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Evaluation of Irrigation Potential in the BC Peace Region

Final Report
February 26, 2016
KWL Project No. 3444.001-300

Prepared for:

B.C. Grain Producers Association

Acknowledgements

This report was prepared for:

The BC Agriculture & Food Climate Action Initiative in partnership with the BC Grain Producers Association.

Project Funding:

Funding for this project has been provided by Agriculture and Agri-Food Canada and the BC Ministry of Agriculture through the Investment Agriculture Foundation of BC under Growing Forward 2, a federal-provincial-territorial initiative. The program is delivered by the BC Agriculture & Food Climate Action Initiative.

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- Peace Forage Seed Association
- Peace River Regional Cattlemen's Association
- BC Ministry of Agriculture
- Peace River Regional District: Bruce Simard
- Peace River Forage Association
- BC Seed Growers' Association
- BC Agriculture & Food Climate Action Initiative

The writers are also most grateful to the Dave Hoffer and the South Peace Hudderite Colony, Barry and Irmi Critcher, and Willie Rath for welcoming our project team to their farms and kitchen tables to gain local perspectives on the potential for irrigation in the BC Peace region. Finally, we wish to thank Julie Robinson and Lori Vickers of the Ministry of Agriculture for their contributions of local expertise and assistance with data collection and analysis.

Agriculture and Agri-Food Canada (AAFC) and the BC Ministry of Agriculture are committed to working with industry partners. Opinions expressed in this document are those of the authors and not necessarily those of AAFC, the Ministry of Agriculture, the Investment Agriculture Foundation, or the Agricultural Research and Development Corporation.

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Executive Summary

Kerr Wood Leidal Associates Ltd. (KWL) was retained in January 2015 by the BC Grain Producers Association to conduct an Evaluation of Irrigation Potential in the BC Peace Region. Funding for the project was provided by Agriculture and Agri-Food Canada and the BC Ministry of Agriculture through the Investment Agriculture Foundation of BC under Growing Forward 2, a federal-provincial-territorial initiative. The program is delivered by the BC Agriculture & Food Climate Action Initiative. This report presents the project methodology, findings and recommendations regarding agricultural irrigation in the region.

Background

During the winter of 2012 and early 2013, the BC Agriculture & Food Climate Action Initiative brought Peace region agricultural groups, producers and government specialists together to develop a plan for supporting the agriculture sector with adapting to climate change. Completed in the spring of 2013, the *Peace Adaptation Strategies* plan identifies priority climate change impacts and strategies for adaptation for the region's agriculture sector.

One of the changes of greatest concern for participating producers is more frequent, and intensifying, dry and drought conditions during the summer. Water shortages and substantial moisture deficits for crop production have been experienced in recent years. Greater water demand from competing uses, and water use restrictions prompted questions about whether the current and future water demand for agriculture has been adequately considered in planning scenarios. While currently there is very little irrigation of crops in the region, the potential for irrigation needs to be established to adequately assess future agricultural water demand.

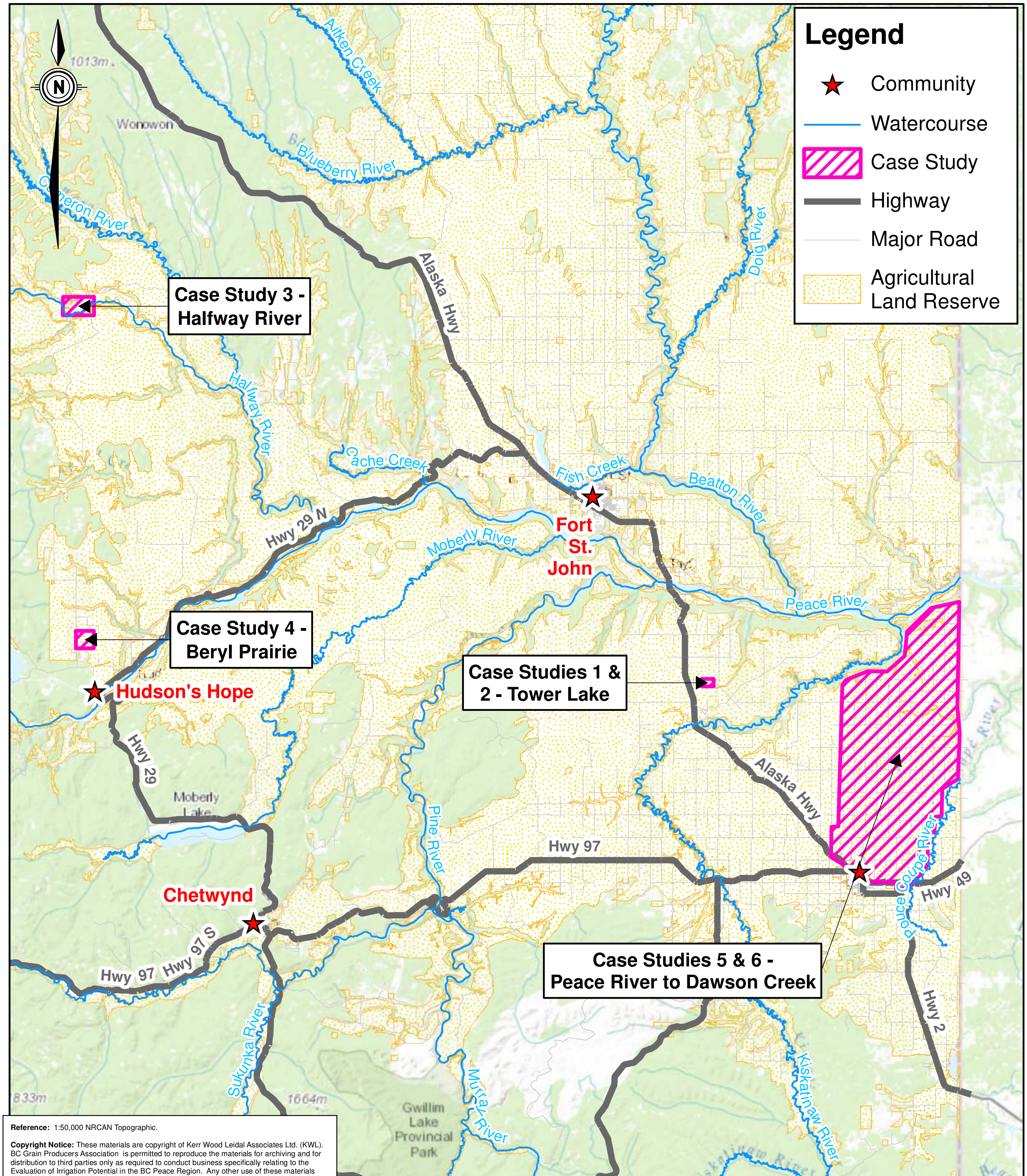
To explore this issue further, an irrigation feasibility study for the Peace region was identified as a logical first step. Input and guidance on the study was provided by the Peace Adaptation working group. The working group was initially formed to support the *Peace Adaptation Strategies* planning process, and continues in their role (providing sector and local expertise) as the plan is implemented.

Purpose

The objectives of the evaluation of Irrigation Potential in the BC Peace Region project are to:

1. produce a thorough cost-benefit analysis, assess the future feasibilities of various irrigation and cropping scenarios for agricultural land in the BC Peace region; and
2. identify suitable scales and structures of irrigation systems, and physical and institutional constraints, for current and future cropping scenarios.

The study area is the Peace River Regional District in northeastern British Columbia. The western portion of the region is mountainous and is generally unsuitable for agriculture. The focus of this study is the agricultural land in the eastern part of the region, as shown in Figure E-1.



Reference: 1:50,000 NRCAN Topographic.

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Evaluation of Irrigation Potential in the BC Peace Region

Project No.	Date
3444-001	February 2016

30 0 30 Kilometers

1:1,375,000

Study Area

Figure E-1

Path: R:\3400-3499\3444-001\430-GIS\MXD-RP\3444001_StudyArea.mxd Date Saved: 26/02/2016 9:56:55 AM
Author: MScruton

Key Terms and Acronyms

Agriculture Water Demand Model (AWDM) is a GIS-based software system developed by the BC Ministry of Agriculture, initially for estimating agricultural water demands in the Okanagan Basin. It has since been deployed for several other areas of the province. The AWDM uses downscaled global climate modelling data from the Pacific Climate Impacts Consortium (PCIC) to estimate current and potential future irrigation demands for reference crops on a 500 m grid.

Benefit Cost Ratio (BCR) is the sum of the present values (PV) of incoming cash flows from an investment divided by the sum of the present values of the outgoing cash flows. A BCR greater than 1 indicates a profit and a value less than 1 indicates a loss.

Discount Rate is the rate at which the value of a capital investment grows over time. Discount rates reflect market and project conditions, consisting of a risk-free rate that an investor would expect from a very safe investment (e.g., Bank of Canada or US Treasury bonds) plus a risk premium that reflects the probability of no return on the investment. A real discount rate of 5% per year (net of inflation) is assumed for this study, and the impact of varying the discount rate between 2% and 10% is evaluated in the sensitivity analysis.

Geographic Information System (GIS) is a software system used to develop, store, process and display spatial or geographical data.

Net Present Value (NPV) is the sum of the present values of incoming and outgoing cash flows over a period of time. In calculating NPV, the values of all future cash flows in the period are adjusted to present value by an assumed discount rate. A positive NPV indicates a profit, while a negative NPV indicates a loss. An investment typically needs to yield a NPV significantly greater than zero (and a BCR significantly greater than 1) to cover investment risks and opportunity cost. For the purpose of this study, the life cycle NPV of an investment in irrigation would also need to be greater than the NPV of unirrigated agriculture (status quo) over the same period in order for the investment to be financially favourable to the producer.

Methodology

The overall approach used for the analysis consisted of three general steps:

1. Estimation of available water supply and potential water demands using GIS-based tools;
2. Development of typical scenarios and example case studies for financial and economic feasibility analysis; and
3. Development of conclusions regarding feasibility of irrigation under a range of typical local conditions throughout the region, and recommendations for further work.

The feasibility of irrigation the BC Peace region was developed with reference to several previous studies, particularly in southern Alberta and Saskatchewan, and published methodologies for feasibility assessment of agricultural projects. Reports, maps and data were provided by the Ministry of Agriculture, particularly for estimation of water demands, unit costs and prices for financial feasibility analysis. Between March 24 and March 26, 2015, members of the project team conducted a field review of agricultural areas in the Peace Region, and visited farms and interviewed producers.

Climate, Water Supply and Demand Forecasts

The climate of the BC Peace region is forecast to become significantly warmer by the 2050s. Forecasts of mean annual temperature change between 1970 and 2050 range from +1.2 to +2.5 °C. On average, summer precipitation may increase by 3% by the 2050s. Climate change is also a major risk factor for future agricultural production in the region. In addition to uncertainty in future average conditions, both the magnitude and frequency of extreme weather events are forecast to increase.

Water supply availability estimates used in this study are based on federal and provincial government data, including Water Survey of Canada streamflow data and the BC Ministry of Environment's *Inventory of Streamflow in the Omineca and Northeast Regions*. The average and 1:10-year drought condition flows were used to simulate typical and drought flows during the growing season of May to August using GIS. There is insufficient data available to forecast the impacts of climate change on stream flows. For the purpose of this study it is assumed that the 1:10-year drought may occur more frequently in the 2050s (two to three years in ten). Water availability for irrigation was limited to 15% of the average monthly streamflow for consistency with provincial water licensing practice.

Water demands for two reference crops (mixed grasses grown for hay, and cereals) are calculated using the Agriculture Water Demand Model (AWDM), which utilizes downscaled climate data from the Pacific Climate Impacts Consortium (PCIC) for both recent historical conditions, and future (2050s) conditions that account for the anticipated warming in the region. Although other crops, particularly canola and pulses, are currently grown in crop rotations in the BC Peace Region, cereals and grasses grown for hay were selected as reference crops for water demand modelling as they represent high and low extreme crop water demands. A canola scenario is included in detailed feasibility case studies, based on interpolation between the water demands for cereals and forage. The future scenario is used for the feasibility assessment. The AWDM utilizes a series of variables to determine irrigation water demand such as crop rooting depth, soil properties, rainfall, temperatures and irrigation efficiency to calculate the amounts of water required throughout the growing season to maximize crop yield.

The forecast maximum irrigation water demands for the 2050s that are used in the feasibility analysis are 13% to 45% greater than estimated demands based on historical conditions, depending on crop type. The feasibility analysis is therefore based on reasonably conservative assumptions for future water supply and demand conditions: Water sources must be able to reliably supply 13% to 45% more than the estimated current maximum water demand under a 1:10 year drought condition. This conservative basis for assessment of water source capacity assures that irrigation water supplies would be reliable when most needed.

Case Study Financial Analysis

A set of typical irrigation scenarios was developed, and a case study was identified for each scenario to evaluate the economic feasibility of irrigation under conditions typically available in the region. Scenarios were developed based on irrigation water demand, proximity to a water supply, and the elevation difference between the water supply and point of irrigation. The scenarios, along with a description and case study, are summarized in Table E-1.

Table E-1: Feasibility Scenarios and Case Studies

Scenario	Description	Case Study	Lift	Distance
1	Single Farm	Tower Lake	< 65 ft	< 0.6 mi
2	Single Farm with Constructed Storage			
3	Small Community System	Halfway River	< 165 ft	< 3 mi
4	Small Community System with Constructed Storage	Beryl Prairie		
5	Large System	Peace River to Dawson Creek	> 700 ft	> 3 mi
6	Large System with Constructed Storage			

The feasibility of irrigation under each scenario was evaluated using an Excel-based financial model developed based on typical agricultural project evaluation practices. The general sequence of analysis is as follows:

1. Define the parameters for evaluating each scenario based on a representative case study;
2. Apply a standard set of assumptions for three reference crops: cereals, canola and forage;
3. Estimate average, maximum and minimum revenues and costs using standard assumptions for each reference crop;
4. Calculate financial feasibility (average, maximum and minimum BCR and NPV) for status quo and irrigated production of each reference crop;
5. Identify water supply capacity limitations for each scenario;
6. Assess the sensitivity of the feasibility results to variations in project life cycle, and discount rate;
7. Consider the overall economic impacts on the region of widespread irrigation based on previous economic assessments of major irrigation projects in Alberta and Saskatchewan;
8. Consider a range of environmental and social implications of widespread irrigation; and
9. Consider potential alternative water supply scenarios and their potential impacts on the feasibility of irrigation in the Peace region.

Case Study Results

Based on average assumptions used for the analysis, estimates of the financial performance of dryland agriculture in the BC Peace Region (status quo) are shown in Table E-2. The results indicate that over 20 years, dryland forage production is expected to return roughly $100/acre, cereals $400/acre, and canola $500/acre. Annual returns are one-twentieth of these values (roughly $5 to $25/acre). The return on inputs of labour, machinery and materials (land and facilities excluded) is estimated to fall between 8% and 14%.

Table E-2: Unirrigated Crop Financial Parameters – Scenario 3, Halfway River

Crop	Average Revenue ($/acre)	Average Operating Expense ($/acre)	20-Year NPV ($/acre)	Benefit-Cost Ratio
Dryland Forage	101	-94	96	1.08
Dryland Cereal	241	-208	415	1.16
Dryland Canola	326	-285	502	1.14

The financial feasibility of irrigation is dependent on capital and operating costs of water supply and irrigation infrastructure, and crop type. Halfway River (Scenario 3) is shown in Table E-3 as an example of varying costs and revenue based on crop under irrigation. Unfavourable results are indicated in red text.

Table E-3: Irrigated Crop Financial Parameters – Scenario 3, Halfway River

Crop	Average Revenue ($/acre)	Average Operating Expense ($/acre)	Irrigation Capital Cost ($/acre)	20-Year NPV ($/acre)	Benefit-Cost Ratio
Irrigated Forage	234	-237	-784	-825	0.78
Irrigated Cereal	368	-285	-784	256	1.06
Irrigated Canola	498	-393	-784	518	1.09

Note: all data is based on the assumption of using a ¼ Section Centre Pivot that irrigates 125 acres, the remaining area is assumed dryland where irrigation does not reach (35 acres).

The results indicate that irrigating forage is not financially feasible in this scenario. Irrigating cereals and canola in this scenario both yield a small net revenue; however, both yield lower net revenue per acre than without irrigation and would therefore not be considered a worthwhile investment based on financial analysis alone.

Capital and operating expenses are relatively low in Scenario 3 as it is located in close proximity to a reliable and plentiful source of water, requiring minimal pumping lift and no water storage. The capital and maintenance costs vary widely between scenarios. Table E-4 shows the case study results for each scenario using canola under average conditions.

Table E-4: Irrigated Crop Financial Parameters – All Scenarios, Canola

Scenario	Average Revenue ($/acre)[a]	Average Operating Expense ($/acre)	Irrigation Capital Cost ($/acre)	20-Year NPV ($/acre)	Benefit-Cost Ratio
1 – Tower Lake	$427[b]	-$389	-$742	-$271	0.95
2 – Tower Lake with Storage	$498	-$415	-$2073	-$1740	0.74
3 – Halfway River	$498	-$393	-$784	$520	1.09
4 – Beryl Prairie with Storage	$498	-$393	-$2015	-$1000	0.86
5 – Peace to Dawson Creek	$498	-$471	-$2906	-$2579	0.71
6 – Peace to Dawson Creek with Storage	$498	-$430	-$2107	-$1654	0.78

[a] All data is based on the assumption of using a quarter Section Centre Pivot that irrigates 125 acres, the remaining area is assumed dryland where irrigation does not reach (35 acres).
[2]. Tower Lake irrigated canola yield is assumed to be limited by the capacity of the source, resulting in reduced revenue per acre than other irrigated canola scenarios.

Where limitations of the water source necessitate constructed storage such as a dugout, irrigation is not financially feasible due to the high capital cost of storage (Scenarios 2 and 4 most notably). Constructing storage in the Peace to Dawson (Scenarios 5 and 6) reduces overall costs as a smaller pump and smaller diameter distribution mains are required; however, irrigation is not financially feasible under either scenario.

Sensitivity Analysis

The financial analysis is based on estimates of average capital costs, annual input costs, market prices, yields and financial analysis parameters, each of which has varying ranges of uncertainty. Probable maximum and minimum values for these parameters were used to develop estimated ranges of uncertainty in the results. Estimates of the range of uncertainty in the financial feasibility results were developed for the following three primary sources of error:

1. Capital cost estimates used in this analysis are considered to have a margin of error of -50% to +100%;
2. Annual revenues and expenses, including market prices, yields and energy prices were varied based on estimated ranges developed by the project team based on recent historical data and market forecasts; and
3. Financial analysis parameters, project life cycle and discount rate, were varied from 20 years at 10% to 50 years at 3% annual discount rate.

The margins of error estimated for the three primary sources are combined using a standard method based on the assumption that the three sources are mutually independent. The combined percent uncertainty is calculated as the square root of the sum of the squares of the relative maximum errors. The results of the financial feasibility analysis and margins of uncertainty for the most favourable scenario evaluated (Scenario 3 – Halfway River) are shown in Figure E-2.

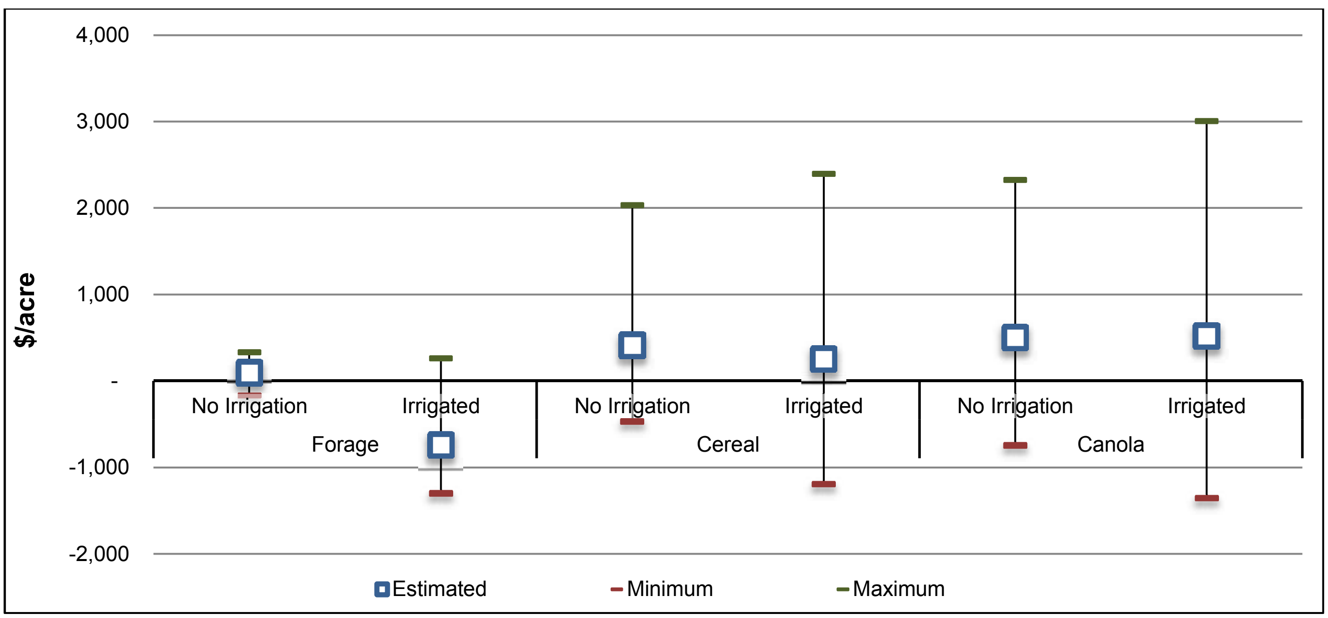


Figure E-2: 20-Year Net Present Value per Acre – Scenario 3, Halfway River

Review of Other Irrigation Scenarios

The case study scenarios are expected to represent favourable scenarios for irrigating the current primary crop types in the BC Peace Region at a range of scales. Although the following additional scenarios were not evaluated in detail, they were compared with the case study scenarios through identification of factors that may increase or decrease their feasibility relative to the case studies.

Site C Reservoir

Utilizing the Site C reservoir as a water source for irrigation is a variant of Scenarios 5 and 6. Using the reservoir as the source for a system that ultimately connects to Dawson Creek would reduce or eliminate intake costs and would reduce the required lift by 215 ft (65 m), reducing the capital and operating costs of pumping. However, the pipeline route would be considerably longer, including at least 9 mi through difficult terrain including crossing the Pine River to reach the northwestern extent of the farmland south of the Peace River. This scenario would certainly be more costly than the case study scenarios, and the shortest route to Dawson Creek (approximately following Highway 97) would not access farmland as efficiently as the case study scenarios.

An alternate scenario that may offer similar benefits to the case studies would be a pipeline from the Site C dam location north to the region between Montney, North Pine and Rose Prairie. This scenario may benefit from the Site C reservoir elevation and water quality while accessing farmland efficiently. As with the Peace to Dawson case study, the feasibility of a Site C to Rose Prairie project would rely on senior government investment to cover most or all of the capital cost of the shared infrastructure. This scenario is unlikely to significantly improve the feasibility of a major irrigation project in the BC Peace region.

In-Stream Storage

Water storage may be developed at a significantly lower construction cost than the $1,200 to 3,700/ac-ft ($1 to $3 per m^3) of live storage assumed for this analysis, by constructing dams to create reservoirs in river valleys or other natural depressions in the landscape. Examples of potential in-stream storage scenarios in the BC Peace Region include:

1. increase Charlie Lake weir height by 6 to 12 inches (0.15 to 0.3 m);
2. Dam Doe Creek or Saskatoon Creek (tributaries to Pouce Coupé River) at 620 m contour;
3. Dam Upper Goleta Creek at 620 m contour; or
4. Dam Alces River at 600 m or Kiskatinaw River at 620 m contour – potentially combine with hydropower project.

Efficiency of the catchment must be considered in each case, and elevation relative to farmland also significantly impacts overall project feasibility.

In the most ideal conditions, storage costs as low as $300/acre-ft ($0.25/m^3) may be achievable with large dams; however, only the largest projects in the most ideally suited locations are likely to achieve unit costs lower than $1200/acre-ft. The most cost-efficient new dam storage scenarios would also involve major changes to regionally significant creeks or rivers, and would require a high level of effort for planning, engineering, environmental assessment, land acquisition and regulatory approvals, with a high initial risk that the project will not proceed. It is therefore very unlikely that developing new in-stream storage would significantly improve the feasibility of irrigation in the BC Peace Region.

If the environmental and shoreline property impacts are acceptable, raising the existing Charlie Lake weir or similar projects to regulate levels of other lakes or wetlands within a level range of up to 1 ft (0.3 m) would likely represent the lowest-cost storage improvement in the region based on unit cost. Irrigating suitable farmland near a regulated lake or wetland may approach the financial feasibility of Scenario 3 (Halfway River). This approach would require coordination with the holders of existing wildlife conservation licenses on these watercourses, to ensure water levels will be managed to prevent harm to nesting waterfowl.

Municipal Wastewater Effluent

The Town of Dawson Creek has partnered with Shell Canada to improve its wastewater treatment system to supply up to 3.2 ac-ft/day (4,000 m^3/day) of reclaimed water to Shell for its operations in the South Peace Region. Shell has constructed a 30 mi (48 km) pipeline to deliver the reclaimed water from Dawson Creek to its Groundbirch area operations. The total cost of the treatment improvements was approximately $13 million.

If the need for fresh water related to gas development activity (primarily for hydraulic fracturing of wells) declines within the next 20 to 30 years as forecast, there may be a longer-term opportunity to purchase or lease the Shell infrastructure for irrigation uses. As the pipeline runs primarily through farmland, the cost of additional conveyance infrastructure would be minimal for farms near the pipeline. However, local storage and pumping would be required to fully utilize the available 1,200 ac-ft/year (1.5 million m^3/year, suitable for roughly 4.5 sections of canola).

A similar reclaimed water project could be developed at Fort St. John for irrigation use. The population and municipal water demand of Fort St. John are roughly 50% greater than that of Dawson Creek, indicating that a wastewater effluent flow of approximately 1,800 ac-ft/year may be available (suitable for roughly seven sections of canola). Requirements for treatment, storage and conveyance under this scenario would likely result in a higher unit cost of irrigation water supply than that of the Beryl Prairie with storage scenario, and a similar or lower financial feasibility.

Groundwater

Groundwater sources in the agricultural areas of the BC Peace Region generally have low to moderate productivity and poor quality. Total dissolved solids (TDS) and hardness of bedrock well water is typically greater than 1,000 ppm. Softer groundwater may have high fluoride and barium concentrations associated with sodium bicarbonate. The most productive bedrock wells in the region are in the range of 250 USgpm (16 L/s) (Dunvegan Formation), and most have much lower yields. Surficial aquifers that produce higher yields and may have better water quality generally follow the major river valleys, and are likely to interact with surface water. Confined aquifers recharge slowly (in the order of centuries or millennia), and are therefore highly vulnerable to over-pumping at the flow rates that would be required for irrigation.

Although groundwater may prove suitable for irrigating on a local scale (1/4 to one section) in some locations, conditions favourable for irrigating on a larger scale using groundwater are unlikely to exist in the BC Peace Region (with the exception of riverbank wells near major rivers). Unconfined aquifers may be unproductive in drought conditions, and the use of confined aquifers for irrigation is likely unsustainable. Storage would likely be required to supply the flow rates required for center pivot irrigation, resulting in a similar or lower financial feasibility to the Tower Lake with storage case study (Scenario 2). Groundwater is therefore unlikely to be a significant source of water for irrigation in the BC Peace Region.

Shared Infrastructure

In recent years, there has been substantial investment in water supply infrastructure in the BC Peace Region, including pump stations, pipelines and storage ponds to supply oil and gas development needs. Although oil and gas companies have developed most of the infrastructure, agricultural producers have developed some. A more deliberate and coordinated effort to develop infrastructure that meets combined agricultural, oil and gas, municipal and other industrial needs may enable a significant area of farmland to be brought under irrigation. The best opportunities currently appear to be in the South Peace region, where concentrated gas development activity coincides with widespread agricultural production.

A major water supply project that brings water from a major surface water source (e.g., Peace, Pine or Beatton River) to an area that shares agricultural opportunities with gas development and possibly municipal needs may be feasible. Based on the Peace to Dawson case studies, it is unlikely that such a project would be cost-effective for a primarily agricultural purpose. Such a project may only be feasible if the scale of irrigation is kept small enough that the majority of the project cost will be paid by the oil and gas development or municipal participants, both of which can justify a much higher unit cost of water than irrigation.

