements. The Southeast Regional Service Commission's planning branch provides land planning and related services to the 12 municipalities and 3 unincorporated areas in the region. They are also tasked with the creation of a regional plan that provides oversight for municipal plans and that includes many different initiatives that are ongoing such as climate change plans, asset management, trail development and flood mapping. The Southeast Regional Service Commission's work with the MNAI team has helped to refine these initiatives and provided the Commission with new tools to incorporate natural assets into policy within a regulatory framework.

2 Approach

This section of the document describes the approach employed to complete the Riverside-Albert project. An overview of the MNAI approach is provided along with a more detailed description of the modelling work that was completed.

2.1 MNAI Approach

MNAI's natural asset methodology is rooted in modern, structured asset management processes. The methodology follows the standard asset management assess, plan and implement steps, highlighting novel considerations required for local natural assets and associated services.

MNAI has a range of tools, including templates and guidelines, that are configured for use according to local government needs. The methodology and tools are delivered through ongoing support from the MNAI technical team over the project life. The levels and details of this support are described in a Memorandum of Understanding that MNAI signs with local government partners.

Asset management strategies require a multi-disciplinary, team-based approach. The MNAI process thus begins with an initial engagement session with community representatives from a range of disciplines. This includes, for example, representatives from Parks, Public Works, GIS, Engineering, Planning, Water and Wastewater, and Finance. During the initial engagement session, plans and priorities of the Village are discussed, and key natural assets within the jurisdictional boundaries of the community are identified along with the important services they provide. Site visits to the natural assets may be undertaken and key geospatial features observed and documented. The objectives of this initial engagement session are to identify:

- the natural asset/s that will be the focus of the natural asset assessment,
- the geographic boundary(ies) of the focus assets,
- the skillsets and expertise of relevance to the natural asset assessment,
- community personnel that will engage in the assessment process, and
- data needs of the assessment and the sources for the relevant data.

The initial MNAI community engagement session for the Riverside-Albert project took place on May 23-24, 2018. It was attended by representatives from both Riverside-Albert (including the mayor and their public works superintendent) and the SERSC team. Appendix A contains the agenda for the session along with a list of participants. At the completion of the session, the focus on the role of natural assets in supporting improved water quality in the Arabian Vault was established.

Following the initial community engagement session, the MNAI team works with the target community to complete a natural asset assessment. The assessment generally involves the following steps:

1. Defining the scope of natural assets.
2. Inventorying the natural assets by collecting and organizing existing information about the assets.
3. Conducting a condition assessment of the assets.
4. Conducting a risk assessment of the assets.
5. Quantifying existing service levels from the assets.
6. Developing scenarios to explore alternative management plans and future implications to existing service levels.
7. Quantifying services levels under alternative scenarios.
8. Developing operation and management plans based on existing conditions, risks, and desired service level trajectories.

The steps above were completed for Riverside-Albert with a focus on drinking water supply. The scope of the project was determined by weighing the project objectives against data availability and proposed modelling and economic approaches. The asset inventory was informed by land cover data obtained for the area. The condition and risk assessments were conducted in consultation with community representatives. The same approach was taken to defining the alternative management scenarios and future implications to existing service levels. As is described in detail below, 4 scenarios were assessed for Riverside-Albert. The modelling approach was employed to quantify the service levels under the alternative scenarios (Step 7 above) is described below.

2.2 Modelling Approach for Scenario Analysis

As is noted above, the natural assets of interest are the watersheds that supply drinking water to the Riverside-Albert community. The modelling steps employed for each scenario are described below.

HEC-HMS software was used to create a hydrologic model of the Arabian Vault Brook watershed. This is a freely available software, which can run both continuous and event- based simulations at a variety of time-steps. HEC-HMS allows users to create a hydrologic model that uses a variety of hydrologic parameters (e.g. runoff, evaporation, snowmelt) to estimate the runoff from a watershed for a given rainfall event, based on a suite of physical characteristics of a given watershed (e.g. size, slope, length/width, surface cover, soil types). For this project, a continuous simulation model was created to estimate the runoff volumes over time based on different climate and land cover assumptions. The model was run between the years 1999 and 2018 to reflect a range of weather conditions and their impact on water supply.

The modelling objective was to understand and quantify the potential water supply that is provided by the watershed. In other words, the model informs the service provision provided by the watershed by:

- estimating average annual runoff volumes from the watershed, and
- exploring the impacts of climate change, including major weather events:
  - » rainfall/runoff will increase/decrease on an annual basis, and
  - » changes will be averaged throughout each year, or be more extreme from season to season (i.e. wetter fall and winter, but drier summer).

To accomplish this, the following model scenarios were developed:

- current climate conditions with current land cover,
- current climate conditions with worst case land cover[1],
- future climate change conditions with full watershed protection, and
- future climate change conditions with worst case land cover.

The following subsections summarize the model setup and describe the scenario development process.

2.2.1 Climate Conditions

It is anticipated that climate change will affect the short- (daily), mid- (monthly) and long- (annual) term water quantity provided by the Arabian Vault for the Village of Riverside-Albert.[2] In the southeastern New-Brunswick region, projections show an increase in seasonal precipitation and temperature. To reflect this, the modelling explores impacts of the projected worst-case scenario of greenhouse gas (GHG) emission (RCP 8.5[3]) in the Arabian Vault Brook watershed for the 2050 horizon. To do so, the Atlantic Climate Adaptation Solutions Association's (ACASA) New Brunswick's Future

1 The worst-case land cover scenario was based on assumed extensive forest clear cutting on Crown land where the prospect of harvesting was deemed the highest. See section 2.2.2 for more details.

2 Roy, P. and Huard D. (2016). Future Climate Scenarios - Province of New-Brunswick. Montreal: Ouranos. http://acasav2.azurewebsites.net/#

3 Climate scientists use a set of four standard 'representative concentration pathways', or RCPs to tell a story about how the climate will fare in the year 2100, A higher RCP number generally denotes a more extreme fate. The worst case scenario is RCP 8.5.

Climate Projections[4] precipitation and temperature data were used, which provided information on the projected change for those variables on a seasonal basis. These changes in climate patterns on the historical observation records (1980-2010) were forecasted by global climate models (GCMs) (Figure 4 and 5). In this project, the Moncton A station (ID: 8103200) and Alma station (ID: 8100200) variables were selected and averaged to represent the Arabian Vault Brook's watershed climate. The percent change in precipitation and the difference in temperature for the meteorological seasons were applied on the entire 20-year simulations.

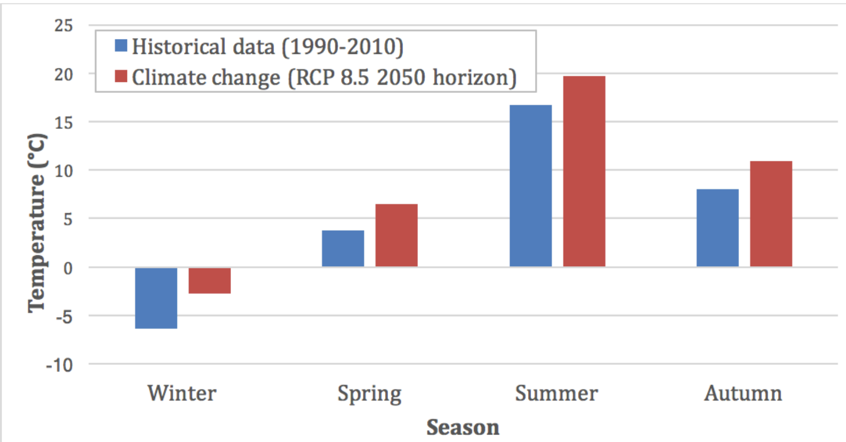

Figure 4. Seasonal average temperature comparison between the historical data and climate change scenario. Source: SERSC

