Chris Sandve
Chief Regulatory Officer
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July 23, 2021

Mr. Patrick Wruck
Commission Secretary and Manager
Regulatory Support
British Columbia Utilities Commission
Suite 410, 900 Howe Street
Vancouver, BC V6Z 2N3

Dear Mr. Wruck:

RE: British Columbia Utilities Commission (BCUC or Commission)
British Columbia Hydro and Power Authority (BC Hydro)
Bridge River Projects

BC Hydro is filing the attached application to the BCUC, pursuant to sections 45 and 46 of the *Utilities Commission Act*, for Certificates of Public Convenience and Necessity (**CPCN**) for the Bridge River 1 Units 1 to 4 Generator Replacement Project and the Bridge River Transmission Project.

BC Hydro is providing the Application as follows:

- Application;
- Application – Chapters 5 and 11 (Confidential Version);
- A Appendices;
- Appendices A-6-2 to A-6-5, A-6-8 (Confidential Version);
- B Appendices;
- Appendices B-2, B-3, B-5 to B-10, B-11, B-13 (Confidential Version);
- C Appendices; and
- Appendices C-1, C-3, C-4, C-9 (Confidential Version).

BC Hydro requests that certain information in the following chapters and appendices be held confidential in accordance with Part IV of the BCUC's Rules of Practice and Procedure.

- Chapter 5 – BR1 Project Description and Impacts;
- Chapter 11 – BRT Project Indigenous Nations Consultation & Public Engagement;

- Appendix A-6-2 to Appendix A-6-5 – Settlement Agreements;
- Appendix A-6-8 - Example of Consultation Material;
- Appendix B-2 – Bridge River System Studies;
- Appendix B-3 – Facility Asset Plans;
- Appendix B-5 – BR1 Alternative Assessment Financial Model;
- Appendix B-6 – BR1 Summary of Power Benefits Study;
- Appendix B-7 – BR1 Preliminary Design Report;
- Appendix B-8 – BR1 Project Procurement Decision;
- Appendix B-9 – BR1 Preliminary Cost Estimate;
- Appendix B-10 – BR1 Project Expenditure Breakdown by Year;
- Appendix B-11 - BR1 Rate Impact Models
- Appendix B-13 – BR1 Environmental Impact Statement;
- Appendix C-1 – Transmission Studies;
- Appendix C-3 – Bridge River Transmission Project Alternative Assessment Financial Model;
- Appendix C-4 – Bridge River Transmission Project Conceptual Design Report; and
- Appendix C-9 – Bridge River BRT Project Stakeholder Engagement Materials

In these chapters and appendices, BC Hydro has redacted commercially sensitive information related to BC Hydro's cost estimates and past settlements which could prejudice BC Hydro's position in future negotiations.

For the purpose of this proceeding and on appropriate undertakings, as contemplated by the BCUC's Rules of Practice and Procedure, BC Hydro can make this information available to registered interveners. BC Hydro reserves the right to object to a request for access to confidential information on a case-by-case basis.

Communications on the Application should be directed to:

Joe Maloney Senior Regulatory Manager, BC Hydro 333 Dunsmuir Street, Vancouver, BC V6B 5R3 604-623-4348 E-mail: bchydroregulatorygroup@bchydro.com	Chris Bystrom Fasken Martineau DuMoulin LLP 2900 – 550 Burrard Street, Vancouver, BC V6C 0A3 Phone: 604-631-4715 Email: cbystrom@fasken.com

Yours sincerely,

Chris Sandve
Chief Regulatory Officer

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Enclosure

BC Hydro
Power smart

List of Appendices

BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Bridge River Transmission Project

BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-1

Bridge River Water Use Plan Order and Variance Orders

BRITISH COLUMBIA
The Best Place on Earth

Province of British Columbia
Water Act

ORDER
Water Act
Sections 87 and 88

File No. 0212289, 0115688, 0161431, 0210947, 0202694, 0265200, 0199585, 3005073, 3005075 and 3005074.

WHEREAS British Columbia Hydro and Power Authority (BC Hydro) is the operator of the Bridge River hydroelectric system which comprises the Lajoie, Bridge 1, Bridge 2, and Seton generating stations, the La Joie, Terzaghi, and Seton dams, Downton, Carpenter and Seton reservoirs, and the Cayoosh diversion facilities, in respect of which it holds Final Water Licences 126279, 126278, 126280, 126281, 126286, 126287, 126288, 126282, 126283, 126080, 126250 and 126259;

WHEREAS an order issued July 28, 2000 requires flow releases from Terzaghi Dam and related monitoring requirements;

WHEREAS BC Hydro has engaged in public consultation to determine values for system parameters and to develop operating procedures which may provide benefits as described below;

WHEREAS the licensee has submitted the Bridge River Power Development Water Use Plan dated March 17, 2011, which recommends operational changes to the Bridge River hydroelectric system and recommends additional works in areas influenced by the system, with the intent of providing benefits to fisheries and wildlife habitat, shoreline conditions, recreation and flood mitigation;

WHEREAS the Bridge River Power Development Water Use Plan has proposed a monitoring programme to determine whether operating the facility in accordance with the operating parameters and procedures in the Water Use Plan will provide the expected benefits; and

WHEREAS I have accepted the Bridge River Power Development Water Use Plan dated March 17, 2011;

I HEREBY ORDER THAT:

1. The Order dated July 28, 2000 for flow releases at Terzaghi Dam and monitoring of the lower Bridge River, is hereby revoked.

