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Technical Memorandum

DATE: July 10, 2015

TO: Susan Burton, BC Hydro

FROM: Kristin Wild, PEng
Colleen O'Toole, PEng

RE: **RUN-OF-RIVER HYDROELECTRIC POTENTIAL FOR BRITISH COLUMBIA**
Summary of 2015 Updates
Our File 0478.177-300

Introduction

In late 2014, BC Hydro hired Kerr Wood Leidal Associates Ltd. (KWL) to update the inventory of run-of-river (RoR) hydroelectric potential in British Columbia for the planned 2015 Resource Options Update. This technical memorandum provides a discussion of updates made and provides a revised inventory of British Columbia's run-of-river hydroelectric potential.

Discussion of Updates to Run-of-River Inventory Analysis

The following updates were made to the 2010 Run-of-River Hydroelectric Resource Assessment (2010 RoR Update).[1]

Site Screening Undevelopable Areas

The potential RoR sites were screened using the most recent Geographic Information System (GIS) data including: parks, glaciers, Fisheries Information Summary System (FISS) salmon observations/reaches, and new electricity purchase agreements.

In addition to establishing new parks, boundaries adjustments are made by governments periodically for legally protected areas. Legally protected areas include National Parks, Conservancies, Wildlife Management Areas, Ecological Reserves, Protected Areas, Provincial Parks, and Recreation Areas. As construction of power projects, access roads or transmission lines is typically not permitted in these area, projects that fall within or cross through an area are screened from the resource options.

The fish inventory database was updated with the latest data from the Fisheries Information Summary System (FISS). The potential sites were screened for anadromous (salmon) fish species presence including Chinook, Chum, Coho, Pink, and Sockeye Salmon. This is consistent with previous studies completed for BC Hydro. Steelhead trout was added to the screening as *"while it was considered a trout species in the past, steelhead are now generally considered to be Pacific salmon*" by Department of Fisheries and Oceans.[2]

[1] In 2010 an update was made to the 2007 ROR Assessment by KWL.
[2] http://www.dfo-mpo.gc.ca/international/media/bk_pacificsal-eng.htm (date last modified 2012/06/08)

The rationale to exclude salmon bearing reaches for hydro development in 2007 was that permitting hydro projects in the reaches of streams with salmon would be difficult. Since then, Brookfield was able to permit Kokish and Elemental was able to permit Box Canyon. Other projects in reaches with salmon presence may also have been permitted. Most projects developed in the last two decades are upstream of salmon migration barriers.

Restoration of salmon migration is being considered and advanced at many hydro/dam projects in BC and western US (i.e., Okanagan River) that were developed in the past that created barriers to salmon migration.

While screening for anadromous fish species presence may underestimate the total hydro potential in the province, there are significant issues (social and environmental) and real costs for screening, two way fish passage, flow ramping and in stream flow requirements for projects with salmon impacts.

Geographic Information System (GIS) Databases

Table 1 summarises the GIS datasets included in the screening for suitable run-of-river power development locations.

Table 1: GIS Data Sources and Date Accessed

GIS Dataset	Database Object Name	Purpose	Record Last Modified	Data Source
Conservancies	WHSE_TANTALIS.TA_CONSERVANCY_AREAS_SVW	Contains the spatial representation of the conservancy areas designated under the Park Act or by the Protected Areas of British Columbia Act	2013-08-26	BCGOV FLNRO[3]
Fisheries Information Summary System	WHSE_FISH.FISS_HIST_FISH_DST_PNT_PUB_SVW	BC Historical Fish Distributions	2015-01-14	BC MOE[4]
	WHSE_FISH.FISS_HIST_FISH_DST_LIN_PUB_SVW	BC Historical Fish Distributions (Points)	2015-01-14	BC MOE
	WHSE_FISH.FISS_FISH_OBSRVTN_PNT_SP	BC Historical Fish Distributions (Lines, or reaches	2015-01-13	BC MOE
Glaciers	WHSE_BASEMAPPING.FWA_GLACIERS_POLY	Glaciers and ice masses for the province	2008-09-01	BCGOV FLNRO
Parks	WHSE_TANTALIS.TA_PARK_ECORES_PA_SVW	BC Parks, Ecological Reserves, and Protected Areas	2005-05-09	BCGOV FLNRO
	WHSE_ADMIN_BOUNDARIES.CLAB_NATIONAL_PARKS	National Parks - National Framework Canada Lands Administrative Boundaries Level 1	2013-08-21	CANGOV NRCAN[5] & BCGOV FLNRO
	WHSE_ADMIN_BOUNDARIES.ADM_BC_PARKS_REGIONS_SP	Parks and Protected Areas Regional Boundaries	2013-08-29	BC MOE
Points of Diversion	WHSE_WATER_MANAGEMENT.BC_POINTS_OF_DIVERSION	Province-wide SDE layer displaying points of diversion locations (for water licensing)	2014-12-11	BCGOV FLNRO
	WHSE_WATER_MANAGEMENT.WLS_POD_LICENCE_SP	BC Points of Diversion with Water Licence Information	2015-01-07	BCGOV FLNRO

[3] British Columbia Forests and Natural Resource Operations
[4] British Columbia Ministry of Environment
[5] Natural Resources Canada

Electricity Purchase Agreements and Existing BC Hydro Facilities

Potential run-of-river projects were screened based on existing BC Hydro Facilities and committed hydroelectric projects (in operation and in development) that have signed Electricity Purchase Agreements (EPA) as of October 1, 2014.[6,7] Any corresponding potential projects were screened within a 500 m buffer from the point of diversion to generating station location.

Site Screening Application and Impacts to Resources

The table below summarises the process used to apply the screens and the number of projects impacted with the updated screens. Projects previously screened out in the 2010 Update are not included in the sum of total projects impacted.

Table 2: Exclusion Areas Process and 2015 Impacted Projects

Feature	Process	Number of Projects Impacted
Salmon Species Presence	No projects within 100 m of exclusion area	79
Biodiversity Areas, National Parks, Legally Protected Areas *Ecological Reserves, Protected Areas, Provincial Parks, Recreation Areas, Migratory Bird Sanctuaries*	No projects within 100 m of exclusion area	5
Wildlife Management Areas *areas for which administration and control has been transferred to the Ministry of Environment (MoE) via the Land Act due to the significance of their wildlife/fish values and designated as Wildlife Management Areas under the Wildlife Act*	No projects within 100 m of exclusion area	1
Conservancy Areas *conservancy areas designated under the Park Act or by the Protected Areas of British Columbia Act, whose management and development is constrained by the Park Act*	No projects within 100 m of exclusion area	94
Energy Purchase Agreements (EPAs)/Existing BC Hydro Facilities	No projects within 500 m of existing projects	14
Canadian Forces Bases	No projects within 100 m of exclusion area	0
Glaciers	No projects within 100 m of exclusion area	0
Total		**193**

[6] BC Hydro IPP Supply List – In Operation (as of October 1, 2014)
[7] BC Hydro IPP Supply List – In Development (as of October 1, 2014)

Capital Costs Updates

The following sections outline the updates to assumptions and process to estimate capital and annual costs for hydro projects. Since this assessment is an inventory level study, the analysis and estimates of costs are intended to provide the magnitude of costs and to gauge relative costs between projects. The cost estimates include a 30% contingency allowance on civil items and a 10% contingency on generation equipment and electronic balance of plant. All costs are presented in 2015 Canadian dollars, and do not include any local (e.g., carbon tax), provincial (PST) or federal taxes (GST). All costs have been increased by 2% per year from the last revision in 2010 to 2015 dollars.

The cost estimates include:

- intakes, size based on design flow of project;
- penstocks, based on diameter, slope and pressure rating (assuming steel pipe);
- powerhouse, based on design flow of project (assumes pre-engineered building);
- energy equipment, including turbine, generator and electric balance of plant (controls, protection and substation), based on head and power output;
- road access;
- power line connection to existing grid;
- mobilization and transport costs, including camp (if required);
- allowance for engineering: 15%;
- bonding and insurance: 2%; and,
- environmental and social mitigation allowance.

The cost estimates do not include the following site-specific considerations (this is not an exhaustive list):

- geotechnical allowances;
- market conditions for labour and/or materials; and
- delays due to difficult construction conditions, terrain or weather.

Penstock

Known capital costs were obtained for typical penstock construction within British Columbia in Canadian dollars. These costs were used to calibrate cost curves that were developed for the assessment. Updates were made to improve the resolution of high head projects to mark a cut-off point where the penstock material would transition from low/medium pressure to high pressure. Previously high head projects were costed based on high pressure material throughout the entire length of the penstock. The result is a slightly lower, more representative cost for the high-pressure projects.

Intake and Powerhouse Civil Works

Intake and powerhouse components were sized and cost developed based on experience with projects in British Columbia. These costs were used to calibrate cost curves that were developed for this assessment.

Generation Equipment – Turbine/Generator and Electric Balance of Plant

Cost tables were based on actual projects. Tables and curves for projects were developed for a variety of project capacity, heads and flows. Cost estimates were updated for the supply and installation of energy equipment (e.g., turbine and generator) and electrical balance of plant (switchgear, controls and substation). The type of turbine (Kaplan, Francis or Pelton) selected for each project was based on the design head at each of the sites (Table 3) and the number of units based on design capacity (Table 4). Mechanical and Electrical installation was updated from a previous value of 10% total Water to Wire cost to 16% based on project experience.

Table 3: Turbine Selection

Head	Turbine Type
8 – 40 m	Kaplan/Propeller
40 – 200 m	Francis
200 – 1,000 m	Pelton

Table 4: Turbine No. of Units Selection

Kaplan		Francis and Pelton	
< 0.5 MW	N/A	< 5 MW	1 Unit
0.5 – 12 MW	1 Unit	5 – 30 MW	2 Units
> 12 MW	2 Units	> 30 MW	3 Units

Roads and Power Line Costs

Information relating to the cost for roads, power lines and interconnection is provided in Appendix B. The methodology for power line costing was revised to include step-up transformation costs associated with transforming the power generated at site from the minimum voltage required based on project capacity, to the required power line voltage for transmission (see Appendix B, Table B-12). Costs for roads and power lines were escalated by 10.4%, based on 2% per year from 2010 dollars.

Potential projects that were sited close to the shoreline of a large lake, the seacoast or a major inlet were given the opportunity to have barge access. In the case of lakes only large lakes (>50 km^2) in close proximity to roads (<500 m) were allowed for barge access. A barge access cost allowance was included for projects based on the construction duration: $773,000 for 1 year, $1,105,000 for 2 years, and $1,435,000 for three years of construction. Ten percent of projects utilize a barge for access.

Construction Camp, Transportation and Mobilization

To account for site variations due to regional factors and remoteness (proximity to city centres), costs for construction camps and transportation of people and equipment are added to estimates. Four site categories were used to indicate the remoteness of location. Category A sites were located within a 50 km radius of a major town or city centre (population of 25,000 or more). Category B or C sites were located within 200 or 400 km for a centre, respectively. Category D sites were located anywhere outside a 400 km radius from a city centre. Camp and transportation cost estimates for Site Categories A through D are shown in Table 5 below. Construction camp costs were modified to include a camp operating allowance in addition to transportation.

Table 5: Total Camp and Transportation Costs ($)

Project Capacity	Location Class A	Location Class B	Location Class C	Location Class D
Less than 1 MW	122,900	245,800	1,046,700	1,194,100
1 to 10 MW	245,800	491,500	1,903,200	2,198,100
Greater than 10 MW	368,700	737,300	2,558,500	3,000,900

Table 6 provides a summary of the additional cost allowance provided for the mobilization and demobilization to and from the site.

Table 6: Additional Site Location Mobilization/Demobilization Allowance

Site Location Class	% of Capital Cost
A	6
B	10
C	18
D	24

Environmental and Social Permitting

The previous allowance of 5% was refined based on project experience. This item includes permitting, mitigation, and environmental assessment. It does not include revenue sharing or landowner compensation. The result of this update is a higher cost for small projects, as they often require similar study and processes as larger projects. Costs for projects greater than 15 MW has been decreased to 3% of capital cost. The following costs are applied:

Table 7: Environmental and Social Costs

Project Size	Environmental/Social Allowance
<0.5 MW	$750,000
0.5 – 10 MW	$1,000,000
>10 – 15 MW	$1,500,000
>15 MW	3% of project capital cost

Annual Cost Updates

Annual costs include operation and maintenance, water rental and taxes, land taxes and acquisition, financing, and interest during construction. The following update was made to the 2010 RoR Update for water rental and taxes:

Water Rental and Taxes

The commercial and general power purpose water rental rates are adjusted annually to reflect changes in the British Columbia consumer price index. Water rental fees were updated to reflect rental rates, with annual adjustment, for power commercial and general purpose for calendar year 2015.[8]

For authorized capacity, the charge is $4.334/kW. For output, the charge is $1.301 for each megawatt-hour (MWh) a year, up to a total of 160,000 MWh and $6.066 for each additional MWh a year, exceeding 160,000 MWh up to a total of 3,000,000 MWh.

[8] http://www.env.gov.bc.ca/wsd/water_rights/water_rental_rates/

For each additional MWh a year, exceeding 3,000,000 MWh, a charge of $7.298 per MWh is applied. The tier three energy rental charge is anticipated to be eliminated in Q4 2018.

The minimum annual rental for each licence is $211.63.

Unit Energy Cost Updates

Unit energy costs were calculated by amortizing the total capital cost for each project at a 5% real discount rate (and 7% real as sensitivity) over the project life, adding the annual costs and dividing by the annual energy estimate for the site.

Results of Assessment

The study identified over 7,000 potential run-of-river hydroelectric sites in BC. These sites have a potential installed capacity of over 16,000 MW and average annual energy of over 53,000 GWh/yr. KWL estimated the cost for each project, including costs for access and power lines to interconnect to the BC Hydro and Fortis BC grids. Table 8 provides the number of projects, energy, and capacity by price bundle.