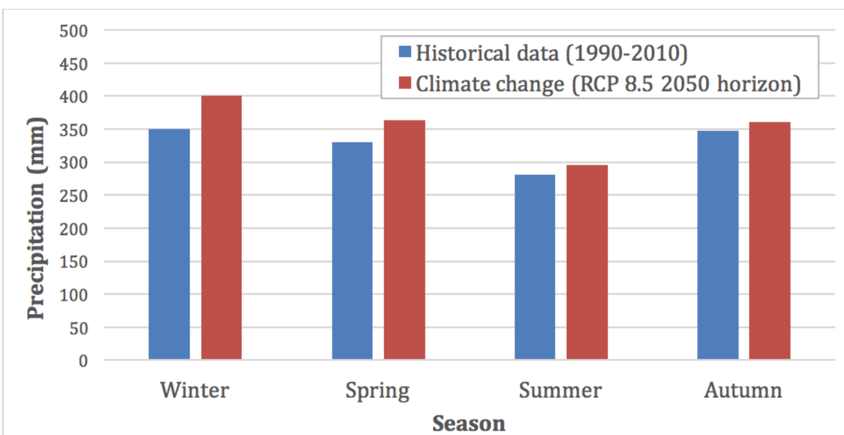

Figure 5. Seasonal average precipitation comparison between the historical data and climate change scenario. Source: SERSC

2.2.2 Land Cover Conditions

The land cover was generated using multiple datasets (Table 3). Land use data (for example evapotranspiration and impervious surface data) is an input into the hydrologic model (Figure 6). Data from the year 2011 was used because it is the middle year of the simulation that runs between 1999 and 2018. The worst- and best-case scenarios were developed according to future forest growth stage (sapling, young and mature) and possible forest harvesting practices on the Crown lands situated upstream of the watershed. The percent impervious cover values for harvested lands were taken from a study in British Columbia (Guthrie and Deniseger, 2001).

4 Roy and Huard, 2016

TABLE 2 - DATA SOURCES USED TO ESTABLISH LAND COVER

Dataset	Resolution	Source	Date
Landcover Data	1m	SERSC	2017
Forest Soils	Vector	GeoNB	2015
Forest Age	Vector	GeoNB	2019

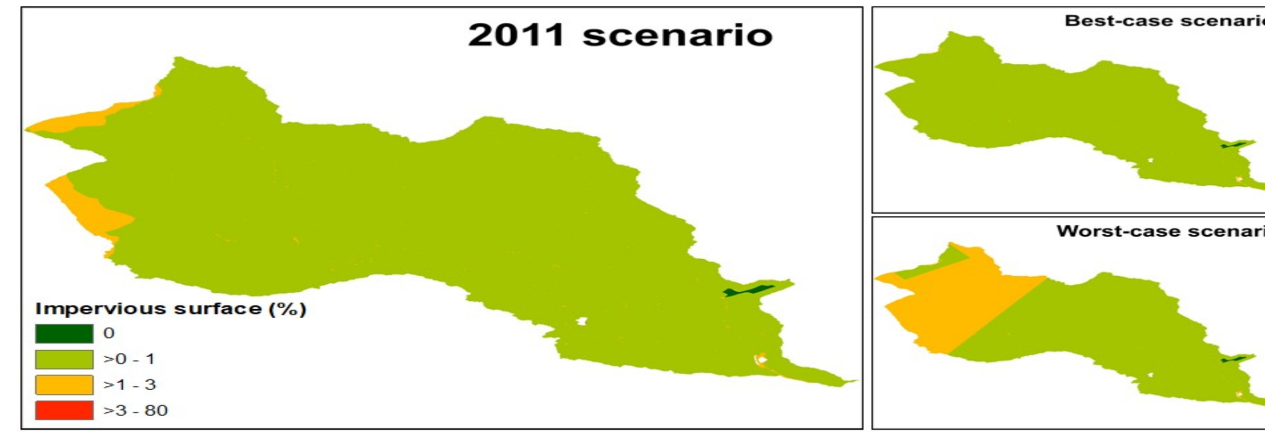

Figure 6. Impervious surface scenarios for the Arabian Vault Brook watershed used for the hydrologic modeling. Source: SERSC

2.2.3 Model Setup

HEC-GeoHMS extension for ESRI ArcMap software was used to extract the physical characteristics of the model. This is a crucial step in hydrologic modelling as the flow regime of a watershed is directly related to its geographical features including slope, land cover, drainage area, and shape. The physical model was prepared to extract key outputs near the reservoirs in the Arabian Vault Brook watershed. During this process, some sub-basins were merged and split in the model to obtain flow, volume and/or stage data at desired hydrologic elements. Based on field data, the reservoirs and water pipe locations were established, as were their characteristics (Table 3). Elevation-storage functions for the reservoirs were added in addition to two auxiliaries (diversions) set between (i) the northern reservoir and the reach upstream of the southern reservoir; and (ii) the southern reservoir and the treatment facility, which completed the parameterization of the two reservoirs.

TABLE 3 - RESERVOIR CHRACTERISTICS USED IN THE HYDROLOGICAL MODEL

Characteristics		Northern reservoir	Southern reservoir
Estimated storage capacity (m^3)		52	1 000
Outlet	Type	Culvert	Culvert
	Length (m)	244	904
	Diameter (m)	0.1	0.1
Spillway	Type	Broad-Crested	Broad-Crested
	Length (m)	2.47	1.88
	Height (m)	1.55	2

Key parameters needed for running the models were either taken from the literature or estimated from field data and empirical equations. Some parameters were calibrated to ensure the output reflected observed water level data and consultant reports. Table 4 provides a summary of these parameters.

TABLE 4 - PHYSICAL PARAMETERS USED IN THE HEC-HMS MODEL

Process	Method	Parameter	Value	Estimation
Surface	Simple	Maximum Surface Storage	100 mm	Estimated from literature
Canopy	Simple	Maximum Canopy Storage	2.5 mm	Estimated from literature
Loss	Deficit and Constant	Constant Rate	0.08 mm/hr	Calibrated
		Maximum Deficit	40 mm	Estimated from a combination of soil data and literature
		Impervious	Varies	Estimated from land cover and forest inventory data
Transform	SCS Unit Hydrograph	Graph Type	Varies	Estimated from basin slope
		Lag Time	Varies	Empirical equation
Baseflow	Recession	Recession Constant	0.85	Estimated from stage data and monthly spring contribution
		Ratio to Peak	0.2	
Routing	Muskingum Cunge	Reach physical characteristics (ex: length, slope, Manning, etc.)	Varies	Estimated from topographic data and literature

For continuous simulations, precipitation, evapotranspiration and snowmelt were considered to represent the seasonal meteorological variability in the Arabian Vault Brook watershed for a 20-year period. The methods for establishing these model components are briefly described below.

- Precipitation: Precipitation was extracted for the entire simulation period from NASA's DAYMET daily surface weather and climatological summaries web-service (Thornton et al, 2018).[5] For simplicity, the hyetograph method for all the sub-basins was used. Therefore, the spatio-temporal precipitation patterns were not considered throughout the simulation. Due to the small area of the watershed and its homogeneous land cover, the effect of these assumptions on the modelling should be minimal.
- Snowmelt: The contribution of snowmelt was estimated using the Temperature Index method in the meteorological component of HEC-HMS. The Temperature Index method uses the degree-day approach to modelling snowpack. The model computes the amount of water stored in the snowpack throughout the cold season as well as the amount of water lost via melt based on atmospheric conditions. This allows for the simulation of water being stored in the snowpack during winter. In spring, the water contained in the snowpack melts and contributes to runoff and groundwater recharge.
- Evapotranspiration: This variable plays an important role in the water cycle and groundwater recharge. The temperature-based Hargreaves method was used to assess the daily potential evapotranspiration amounts for the entire simulation period. It was selected as it provides accurate and consistent estimates of daily evapotranspiration values.
- Baseflow: Baseflow parameters influencing the shape of the hydrograph were estimated with stage data. The baseflow was also affected by the influence of 5 springs in the watershed. Their average monthly contribution was estimated using field data conducted by Jacques Whitford Environment Limited (2001) as well as flow trends from a nearby hydrometric station compiled from Environment and Climate Change Canada data (Holmes Brook site no. 9 near Petitcodiac (01BU009)).