Downton Lake Reservoir and La Joie Generating Station

2. Downton Lake Reservoir shall be operated above a minimum level of 710.00 metres, measured at the dam using the Geodetic Survey of Canada (GSC) datum.

3. Subject to approval from the Comptroller of Water Rights, the minimum elevation of 710.00 metres may decrease to 697.38 metres to continue providing minimum flows for middle Bridge River as specified in clause 4, or for maintenance purposes.

4. The licensee shall operate the La Joie Generating Station and Dam in such a manner as to provide minimum flow down the natural course of the Bridge River, in the following quantities, measured immediately downstream of the dam based on the elevation of Downton Lake Reservoir:

Downton Lake Reservoir Elevation (metres)	Bridge River Minimum Discharge (cubic metres per second)
>718.00	> 18.4
718.00 to 715.00	18.4 to 17.0
715.00 to 710.00	17.0 to 11.3
710.00 to 705.00	11.3 to 5.7
705.00 to 697.38	5.7

5. The licensee shall ramp down at a rate not exceeding 2.5 centimetres per hour and 15 centimetres per day as measured in the Bridge River in the vicinity of the Hurley Bridge. Operations in excess of these ramping rates are permitted if fish salvages along middle Bridge River are implemented as part of the operational change.

Carpenter Lake Reservoir, Bridge River Generating Stations

6. Carpenter Lake Reservoir shall be operated above the minimum level of 606.55 metres as measured at Terzaghi Dam using the Geodetic Survey of Canada (GSC) datum.

7. The licensee shall target a maximum elevation of 648.00 metres for the end of snowmelt season in mid August. If operations are expected to exceed 648.00 metres for 8 weeks or more, BC Hydro will inform the Comptroller of Water Rights.

Terzaghi Dam

8. For the period between May 1, 2011 and April 1, 2015, the licensee shall discharge from Terzaghi Dam to the Bridge River the equivalent to an annual water budget of 6.0 cubic metres per second (cms) and target the following monthly flows:

Date	Target Monthly Flow (cms)*
January	1.5
February	2.0
March	3.0
April	5.0
May	10
June	15
July	15
August	12
September	3.0
October	1.5
November	1.5
December	1.5

* The transition between target monthly flows may occur up to ± 5 days of the beginning of each month. Target monthly flows less than 5.0 cms may vary instantaneously by ± 0.25 cms from the target flow. Target monthly flows greater than 5.0 cms may vary instantaneously by ± 5%. The total annual flow will be determined on a calendar year basis and may vary ± 5%.

9. After April 1, 2015, the licensee will work with the Comptroller of Water Rights, provincial and federal fisheries agencies to determine a long term flow release strategy for the Terzaghi Dam based upon information and data from the flow trials collected under Appendix A. May 1, 2015 will be the target decision and implementation date for a long term flow release strategy. The subsequent recommended flow release from Terzaghi Dam will not be less than an annual water budget of 3.0 cms and will not exceed an annual water budget of 6.0 cms.

10. The licensee shall ramp down releases from Terzaghi Dam at a rate not exceeding 2.5 centimetres per hour and 15 centimetres per day as measured in the Bridge River in the vicinity of km 36.8 (Reach 4) of lower Bridge River. Operations in excess of these ramping rates are permitted if fish salvages are implemented as part of the operational change.

Seton Lake and Seton Generating Station

11. Seton Lake shall be operated between the minimum operating level of 235.76 metres and full supply level of 236.36 metres, measured in the vicinity of the Bridge 1 Generating Station using the Geodetic Survey of Canada (GSC) datum.
12. Upon prior approval from the Comptroller of Water Rights, Seton Lake may be operated above 236.36 metres to accommodate high inflow events and below 235.76 metres to accommodate planned maintenance or implementation of the Seton Lake Erosion Mitigation Plan.
13. In an effort to decrease the mortality of sockeye smolts migrating past Seton Dam and Seton Generating Station, the licensee will conduct partial (6+ hours) or blanket (24 hours) daily shut downs of Seton Generating Station during smolt out-migration between April 20th and May 20th.
14. A discharge between a minimum of 5 cms and a maximum of 60 cms shall be released from Seton Dam to Seton River at all times. Discharge in excess of 60 cubic metres per second is permitted if required to minimize spill from Terzaghi Dam into lower Bridge River in excess of the target flow schedules in 0) and 9) above.
15. The following target flows shall be released from Seton Dam to the Seton River. Excursions above or below the target flows are expected under normal operations to accommodate maintenance or to manage other system constraints. If operations deviate from the target flows by more than ±25% for more than a week, BC Hydro will inform the Comptroller of Water Rights.