Table 8: Total Run-of-River Hydro Potential in BC

Price Bundle ($/MWh)	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
80 - 84	2	220	187	65	1
85 - 89	1	69	64	16	2
90 - 94	3	484	422	126	9
95 - 99	2	438	388	147	-
100 - 109	4	543	447	154	6
110 - 119	12	891	683	241	22
120 - 129	17	1,693	1,234	448	34
130 - 139	15	698	507	209	6
140 - 149	17	1,052	789	305	16
150 - 159	1	1,383	1,103	381	23
160 - 169	17	689	542	211	7
170 - 179	26	1,631	1,317	479	9
180 - 189	20	1,151	940	331	12
190 - 199	26	1,123	860	333	25
200 - 299	311	8,596	6,572	2,682	99
300 - 399	270	5,352	4,042	1,636	46
400 - 499	284	4,252	3,222	1,314	38
500 - 599	220	2,251	1,625	734	22
600 - 699	236	2,219	1,628	699	18
700 - 799	206	1,495	1,066	484	11
800 - 899	195	1,469	1,089	474	10
900 - 999	183	1,435	1,101	454	8
1000 +	5,003	14,001	9,590	4,384	119
Total	**7,088**	**53,134**	**39,418**	**16,303**	**543**

A supply curve for run-of-river hydroelectric potential in BC is presented in Figure 1. Supply curves for the ten (10) major transmission regions in BC are presented in Figure 2. Figures 3 and 4 provide a supply curve broken down by site infrastructure (At-Gate Cost) and access/power line costs. The unit energy cost is great influenced by the remoteness of the site. Breakdowns of the cost by component for each site remoteness category are provided in average costs and percentages in Figures 5 and 6.

The monthly energy distribution of the projects in each region can be found in Figure 7.

Supply curves are shown in Figure 8 for both 5% and 7% real discount rates.

The attached Map 1 (Appendix A) of BC entitled Run-of-River Hydroelectric Potential in British Columbia 2015 Revision shows the location of the over 7,000 sites with associated size denoted by symbols and estimated unit energy cost range denoted by colour.

Discussion of Results

Given the large number of potential hydropower sites identified, there is considerable potential for future development of run-of-river hydroelectric projects in BC.

As this study involved identifying a complete inventory of potential run-of-river hydroelectric projects, the unit energy costs presented include both the most and least cost-effective projects. The assessment identified eight projects estimated to have a unit energy cost under $100/MWh with approximately 350 MW of installed capacity (11 MW of dependable capacity) and approximately 1,200 GWh/yr of average annual energy. Table 9 provides a breakdown of the projects with estimated unit energy costs under $100/MWh by major transmission region. Tables 10, 11 and 12 present a breakdown by project size and unit energy cost of total annual energy, capacity, and number of sites respectively.

Table 9: Run-of-River Hydro Potential in BC for Sites under $100/MWh[1]

Region	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
East Kootenay	1	132	114	41	0
Kelly Nicola	2	438	388	147	0
Lower Mainland	3	158	127	43	3
North Coast	1	168	151	49	0
Vancouver Island	1	314	282	73	8
Total	**8**	**1,210**	**1,061**	**353**	**11**

Table 10: Energy by Project Size[1]

Price Bundle	Annual Energy (GWh/year)			
	< 1 MW	1 to 30 MW	> 30 MW	Total
< $100/MWh		158	1,052	1,210
$100 to 149/MWh		2,717	2,160	4,877
> $150/MWh	5,165	38,372	3,510	47,047
Total	**5,165**	**41,247**	**6,722**	**53,134**

Table 11: Capacity by Project Size[1]

Price Bundle	Installed Capacity (MW)			
	< 1 MW	1 to 30 MW	> 30 MW	Total
< $100/MWh		43	310	353
$100 to 149/MWh		791	565	1,356
> $150/MWh	1,707	11,932	954	14,594
Total	**1,707**	**12,767**	**1,829**	**16,303**

Table 12: Number of Sites by Project Size[1]

Price Bundle	Number of Projects			
	< 1 MW	1 to 30 MW	> 30 MW	Total
< $100/MWh		3	5	8
$100 to 149/MWh		54	11	65
> $150/MWh	3,858	3,133	24	7,015
Total	**3,858**	**3,190**	**40**	**7,088**

Each site was treated as though it were developed in isolation of other projects so no savings (shared roads, power lines, camps, mobilization, share operators and other synergies) due to clustering has been considered. The study is an inventory level assessment and has not individually optimised each plant. The assumptions used to size and locate potential sites in this study may not provide the most economically site configuration or sizing.

More comprehensive site investigation, First Nations consultation and accommodation, environmental and social assessments, hydrologic data collection and analysis, concept development and interconnection studies is required for developers to proceed with potential project applications prior to licensing, electricity purchase agreements, and construction.

Looking Ahead

No major innovations in run-of-river are expected in the next decade, as this is a mature technology that has been around for over 100 years. Over the next five to ten years there are a few considerations that may affect hydropower pricing:

1. low oil prices will lower prices for HDPE pipe and construction (due to reduced costs for fuel for heavy equipment);
2. low debt and equity cost will continue to keep financing costs low;
3. innovation in material application (e.g., carbon fibre composite) could lower the cost of some components in the next decade; and
4. innovation will continue to drive price down for low-head technologies.

Quality Assurance/Quality Control

KWL developed and maintains a comprehensive Professional Practice Manual, which covers all aspects of project delivery from staff roles and responsibilities to document control, design and drawings standards, document standards, and communications standards and protocols. Reviews are performed by qualified staff in accordance with the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) and other requirements, and commensurate with the scale and sensitivity of the project.

The review team is made up of a technical reviewer and others who are referred to as 'calculation checkers', 'drawing checkers'. The role of the 'checker' is to check specific items such as computations and intermediate documents. The technical reviewer is a technically qualified person who is sufficiently independent to undertake review of the project, but may not be completely removed from the project.

An important part of the technical reviewer's task is to ensure consistency between the various parts of the design/report submission, e.g., between drawings and specs, and between work components prepared by different team members and sub-consultants. The formal review process may involve some or all of the following (the list is not intended to be exhaustive):

1. confirming general concepts for conformance with good practice, applicable codes and client requirements;
2. checking calculations and analyses for completeness and correctness;
3. reviewing the inputs and results from computer models;
4. checking drawings for completeness, constructability and conformance with KWL and other professional standards;
5. checking specifications and contract documents for completeness and consistency; and/or
6. checking reports for overall quality and context.

KWL is Organizational Quality Management (OQM) certified by APEGBC. The OQM certification verifies that KWL's professional practice systems meet APEGBC requirements for project execution, delegation of work and direct supervision, technical review and checking, field reviews, records management, and use of the P.Eng. Seal.

On this project checking was completed on each set of calculations and analyses for completeness and correctness.

Technical review was conducted to confirm general concepts for conformance with good practice, applicable codes and client requirements, in addition to, reviewing the inputs and results from computer models.

Closing

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

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This document is a copy of the sealed and signed original retained on file.
The content of the electronically transmitted document can be confirmed by referring to the filed original.

Ron Monk, MEng, PEng
Energy Sector Leader

KAW/cot/sk

Encl.
- Figure 1: Supply Curve for Run of River Hydroelectric Potential in BC
- Figure 2: Run of River Supply Curves by Transmission Region at 5% Discount Rate
- Figure 3: Supply Curve Breakdown for Run of River Potential in BC at 5% Discount Rate
- Figure 4: Supply Curve Breakdown for Run of River Potential in BC at 5% Discount Rate and Unit Energy Cost under $150/MWh
- Figure 5: Run of River Average Capital Cost Breakdown by Site Location Category
- Figure 6: Average Capital Cost Breakdown as a per cent of Total Capital Cost
- Figure 7: Run of River Monthly Energy Profiles by Transmission Region
- Figure 8: Run of River Supply Curve with Unit Energy Cost Sensitivity to Discount Rate
- Appendix A: Map 1: Run of River Hydroelectric Potential in British Columbia, 2015 Revision
- Appendix B: Roads and Power Lines Methodology

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of the intended recipient. 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
0	May 29, 2015	Draft		KAW/COT
1	July 10, 2015	Final	Revisions per BC Hydro comments received 2015-06-19	KAW/COT

Supply Curve for Run of River Hydroelectric Potential in BC

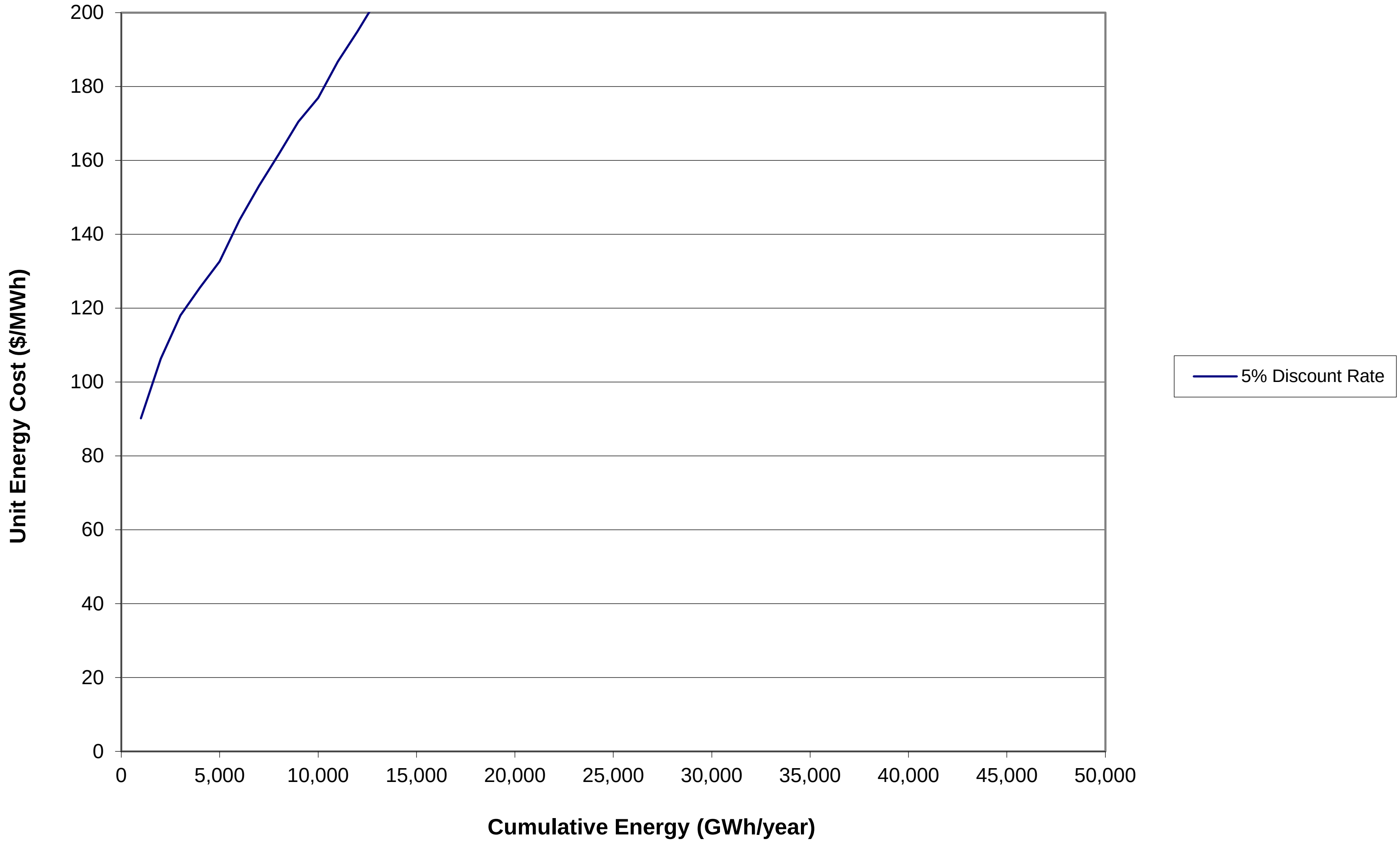

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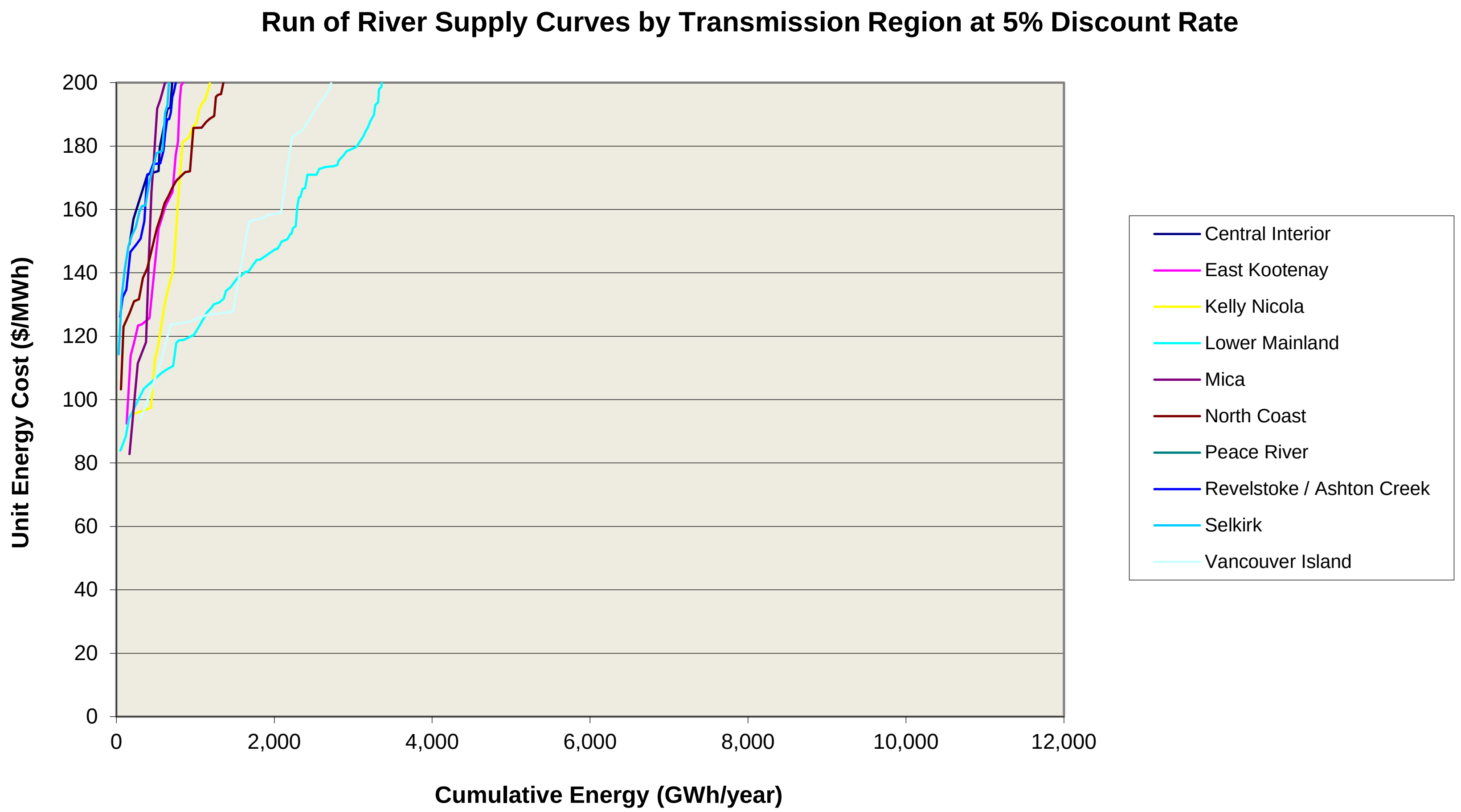
Figure 1