5 https://daymet.ornl.gov/citations

3 Natural Asset Assessment

This section of the report presents the results of the assessment of natural assets within the Arabian Vault Brook watershed project area. As is noted in the Approach section, the natural asset assessment process begins with the completion of an asset inventory.

3.1 Asset Inventory

Land cover data was gathered and organized to develop the asset inventory. Table 2 summarizes the primary data inputs used to establish the natural asset inventory. The data was managed in an ArcGIS software allowing the natural asset information to be summarized and analyzed alongside other spatial data. An asset ID structure was developed to nest different organizational levels of natural assets. This approach helps track specific assets as the inventory is expanded over time to include asset attributes, their individual conditions, their relative contribution to services, and any management actions or prescriptions undertaken in the area.

The highest level of the ID structure captures watershed boundaries. The second level further specifies any sub-catchment boundaries. The third level differentiates between wetland and forest cover within each catchment boundary. Sub-catchments were used to organize the natural assets as doing so provides a way to relate the condition of the natural assets to the supply of drinking water. Figure 6 maps the landcovers within the sub-catchment areas.

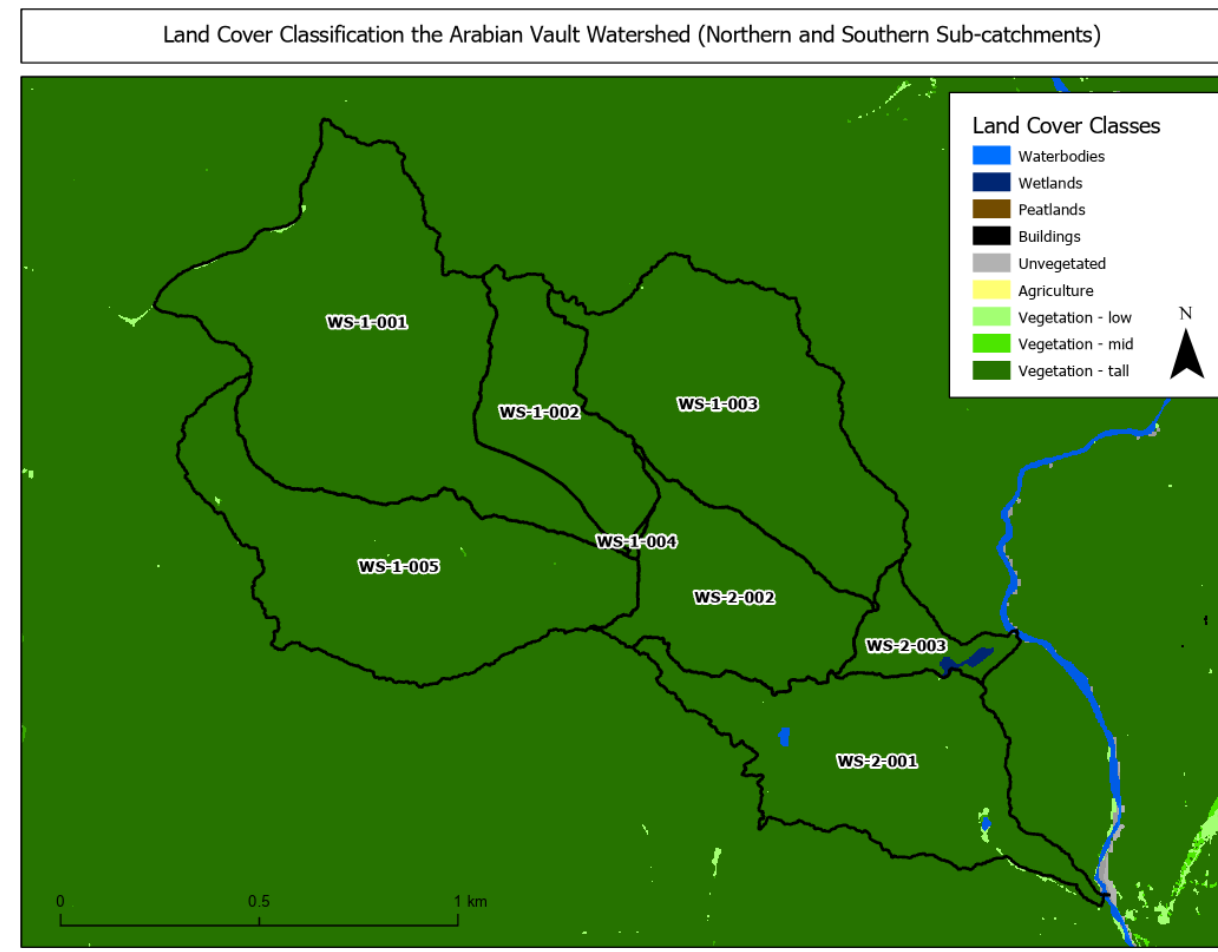

Figure 6. Land cover classication within sub-catchment areas.

TABLE 5 - LANDCOVER CLASSES BY PERCENT FOR NORTHERN AND SOUTHERN SUB-CATCHMENT		
Landcover Class	Percent of Watershed (%)	
	Northern Catchment	Southern Catchment
Waterbodies	>0.01	0.53
Wetlands	0.19	0.03
Low vegetation (Grass)	0.07	0.35
Mid Vegetation (Shrub)	0.01	0.07
Tall Vegetation (Forest)	99.71	99.01
Unvegetated	>0.01	>0.01

The asset inventory is contained in a spatial database that houses key attributes for the watersheds to help track and monitor the assets. These attributes include:

- Asset ID
- Vegetation health index (average NDVI, 0=low, 1=high)
- Runoff index (average curve number, 0=low, 100=high)
- Percent waterbodies
- Percent wetlands
- Percent unvegetated
- Percent forest by condition (good, fair, poor)
- Physical condition rating

3.2 Condition and Risk Assessment

Once the inventory was established, land cover data was organized and summarized by watershed boundary to support the condition assessment process. The goal of the condition assessment was to provide a high-level assessment of the existing natural assets to help inform future management actions and decisions pertaining to those assets. This was achieved by classifying the condition of sub-catchments. Condition ratings range from very poor to very good and were allocated based on the time since the last harvest in each sub-catchment. Very good conditions reflects old growth forest. All forest stands in the Arabian Vault Brook watershed fall into this category.

Overall, the watershed is in excellent condition. Most of the watershed is in a natural state with limited disturbance. Portions of the watershed are protected and considered to be an example of high-value, mature, Acadian forest with a mixture of northern hardwood and boreal forest. The Acadian Forest is an endangered forest type, with less than 5% of the original forest intact in the Maritimes.[6] Table 6 summarizes the condition of the project area by sub-catchment along with a sample of the data contained within the asset inventory.