To date, oil and gas companies have been reluctant to share water supply infrastructure with other users. It is likely that agricultural producers would need to play a lead role in developing the shared infrastructure, potentially including ownership. The risks associated with developing infrastructure without a firm revenue stream from other users must be considered carefully. Water licensing for multiple uses may also be significantly more complex than for irrigation alone.

Other Crops and Larger Herds

The climate in the BC Peace region is suitable for production of a wider range of crops under irrigation than are currently grown in significant quantities in the region. In particular, a mix of vegetables is estimated to generate gross revenues ranging from $5,000 to 8,000/acre at a variable production cost of approximately $1,700/acre (2011 dollars). Sugar beets also generally yield higher returns per acre than cereals or oilseeds. However, realizing higher returns would require investment in new harvesting equipment and may greatly increase labour requirements. Transitioning to new crops and production methods typically requires several years, and a commitment by producers to make the required investments in equipment and capacity building on top of major investments in irrigation. New crops that are more dependent on irrigation may also increase risks of a shortfall in water supply in a drought year.

A 2012 study of the potato, fruit and vegetable market in Alberta identified the following eight competitive issues for these crops:

- Low cost of import competition;
- Local food trends;
- Climatic conditions;
- Labour;
- Temperature and humidity controlled storage capacity;
- Technology and innovation support;
- Industry organizational structure; and
- Branding.

The same study estimated net returns per acre of several crops as shown in the Table E-5.

Table E-5: Estimated Profitability per Acre of Vegetable Crops in Alberta

Crop	Gross Revenue	Irrigation	Other Costs	Total Cost	Net Revenue
Sweet corn	$3,500	- $73	- $3,031	- $3,104	$396
Cucumbers	$6,000	- $73	- $5,923	- $5,996	$4
Fresh potatoes	$2,400	- $79	- $2,436	- $2,515	-$115
Dryland carrots	$1,800		- $1,770	- $1,770	$30
Irrigated carrots	$2,520	- $79	- $2,127	- $2,206	$314

For comparison, the estimated annual cost of irrigation based on the most favourable conditions (Tower Lake and Halfway Case studies) ranges from $115/acre without storage to $250/acre with storage, including capital costs amortized at 5% over 20 years. This indicates potential for transitioning to certain higher-value crops such as sweet corn or carrots to increase the feasibility of irrigation in the BC Peace Region. However, market volatility and uncertainty in yields translate to a high degree of risk in investments in irrigation and production equipment for vegetables. In addition, yields are likely to be significantly lower in the cooler climate of the BC Peace Region than in southern Alberta.

By reducing risks of feed shortages, irrigation may also support safe increases in herd sizes, potentially allowing large increases in revenues per hectare for beef and other livestock operations. New cow-calf operations, feedlots and processing facilities may locate in the region if substantial areas of the BC Peace region have access to irrigation. However, careful management of feed supplies to hedge against drought risk is likely a more cost-effective strategy for safely increasing herd sizes than irrigating forage.

Further study including small-scale piloting to prove out yields and production costs would be required to quantitatively assess the potential impact of higher-value crops and increasing herd sizes on the feasibility of irrigation in the BC Peace Region.

Economic Analysis

A rigorous analysis of the impacts of irrigation on the regional economy of the BC Peace Region is beyond the scope of this study. However, similar analyses of the major irrigation projects in southern Alberta and Saskatchewan provide an indication of the potential magnitude of impacts of widespread irrigation in the BC Peace Region. For this study, economic analysis includes consideration of social and environmental costs, benefits and risks. The following elements were considered in a subjective review of economic factors:

Scale of Impacts

Irrigation of a small proportion of farmland (most likely scenario) will have minor impact on the economy of the BC Peace region, and is expected to have no material economic impact on a larger scale. While irrigation of more than a few percent of the area of farmland in the region is unlikely in the foreseeable future, more widespread irrigation may significantly impact the regional economy and have minor impact on a larger scale.

For the purpose of this analysis, a single local irrigation system is considered to have negligible impact regionally. This analysis is focused primarily on regional impacts (i.e., Peace River Regional District and local communities), and possible provincial impacts, of at least 5 to 10% of the field crop area in the BC Peace region (15,000 to 30,000 ha) coming under irrigation.

Baseline Economic Activity

Although agriculture is the dominant land use in the BC Peace Region, its economic impacts are currently relatively small and declining. However, in contrast to oil and gas development, agriculture in the region is stable and sustainable, and currently relies heavily on local labour, supply and distribution networks.

Of the roughly 3.7 million acres (1.5 million ha) of land in the Agricultural Land Reserve in the BC Peace region, approximately 1.5 million acres are improved and farmed. Roughly 0.74 million acres are in unmanaged pasture, and 0.74 million acres are in field crops primarily including alfalfa and other forages, canola and cereals. A very small proportion of the farmland is used for nursery products, fruits, berries, nuts, vegetables, silage corn and other field crops (roughly 2,470 acres total). The region supports a herd of roughly 100,000 cattle and calves almost exclusively for beef production, and smaller numbers of other animals. Beef production represents approximately one quarter of the BC total.

Agriculture in the BC Peace Region is primarily oriented toward export of crops and livestock. Gross farm receipts in the BC Peace region are roughly $150 million, or approximately $101/acre ($250 per hectare) of improved farmland, representing 0.6% of provincial GDP. Contribution margins are roughly half the provincial average, at 5.4% of farm cash receipts. Total farm capital in the region is approximately $1.8 billion, including $1.6 billion in land and buildings, and $230 million in machinery and equipment.

Dawson Creek and Fort St. John were each estimated to be 3% income-dependent on the agriculture and food sector in 2006, having declined from 6 and 7% respectively in 1991 (BC Stats). The labour force in “agriculture and other resource-based industries” was approximately 7,200 in 2006 (Statistics Canada). Of the 45,000 population of the Peace River Regional District (PRRD) aged 15 or older, 990 (2%) have post-secondary education in agriculture, natural resources and conservation.

Backward Linkages

Developing and operating irrigation will increase the need for equipment, supplies and services in the BC Peace region. The economic impacts of inputs to irrigated agriculture in the region may include:

1. investment and employment in irrigation system construction, operation and maintenance;
2. increased sales of seed, fertilizer and equipment, and new business opportunities related to training and supply chain; and
3. if large reservoirs are developed, potential for hydropower or recreational uses.

Forward Linkages

Increased and more reliable productivity of farmland, the capacity to produce a wider range of crops, and new water infrastructure will have a range of impacts on the BC Peace region. The economic impacts of outputs from irrigated agriculture in the region would include, including:

1. increased farmland value, as land becomes more productive and yields become more stable;
2. if irrigation is developed on a sufficient scale, investment and employment in processing and distribution; and
3. if irrigation is developed on a sufficient scale, growth in local communities as businesses are established to provide services to support more intensive, more diverse and more technically sophisticated agriculture.

Market Access and Competition

The BC Peace region is at a significant competitive disadvantage relative to the southern Alberta and Saskatchewan growing regions, where large areas of farmland are already under irrigation and the growing regions are near major population centres and have high distribution capacity. In particular, the Diefenbaker Lake system in Saskatchewan has unused capacity to irrigate at least 500,000 additional acres (200,000 ha), increasing the land area in Saskatchewan under irrigation by a factor of six. With the major reservoir infrastructure already in place and at higher elevation than the land to be irrigated, the cost of developing irrigation in Saskatchewan is substantially less than in the BC Peace Region.

Saskatchewan is closer to major markets and sources of supply, and its provincial economy would realize several additional benefits of expanding water supply systems for irrigation. These include increased potash production within the province, and addressing urban and industrial water needs with the same infrastructure used to supply irrigation.

Risks

Bringing farmland under irrigation can provide high value to producers and local communities by reducing risks, primarily the risk of crop loss and feed shortages due to drought. However, irrigation also introduces new risks and increases others. The following risks were assessed:

Drought

Drought is currently a primary risk to agriculture in the BC Peace Region, which is expected to become more prevalent with climate change. Currently, producers generally manage drought risk by managing herd sizes and areas of land in forage to ensure a modest surplus of hay each year, which can be sold into local and regional markets in most years. Drought risk to cereal and oilseed crops is typically covered through insurance.

The value of irrigation as a means of mitigating drought risk was assessed using the Tower Lake financial model as follows:

Net Cost of Irrigation as a Risk Mitigation Measure

Although irrigation is estimated to be less cost-effective in an average year than dryland production for each of the case studies analyzed, some producers may be willing to accept a reduction in annual average revenue to mitigate the risk of a large loss in the event of a severe drought. Over a 20-year life cycle, irrigated canola production without constructed water storage at Tower Lake (Scenario 1) is estimated to produce $180/acre/year less net revenue than unirrigated canola. This reduction in average revenue may be an acceptable cost to reduce drought-related financial risk. If constructed storage were required, the reduction in annual average net revenue would be an estimated $480/acre, which cannot be justified.

Increased Frequency of Historical 1:10 Year Drought

The greatest risk to unirrigated agriculture is a severe multi-year drought, a scenario which is predicted to become more likely by the 2050s. An increase in drought risk was modeled as an increase in the frequency of the current one in ten-year drought to two or more years in ten by the 2050s, and a correspondingly greater risk of a severe multi-year drought. As drought frequency increases and unirrigated yields decrease, irrigation becomes financially more favourable. The effect of more frequent drought on the financial feasibility of irrigating canola without constructed storage at Tower Lake (Scenario 1) was evaluated using the financial feasibility model. In order for irrigated canola at Tower Lake to generate equivalent life cycle net revenue to unirrigated canola, the frequency of the historical 1:10 year drought would need to increase to 1:2 years or more. This scenario is outside the range of likely impacts of climate change within the next 40 years, indicating that irrigation is unlikely to become financially favourable for canola at Tower Lake by the 2050s.

Solonetzic Soils

Solonetzic soils (also known as gumbo) are prevalent in the BC Peace Region, and are highly sensitive to the accumulation of salts. Land with up to 30% Solonetzic soils can be irrigated successfully; however, careful management is necessary to prevent loss of yield. Yields are generally lower and production costs may be significantly greater in these soils than in other types, reducing the cost-effectiveness of irrigation. Farmland with more than 30% Solonetzic soils is classified as non-irrigable in Alberta.

Soil Acidification

Irrigation necessitates higher fertilizer application rates. As fertilizers reduce soil pH, liming may be necessary to maintain pH within an acceptable range. Liming adds to the cost of production, and may diminish the cost-effectiveness of irrigation.

Water Availability and Quality

Most rivers, streams with very low summer and autumn flows, and lakes and aquifers in the main agricultural areas of the BC Peace region, are vulnerable to excessive use at the flow rates that are required for centre pivot irrigation. Groundwater resources in the BC Peace region can be extremely hard, and surface water sources fed from groundwater may also have relatively high hardness at times of minimum flow. There is a significant risk that water will be unavailable or of unacceptable quality in severe drought conditions, negating the benefit of irrigation as a drought management strategy. Climate change is likely to increase these risks.

Introduction of Pests and Disease with Irrigation

Pests that would normally die in the heat and dry weather will be able to flourish under irrigation. Certain plant diseases may also be promoted by irrigation. There is a risk that irrigation could contribute to reduced yields or crop losses in years that may otherwise produce good dryland yields. Pest and disease risks under irrigation will require new management techniques, adding to the cost of irrigated production and weakening the business case for irrigation development.

Safety

Irrigation will introduce new hazards to agricultural workers and the public, including:

- **Storage impoundments** – Larger dikes and dams are subject to the BC Dam Safety Regulation and must be classified, monitored and maintained in accordance with the regulation;
- **Major pipelines** – A break or accidental release of water from a high-capacity water pipeline could cause flooding, damage to nearby property or serious injury to anyone in the immediate area; and
- **New occupational hazards** – The construction and operation of water supply and irrigation systems will introduce several new occupational hazards to the local agricultural industry, including water under pressure, unfamiliar mechanical and electrical systems and controls, and new types of automated mobile equipment.

The cost of effectively managing all related risks must be considered in the business case to develop an irrigation system.

Summary of Findings

The central finding of this study is that in current market conditions, irrigated agriculture in the BC Peace Region is economically feasible only in very specific circumstances, generally at a small to medium scale where water of acceptable quality is locally available in sufficient quantity throughout the growing season. Combined with relatively low financial returns to land limited by the climate and soils of the BC Peace Region, the lack of local availability of water in most of the agricultural areas of the region generally limits the scale of feasible irrigation water supply systems to a few sections (hundreds of hectares).

Climate change will increase the feasibility of irrigation. However, the increase in drought frequency that would result in net returns from irrigated agriculture equivalent to those of unirrigated agriculture is outside the range of probable 2050s forecast scenarios. Substantial changes in economic conditions would also be necessary to develop a business case for irrigation on a larger scale.

The overall findings of the feasibility analysis are summarized in the Table E-6. Financial feasibility based on assumed average conditions is assessed for each scenario based on the case study analysis is shown as the 20-year NPV per acre for canola at a 5% annual discount rate, the BCR, and the difference in BCR from the status quo. These parameters indicate the expected life cycle impacts of irrigation on a producer's net returns to land investments. The influence of other factors on overall economic feasibility is indicated using '+', '-' or '0', reflecting the subjectivity of the analysis.

A scenario that is financially marginal but is positively influenced by most other factors may be economically feasible. The overall impact of these factors is summarized in the right column of the table.

The following findings are drawn from the case study analysis:

1. In all cases, dryland agriculture is estimated to be more profitable than irrigated agriculture when the life cycle capital, operation and maintenance costs of the irrigation system are taken into account. Investing in irrigation at any scale in the BC Peace Region is unlikely to increase net revenue to a producer growing traditional crops (cereals, oilseeds or forage grasses);
2. Irrigating forage grass in the BC Peace Region is not cost-effective under current or foreseeable future economic conditions. Maximizing forage production would require substantially more irrigation than cereals or oilseeds, and the increased net revenue per unit area of forage under irrigation is insufficient to cover the costs of irrigation;
3. Where an adequate water source is available near suitable farmland, irrigation of cereals or oilseeds may provide sufficient benefits to justify investment in water supply and irrigation infrastructure. The benefits to producers of revenue stabilization, reduction in drought risk and increased land value justify the net cost of irrigation in circumstances where irrigation is marginally feasible based on direct life cycle revenues and expenses. The business case must be considered for each individual project based on conditions available at the site;
4. Sufficient data are not available to assess the feasibility of irrigating forage seed crops as well as vegetables, sweet corn or other non-traditional crops in the BC Peace region. If similar net annual revenues to those in southern Alberta could be achieved in the BC Peace region for sweet corn and carrots, irrigation of those crops may be financially feasible. However, market volatility and uncertainty in yields translate to a high investment risks, and yields are likely to be significantly lower in the cooler climate of the BC Peace Region than in southern Alberta;

5. The value of irrigation to reduce drought risk may be sufficient to justify the cost of irrigation only in the most favourable scenarios. Under the most favourable scenarios evaluated, a producer would need to accept a reduction in average annual net revenue in the order of $200/acre to achieve the risk reduction benefit of irrigating canola. Although weather will become warmer and drought frequency may increase, a drought equivalent to the worst in the last 15 years would need to occur at least five of every ten years to reduce the benefit-cost ratio of dryland canola production to equal the life cycle benefit-cost ratio of irrigated production;
6. The distance of the BC Peace Region to major North American markets is a significant competitive disadvantage relative to irrigation districts in Alberta and Saskatchewan. Proposed projects such as the Upper Qu'Appelle in Saskatchewan, already well serviced with supply and distribution infrastructure, are likely to present a substantially stronger business case for investment than a similar project in the BC Peace Region;
7. Existing infrastructure needed for other purposes may provide important future opportunities for irrigation on a small to medium scale. Some agricultural producers have constructed water storage ponds for purposes mostly unrelated to irrigation, which may include livestock watering and sale of bulk water to the oil and gas industry. Oil and gas companies have cooperated with BC Hydro and the City of Dawson Creek to procure water, and have developed pipelines and storage facilities to meet their current needs. If the recent boom in oil and gas well completions declines within 20 to 30 years as predicted, water infrastructure may become available for irrigation; and

Coordinated planning may help to ensure that water infrastructure developed for other purposes will also be well suited to irrigation needs. The capacity of such infrastructure will be limited to relatively small irrigation projects, due to the relatively high volumes and peak flow rates required for irrigation. Although oil and gas companies are generally reluctant to share capacity in their infrastructure while they have potential needs for it, they are often willing to purchase water at favourable prices, potentially improving the business case for developing water supply infrastructure for irrigation. Licensing arrangements specific to this purpose need to be developed to ensure water sources are protected and usage is accurately reported while enabling sufficient flexibility for producers to recover their infrastructure costs.

Table E-6: Feasibility Analysis Summary

Scenario	NPV per acre (Canola)	BCR	Net BCR[1]	Backward Linkages	Forward Linkages	Drought Risk	Solonetzic Soils	Soil Acidification	Water Quantity	Pests and Disease	Safety	Summary
1 – Tower Lake	-$271	0.95	-0.19	0	+	0	-	-	-	-	-	Insufficient water supply to irrigate half section of canola without constructed storage. Near break-even for canola, but still not financially feasible. Increase in land value may justify irrigation development.
2 – Tower Lake w/ storage	-$1,865	0.74	-0.40	0	+	+	-	-	0	-	-	Constructed storage is not financially feasible and economic and risk reduction benefits do not justify the cost.
3 – Halfway River	$518	1.09	-0.05	+	+	++	0	-	++	-	-	Irrigation is slightly less cost-effective than dryland canola production; however land value and drought risk reduction benefits justify the cost.
4 – Beryl Prairie	-$1,000	0.86	-0.28	+	+	++	0	-	+	-	-	Constructed storage is not financially feasible and economic and risk reduction benefits do not justify the cost.
5 – Peace to Dawson	-$2,579	0.71	-0.43	++	++	+	-	-	+	-	--	Direct and indirect economic benefits combined do not justify the cost of a major irrigation project in the BC Peace region.
6 – Peace to Dawson with Storage	-$1,654	0.78	-0.36	++	++	+	-	-	+	-	--	
Site C to Rose Prairie[2]	-$1,417	0.85	-0.29	++	++	+	-	-	+	-	--	
Dam on Creek[3]	-$729	0.97	-0.17	++	++	+	0	-	+	-	--	These scenarios involve higher unit costs and risks than Scenarios 1 and 3, and no significant relative advantages. Benefits to producers and the community do not justify the costs and risks.
Sewage Effluent[d]	-$1,215	0.80	-0.34	+	+	+	-	-	0	-	--	
Groundwater[5]	-$2,105	0.70	-0.44	0	0	0	--	-	--	-	-	
Shared Infrastructure[6]	-$1,619	0.85	-0.29	++	+	+	0	-	0	-	--	
New Crop[7]	$-	1.00	-0.14	+	+	+	0	-	-	--	-	New irrigated crops including sweet corn and vegetables have the potential to improve the financial feasibility of marginal scenarios, including Scenarios 1 and 3.

1. BCR with irrigation minus BCR without irrigation
2. Site C dam to Rose Prairie - assume slightly more cost-effective than Peace to Dawson Creek due to reservoir elevation advantage
3. Assume slightly more cost-effective than Scenario 4 due to lower unit cost of storage
4. Assume Fort St. John lagoon effluent treatment and local distribution - less cost-effective than Scenario 4 due to added treatment requirement
5. Assume slightly less cost-effective than Scenario 2 due to cost of well construction
6. Assume substantially more cost-effective than Scenario 5 due to cost sharing with other users
7. Assume slightly more cost-effective than Scenario 1 due to higher net revenue per hectare

-- = major negative impact
- = minor negative impact
0 = negligible impact
+ = minor positive impact
++ = major positive impact

Recommendations and Next Steps

The following actions are recommended, which are consistent with the previous recommendations of the *Regional Adaptation Strategies series: Peace Region* report as noted:

1. Using the case studies described in this report as benchmarks, consider conducting site-specific feasibility assessments and pilot irrigation projects where most or all of the following conditions are met:
    a. The soils, climate and topography are suitable for production of grains and oilseeds;
    b. Soils are relatively well drained and less than 30% Solonetzic;
    c. A source of water supply is available throughout the growing season, with at least 1,174 m³/acre of irrigated area (11.4 inches) per year in a dry year;
    d. The water source can reliably deliver a peak flow of 5 USgpm/acre (47 L/min/ha) for a single center pivot, or 1.7 USgpm/acre (16 L/min/ha) for every three center pivots, in a dry year;
    e. The water source is less than 0.6 miles (1 km) away and 65 feet (20 m) lower in elevation than the nearest centre pivot for projects to irrigate a quarter section (160 acres) or less; or less than 3 mi (5 km) away and 165 feet (50 m) lower in elevation for projects to irrigate more than one section;
    f. Hardness of the source water is low to moderate in mid to late summer;
    g. Three-phase power with adequate capacity is available within 0.6 miles (1 km) for projects to irrigate up to one section, and within 3 mi (5 km) for larger projects;
    h. Primary crops are cereals, canola, or other crops generating a similar or greater net revenue per unit area; and
    i. The producer has access to low-cost capital and will significantly benefit from increased revenue stability, reduced drought risk and improved land value.

    Pilot studies should include opportunities to evaluate inputs of capital, materials and labour, water demands, yields, costs, revenues and net returns to land for existing and potential future Peace region crop types including cereals, oilseeds, pulses, sweet corn, carrots, and forage seed crops. This recommendation supports Action 1.2B and Strategy 1.4 of the *Regional Adaptation Strategies series: Peace Region* report.
2. Further develop and formalize drought risk management strategies already in use for dryland forage production, including modest overproduction of hay, facilities and techniques for hay storage, and careful management of herd sizes within drought-resilient forage production limits. These strategies should be compared with the costs and risk-reduction benefits of irrigated feed production where irrigation is developed. This recommendation supports Strategies 1.5 and 3.2 of the *Regional Adaptation Strategies series: Peace Region* report.
3. Encourage collaboration between producers, governments, universities and industry organizations to fund and conduct pilot testing of irrigated agriculture in the BC Peace Region, including selection and optimization of a range of plant varieties, pest and disease management strategies, irrigation rates for a range of soil and climate conditions, and irrigation methods. Develop and maintain economic data to guide further development of irrigation where it yields the most benefit. This recommendation supports Strategies 1.4, 3.2, 4.2 and 4.3 of the *Regional Adaptation Strategies series: Peace Region* report.

1. Introduction

Kerr Wood Leidal Associates Ltd. (KWL) was retained in January 2015 by the BC Grain Producers Association (BCGPA) to conduct an Evaluation of Irrigation Potential in the BC Peace Region. Funding for the project was provided by Agriculture and Agri-Food Canada and the BC Ministry of Agriculture through the Investment Agriculture Foundation of BC under Growing Forward 2, a federal-provincial-territorial initiative. The program is delivered by the BC Agriculture & Food Climate Action Initiative. KWL was supported by the Partnership for Water Sustainability (Ted van der Gulik, P.Eng.) and InterAg Consulting (Jim Collins) as sub-consultants. This report presents the project methodology, findings and recommendations regarding agricultural irrigation in the Peace Region.

1.1 Background

During the winter of 2012 and early 2013, the BC Agriculture & Food Climate Action Initiative brought Peace region agricultural groups, producers and government specialists together to develop a plan for supporting the agriculture sector with adapting to climate change. Completed in the spring of 2013, the *Peace Adaptation Strategies* plan identifies priority climate change impacts and strategies for adaptation for the region's agriculture sector.

One of the changes of greatest concern for participating producers is more frequent, and intensifying, dry and drought conditions during the summer. Water shortages and substantial moisture deficits for crop production have been experienced in recent years. Greater water demand from competing uses, and water use restrictions prompted questions about whether the current and future water demand for agriculture has been adequately considered in planning scenarios. While currently there is very little irrigation of crops in the region, the potential for irrigation needs to be established to adequately assess future agricultural water demand.

To explore this issue further, an irrigation feasibility study for the Peace region was identified as a logical first step. Input and guidance on the study was provided by the Peace Adaptation working group. The working group was initially formed to support the *Peace Adaptation Strategies* planning process, and continues in their role (providing sector and local expertise) as the plan is implemented.

1.2 Project Objectives

The objectives of the evaluation of Irrigation Potential in the BC Peace Region project are to:

- through cost-benefit analysis, assess the future feasibilities of various irrigation and cropping scenarios for agricultural land in the BC Peace region; and
- identify suitable scales and structures of irrigation systems, and physical and institutional constraints, for current and future cropping scenarios.

The findings of this study will be shared with local governments and agricultural organizations for potential integration in planning initiatives for further study.

1.3 Project Context

Climate and Agriculture in the Peace Region

One third of BC's agricultural land and nearly all its grain and oilseed production are located in the Peace region. The Peace differs substantially from all other agricultural regions of BC due to its location east of the Rocky Mountains. Unlike other regions of BC, agriculture in the Peace region benefits from the typical northern prairie climate. Summer rains in a typical year enable successful dryland production of grains, oilseeds, forage and a variety of other crops. Nonetheless, summer soil moisture deficit is the primary limiting factor in agricultural productivity. In 2001, only 0.05% of the agricultural land in the Peace region was in irrigation. Although irrigation can increase yields, reduce drought-related risks or enable higher value crops to be grown, the costs have historically outweighed the benefits for most farmland in the region (except lands immediately adjacent to a reliable water source).

Climate change has a range of potential impacts on agriculture in the Peace region, including factors impacting the feasibility of irrigation:

- Warmer temperatures in general, increasing the length of the growing season, heat units, and seasonal soil moisture deficit; and
- More extreme weather, increasing risks of crop losses or poor yields.

Feasibility of Irrigation

The potential for irrigation in the region is heavily dependent on location. Plenty of water is available year-round in the Peace River, but the feasibility of using it is limited by costs of pumping and conveyance. Other water sources have seasonal capacity limitations, and some such as the Kiskatinaw are already heavily allocated. However, conditions may become more favourable for irrigation in coming years for a variety of reasons:

1. The Site C project could reduce infrastructure and pumping costs for downstream irrigation uses, although there would likely be offsetting costs of purchasing capacity from BC Hydro;
2. The widespread adoption of hydraulic fracturing for oil and gas in the past five to ten years has introduced new water demands throughout the region, and the possibility of sharing water supply infrastructure and costs; and
3. Communities such as Dawson Creek are reaching water supply capacity limits, and are also considering major pipeline projects.

These factors tend to increase the feasibility of water supply projects for irrigation; however, the economics are still heavily dependent on:

- proximity to a reliable source, timing of water availability for needs, and the elevation of sources relative to needs (pumping costs);
- regulatory approvals (surface and groundwater licencing); and
- availability and vulnerability of water resources in smaller streams and aquifers.

Key Issues

Key issues to be addressed though the evaluation of irrigation potential include:

- a high degree of uncertainty in the climate-related inputs to cost-benefit analysis, mainly due to the wide range in forecasts;
- uncertainty in future water needs for other uses, including hydroelectric power, oil and gas development, and municipal waterworks (impacting the availability of water in smaller catchments or aquifers, the feasibility of shared water supply infrastructure, and the commodity cost of water for irrigation); and
- uncertainty in market values of farm produce.