Run of River Supply Curves by Transmission Region at 5% Discount Rate
Unit Energy Cost ($/MWh)
200
180
160
140
120
100
80
60
40
20
0
0
2,000
4,000
6,000
8,000
10,000
12,000
Cumulative Energy (GWh/year)
Central Interior
East Kootenay
Kelly Nicola
Lower Mainland
Mica
North Coast
Peace River
Revelstoke / Ashton Creek
Selkirk
Vancouver Island

Figure 2

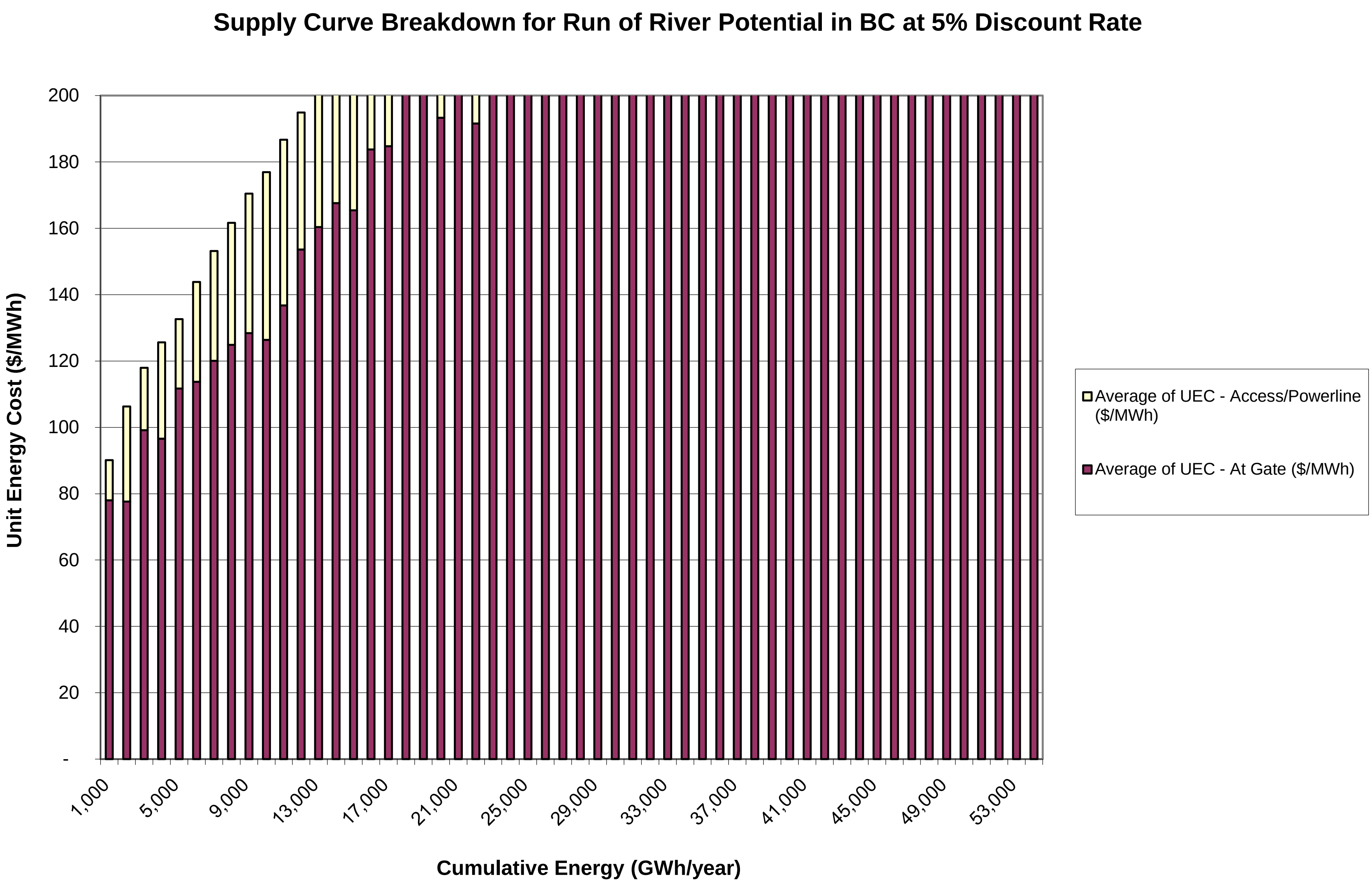


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Figure 3

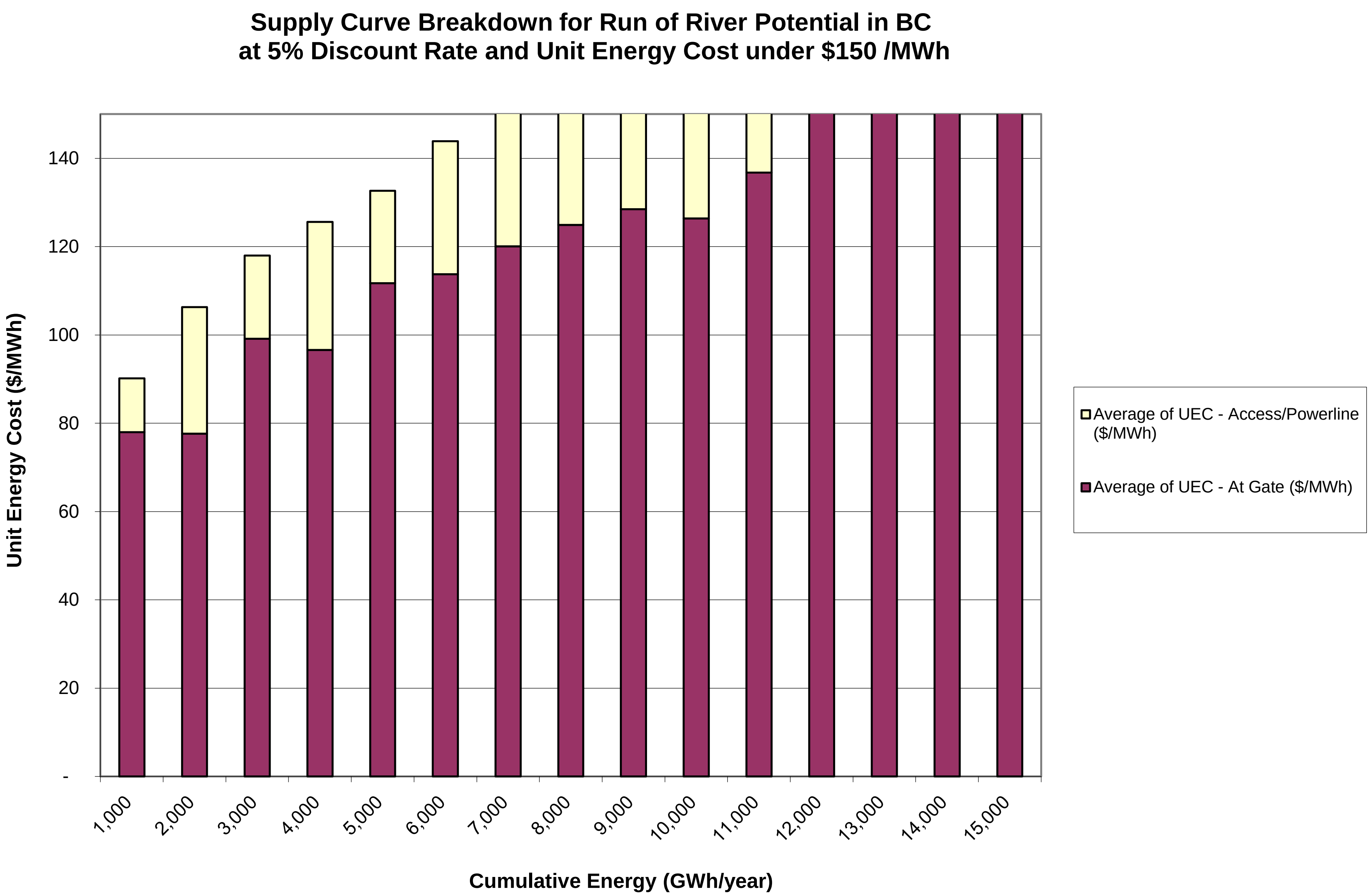

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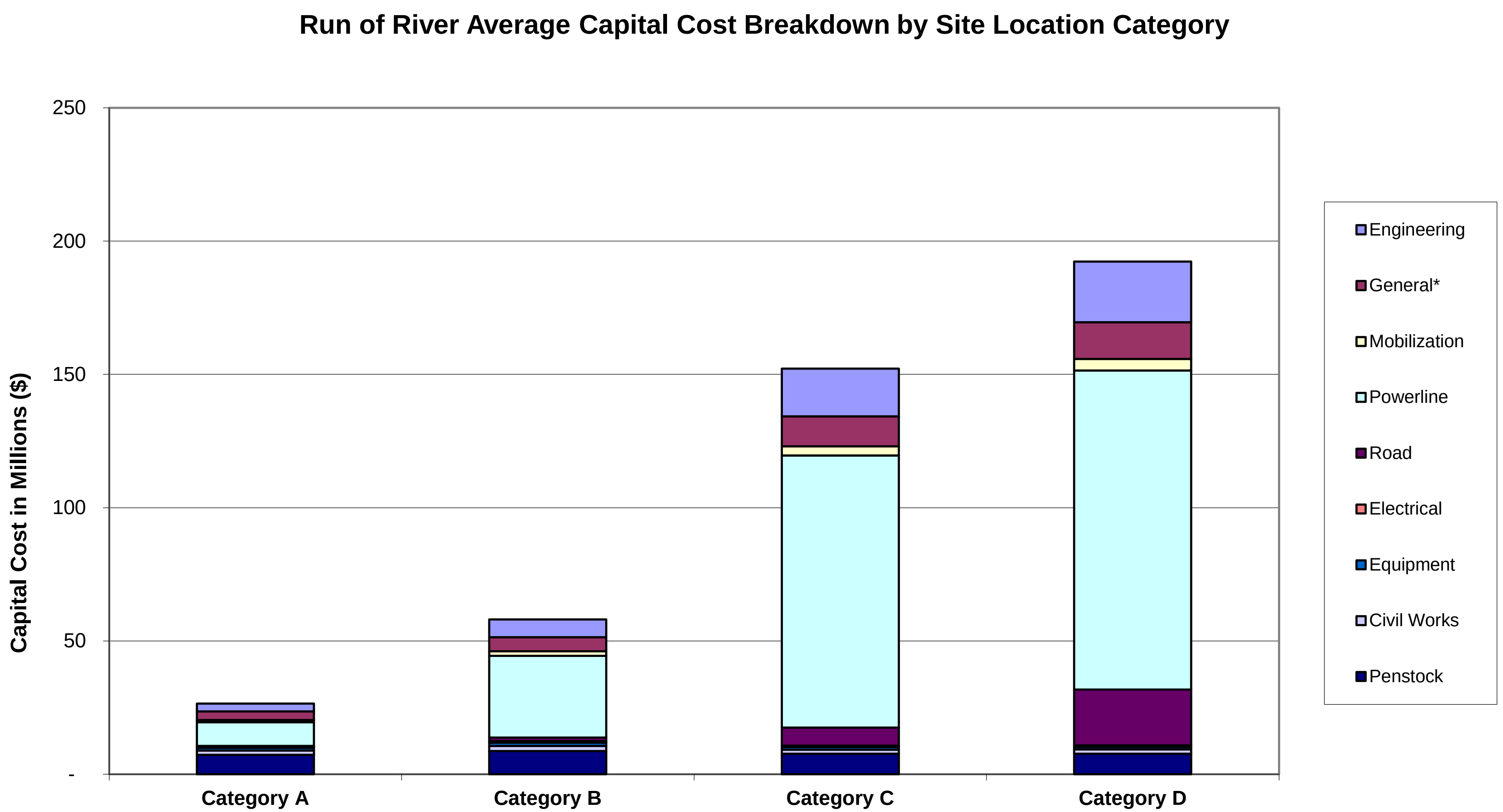
Figure 4



Site Category A: < 50 km radius from a major town or city centre
Site Category B: 50 to 199 km radius
Site Category C: 200 to 399 km radius
Site Category D: >= 400 km radius
** General Costs include bonding, insurance, environmental and social costs*