6 Nature Conservancy of Canada, 2019.

TABLE 6 - ARABIAN VAULT BROOK CONDITION SUMMARY BY SUB-CATCHMENT				
Asset ID	Average Curve Number	Average NDVI	Vegetation (%)	Condition Rating
WS-2-001	30.47	0.81	93.78	Very Good
WS-1-001	30.03	0.82	100.00	Very Good
WS-1-002	30.01	0.80	100.00	Very Good
WS-1-003	30.01	0.81	100.00	Very Good
WS-1-004	30.00	0.80	100.00	Very Good
WS-1-005	30.02	0.82	100.00	Very Good
WS-2-002	30.01	0.78	100.00	Very Good
WS-2-003	34.16	0.79	94.25	Very Good

A portion of the forest in the North watershed is Crown land and has been harvested for timber. The last harvest in this area occurred 20 years ago. As a result, the area has had enough time to establish regrowth and is also in good condition. However, since these areas have not been harvested in several years, there is potential for harvest in the near to medium term. Harvesting in the watershed could pose a risk to the supply of water. As a result, one of the scenarios examined is a worst-case land cover scenario in which large tracks of the forest on Crown land are harvested.

3.3 Water Supply Benefits

This section summarizes water supply benefits provided by the entire watershed for the Village of Riverside-Albert. With current built infrastructure (i.e. 2 reservoirs and the water tower storage tank) the watershed provides ample supply to meet the existing water supply needs of the Village. Before the existence of storage capacity, shortages did occur infrequently. Since the watershed's water supply benefit is a function of its ability to meet water demand, this section begins by summarizing existing water demand. This is followed by an examination of simulated water supply flows in the context of that demand.

3.3.1 Existing Water Demand

The average daily water demand as measured in 2010/2011 was 178.6 m^3 per day.[7] This is approximately the expected demand for a municipality the size of Riverside-Albert (400 people) of 183 m^3 per day.[8] The typical water use for Riverside-Albert is roughly 65,000 m^3 per year based on the 2010/2011 usage data. During the time period for which data was available, the maximum daily extraction was 252.8 m^3 per day.

In 2006, upgrades were made to the water supply system to address water leakage. Those upgrades reduced the average daily demand from 278 cubic m^3 per day in 2005 to roughly 180 m^3 per day following the upgrades. Additional pipes were replaced in 2017, which may have further reduced leakage in the system. However, since 2010/11, supply is close to expected demand for a village of this size, and more recent data is not available. Thus, the 2010/11 data was used as the basis for estimating water demand.

7 The 2010/2011 actual water extraction data was the only data available for Riverside-Albert. Other data could not be extracted from the outdated computer system.

8 Groundwater Supply Source Investigation, Riverside-Albert, NB prepared by Exp Services Inc December 2015.

The population of Riverside-Albert has been reasonably stable since 1996 and future population growth is not expected (Figure 7). However, as noted above, there is potential for significant increases in summer tourism. At a population of 350, the average daily water taking of 178.6 m^3 per day equates to roughly 0.51 m^3 per person per day. Environment Canada (2009) estimated that municipalities in Canada with less than 1,000 people use an average of 0.756 m^3 per person per day and an average residential water use of 0.426 m^3 per person per day. Riverside-Albert's average total water use per person aligns with these national statistics.

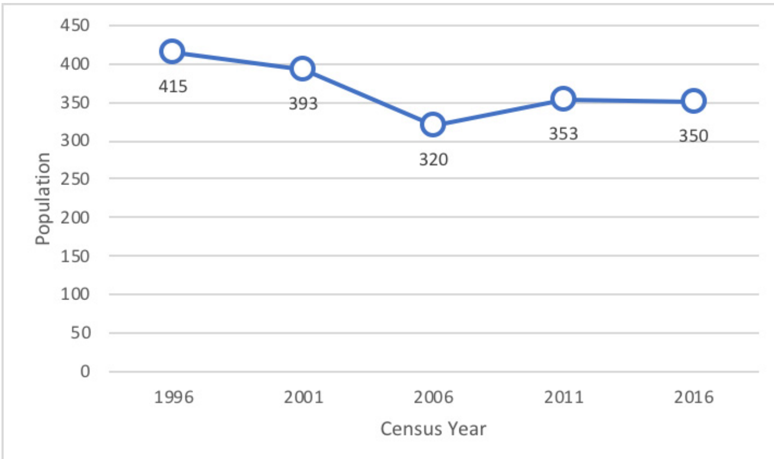

Figure 7. Population trend for Riverside-Albert by census year.

3.3.2 Total Potential Supply

Simulated water flows to the towns water storage reservoirs were estimated to range from 200 m^3 per day to over 1,100 m^3 per day, depending on the time of year. Figure 8 depicts the simulated daily water flows to the entrance of the water storage reservoirs. As depicted, the watershed provides a significant volume of water during the spring when the snowpack melts. The other key pattern that stands out in Figure 8 is the consistently low flows every year during August and September, and occasionally October.[9] Along with the simulated daily flows, Figure 8 shows the average (dashed blue horizontal line) and maximum (dashed green horizontal line) daily water taking by the Village of Riverside-Albert. As the figure demonstrates, simulated flow rates never fall below the average daily water taking. However, every year during the low flow periods, the maximum daily water taking exceeds the simulated water flow.

These results suggest that while there is generally ample water flows available to meet the community's needs, there are annual low flow periods that could result in water shortages, especially in the context of climate change and economic development. Table 8 shows the potential number of water shortage days if water use rates are extracted based on the maximum water taking rate. Increased tourism could further exacerbate this risk especially during summer months when tourism is highest in the region. For instance, Gossling et al. (2012) estimates that tourists to Canada consume roughly 150 L per person per day (or 0.15 m^3 per tourist per day). If the average daily extraction rate is taken as the expected consumption rate for local users (i.e. 180 m^3 per day) to push this to the maximum rate of 250 m^3 per day would require 466 visitors to the village. However, as can been seen in Figure 8, during low flow periods, the threshold can be as low as 200 m^3 per day. To surpass this threshold would only require 133 visitors to the village.

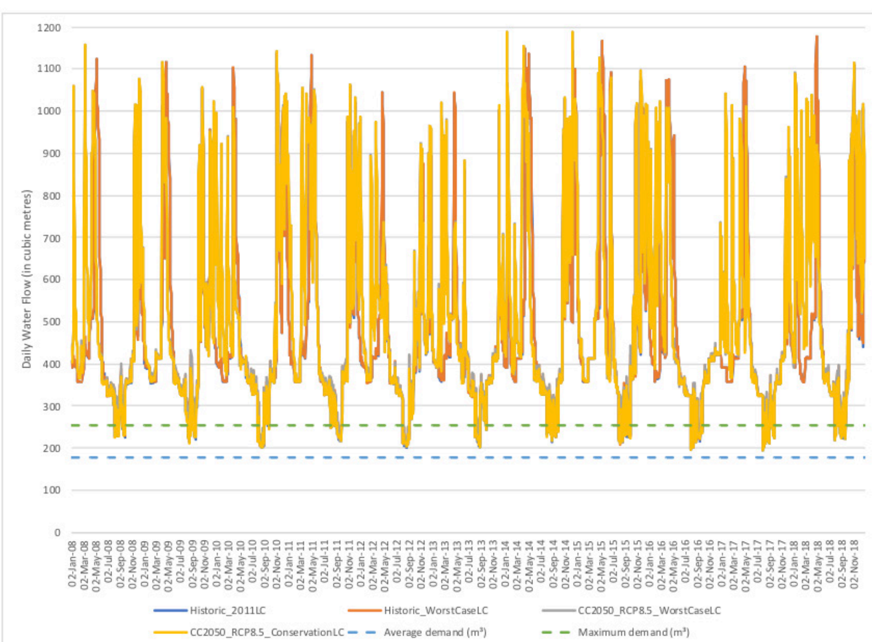

Figure 8. Simulated daily water flows by land cover and climate scenario from 2008 to 2018.

Note: 'Historic' climate scenario refers to current climate'

9 These patterns were found for all 20 years of the simulation. For simplicity, Figure 8 only shows the most recent 10-year period.