1.4 References

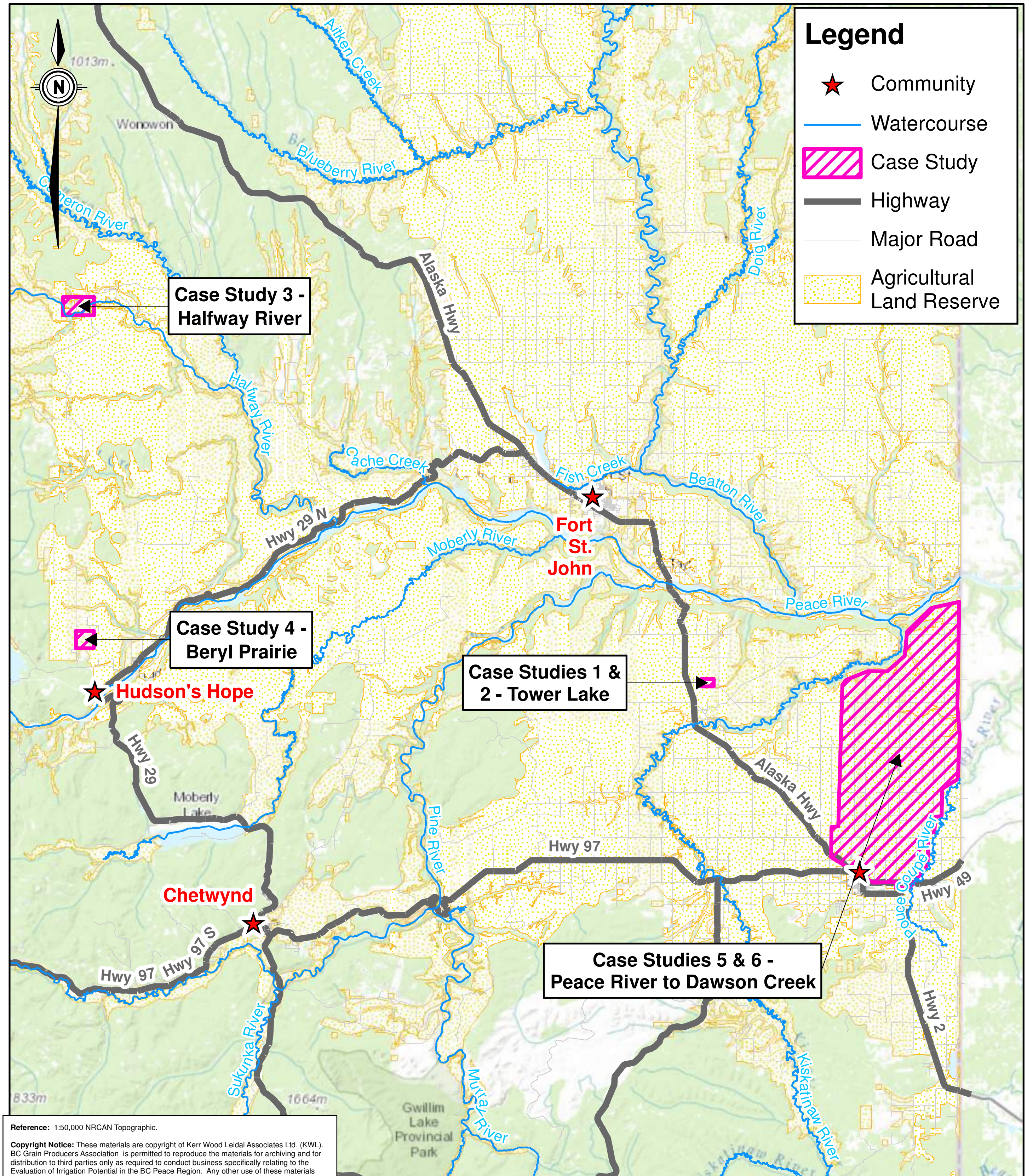
Primary references cited for this study include:

- Regional Adaptation Series: Peace Region – BC Agriculture and Food Climate Action Initiative;
- Grain and Oilseed Production Snapshot Report – BC Agriculture and Food Climate Action Initiative;
- Regional Agricultural Plan – Draft Background Report – Peace River Regional District (PRRD)
- Site C Clean Energy Project - Agricultural Assessment Supporting Documentation – Golder Associates, 2012;
- Irrigation resources available at the Ministry of Agriculture website;
- BC Oil and Gas Commission website and GIS dataset; and
- FLNRO water license data.

Several reports describing feasibility assessments and physical and economic parameters of the Lake Diefenbaker Development Area (LDPA) in Saskatchewan and major irrigation projects in Alberta were also cited in preparing this study. Technical and economic analysis of recent LDPA projects in particular provides a useful case study of the conditions favourable for irrigation development in western Canada, the planning/policy framework required, and important non-economic factors impacting decisions whether to proceed with major irrigation water supply projects.

1.5 Study Area

As described in the *Regional Adaptation Series – Peace Region* report, the study area is the Peace River Regional District in northeastern British Columbia. The western portion of the region is mountainous and is generally unsuitable for agriculture. The focus of this study is the agricultural land in the eastern part of the region (Figure 1-1).



KERR WOOD LEIDAL
consulting engineers

Evaluation of Irrigation Potential in the BC Peace Region

Project No.	Date
3444-001	February 2016

30 0 30 Kilometers

1:1,375,000

Study Area

Figure 1-1

Path: R:\3400-3499\3444-001\430-GIS\MXD-RP\3444001_StudyArea.mxd Date Saved: 26/02/2016 9:56:55 AM
Author: MScruton

2. Methodology

This section describes the development of water supply and demand scenarios for evaluation of irrigation feasibility, and the approach used for financial and economic analysis. The overall approach used for the analysis consisted of three general steps:

1. Estimation of available water supply and potential water demands using GIS-based tools;
2. Development of typical scenarios and example case studies for financial and economic feasibility analysis; and
3. Development of conclusions regarding feasibility of irrigation under a range of typical local conditions throughout the region, and recommendations for further work.

2.1 Field Review and Research

The feasibility of irrigation the BC Peace region was developed with reference to several previous studies, particularly in southern Alberta and Saskatchewan, and published methodologies for feasibility assessment of agricultural projects. Reports, maps and data were provided by the Ministry of Agriculture, particularly for estimation of water demands, unit costs and prices for financial feasibility analysis. Key project references are listed in Appendix A.

Between March 24 and March 26, 2015, members of the project team conducted a field review of agricultural areas in the Peace Region, and visited farms and interviewed producers. The tour group consisted of Colwyn Sunderland, Ted van der Gulik, Jim Collins, Julie Robinson (Ministry of Agriculture), and Lori Vickers (Ministry of Agriculture). Farms, potential water sources and other features were viewed on a driving tour from Fort St. John west to Bear Flat Lookout, north along Prespatou Road north of Montney Creek, east to Clayhurst and south to Dawson Creek. The team interviewed local producers to gain a practical understanding of the technical and financial conditions that may favour irrigation, and identified the scenarios and case studies that form the core of the analysis for this study. A summary of the field review is provided in Appendix B.

2.2 Climate

The earth's climate system is changing with a trend towards a warming of the planet. The Intergovernmental Panel on Climate Change (IPCC) has stated that global climate records and modelling indicate a warming of the global system is unequivocal (IPCC, 2013). A changing climate is anticipated to have significant impacts in the Peace Region. Dryland agriculture is vulnerable to extremes in temperature and precipitation. Climate directly impacts both water availability and water demand of crops.

The feasibility of irrigation in the Peace may change with climate; therefore, this study examines the viability of irrigating under in the current climate (based on recent weather and production data) and under a projected 2050s climate scenario.

Climate data was collected using historic information from Environment Canada (EC) climate stations. The 2050s climate scenario is based on the 'Plan2Adapt' tool for the Peace region developed by the Pacific Climate Impacts Consortium (PCIC) at the University of Victoria. These climate assumptions are consistent with those used in the *BC Agriculture & Climate Change Regional Adaptation Strategies Series: Peace Region*, and with the Ministry of Agriculture's Agriculture Water Demand Model (AWDM) that was used for estimating irrigation water demands for this study.

The AWDM contains daily climate data on a 500 m grid, supplied by PCIC. This data was used to calculate a crop water demand for which soil map data was available digitally. The climate grid data is available for current climate conditions as well as future climate data sets for the 2050s.

The impact of climate change on irrigation potential is assessed by using averages of future climate projections from PCIC to estimate water demands in the irrigation scenarios developed for this study. The magnitude and frequency of extreme droughts or floods cannot be reliably estimated based on the available climate projections; however, more frequent droughts and floods are expected. The AWDM 2050s results were used to simulate a drier average climate during the irrigation season that results in a higher irrigation water demand than currently required, as well as a lower unirrigated yield. The irrigated water demand was used in conjunction with available water supply which was estimated using the current 1:10-year low flow.

2.3 Water Supply

A regional hydrology assessment was undertaken for the Peace Region using the *Inventory of Streamflow in the Omineca and Northeast Regions* produced by the Ministry of Environment (MoE) in February 2015 for the purpose of water supply. The MoE report summarizes all of the Water Survey of Canada (WSC) hydrometric data in the region including monthly average flows and 1:10-year drought low-flows.

GIS was used with 1:50,000 Digital Elevation Models (DEMs) data to delineate watersheds and watercourses throughout the region. The watercourses were subsequently broken into a series of points for the purpose of using GIS to identify the closest water supply to a farmable area. The watercourse points were overlaid with WSC hydrometric station locations for the purpose of flow estimation. The WSC hydrometric data was applied to the watercourse points, and subsequently simulated flows upstream and downstream of their locations based on the contributing watershed at each watercourse point.

The watercourse points only identified sources that typically have water flowing all year. Small water supplies were not identified due to lack of high-resolution data; this was deemed acceptable as irrigation will become unfeasible as water supply decreases.

The average and the 1:10-year drought condition flows from the WSC data and MoE report were applied to the watercourse points to simulate typical and drought flows during the growing season of May to August. Water available for irrigation was limited to 15% of the average monthly flow which is assumed to be available for water licence while the remaining 85% is retained for environmental flows.

Watersheds that have a 1:10-year low flow less than the water available for licencing will have insufficient supply to maintain the environmental flow and supply water for irrigation. An irrigation system that draws from a low flow supply source will likely be unusable during a drought, when it is most needed.

2.4 Water Demand

Current and future irrigation water demands are calculated using the Ministry of Agriculture's Agriculture Water Demand Model (AWDM), which utilizes climate data downscaled by PCIC for the years 2000-2009, and forecast weather modelling for the years 2050-2059 based on the access1 rcp85, canesm2 rcp85 and cnrm-cm5 rcp45 models.[1]

Water demand in the region was estimated using climate data for both the current and future scenario. The AWDM uses a series of variables such as rooting depth, soil properties, rainfall, temperatures and irrigation efficiency to simulate the ideal amount of irrigation required to maximize crop growth.

Irrigation is heavily dependent on rooting depth, where less water is typically required for deeper-rooted crops. Each crop will have a different water demand; therefore, a range of expected irrigation requirements was developed to cover the wide range of possible crops. The most water intensive crops were modelled using a shallow rooted forage (mixed grass for hay, 12 inches) while a deep rooted cereal crop (wheat, 35 inches) was used to simulate less water intensive crops. Although other crops, particularly canola and pulses, are currently grown in crop rotations in the BC Peace Region, cereals and grasses grown for hay were selected as reference crops for water demand modelling as they represent high and low extreme rooting depths and crop water demands. Crops with a rooting depth between the shallow and deep rooting depths are expected to lie within the irrigation demand range. Canola is evaluated in the detailed case study analysis described in Part 4 of this report based on interpolation between the water demands for cereals and forage, and other crops are considered in Section 5.4.

Soil data was obtained from digitized provincial maps. The most accurate data available was 1:100,000 mapping used in conjunction with the companion soils report to develop soil moisture capacity and drainage rates for each type of soil (e.g., sandy soils have a low moisture capacity and are rapidly drained; therefore, they require more irrigation than a loamy soil). The data does not have the accuracy to assess the quality of topsoil, which is highly dependent on local conditions. Under the Ministry of Agriculture's Growing Forward program soil attribute data is currently being improved for the Peace River. This information is expected to be completed by the end of 2015, allowing the AWDM outputs to be improved.

The water demand model simulated future climate conditions (2050s) to assess irrigation feasibility. The model accounts for precipitation, and estimates required irrigation depth for optimal plant growth. The 2050s climate scenario was developed using downscaled 500 m x 500 m gridded climate data for the 2050-2059 period. The downscaled data represents the latest models developed for climate change that take into account topography, aspect and many other factors; the data cannot be perfect but provides the best estimate to date. The average of the three highest annual water demands modeled for 2050-2059 is assumed to represent a moderate drought year for the future scenario. The results are based on center pivot irrigation (78% efficiency).

[1] The AWDM is described in the following:

- Fretwell, Ron. "Irrigation Water Demand Model Technical Description." Technical Description. Ministry of Agriculture and Lands, Agriculture and Agri-Food Canada, 2009. http://www.obwb.ca/obwrid/docs/336_2009_App%20I2%20iwdm_technical_desc.pdf.
- van der Gulik, Ted, Denise Neilsen, and Ron Fretwell. "Agriculture Water Demand Model Report for the Okanagan Basin." BC Ministry of Agriculture, 2010. http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/water/agriculture-water-demand-model/500300-3_agric_water_demand_model-okanagan_report.pdf.

2.5 Scenario Development

The project team developed a set of typical scenarios and a case study was identified for each scenario. GIS was used to identify case study sites and relevant water demand and supply parameters. The case studies were used to validate each scenario and provide context to the feasibility of irrigation in the region. The overall objective of the scenarios is to evaluate the economic feasibility of irrigation under conditions typically available in the region.

Scenarios were developed based on irrigation water demand, proximity to a water supply, and the elevation difference between the water supply and point of irrigation. The scenarios, along with a description and case study, are presented in Table 2-1. The case studies are illustrated in Figures 2-1 through 2-4.

Table 2-1: Feasibility Scenarios and Case Studies

<table>
<tr><th>Scenario</th><th>Description</th><th>Case Study</th><th>Lift</th><th>Distance</th></tr>
<tr><td>1</td><td>Single Farm</td><td rowspan="2">Tower Lake</td><td rowspan="2">< 65 ft</td><td rowspan="2">< 0.6 mi</td></tr>
<tr><td>2</td><td>Single Farm with Constructed Storage</td></tr>
<tr><td>3</td><td>Small Community System</td><td>Halfway River</td><td rowspan="2">< 165 ft</td><td rowspan="2">< 3 mi</td></tr>
<tr><td>4</td><td>Small Community System with Constructed Storage</td><td>Beryl Prairie</td></tr>
<tr><td>5</td><td>Large System</td><td rowspan="2">Peace River to Dawson Creek</td><td rowspan="2">> 700 ft</td><td rowspan="2">> 3 mi</td></tr>
<tr><td>6</td><td>Large System with Constructed Storage</td></tr>
</table>

The scenarios were developed using the 500 x 500 m grids following these steps in GIS:

1. Assign each grid cell the irrigation water demand for forage and wheat crops under the current and 2050s climate (four different irrigation demands) using the Water Demand model;
2. Identify and report the closest water source using the watercourse points generated for the Water Supply model. This is used to assess water availability and if storage is required based on the irrigated water demand; and
3. Attribute an elevation to each grid cell and watercourse point by using 1:250,000 topographic data for the Peace region. The elevation difference between the grid cell and the closest water supply is used for determining pumping requirements.

Proximity of the electrical grid and available capacity were not factored into the scenario mapping, as the GIS data was unavailable. Feasibility for irrigation is impacted significantly by power availability.

2.6 Economic Feasibility Assessment

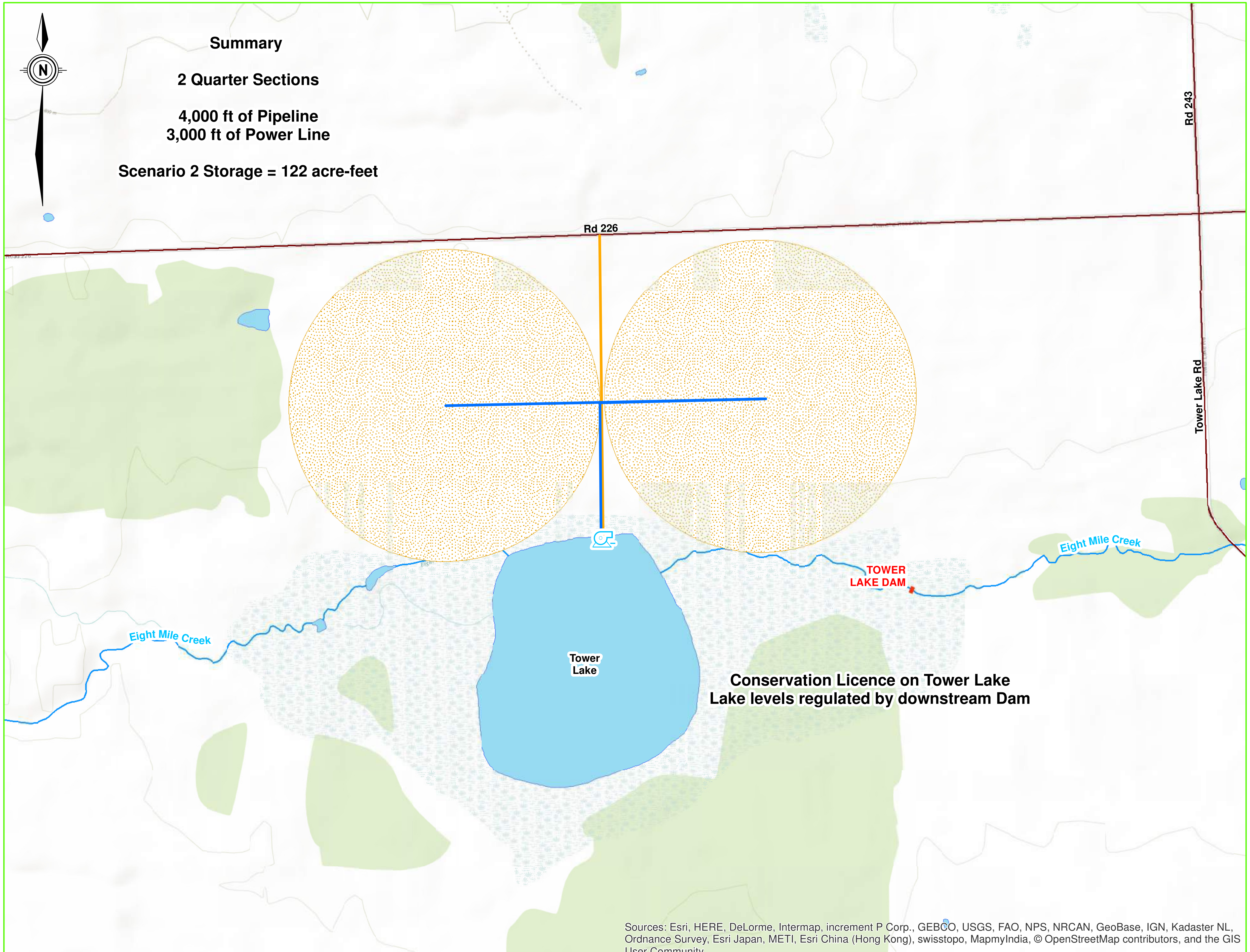
The feasibility of irrigation under each scenario was evaluated using an Excel-based financial model developed based on typical agricultural project evaluation practices.[2] The general sequence of analysis is as follows:

1. Define the physical and technical parameters for evaluating each scenario based on a representative case study (location, field area, water source location, electrical grid location, water supply and demand parameters from GIS models, and configuration of water supply and irrigation systems);
2. Apply a standard set of assumptions (including ranges for sensitivity analysis on input costs, yields and sale prices) for three reference crops: Cereals, canola and forage;
3. Estimate average, maximum and minimum annual revenues, capital and operating costs using the inputs and standard assumptions for each reference crop;
4. Calculate average, maximum and minimum direct benefit-cost ratios (BCR) and net present values (NPV) for status quo and irrigated production of each reference crop;
5. Identify limitations in the scenario such as availability of water supply capacity for licensing and water supply shortfall in a drought year;
6. Assess potential impacts of climate change in terms of increased frequency of drought, and impacts on BCR and NPV;
7. Assess the sensitivity of the results to variations in project life cycle (increase from 20 to 50 years), and variations in discount rate;
8. Consider the overall economic impacts on the region of widespread irrigation (i.e. more than 200,000 acres (80,000 ha), or about 10% of the agricultural land in the region) through comparison with rigorous economic assessments of similar-scale projects in Alberta and Saskatchewan;
9. Consider a range of environmental and social implications of widespread irrigation; and
10. Consider potential alternative water supply scenarios and their potential impacts on the feasibility of irrigation in the Peace region, including:
    a. use of groundwater;
    b. use of municipal wastewater effluent;
    c. major changes in crop and livestock mix;
    d. sharing water supply infrastructure with oil and gas industry; and
    e. constructing a major in-stream storage project.

[2] Sources cited include:

- "Cost-Benefit Analysis I – Key Concepts"; International Centre for Development Oriented Research in Agriculture (ICRA);
- Savva and Frenken; *Financial and Economic Appraisal of Irrigation Projects*; Food and Agriculture Organization of the United Nations (FAO), Harare, 2002.
- Parsons et.al.; Upper Qu-Appelle Water Supply Project – Economic Impact and Sensitivity Analysis; Regina, 2012.

Evaluation of Irrigation Potential in the BC Peace Region



Legend

- Pump Station
- Power Line for Pump
- Water Line for Centre Pivots
- Quarter Section for Irrigation
- Road
- Dam
- Lake
- Watercourse

KERR WOOD LEIDAL
consulting engineers

200 0 200 Meters

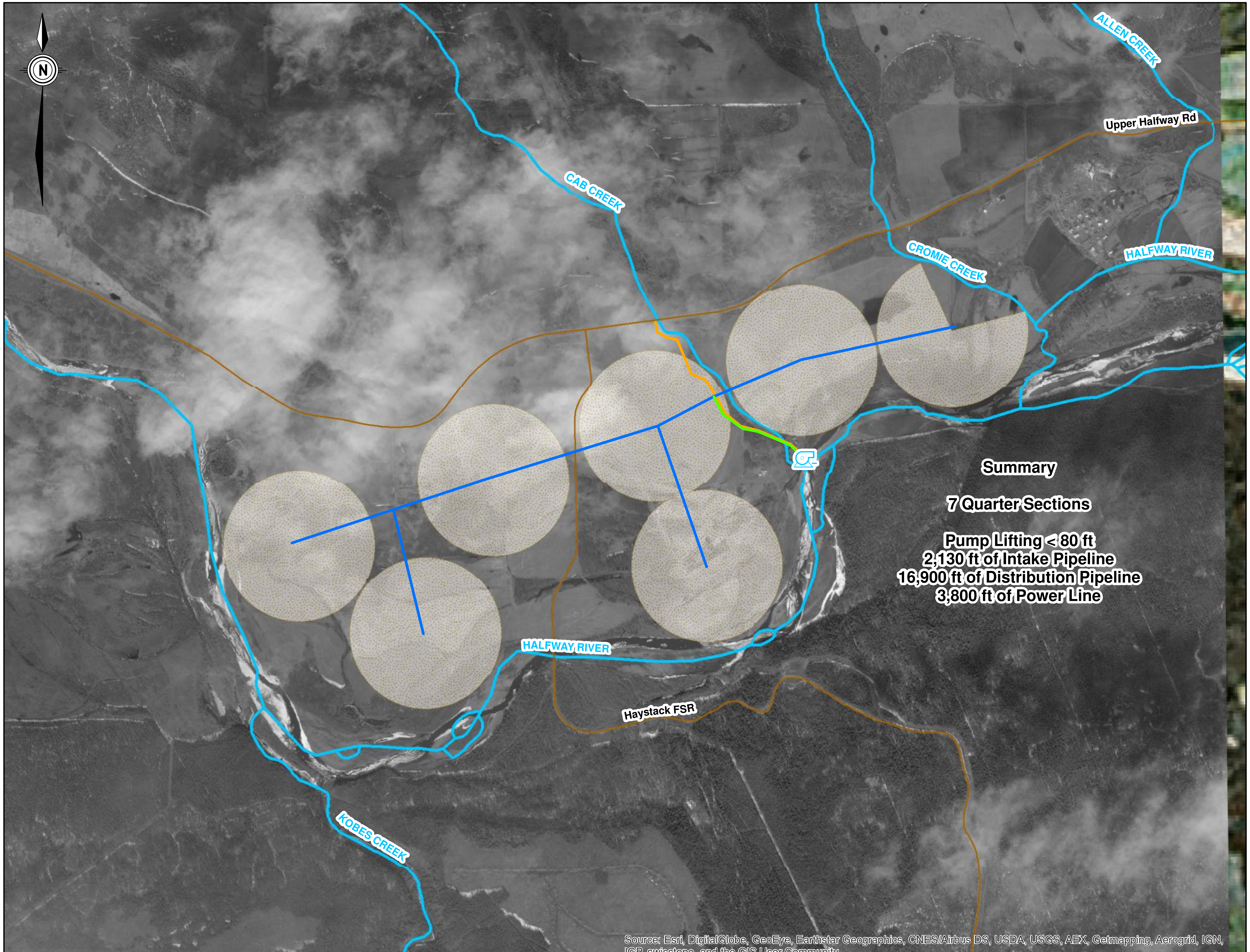
1:10,000

Project No.	Date
3444-001	February 22, 2016

Scenario 1-2 Case Study - Tower Lake

Figure 2-1

Path: R:\3400-3499\3444-001\430-GIS\MXD-RP\3444001_TowerLake_Scenario_20151013.mxd Date Saved: 22/02/2016 5:17:43 PM
Author: MScruton



Evaluation of Irrigation Potential in the BC Peace Region

Legend

- Pump Station
- Intake Pipeline
- Power Line
- Distribution Pipeline
- Quarter Section for Irrigation
- Major Road
- Watercourse

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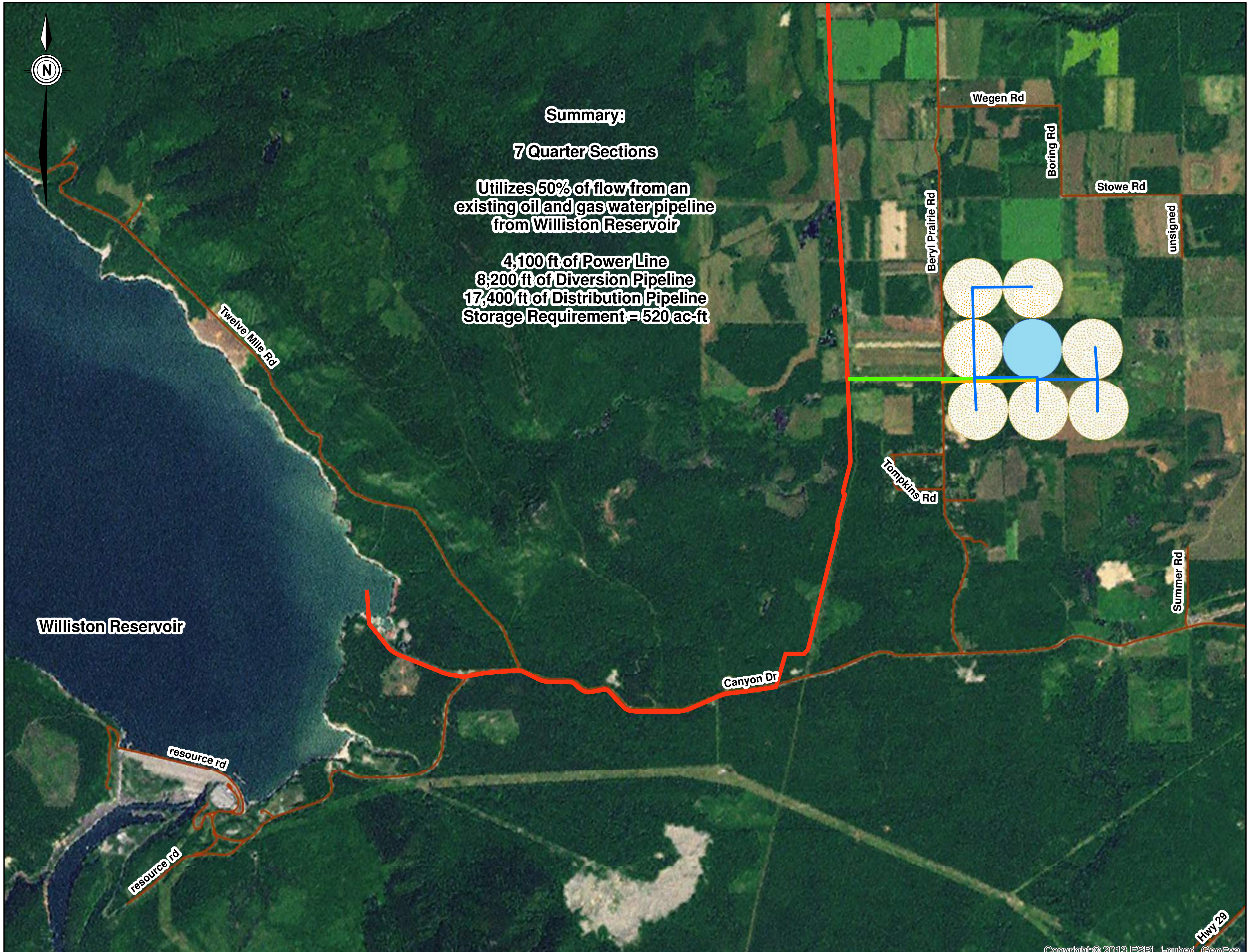
400 0 400
Meters

Project No.	Date
3444.001	February 2016

Scenario 3 Case Study - Halfway River Ranch

Figure 2-2



Evaluation of Irrigation Potential in the BC Peace Region

Legend

- Distribution Pipeline
- Water Diversion Pipeline
- Existing Water Pipeline
- Power Line for Pump
- Quarter Section for Irrigation
- Storage Reservoir
- Major Road

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1,500 0 1,500
Meters

Project No.	Date
3444.001	February 2016

Scenario 3-4 Case Study - Beryl Prairie

Figure 2-3

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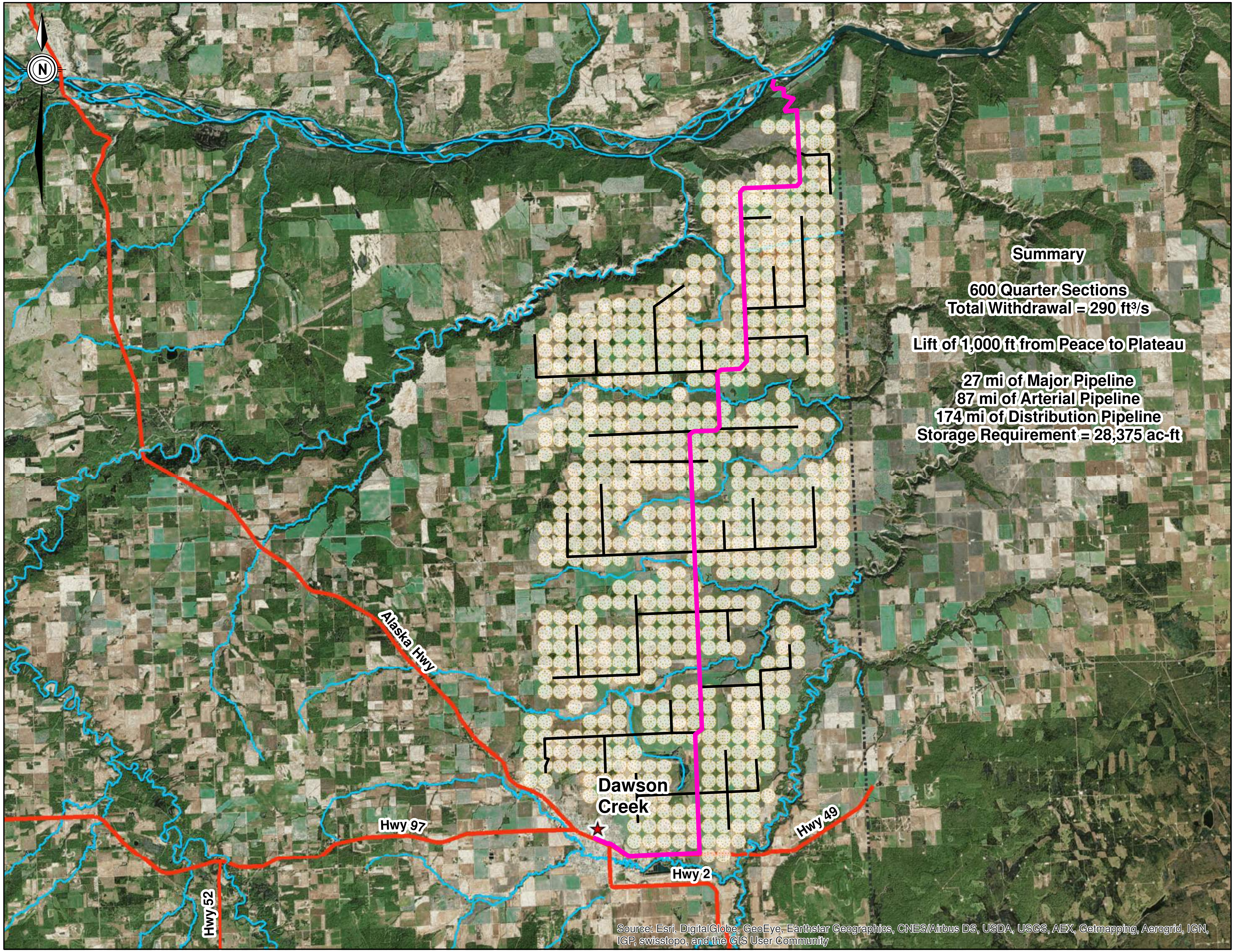
Author: MScruton

Evaluation of Irrigation Potential in the BC Peace Region



Legend

- Major Pipeline
- Arterial Pipeline
- Quarter Section for Irrigation
- Highway
- Watercourse
- Provincial Boundary

KERR WOOD LEIDAL
consulting engineers

5 0 5 Kilometers
1:200,000

Project No.	Date
3444.001	February 2016

Scenario 5-6 Case Study - Peace River to Dawson Creek

Figure 2-4

Path: R:\3400-3499\3444-001\430-GIS\MXD-RP\3444001_PeaceToDawson_20151210.mxd Date Saved: 26/02/2016 10:02:54 AM
Author: MScruton

3. Feasibility Analysis Parameters

The input parameters for the feasibility analysis are summarized in Table 3-1 and are described in the following sections. The complete set of typical assumptions is provided in Appendix C.