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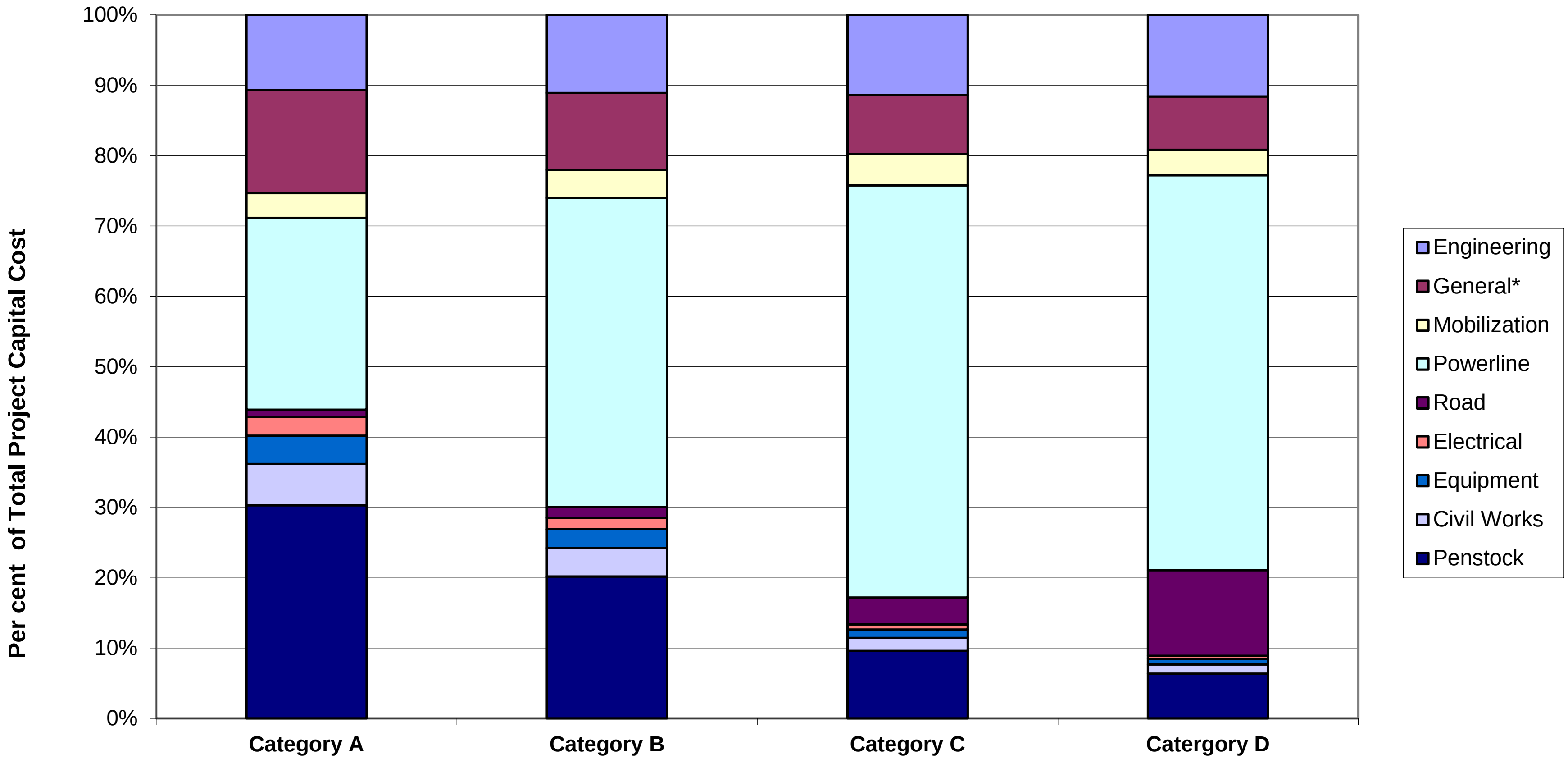
Figure 5

Average Capital Cost Breakdown as a per cent of Total Capital Cost



Site Category A: < 50 km radius from a major town or city centre
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Figure 6

Run of River Monthly Energy Profiles By Transmission Region

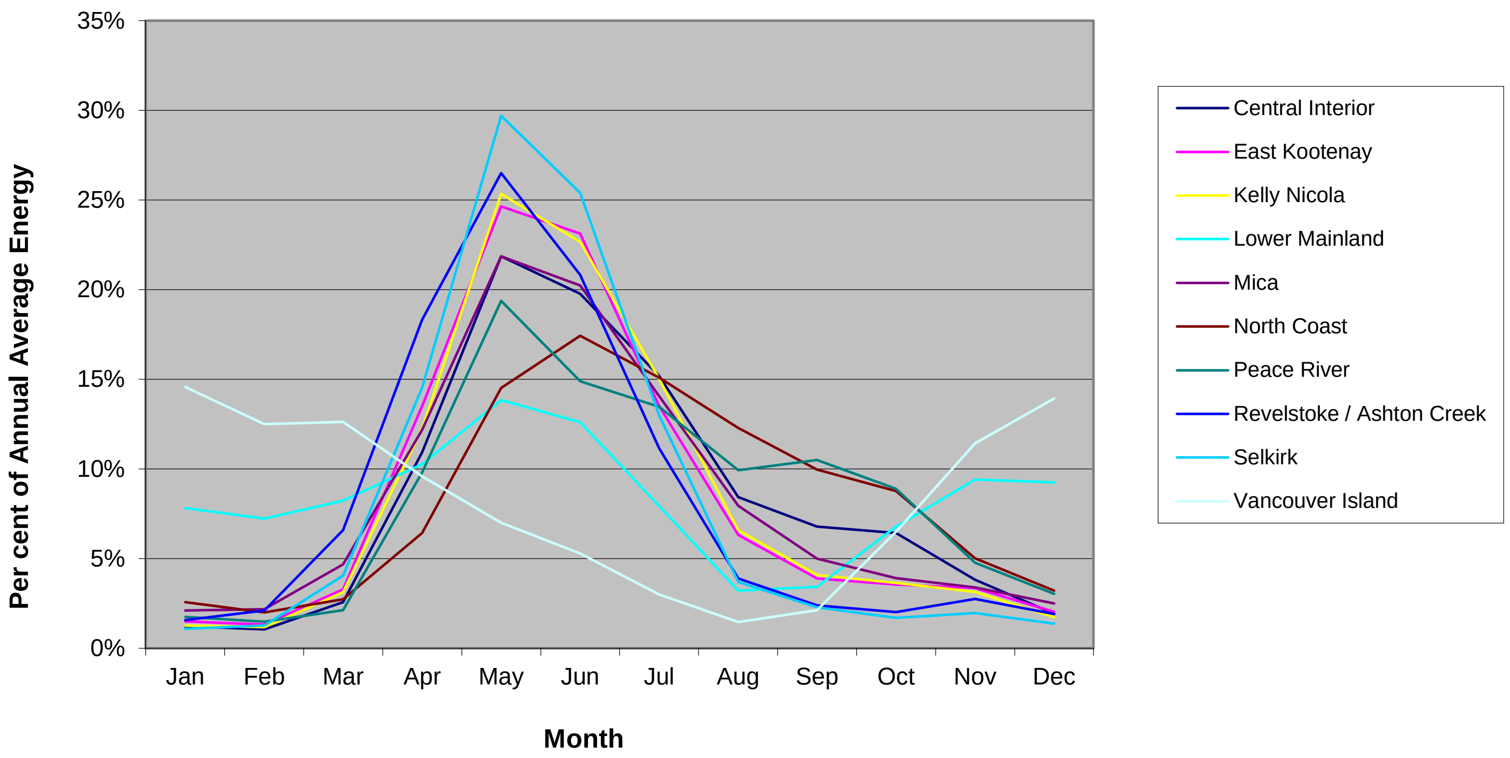

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Figure 7

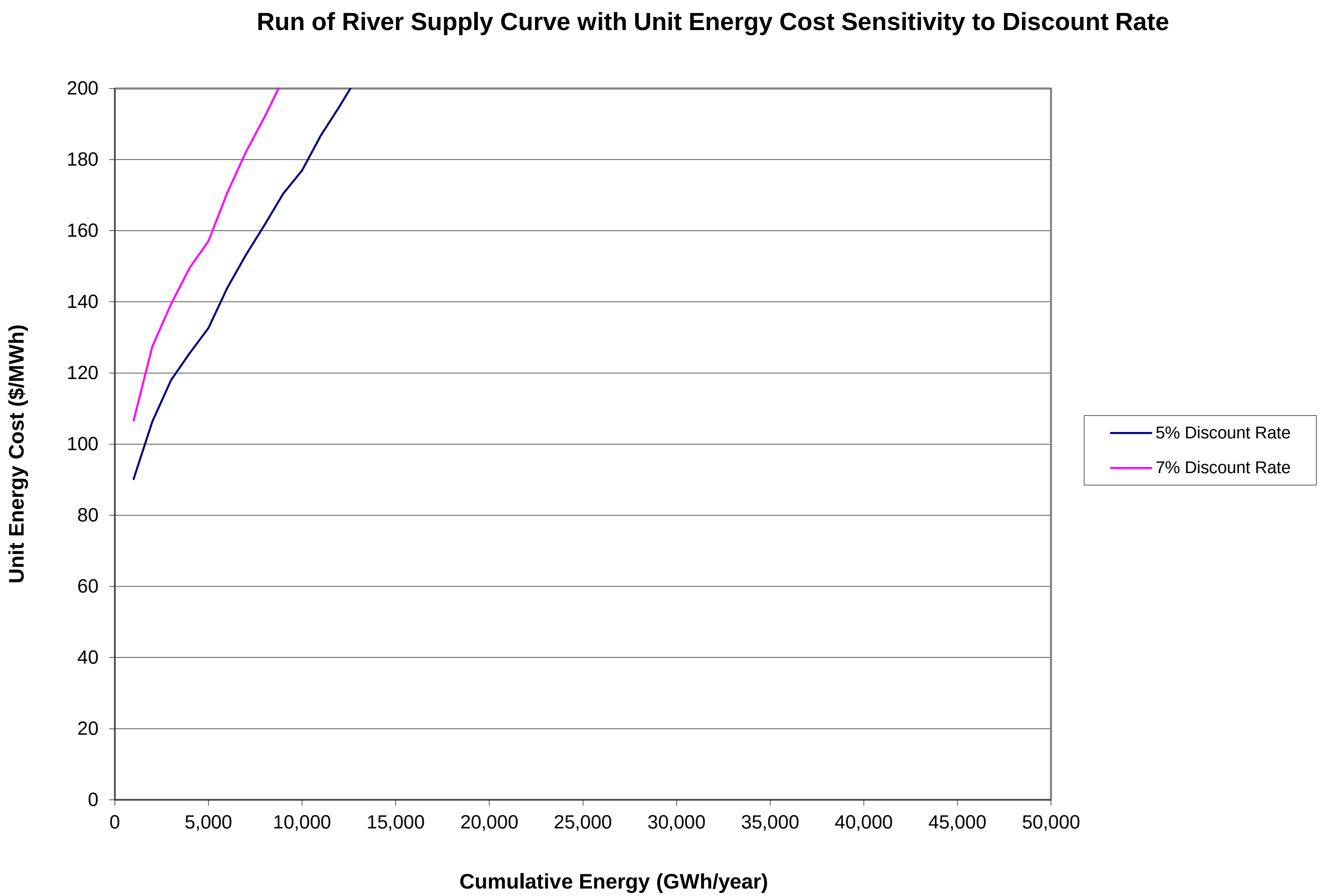

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Figure 8

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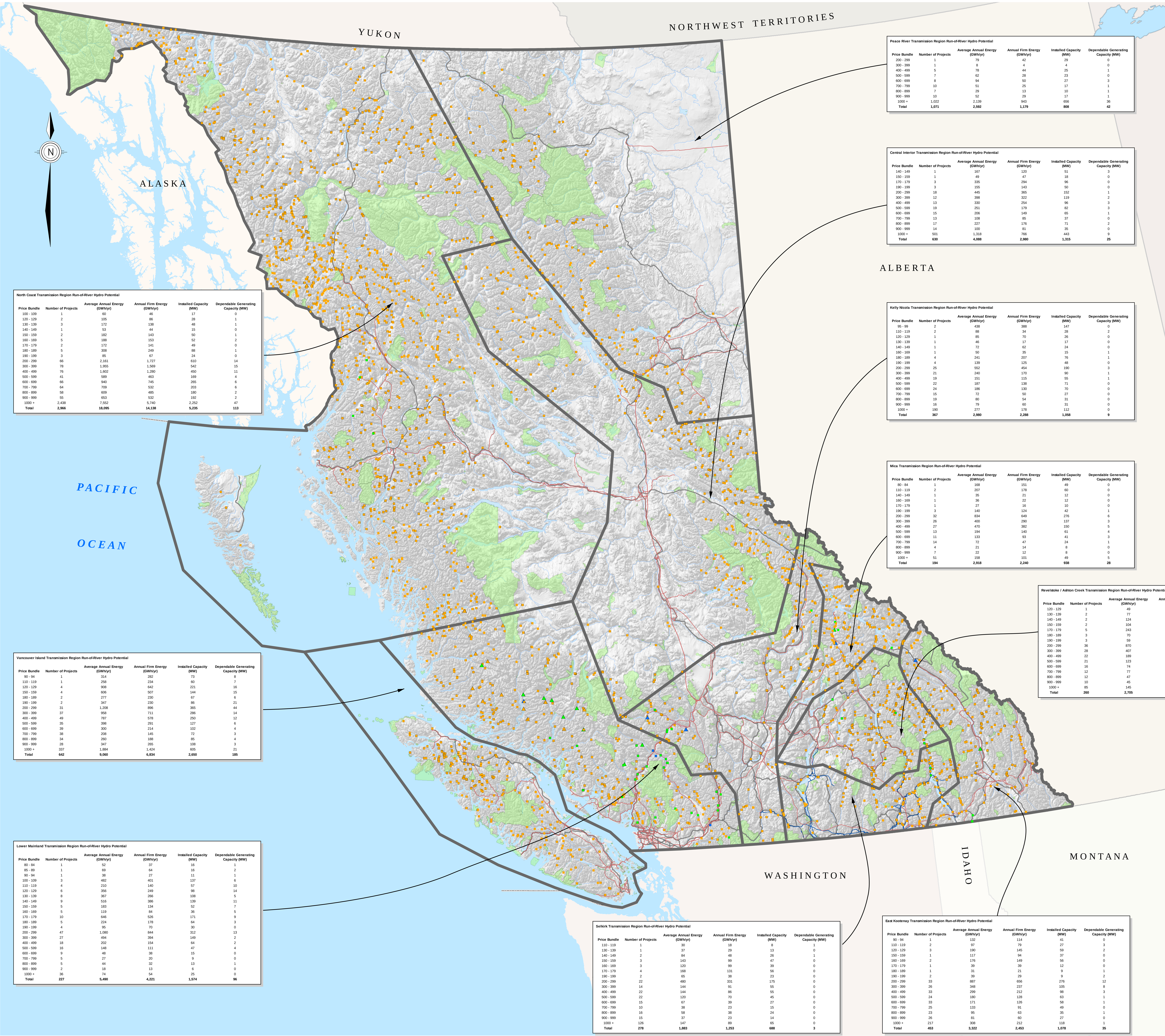
Appendix A

Map 1 – Run of River Hydroelectric Potential in British Columbia



BC hydro

Run-of-River Hydroelectric Resource Assessment for British Columbia 2015 Update

Legend

- Parks
- Transmission Region Boundary
- Major Road
- BC Hydro Transmission Line
- Fortis BC Transmission Line

Potential Power Projects

	< $100/MWh	$100 - $150/MWh	> $150/MWh
< 1 MW			
1 - 30 MW			
> 30 MW			

40 20 0 40 Kilometres
Scale 1:2,000,000

This map identifies over 7,000 potential run-of-river hydro power projects in B.C. These locations represent sites that could potentially be developed based on an inventory level analysis of available in-stream power resources. Sites within Provincial and National Parks and Protected Areas, identified salmon streams and in the vicinity of existing hydropower projects have been excluded. Actual development of the locations presented on this map would require site-level assessment including review of First Nations, environmental, social, economic and technical issues, as well as Government approvals.