TABLE 7 - SUMMARY OF DAYS WHERE WATER FLOWS WERE LESS THAN THE MAXIMUM WATER TAKING RATE FOR EACH MODELLED SCENARIO	
Scenario	**Number of days water flows were below the maximum water taking rate during the 20-year simulation**
Historic_2011LC	623
Historic_WorstCaseLC	477
CC2050_RCP8.5_ConservationLC	619
CC2050_RCP8.5_WorstCaseLC	469

Comparing the average monthly conditions over the 20-year simulation relative to the baseline conditions (Figure 9), shows that for both climate change scenarios, regardless of land cover change, there are significant increased flows for most of the year and particularly during the winter months (December through March), significantly reduced flows in May (the result of early snowmelt), and relatively similar flows in June through November. Overall, Figure 9 highlights that the simulation results suggest limited impact from land cover on the flow rates can be expected. However, climate change could impose significant changes to the flow patterns as a result of greater precipitation in winter and earlier snow melt.

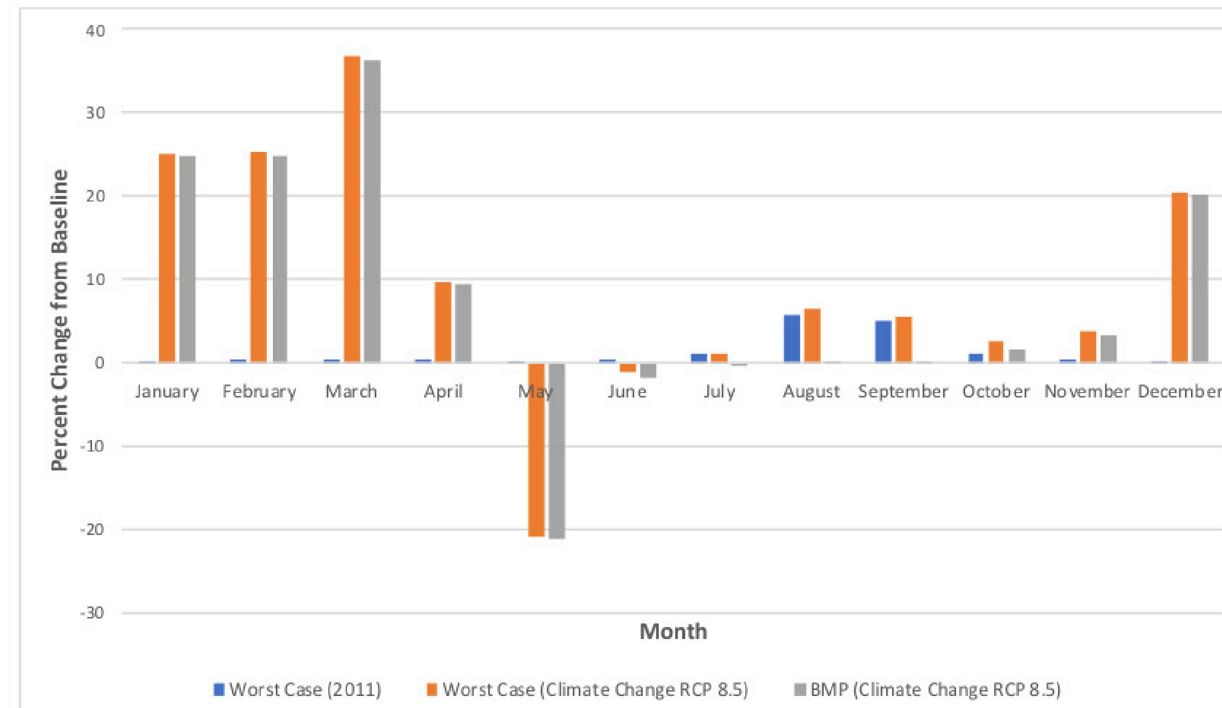

Figure 9. Monthly average percent change in flows from baseline by scenario.

3.3.3 Existing Storage Capacity

In addition to the flow of surface water, the village has some water storage capacity. This limits their reliance solely on stream flow (during water flow shortages) and helps deal with water quality issues (during high turbidity events). The current total storage capacity is provided by 2 reservoirs and one water holding tank as follows:

- Northern reservoir = 52 m^3
- Southern reservoir = 1,000 m^3
- Water holding tank = 722 m^3

At any given time, Riverside-Albert can store up to 1,774 m^3 of drinking water. Only the holding tank stores treated water and the reservoirs are exposed to evapotranspiration. The stored water is sufficient to supply the village for just shy of 10 days based on an average daily water demand of 180 m^3 per day.

3.4 Value of Water Supply Benefits

Two different valuation approaches were used to estimate the value of water supply benefits. One approach considered the replacement cost (also referred to as avoided cost) associated with the service provision provided by the natural assets. In this case, the replacement cost associated with switching to a groundwater system was explored. It is recognized that this replacement cost estimate is likely an underestimate of the value of the drinking water benefit since the groundwater source is also a natural asset, which is highly dependent on water recharge from a healthy watershed. As such, a number of co-benefits are not included in the value. The second approach considers the cost of pumping or trucking drinking water from elsewhere. Table 8 summarizes the water supply values provided by the watershed for a range of assumptions.

TABLE 8 - SUMMARY OF WATER SUPPLY BENEFIT VALUATION

Valuation Assumption	Calculation	Water Supply Value of the Watershed
Replacement capital costs associated with establishing a groundwater supply system	$400,000 per well * 2 to 3 wells	$800,000 to $1,200,000 total
Avoided costs associated with trucking in water at average water usage rates	$12 per m^3 * 65,000 m^3 per year	$810,000 per year $26.9 million total (present value)[10]
Avoided costs associated with trucking in water at maximum water usage rates	$12 per m^3 * 92,000 m^3 per year	$1,104,000 per year $36.8 million total (present value)[11]

10 Present value of $810,000 perpetuity cost assuming a discount rate of 3%.

11 Present value of $1,104,000 perpetuity cost assuming a discount rate of 3%.

The groundwater supply assessment for Riverside-Albert indicated that groundwater could be a feasible alternative to the current surface water system.[12] Based on existing data of wells in the vicinity of the community, the average yield of 8 nearby wells was determined to be 334 m^3 per day. Given these recharge rates, a groundwater source system for the village of Riverside-Albert should be comprised of 2 or more wells. This would be sufficient to meet existing demand and to have redundancy in the event of failure or contamination. While no costing has been completed for this alternative, a nearby community (Alma) with a similar year-round population, has been investigating the cost of drilling a new well to meet their increased water quantity and quality needs. The cost of well drilling in Alma was estimated to be roughly $417,000. This covers research, design and implementation of a new well. Based on this information, it was assumed that wells for Riverside-Albert would cost $400,000 per well for a total replacement cost ranging from $0.8 to $1.2 million. As is noted above, this likely to be an underestimate of the actual replacement cost.

An alternate replacement cost considered the cost of bulk imports of water via pumping or trucking from another location. Bulk water delivery by truck in Canada is estimated to cost $0.047 per gal or roughly $12 per m^3.[13] Using this approach, the water supply value provided by the watershed was estimated to be $0.8 million per year based on current average water demand or $1.1 million per year assuming the maximum daily demand occurred. These perpetual annual costs were converted to present values demonstrating a value of the watershed's water supply in the range of $27 to $37 million dollars.

3.5 Natural Asset Co-benefits

This project focused on the value of drinking water supply benefits provided by the natural assets in the Arabian Vault Brook watershed. Estimated values (presented above) reflect the costs of providing the equivalent water supply services through alternative means. They do not account for the value of other services provided by natural assets such wildlife habitat, hydraulic detention, and health benefits. Consideration of these co-benefits would increase the estimated service value. Because of this, care must be taken to acknowledge the range of co-benefits from the natural assets of interest to decision-makers. Economic and policy decisions that focus narrowly on the trade-offs between conventional infrastructure and natural infrastructure may overlook the broader range of benefits to the potential detriment of the surrounding community.