Table 3-1: Summary of Feasibility Parameters

Parameter	Primary Data Source(s)	Notes
Weather and climate (current and future, averages and extremes), degree-days, heat units, evapotranspiration rates	Agricultural Water Demand Model (AWDM) results, Peace Region, 2015 (Ministry of Agriculture)	AWDM includes PCIC climate models and Ministry of Agriculture crop data
Current farm types: land uses, typical crops/rotations, tillage/seeding practices, weed and pest control, timing of water needs	AWDM results; producer interviews, March 2015	AWDM data based on Agriculture and Agri-Food Canada satellite-based land use inventory, 2015
Potential farm types with irrigation: land uses, typical crops/rotations, tillage/seeding practices, weed and pest control practices	Alberta and Saskatchewan reports and data; producer interviews, March 2015; J. Robinson (Regional Agrologist); Project team experience	Typical crop rotations under irrigation in and near the Peace, and associated requirements
Soil properties	AWDM Results	Based on *Soils of the Fort St. John-Dawson Creek Area, British Columbia*, Report No. 42, BC Soil Survey, 1986
Topography: Elevation and slope	AWDM Results	Based on Provincial Digital Elevation Model dataset incorporated in AWDM
Potential water sources and available capacities, with seasonal and weather–related limitations	Water Survey of Canada	Average, wet year and drought year capacities, locations and elevations of water sources
Existing water infrastructure	Project team experience	Existing wells, dams, pump stations, pipelines
Irrigation methods and parameters	Project team experience	Costs, efficiencies and practical limitations
Asset/capital costs for each farm type	Alberta and Saskatchewan reports and data; project team experience	Cost of retooling, asset lifespans for annualized costs
Operating costs for each farm type	Alberta and Saskatchewan reports and data; project team experience	Comparative costs of irrigated and dry land production
Crop yields, dry land and irrigated (average, maximum and minimum adjusted for water availability; e.g. seed quality, disease, pests etc.)	Ministry of Agriculture data; Alberta and Saskatchewan reports; Statistics Canada; project team experience	Economic benefit of irrigation, and basis for optimization
Market conditions: farm gate prices, price volatility, market transition time, processing and distribution infrastructure needs	Ministry of Agriculture data; Alberta and Saskatchewan reports; Statistics Canada; project team experience	Provide averages and ranges of market parameters for sensitivity analysis

3.1 Weather and Climate

Climate information used for agricultural water demands in this report is based on historical weather data and downscaled global circulation modelling of future climate. Current and future irrigation water demands are calculated using the Ministry of Agriculture's Agriculture Water Demand Model (AWDM), which utilizes climate data downscaled by PCIC for the years 2000-2009, and forecast weather modelling for the years 2050-2059 based on the access1 rcp85, canesm2 rcp85 and cnrm-cm5 rcp45 models.

Weather data for the year 2009 was used to calculate water demand under current conditions. Although 2009 was the third driest year of the 2000 to 2009 period, it corresponds with the lowest yields. The years 2050, 2052, 2053, 2056, and 2058 were used for the future scenario as they represent a drought year based on the average of the three climate models. The three models were run for all five of these years and an average of the fifteen values (three models for five years) then presented for the grid cell.

Future Changes of Regional Agriculture

A warming climate will have significant impacts on agriculture in the Peace region. The projections described from Regional Adaptation report indicate the following key changes:

1. Warming temperatures will lead to a longer growing season (increased growing degree days);
2. Increased evapotranspiration and water demand from the warmer temperatures;
3. Earlier and less snowmelt resulting in lower summer flows in most river systems; and
4. Summer precipitation to remain relatively constant.

It should be emphasized that these are the forecasted average conditions over the 30-year period (2041 to 2069) and cannot accurately represent extreme rainfall or drought events and their associated occurrence frequency. Climate experts do anticipate a change in extremes:

- more extreme high temperatures leading to more crop stresses;
- longer dry periods in the summer leading to more frequent droughts; and
- increased intensity and magnitude of extreme rainfall leading to flooding and crop failure.[3]

In summary, in the 2050s the Peace Region is expected to have a longer growing period with a warmer climate which will entail more water demands. Irrigation would provide insurance against droughts and increase crop yields with the longer growing seasons; however, reliable water sources such as rivers and lakes will need to be managed effectively to maintain flows through the seasons.

[3] Climate Action Initiative, 2013

3.2 Water Resources

Water availability in the Peace Region can vary drastically through the irrigation season and can be a limiting factor for irrigation potential. Water is abundantly available during the spring when the snowpack melts while the summer flows are dependent on rainfall and groundwater base flows; this is reflected in the Water Supply model.

The irrigation potential was assessed using estimated 1:10-year low flows as irrigation will likely be most critical during a drought and the irrigation system should be designed for a minimum 1:10-year drought. Farms withdrawing from a watercourse that cannot support irrigation during a drought require construction of a reservoir to store water during the spring freshet for use during the dry summer. The cost of storage is accounted for in the case studies where water is unavailable during a drought.

Water availability in watercourses over the next 30 years into the 2050s is not well understood. It is anticipated that water availability during freshet will be reduced with smaller snow packs; however, summer low flows could remain relatively constant with the summer precipitation projections.

Water can be limited by existing water licence holders. The water available for irrigation was adjusted to take into account the existing water licences which can further exacerbate the challenge of water availability.

A risk assessment of water availability in the Peace Region to identify watersheds that are either over allocated with water licences or have low flows that could not support large-scale irrigation, is shown in Figure 3-1. The majority of watersheds in the region are subject to extreme low-flows that would struggle to support irrigation without storage. Watersheds that are supplied by the Rockies glaciers such as the Halfway River and Pine River or are regulated such as the Peace River typically maintain sufficient low-flows to support irrigation.

Groundwater aquifers could provide a supply for irrigation; however, the aquifers are currently not reliably quantified to understand recharge rates and storage volumes. Groundwater aquifers were not used in this study as a water resource; however, this could change as a detailed groundwater monitoring program is being initiated to assess water availability.

3.3 Water Demands

The Agricultural Water Demand Model was used in conjunction with water resources to assess irrigation potential. Crops with higher irrigation demands will require more available water; in the event that insufficient water is available, additional costs for storage will be incurred.

The model estimates irrigation demands for shallow rooted forage (mixed grass grown for hay) and deep-rooted cereals for both the current and future scenarios. On average, cereals are forecast to require 4 inches (110 mm) of irrigation while forage is forecast to require 14 inches (350 mm) under the 2050s scenario. The future scenario is used for the feasibility assessment, as it is prudent to design irrigation systems based on future needs.

3.4 Economic Variables

The financial feasibility analysis is based on the general assumptions set out in Appendix C, and input parameters specific to each case study scenario (Appendix D). The assumptions and sources are described in this section.

Irrigation Water Demands

Irrigation water demands were developed using the Agriculture Water Demand Model (AWDM). The demand calculated for the model is used in developing the irrigation scenario. The depth provided by the model is multiplied by the area irrigated to provide an overall volume of irrigation for the year. A peak flow rate of 5 USgpm/acre (47 lpm/ha) is used to determine the pump flow rate to operate all of the irrigation equipment on the project site.

A peak flow rate of 5 USgpm/acre is required to keep up with the peak evapotranspiration demand of 0.2 in/day (5 mm/day) in the BC Peace region. Normally irrigation systems would have to operate 24/7 to keep up with this evapotranspiration demand if peak conditions lasted for a number of weeks. However it is assumed that these peak conditions would not last a very long time in the Peace region and irrigation equipment may be operated sequentially (i.e., one center pivot would complete one full rotation, and then a second center pivot would complete a rotation after the first pivot has been turned off). This reduces the peak flow rate per hectare by half, reducing the required sizes of pumps and supply pipes. The smaller pump will however need to run twice as long.

Irrigation Operation and Maintenance

The annual cost of labour and materials for operation and maintenance of irrigation systems is assumed to be 2% of the capital cost. Irrigation will also increase the quantities of seed and fertilizer required to maximize production; higher costs for these materials are assumed under irrigation as indicated in Appendix C. It is assumed that three phase electric pumps with 70% overall efficiency will be used for irrigation. The cost of operating an irrigation system on diesel is roughly four times the cost of using electricity.

Crop Yields

Assumed minimum, average and maximum crop yields with and without irrigation are based on historical BC yield data from the Ministry of Agriculture and Statistics Canada. Yields without irrigation are assumed to be the averages (and minimum and maximum for sensitivity analysis) for the years 1993 to 2012. The project team estimated a range of potential yields under irrigation for each crop in consultation with the Ministry of Agriculture regional agrologist, based primarily on maximum yields without irrigation.

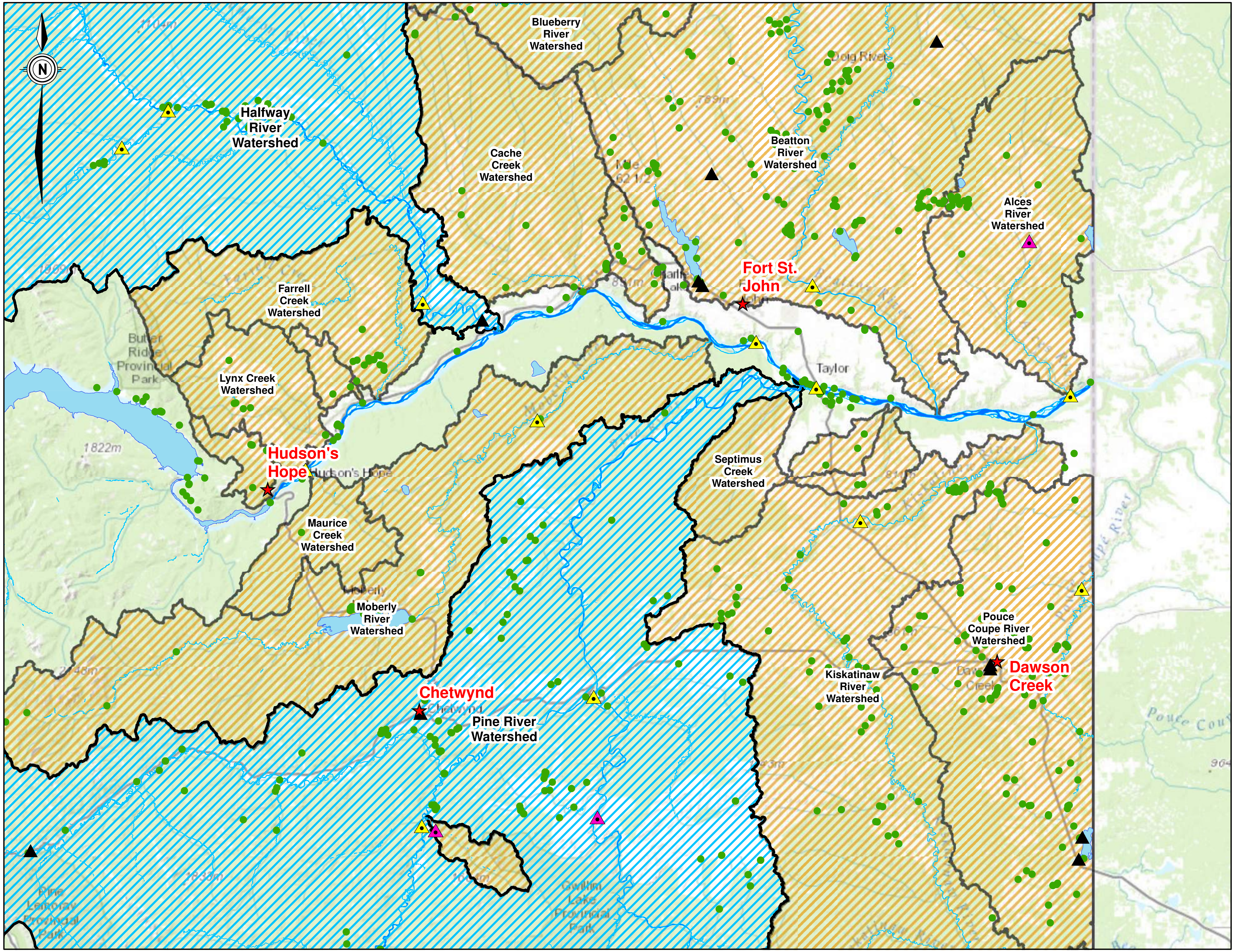
Unit Costs and Prices

Assumed minimum, average and maximum crop prices are based on historical BC price data from the Ministry of Agriculture and Statistics Canada, adjusted for inflation to 2015 dollars. The project team estimated a range of potential costs of seed, fertilizer and non-irrigation equipment operation with and without irrigation for each crop in consultation with the Ministry of Agriculture regional agrologist.

Life Cycle and Discount Rate

For the base case net present value (NPV) analysis of all scenarios, a project life cycle of 20 years and a discount rate of 5% are assumed. These parameters reflect the life expectancy of irrigation equipment and the assumed interest rate for a 20-year secured loan. Recognizing that interest rates may be greater for small projects, or some producers may compare the opportunity to invest in irrigation with other high-return investment opportunities, for sensitivity analysis the most pessimistic case is assumed to be a 20-year life cycle at a 10% discount rate. On the other hand, the water supply infrastructure included in larger-scale scenarios will last much longer than 20 years, and may be financed by government. The most optimistic case for sensitivity analysis is assumed to be a 50-year project life cycle, and a 3% discount rate.

Evaluation of Irrigation Potential in the BC Peace Region



Legend

- Community
- Active Hydrometric Site
- Active-Realtime Hydrometric Site
- Discontinued Hydrometric Site
- Active Water Licences
- Watercourse
- Low Risk - Moderate/High Summer Flows
- High Risk - Low Summer Flows

Reference: Basemap from NRCAN 1:50,000 Topo

KERR WOOD LEIDAL
consulting engineers

20 0 20 Kilometers
1:1,000,000

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Peace Region Watershed Risk Assessment

Figure 3-1

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Author: MScruton

4. Irrigation Scenarios

4.1 Scenarios 1 and 2

Scenarios 1 and 2 are identified as farms in close proximity to a water (< 0.6 mi) source that requires minimal pumping lift for irrigation (< 65 ft). These scenarios are intended to assess the feasibility of small-scale (i.e., single farm) irrigation in these situations.

Scenario 1 has a local water source that is able to provide sufficient water supply throughout the growing season while Scenario 2 requires storing water during high flows to support irrigation through the season. The case study used to evaluate these scenarios is the farm adjacent to Tower Lake.

Scenario 1 Case Study – Tower Lake

The Scenario 1 case study is shown in Figure 2-1 and consists of two quarter section fields on the Critcher Farm immediately adjacent to Tower Lake, approximately 11 mi southeast of Taylor. Tower Lake is used as storage to support irrigation throughout the irrigation season.

The quarter sections lie directly adjacent to Tower Lake and would require little lift; therefore, providing an opportunity to provide irrigation with relatively low operating costs. It is estimated that a 25 hp pump would be sufficient to provide adequate flows to a mobile quarter section centre pivot used on two sections. To minimize capital cost, it is assumed that a single mobile center pivot would be used at an initial cost of $100,000, rather than two fixed center pivots at a total cost of $160,000. However, the allowances for operation and maintenance cost may underestimate the actual labour required to move the system between fields as frequently as would be required to maximize crop production. An alternative to a mobile center pivot at a similar initial cost would be to purchase used pivots.

Tower Lake provides important wildlife habitat and conservation water licences exist. Water available for licencing is limited by the summer low flows and the water rights of other licensees. Tower Lake does not have sufficient inflow to meet irrigation needs in a drought year while maintaining existing licensees rights. On an average year there should be sufficient inflow to Tower Lake to support both irrigation and existing water licensees.

The infrastructure required for irrigating the Critcher Farm is:

- 25 hp Pump including installation: $20,000
- 4,000 ft of pipe: $28,000
- 1 Mobile Quarter Section Centre Pivot: $100,000
- 3,000 ft of 3-Phase electrical service: $90,000
- Total Cost: $238,000.

Scenario 2 – Tower Lake with Storage

Tower Lake cannot provide sufficient water for irrigation in a drought year, when crops would most need water. Water from Tower Lake would need to be diverted into storage during freshet in order to provide the required irrigation demand. Scenario 2 uses the same infrastructure as Scenario 1, with the added cost of building a storage dugout. Depending on the storage location, an additional pump may also be needed to supply the irrigation system. The dugout would need to be approximately 122 ac-ft (150,000 m³) to provide the irrigation demand of canola for an estimated cost of $425,000 and $20,000 for the pump for a total cost of $663,000.

4.2 Scenarios 3 and 4

Scenarios 3 and 4 are identified as small community systems within 3 mi from a water source that requires a maximum lift of 700 ft. These scenarios are intended to assess the irrigation feasibility of larger farms or a small community system (2+ farms).

Scenario 3 has a local water source that is able to provide sufficient water supply throughout the irrigation season while Scenario 4 utilizes the potential to share resources and infrastructure with the oil and gas industry.

Scenario 3 Case Study – Halfway River Ranch

The case study is shown in Figure 2-2 and consists of seven quarter-section fields on the Halfway River Ranch immediately adjacent to the Halfway River. The Halfway River is supplied by the Rockies and has sufficient water to support irrigation during a drought year.

The quarter sections are spread out along the north banks of the Halfway River and would require little lift. It is estimated that a 185 hp pump would be required to irrigate the quarter sections. A center pivot on each quarter section was assumed. The infrastructure required for irrigating the Halfway River Ranch is:

- 185 hp Pump including installation: $50,000
- 16,900 ft of distribution pipe: $118,000
- 2,130 ft of intake pipe: $30,000
- 7 Quarter Section Centre Pivots: $560,000
- 3,800 ft of 3-Phase Electrical service: $120,000
- Total Cost: $878,000.

Scenario 4 Case Study – Beryl Prairie with Existing Pipeline

This case study is strictly hypothetical and explores the possibility of sharing resources and infrastructure with the oil and gas industry to provide irrigation affordably to farms. Beryl Prairie was used as a large existing water pipeline runs through the region.

This scenario is shown in Figure 2-3 and utilizes existing oil and gas infrastructure for irrigation purposes. The existing system has a water licence to withdraw 8.1 ac-ft/day (10,000 m³/day) from Williston Reservoir. The water pipeline travels north through Beryl Prairie to deliver water for oil and gas purposes. The water pipeline cannot provide adequate demand to irrigate a large number of farms. A storage reservoir must be constructed in order to divert water before the irrigation season to provide the required irrigation demand.

This scenario assumed that 50% of the water (4.05 ac-ft/day) is available for irrigation and that pumping is only active from March 15 through October 15 (temperatures are on average above 0 °C). The limited water pipeline capacity, utilizing storage to a maximum, can only provide enough irrigation for seven quarter sections. The infrastructure required for irrigating with the existing water pipeline is:

- 8,200 ft of diversion pipeline (12”): $115,000
- 17,400 ft of distribution pipeline (8”): $122,000
- 520 ac-ft storage pit: $1,280,000
- 150 hp pump including installation: $50,000
- seven quarter section pivots: $560,000
- 4,100 ft of 3-Phase Electrical Service: $130,000
- Total Cost: $2,257,000.

4.3 Scenarios 5 and 6

Scenario 5 and 6 represent large regional systems that would lift water greater than 700 ft over distances greater than 3 mi. These scenarios are intended to assess the irrigation feasibility of a region wide system.

Scenario 5 and 6 withdraw water from the Peace River and move water through a large water pipeline ending in Dawson Creek where there is a growing need for a reliable water source. The feasibility of irrigation may increase when the water supply infrastructure serves multiple needs. Scenario 6 utilizes storage and to reduce the required size of the intake and pump station at the Peace River and the trunk water supply mains; however, a smaller pump station would be required at each storage location to feed distribution networks and provide adequate pressure for irrigation.

Scenario 5 Case Study – Peace River to Dawson Creek

This case study is shown in Figure 2-4. The irrigation system would provide water to 600 quarter sections between the Peace River and Dawson Creek.

The infrastructure required for a pipeline from the Peace River to Dawson Creek is:

- 27 mi of major pipeline: $89,600,000
- 87 mi of arterial pipeline: $56,000,000
- 174 mi of distribution pipeline: $6,400,000
- Large Pump Station with installation: $77,500,000
- 600 Quarter Section Centre Pivots: $48,000,000
- Total Cost: $279,000,000

Scenario 6 Case Study – Peace to Dawson Creek with Storage

In this scenario, peak demand on the pump station and pipeline would be reduced by implementing storage and pumping water into storage before and after the peak irrigation season. The irrigation system would provide water to 600 quarter sections between the Peace River and Dawson Creek.

The infrastructure required for a pipeline from the Peace River to Dawson Creek is:

- 27 mi of major pipeline: $38,300,000
- 87 mi of arterial pipeline: $23,000,000
- 174 mi of distribution pipeline: $6,400,000
- Large Pump Station with installation: $50,000,000
- 28,375 ac-ft storage reservoir: $35,000,000
- 600 Quarter Section Centre Pivots: $48,000,000
- Total Cost: $202,000,000.

4.4 Summary of Scenario Capital Costs

The capital costs of irrigation for each scenario are shown in the following table. The costs do not include operating expenses such as electricity or maintenance.

Table 4-1: Scenario Total Capital Irrigation Costs

Parameter	Acre	Total Irrigation Capital Costs	Irrigation Capital Costs per Acre
Scenario 1 – Tower Lake	320	$238,000	$744
Scenario 2 – Tower Lake with Storage	320	$663,000	$2,072
Scenario 3 – Halfway River or Beryl Prairie	1,120	$878,000	$784
Scenario 4 – Beryl Prairie with Storage	1,120	$2,257,000	$2,015
Scenario 5 – Peace to Dawson Creek	96,000	$279,000,000	$2,906
Scenario 6 – Peace to Dawson Creek with Storage	96,000	$202,000,000	$2,104

The irrigation capital cost brake-down can be reviewed in previous sections (Sections 4.1 to 4.3).

5. Feasibility Analysis

5.1 Financial Analysis

A financial analysis of each scenario case study was conducted using Microsoft Excel to enable comparison of each scenario against the status quo based on benefit-cost ratio (BCR) and 20-year net present value (NPV) for three representative crop types. The financial analysis considers only the direct benefits and costs of the water supply and irrigation system. The results of the analysis based on average parameters are presented in Tables 5-1 through 5-4. Sources and margins of error in the analysis are presented in Section 5.2. Where water sources are incapable of delivery peak irrigation flows under all crop scenarios, costs and benefits of including water storage ponds are evaluated. Capital costs included in the analysis are only those directly related to water supply and irrigation (capital investments necessary for production under all scenarios such as land, buildings and equipment are excluded).

The NPV is an estimate of the total net benefit (or cost) of production over a 20-year life cycle, with and without irrigation, where annual revenues and expenses are discounted at 5% per annum. The NPV is the difference between the present value of gross revenue to the combined present value of operating costs and capital investments in irrigation. A negative NPV (shown in red text) indicates that the combined present value of costs of investment and production over 20 years exceeds the present value of total revenue. The BCR is the ratio of the present value of gross revenue to the present value of total cost. A BCR of one is equivalent to zero NPV, and a BCR less than one (shown in red text) indicates a net cost over the 20-year life cycle. To cover overhead costs excluded and generate a satisfactory return on investments in land, facilities and equipment, the BCR must be significantly greater than 1.