SOURCE MAP BACKGROUND LAYERS:

Canadian Digital Elevation Data (NRCan), 1:250,000 with Hillshade

B.C. Watershed Atlas (B.C. Ministry of Environment)

B.C. Transmission System (B.C. Hydro)

Fortis B.C. Transmission system (Fortis B.C.)

Highways (NRCan)

Provincial Parks (BCGOV ILMB Crown Registry and Geographic Base Branch)

National Parks (NRCan)

STATEMENT OF LIMITATIONS
This document was prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of BC Hydro. 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 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.

Peace River Transmission Region Run-of-River Hydro Potential

Price Bundle	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
200 - 299	1	79	42	29	0
300 - 399	1	8	4	4	0
400 - 499	5	78	44	25	1
500 - 599	7	62	28	23	0
600 - 699	8	94	50	27	3
700 - 799	10	51	25	17	1
800 - 899	7	29	13	10	1
900 - 999	10	52	29	17	1
1000 +	1,022	2,139	943	656	36
Total	**1,071**	**2,592**	**1,179**	**808**	**42**

Central Interior Transmission Region Run-of-River Hydro Potential

Price Bundle	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
140 - 149	1	167	120	51	3
150 - 159	1	49	47	18	0
170 - 179	3	335	294	96	0
190 - 199	3	155	143	50	0
200 - 299	18	445	365	152	1
300 - 399	12	398	322	119	2
400 - 499	13	330	254	96	3
500 - 599	19	251	179	82	3
600 - 699	15	206	149	65	1
700 - 799	13	108	85	37	0
800 - 899	17	227	176	71	2
900 - 999	14	100	81	35	0
1000 +	501	1,318	766	443	9
Total	**630**	**4,088**	**2,980**	**1,315**	**25**

Kelly Nicola Transmission Region Run-of-River Hydro Potential

Price Bundle	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
95 - 99	2	438	388	147	0
110 - 119	2	88	34	28	2
120 - 129	1	85	70	26	0
130 - 139	1	46	17	17	0
140 - 149	1	72	62	24	0
160 - 169	1	50	35	15	1
180 - 189	4	241	207	76	1
190 - 199	4	139	125	48	0
200 - 299	25	552	454	190	3
300 - 399	21	240	170	90	1
400 - 499	19	151	115	55	1
500 - 599	22	187	138	71	0
600 - 699	24	186	130	70	0
700 - 799	15	72	50	27	0
800 - 899	19	80	54	31	0
900 - 999	16	79	60	31	0
1000 +	190	277	178	112	0
Total	**367**	**2,980**	**2,288**	**1,058**	**9**

Mica Transmission Region Run-of-River Hydro Potential

Price Bundle	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
80 - 84	1	168	151	49	0
110 - 119	2	207	178	60	0
140 - 149	1	35	21	12	0
160 - 169	1	36	22	12	0
170 - 179	1	27	16	10	0
190 - 199	3	140	124	42	1
200 - 299	32	834	649	276	6
300 - 399	26	400	290	137	3
400 - 499	27	470	382	150	5
500 - 599	13	194	140	61	4
600 - 699	11	133	93	41	3
700 - 799	14	72	47	24	1
800 - 899	4	21	14	8	0
900 - 999	7	22	12	8	0
1000 +	51	158	101	49	5
Total	**194**	**2,918**	**2,240**	**938**	**28**

Revelstoke / Ashton Creek Transmission Region Run-of-River Hydro Potential

Price Bundle	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
120 - 129	1	49	43	16	0
130 - 139	2	77	56	24	0
140 - 149	2	124	109	39	0
150 - 159	2	104	79	32	1
170 - 179	5	243	170	85	0
180 - 189	3	70	55	27	0
190 - 199	3	59	34	22	0
200 - 299	36	870	608	297	5
300 - 399	28	407	255	151	0
400 - 499	22	189	117	71	0
500 - 599	21	123	77	46	0
600 - 699	16	74	45	28	0
700 - 799	12	77	48	30	0
800 - 899	12	47	28	18	0
900 - 999	10	45	27	16	1
1000 +	85	145	81	58	0
Total	**260**	**2,705**	**1,832**	**959**	**7**

North Coast Transmission Region Run-of-River Hydro Potential

Price Bundle	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
100 - 109	1	60	46	17	0
120 - 129	2	105	86	28	1
130 - 139	3	172	138	48	1
140 - 149	1	53	44	15	0
150 - 159	2	182	143	50	1
160 - 169	5	188	153	52	2
170 - 179	2	172	141	49	0
180 - 189	5	308	249	88	1
190 - 199	3	85	67	24	0
200 - 299	66	2,161	1,727	610	14
300 - 399	78	1,955	1,569	542	15
400 - 499	76	1,602	1,280	450	11
500 - 599	41	589	463	169	4
600 - 699	66	940	745	265	6
700 - 799	64	709	532	203	6
800 - 899	58	609	485	180	2
900 - 999	55	653	532	192	2
1000 +	2,438	7,552	5,740	2,252	47
Total	**2,966**	**18,095**	**14,138**	**5,235**	**113**

Vancouver Island Transmission Region Run-of-River Hydro Potential

Price Bundle	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
90 - 94	1	314	282	73	8
110 - 119	1	258	234	60	7
120 - 129	4	908	642	221	16
150 - 159	4	606	507	144	15
180 - 189	2	277	230	67	6
190 - 199	2	347	230	86	21
200 - 299	31	1,208	896	365	44
300 - 399	37	958	711	286	14
400 - 499	49	787	578	250	12
500 - 599	35	398	291	127	6
600 - 699	39	300	214	102	4
700 - 799	38	208	145	72	3
800 - 899	34	260	188	85	4
900 - 999	28	347	265	108	3
1000 +	337	1,884	1,424	605	21
Total	**642**	**9,060**	**6,834**	**2,650**	**185**

Lower Mainland Transmission Region Run-of-River Hydro Potential

Price Bundle	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
80 - 84	1	52	37	16	1
85 - 89	1	69	64	16	2
90 - 94	1	38	27	11	1
100 - 109	3	482	401	137	6
110 - 119	4	210	140	57	10
120 - 129	6	356	249	98	14
130 - 139	8	367	266	108	5
140 - 149	9	516	386	139	11
150 - 159	5	183	134	52	7
160 - 169	5	119	84	36	5
170 - 179	10	646	526	171	9
180 - 189	5	224	178	64	3
190 - 199	4	95	70	30	0
200 - 299	47	1,080	844	312	13
300 - 399	27	494	394	149	2
400 - 499	18	202	154	64	2
500 - 599	16	148	111	47	4
600 - 699	9	48	38	15	0
700 - 799	5	27	20	9	0
800 - 899	5	44	32	13	1
900 - 999	2	18	13	6	0
1000 +	36	74	54	25	0
Total	**227**	**5,490**	**4,221**	**1,574**	**96**

Selkirk Transmission Region Run-of-River Hydro Potential

Price Bundle	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
110 - 119	1	30	18	8	1
130 - 139	1	37	29	13	0
140 - 149	2	84	48	26	1
150 - 159	3	143	99	47	0
160 - 169	3	120	99	39	0
170 - 179	4	168	131	56	0
190 - 199	2	65	38	23	0
200 - 299	22	480	331	175	0
300 - 399	14	144	91	55	0
400 - 499	22	144	86	55	0
500 - 599	22	120	70	45	0
600 - 699	15	67	39	27	0
700 - 799	10	38	23	15	0
800 - 899	16	58	38	24	0
900 - 999	15	37	23	14	0
1000 +	126	147	89	65	0
Total	**278**	**1,883**	**1,253**	**688**	**3**

East Kootenay Transmission Region Run-of-River Hydro Potential

Price Bundle	Number of Projects	Average Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	Installed Capacity (MW)	Dependable Generating Capacity (MW)
90 - 94	1	132	114	41	0
110 - 119	2	97	79	27	3
120 - 129	3	190	145	59	2
150 - 159	1	117	94	37	0
160 - 169	2	176	149	56	0
170 - 179	1	39	39	12	0
180 - 189	1	31	21	9	1
190 - 199	2	39	29	9	2
200 - 299	33	887	656	276	12
300 - 399	26	348	237	105	8
400 - 499	33	299	212	98	3
500 - 599	24	180	128	63	1
600 - 699	33	171	126	58	1
700 - 799	25	133	91	49	0
800 - 899	23	95	63	35	1
900 - 999	26	81	60	27	0
1000 +	217	308	212	118	1
Total	**453**	**3,322**	**2,453**	**1,078**	**35**

Run-of-River Hydroelectric Potential in British Columbia 2015 Update

July 2015

Map 1

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Appendix B

Roads and Power Lines Methodology

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Appendix B: Road and Power Line Cost Estimating Using GIS

Access road and power line costs were developed using GIS tools. The toolset identifies the least expensive route from power projects to existing roads or existing power systems.

These tools were used to develop unit cost surfaces of the entire province for road and power line construction.

The sources and processes for developing the road and power line costs are described in Table B-1.

Table B-1: Cost Surface Development Process

Feature	Source/Author	Usage	Process
Public Roads	National Road Network (geobase.ca)	Roads	Used as sources for road cost routine.
Power Lines	BC Hydro and Fortis BC	Power Lines	Used as sources for power line cost routine.
Slope	Canadian Digital Elevation Data (CDED)	Roads and Power Lines	Elevation data converted to slope, and categorized into cost classes. Slopes exceeding 30% and 75% were considered to be not feasible for construction of roads and power lines, respectively.
Proximity to Major Cities	Site classification (see Section 3.2.1)	Roads	Greater cost values were assigned to locations further away from city centres.
Land Cover	AVHRR 1:2M Land Cover (geogratis.ca)	Roads and Power Lines	Costs were adjusted based on land cover (i.e. forest, rock, croplands). Permanent snow and ice were considered infeasible for construction.
Parks	BC Parks and Protected Areas (lrdw.ca) Canada Lands Administrative Boundaries (geogratis.ca)	Roads and Power Lines	Parks were masked out so that no new roads or power lines can cross provincial and federal parks.
Water	Output from the Power calculation model Watershed Atlas	Roads and Power Lines	Costs were assigned to small rivers that can be crossed by road with culverts or small bridges. Large rivers and lakes were not considered for crossing.
Forest Roads	Forest Tenure Roads (lrdw.ca)	Roads and Power Lines	Construction costs were discounted along existing forest roads.

The proposed project locations were overlaid with the resulting accumulated cost output and total road cost extracted. Some locations were found to be inaccessible as determined by the cost routine. These locations were reviewed and either assigned an approximate cost based on the output or assigned a $100 million cost for roads if the project is technically inaccessible.

Similarly, locations found to be inaccessible by power line were assigned a cost as presented in Table B-2.

Table B-2: Power Line Costs for Technically Inaccessible Projects

New Power Line Voltage (kV)	Technically Inaccessible Cost ($2015)
25	55,200,000
69	132,480,000
138	331,200,000
230	1,104,000,000
500	3,312,000,000

The above costs are much higher than any of the cost output from the GIS routine, and are intended to render a project economically infeasible due to inaccessibility to roads or power lines.

Clustering of projects to reduce costs through sharing of common infrastructure was outside of this study's scope.

After the cost accumulation process, individual paths from sources to project locations were traced using the GIS tools. While this process identified common paths amongst adjacent projects, it was assumed that each project would be constructed independently. This is a key factor in the overall cost estimate as road and power line costs make up a significant portion of most projects, especially in remote areas.

Access Roads

Access roads were considered to begin at an existing, documented road and follow the least-cost path to the project location. The primary costs for roads were based on road gradient and distance to major centres. Adjustments to unit costs were made for crossing barren rocky areas, wetlands and agricultural areas. Nominal costs were assigned to existing forestry roads to account for maintenance and road upgrading. The forestry road costs were approximately an order of magnitude less than construction of new roads. This resulted in the least-cost path generally following these corridors until the vicinity of a proposed site was reached.

Roads were assumed not to traverse legally protected areas, large water bodies or glaciers. Road grades exceeding 30% were not permitted. If the site was in proximity to a large body of water, barge access was considered.

Development (engineering, environmental and other) and annual costs (O&M, land acquisition and property taxes) were added on as a percentage of capital cost. The percentages used are noted in the Resource Options Mapping for British Columbia 2015 Update.

Road costs also included a 30% contingency.

Four site categories were used to indicate remoteness of location. Category A sites were located within a 50 km radius of a major town or city centre (population of 25,000 or more). Category B and C sites were located within 200 and 400 km from a centre, respectively, and Category D sites were located anywhere outside a 400 km radius from a centre.

Table B-3: Road Construction Unit Cost ($2015/m)

Site Location Category	Slope	$/m
A	0-5%	150
	5-10%	180
	10-15%	260
	15-20%	330
	20-30%	480
B	0-5%	250
	5-10%	290
	10-15%	360
	15-20%	440
	20-30%	590
C & D	0-5%	350
	5-10%	390
	10-15%	470
	15-20%	540
	20-30%	690

Barge Access

Potential projects that were sited close to the shoreline of a large lake, the seacoast or a major inlet were given the opportunity to have barge access. In the case of lakes only large lakes (>50 km^2) in close proximity to roads (<500 m) were allowed for barge access. A barge access cost allowance was included for projects based on the construction duration: $773,000 for 1 year, $1,105,000 for two years, and $1,435,000 for three years of construction.