In addition to supporting the provision of drinking water, the natural assets of the project site, which include trails, meadows, wetlands and riparian areas, provide a range of co-benefits including improvements to water quality, provision of wildlife and aquatic habitat, health and recreational benefits, transportation benefits, safety and social benefits, educational benefits, promotion of environmental sustainability, and economic benefits.

12 Gallagher, R. 2015. Groundwater Supply Source Investigation, Riverside-Albert, NB. Report prepared by exp Services Inc.

13 This rate is based on a review of current advertised water delivery rates in Canada. For example: https://www.leeswaterdelivery.ca/rates. Similar rates were found in Ontario, and BC.

4 Planning for Natural Asset Management

The effectiveness of natural assets to provide services should be measured periodically to ensure that the assets are functioning as expected over time. To facilitate this process, a management plan for the watershed should be established. A management plan sets out strategies and tasks for conservation, land use, interpretation, operations and maintenance of the natural assets under consideration. The goal of such a plan is to ensure management decisions protect and enhance service benefits and that human use within the area does not cause unacceptable impacts to their condition and level of service.

Currently, no management plan has been developed for the watersheds. However, given the current condition of the watersheds, ongoing operation and maintenance costs for the watersheds are likely to be limited. The primary considerations for the Village are: a) whether to purchase and protect land within the watersheds; and b) whether to establish land use agreements with the landowners in the watersheds. While this project found little impact from climate change and harvesting on the quantity of water supply, justification for protecting the remaining watershed may exist on the grounds of risks to water quality.

While the primary focus of this project was on water quanity, the village of Riverside-Albert has experienced problems with poor water quality. These problems have resulted from easily erodible soil that results in high tubidity. A boil water advisory (BWA) is a recommendation to boil water for at least 1 minute before using it. Between November 2014 and September 2018 high turbidity resulted in 10 BWAs that totalled 79 days for the village of Riverside-Albert. Five (5) of the BWAs occurred during high rainfall events, 2 during maintenace to the reservoirs in the Arabian Vault and 3 for unspecified events (either maintenance or heavy rainfall). Measures to reduce turbidy include the creation of ponds in the Arabian Vault to settle sediment. These ponds require annual maintenance to remove sediment from the bottom of the ponds using a backhoe, which has itself resulted in a BWA. The water tower provides drinking water to the village during high turbidy events. There have been no BWAs since the water tower was installed in 2018.

BWAs in the village have been correlated to precipitation data. A threshold of 37 mm of rainfall in 24h was established to trigger such a response. Taking into consideration expected increases in precipitation due to climate change (2050, RPC8.5), it was found that the number of BWAs could increase from an average of 3.7 per year to 4.18 per year by 2050. Since forest harvesting has not recently occurred in the watershed, there is not a history of turbidity problems due to forest harvesting. This could change in the future if harvesting takes place; disturbing and exposing the forest soil during forest harvesting would likely increase the amount of suspended sediment in the stream, resulting in higher turbidity.[14]

To understand the potential impacts climate change and forestry practices may have on the quality of the community's water supply, an integrated valuation of ecosystem services and trade-offs (InVEST) Sediment Delivery Ratio (SDR) model was run on the northern and southern sub-catchments of the watershed. Results are reported for the northern sub-catchment as no future land cover change is expected in the southern sub-catchment and the effects of climate change are likely to be minimal in this location.

The SDR model estimates overland annual sediment retention and erosion adapted from an approach described by Borselli et al. (2008) and provided as a free and open-source software tool by InVEST (Sharp et al., 2018). The model requires a variety of inputs including elevation data, rainfall erosivity index (climate based), annual precipitation, soil erodibility, and a land use/landcover raster. Two land cover and two climate change scenarios were modelled. The land cover scenarios were comprised of a baseline (intact forest) scenario and a worst-case (harvesting of all Crown land in the watershed outside of a 50 m watercourse buffer) scenario. Unlike the HEC-HMS model, which assumes land cover is homogeneous within sub-catchments, the InVEST model considers the surface flow across various land covers within sub-watersheds. This distinction allowed for inclusion of a forested 50 m watercourse buffer. The climate scenarios that were used for the HEC-HMS model were also used for the SDR model, namely the current climate scenario and the future climate (RCP 8.5) scenario in 2050. The climate data inputs to the model included annual precipitation[15] and a 1 in 2-year, 6-hour precipitation event[16]. The results demonstrate the volume of overland sediment loss that reaches the watercourse. The results are presented in comparison to the baseline scenario of current land cover (intact forest cover) and current climate. The results are given for a period of 10-years post-harvest using model parameters from Borrelli et al. (2017). While the magnitude and timing of sediment loss can vary due to many site-specific factors that were not captured in the model, the model does present a range of possible magnitudes of sediment loss that is consistent with the literature (Figure 10).

When comparing the worst-case harvest scenario for both climate scenarios to the baseline scenario, the forest harvest scenario had a greater impact on total sediment loss than climate change. Over the 10-year post-harvest period, the change in sediment loss from the baseline scenario varies from 2.4 to 402.7 times greater for the current climate scenario and 0.2 to 483.1 for the future climate change scenario.

The sediment retention by the forest cover decreases by 0.001% to 0.8% over the 10-year post-harvest period considering the current climate. Under the future climate scenario, the northern watershed sees a 19.1% to 19.9% increase in sediment retention services (Figure 10). This demonstrates that in a climate change scenario, the importance of vegetation in providing sediment retention services is amplified.

The results highlight the importance of the forest as a natural asset to retain soil in the watershed. This analysis does not translate the soil loss from the forest to changes in water quality but given the magnitude of the increase in soil loss under the worst-case land cover scenario, it is highly reasonable to assume that harvesting and climate change will negatively impact water quality in the watershed. Negative impacts could result in increased cost to treat the drinking water supply, increased reservoir sedimentation leading to more frequent maintenance, and a degradation in aquatic habitats due to increased total suspended solids in waterbodies (Sharp et al., 2018).

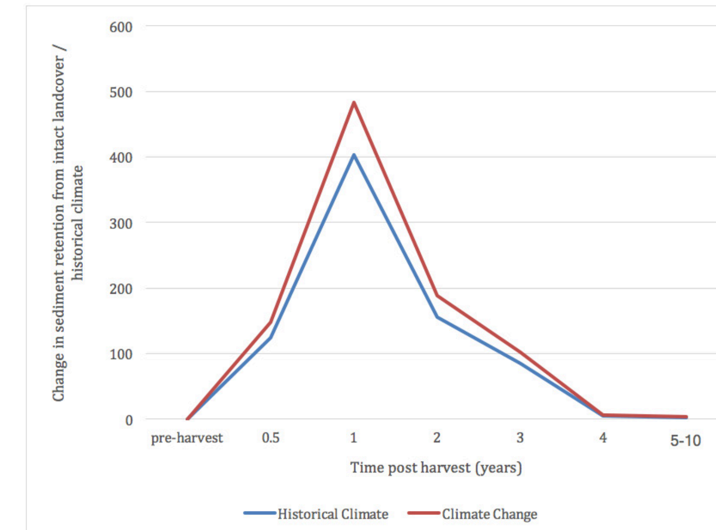

Figure 10. Change in sediment export (in tons) post worst-case harvest scenario over a 10-year period when compared to intact forest (pre-harvest)

The current water supply treatment process relies on a hypochlorite solution. The total annual cost of water plant operations (including power, treatment, staff, and maintenance) is $21,270 (2018 village budget). Given the potential for negative impacts to water quality from forest harvesting and anticipated increased heavy rainfall events resulting from climate change, it is likely that these annual treatment costs will increase. However, water treatment is only effective at low levels of turbidity. The bigger concern is that prolonged high turbidity due to increased soil loss will exceed the 3 days storage of treated water in the village water tower. In this event, BWAs or short- or long-term replacement cost options would need to be explored, all of which limit the quality of life and economic development of the village.