Table 5-1: Financial Analysis – Scenarios 1 and 2 (Tower Lake – 320 acres)

Scenario	Capital Cost (Total)	Annual Operating Cost (Total)	Gross Annual Revenue (Total)	Net Annual Revenue (Total)	20-Year Net Present Value (Total)	Benefit-Cost Ratio
Forage – No Irrigation	$-	$29,943	$32,400	$2,457	$30,619	1.08
Forage – Irrigated	$237,559	$73,400	$48,383	-$25,017	-$549,325	0.52
Forage – Irrigated w/ Storage	$875,607	$86,161	$74,790	-$11,371	-$1,321,253	0.32
Cereal – No Irrigation	$-	$66,493	$77,146	$10,653	$132,757	1.16
Cereal – Irrigated	$237,559	$90,587	$117,765	$27,178	$101,138	1.07
Cereal – Irrigated w/ Storage	$237,559	$90,587	$117,765	$27,178	$101,138	1.07
Canola – No Irrigation	$-	$91,322	$104,214	$12,893	$160,673	1.14
Canola – Irrigated	$237,559	$124,370	$136,478	$12,108	-$86,669	0.95
Canola – Irrigated w/ Storage	$663,246	$132,884	$159,223	$26,339	-$596,79	0.74

Table 5-2: Financial Analysis – Scenario 3 (Halfway – 1,120 acres)

Scenario	Capital Cost (Total)	Annual Operating Cost (Total)	Gross Annual Revenue (Total)	Net Annual Revenue (Total)	20-Year Net Present Value (Total)	Benefit-Cost Ratio
Forage – No Irrigation	$-	$104,801	$113,400	$8,599	$107,165	1.08
Forage – Irrigated	$878,130	$265,433	$261,765	$3,668	-$923,838	0.78
Cereal – No Irrigation	$-	$232,725	$270,010	$37,285	$464,651	1.16
Cereal – Irrigated	$878,130	$318,730	$412,176	$93,447	$286,422	1.06
Canola – No Irrigation	$-	$319,626	$364,750	$45,125	$562,355	1.14
Canola – Irrigated	$878,130	$440,072	$557,282	$117,024	$580,246	1.09

Table 5-3: Financial Analysis – Scenario 4 (Beryl Prairie – 1,120 acres)

Scenario	Capital Cost (Total)	Annual Operating Cost (Total)	Gross Annual Revenue (Total)	Net Annual Revenue (Total)	20-Year Net Present Value (Total)	Benefit-Cost Ratio
Forage – No Irrigation	$-	$104,801	$113,400	$8,599	$107,165	1.08
Forage – Irrigated	$976,549	$263,349	$213,999	-$49,350	-$1,591,558	0.63
Forage – Irrigated w/ Storage	$2,256,549	$288,949	$261,765	-$27,184	-$3,145,099	0.46
Cereal – No Irrigation	$-	$232,725	$270,010	$37,285	$464,651	1.16
Cereal – Irrigated	$976,549	$321,070	$412,176	$91,106	$158,835	1.03
Cereal – Irrigated w/ Storage	$2,256,549	$346,670	$412,176	$65,506	-$1,440,198	0.78
Canola – No Irrigation	$-	$319,626	$364,750	$45,125	$562,355	1.14
Canola – Irrigated	$976,549	$440,479	$557,282	$116,803	$479,079	1.07
Canola – Irrigated w/ Storage	$2,256,549	$466,079	$557,282	$91,203	-$1,119,954	0.86

Table 5-4: Financial Analysis – Scenarios 5 and 6 (Peace to Dawson – 96,000 acres)

Scenario	Capital Cost (Total)	Annual Operating Cost (Total)	Gross Annual Revenue (Total)	Net Annual Revenue (Total)	20-Year Net Present Value (Total)	Benefit-Cost Ratio
Forage – No Irrigation	$-	$8,982,923	$9,720,000	$737,077	$9,185,608	1.08
Forage – Irrigated	$279,017,729	$29,635,746	$22,437,000	-$7,198,746	-$368,730,018	0.43
Forage – Irrigated w/ Storage	$209,226,138	$25,844,378	$22,437,000	-$3,407,378	-$322,311,034	0.39
Cereal – No Irrigation	$-	$19,947,840	$23,143,680	$3,195,840	$39,827,230	1.16
Cereal – Irrigated	$279,017,729	$34,004,840	$35,329,392	$1,324,552	-$262,510,886	0.63
Cereal – Irrigated w/ Storage	$190,226,138	$31,225,672	$35,329,392	$4,103,720	-$139,084,721	0.76
Canola – No Irrigation	$-	$27,396,480	$31,264,320	$3,867,840	$48,201,836	1.14
Canola – Irrigated	$279,017,729	$45,242,129	$47,767,030	$2,524,901	-$247,551,881	0.71
Canola – Irrigated w/ Storage	$202,226,138	$41,310,760	$47,767,030	$6,456,269	-$158,801,006	0.78

The results of the financial analysis based on average input assumptions generally indicate the following:

1. Dryland production of forage is marginally feasible based on operating costs alone;
2. Dryland production of cereals and canola yields a gross margin of roughly 15% over annual operating costs;
3. A producer paying the full cost of developing and operating irrigation would not achieve a net life-cycle financial benefit relative to the status quo in any of the project size, location or cropping scenarios evaluated;
4. Irrigating forage grass in the BC Peace Region is not cost-effective; and
5. Where water sources are insufficient to meet peak irrigation demands, developing water storage dugouts of sufficient size to supply peak irrigation needs is generally not cost-effective (yielding poorer financial results than either dryland production or partially irrigating without storage).

5.2 Sensitivity Analysis

The financial analysis is based on estimates of average capital costs, annual input costs, market prices, yields and financial analysis parameters, each of which has varying ranges of uncertainty. The consulting team identified probable maximum and minimum values for these parameters to develop estimated ranges of uncertainty in the results. An assessment of the sensitivity of the analysis results to variations in the input parameters is presented in this section.

Capital Costs

Capital cost estimates for the scenario case studies are highly conceptual, based on rough estimates of distances and elevations taken from imprecise satellite mapping and digital elevation data. Pump and pipe sizes are estimated using basic hydraulic calculations, and cost estimates are developed using available unit cost data that may not accurately reflect current market conditions in the BC Peace Region. Lump sum allowances are made for intake and pump station structures based primarily on experience in other regions. The capital cost estimates used in this analysis are considered to have a margin of error of -50% to +100%. The capital cost sensitivity of NPV and BCR for each irrigated scenario are shown in Table 5-5.

No irrigation scenario would be financially viable if capital costs were double the estimates. If capital costs were 50% of the estimates, the life-cycle benefits of irrigating cereals and canola under several scenarios would outweigh costs. Where water sources are adequate for irrigating cereals or canola without storage, developing irrigation at 50% of the estimated capital costs would yield a direct life-cycle benefit roughly equal to the status quo (BCR in the range of 1.15 to 1.20). Although this indicates that a producer investing in a low-cost irrigation project may recover the initial investment, the rate of return on the investment at would be roughly zero. Even at low capital costs, irrigating forage is not financially feasible.

Table 5-5: Sensitivity to Capital Cost Variation

Irrigation Scenario		At Estimated Capital Cost		100% Above Estimated Capital Cost		50% Below Estimated Capital Cost	
		Net Present Value (Total)	Benefit-Cost Ratio	Net Present Value (Total)	Benefit-Cost Ratio	Net Present Value (Total)	Benefit-Cost Ratio
1 – Tower Lake (without storage): 320 acres	Forage	-$549,325	0.52	-$846,094	0.42	-$400,940	0.60
	Cereal	$101,138	1.07	-$195,631	0.88	$249,523	1.20
	Canola	-$86,669	0.95	-$383,438	0.82	$61,715	1.04
2 – Tower Lake (with storage): 320 acres	Forage	-$1,321,253	0.32	-$2,415,100	0.21	-$774,330	0.45
	Cereal	$101,138	1.07	-$195,631	0.88	$249,523	1.20
	Canola	-$596,794	0.74	-$1,425,351	0.55	-$182,516	0.90
3 – Halfway: 1,120 acres	Forage	-$923,838	0.78	-$1,898,270	0.63	-$297,636	0.92
	Cereal	$286,422	1.06	-$780,667	0.87	$819,967	1.19
	Canola	$580,246	1.09	-$484,525	0.93	$1,116,109	1.19
3b – Beryl (without storage): 1,120 acres	Forage	-$1,591,558	0.63	-$2,755,955	0.49	-$926,034	0.74
	Cereal	$158,835	1.03	-$1,061,113	0.83	$768,809	1.18
	Canola	$479,079	1.07	-$740,86	0.90	$1,089,052	1.19
4 – Beryl (with storage): 1,120 acres	Forage	-$3,145,099	0.46	-$5,908,529	0.31	-$1,680,059	0.62
	Cereal	-$1,440,198	0.78	-$4,259,178	0.55	-$30,708	0.99
	Canola	-$1,119,954	0.86	-$3,938,934	0.64	$289,536	1.04
5 – Peace to Dawson: 96,000 acres	Forage	-$368,730,018	0.43	-$717,291,300	0.28	-$194,449,377	0.59
	Cereal	-$262,510,886	0.63	-$611,072,168	0.42	-$88,230,245	0.83

Irrigation Scenario		At Estimated Capital Cost		100% Above Estimated Capital Cost		50% Below Estimated Capital Cost	
		Net Present Value (Total)	Benefit-Cost Ratio	Net Present Value (Total)	Benefit-Cost Ratio	Net Present Value (Total)	Benefit-Cost Ratio
	Canola	-$247,551,881	0.71	-$596,113,163	0.50	-$73,271,240	0.89
6 – Peace to Dawson (with storage): 96,000 acres	Forage	-$322,311,034	0.39	-$583,685,575	0.26	-$191,623,764	0.52
	Cereal	-$139,084,721	0.76	-$376,723,622	0.54	-$20,265,271	0.96
	Canola	-$158,801,006	0.78	-$411,430,837	0.58	-$32,486,090	0.95

Operating Revenues and Costs

The financial analysis parameters listed in Appendix A include a range of average, high and low values for:

- unit costs of energy, labour, equipment, fertilizer and seed with and without irrigation;
- crop yields (tons or bushels per acre); and
- market prices per ton or bushel.

These values are based primarily on historical variations without irrigation in the Peace Region (Statistics Canada and BC Ministry of Agriculture data). Since the historical extremes are extremely unlikely to occur every year over a 20-year life cycle, the maximum and minimum values for life cycle analysis are assumed to be the historical average plus half of the difference between the average and the single-year extreme for each parameter (reflecting the averaging effect over a 20-year period). This approach accounts for the possibility of a significant and gradual change in the multi-year average values. The assumption underlying this approach is that future 20-year average prices and unirrigated yields will not vary beyond 50% of the range of historical single-year extremes.

There is no data available for irrigated yields in the BC Peace Region. Average, maximum and minimum irrigated yields were estimated by the consulting team in consultation with the Ministry of Agriculture regional agrologist. The estimates are based on current conditions. Although yields may change as climate changes in the future, the nature and magnitude of any changes in the averages cannot be predicted with any certainty.

The best case for each scenario is based on the following assumed combination of conditions:

- Market prices are above the historical average;
- Irrigated yields are above the predicted average; and
- All input costs are average (it is considered extremely unlikely that energy, labour, equipment, fertilizer or seed costs would be low while market prices are high).

The worst case for each scenario is based on the following assumed combination of conditions:

- Market prices are below the historical average;
- Irrigated yields are below the predicted average;
- Energy costs are double the predicted average; and
- Other input costs are average (it is considered extremely unlikely that labour, equipment, fertilizer or seed costs would be high while market prices are low).

The results of varying average yields, operating costs and market prices on NPV and BCR for each irrigated scenario are shown in Table 5-6.

Table 5-6: Sensitivity to Operating Revenue and Cost Variation

Irrigation Scenario		Estimated		Worst Case		Best Case	
		Net Present Value (Total)	Benefit-Cost Ratio	Net Present Value (Total)	Benefit-Cost Ratio	Net Present Value (Total)	Benefit-Cost Ratio
1 – Tower Lake (without storage): 320 acres	Forage	-$549,325	0.52	-$639,547	0.44	-$472,790	0.59
	Cereal	$101,138	1.07	-$232,875	0.83	$664,905	1.49
	Canola	-$86,669	0.95	-$544,634	0.70	$518,959	1.29
2 – Tower Lake (with storage): 320 acres	Forage	-$1,321,253	0.32	-$1,411,978	0.28	-$1,243,488	0.36
	Cereal	$101,138	1.07	-$232,875	0.83	$664,905	1.49
	Canola	-$596,794	0.74	-$1,058,084	0.54	$11,478	1.00
3 – Halfway: 1,120 acres	Forage	-$923,838	0.78	-$1,169,994	0.71	-$506,996	0.88
	Cereal	$286,422	1.06	-$882,624	0.82	$2,259,604	1.47
	Canola	$580,246	1.09	-$1,172,570	0.82	$2,823,379	1.44
3b – Beryl (without storage): 1,120 acres	Forage	-$1,591,558	0.63	-$1,862,916	0.56	-$1,240,925	0.70
	Cereal	$158,835	1.03	-$1,010,212	0.80	$2,132,017	1.43
	Canola	$479,079	1.07	-$1,276,056	0.80	$2,719,893	1.42
4 – Beryl (with storage): 1,120 acres	Forage	-$3,145,099	0.46	-$3,417,367	0.41	-$2,792,242	0.52
	Cereal	-$1,440,198	0.78	-$2,609,244	0.60	$532,984	1.08
	Canola	-$1,119,954	0.86	-$2,875,088	0.64	$1,120,860	1.14
5 – Peace to Dawson: 96,000 acres	Forage	-$368,730,018	0.43	-$397,771,205	0.39	-$340,942,778	0.47
	Cereal	-$262,510,886	0.63	-$362,714,871	0.48	-$93,380,991	0.87
	Canola	-$247,551,881	0.71	-$397,991,961	0.53	-$55,482,110	0.93
6 – Peace to Dawson (with storage): 96,000 acres	Forage	-$322,311,034	0.39	-$349,939,793	0.34	-$297,976,398	0.44
	Cereal	-$139,084,721	0.76	-$239,288,706	0.59	$30,045,175	1.05
	Canola	-$158,801,006	0.78	-$303,557,460	0.58	$28,747,614	1.04

Under the most favourable operating conditions, irrigating cereals and canola would be financially feasible both with and without storage in most cases. Under the least favourable conditions, no irrigation scenario would be financially feasible.

Life Cycle and Discount Rate

Net present value analysis enables the overall costs and benefits of an investment to be evaluated by adjusting returns on investment for the time value of money. This analysis is based on two major assumptions: The time period over which the investment is recouped (life cycle), and the annual discount rate at which future values are adjusted for comparison with present value. The NPV estimates presented in this study are based on the following parameters:

1. 20-year life cycle, reflecting the expected lifespan of irrigation equipment and pumps that comprise most of the capital investment by an individual producer, and a reasonable maximum timeframe for an individual producer to expect a full return on an investment in equipment; and
2. 5% discount rate, representing the current cost of long-term secured debt.

For large government projects such as the largest-scale scenarios considered in this study, lower discount rates and much longer life cycles are typical. Lower discount rates and longer terms increase the favourability of irrigation scenarios that have a positive annual cash flow (i.e., where revenues exceed operating costs). On the other hand, for small-scale projects, a 5% discount rate may not be sufficient to cover investment risks. Therefore, to review the sensitivity of the financial analysis to variation of the life cycle and discount rate, it is assumed that:

- the worst case scenario is a 20-year life cycle at a 10% discount rate; and
- the best case scenario is a 50-year life cycle at a 3% discount rate.

The results of varying financial parameters on NPV and BCR for each irrigated scenario are shown below. Varying the NPV parameters is generally low; however, optimum financial conditions would bring the benefit-cost ratio of irrigating cereals in Scenarios 1-3 roughly equivalent to the status quo.

Table 5-7: Sensitivity to Present Value Analysis Assumptions

Irrigation Scenario		Estimated – 20 yr, 5%		20 yr, 10%		50 yr, 3%	
		Net Present Value (Total)	Benefit-Cost Ratio	Net Present Value (Total)	Benefit-Cost Ratio	Net Present Value (Total)	Benefit-Cost Ratio
1 – Tower Lake (without storage): 320 acres	Forage	-$549,325	0.52	-$450,542	0.48	-$881,238	0.59
	Cereal	$101,138	1.07	-$6,178	0.99	$461,723	1.18
	Canola	-$86,669	0.95	-$134,479	0.90	$73,972	1.02
2 – Tower Lake (with storage): 320 acres	Forage	-$1,321,253	0.32	-$1,173,225	0.27	-$1,821,985	0.41
	Cereal	$101,138	1.07	-$6,178	0.99	$461,723	1.18
	Canola	-$596,794	0.74	-$611,971	0.66	-$548,690	0.87
3 – Halfway: 1,120 acres	Forage	-$923,838	0.78	-$878,942	0.72	-$880,584	0.88
	Cereal	$286,422	1.06	-$98,876	0.97	$1,476,939	1.16
	Canola	$580,246	1.09	$86,859	1.02	$2,038,266	1.17
3b – Beryl (without storage): 1,120 acres	Forage	-$1,591,558	0.63	-$1,446,712	0.56	-$2,397,481	0.70
	Cereal	$158,835	1.03	-$241,686	0.94	$1,244,360	1.13
	Canola	$479,079	1.07	-$65,539	0.99	$1,776,712	1.14
4 – Beryl (with storage): 1,120 acres	Forage	-$3,145,099	0.46	-$2,901,236	0.39	-$4,289,788	0.56
	Cereal	-$1,440,198	0.78	-$1,739,633	0.67	-$694,322	0.94
	Canola	-$1,119,954	0.86	-$1,563,486	0.75	-$161,970	0.99
5 – Peace to Dawson: 96,000 acres	Forage	-$368,730,018	0.43	-$340,304,713	0.36	-$464,239,768	0.55
	Cereal	-$262,510,886	0.63	-$267,741,073	0.53	-$244,937,324	0.79
	Canola	-$247,551,881	0.71	-$257,521,823	0.61	-$214,052,621	0.85
6 – Peace to Dawson (with storage): 96,000 acres	Forage	-$322,311,034	0.39	-$284,894,211	0.34	-$448,811,529	0.49
	Cereal	-$139,084,721	0.76	-$155,288,860	0.66	-$84,638,401	0.91
	Canola	-$158,801,006	0.78	-$171,728,579	0.69	-$115,772,545	0.91

Combined Margin of Uncertainty

The sources of uncertainty evaluated in the previous sections are assumed to be mutually independent. Since it is extremely unlikely that two or more sources of uncertainty will be maximized concurrently in the same direction, the combined margin of uncertainty is less than the sum of the margins of uncertainty on individual parameters. The following algorithm is used to estimate the combined margin of uncertainty for each case study and crop scenario:

1. Calculate the positive and negative relative error in NPV for each error source:
   a. Max% = (maximum NPV/estimated NPV – estimated NPV) x 100%; and
   b. Min% = minimum NPV/estimated NPV – estimated NPV) x 100%.

2. Calculate the maximum NPV as the estimated NPV times the square root of the sum of the squares of the relative maximum errors:
   a. Combined Max% = ($Max\%capital^2$ + $Max\%operating^2$ + $Max\%financial^2$ $)^{0.5}$; and
   b. Combined Min% = – ($Min\%capital^2$ + $Min\%operating^2$ + $Min\%financial^2$ $)^{0.5}$.
3. Calculate absolute combined error in NPV for the scenario:
   a. MaxNPV = Max% x estimated NPV/100%; and
   b. MinNPV = Min% x estimated NPV/100%.

The results of the NPV analysis with combined margins of uncertainty are presented and discussed in the following section.

5.3 Scenario Analysis Results and Discussion

The NPV with the combined margin of uncertainty for each case study and crop scenario is shown in Figures 5-1 through 5-4, and the analysis results are discussed following each figure.

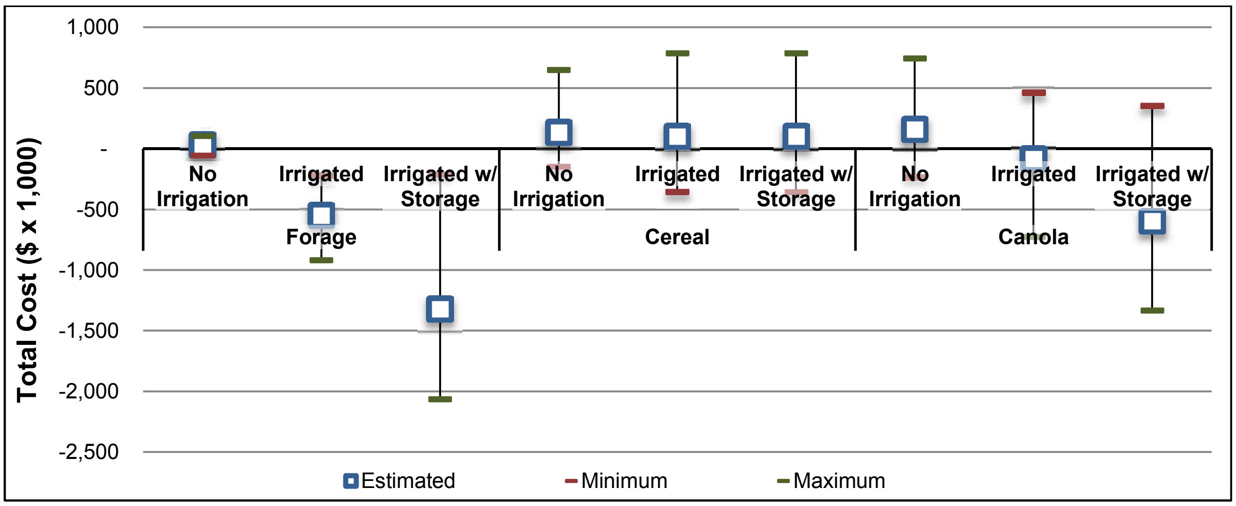

Figure 5-1: Net Present Value – Scenarios 1 & 2, Tower Lake ($ x 1,000)

Tower Lake is estimated to have sufficient storage capacity (based on a maximum lake level variance of 6 inches to maintain waterfowl habitat) to reliably irrigate half section of cereals; however, additional storage is required to irrigate half section of forage or canola. As shown in Figure 5-1, the added cost of a storage pond decreases the NPV of irrigating forage and canola; avoiding constructed storage and irrigating only quarter section results in a greater NPV in both cases. Only cereals can be irrigated at a NPV comparable to that of dryland agriculture. Irrigation increases the maximum potential NPV; however, it also slightly increases the risk of a net loss.

Since crop rotation is necessary to maintain soil productivity and manage weeds and disease, the overall indication is that developing irrigation without constructed storage would slightly decrease the 20-year net revenue of the Critcher farm. Introducing new, higher-value crops that benefit from a reliable supply of 4 to 6 inches of irrigation may improve the business case for irrigation. A small potential decrease in average revenue may also be an acceptable cost to reduce the revenue instability of dryland production, and the risk of diminishing average yield as the region's climate changes in coming decades.

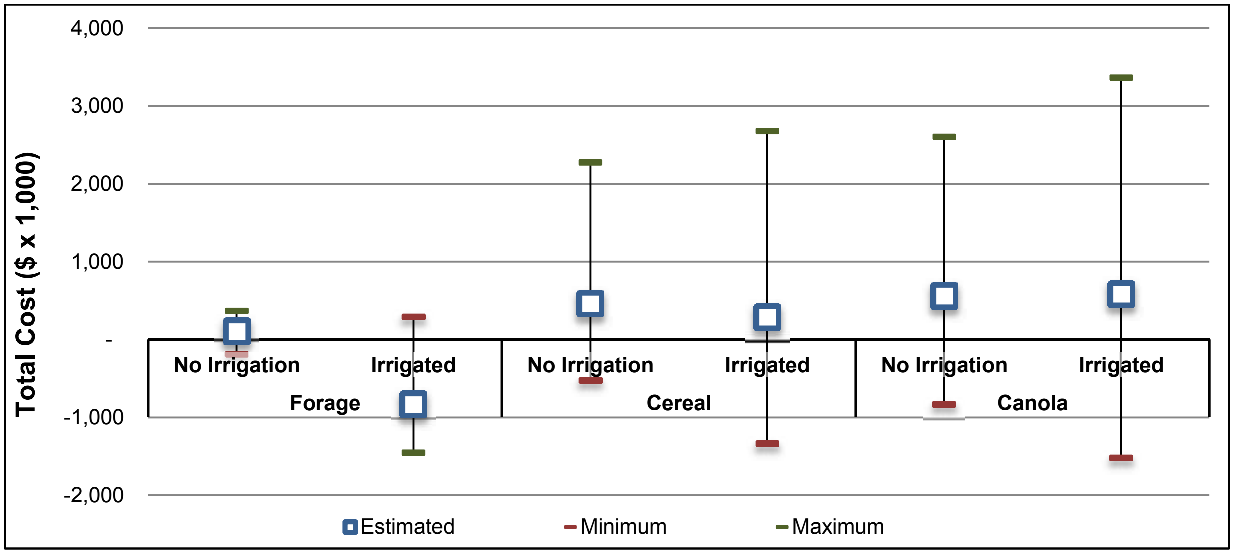

Figure 5-2: Net Present Value – Scenario 3, Halfway Ranch ($ x 1,000)

The snowmelt-fed base flow in the Halfway River is sufficient to supply irrigation of most or all of the farmland in the vicinity of the Halfway Ranch without constructed storage. For the portion nearest the River and at similar elevation (roughly 500 acres), developing irrigation is estimated to slightly increase the 20-year NPV for canola, and to nearly break even for cereals. As with Tower Lake, irrigation increases the maximum potential NPV for both cereals and canola, but slightly increases the risk of a net loss.

The Halfway Ranch represents the strongest financial business case for irrigation among the case studies evaluated for this study.

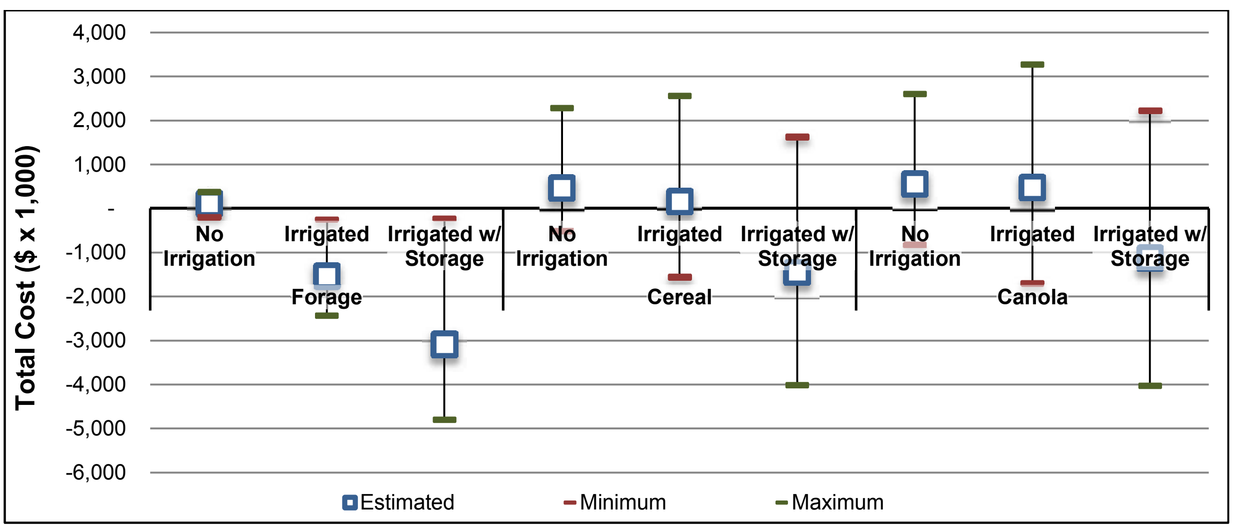

Figure 5-3: Net Present Value – Scenarios 3 & 4, Beryl Prairie ($ x 1,000)

An existing water pipeline constructed for oil and gas development that runs through Beryl Prairie provides an opportunity to hypothetically evaluate the potential to negotiate to share unused capacity in existing infrastructure. Although the feasibility of such an arrangement depends entirely on the ability of the parties to reach a mutually beneficial agreement, the technical and financial feasibility of connecting fields to the existing infrastructure can readily be assessed.

The flow rates required to irrigate the large farms in the Peace Region are large relative to all other uses of water in the region, including gas development and processing. Assuming 50% of the capacity in the existing pipeline through Beryl Prairie is available for agriculture, the available water is sufficient to irrigate only four sections of cereals, two sections of canola or one and a half sections of forage. Without constructed storage to supply peak irrigation demands, only about half of these areas could be fully irrigated.

The cost of constructed storage results in a weak business case for irrigation using the existing pipeline even in the most optimistic conditions.