Power Line, Interconnection and Transformation Costs

As with access roads development (engineering, environmental and other) and annual costs (O&M, land acquisition and property taxes) were added on as a percentage of capital cost. The percentages used are noted in the Resource Options Mapping for British Columbia 2015 Update report.

These costs also included a 30% contingency.

Allowable Interconnection Locations

An independent power line (an unshared line that is used by one project to interconnect to the BC Hydro grid) interconnection to the grid can occur at either:

- an existing power line (BC Hydro or Fortis BC grid); or
- an existing substation (BC Hydro or Fortis BC grid).

Interconnection to the existing system with independent power lines are not allowed at non-integrated substations or to power lines only connected to a non-integrated substation. This includes the non-integrated existing Fort Nelson Substation (FNG) and line 1L359 from Alberta to FNG. Table B-4 details the interconnection rules used to define whether a new power line can connect to an existing power line. Table B-5 details the interconnection rules used to define whether a new power line can connect to an existing substation. Shaded grey cells with an ‘X’ indicate that interconnection is not allowed.

Table B-4: Interconnection Rules – New Power Line to Existing Power Line

New Power Line Voltage (kV)	Existing Power Line Voltage (kV)[a]				
	12.5[b], 25, & 34.5[c]	60, 63[e] & 69	138, 132[e], 161[e]	230, 238[g], 287[g]	360 & 500
25	D.I.[d]	S.S.[f]	S.S.	S.S.	X
69	X	S.S.	S.S.	S.S.	X
138	X	X	S.S.	S.S.	X
230	X	X	X	S.S.	X
500	X	X	X	X	X

Notes:
a. If the voltage level of the new power line is not available at the sectionalizing substation, then a transformation cost will apply.
b. 25 kV power lines were allowed to connect to 12.5 kV power lines in the BC Hydro system, as it was assumed the system will eventually be upgraded to 25 kV. Either a 25 kV to 12.5 kV transformer would be required at the point of interconnection or the 12.5 kV power line would be upgraded to 25 kV. This transformation or upgrade cost was considered to be small and was not included in the overall cost.
c. 25 kV power lines were allowed to connect to the 34.5 kV power lines in the BC Hydro system. It was assumed that a 34.5 kV power line would be built at approximately the same cost as a 25 kV power line. A 25 kV to 34.5 kV transformer would be required at the point of interconnection. The cost of transformation was considered to be small and was not included in the overall cost.
d. D.I. = direct interconnection (tap) without a sectionalizing substation
e. In this analysis, the 60 kV, 63 kV and 69 kV voltage levels are used interchangeably in both BC Hydro and Fortis BC systems. It was assumed that a 60 kV or 63 kV power line would be built at approximately the same cost as a 69 kV power line. Also, in this analysis, the 138 kV and 161 kV voltage levels are used interchangeably. It was assumed that a 132 kV or 161 kV power line would be built at approximately the same cost as a 138 kV power line.
f. S.S = interconnection only by building a new sectionalizing substation
g. In this analysis, the 230 kV, 238 kV and 287 kV voltage levels are used interchangeably. It was assumed that a 230 kV power line would be built at approximately the same cost as a 238 kV or 287 kV power line.

Table B-5: Interconnection Rules – New Power Line to Existing Substation

New Power Line Voltage (kV)	Lowest Voltage Available at Existing Substation (kV)[a]					
	12.5, 25, & 34.5	60, 63[b] & 69	138 132[b], 161[b]	230, 238[c] & 287[c]	360	500
25[d]	√	√	√	√	X	X
69	X	√	√	√	√	X
138	X	X	√	√	√	√
230	X	X	X	√	√	√
500	X	X	X	X	X	√

Notes:
a. If the voltage level of the new power line is not available at the existing substation, then a transformation cost will apply.
b. See Footnote e in Table B-4.
c. See Footnote g in Table B-4.
d. 25 kV power lines were allowed to connect to 12.5 kV substations in the BC Hydro system as the system will eventually be upgraded to 25kV. A 25 kV to 12.5 kV transformer would be required at the point of interconnection. This transformation cost was considered to be small and was not included in the overall cost. 25 kV power lines were allowed to connect to the 34.5 kV substations in the BC Hydro system. It was assumed that a 34.5 kV power line would be built at approximately the same cost as a 25 kV power line.

New power lines were only allowed to connect at specific points along an existing power line (be it a direct tap in the case of 25 kV or a new sectionalizing substation in the case of 60, 69, 138, 230, or 287 kV). Allowable interconnection locations were positioned a minimum distance between each other and existing substations (Table B-6). The allowable interconnection locations also were placed in locations with lower terrain slope (i.e., at flatter locations not on the side of a hill).

Table B-6: Minimum Distance between Potential Interconnection Points[1]

Existing Power Line Voltage (kV)	Min. Distance (km)
12.5, 25, & 34.5	10
60, 63 & 69	20
132, 138 & 161	60
230, 238 & 287	100
500	Not permitted

Power Line Costs

The power line costs estimated for the 2010 Run-of-River (RoR) study by KWL were escalated from 2010 to 2015 dollars using 2% per year (10.4% total). Costs vary with the slope in KWL's least-cost routing method (see KWL's Run-of-River Hydroelectric Resource Assessment for British Columbia 2007 study for discussion). The estimated 2015 power line costs are presented in Table B-7.

Power lines were assumed to not traverse legally protected areas, glaciers or topography with grades exceeding 75%.

Table B-7: Power Line Cost

New Power Line Voltage (kV)	Cost ($/km), 2015 Dollars		
	Avg. Slope (0-15%)	Avg. Slope (16-30%)	Avg. Slope (31-75%)
25	100,000	200,000	300,000
69	130,000	250,000	380,000
138	190,000	380,000	570,000
230	320,000	630,000	950,000
500	630,000	1,300,000	1,900,000

Table B-8 is used as an approximation guide for selecting the transmission voltage based on the distance and capacity of a transmission line.

Table B-8: Transmission Voltages – Capacity and Distance

Voltage Level (kV)	Capacity Range (MW)		Distance from Cluster's Central Substation (Km)		75% of Distance x 75% of Capacity (MW x km) (This is used as a check)	
	Min	Max	Min	Max	Min	Max
25	0	20	1	20	57	225
69	20	60	20	60	226	2,025
138	60	150	60	100	2,026	8,438
230	150	500	N/A	N/A	N/A	N/A
500	500	1,500	N/A	N/A	N/A	N/A

Notes:
a. For T1 at 230 kV and 500 kV, only capacity is considered.
b. Projects connected to 25 kV are currently permitted to be up to 20 MW and up to 20 km from point of interconnection. Distribution studies by BC Hydro or Fortis BC may restrict the size and distance depending on the local conditions of the distribution line.

[1] Direct Tap or Sectionalising Substation

Table B-9 provides estimated submarine cable costs.

Table B-9: Submarine Cable Cost ($2015)

New Submarine Cable Voltage (kV)	$M/km
25	0.5
69	1.1
138	4.0
230	5.8
500	7.8

Interconnection and Transformation Costs

Tables B-10, B-11, and B-12 provide estimates for the interconnecting cost (existing power line, existing substation or new sectionalising substation) and transformation costs.

Table B-10: Interconnection Cost to Existing Substations, New Sectionalising Substations or Existing Power Lines

New Power Line Voltage (kV)	Interconnecting Existing Station Cost or Sectionalizing Substations (required to connect to 69kV, 138kV and 230kV, and 287 kV)	Interconnection Costs to an Existing Power Line – Without Sectionalizing Substation Required (only 25kV to 25kV, 12 kV and 35kV)
25	$1.7M	$442k
69	$8.3M	X
138	$10.5M	X
230	$11.6M	X
500	$12.3M	X

Table B-11: Transformation Cost at Point of Interconnection

New Generation Power Line Voltage (kV)	Lowest Voltage Available at Substation (kV) (Only apply if there is not a voltage level available at the substation)						
	25 & 34.5	69	138	230	287	360	500
25[a]	$0	$1.7M	$1.7M	$1.7M	$1.7M	X	X
69	X	$0	$8.3M	$8.3M	$8.3M	$8.3M	X
138	X	X	$0	$13.2M	$13.2M	$16.6M	$19.9M
230	X	X	X	$0	$0 [b]	$14.9M	$18.2M
500	X	X	X	X	X	X	$0

Notes:
a. In this analysis, approximation used for 25 kV step up transformation is extended to 13.8 kV transformation as well.
b. See Footnote g in Table B-4.

Table B-12: Step-Up Transformation Cost[a,b] at Resource Site to Power Line Voltage

Generation Voltage Level (kV)	Power Line Voltage Level (kV)				
	25	69[d]	138[e]	230	500
4.16	$1.0M	X	X	X	X
13.8[c]	X	$ 1.3M	$2.0M	$6.2M	X

Notes:
a. Costs represent the installed cost (supply, delivery and installation) of transformers including all applicable taxes in $2015.
b. Costs include land, site preparation, grounding, instrument transformers, power and control.
c. Generation voltages of 13.8 kV and 12.6 kV have similar transformer cost estimates;
d. Transmission voltages of 60 kV, 64.5 kV, and 69 kV have similar transformer cost estimates; and,
e. Transmission voltages of 130 kV and 138 kV have similar transformer cost estimates.

Total Power Line, Interconnection and Transformation Costs

The total cost was calculated as follows for the two scenarios:

1. New power line and interconnection to an existing power line was calculated as follows:

   Total cost = $C_{StepUp} + C_{PL} \times L_{PL} + (C_{Int\_PL\_Direct}$ or $C_{Int\_PL\_SS}) + C_{Tran}$

   Where:

   C_{StepUp} = cost of transformation at site to step up from generation voltage to transmission voltage

   C_{PL} = per km cost of power line (varies with slope and kV)

   L_{PL} = power line length

   $C_{Int\_PL\_Direct}$ = cost of direct tap interconnection to an existing power line only applies to 25kV to 25kV (and also for 25 kV to 12.5 kV or 35kV in the BC Hydro system)

   $C_{Int\_PL\_SS}$ = cost of interconnection using a new sectionalizing substation to connect to an existing power line. (Not required for 25kV to 25kV, 12.5 kV, or 34.5 kV power lines.)

   C_{Tran} = cost of transformation (only applies if the kV of the new power line does not exist in the sectionalizing substation).

2. New power line and interconnection to an existing substation would include:

   Total cost = $C_{StepUp} + C_{PL} \times L_{PL} + C_{Int\_ES} + C_{Tran}$

   Where:

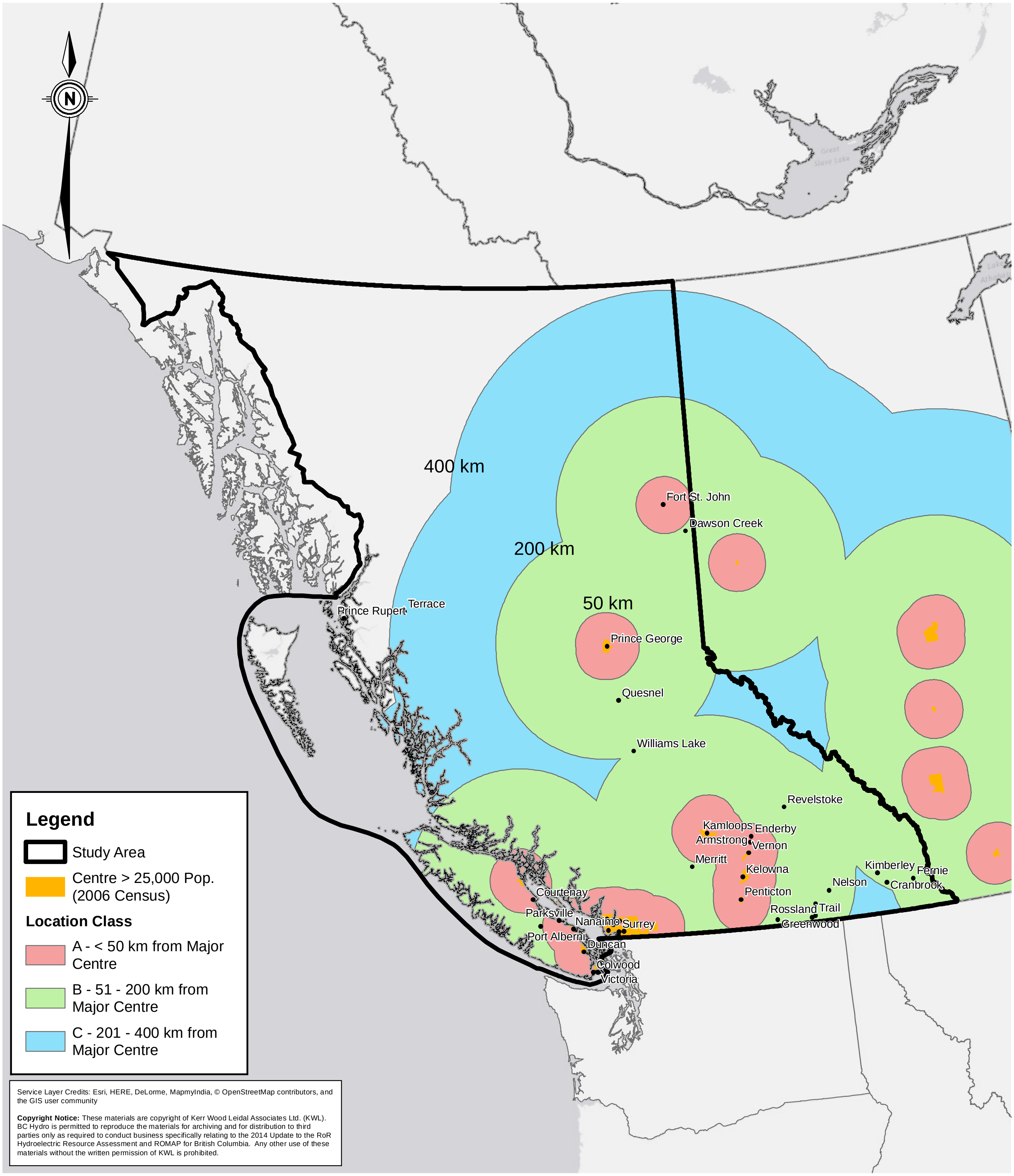
   C_{StepUp} = cost of transformation at site to step up from generation voltage to transmission voltage

   C_{PL} = per km cost of power line (varies with slope and kV)

   L_{PL} = power line length

   C_{Int_ES} = cost of interconnection from project power line to an existing substation (Not required for 25kV to 25kV, 12.5 kV, or 34.5 kV power lines.)