Date	Target Flow (cms)*	Date	Target Flow (cms)*
Jan 1	11	Jun 15	34
Mar 31	12	Jun 30	30
Apr 7	15	Jul 6	26
Apr 15	25	Aug 15	21
May 7	26	Sep 14	16
May 15	29	Oct 14	14
May 21	32	Nov 14	13
May 31	36	Dec 14	11

Transition from one target flow to the next may occur within ± 5 days of the dates shown above. Target flows measured instantaneously may vary by ± 25%.

16. The licensee shall ramp down releases from Seton Dam at a rate not exceeding 2.5 centimetres per hour and 15 centimetres per day as measured in the vicinity of the Water Survey Canada gauge (WSC 08ME003) upstream of the confluence with Cayoosh River. Operations in excess of the aforementioned ramping rates are permitted if fish salvages are implemented as part of the operational change.

17. The licensee will target the ratio of Cayoosh Creek water to Seton River discharge as specified below. The ratio is calculated as Cayoosh Creek flow (measured in the vicinity of WSC 08ME002) to total Seton River flow (as measured downstream of the confluence of Cayoosh Creek). Excursions from the target ratio are expected as a result of managing other system constraints, to accommodate facility maintenance under normal operations, or because of factors outside of BC Hydro's control (e.g. Cayoosh Creek inflows).

Date	Target Ratio*
20 July to 31 Aug	< 20%
28 Sep to 15 Nov	< 10%

* The licensee will use the flexibility within the Seton target flow requirements specified in clause 15 above to manage the dilution flows. Efforts to maintain the maximum ratio however will be secondary to meeting the target flow release hydrograph from Seton Dam. The target dilution ratios will be re-assessed upon completion of the Adult Fish Passage Research Program.

Priorities

18. The licensee shall implement the above clauses using the following priorities rank-ordered from highest to lowest:

a) Dam Safety requirements as defined in the Operation Maintenance and Surveillance Manuals;

b) Flood routing requirements;

c) Terzaghi target flow schedule;

d) Generation and spill at Seton in preference to spilling at Terzaghi Dam in excess of the target flow schedule;

e) All specified ramping rates;

f) Seton Generating Station shut downs for smolt outmigration;

g) Carpenter Lake Reservoir elevations;

h) Seton Lake elevations;

i) Seton Dam target flow schedule; and

j) Downton Lake Reservoir elevations.

Works and Monitoring

19. The licensee shall submit, within 9 months of the date of this Order, for approval by the Comptroller of Water Rights, terms of reference for works and monitoring studies listed in Schedule A.

20. Upon approval from the Comptroller of the terms of reference and leave to commence, the licensee shall

   a) implement the works and effectiveness monitoring programmes in accordance with the approved terms of reference; and

   b) submit annual reports in February of each year to the Comptroller of Water Rights on the results of the approved works and effectiveness monitoring programmes until the conclusion of the programmes as specified in each terms of reference.

Records

21. With respect to the maintenance and provision of records the licensee must:

   a) Keep records of

      i) elevations of the Downton and Carpenter Reservoirs and Seton Lake;

      ii) flow release from the low-level outlet of Terzaghi Dam;

      iii) flow releases from the spillways at La Joie Dam, Terzaghi Dam and Seton Dam;

      iv) generation discharge from La Joie, Bridge 1, Bridge 2, and Seton Generating Stations;

      v) annual flow diversion from Carpenter Reservoir into Seton Lake; and

      vi) flow diversion from Cayoosh Creek into Seton Lake.

b) Provide a written report to the Comptroller of Water Rights on or before February 15 of each year summarizing the records from the previous calendar year; and

c) Provide on request of the Comptroller of Water Rights records collected under 21 a).

22. The licensee may operate the works in an alternate manner in the event of an emergency, dam safety requirement, or an extreme hydrological event.

23. All emergency operations or other deviations from operations ordered above shall be reported to the Comptroller of Water Rights in a timely manner.

Dated at Victoria, B.C., this 30th day of March, 2011.

Glen Davidson, P. Eng.
Comptroller of Water Rights

Schedule A
Works and Monitoring

The licensee shall submit within 9 months of the date of this Order, for approval by the Comptroller, terms of reference for the following:

Bridge-Seton Power Development Projects

1. Bridge-Seton Metals and Contaminant Monitoring Program
    a. Monitor if operating conditions change the concentration of metals and other contaminants in the water and sediments of reservoirs, lake and rivers in the Bridge River system.
    b. If redistribution of metals and contaminants occurs, monitor if this results in increased bio-accumulation in fish in the Bridge River system.

Downton Lake Reservoir and La Joie Generating Station Projects

2. Downton Lake Reservoir Riparian Vegetation Monitoring
    a. Monitor the effect of Downton Lake operating conditions on the upper Bridge River riparian area and in the adjacent Downton Lake Reservoir drawdown zone;
    b. Monitor the effect of Downton Lake operating conditions on riparian vegetation and wildlife habitat; and
    c. Determine what activities could be undertaken to preserve these habitat areas.