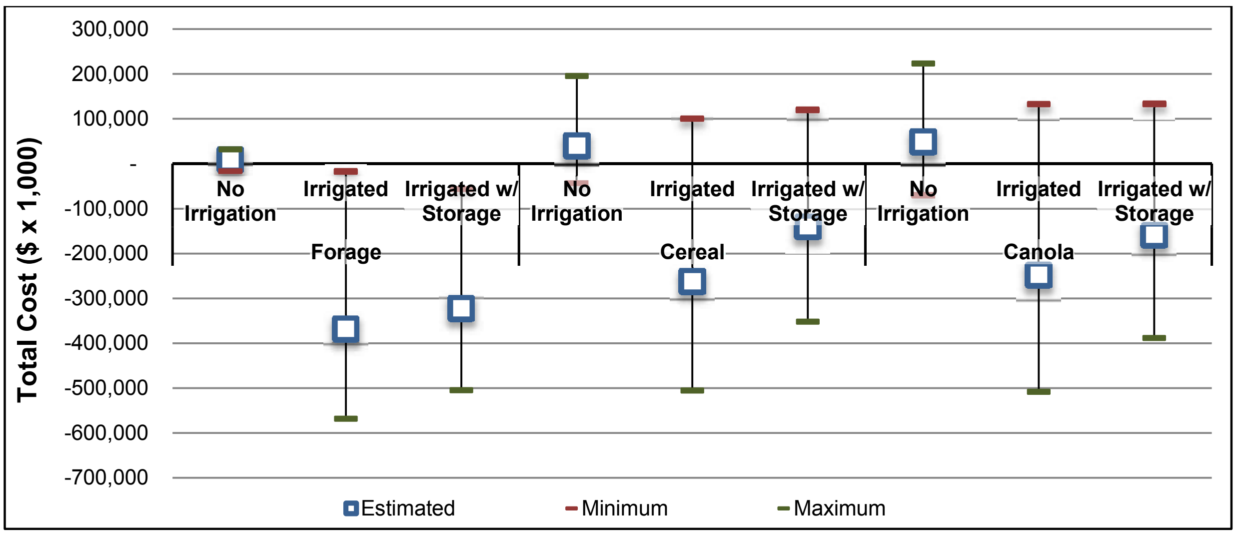

Figure 5-4: Net Present Value – Scenarios 5 & 6, Peace to Dawson Creek ($ x 1,000)

The Peace River to Dawson Creek case study is intended to evaluate the feasibility of a major irrigation project, similar in scale to irrigation districts in southern Alberta and the Diefenbaker Lake system in Saskatchewan. The project could hypothetically serve at least two primary purposes, providing irrigation for many farms in the South Peace region and a dry season water supply to Dawson Creek, which experiences recurrent water shortages due to the lack of natural or constructed storage in the Kiskatinaw watershed that serves as its current water source.

The infrastructure required to lift water 1000 ft (300 m) from the Peace River and transport it to 600 quarter sections between the River and Dawson Creek is substantial. Without storage, a 50,000 hp pump station and intake structure on the River would feed a bank of four six-foot diameter pipes to transfer water up the embankment to Doe River. The number of pipes in the trunk line would decrease as the main stem of the system continues south to Rolla and Dawson Creek, feeding a system of three-foot diameter branch lines that in turn connect to 8-inch service lines to individual fields.

An alternate scenario that includes constructed storage to meet peak demands could reduce the size of the Peace River pump station to 23,000 hp and reduce the number and sizes of trunk mains; however, at a storage depth of 20 feet, 2.5 sections (1600 acres) of land would be required for the estimated 35 million m^3 of storage that would be required for canola. Booster pump stations would be required at storage locations to provide pressure for irrigation.

The life cycle cost would substantially outweigh the direct benefits of the Peace River to Dawson Creek scenario for all assessed crop types, with or without storage, in all but the most optimistic conditions. It is extremely unlikely that irrigation would yield a direct financial benefit relative to the status quo for any of the evaluated alternatives.

5.4 Other Potential Irrigation Scenarios

The scenarios evaluated in the previous sections are expected to represent the most favourable scenarios for irrigating the current primary crop types in the BC Peace Region at a range of scales. Although the following additional scenarios are not evaluated in detail, they are compared in this section with the case study scenarios through identification of factors that may increase or decrease their feasibility relative to the case studies.

Site C Reservoir

Utilizing the Site C reservoir as a water source for irrigation is a variant of Scenarios 5 and 6. Using the reservoir as the source for a system that ultimately connects to Dawson Creek would reduce or eliminate intake costs and would reduce the required lift by 215 ft (65 m), reducing the capital and operating costs of pumping. However, the pipeline route would be considerably longer, including at least 15km through difficult terrain including crossing the Pine River to reach the northwestern extent of the farmland south of the Peace River. This scenario would certainly be more costly than the case study scenarios, and the shortest route to Dawson Creek (approximately following Highway 97) would not access farmland as efficiently as the case study scenarios.

An alternate scenario that may offer similar benefits to the case studies would be a pipeline from the Site C dam location north to the region between Montney, North Pine and Rose Prairie. This scenario may benefit from the Site C reservoir elevation and water quality while accessing farmland efficiently. As with the Peace to Dawson case study, the feasibility of a Site C to Rose Prairie project would rely on senior government investment to cover most or all of the capital cost of the shared infrastructure. This scenario is unlikely to significantly improve the feasibility of a major irrigation project in the BC Peace region.

In-Stream Storage

Water storage may be developed at a significantly lower construction cost than the $1230 to 3690/ac-ft (\$1 to \$3/m^3) of live storage assumed for this analysis, by constructing dams to create reservoirs in river valleys or other natural depressions in the landscape. Examples of potential in-stream storage scenarios in the BC Peace Region include:

- increase Charlie Lake weir height by 12 inches (0.3 m);
- dam Doe Creek or Saskatoon Creek (tributaries to Pouce Coupé River) at 620 m contour;
- dam Upper Goleta Creek at 620 m contour; or

- dam Alces River at 600 m or Kiskatinaw River at 620 m contour – potentially combine with hydropower project.

Efficiency of the catchment must be considered in each case, and elevation relative to farmland also significantly impacts overall project feasibility.

In the most ideal conditions, storage costs as low as \$300/ac-ft (\$0.25/m^3) may be achievable with large dams; however, only the largest projects in the most ideally suited locations are likely to achieve unit costs lower than \$1200/ac-ft. The most cost-efficient new dam storage scenarios would also involve major changes to regionally significant creeks or rivers, and would require a high level of effort for planning, engineering, environmental assessment, land acquisition and regulatory approvals, with a high initial risk that the project will not proceed. It is therefore very unlikely that developing new in-stream storage would significantly improve the feasibility of irrigation in the BC Peace Region.

If the environmental and shoreline property impacts are acceptable, raising the existing Charlie Lake weir or similar projects to regulate levels of other lakes or wetlands within a level range of up to 12 inches (0.3m) would likely represent the lowest-cost storage improvement in the region based on unit cost. Irrigating suitable farmland near a regulated lake or wetland may approach the financial feasibility of Scenario 3 (Halfway River). This approach would require coordination with the holders of existing wildlife conservation licenses on these watercourses, to ensure water levels will be managed to prevent harm to nesting waterfowl.

Municipal Wastewater Effluent

The Town of Dawson Creek has partnered with Shell Canada to improve its wastewater treatment system to supply up to 3.2 ac-ft/day (4,000 m^3/day) of reclaimed water to Shell for its operations in the South Peace Region. Shell has constructed a 30 mi (48 km) pipeline to deliver the reclaimed water from Dawson Creek to its Groundbirch area operations. The total cost of the treatment improvements was approximately \$13 million. Additional treatment may not be necessary for irrigation use; regulatory requirements for effluent quality for irrigation are dependent on several factors, including the method of application.

If the need for fresh water related to gas development activity (primarily for hydraulic fracturing of wells) declines within the next 20 to 30 years as forecast, there may be a longer-term opportunity to purchase or lease the Shell infrastructure for irrigation uses. As the pipeline runs primarily through farmland, the cost of additional conveyance infrastructure would be minimal for farms near the pipeline. However, a storage and local pumping would be required to fully utilize the available 1,200 ac-ft/year (1.5 million m^3/year) (suitable for roughly 4.5 sections of canola).

A similar reclaimed water project could be developed at Fort St. John for irrigation use. The population and municipal water demand of Fort St. John are roughly 50% greater than that of Dawson Creek, indicating that a wastewater effluent flow of approximately 1,800 ac-ft/year may be available (suitable for roughly 7 sections of canola). The requirement for treatment, storage and conveyance for this scenario would result in a considerably higher unit cost of irrigation water supply than that of the Beryl Prairie with storage scenario, and a correspondingly lower financial feasibility.

Groundwater

Groundwater sources in the agricultural areas of the BC Peace Region generally have low to moderate productivity and poor quality. Total dissolved solids (TDS) and hardness of bedrock well water is typically greater than 1,000 mg/l. Softer groundwater may have high fluoride and barium concentrations associated with sodium bicarbonate. The most productive bedrock wells in the region are in the range of 250 USgpm (16 L/s) (Dunvegan Formation), and most have much lower yields. Surficial aquifers that produce higher yields and may have better water quality generally follow the major river valleys, and are likely to interact with surface water. Confined aquifers recharge slowly (in the order of centuries or millennia), and are therefore highly vulnerable to over-pumping at the flow rates that would be required for irrigation.[4]

Although groundwater may prove suitable for irrigating on a local scale (1/4 to one section) in some locations, conditions favourable for irrigating on a larger scale using groundwater are unlikely to exist in the BC Peace Region (with the exception of riverbank wells near major rivers). Unconfined aquifers may be unproductive in drought conditions, and the use of confined aquifers for irrigation is likely unsustainable. Storage would likely be required to supply the flow rates required for center pivot irrigation, resulting in a similar or lower financial feasibility to the Tower Lake with storage case study (Scenario 2). Groundwater is therefore unlikely to be a significant source of water for irrigation in the BC Peace Region.

Shared Infrastructure

In recent years, there has been substantial investment in water supply infrastructure in the BC Peace Region, including pump stations, pipelines and storage ponds to supply oil and gas development needs. Although most of the infrastructure has been developed by oil and gas companies, some has been developed by agricultural producers. A more deliberate and coordinated effort to develop infrastructure that meets combined agricultural, oil and gas, municipal and other industrial needs may enable a significant area of farmland to be brought under irrigation. The best opportunities currently appear to be in the South Peace region, where concentrated gas development activity coincides with widespread agricultural production.

A major water supply project that brings water from a major surface water source (e.g., Peace, Pine or Beatton River) to an area that shares agricultural opportunities with gas development and possibly municipal needs may be feasible. Based on the Peace to Dawson case studies, it is unlikely that such a project would be cost-effective for a primarily agricultural purpose. Such a project may only be feasible if the scale of irrigation is kept small enough that the majority of the project cost will be paid by the oil and gas development or municipal participants, both of which can justify a much higher unit cost of water than irrigation.

To date, oil and gas companies have been reluctant to share water supply infrastructure with other users. It is likely that agricultural producers would need to play a lead role in developing the shared infrastructure, potentially including ownership. The risks associated with developing infrastructure without a firm revenue stream from other users must be considered carefully. Water licensing for multiple uses may also be significantly more complex than for irrigation alone.

[4] *Aquifer Classification Mapping in the BC Peace Region for the Montney Water Project.* Loewen Hydrogeology Consulting Ltd., June 2011. Prepared for Geoscience BC.

Other Crops and Larger Herds

In addition to the three reference crops included in the economic case-study analysis, other significant crops currently grown in the BC Peace Region include pulses and forage seed. Pulses typically require less water than cereals, and without irrigation have yielded slightly lower gross revenues per acre on average than spring wheat in BC (CANSIM 1993 to 2012 data). Pulses would therefore result in a slightly lower BCR than cereals in the BC Peace Region (slightly lower economic feasibility). When considered as part of a rotation including canola, cereals and forage, pulses would have negligible effect on the overall feasibility of irrigation.

Although the acreage devoted to forage seed crops is much less than forage for feed or cereals and oilseeds, they are a significant crop category in the BC Peace region. There are up to 10 different crops, each having different moisture requirements and market value. The water requirements for forage seed crops in the BC Peace region are unknown. Typical gross revenues vary widely from the range of $140/ac for Timothy to $410/ac for alfalfa,[5] and crop longevity ranges from 1 year for fescue to more than 10 years for Timothy and alfalfa. Given the complexity of forage seed production, the currently available data are insufficient to estimate the economic feasibility of irrigating forage seed crops.

The climate in the BC Peace region is suitable for production of a wider range of crops under irrigation than are currently grown in significant quantities in the region. In particular, a mix of vegetables [6] is estimated to generate gross revenues ranging from $5,000 to 8,000/acre at a variable production cost of approximately $1,700/acre (2011 dollars).[7] Sugar beets also generally yield higher returns per acre than cereals or oilseeds. However, realizing higher returns would require investment in new harvesting equipment and may greatly increase labour requirements. Transitioning to new crops and production methods typically requires several years, and a commitment by producers to make the required investments in equipment and capacity building on top of major investments in irrigation. New crops that are more dependent on irrigation may also increase risks of a shortfall in water supply in a drought year.

A 2012 study of the potato, fruit and vegetable market in Alberta[8] identified the following eight competitive issues for these crops:

1. Low cost of import competition;
2. Local food trends (e.g., 100 mile diet);
3. Climatic conditions (e.g., California growers can produce two crops of carrots in a single year);
4. Labour (availability and cost);
5. Temperature and humidity controlled storage capacity;
6. Technology and innovation support (funding for applied research and development);
7. Industry organizational structure (lack of strong industry organizations); and
8. Branding (reference to successful Manitoba ‘Peak of the Market’ brand).

The same study estimated net returns per acre of several crops as shown in Table 5-8.

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[5] From Peace River Forage Seed Association data, collated by Dave Wong

[6] cabbage – 6.90%; turnips – 2.61%; sweet corn – 2.25%; potatoes – 76.64%; cucumbers – 1.87% and lettuce – 9.73%

[7] Brisbin and Gamble. *Site C Clean Energy Project Environmental Impact Assessment – Volume 3, Appendix D – Agricultural Assessment Supporting Documentation.* Prepared for BC Hydro and Power Authority - Report No. 11-1422-0001. Golder Associates, December 2012.

[8] *Profitability of Potatoes, Vegetables and Fruit*. Prepared for Alberta Agriculture and Rural Development, Economics and Competitiveness Division. Serecon Management Consulting Inc., March 2012.

Table 5-8: Estimated Profitability per Acre of Vegetable Crops in Alberta[6]

Crop	Gross Revenue	Irrigation	Other Costs	Total Cost	Net Revenue
Sweet corn	$3,500	-$73	-$3,031	-$3,104	$396
Cucumbers	$6,000	-$73	-$5,923	-$5,996	$4
Fresh potatoes	$2,400	-$79	-$2,436	-$2,515	-$115
Dryland carrots	$1,800		-$1,770	-$1,770	$30
Irrigated carrots	$2,520	-$79	-$2,127	-$2,206	$314

For comparison, the estimated annual cost of irrigation based on the most favourable conditions (Tower Lake and Halfway Case studies) ranges from $115/acre without storage to $250/acre with storage, including capital costs amortized at 5% over 20 years. This indicates potential for transitioning to certain higher-value crops such as sweet corn or carrots to increase the feasibility of irrigation in the BC Peace Region. However, market volatility and uncertainty in yields translate to a high degree of risk in investments in irrigation and production equipment for vegetables. In addition, yields are likely to be significantly lower in the cooler climate of the BC Peace Region than in southern Alberta.

By reducing risks of feed shortages, irrigation may also support safe increases in herd sizes, potentially allowing large increases in revenues per hectare for beef and other livestock operations. New cow-calf operations, feedlots and processing facilities may locate in the region if substantial areas of the BC Peace region have access to irrigation. However, careful management of feed supplies to hedge against drought risk is likely a more cost-effective strategy for safely increasing herd sizes than irrigating forage.

Further study including small-scale piloting to prove out yields and production costs would be required to quantitatively assess the potential impact of higher-value crops and increasing herd sizes on the feasibility of irrigation in the BC Peace Region.

Other Irrigation Systems

The feasibility analysis is based on the use of quarter-mile low-pressure center pivots. Center pivots are the predominant type of system used for irrigating large areas of relatively level land including most of Alberta, Saskatchewan and the Midwestern United States. Low-pressure systems are the current standard for water efficiency, pumping energy efficiency and overall operating cost. However, other types of irrigation systems offer advantages for certain applications relative to center pivots, and may be preferred or necessitated based on site conditions for some situations in the BC Peace region:

Travelling Gun

At a purchase cost of approximately $40,000 for a travelling gun suitable for a quarter section, the initial cost of the equipment is roughly half that of a centre pivot. A travelling gun can easily be moved between fields, although one per quarter may be required to supply peak irrigation demand. The pressure requirement of 85 to 110 psi necessitates a higher-pressure pump and piping, and increases energy and maintenance costs (the analysis assumes 50 psi for a center pivot). A travelling gun is 65% water efficient, compared to center pivot at 78%, and requires significantly more operating labour. A travelling gun may also be used on more irregular terrain and is likely better suited to long, narrow fields, irregularly shaped fields or those that include obstacles to the operation of a centre pivot such as gas wells or buildings. Given the lower initial cost and flexibility in use, a travelling gun may be economically favourable to a centre pivot for smaller fields, particularly where a water source is readily available and irrigation may be intermittent (e.g., to finish a crop in a dry year). Irrigation on a scale larger than a half section is generally expected to favour centre pivot systems due to the labour, water and energy savings.

Drip Systems

Drip irrigation systems are impracticable for all large-scale agriculture currently practiced in the BC Peace region; however, it may be well suited to smaller-scale production of vegetables or berries where water is available. Drip systems are the most efficient irrigation technology, and may reduce water demand by up to 10% relative to centre pivot. They may be used in virtually any terrain and field shape, and operate at low pressure. However, both the initial and operating costs of drip systems per unit of area are substantially higher than for a center pivot system. As such, drip systems are expected to be suitable only for berries or vegetables on a relatively small scale (less than a one-eighth section).

5.5 Economic Analysis

A rigorous analysis of the impacts of irrigation on the regional economy of the BC Peace Region is beyond the scope of this study. However, similar analyses of the major irrigation projects in southern Alberta and Saskatchewan provide an indication of the potential magnitude of impacts of widespread irrigation in the BC Peace Region. For this study, economic analysis includes consideration of social and environmental costs, benefits and risks.

Irrigation in only a few locations on a small, local scale is unlikely to significantly impact the regional economy or environment; therefore, this section focuses primarily on the potential impacts of irrigating a significant proportion of the region's agricultural land (e.g., one major project such as the Peace River to Dawson Creek case study, or several local area projects such as the Halfway River or Beryl Prairie case studies).

Economic evaluation looks beyond the assessment of direct financial costs and benefits (Section 5.1), and includes the following elements:

1. **Scale of Impacts** – boundary definition for the area(s) impacted by irrigation;
2. **Baseline Economic Activity** – current conditions and constraints;
3. **Backward Linkages** – implications of providing the required inputs to irrigated agriculture;
4. **Forward Linkages** – implications of irrigated production; and
5. **Risks** – Likelihood and potential consequences of unplanned economic, social or environmental conditions resulting from irrigation.

Scale of Impacts

Irrigation will have impacts at a variety of scales. The impacts of irrigation on a small scale (i.e. tens of hectares) will be predominantly local, including the farm(s) under irrigation, the water source and points downstream to the nearest larger watercourse. Regional impacts of small-scale irrigation are unlikely to be significant unless a large number of small systems are developed.

Irrigation on a larger scale (hundreds or thousands of hectares) will have regional economic, social and environmental impacts, and certain impacts may be significant outside the BC Peace region. The largest scale of irrigation (10% or more of the total agricultural area in the region; e.g., Peace River to Dawson Creek case study) may significantly impact markets in BC and Alberta, and may have measurable impacts on the Peace-Athabaska watershed.

For the purpose of this analysis, a single local irrigation system is considered to have negligible impact regionally. This analysis is focused primarily on regional impacts (i.e., Peace River Regional District and local communities), and possible provincial impacts, of at least 5 to 10% of the field crop area in the BC Peace region (15,000 to 30,000 ha) coming under irrigation.

Baseline Economic Activity

Of the roughly 3.7 million acres (1.5 million ha) of land in the Agricultural Land Reserve in the BC Peace region, approximately 1.5 million acres are improved and farmed. Roughly 0.74 million acres are in unmanaged pasture, and 0.74 million acres are in field crops primarily including alfalfa and other forages, canola and cereals. A very small proportion of the farmland is used for nursery products, fruits, berries, nuts, vegetables, silage corn and other field crops (roughly 2,470 acres total). The region supports a herd of roughly 100,000 cattle and calves almost exclusively for beef production, and smaller numbers of other animals. Beef production represents approximately one quarter of the BC total.

Agriculture in the BC Peace Region is primarily oriented toward export of crops and livestock. Gross farm receipts in the BC Peace region are roughly $150 million, or approximately $101/acre ($250/hectare) of improved farmland, representing 0.6% of provincial GDP. Contribution margins are roughly half the provincial average, at 5.4% of farm cash receipts. Total farm capital in the region is approximately $1.8 billion, including $1.6 billion in land and buildings, and $230 million in machinery and equipment.

Agriculture is not currently recognized as a significant employer in the Peace Region;[9] however, the labour force in “agriculture and other resource-based industries” was approximately 7,200 in 2006 (Statistics Canada). This may reflect the large number of sole proprietors and informal (e.g., family) employment arrangements in the agriculture sector, or a large proportion of non-agricultural jobs included in the total. Northeast BC has the province’s lowest unemployment rate, at 5.5% in September 2015. Of the 45,000 population of the Peace River Regional District (PRRD) aged 15 or older, 990 (2%) have post-secondary education in agriculture, natural resources and conservation.

Dawson Creek and Fort St. John were each estimated to be 3% income-dependent on the agriculture and food sector in 2006, having declined from 6 and 7% respectively in 1991.[10] Both communities are primarily income-dependent on mining (including oil and gas) and the public sector. Recent consolidation of supply and distribution service providers may have resulted in reductions in the local workforce, and changes to federal and provincial abattoir regulation in the past decade have forced small-scale meat processing operations to close.

Although agriculture is the dominant land use in the BC Peace Region, its economic impacts are currently relatively small and declining. However, in contrast to oil and gas development, agriculture in the region is stable and sustainable, and currently relies heavily on local labour, supply and distribution networks.

[9] Statistics Canada Labour Force Survey – data prepared by BC Stats. Fewer than 1,500 persons directly employed in the agriculture sector in Northeast BC (PRRD and Northern Rockies Regional Municipality combined). Total employment in the region in 2014 was approximately 38,500.

[10] Garry Horne. *British Columbia Local Area Economic Dependencies – 2006*. BC Stats, March 2009.

Backward Linkages

Developing and operating irrigation will increase the need for equipment, supplies and services in the BC Peace region.

Irrigation System Construction, Operation and Maintenance

Developing irrigation would increase the level of infrastructure investment in agriculture in the region, including irrigation equipment, pumps, pipelines and water storage facilities. The construction, operation and maintenance of water supply and irrigation systems would also generate indirect employment. This investment generates business for equipment suppliers, construction contractors, and financial institutions in the region. Improvements to the electrical distribution network would also be required to supply power to pumps.

Increased and Higher-Value Inputs to Agriculture

Irrigation would increase the required quantities of seed and fertilizer per hectare, increasing the flow of supplies for operation. Changing crop types to maximize the value of irrigation would also require new facilities, equipment and skills, providing new opportunities for local machinery dealers, contractors and training providers.

The increased levels of economic activity associated with supplying inputs to irrigated agriculture would also increase greenhouse gas emissions and other environmental impacts of agriculture, including those associated with the manufacture, installation and operation of water supply and irrigation systems, and the increased production and use of seed, fertilizer and fuel.

Recreation and Hydropower

Developing large reservoirs by constructing dams on significant watercourses can create recreational opportunities such as swimming and fishing. There may also be potential to develop recreational property along the shoreline of a large reservoir. Reservoirs on large catchments with high seasonal flows may also present opportunities for hydropower generation. Establishing a business case for both irrigation and hydropower uses of a reservoir would likely require a portion of the reservoir capacity to be reserved for hydropower use. Reservoirs of sufficient size to create recreation and hydropower opportunities will result in major changes to significant watercourses and require large dams, necessitating environmental impact assessments, land negotiations and ongoing dam management programs.

Forward Linkages

Increased and more reliable productivity of farmland, the capacity to produce a wider range of crops, and new water infrastructure will have a range of impacts on the BC Peace region.

Farmland Value

The increase in productivity and reliability of high quality farmland under irrigation will substantially increase its value. This directly benefits producers who own the land they farm, and may justify an investment in irrigation that is otherwise predicted to result in no increase in net revenue relative to dryland production. Simply securing the right to a water source for irrigation (e.g., a water licence, a reliable well or the right to connect to a shared water supply system near the farm) would likely significantly increase the value of good farmland.

Processing and Distribution

Irrigation development would increase farmland productivity and stabilize annual yields, and may also introduce new products to the regional market. At a sufficient scale of irrigation, these changes would increase the needs for processing and distribution. Stable supplies of farm produce may enable value-added processing facilities to be developed in the region. For example, large areas of irrigated forage and potatoes have enabled major beef and potato processing plants to locate in southern Alberta. Irrigation could substantially improve the business case for local processing, and could significantly expand the range and quality of produce grown for the local market such as fresh vegetables.

Community Development

There is strong evidence that the economic development associated with major irrigation projects such as the Diefenbaker Lake systems in Saskatchewan sustain and grow small, local service centres in nearby communities. A project of the scale of the Peace River to Dawson Creek case studies may cause agriculture-oriented businesses to locate in communities such as Rolla or Doe River. Significant community growth would also likely occur in Dawson Creek as services related to a more technically sophisticated, productive and diverse agricultural sector are established.

Access to Markets and Competition

Access to markets is a very important consideration in evaluating the economic opportunities associated with large-scale irrigation projects. The BC Peace region is at a significant competitive disadvantage relative to the southern Alberta and Saskatchewan growing regions, where large areas of farmland are already under irrigation and the growing regions are near major population centres and have high distribution capacity. Although the potential to expand production in southern Alberta is constrained by available water resources, the roughly 1.5 million acres (600,000 ha) already under irrigation is equivalent to the total area of improved farmland in the BC Peace region. There is sufficient capacity in the Diefenbaker Lake system to irrigate at least 500,000 additional acres (200,000 ha), increasing the land area in Saskatchewan under irrigation by a factor of six.

With the major reservoir infrastructure already in place and at higher elevation than the land to be irrigated, the cost of developing irrigation in Saskatchewan is substantially less than in the BC Peace Region. Saskatchewan is closer to major markets and sources of supply, and its provincial economy would realize several additional benefits of expanding water supply systems for irrigation. These include increased potash production within the province, and addressing urban and industrial water needs with the same infrastructure used to supply irrigation.

Risks

Drought

Drought is currently a primary risk to agriculture in the BC Peace Region, which is expected to become more prevalent with climate change. Currently, producers generally manage drought risk by managing herd sizes and areas of land in forage to ensure a modest surplus of hay each year, which can be sold into local and regional markets in most years.[11] Drought risk to cereal and oilseed crops is typically covered through insurance.

[11] Brisbin and Gamble, 2012.

Irrigation can reduce or eliminate drought risk where water supplies are reliable through the growing season, or where catchments and constructed storage are adequately sized to reliably provide enough water for a full season. However, irrigation introduces a number of new risks that must be weighed against the opportunity to manage drought risk, as outlined in this section.

Two methods were used to assess the value of irrigation as a means of mitigating drought risk, using the Tower Lake financial model as a basis:

1. Increase gross revenue per acre until irrigation BCR = dryland BCR

   Although irrigation is estimated to be less cost-effective in an average year than dryland production for each of the case studies presented in this report, some producers may be willing to accept a reduction in annual average revenue to mitigate the risk of a large loss in the event of a severe drought.

   To estimate the cost of this 'risk premium' for canola production at Tower Lake, the gross revenue per acre of irrigated canola artificially was increased until the benefit-cost ratio (BCR) of irrigated canola matched that of dryland canola production (BCR = 1.14). To achieve a BCR of 1.14 under irrigation, the gross revenue per acre of canola (yield x price) would need to reach the following thresholds:

   - $725/acre without storage; or
   - $1,025/acre with storage.

   The gross revenue per acre of irrigated canola is estimated at $544/acre; therefore the producer would need to accept a reduction in annual average net revenue of $180/acre to reduce drought risk through irrigation without storage. Due to the limited capacity of the source, irrigation without storage would not eliminate loss of revenue in a drought, but would reduce the severity of the loss.

   To ensure that adequate water supply is available in any year, off-stream storage such as a large dugout would need to be constructed. The cost of including storage represents a risk premium of $480/acre, which cannot be justified.

2. Simulate Increased Frequency of Historical 1:10 Year Drought

   The greatest risk to dryland agriculture is a severe multi-year drought, a scenario which is predicted to become more likely by the 2050s. For this study, this increase in risk was modeled as an increase in the frequency of the current one in ten-year drought to two or more years in ten by the 2050s, and a correspondingly greater risk of a severe multi-year drought. The historical precedent for this scenario is the drought that occurred in the 1930s across the North American prairies.

   The historical canola yields used to calculate the average for the financial analysis are shown as green "X" markers in Figure 5-5. In order to determine the drought frequency that would reduce the BCR of dryland canola production to that of irrigated canola production (without storage), canola yields for approximately average years were sequentially reduced to the equivalent of the ten year minimum until the BCR reached 0.95, equal to that of irrigated canola.