   C_{Tran} = cost of transformation (only applies if the kV of new power line does not exist in the existing substation) = $0 if the voltage of the power line is available at the existing substation



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BC hydro

Project No.	Date
478-177	July 2015

Site Location Categories

Figure B-1

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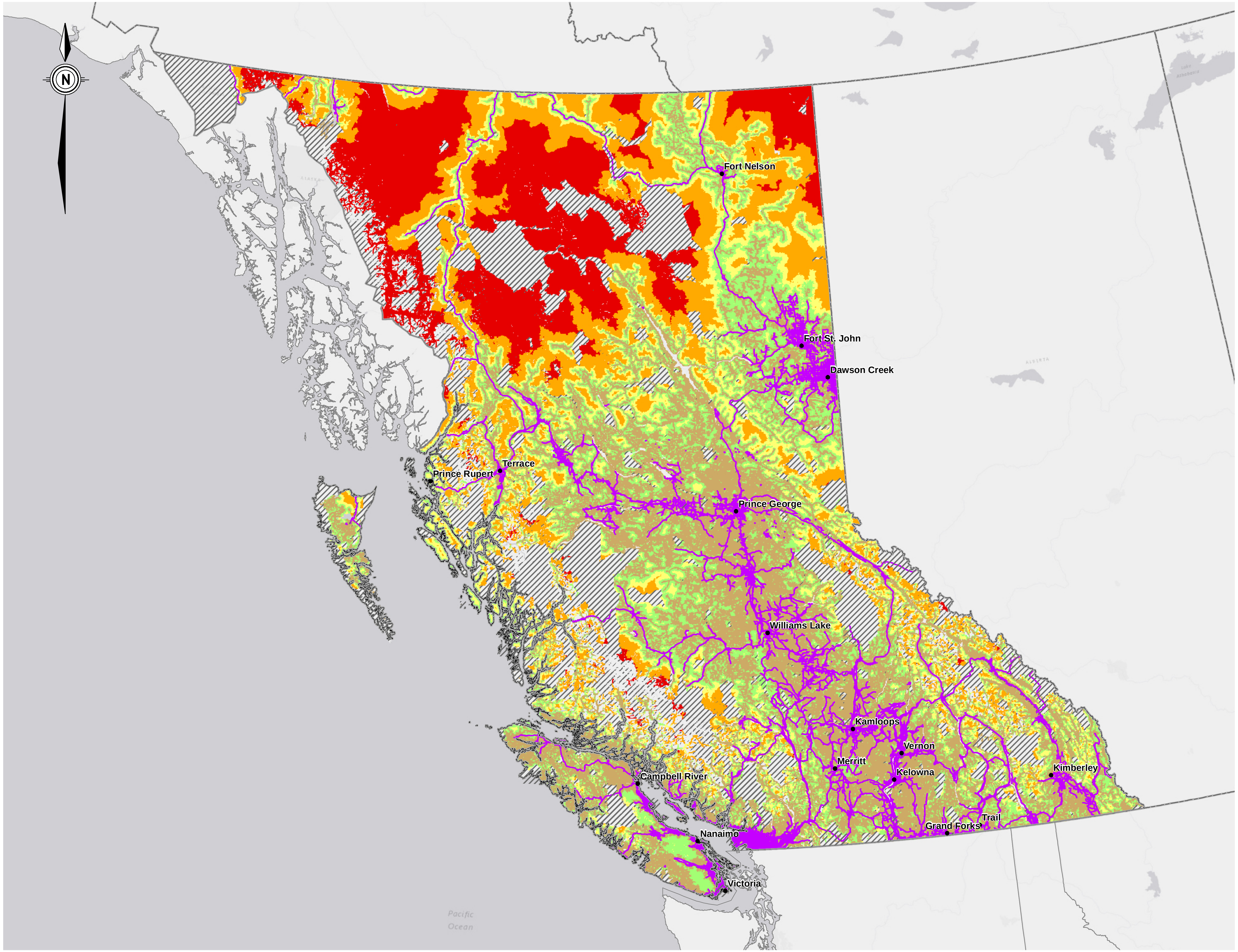
Author: JLau



BC hydro

2015 Resource Options Update

Legend

- Major Road
- Legally Protected Area & Glacier

Accumulated Cost for Access ($ Millions)

- < 0.25
- 0.25 - 1
- 1 - 2.5
- 2.5 - 10
- > 10

Note: Areas with dense existing road networks (purple) generally correspond to cheaper road costs

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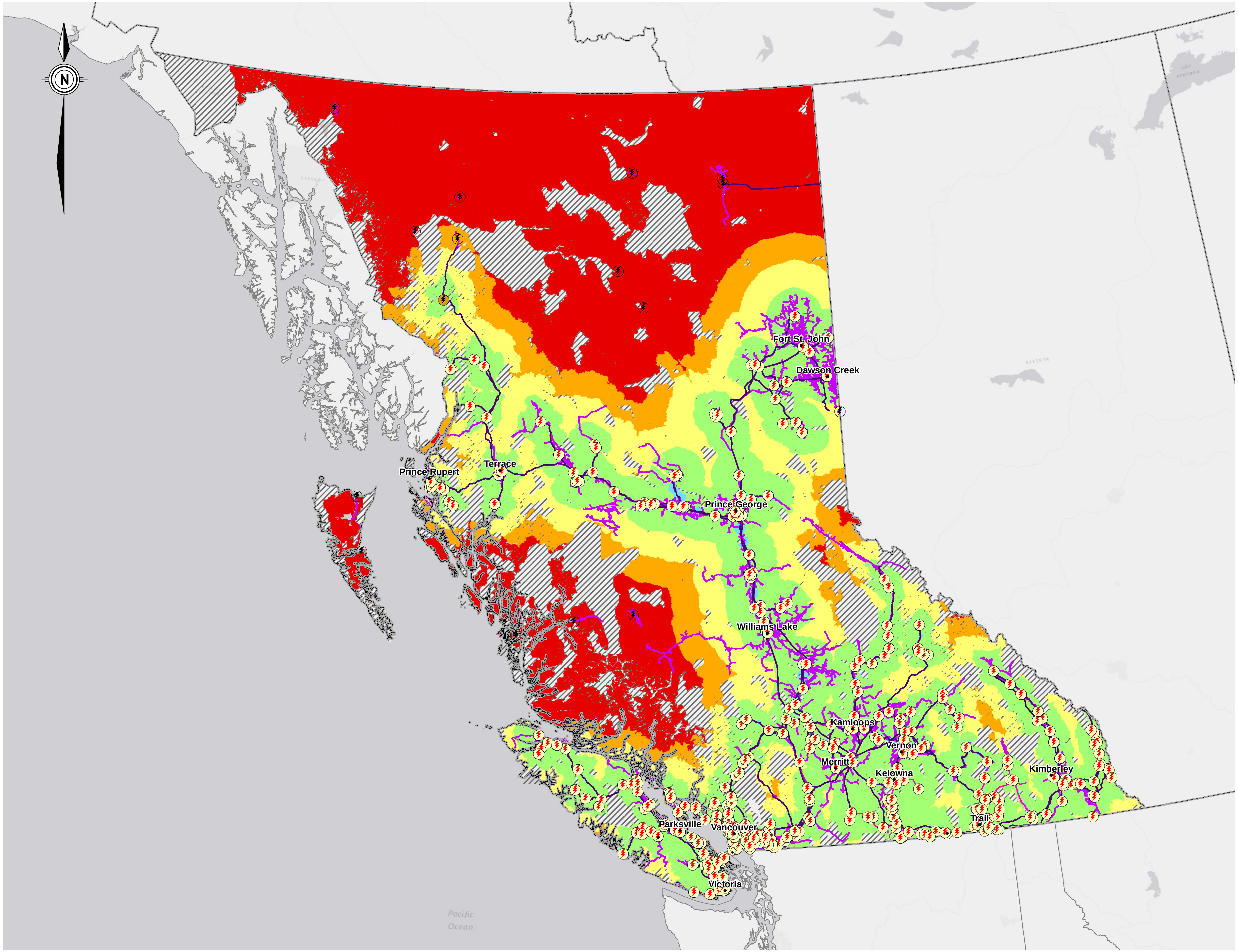
100 0 100
kilometers

Project No.	Date
478-177	July 2015

Estimated Cost for Access

Figure B-2

Path: O:\0400-0499\478-177\430-GIS\MXD-RP\478177_FigB-2_EstimatedCostForAccess.mxd Date Saved: 19/05/2015 12:33:46 PM
Author: JLau



BChydro

2015 Resource Options Update

Legend

- Substation
- Non-Integrated Substation[1]
- Proposed Substation[2]
- Transmission Line
- Fortis BC Transmission Line
- Distribution Line
- Legally Protected Area or Glacier

Accumulated Cost for Power Line ($ Millions)[3]

- < 1
- 1 - 5
- 5 - 10
- 10 - 15
- > 15

Notes:
1. Non-integrated substations and power lines were not included in the costing process.
2. Proposed substation at time of study. Substation is currently energized.
3. Cost does not include interconnection costs.

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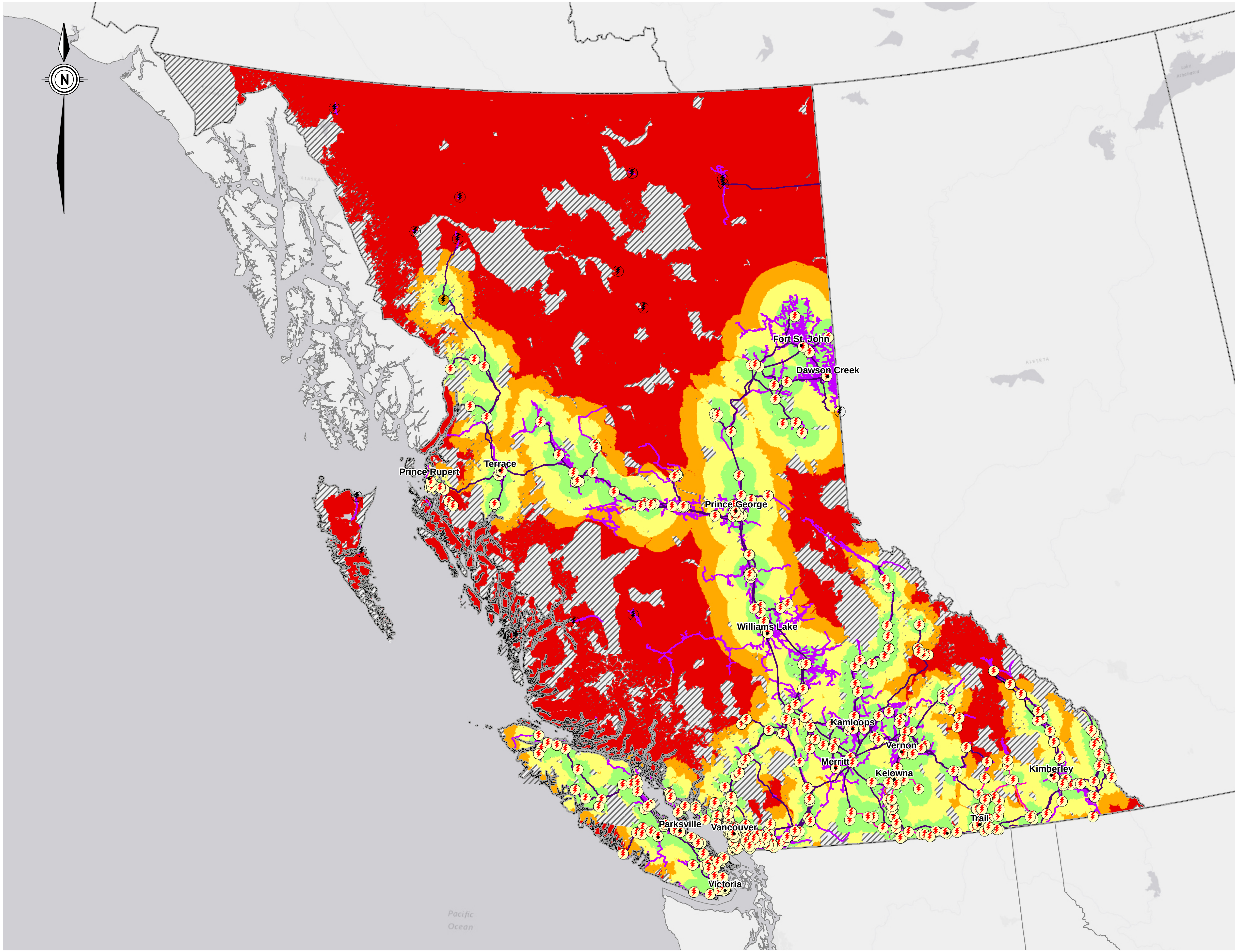
100 0 100
kilometers

Project No.	Date
478-177	July 2015

Estimated Cost for 69 kV Power Lines

Figure B-4

Path: O:\0400-0499\478-177\430-GIS\MXD-RP\478177_FigB-4_EstimatedCost69kVPowerLines.mxd Date Saved: 29/05/2015 11:39:45 AM
Author: JLau



BC hydro

2015 Resource Options Update

Legend

- Substation
- Non-Integrated Substation[1]
- Proposed Substation[2]
- Transmission Line
- Fortis BC Transmission Line
- Distribution Line
- Legally Protected Area or Glacier

Accumulated Cost for Power Line ($ Millions)[3]

- < 1
- 1 - 5
- 5 - 10
- 10 - 15
- > 15

Notes:
1. Non-integrated substations and power lines were not included in the costing process.
2. Proposed substation at time of study. Substation is currently energized.
3. Cost does not include interconnection costs.