3. Downton Lake Reservoir Fish Habitat and Population Monitoring
    a. Monitor biological characteristics of fish populations in Downton Lake Reservoir and its tributaries;
    b. Monitor the effect of Downton Lake Reservoir operating conditions on abundance and diversity of fish populations;
    c. Monitor key habitat factors that contribute to the productivity of Downton Lake Reservoir fish populations;
    d. Monitor the relationship between the minimum reservoir elevation and productivity of fish populations;
    e. Monitor the effects of periodic deep drawdowns on rainbow trout populations; and
    f. Determine if refinements can be made to operating conditions, without significantly affecting the instream flow conditions in middle Bridge River, which would improve habitat conditions or enhance fish populations in Downton Lake Reservoir.

Carpenter Lake Reservoir Projects

4. Carpenter Lake Reservoir Revegetation Program
   a. Implement a short term re-vegetation program to mitigate the effects of dust storms, increase the aesthetic quality, enhance the quality of riparian habitats, and provide localized improvements in the quality and productivity of aquatic habitats in areas affected by the drafting of Carpenter Lake Reservoir.

5. Carpenter Lake Reservoir Productivity Model Validation and Refinement
   a. Monitor the effects of inflow, nutrients and suspended sediment into Carpenter Lake Reservoir on benthic and pelagic productivity;
   b. Monitor the relative importance of littoral and pelagic food sources on Carpenter Lake Reservoir aquatic productivity;
   c. Monitor the differential effects of reservoir operations on productivity of pelagic and littoral habitats; and
   d. Determine if monitoring program information can refine current models for predicting productivity relationships.

6. Carpenter Lake Reservoir Riparian Vegetation Monitoring
   a. Monitor the effects of Carpenter Lake Reservoir operating conditions on the riparian area surrounding Carpenter Lake Reservoir; and
   b. Monitor the effects of the short term reservoir re-vegetation program in 4) with respect to Carpenter Lake Reservoir operating conditions.

7. Middle Bridge River and Carpenter Lake Reservoir Fish Habitat and Population Monitoring
   a. Monitor the biological characteristics of fish populations in Carpenter Lake Reservoir and middle Bridge River;
   b. Monitor the effects of operating Carpenter Lake Reservoir and La Joie Generating Station on abundance and diversity of fish populations in Carpenter Lake Reservoir and middle Bridge River;
   c. Monitor the key operating parameters that contribute to productivity of fish populations in Carpenter Lake Reservoir and middle Bridge River;
   d. Monitor the relationship between instream flow in middle Bridge River on productivity of fish populations in Carpenter Lake Reservoir and middle Bridge River;
   e. Determine if refinements to the operation of Carpenter Lake Reservoir and management of flow releases from La Joie Generating Station into middle Bridge River improve fish populations in both of these areas or if existing reservoir operating constraints may be relaxed; and

f. Monitor if flow restrictions of 24 cms or less from October 15 to December 15 minimize the potential for dewatering mountain whitefish eggs after spawning.

Bridge River Projects

8. Lower Bridge River Riparian Vegetation Monitoring
   a. Monitor influence of the flow regime on the riparian community of lower Bridge River; and
   b. Monitor if changes in riparian community and instream flow conditions influence lower Bridge River corridor wildlife populations.

9. Lower Bridge River Aquatic Monitoring
   a. Monitor influence of the flow regime on the physical conditions in aquatic and riparian habitats of lower Bridge River ecosystem;
   b. Monitor how changes in aquatic habitat from the flow regime influences community composition and primary and secondary productivity of producers in lower Bridge River; and
   c. Monitor how flow changes influence the recruitment of fish populations in lower Bridge River.

10. Lower Bridge River Adult Salmon and Steelhead Enumeration
    a. Monitor how flow regimes affect spawning habitat for adult salmon and adult steelhead.
    b. Monitor annual abundance of salmon and steelhead spawning in lower Bridge River and its relations with long term flow requirements at Terzaghi Dam.
    c. Determine if flow releases from Carpenter Lake Reservoir have altered the life history and productivity of the Chinook salmon in lower Bridge River.

11. Lower Bridge River Spiritual and Cultural Value Monitoring
    a. Monitor if flow releases from Terzaghi Dam effect the cultural and spiritual attributes of lower Bridge River for the St'at'imc.

Seton Lake Projects

12. Seton Lake Erosion Management Program (SLEMP)
    a. Implement a program to develop and deliver an effective long term program for addressing moderate and high risk shoreline erosion issues for Seton Lake and along Seton River with particular reference to heritage, cultural and aesthetic resources that may be affected;

13. Seton Lake Erosion Mitigation Program
    a. Monitor what erosion sites, other than heritage or cultural sites, around Seton Lake are affected by Seton Lake fluctuations resulting from operation of the generating facilities.
    b. Determine what actions are required to protect those sites from further erosion.
    c. Determine what mitigation plans can be developed to address such erosion sites.
    d. Monitor if the actions implemented to mitigate erosion at the sites are effective.