Given the foregoing analysis, there is potential for significant and negative impacts under future forest harvest and climate change scenarios. As such, an argument can be made to consider both purchasing land and establishing land use agreements with existing land owners.

14 Correlating the BWAs with the modelled flows would have been ideal as it would have allowed us to estimate how the number of BWAs would change due to both land cover and climate change, but the continuous simulation model does not model individual storm events very well and a such relationship could not be established.

15 Historic: 1210 mm; Future climate: 1452 mm

16 Historic: 39.43 mm; Future climate: 42.87 mm

5 Implementation of Natural Asset Plan

It has been demonstrated that future risks to the watershed exist. This section summarizes specific actions that should be considered as a natural asset plan, namely the conservation and protection of the watershed and improvements to storage capacity.

Twenty-two percent of the watershed is currently conserved between the Nature Conservancy of Canada and the Village of Riverside-Albert. This project demonstrates the importance of continued work to conserve the remaining private lands. As a first step, the Town and SERSC should engage the province to discuss conservation of the Crown land, or at a minimum, participate in a watershed management planning process to ensure any forest activity on the land protects water supply quality. One such tool is a covenant. A covenant may be applied to a whole property or just to specified portions of it. It helps to protect sensitive features, areas, or uses in perpetuity, since the covenant remains in effect after the land is sold or transferred. Typical covenants provisions include prohibitions on altering ecologically sensitive areas, limits on types of land use and land cover, distance between buildings, and where cattle are allowed to graze.

In response to the risks posed by future harvest and climate change, water storage capacity should be improved. Increased capacity will allow the village to reduce reliance on stream flow, assist with water quality issues, and improve conditions for increased tourism. Efforts can be directed towards increasing the volume of water than can be stored in the system (i.e. through additional retention ponds and other water storage infrastructure), especially during summer months when water flows are lower and tourism potential is greatest. Opportunities to reduce lost water from the spillways in the north and south ponds should also be considered. This could include consideration of naturalized/green infrastructure options.

6 Conclusion

This project focused on the water supply benefits of the natural assets in the Arabian Vault Brook watershed. The assessment estimated the value of the watershed in providing drinking water to the village of Riverside-Albert and considered the potential implications of climate change, land cover change, and water shortages on the quantity and quality of drinking water. The findings are summarized below.

Climate change is altering the water supply throughout the year

Climate change is expected to have a considerable impact on the availability of water throughout the year. For example, by 2050, the average annual water supply is expected to be 7% greater than current conditions. That said, the timing of the flows will not be distributed equally throughout the year. Large increases in flow are expected to occur during the winter months (Jan-March) due to warmer winter temperatures (on average an increase of 23%). Warmer future temperatures mean that more precipitation is expected to fall as rain, with more snow melting throughout the winter. This will reduce the likelihood of water shortages during the winter. However, warmer winters and springs will lead to earlier snowpack melts and as a result May is expected to have much less flow than has occurred historically (on average 21% less). The modelling indicated that there is likely to be little change in flows over the summer months. The increase in both precipitation and evapotranspiration are not expected to have substantive impacts on water availability. Much of the increased flows due to climate change will be lost from the system at overflows at the north, and to a lesser extent at the south, reservoirs, especially during the winter. While the increase in water quantity has the potential to provide increased water to the village, the current reservoirs are not designed to capture and store more water.

Land cover change increases flows but also poses risks to water quality

When modelling the impacts of forest harvesting on the water supply, an increase in flow was observed. This is mostly due to less water being lost to evapotranspiration in the water cycle. The increase in flow due to lost forest cover is considerably less than that is expected from climate change.

Turbidity is the main water quality concern in the water supply, even as the watershed is predominantly undisturbed forest. High turbidity is due to sedimentation and has resulted in boil water orders in the village in the past. While forest harvesting will result in increases in water flows, a sediment loss analysis showed that there would be considerably higher sediment being lost in the watershed due to erosion following harvesting. This will pose risks to water quality leading to increased water treatment costs and the likelihood of more boil water advisories in the future.

Potential for summer water shortages when flows are lowest and demand for water may increase with tourism

Historically, the summer months have had the lowest water flows. During the summer there has been sufficient water for average rates of water use, but rates of maximum water use over an extended period of time could result in water shortages. Since July-October are the dry months, there is a concern that an earlier snow melt due to climate change may limit the availability of water in the summer months. A year with low precipitation in both spring and summer would be a concern for the village's water supply. This occurred in 2011, when a very wet winter and early snow melt resulted in a summer drought. There is also potential for increased tourism in the summer. Given the positive contribution that tourism makes to the village, steps should be taken to ensure a sufficient water supply during the summer months.

The value of the watershed as a natural asset

If the watershed could no longer provide a clean and abundant water supply to the village, there would be considerable costs to establish a replacement water source. The capital cost to establish a groundwater supply is between $0.8 and $1.2 million. Alternatively, it would cost between $26.9 and $36.8 million dollars per year (present day value) to purchase and truck in water to the village.

Strategies to address water supply

Since the watershed provides ample annual water supply, and more water is expected in the system due to climate change, there is an opportunity to store water to supplement supply during periods of drought or increased water demand in the summer. Options to increase storage include:

- Create a new storage area potentially located to the south of the North pond. This is an ideal area because it is large and flat and is where the majority of the water will be lost under future climate conditions. A second spillway could be built that diverts a portion of the overflow into a storage area. A naturalized storage pond would have minimal maintenance costs and help filter the water.
- Increase the storage capacity of the 2 ponds that already exists. This would require increased construction, maintenance and replacement costs. For instance, the existing concrete reservoir requires $50,000 in upgrades.

7 Model Limitations and Recommendations

Model limitations and recommendations for addressing them are described below.

1. Meteorological data

As daily, rather than hourly, data were used to compute runoff rates, the model is able to extract annual, seasonal and monthly discharge outputs at the desired locations in the Arabian Vault Brook watershed. Hourly data would allow the quantification of the services provided by the natural assets for both water quantity and quality on a daily basis. Specifically, using hourly data would generate results at a finer temporal scale and extract daily water quantity for shorter (but impactful) drought periods. While the interpolated climate data employed in this exercise was very useful given the data scarce environment, this approach does not fully take into consideration the spatio-temporal variation in the meteorological patterns. Multiple experts (Corbari et al. (2017), Förster et al. (2016)) suggest using local ground measurements to improve data quality in the watershed. Using a meteorological station in or near the watershed with multiple years of data would be a good asset for future work of this nature.

2. Hydrology and snowpack data

The model calibration process could be improved by having more accurate water flow data. In this project, water flow was estimated using stage data as well as the physical characteristics of the stream. While the flow estimates were sufficient for deriving general trends, the uncertainty in field measurements would need to be improved for improved model calibration and higher-resolution modelling.

Additionally, installation of discharge gauge stations at strategic locations, such as at the treatment facility, would be an asset for future work in this area. The model could also be improved by having local ground measurements of snowpack including snow water equivalent metrics. Such information would improve the calibration process of the snow parameters in the model and consequently improve the estimated effects of snow on water flow. A longer calibration period through winter as well as better meteorological data as described above would also be required.

Appendix A

Municipal Natural Assets Initiative (MNAI) – Cohort 1 Launch Workshop

For Southeast Regional Service Commission

May 22-23 2018 - 0800-1830

Location:

Draft Annotated Agenda

Meeting purpose

Launch MNAI project.