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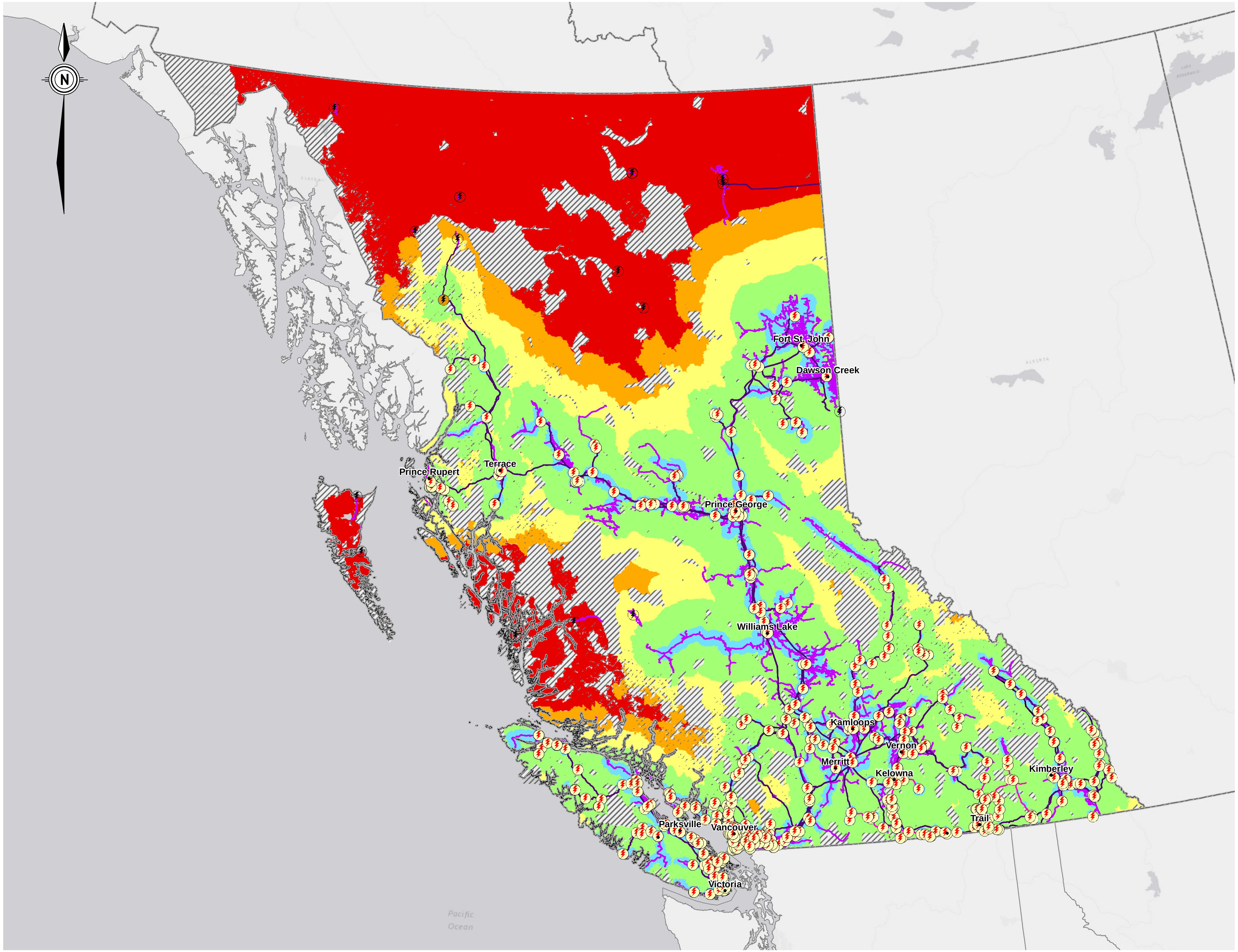
100 0 100
kilometers

Project No.	Date
478-177	July 2015

Estimated Cost for 138 kV Power Lines

Figure B-5

Path: O:\0400-0499\478-177\430-GIS\MXD-RP\478177_FigB-5_EstimatedCost138kVPowerLines.mxd Date Saved: 29/05/2015 11:42:30 AM
Author: JLau



BChydro

2015 Resource Options Update

Legend

- Substation
- Non-Integrated Substation[1]
- Proposed Substation[2]
- Transmission Line
- Fortis BC Transmission Line
- Distribution Line
- Legally Protected Area or Glacier

Accumulated Cost for Power Line ($ Millions)[3]

- < 1
- 1 - 5
- 5 - 10
- 10 - 15
- > 15

Notes:
1. Non-integrated substations and power lines were not included in the costing process.
2. Proposed substation at time of study. Substation is currently energized.
3. Cost does not include interconnection costs.

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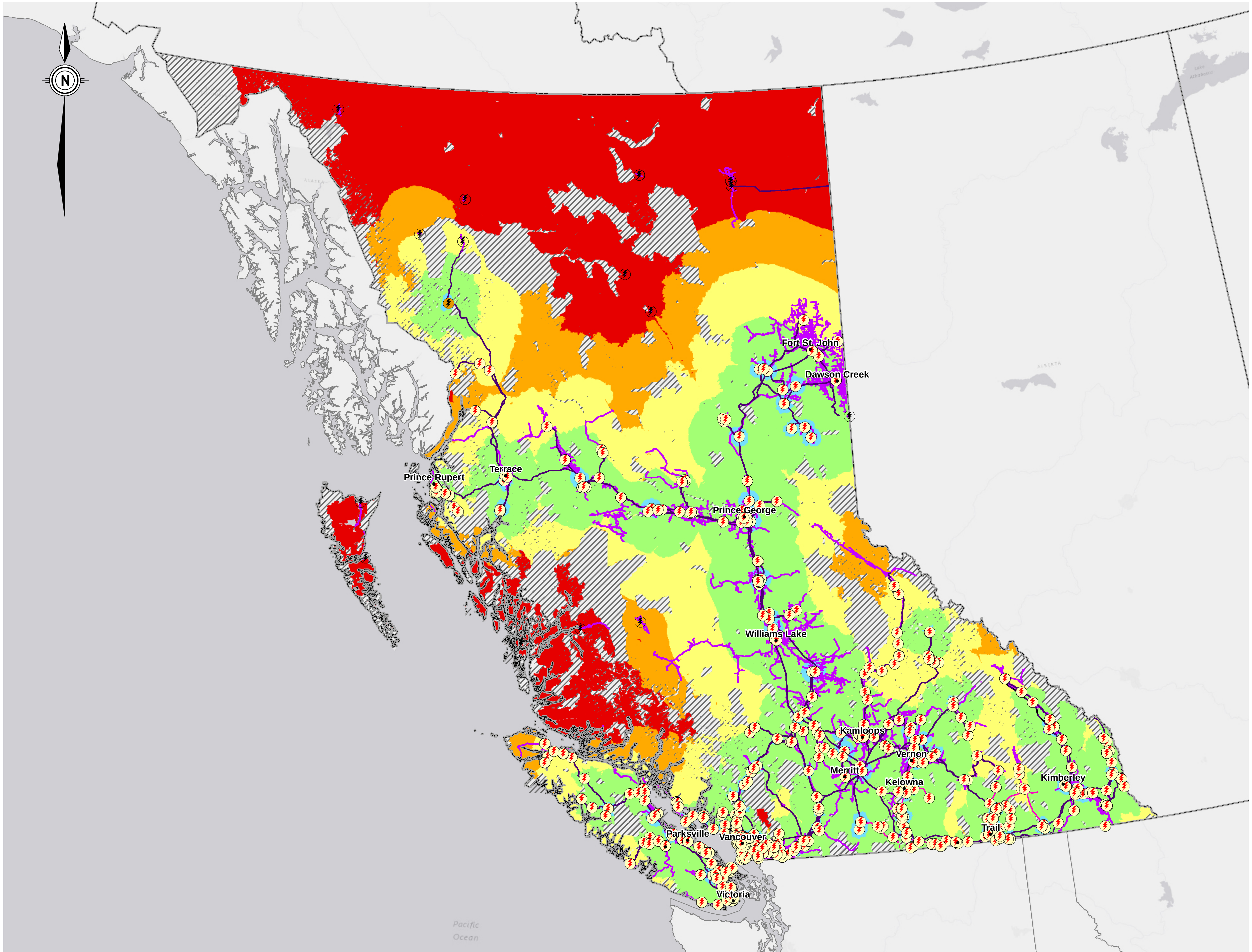
100 0 100
kilometers

Project No.	Date
478-177	July 2015

Estimated Cost for 25 kV Power Lines

Figure B-3

Path: O:\0400-0499\478-177\430-GIS\MXD-RP\478177_FigB-3_EstimatedCost25kVPowerLines.mxd Date Saved: 29/05/2015 11:37:07 AM
Author: JLau



BChydro

2015 Resource Options Update

Legend

- Substation
- Non-Integrated Substation[1]
- Proposed Substation[2]
- Transmission Line
- Fortis BC Transmission Line
- Distribution Line
- Legally Protected Area or Glacier

Accumulated Cost for Power Line ($ Millions)[3]

- < 5
- 5 - 25
- 25 - 50
- 50 - 75
- > 75

Notes:
1. Non-integrated substations and power lines were not included in the costing process.
2. Proposed substation at time of study. Substation is currently energized.
3. Cost does not include interconnection costs.

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100 0 100
kilometers

Project No.	Date
478-177	July 2015

Estimated Cost for 230 kV Power Lines

Figure B-6

Path: O:\0400-0499\478-177\430-GIS\MXD-RP\478177_FigB-6_EstimatedCost230kVPowerLines.mxd Date Saved: 29/05/2015 11:45:40 AM
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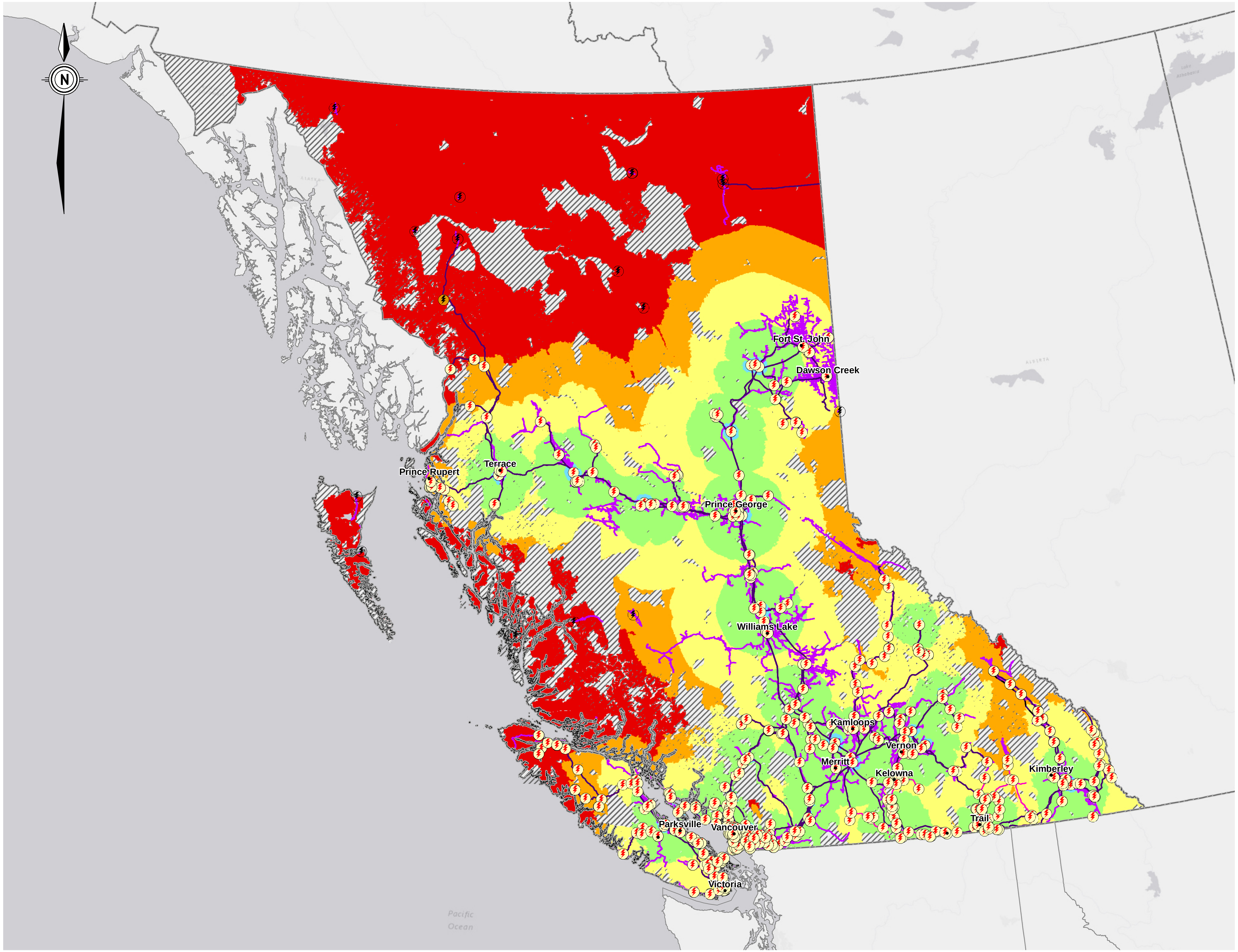

BC hydro

2015 Resource Options Update

Legend

- Substation
- Non-Integrated Substation[1]
- Proposed Substation[2]
- Transmission Line
- Fortis BC Transmission Line
- Distribution Line
- Legally Protected Area or Glacier

Accumulated Cost for Power Line ($ Millions)[3]

- < 9
- 9 - 45
- 45 - 90
- 90 - 135
- > 135

Notes:
1. Non-integrated substations and power lines were not included in the costing process.
2. Proposed substation at time of study. Substation is currently energized.
3. Cost does not include interconnection costs.

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100 0 100
kilometers

Project No.	Date
478-177	July 2015

Estimated Cost for 500 kV Power Lines

Figure B-7

Path: O:\0400-0499\478-177\430-GIS\MXD-RP\478177_FigB-7_EstimatedCost500kVPowerLines.mxd Date Saved: 29/05/2015 11:47:12 AM
Author: JLau