14. Seton Lake Aquatic Productivity Monitoring
    a. Monitor if operations for Seton Lake and Bridge River Generating Stations have an effect on aquatic productivity of Seton Lake.
    b. Monitor if the inter-annual conditions in Seton Lake associated with diversion affects aquatic productivity.
    c. Monitor the relationship between quality, quantity, and timing of water from Carpenter Lake Reservoir and the productivity of Seton Lake resident fish.
    d. Monitor the extent to which aquatic productivity limits the abundance and diversity of fish populations in Seton Lake.
    e. Monitor what operating refinements may improve habitat conditions or enhance fish populations in Seton Lake.

15. Seton Lake Resident Fish Habitat and Population Monitoring
    a. Monitor the biological characteristics of resident fish populations in Seton Lake and its tributaries.
    b. Monitor if operating conditions affect abundance and diversity of fish populations in Seton Lake.
    c. Monitor if there is a relationship between the quality, quantity, and timing of water diverted from Carpenter Lake Reservoir and the productivity of Seton Lake resident fish populations.
    d. Monitor what operating refinements may improve habitat conditions or enhance resident fish populations in Seton Lake.

16. Seton River Habitat and Fish Monitoring
    a. Monitor the biological characteristics of the rearing and spawning fish populations in Seton River in terms of relative abundance, distribution, and life history.
    b. Monitor if the proposed Seton River hydrograph influences the hydraulic condition of juvenile fish rearing habitats downstream of Seton Dam.

c. Monitor the potential risk for salmon and steelhead redd dewatering between spawning and incubation periods due to changes in flow imposed by Seton River flows.
d. Monitor if the target Seton River flows influence short and long-term availability of gravel suitable for use by anadromous and resident fish for spawning and egg incubation.
e. Monitor if discharge from Seton Generating Station significantly affects fish habitat in the Fraser River above and beyond its natural variation.

17. Seton River Sockeye Smolt Monitoring
a. Monitor variation in diel and seasonal timing of the annual out migration of sockeye salmon smolts from Seton-Anderson watershed.
b. Monitor if the operation of Seton Generating Station and Seton Dam affect the relative distribution of fish migrating past the facility in the Seton watershed.
c. Monitor if the implementation of planned partial or blanket shutdowns of the Seton generating station meet sockeye salmon smolt population protection targets. The frequency and duration of the shutdowns along with the expected benefits in reducing mortality will be reported to the Comptroller of Water Rights annually.

18. Seton Adult Fish Passage Program
a. Monitor the factors impeding the success of upstream migration of salmon and steelhead.
b. Monitor if upstream passage of salmon are affected due to dilution of Seton River with Cayoosh Creek.
c. Determine if the operation of the dam and fish ladder impede fish passage upstream of Seton Dam.
d. Monitor what changes to the fishway or operation may mitigate upstream migration issues.

BRITISH COLUMBIA

February 16, 2017

File: 76975-35/Bridge

Heather Matthews
Director, Generation Resource Management
BC Hydro
9-6911 Southpoint Dr
Burnaby BC V3N 4X8

Via Email: Heather.Matthews@bchydro.com

Dear Ms. Matthews:

Re: Section 93 Order – Terzaghi Target Flow Release and Annual Water Budget

British Columbia Hydro and Power Authority is the operator of the Terzaghi Dam. A Section 87 & 88 Order dated March 30, 2011 under the *Water Act* directs the implementation of the operating parameters and procedures of the Bridge River Water Use Plan.

Clause 8 of the Order reads as follow:

> *8. For the period between May 1, 2011 and April 1, 2015, the licensee shall discharge from Terzaghi Dam to the Bridge River the equivalent to an annual water budget of 6.0 cubic metres per second (cms) and target the following monthly flows:*

DATE	*TARGET FLOW (CMS)**	*DATE*	*TARGET FLOW (CMS)**
Jan 1	*1.5*	*Aug 2*	*11.0*
Feb 1	*2.0*	*Aug 8*	*9.3*
Mar 1	*3.0*	*Aug 9*	*7.7*
Apr 1	*6.0*	*Aug 16*	*6.4*
Apr 15	*8.5*	*Aug 17*	*5.1*
Apr 23	*11.0*	*Aug 23*	*4.1*
May 1	*11.0*	*Aug 24*	*3.0*
May 7	*13.0*	*Sept 1*	*3.0*
May 21	*14.0*	*Oct 1*	*1.5*
Jun 1	*15.0*	*Nov 1*	*1.5*
Jul 1	*15.0*	*Dec 1*	*1.5*
Aug 1	*12.9*		

**The transition between target monthly flows may occur up to ±5 days of the beginning of each month. Target monthly flows less than 5.0 cms may vary instantaneously by ±0.25cms from the target flow. Target monthly flows greater than 5.0cms may vary instantaneously by ±5%. The total annual flow will be determined on a calendar year basis and may vary ±5%.*

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A variance order was granted to BC Hydro on May 8, 2012, providing BC Hydro with the approval to implement the above target flow schedule at Terzaghi Dam having an annual water budget of 6.0 cms. BC Hydro has been directed by the Comptroller of Water Rights, in a letter dated May 28, 2015, to operate under this annual water budget until a decision under Clause 9 of the Bridge River Water Use Plan (WUP) Section 87 and 88 Order dated March 30, 2011 under the *Water Act* is made. Clause 9 requires the determination of a long term flow release strategy for Terzaghi Dam, which BC Hydro has been granted approval to defer the decision until December 31, 2017.