Objectives

1. Ensure common understanding of: MNAI method, process & milestones; project details; roles, responsibilities and expectations
2. Develop detailed roadmap towards Milestone 1, including understanding of roles and responsibilities

Anticipated outputs

1. Final project document (although some details may continue to evolve)
2. Roadmap towards Milestone 1* including specific dates and times for regular check-ins and product deadlines.
3. Description of next steps

Meeting documents (available at https://tinyurl.com/y8ynjjvu)

- Signed MOU
- Project document
- MNAI introductory presentation
- MNAI presentation on data needs and collection
- Enlarged maps of site (provided by local government)
- Workplan template (to fill out at end of meeting)
- MNAI Communications plan
- ***Note on Milestone 1**
- Milestone 1 needs to be reached by Week 1 of September 2018.
- The Milestone is: *Creating foundation: biophysical characteristics and condition of municipal natural assets are understood and documented, all data is gathered.*
- Milestone 1 webinar will occur in first 2 weeks of September with objective of extracting and sharing key lessons or findings from data gathering (e.g. are there particular challenges or opportunities in terms of finding good data, and lessons that can be shared.
- MNAI team will provide help desk support between launch workshop and Milestone 1 webinar to make sure Milestone is reached.

AGENDA			
Time	**Item**	**Lead**	**Outcome & Comments**
Riverside-Albert, N.B.			
Part 1: Creating a common understanding			
0800-0815	Welcome and introductions	Local government	
0815-0845	Overview of MNAI process: how we got here and what to expect	Roy	Objective: ensure participants understand have shared understanding of MNAI and what to expect
0845-1000	Overview of project document: goals, objectives, outputs of project	Local government with Michelle and Jeff	Objective: ensure common understanding of project
1000-1015	Break		
1015-1115	Introduction to goals, objectives and activities towards Milestone 1	Michelle & Jeff	Objective: ensure common understanding of what is required for effective data gathering to meet project goals
1115-1215	Discussion on roles and responsibilities towards Milestone 1	Michelle & Jeff with support from Roy	
12h15-13h30	Conclusions, next steps	Roy, Michelle, Jeff	[This part can be shortened or used to cover additional issues raised during the day]
1330-1400	Working Lunch	All	Discussion: did the site visit change anyone's understanding of the project? Lunch provided by local government

Initial engagement session agenda and list of participants

Attendee	Organization	Title/Role
Roy Brooke	Municipal Natural Assets Initiative	Project coordinator
Michelle Molnar	Municipal Natural Assets Initiative	Economic/technical coordinator
Jeff Wilson	Municipal Natural Assets Initiative	Lead technical support
Sebastien Doiron	Southeast Regional Service Commission	Planning Director
James Bornemann	Southeast Regional Service Commission	Geomatics Analyst
Stephanie Thorne	Southeast Regional Service Commission	Assistant Treasurer
Joshua Adams	Southeast Regional Service Commission	Planner
Phil Robichaud	Southeast Regional Service Commission	Development Officer / Subdivisions
Marc Leger	Southeast Regional Service Commission	Regional Trails Coordinator
Tyler Searls	Southeast Regional Service Commission	GIS specialist
Jim Campbell	Village of Riverside-Albert	Mayor
Heather Cail	Village of Riverside-Albert	Public Works Superintendent
Denise Roy	Nature Conservancy of Canada	Conservation Representative
David Crandall	Southeast Regional Service Commission	Senior Engineer

References

Borrelli, P., Panagos, P., Märker, M., Modugno, S., and Schütt, B. 2017. Assessment of the impacts of clear-cutting on soil loss by water erosion in Italian forests: First comprehensive monitoring and modelling approach. Catena, 149, pp. 770-781

Borselli, L., Cassi., P. and Torri, D. 2008. Prolegomena to sediment and flow connectivity in the landscape: A GIS and field numerical assessment. Catena 75(3): 268-277. https://doi.org/10.1016/j.catena.2008.07.006.

Corbari, Chiara & Ravazzani, Giovanni & Galvagno, Marta & Cremonese, Edoardo & Mancini, Marco. 2017. Assessing Crop Coefficients for Natural Vegetated Areas Using Satellite Data and Eddy Covariance Stations. Sensors. 17. 2664. 10.3390/s17112664.

Förster, K., Hanzer, F., Winter, B., Marke, T., and Strasser, U. 2016. An open-source MeteoroLogical observation time series Disaggregation Tool (MELODIST v0.1.1), Geosci. Model Dev., 9, 2315–2333, https://doi.org/10.5194/gmd-9-2315-2016, 2016.

Gallagher, R. 2015. Groundwater Supply Source Investigation, Riverside-Albert, NB. Report prepared by exp Services Inc.

Gössling, S., Scott., D., Hall, C.M., Ceron, J-P., and Dubois, G. 2012. Consumer behanviour and demand response of tourists to climate change. Annals of Tourism Research 39(1): 36-58. https://doi.org/10.1016/j.annals.2011.11.002.

Guthrie, R., & Deniseger, J. 2001. Impervious surfaces in French Creek. Victoria B.C.: Ministry of Water, Land and Air Protection.

MNAI. 2017. Defining and Scoping Municipal Natural Assets. Available at: https://mnai.ca/key-documents/.

Nature Conservancy of Canada. 2019. Riverside-Albert. Available at: http://www.natureconservancy.ca/en/where-we-work/new-brunswick/featured-projects/bay-of-fundy/riverside-albert.html.

Roy, P. and Huard D. 2016. Future Climate Scenarios - Province of New-Brunswick. Montreal: Ouranos. http://acasav2.azurewebsites.net/#

Sharp, R., Tallis, H.T., Ricketts, T., Guerry, A.D., Wood, S.A., Chaplin-Kramer, R., Nelson, E., Ennaanay, D., Wolny, S., Olwero, N., Vigerstol, K., Pennington, D., Mendoza, G., Aukema, J., Foster, J., Forrest, J., Cameron, D., Arkema, K., Lonsdorf, E., Kennedy, C., Verutes, G., Kim, C.K., Guannel, G., Papenfus, M., Toft, J., Marsik, M., Bernhardt, J., Griffin, R., Glowinski, K., Chaumont, N., Perelman, A., Lacayo, M. Mandle, L., Hamel, P., Vogl, A.L., Rogers, L., Bierbower, W., Denu, D., and Douglass, J. 2018. InVEST 3.6.0 User's Guide. The Natural Capital Project, Stanford University, University of Minnesota, The Nature Conservancy, and World Wildlife Fund.

Thornton, P.E., Running, S.W., White, M.A. 1997. Generating surfaces of daily meteorological variables over large regions of complex terrain. Journal of Hydrology 190: 214 - 251. https://doi.org/10.1016/S0022-1694(96)03128-9

Thornton, P.E., M.M. Thornton, B.W. Mayer, Y. Wei, R. Devarakonda, R.S. Vose, and R.B. Cook. 2018. Daymet: Daily Surface Weather Data on a 1-km Grid for North America, Version 3. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1328

Thornton, M.M., P.E. Thornton, Y. Wei, B.W. Mayer, R.B. Cook, and R.S. Vose. 2018. Daymet: Annual Climate Summaries on a 1-km Grid for North America, Version 3. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1343

Thornton, M.M., P.E. Thornton, Y. Wei, B.W. Mayer, R.B. Cook, and R.S. Vose. 2018. Daymet: Monthly Climate Summaries on a 1-km Grid for North America, Version 3. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1345

Thornton, M.M., P.E. Thornton, Y. Wei, R.S. Vose, and A.G. Boyer. 2018. Daymet: Station-Level Inputs and Model Predicted Values for North America, Version 3. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1391.

Thornton, P.E., M.M. Thornton, and R.S. Vose. 2018. Daymet: Annual Tile Summary Cross-Validation Statistics for North America, Version 3. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1348.