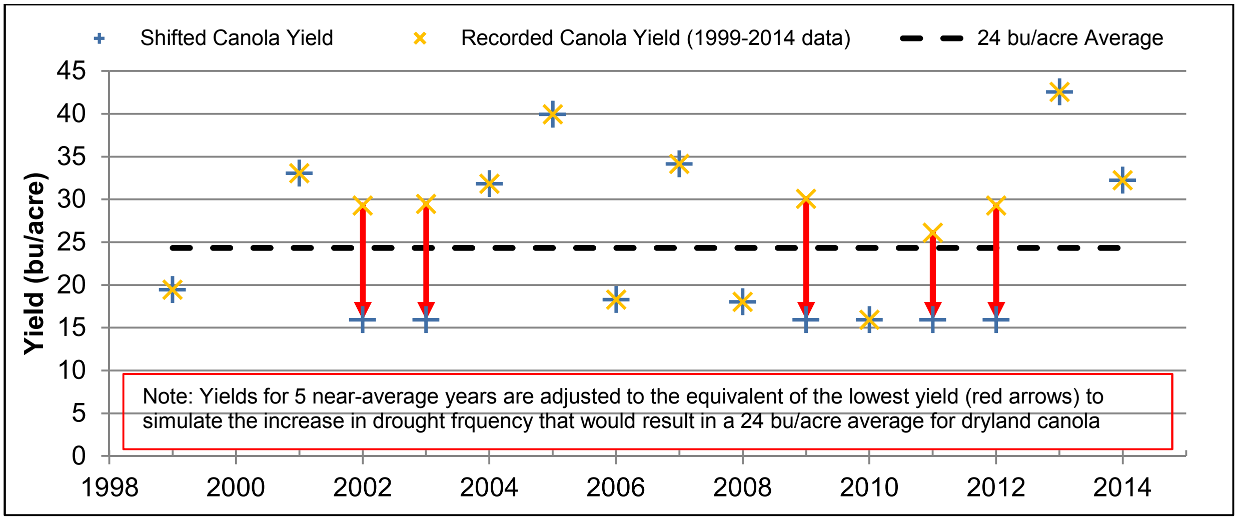

Figure 5-5: Simulation of Increased Drought Frequency

In the financial model, the BCR of dryland canola production reaches 0.95 when the annual average yield reaches 24 bu/acre. As shown in the figure, to reduce the average yield to 24 bu/acre from 29 bu/acre, the yields in five of the 15 years were adjusted from near the average to the 1:10 year drought level (blue markers). This scenario is outside the range of likely impacts of climate change within the next 40 years, indicating that irrigation cannot be justified solely based on its value for reducing the drought-related risk of reduced canola yields at Tower Lake. In any case, since the BCR for irrigated canola at Tower Lake is estimated to be less than one (costs outweighing financial benefits to the producer), under the severe drought scenario shown in Figure 5-5 neither dryland nor irrigated canola production is estimated to be cost-effective. A preferable alternative would be to plant a more drought-tolerant dryland crop such as wheat.

Irrigation may only be beneficial as a climate change risk reduction strategy in the most ideal conditions, such as in the Halfway River case study.

Solonetzic Soils

Irrigating introduces several new and significant risks. Certain soils and water resources in the BC Peace Region are relatively saline, and some soil types are highly sensitive to the accumulation of salts. In particular, Solonetzic soils (also known as gumbo) are prevalent in the BC Peace Region, including Alcan, Murdale, Hanshaw, Donnelly, Esher, Hazelmere, Roseland, Devereau and Falher soils. Yields are generally lower in these soils than in other types, reducing the cost-effectiveness of irrigation. Land with up to 30% Solonetzic soils can be irrigated successfully; however, careful management is necessary to prevent loss of yield. Improvement techniques including deep tillage and sub-soiling (deep ripping) were estimated to cost \$50-\$150/acre in 1993, and to pay back in improved wheat yields within two to four years. These soils require good drainage, are difficult to seed, and are vulnerable to over-application of fertilizer and irrigation. Standing water on Solonetzic soils draws salts to the surface, Lands with more than 30% Solonetzic soils are classified as non-irrigable in Alberta.[12]

[12] J. Lickacz. *Management of Solonetzic Soils.* Alberta Agriculture and Forestry, January 1993.

Soil Acidification

Irrigation necessitates higher fertilizer application rates. As fertilizers reduce soil pH, liming may be necessary to maintain pH within an acceptable range. Liming adds to the cost of production, and may diminish the cost-effectiveness of irrigation.

Water Availability and Quality

Irrigation on a significant scale would be among the largest uses of water in the BC Peace region. Irrigating 10% of the area in field crops in the region (74,000 acre) would require 54,300 ac-ft (67 million m^3), eclipsing the combined water use by the oil and gas and municipal sectors. The primary challenge for irrigation is storage, as most watercourses in the agricultural area have negligible flows during the peak irrigation season.

Natural water storage in the Peace region is provided primarily by local snowpack, soil moisture retention, and snowpack in the Rocky Mountains. High elevation snowpack provides substantial base flows in certain rivers including the Peace, Pine, Halfway and Beatton. However, snowpack is forecast to diminish as climate changes. An earlier spring and faster melt may cause a larger freshet, followed by a longer season with little or no streamflow.

Rivers and streams with very low summer and autumn flows, and lakes and aquifers in the main agricultural areas of the BC Peace region, are vulnerable to excessive use at the flow rates that are required for centre pivot irrigation. Vulnerable surface watercourses are generally identified in the water licencing database as unavailable for allocation in late summer and fall. There is a significant risk that lakes and streams with low base flows will be unavailable in severe drought conditions, negating the benefit of irrigation as a drought management strategy. Watercourses with very low base flows may also be groundwater fed and may have unacceptable quality for irrigation.

The use of groundwater for irrigation, aside from shallow aquifers directly interconnected with major rivers, poses a relatively high risk of depletion. Groundwater resources in the BC Peace region can be extremely hard, and surface water sources fed from groundwater may also have relatively high hardness at times of minimum flow. Irrigating with hard water can lead to salt accumulation in the soil, which reduces yields and permeability.

Introduction of Pests and Disease with Irrigation

Changing the agricultural environment may provide a moist place for pests to thrive. Pests that would normally die in the heat and dry weather will be able to flourish under irrigation. Certain plant diseases may also be promoted by irrigation. There is a risk that irrigation could contribute to reduced yields or crop losses in years that may otherwise produce good dryland yields. Pest and disease risks under irrigation will require new management techniques. Pest and disease management may significantly add to the cost of irrigated production, weakening the business case for irrigation development.

Safety

Irrigation will introduce new hazards to agricultural workers and the public. Systems for managing these risks are well established, but the costs and knowledge needs associated with safety programs must be included in plans and budgets for irrigation projects. The major safety risks are:

1. **Storage impoundments** – Dikes and dams over 3 ft (1 m) in height that impound more than 811 ac-ft (1 million m^3), or more than 8 ft (2.5 m) in height that impound more than 24 ac-ft (30,000 m^3), pose substantial risks, and are subject to the BC *Dam Safety Regulation*. Owners of regulated dams are required to classify, monitor and maintain them in accordance with the regulation. Feasibility assessments and budgets for irrigation projects involving storage must allow for the costs of safe operation and maintenance of storage impoundments.
2. **Major pipelines** – Major irrigation projects would require high-power pumps and large diameter pipes that store and convey very large amounts hydraulic energy. A break or accidental release of water from a high-capacity water pipeline could cause flooding, damage to nearby property or serious injury to anyone in the immediate area. Feasibility assessments and budgets for major irrigation projects must allow for the costs of design, construction, operation and maintenance of safe pipelines.
3. **New occupational hazards** – Irrigation is essentially unused in the BC Peace region. The construction and operation of water supply and irrigation systems will introduce several new occupational hazards to the local agricultural industry, which will necessitate safety training and management systems. New hazards include water under pressure, unfamiliar mechanical and electrical systems and controls, and new types of automated mobile equipment. Budgets must allow for training and adoption of safe work practices including lockout/tagout and the use of appropriate personal protective equipment.

6. Summary of Findings

The central finding of this study is that in current market conditions, irrigated agriculture in the BC Peace Region is economically feasible only in very specific circumstances, generally at a small to medium scale where water of acceptable quality is locally available in sufficient quantity throughout the growing season. Combined with relatively low financial returns to land limited by the climate and soils of the BC Peace Region, the lack of local availability of water in most of the agricultural areas of the region generally limits the scale of feasible irrigation water supply systems to a few sections (hundreds of hectares).

Climate change will increase the feasibility of irrigation. However, the increase in drought frequency that would result in net returns from irrigated agriculture equivalent to those of unirrigated agriculture is outside the range of probable 2050s forecast scenarios. Substantial changes in economic conditions would also be necessary to develop a business case for irrigation on a larger scale.

Irrigation has the potential to use much more water than all other non-hydropower uses in the BC Peace region combined. Irrigating canola on all the improved and actively farmed land in the BC Peace region (approximately 1.5 million acres) would require approximately 1.38 million ac-ft (1.7 billion m^3/year), and a peak flow of 5,650 ft^3/s (160 m^3/s). There is sufficient flow available in the Peace River to irrigate this entire area. The annual average flow in the Peace River at Taylor is approximately 53,000 ft^3/s (1,500 m^3/s), and due to the regulation of flows by BC Hydro, the minimum monthly flow is reliably about 17,660 ft^3/s (500 m^3/s).

Large-scale irrigation water supply systems in the BC Peace region would require very large, high-pressure pump stations and long, high-capacity pipelines, as the only adequate water sources for such systems are major rivers at much lower elevation than most agricultural lands. For these reasons, large systems capable of irrigating thousands of hectares will not be economically feasible in the foreseeable future.

6.1 Feasibility of Irrigation Scenarios

The overall findings of the feasibility analysis are summarized in Table 6-1. Financial feasibility based on assumed average conditions is assessed for each scenario based on the case study analysis is shown as the 20-year NPV per hectare for canola at a 5% annual discount rate, the BCR, and the difference in BCR from the status quo. These parameters indicate the expected life cycle impacts of irrigation on a producer's net returns to land investments.

The influence of other factors on overall economic feasibility is indicated using '+', '-' or "0", reflecting the subjectivity of the analysis. A scenario that is financially marginal but is positively influenced by most other factors may be economically feasible. The overall impact of these factors is summarized in the right column of the table.

The following findings are drawn from the case study analysis:

1. In all cases, dryland agriculture is estimated to be more profitable than irrigated agriculture when the life cycle capital, operation and maintenance costs of the irrigation system are taken into account. Investing in irrigation at any scale in the BC Peace Region is unlikely to increase net revenue to a producer growing traditional crops (cereals, oilseeds or forage grasses);

2. Irrigating forage grass in the BC Peace Region is not cost-effective under current or foreseeable future economic conditions. Maximizing forage production would require substantially more irrigation than cereals or oilseeds, and the increased net revenue per unit area of forage under irrigation is insufficient to cover the costs of irrigation;
3. Where an adequate water source is available near suitable farmland, irrigation of cereals or oilseeds may provide sufficient benefits to justify investment in water supply and irrigation infrastructure. The benefits to producers of revenue stabilization, reduction in drought risk and increased land value justify the net cost of irrigation in circumstances where irrigation is marginally feasible based on direct life cycle revenues and expenses. The business case must be considered for each individual project based on conditions available at the site;
4. Sufficient data are not available to assess the feasibility of irrigating forage seed crops as well as vegetables, sweet corn or other non-traditional crops in the BC Peace region. If similar net annual revenues to those in southern Alberta could be achieved in the BC Peace region for sweet corn and carrots, irrigation of those crops may be financially feasible. However, market volatility and uncertainty in yields translate to a high investment risks, and yields are likely to be significantly lower in the cooler climate of the BC Peace Region than in southern Alberta;
5. The value of irrigation to reduce drought risk may be sufficient to justify the cost of irrigation only in the most favourable scenarios. Under the most favourable scenarios evaluated, a producer would need to accept a reduction in average annual net revenue in the order of $200/acre to achieve the risk reduction benefit of irrigating canola. Although weather will become warmer and drought frequency may increase, a drought equivalent to the worst in the last 15 years would need to occur at least five of every ten years to reduce the benefit-cost ratio of dryland canola production to equal the life cycle benefit-cost ratio of irrigated production;
6. The distance of the BC Peace Region to major North American markets is a significant competitive disadvantage relative to irrigation districts in Alberta and Saskatchewan. Proposed projects such as the Upper Qu'Appelle in Saskatchewan, already well serviced with supply and distribution infrastructure, are likely to present a substantially stronger business case for investment than a similar project in the BC Peace Region; and
7. Existing infrastructure needed for other purposes may provide important future opportunities for irrigation on a small to medium scale. Some agricultural producers have constructed water storage ponds for purposes mostly unrelated to irrigation, which may include livestock watering and sale of bulk water to the oil and gas industry. Oil and gas companies have cooperated with BC Hydro and the City of Dawson Creek to procure water, and have developed pipelines and storage facilities to meet their current needs. If the recent boom in oil and gas well completions declines within 20 to 30 years as predicted, water infrastructure may become available for irrigation.

   Coordinated planning may help to ensure that water infrastructure developed for other purposes will also be well suited to irrigation needs. The capacity of such infrastructure will be limited to relatively small irrigation projects, due to the relatively high volumes and peak flow rates required for irrigation. Although oil and gas companies are generally reluctant to share capacity in their infrastructure while they have potential needs for it, they are often willing to purchase water at favourable prices, potentially improving the business case for developing water supply infrastructure for irrigation. Licensing arrangements specific to this purpose need to be developed to ensure water sources are protected and usage is accurately reported while enabling sufficient flexibility for producers to recover their infrastructure costs.

Table 6-1: Feasibility Analysis Summary

Scenario	NPV per ha (Canola)	BCR	Net BCR[1]	Backward Linkages	Forward Linkages	Drought Risk	Solonetzic Soils	Soil Acidification	Water Quantity	Pests and Disease	Safety	Summary
1 – Tower Lake	-$271	0.95	-0.19	0	+	0	-	-	-	-	-	Insufficient water supply to irrigate half section of canola without constructed storage. Near break-even for canola, but still not financially feasible. Increase in land value may justify irrigation development.
2 – Tower Lake w/ storage	-$1,865	0.74	-0.40	0	+	+	-	-	0	-	-	Constructed storage is not financially feasible and economic and risk reduction benefits do not justify the cost.
3 – Halfway River	$518	1.09	-0.05	+	+	++	0	-	++	-	-	Irrigation is slightly less cost-effective than dryland canola production; however land value and drought risk reduction benefits justify the cost.
4 – Beryl Prairie	-$1,000	0.86	-0.28	+	+	++	0	-	+	-	-	Constructed storage is not financially feasible and economic and risk reduction benefits do not justify the cost.
5 – Peace to Dawson	-$2,579	0.71	-0.43	++	++	+	-	-	+	-	--	Direct and indirect economic benefits combined do not justify the cost of a major irrigation project in the BC Peace region.
6 – Peace to Dawson with Storage	-$1,654	0.78	-0.36	++	++	+	-	-	+	-	--	
Site C to Rose Prairie[2]	-$1,417	0.85	-0.29	++	++	+	-	-	+	-	--	
Dam on Creek[3]	-$729	0.97	-0.17	++	++	+	0	-	+	-	--	These scenarios involve higher unit costs and risks than Scenarios 1 and 3, and no significant relative advantages. Benefits to producers and the community do not justify the costs and risks.
Sewage Effluent[d]	-$1,215	0.80	-0.34	+	+	+	-	-	0	-	--	
Groundwater[5]	-$2,105	0.70	-0.44	0	0	0	--	-	--	-	-	
Shared Infrastructure[6]	-$1,619	0.85	-0.29	++	+	+	0	-	0	-	--	
New Crop[7]	$-	1.00	-0.14	+	+	+	0	-	-	--	-	New irrigated crops including sweet corn and vegetables have the potential to improve the financial feasibility of marginal scenarios, including Scenarios 1 and 3.

1. BCR with irrigation minus BCR without irrigation
2. Site C dam to Rose Prairie - assume slightly more cost-effective than Peace to Dawson Creek due to reservoir elevation advantage
3. Assume slightly more cost-effective than Scenario 4 due to lower unit cost of storage
4. Assume Fort St. John lagoon effluent treatment and local distribution - less cost-effective than Scenario 4 due to added treatment requirement
5. Assume slightly less cost-effective than Scenario 2 due to cost of well construction
6. Assume substantially more cost-effective than Scenario 5 due to cost sharing with other users
7. Assume slightly more cost-effective than Scenario 1 due to higher net revenue per hectare

-- = major negative impact
- = minor negative impact
0 = negligible impact
+ = minor positive impact
++ = major positive impact

7. Recommendations

The following actions are recommended, with reference to the strategies identified in the *Regional Adaptation Strategies series: Peace Region* report:

1. Using the case studies described in this report as benchmarks, consider conducting site-specific feasibility assessments and pilot irrigation projects where most or all of the following conditions are met:
    a. The soils, climate and topography are suitable for production of grains and oilseeds;
    b. Soils are relatively well drained and less than 30% Solonetzic;
    c. A source of water supply is available throughout the growing season, with at least 0.95 ac-ft/acre (2,900 m^3/ha) of irrigated area (11.4 inches) per year in a dry year;
    d. The water source can reliably deliver a peak flow of 5 USgpm/acre (47 L/min/ha) for a single center pivot, or 1.7 USgpm/acre (16 L/min/ha) for every three center pivots, in a dry year;
    e. The water source is less than 0.6 mi (1 km) away and 65 ft (20 m) lower in elevation than the nearest centre pivot for projects to irrigate one section (640 acres) or less; or less than 3 mi (5 km) away and 165 ft (50 m) lower in elevation for projects to irrigate more than one section;
    f. Hardness of the source water is low to moderate in mid to late summer;
    g. Three-phase power with adequate capacity is available within 0.6 mi (1 km) for projects to irrigate up to one section, and within 3 mi (5 km) for larger projects;
    h. Primary crops are cereals, canola, or other crops generating a similar or greater net revenue per unit area; and
    i. The producer has access to low-cost capital and will significantly benefit from increased revenue stability, reduced drought risk and improved land value.

Pilot studies should include opportunities to evaluate inputs of capital, materials and labour, water demands, yields, costs, revenues and net returns to land for existing and potential future Peace region crop types including cereals, oilseeds, pulses, sweet corn, carrots, and forage seed crops. This recommendation supports Action 1.2B and Strategy 1.4 of the *Regional Adaptation Strategies series: Peace Region* report.

2. Further develop and formalize drought risk management strategies already in use for dryland forage production, including modest overproduction of hay, facilities and techniques for hay storage, and careful management of herd sizes within drought-resilient forage production limits. These strategies should be compared with the costs and risk-reduction benefits of irrigated feed production where irrigation is developed. This recommendation supports Strategies 1.5 and 3.2 of the *Regional Adaptation Strategies series: Peace Region* report; and
3. Encourage collaboration between producers, governments, universities and industry organizations to fund and conduct pilot testing of irrigated agriculture in the BC Peace Region, including selection and optimization of a range of plant varieties, pest and disease management strategies, irrigation rates for a range of soil and climate conditions, and irrigation methods. Develop and maintain economic data to guide further development of irrigation where it yields the most benefit. This recommendation supports Strategies 1.4, 3.2, 4.2 and 4.3 of the Regional Adaptation Strategies series: Peace Region report.

7.1 Report Submission

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Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of BC Grain Producers Association for the Evaluation of Irrigation Potential in the BC Peace Region. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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Revision History

Revision #	Date	Status	Revision	Author
A	November 8, 2015	Draft	Draft Report Issued for Client Review	CPS
0	December 20, 2015	Final Draft	Issued for Internal Review	CPS
1	February 26, 2016	Final		CPS

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Appendix A

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Appendix B

Field Review Summary

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Contents

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1. Background and Purpose

Kerr Wood Leidal Associates Ltd. (KWL) was retained in January 2015 by the BC Grain Producers Association to conduct an Evaluation of Irrigation Potential in the BC Peace Region. This progress report summarizes the project team's activities to date, outcomes of field review and producer interviews, a recommended analysis structure, and remaining activities to complete the project.

1.1 Project Objectives

The objectives of the Evaluation of Irrigation Potential in the BC Peace Region project are to:

- Through cost-benefit analysis, assess the future feasibilities of various irrigation and cropping scenarios for agricultural land in the BC Peace region; and
- Identify suitable scales and structures of irrigation systems, and physical and institutional constraints, for current and future cropping scenarios.

The findings of this study will be shared with local governments and agricultural organizations for potential integration in planning initiatives or further study.

1.2 Key Issues

Key issues to be addressed though the evaluation of irrigation potential include:

- High degree of uncertainty in the climate-related inputs to cost-benefit analysis, mainly due to the wide range in forecasts;
- Uncertainty in future water needs for other uses, including hydroelectric power, oil and gas development, and municipal waterworks (impacting the availability of water in smaller catchments or aquifers, the feasibility of shared water supply infrastructure, and the commodity cost of water for irrigation); and
- Uncertainty in market values of farm produce.

2. Field Review

Between March 24 and March 26, 2015, the project team conducted a field review of agricultural areas in the Peace Region, and visited farms and interviewed producers. The tour group consisted of Colwyn Sunderland, Ted van der Gulik, Jim Collins, Julie Robinson (Ministry of Agriculture), and Lori Vickers (Ministry of Agriculture). The tour was conducted using a Ministry of Agriculture Chevrolet Suburban.

2.1 Tour Overview

The tour route and significant features are summarized in this section. The waypoints in Figure 1 illustrate the extents of the tour.

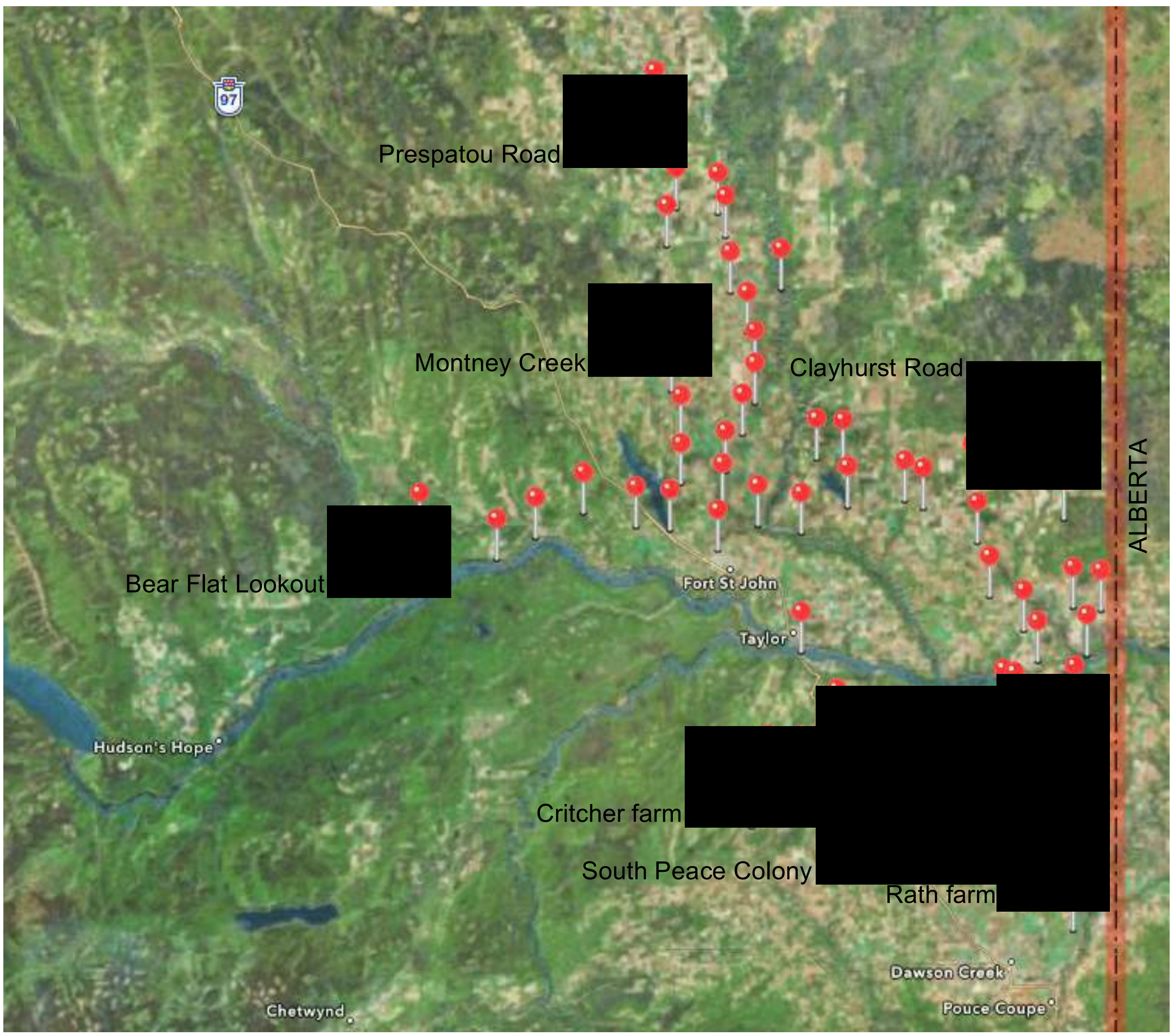

Figure 1: Tour Overview

Tuesday, March 24

- Fort St. John sewage lagoons
- Tour group met at Ministry of Agriculture office in Fort St. John 10:30 AM.
- Bear Flat lookout
- Charlie Lake weir
- North to Montney – reviewed upper Montney Creek irrigation scenario
- Prespatou Road
- Rose Prairie
- Milligan Creek Road across Beatton River
- Dammed creek at 252 Rd between Rose Prairie Road and 259
- West to Beatton River, south to Fort St. John

Wednesday, March 25

- Ministry of Agriculture office – reviewed maps and discussed strategies
- South across Peace River
- South Peace Colony – Met Dave ___, manager; reviewed water supply system and reservoir; discussed details of Colony's centre pivot system.
- Colony's new 100,000 m^3 reservoir (under construction)
- Sunset Community Pasture – Shell water storage facility, Tourmaline wellsites, Encana camp
- Northeast to Tower Lake – met Barry and Irmi Critcher – discussed Tower Lake irrigation scenario
- East to Rolla, north to Doe River
- Hilltop shale pit, well and large truck filling reservoirs (15-20 acres?)
- North to Shearer Dale – met Willy Rath – discussed crop economics, reviewed fields
- Hwy 97 Near South Taylor – truck filling reservoirs (creek-fed, 20 acres?)
- North to Fort St. John

Thursday, March 26

- East across Montney/Beatton River
- Around Cecil Lake – marginal land north of lake
- East to Alces River, view across Peace River to bench at south end of Clayhurst bridge
- Clayhurst Road north to Cecil Lake Road
- Cecil Lake Road across Beaton River to Fort St. John
- Beatton Building, Fort St. John – reviewed irrigation scenarios, strategy to identify high potential lands for irrigation
- Adjourned 4:30PM

2.2 Interview – Dave (Manager), South Peace Colony

- Water supply system recently developed for all Colony uses, including community and lifestock
- Shallow well near Peace River bank (30' deep)
- 100 hp well pump
- 100mm water supply main from well to reservoir, approx.1,140' lift and 3km length
- pipe is buried 4 feet, need to keep it flowing in winter to prevent freezing
- Reservoir 58 Mgal. (260,000 m^3)
- 500mm main from reservoir to field, approx. 2km
- Centre pivot on ¼ section clay loam soil

- 140 acres of barley at 9-11 tonnes/acre under irrigation (approx. 10 Mgal/year = 3" irrigation)
- Before irrigation, same field produced alfalfa at 6 wet tonnes/acre
- Irrigate approx. 3 weeks after seeding (Jun 1, 2014) to Aug 15
- Reservoir construction cost: $30,000 fuel only (Colony labour and equipment) – maybe $250,000 total cost of construction
- Centre pivot cost $70,000 (used)
- Electricity cost $2,000/month (not on irrigation rate)
- Second reservoir under construction, 100,000m^3, $200,000 total cost

2.3 Interview – Barry and Irmi Critcher, Tower Lake

- Water license application on Tower Lake (immediately adjacent to farm) for 3" on ½ section (40 acre-feet, or 49,300 m^3) – have been waiting 3 years for approval
- Ducks Unlimited currently has a conservation license on Tower Lake
- There are 4 ponds in the vicinity of Tower Lake, perhaps 50 acres each, selling water to the gas industry
- Julie has done soils work at Critcher farm – could be used to estimate moisture deficit for an irrigation case study
- Critchers produce dryland wheat, canola, barley, oats and peas in rotation
- Interested in centre pivot; estimate it could double canola production from 40 to 80 bushels/acre in an average year (increase gross revenue from $400 to $800/acre
- 3-phase power is available ½ mile from where the pump would be located
- Ted compared centre pivot to travelling gun:
  - Centre pivot $80,000 to purchase, covers ¼ section, operates at low pressure (low operating cost)
  - Travelling gun $40,000 to purchase, covers 1/8 section, operates at high pressure (high operating cost)
- Would need 400mm pipe to deliver 400 gpm for ¼ section pivot
- Current input costs $90/acre fertilizer (80 lb/acre) + labour, fuel, equipment costs
- Under irrigation, may need $130/acre fertilizer (130 lb/acre) and second pass with machine to apply it (probably should be doing 2 passes now anyway)
- Barry is concerned about the impacts of oil and gas industry on agriculture: the playing field is not level, as companies negotiate individually with producers

2.4 Interview – Willie Rath

- Raths have 6,500 acres in grain and 300-400 acres in fescue
- Does it pay to irrigate fescue?
- Most of Raths' land is heavy gumbo (clay loam)
- 2010 was the worst recent year for Raths – wet spring and dry summer
- Raths would probably put irrigation on their lighter (more free-draining) soils closer to the river
- Irrigation would be beneficial from mid-June to mid-August in a typical year
- Alfalfa typically gets 1-1/2 cuts/year (June 20 and early August); would probably irrigate May 15-Aug 1 in a typical year.