In a letter dated February 2, 2017, BC Hydro requested a modification to the discharge from Terzaghi Dam to the Lower Bridge River outside the boundaries of an annual water budget of 6.0 cms and associated target monthly flows as defined in Clause 8 of the Bridge River WUP.

As per BC Hydro's notification on February 6, 2015, BC Hydro has modified the operations at Downton Reservoir by lowering the maximum normal reservoir elevation from 749.8 m to 734.00 m. The elevation reduction was achieved in 2016 operations as direct by BC Hydro Dam Safety in January 2016 as a risk reduction measure to address seismic and seepage issues at Lajoie Dam.

It is noted that BC Hydro is moving forward on its capital replacement plan for Bridge 1 and 2 generating station units, which are scheduled over the next 10 years. It is understood that during this time the outages required to complete the work, in addition to work at Seton and Lajoie generating stations, will affect the volume and timing of the discharges down Lower Bridge River. Therefore annual discharge during the capital program is forecasted to exceed the 6 cms annual average water budget identified in Clause 8 of the Bridge River WUP.

BC Hydro is proposing that the discharge regime will be based on the water supply forecast, timelines of capital works, and collaborative application of a set of Guiding Principles developed by BC Hydro, Fisheries and Oceans Canada (DFO), Ministry of Forest, Lands, and Natural Resource Operations (FLNRO) (fisheries) and the St'at'imc Nation, which will shape the rate of increase and actual flows.

It is understood that the guiding principles that BC Hydro has proposed for the Lower Bridge River will consist of:

1. Mimic a natural hydrograph shape in the Lower Bridge River
    a. Annual shape- manage flows in the Lower Bridge River to emulate a preferred natural hydrograph shape on an annual basis.
    b. Weekly variability at high flows- flows may be varied weekly when they are expected to remain constant and above 50 cms for longer than a week.
2. Reduce risk of high flows in summer and fall in Lower Bridge River- manage flows to reduce the risk of high flows in the summer and fall in Lower Bridge River to meet the August 1st objective to return to the WUP target flows (under guiding principle 4).
3. Minimize risk of early Chinook emergence in Lower Bridge River- flows should target a fix flow of ~1.6 cms from October 1, 2017 to January 15, 2018.
4. Preserve summer rearing Lower Bridge River- reduce flow releases across July and August in Lower bridge River (target flows of 20 cms or below by August 1, 2017) to increase the useable habitat area for rearing during the important growth period for juvenile salmon.

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Under Section 93 of the *Water Sustainability Act* I approve BC Hydro to operate outside of the 6 cms annual water budget as defined in Clause 8 of the Bridge River WUP from the date this Order is issued to **February 28, 2018**. I understand the guiding principles listed above will guide BC Hydro flow management decisions. In addition:

- BC Hydro is expected to reach a target flow of 20 cms or lower by August 1, 2017, if the target flow is not reach BC Hydro will provide notification and a rationale as to why the target was not met.
- BC Hydro is expected to reach a target flow of ~1.6 cms for the period of October 1, 2017 to January 15, 2018, if the target flow is not reach BC Hydro will provide notification and a rationale as to why the target was not met.
- BC Hydro will be required to provide updated forecasts of discharges and succinct rationale for flow adjustments to the Comptroller of Water Rights, in addition to supporting rational and if consensus of the water operations group was met, if the water operations group is implemented.
- BC Hydro will be required to notify the Comptroller of Water Rights once flows reach 100 cms and for every incremental increase of 10 cms.
- BC Hydro is required to invite DFO and FLNRO (fisheries) to the water operations group, if implemented.
- BC Hydro will be required to submit to the Comptroller of Water Rights office by September 30, 2017 an output of the actual flows released from the Terzaghi Dam for the period of January 1 to August 31, 2017.
- BC Hydro will be financially responsible for any Bridge River WUP currently ordered physical works that have been implemented and are affected by the increased flows at Terzaghi Dam.
- BC Hydro will be financially responsible for the monitoring identified in Schedule B that accompanied BC Hydro letter dated February 2, 2017 that is outside of the scope of the WUP monitoring studies.

If BC Hydro cannot meet the targets within this Order they may default to the Bridge River WUP Order Clause 22, which states "The licensee may operate the works in an alternate manner in the event of an emergency, dam safety requirement, or an extreme hydrological event." Subsequently clause 23 of the Order will have to be met, which states "All emergency operations or other deviations from operations ordered above shall be reported to the Comptroller of Water Rights in a timely manner." Timely manner is defined as a 2 week period.

Please keep me apprised of any changes as you progress through the above time period.

Yours truly,

Glen Davidson, P.Eng.
Comptroller of Water Rights

pc: Rich McCleary, Regional Aquatic Ecologist, Thompson-Okanagan Region, FLNR
Dan Sneep, Habitat Assessment Biologist, DFO
Chief Don Harris, Chair, St'at'imc Chiefs Council, Lillooet, BC

BRITISH COLUMBIA

February 21, 2018 File: 76975-35/Bridge

Heather Matthews
Director, Generation Resource Management
BC Hydro
9-6911 Southpoint Dr
Burnaby BC V3N 4X8

Via Email: Heather.Matthews@bchydro.com

Dear Ms. Matthews:

Re: Terzaghi Target Monthly Flow Releases and Long Term Flow Strategy

British Columbia Hydro and Power Authority (BC Hydro) holds water licences for and is the dam owner and operator of the Terzaghi Dam (part of the Bridge-Seton Generation Facilities). An Order dated March 30, 2011, made pursuant to Sections 87 and 88 of the *Water Act*, directed the implementation of operating parameters and procedures for the facilities based on the Bridge River Power Development Water Use Plan.

Clause 8 of the March 30, 2011 Bridge Seton Water Use Plan Order read as follow:

> *8. For the period between May 1, 2011 and April 1, 2015, the licensee shall discharge from Terzaghi Dam to the Bridge River the equivalent to an annual water budget of 6.0 cubic metres per second (cms) and target the following monthly flows:*

DATE	*TARGET FLOW (CMS)**	*DATE*	*TARGET FLOW (CMS)**
Jan 1	*1.5*	*Aug 2*	*11.0*
Feb 1	*2.0*	*Aug 8*	*9.3*
Mar 1	*3.0*	*Aug 9*	*7.7*
Apr 1	*6.0*	*Aug 16*	*6.4*
Apr 15	*8.5*	*Aug 17*	*5.1*
Apr 23	*11.0*	*Aug 23*	*4.1*
May 1	*11.0*	*Aug 24*	*3.0*
May 7	*13.0*	*Sept 1*	*3.0*
May 21	*14.0*	*Oct 1*	*1.5*
Jun 1	*15.0*	*Nov 1*	*1.5*
Jul 1	*15.0*	*Dec 1*	*1.5*
Aug 1	*12.9*		

> **The transition between target monthly flows may occur up to ±5 days of the beginning of each month. Target monthly flows less than 5.0 cms may vary instantaneously by ±0.25cms from the target flow. Target monthly flows greater than 5.0cms may vary instantaneously by ±5%. The total annual flow will be determined on a calendar year basis and may vary ±5%.*

.../2

Ministry of Forests, Lands, Natural Resource Operations and Rural Development
Resource Stewardship Division

Office of the Comptroller of Water Rights
Water Management Branch

Mailing Address:
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Victoria BC V8T 5K7

Clause 9 of the March 30, 2011 Bridge Seton Water Use Plan Order reads as follow:

> *9. After April 1, 2015 the licensee will work with the Comptroller of Water Rights, provincial and federal fisheries agencies to determine a long term flow release strategy for the Terzaghi Dam based upon information and data form the flow trials collected under Appendix A. May 1, 2015 will be the target decision and implementation date for a long term flow release strategy. The subsequent recommended flow release from Terzaghi Dam will not be less than an annual water budget of 3.0cms and will not exceed an annual water budget of 6.0 cms.*

I am in receipt of BC Hydro's letter dated December 20, 2017 requesting an extension of the decision date on the long term flow strategy for Terzaghi Dam from that identified in Clause 9 of the Bridge Seton Water Use Plan Order to December 31, 2018.

In addition, I am in receipt of BC Hydro's letter dated January 23, 2018 requesting an order to alter the operations of the Terzaghi Dam to vary releases from those outlined in Clause 8 of the Bridge-Seton Water Use Plan Order for a further period of March 1, 2018 to February 28, 2019.

The above variance request is due to a dam safety requirement to reduce storage on LaJoie Dam at Downton Reservoir and due to capital works upgrades on Bridge 1 and Bridge 2, which are also part of the Bridge Seton system. As a consequence, BC Hydro advises that it is not in a position to meet the terms and conditions set out in Clause 8 and Clause 9 of the Bridge- Seton Water Use Plan Order (hereinafter the "WUP order"). It is recognized that, while BC Hydro is not in a position to meet Clause 8 and 9 of the WUP order, BC Hydro is remaining in compliance with the rest of the WUP order, specifically following clause 18 which identifies the priorities for operation of the Bridge Seton system.

In that regard, dam safety concerns are always an important consideration, which the province does not take lightly. Currently available information supplied to this office and shared by BC Hydro with other parties suggests that the dam safety concern at LaJoie Dam poses a significant public safety concern due to seismic and other considerations. As defined in the Bridge River Power Development Water Use Plan, dam safety requirements are a priority, which is the case for all dams in British Columbia. Section 4.4. of the Bridge River Power Development Water Use Plan (Emergencies and Dam Safety) contemplates that "*...emergencies and dam safety requirements shall take precedence over the operational constraints outlined in this Water Use Plan...*".