[redacted]

Table 1: Crop Economic Data (Willie Rath)

Crop	Unit Price	Input Cost per Acre per Year	Typical Yield per Acre per Year	Typical Gross Revenue per Acre	Typical Net Income per Acre
Canola	$10 / bushel	$300	40 bushels	$400	$100
Wheat	$6 / bushel	$250	50-60 bushels	$300-$360	$50-110
Yellow Peas	$5-8.50 / bushel	$180-200	30-60 bushels	$150-510	$(50)-330
Fescue	$0.40-0.70 / lb	$125-150	1,000 lb	$400-700	$250-575

3. Model Development

The Peace Region Irrigation Feasibility model is being developed using Geographic Information System (GIS) software. The model incorporates a set of input data from publicly available sources.

The Peace Region is a large area with limited available GIS data. A gap analysis of data sources is being completed as part of the study to identify where the analysis will rely on assumptions.

The model is being developed using three interdependent components to assess the irrigation feasibility of a given region: Water Supply, Water Demand, and Economics. Each component is developed independently before being compiled together to assess the feasibility of irrigation. The following sections provide a summary of progress on each component.

3.1 Water Supply

The water supply component of the model is being developed by KWL to assess potential water sources for the purpose of irrigation. As part of the feasibility study, the following water sources are being investigated:

- Site C;
- Surface Water (lakes, Rivers, etc.);
- Ground Water; and
- Other Sources (dugouts, sewage lagoons, LNG infrastructure).

The Peace Region includes a few different climatic and hydrologic zones, leading to varying water availability throughout the region. The Peace Region will be divided into the different hydrologic zones (Obedkoff) and water availability will be analyzed using Water Survey of Canada (WSC) hydrometric data. Areas without WSC data will be estimated through Regional Analysis. Surface water availability for irrigation must take into account environmental flows (85% of monthly average flow) and existing water licences.

Water supply sources will be analyzed under three climate conditions:

- Drought Year (1:10 or 1:50-year return period);
- Current Climate (1981-2010 Climate Normal); and
- Future Climate (Upper and Lower bounds of climate change projections).

Assessing different climate scenarios creates a risk envelope which is then used in the economic analysis. For example, irrigation reduces the risk of crop loss in a drought and the feasibility of irrigation will increase in the future as droughts are anticipated to become more frequent and intense.

The project team proposes seven water supply scenarios, with case studies as indicated in Table 2.

Table 2: Water Supply Scenarios and Case Studies

	Scenario	Constructed Storage Required?	Example Case Study
1	Source immediately adjacent to irrigation, at similar elevation, sufficient source water available during irrigation season	N	• Tower Lake – Critcher Farm
2	Scenario 1, but source water unavailable for irrigation season	Y	• Upper Montney Creek
3	Pump station and pipeline from source, less than 5km length and 700 ft. lift, sized for peak flow	N	• Halfway River
4	Scenario 3, sized for average flow	Y	
5	Pump station and pipeline from river, more than 5km length or 700 ft. lift, sized for peak flow (may share infrastructure with other uses)	N	• Peace River to Dawson Creek • Site C • Williston Lake to Beryl Prairie • Sunset Community Pasture (Shell water hub) • South Peace Colony
6	Scenario 5, sized for average flow	Y	
7	Collect overland flow into reservoir	Y	• Goleta Creek

Suitable locations for Scenarios 3 and 4 will be mapped in GIS based on identification of surface water sources and generating 5km offsets, and calculating differential elevations from a digital elevation model. Although the locations and capacities of groundwater resources are largely unknown, Scenarios 1-4 could include irrigation where adequate groundwater resources are available. Other resources to be considered include wastewater lagoons (Fort St. John, Taylor, Pouce Coupé?).

3.2 Water Demand

Ted van der Gulik is leading the development of the water demand component of the model. This component will estimate soil moisture deficit (annual irrigation requirement) and timing of need for different crop and weather scenarios.

The Water Demand model will employ soil mapping data which is in the process of being digitized by the Ministry of Agriculture (*Soils of the Fort St. John-Dawson Creek Area, British Columbia*, Report No. 42, BC Soil Survey, 1986). The two eastern map sheets from the report (covering a region bounded by the Alberta border on the east, Charlie Lake on the west, Roseland Creek on the north and Swan Lake on the south) have been digitized and will be used for the initial analysis.

A set of uniquely identified polygons will be established based on soil type boundaries, and a reference climate soil moisture deficit will be calculated for each polygon, enabling moisture deficit to be mapped in the areas for which digital soils data is available. Areas with the greatest moisture deficits will require more irrigation, but will also yield the greatest economic benefits of irrigation (largest gains in yield).

A set of assumptions regarding irrigation technology will be made for modelling. (e.g. typical configuration will be low-pressure, ¼-section centre pivot, with associated application efficiency and coverage. A table of typical crops will be developed including seasonal irrigation demand profiles and rooting depths. Demands will also be calculated for a set of climate scenarios, representing recent historical average and drought conditions (e.g. year 2003), and future scenarios likely at 20- and 50-year horizons.

3.3 Economics

The economics are a function of water demand and water supply and ultimately drives the feasibility of irrigation. The following parameters are the major drivers of the economics:

- Gross yield (market value per hectare) of each crop/soil combination under average and drought conditions, and under irrigation;
- Typical input costs per hectare for each crop/soil combination, with and without irrigation, including:
    - Fertilizer
    - Seed
    - Labour
    - Fuel
    - Machine hours (consumption of capital)
    - Irrigation capital
    - Irrigation operating
    - Insurance;
- Proximity of three phase power for pumps;
- Constraints for irrigation, including field size and shape, obstructions (oil and gas wellheads, trees, terrain, soil variability); and
- Market conditions, including price volatility, and constraints in getting new products to market

Each driver is subject to market conditions and a sensitivity analysis on projected market demands will need to be developed to assess the economics of irrigation.

[redacted]

4. Summary and Next Steps

4.1 Summary

The Evaluation of Irrigation Potential in the BC Peace Region project is roughly 50% complete:

- An analytical method has been established;
- Irrigation scenarios for analysis have been identified;
- Approaches for assessment of water supply capacity and irrigation demand have been determined;
- Representative case studies have been identified for each irrigation scenario;
- A current sample of economic parameters for feasibility analysis has been obtained; and
- The project team has observed conditions in the field for irrigation in the primary agricultural area of the BC Peace Region.

4.2 Next Steps

The following work will be completed between April and August 2015:

- Schedule a teleconference / webinar to present and discuss interim findings (Client Meeting #2);
- Establish polygons for calculation of irrigation water demands based on available digitized soils mapping;
- Run water demand model to calculate soil moisture deficits for each polygon under average and drought conditions in historical and anticipated future climates;
- Map known water supply sources, initial field areas for feasibility analysis, and case study locations;
- Develop conceptual designs and "Class D" capital and operating cost estimates for water supply and storage to meet calculated demands, and prepare construction and operating cost estimates;
- Complete economic feasibility analysis;
- Prepare and issue draft report;
- Review draft report by teleconference / webinar (Client Meeting #3);
- Prepare and issue final report; and
- Present findings to stakeholder groups (up to three webinar meetings).

4.3 Closure

We trust that the foregoing meets your immediate requirements.

KERR WOOD LEIDAL ASSOCIATES LTD.

Colwyn Sunderland, AScT
Project Manager

Statement of Limitations

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Revision History

Revision #	Date	Status	Revision	Author

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Appendix C

Typical Assumptions for Feasibility Analysis

Appendix C - Typical Assumptions for Feasibility Analysis

	Description	Assumed Value	Units	Note / Reference
Irrigation Assumptions	Typical Cereal Crop	Wheat	Bu	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Cereal Irrigation Demand - 2009	75	mm	
	Cereal Irrigation Demand - 2050	110	mm	from water demand model
	Typical Forage Crop	Alfalfa/Brome	Ton	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Forage Irrigation Demand - 2009	300	mm	
	Forage Irrigation Demand - 2050	350	mm	from water demand model - not for seed production.
	Typical Cash Crop	Canola	Bu	
	Canola Irrigation Demand - 2009	200	mm	
	Canola Irrigation Demand - 2050	225	mm	estimated
	Centre Pivot Irrigation Efficiency	78%		Based on project team experience
	Travelling Gun Irrigation Efficiency	62%		
	Wheel Line irrigation Efficicncy	72%		
	Irrigation Season	May 15 to Aug 15		From climate model values
	Centre Pivot - Irrigation Area (% of 1/4 Section)	78.5%		Area of a circle drawn in centre of quarter section plot
	Centre Pivot - Irrigation Area	50.2	ha	
	Centre Pivot - Irrigation Area	125.6	acres	
	May - % of Irrigation	10%		Based on project team experience
	June - % of Irrigation	30%		
	July - % of Irrigation	40%		
	August - % of Irrigation	20%		
Pump Requirements	Design Flow	47	lpm/ha	Based on project team experience
	Design Flow	5	gpm/acre	
	Centre Pivot operating pressure	50	PSI	
	Minor Loss Coefficient	20		standard reference
	Pump Efficiency	70%		
	Pipe Material	PVC		
	Relative Roughness	0.0015	mm	
Annual Expenses Under Irrigation - Forage	Forage - Fertilizer Cost - Average	$ 90.00	/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Forage - Seed Cost - Average	$ 16.25	/acre	
	Forage - Cut/Rake Cost - Average	$ 62.00	/acre	
	Forage - Baling Cost - Average	$ 67.69	/acre	
	Forage - Fertilizer Cost - High	$ 90.00	/acre	
	Forage - Seed Cost - High	$ 19.17	/acre	
	Forage - Cut/Rake Cost - High	$ 70.00	/acre	
	Forage - Baling Cost - High	$ 73.85	/acre	
	Forage - Fertilizer Cost - Low	$ 90.00	/acre	
	Forage - Seed Cost - Low	$ 13.33	/acre	
	Forage - Cut/Rake Cost - Low	$ 54.00	/acre	
	Forage - Baling Cost - Low	$ 61.54	/acre	
Annual Expenses Under Irrigation - Cereal	Cereal - Fertilizer Cost - Average	$ 179.98	/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Cereal - Seed Cost - Average	$ 53.63	/acre	
	Cereal - Labour Cost - Average	$ 12.50	/acre	
	Cereal - Equipment Cost - Average	$ 35.00	/acre	
	Cereal - Fertilizer Cost - High	$ 205.95	/acre	
	Cereal - Seed Cost - High	$ 64.50	/acre	
	Cereal - Labour Cost - High	$ 15.00	/acre	
	Cereal - Equipment Cost - High	$ 40.00	/acre	
	Cereal - Fertilizer Cost - Low	$ 154.00	/acre	
	Cereal - Seed Cost - Low	$ 42.75	/acre	
	Cereal - Labour Cost - Low	$ 10.00	/acre	
	Cereal - Equipment Cost - Low	$ 30.00	/acre	
Annual Expenses Under Irrigation - Canola	Canola - Fertilizer Cost - Average	$ 210.00	/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Canola - Seed Cost - Average	$ 133.00	/acre	
	Canola - Labour Cost - Average	$ 12.50	/acre	
	Canola - Equipment Cost - Average	$ 35.00	/acre	
	Canola - Fertilizer Cost - High	$ 241.00	/acre	
	Canola - Seed Cost - High	$ 162.00	/acre	
	Canola - Labour Cost - High	$ 15.00	/acre	
	Canola - Equipment Cost - High	$ 40.00	/acre	
	Canola - Fertilizer Cost - Low	$ 179.00	/acre	
	Canola - Seed Cost - Low	$ 104.00	/acre	
	Canola - Labour Cost - Low	$ 10.00	/acre	
	Canola - Equipment Cost - Low	$ 30.00	/acre	
Annual Operating Irrigation	Minimum Seasonal Rate - Electricity	$ 41.28	/kW of Pump	used if usage cost is below the minimum charge rate
	Electricty Usage Rate - Irrigation	$ 0.0516	/kWh	
	Repair and Maintenance Cost	2.0%	of Capital Cost	
Annual Expenses Without Irrigation - Forage	Forage - Fertilizer Cost - Average	$ 25.00	/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Forage - Seed Cost - Average	$ 12.19	/acre	
	Forage - Cut/Rake Cost - Average	$ 31.00	/acre	
	Forage - Baling Cost - Average	$ 25.38	/acre	
	Forage - Fertilizer Cost - High	$ 50.00	/acre	
	Forage - Seed Cost - High	$ 14.38	/acre	
	Forage - Cut/Rake Cost - High	$ 35.00	/acre	
	Forage - Baling Cost - High	$ 27.69	/acre	
	Forage - Fertilizer Cost - Low	$ -	/acre	
	Forage - Seed Cost - Low	$ 10.00	/acre	
	Forage - Cut/Rake Cost - Low	$ 27.00	/acre	
	Forage - Baling Cost - Low	$ 23.08	/acre	

Appendix C - Typical Assumptions for Feasibility Analysis

	Description	Assumed Value	Units	Note / Reference
Annual Expenses Without Irrigation - Cereal	Cereal - Fertilizer Cost - Average	$ 106.66	/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Cereal - Seed Cost - Average	$ 53.63	/acre	
	Cereal - Labour Cost - Average	$ 12.50	/acre	
	Cereal - Equipment Cost - Average	$ 35.00	/acre	
	Cereal - Fertilizer Cost - High	$ 122.74	/acre	
	Cereal - Seed Cost - High	$ 64.50	/acre	
	Cereal - Labour Cost - High	$ 15.00	/acre	
	Cereal - Equipment Cost - High	$ 40.00	/acre	
	Cereal - Fertilizer Cost - Low	$ 90.59	/acre	
	Cereal - Seed Cost - Low	$ 42.75	/acre	
	Cereal - Labour Cost - Low	$ 10.00	/acre	
	Cereal - Equipment Cost - Low	$ 30.00	/acre	
Annual Expenses Without Irrigation - Canola	Canola - Fertilizer Cost - Average	$ 127.00	/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Canola - Seed Cost - Average	$ 110.88	/acre	
	Canola - Labour Cost - Average	$ 12.50	/acre	
	Canola - Equipment Cost - Average	$ 35.00	/acre	
	Canola - Fertilizer Cost - High	$ 147.00	/acre	
	Canola - Seed Cost - High	$ 150.00	/acre	
	Canola - Labour Cost - High	$ 15.00	/acre	
	Canola - Equipment Cost - High	$ 40.00	/acre	
	Canola - Fertilizer Cost - Low	$ 107.00	/acre	
	Canola - Seed Cost - Low	$ 71.75	/acre	
	Canola - Labour Cost - Low	$ 10.00	/acre	
	Canola - Equipment Cost - Low	$ 30.00	/acre	
Annual Gross Revenue - Forage	Forage Low Yields without Irrigation	1.1	ton/acre	Statistics Canada, Canada Tame Hay 1998-2007 minimum
	Forage Avg Yields without Irrigation	1.5	ton/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Forage Max Yields without Irrigation	1.7	ton/acre	Statistics Canada, Canada Tame Hay 1998-2007 minimum
	Forage Low Yields with Irrigation	4.0	ton/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Forage Avg Yields with Irrigation	4.0	ton/acre	
	Forage Max Yields with Irrigation	4.0	ton/acre	
	Forage Price - Low	$ 55.00	$/ton	
	Forage Price - Average	$ 67.50	$/ton	Avg of Low and High
	Forage Price - High	$ 80.00	$/ton	Ministry of Agriculture (Personal comm., Reg. Agrologist)
Annual Gross Revenue - Cereal	Cereal Low Yields without Irrigation	27	bushel/acre	Statistics Canada, BC Annual Average Yield, 1993-2002 (Minimum year)
	Cereal Avg Yields without Irrigation	41	bushel/acre	
	Cereal Max Yields without Irrigation	58	bushel/acre	
	Cereal Low Yields with Irrigation	57	bushel/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Cereal Avg Yields with Irrigation	68.5	bushel/acre	Avg of Low and High
	Cereal Max Yields with Irrigation	80	bushel/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Cereal Price - Low	$ 4.17	$/bushel	Statistics Canada, BC Annual Average Price, 1993-2002, adjusted for CPI to $2015 (Minimum year)
	Cereal Price - Average	$ 5.88	$/bushel	
	Cereal Price - High	$ 8.90	$/bushel	
Annual Gross Revenue - Canola	Canola Low Yields without Irrigation	18	bushel/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist)
	Canola Avg Yields without Irrigation	29	bushel/acre	
	Canola Max Yields without Irrigation	42	bushel/acre	
	Canola Low Yields with Irrigation	37	bushel/acre	
	Canola Avg Yields with Irrigation	48.5	bushel/acre	Avg of Low and High
	Canola Max Yields with Irrigation	60	bushel/acre	Ministry of Agriculture (Personal comm., Reg. Agrologist, assumes #1 Grade)
	Canola Price - Low	$ 8.03	$/bushel	
	Canola Price - Average	$ 11.23	$/bushel	
	Canola Price - High	$ 14.98	$/bushel	
Economics	Discount Rate	5%		
	Project Lifespan	20	years	

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Appendix D

Case Study Input Parameters

Inputs

	Description	Input Value	Units	notes
General	Scenario	1 & 2 - Tower Lake		
	Farm Name	Crticher		
	Water Source	Tower Lake		
	Quarter Section Plots	2	#	Size of Critcher farm (to be irrigated under pending water license application)
Hydraulic Inputs	Mean farm elevation	745	m	Approximate value at Critcher Farm (GIS)
	Mean water source elevation	742	m	
	Distance from water source	0.50	km	
	Distance to electrical grid	0.815	km	
	Three-phase power available	yes		
	Estimated length of pipe	1,200	m	
	Pipe Size	200	mm	
Water Source Characteristics	Water source	Tower Lake		
	Average Available Water for Licencing	170,000	m3	<--NEWT Tool from May - Sept
	10-Year Low Flow assumes august flow all season	160,850	m3	<--6" of water on the lake during low flow available
	Licensed Water Available	49,300	m3	
Capital Costs	Cost of New 1/4 Section Centre Pivot	$ 50,000	each	One mobile centre pivot shared between 2 fields at $100k total
	Grants (% of total capital cost)	0%		
	Pump and Infrastructure	$ 20,000	each	
	Pipe including fittings	$ 7.00	/ft	
	Connection to Power	$ 10,000	/pole	poles spaced every 100 m
	Storage Cost (<300,000m3)	$ 3.00	/m3	See references at right. Cost varies widely with dugout size. The smallest
	Storage Cost (300,000-1,000,000m3)	$ 2.00	/m3	irrigation dugout in the Peace will be large relative to any other in BC
	Storage Cost (>1,000,000m3)	$ 1.00	/m3	
	Single phase to 3-Phase Power Conversion	$ 20,000	each	Variable frequency drive, only needed if single phase is available only
Irrigation Requirements	Crop Type	Canola		
	Irrigable Area (Centre)	100	ha	
	Non-Irrigable Area (Corners)	28	ha	
	Future Cereal Irrigation Demand	110	mm/year	Approximate value
	Future Forage Irrigation Demand	350	mm/year	Approximate value
	Future Canola Irrigation Demand	225	mm/year	
	Target Irrigation Depth	225	mm	
Storage	Available Water for Irrigation from Avg Flow (mm)	132	mm	
	Available Water for Irrigation from Low Flow (mm)	125	mm	
	Additional Storage to meet Target Depth (mm)	100	mm	
	Storage (m3)	141,896	m3	<---includes efficiency loss in center pivot and 10% extra storage seepage+evaporation loss

Inputs

	Description	Input Value	Units	notes
General	Scenario	3 - Halfway		
	Farm Name	Halfway Ranch		
	Water Source	Halfway River		
	Quarter Section Plots	7	#	
Hydraulic Inputs	Mean farm elevation	650	m	
	Mean water source elevation	620	m	
	Distance from water source	1.00	km	
	Distance to electrical grid	1.15	km	
	Three-phase power available	yes		
	Intake Pipeline Length	650		
	Intake Pipe Size	300		
	Distribution Pipe Length	5,150	m	
	Distribution Pipe Size	200	mm	
Water Source Characteristics	Water source	Halfway River		
	Average Available Water for Licencing	304,320,126	m3	<--NEWT Tool from May - Sept
	10-Year Low Flow assumes august flow all season	152,160,063	m3	<--6" of water on the lake during low flow available (3" on 2 quarter sections)
	Licensed Water Available	1,000,000	m3	
Capital Costs	Cost of New 1/4 Section Centre Pivot	$ 80,000	each	
	Grants (% of total capital cost)	0%		
	Pump and Infrastructure	$ 50,000	each	
	Intake Pipe	$ 14.00	/ft	12" intake pipe
	Distribution Pipe	$ 7.00	/ft	8" distribution pipe
	Connection to Power	$ 10,000	/pole	poles spaced every 100 m
	Storage Cost (<300,000m3)	$ 3.00	/m3	See references at right. Cost varies widely with dugout size. The smallest
	Storage Cost (300,000-1,000,000m3)	$ 2.00	/m3	irrigation dugout in the Peace will be large relative to any other in BC
	Storage Cost (>1,000,000m3)	$ 1.00	/m3	
	Single phase to 3-Phase Power Conversion	$ 20,000	each	Variable frequency drive, only needed if single phase is available only
Irrigation Requirements	Crop Type	Forage		
	Irrigable Area (Centre)	352	ha	
	Non-Irrigable Area (Corners)	96	ha	
	Future Cereal Irrigation Demand	110	mm/year	Approximate value
	Future Forage Irrigation Demand	350	mm/year	Approximate value
	Future Canola Irrigation Demand	225	mm/year	
	Target Irrigation Depth	350	mm	
Storage	Available Water for Irrigation from Avg Flow (mm)	67,496	mm	
	Available Water for Irrigation from Low Flow (mm)	33,748	mm	
	Additional Storage to meet Target Depth (mm)	- 33,398	mm	
	Storage (m3)	-	m3	<---includes efficiency loss in center pivot and 10% extra storage seepage+evaporation loss

Inputs

	Description	Input Value	Units	notes
General	Scenario	4-Beryl		
	Farm Name	Beryl Prairie		
	Water Source	Existing gas industry pipeline		
	Quarter Section Plots	7	#	
Hydraulic Inputs	Mean farm elevation	725	m	
	Mean water source elevation	725	m	
	Distance from water source	2.50	km	
	Distance to electrical grid	1.25	km	
	Three-phase power available	yes		
	Distribution Pipe Length (300 mm)	5,300	m	
	Diversion Pipe Length (200 mm)	2,500	m	
	Pipe Size	300	mm	
Water Source Characteristics	Water source	Williston Lake		
	Average Available Water for Licencing	1,070,000	m3	Assume pump operates full time from March 15 - Oct 15 at 10,000m3/d.
	10-Year Low Flow assumes august flow all season	1,070,000	m3	Storage pits are filled initially to support irrigation all season
	Licensed Water Available	1,070,000	m3	Assume 50% of 2,140,000m3 total is available for agriculture
Capital Costs	Cost of New 1/4 Section Centre Pivot	$ 80,000	each	
	Grants (% of total capital cost)	0%		
	Pump and Infrastructure	$ 50,000	each	To drive centre pivots from storage ponds
	Distribution Pipe including fittings	$ 7	/ft	
	Diversion Pipe including fittings	$ 14.00	/ft	
	Connection to Power	$ 10,000	/pole	poles spaced every 100 m
	Storage Cost (<300,000m3)	$ 3.00	/m3	See references at right. Cost varies widely with dugout size. The smallest
	Storage Cost (300,000-1,000,000m3)	$ 2.00	/m3	irrigation dugout in the Peace will be large relative to any other in BC
	Storage Cost (>1,000,000m3)	$ 1.00	/m3	
	Single phase to 3-Phase Power Conversion	$ 20,000	each	Variable frequency drive, only needed if single phase is available only
Irrigation Requirements	Crop Type	Canola		
	Irrigable Area (Centre)	352	ha	
	Non-Irrigable Area (Corners)	96	ha	
	Future Cereal Irrigation Demand	110	mm/year	Approximate value
	Future Forage Irrigation Demand	350	mm/year	Approximate value
	Future Canola Irrigation Demand	225	mm/year	
	Target Irrigation Depth	225	mm	
Storage	Available Water for Irrigation from Avg Flow (mm)	237	mm	
	Available Water for Irrigation from Low Flow (mm)	237	mm	
	Additional Storage to meet Target Depth (mm)	- 12	mm	
	Storage (m3)	640,000	m3	<--calculated assuming 50% pumping during entire time pumps are on. Buffers additional storage for only 50% being withdrawn during irrigation season

Inputs

	Description	Input Value	Units	notes
General	Scenario	5 & 6 - Peace to Dawson		
	Farm Name	South Peace Region		
	Water Source	Peace River		
	Quarter Section Plots	600	#	
Hydraulic Inputs	Mean farm elevation	750	m	
	Mean water source elevation	450	m	
	Distance from water source	10.00	km	
	Distance to electrical grid	10.00	km	
	Three-phase power available	yes		
	Pipe Length - 4 x 1.8	11,000	m	<--10 km accounted for up to plateau in pump cost estimate
	Pipe Length - 3 x 1.8	11,000	m	
	Pipe Length - 2 x 1.8	13,000	m	
	Pipe Length - 1 x 1.8	9,000	m	
	Estimated length of pipe - Arterial	140,000	m	
	Estimated length of pipe - Distribution	280,000	m	
	Pipe Size	4,050	mm	Actual would be 4 x 1,800mm (hydraulically equivalent)
Water Source Characteristics	Water source	Peace River		
	Average Available Water for Licencing	999,999,999	m3	Assume pump operates full time from March 15 - Oct 15 at 10,000m3/d.
	10-Year Low Flow assumes august flow all season	999,999,999	m3	Storage pits are filled initially to support irrigation all season
	Licensed Water Available	999,999,999	m3	Assume 50% of 2,140,000m3 total is available for agriculture
Capital Costs	Cost of New 1/4 Section Centre Pivot	$ 80,000	each	
	Grants (% of total capital cost)	75%		
	Pump and Infrastructure	$ 77,450,000	each	Per Robin Parker estimate (excludes powerline, costed separately)
	Major Pipeline	$ 244	/ft per pipe	<--1.8 m diam pipe
	Arterial Pipeline	$ 122	/ft	<--36" diam pipe
	Distribution Pipeline	$ 7	/ft	<--8" pipe
	Pipe including fittings	$ 300.00	/ft	Assume average pipe size of 1,200mm
	Connection to Power	$ 15,000	/pole	poles spaced every 100 m
	Storage Cost (<300,000m3)	$ 3.00	/m3	See references at right. Cost varies widely with dugout size. The smallest
	Storage Cost (300,000-1,000,000m3)	$ 2.00	/m3	irrigation dugout in the Peace will be large relative to any other in BC
	Storage Cost (>1,000,000m3)	$ 1.00	/m3	
	Single phase to 3-Phase Power Conversion	$ 20,000	each	Variable frequency drive, only needed if single phase is available only
Irrigation Requirements	Crop Type	Forage		
	Irrigable Area (Centre)	30,144	ha	
	Non-Irrigable Area (Corners)	8,256	ha	
	Future Cereal Irrigation Demand	110	mm/year	Approximate value
	Future Forage Irrigation Demand	350	mm/year	Approximate value
	Future Canola Irrigation Demand	225	mm/year	
	Target Irrigation Depth	350	mm	
Storage	Available Water for Irrigation from Avg Flow (mm)	2,588	mm	
	Available Water for Irrigation from Low Flow (mm)	2,588	mm	
	Additional Storage to meet Target Depth (mm)	- 2,238	mm	
	Storage (m3)	-	m3	<---includes efficiency loss in center pivot and 10% extra storage seepage+evaporation loss