As concerns about the Bridge Seton system operations have been raised by the St'at'imc Chiefs Council, including certain members of their communities, the province will be entering into consultation with the St'at'imc. While consultation is underway and until a decision is made, BC Hydro is to continue to operate Terzaghi Dam in accordance with the Variance order made pursuant to Section 93 of the *Water Sustainability Act* on February 16, 2017. Please advise this office, through notification, the day when the flows shift from those identified in Clause 8 of the WUP order in order to meet the terms and conditions identified under the February 16, 2017 Variance order.

.../3

If BC Hydro is unable meet terms and conditions of the February 16, 2017 Variance order relative to target monthly flow releases from Terzaghi Dam, due to an emergency, other dam safety requirement, or an extreme hydrological event, operations in accordance with Clause 22 of the WUP order are permitted. Clause 22 states "...*The licensee may operate the works in an alternate manner in the event of an emergency, dam safety requirement, or an extreme hydrological event*..." However, the requirements of Clause 23 of the WUP order will also have to be met in that case. Clause 23 states that "...*All emergency operations or other deviations from operations ordered above shall be reported to the Comptroller of Water Rights in a timely manner*..." For those purposes, "timely manner" is defined as a 2 week period.

Finally, we have asked the St'at'imc Chiefs Council to provide any written information and comments on BC Hydro's applications within 60 days of our correspondence to them and we have requested that they copy BC Hydro with their submissions on the applications. It is my intention to review the parties' submissions on these applications, as well as to consider the results of any consultation with the St'at'imc, in making my decisions on these applications. Taking into account the dam safety concerns and other operational considerations, I would like to proceed with decision-making on these applications before this year's freshet.

Please keep this office apprised of any changes.

Yours truly,

Ted White, BSc.
Comptroller of Water Rights

pc: Chief Don Harris, Chair, St'at'imc Chiefs Council, Lillooet, BC
Rich McCleary, Regional Aquatic Ecologist, Thompson-Okanagan Region, FLNRORD
Dan Sneep, Habitat Assessment Biologist, DFO

BC Hydro
Power smart

BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-2

Bridge River System Studies

PUBLIC

BC Hydro
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BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-2-1

2014 Bridge River System Study Summary Memo

PUBLIC

BRIDGE RIVER SYSTEM STUDY

ACTIVITY 3:

SUMMARY MEMO REPORT

ENGINEERING

MER No. 2014-032
March 2014

BRIDGE RIVER SYSTEM STUDY

ACTIVITY 3 - SUMMARY MEMO REPORT

Prepared by: ______________________
Graham Lang - Generation Engineering, Civil Design

Prepared by: ______________________
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Reviewed by: ______________________
for Ken Lum - Generation Engineering, Civil Design

Submitted by: ______________________
David McEachern - Generation Project Delivery

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Kirsten Peck - Generation Asset Management

Accepted by: ______________________
Stephen Rigbey - Generation Dam Safety

BC hydro

ENGINEERING
MER No. 2014-032
March 2014

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EXECUTIVE SUMMARY

The Bridge River System is a three hydroelectric project cascade located in the interior of British Columbia. Many of BC Hydro's assets in the Bridge River system were constructed in the 1950's and 1960's and are in the late stages of their life cycle. Consequently, a number of large Dam Safety and Generation Asset Management capital projects will be required at these facilities over the next 25 years. The Bridge River System Study examines the risks associated with operation of the entire La Joie, Terzaghi, Seton project cascade and considers concepts and configurations to minimize identified dominant risk factors associated with the dams and to maximize energy and other societal benefits.

From an energy perspective, the primary value of the Bridge River system is derived from the storage and high head available from Carpenter Reservoir. However, these physical features also pose significant hazards. For the La Joie and Seton projects, the consequences of dam failure are very significant but are primarily limited to the immediate downstream areas. For Terzaghi Dam, the consequences of dam failure have the potential to impact zones along the Lower Bridge and Fraser Rivers extending downstream to Mission and with the potential for tens of thousands of people to be located in the inundation zones. Failure of La Joie Dam also has the potential to result in a breach of Terzaghi Dam. Thus from the perspective of both maximizing energy benefits and minimizing contributions from the identified dominant risk factors associated with the dams, the highest objectives for the Bridge system configuration are to preserve and provide safe impoundment for Carpenter Reservoir storage, and to preserve the high head on the Bridge generating stations.

The Bridge System Study examined a number of alternative system configurations that are consistent with these objectives and the broader objective to mitigate risks throughout the three project cascade. The study concluded that the preferred future configuration is substantially the same as the existing, with no major re-configuration of the system. However, system upgrades are proposed that would:

- better meet BC Hydro's capability requirements for the river system, and in doing so improve management of the river system for other beneficial uses such as fisheries;
- reduce or eliminate the identified dominant risks; and
- increase generation revenue.

The study included scoping level assessment of the capital costs, energy benefits, and risk reduction achieved by the alternatives. The study also included qualitative consideration of potential environmental and social impacts associated with system alternatives but did not include a detailed examination of these complex interactions. However, it was assumed that the future operation of the Bridge River System should continue to comply with general objectives and project operating constraints that were agreed to with input from a multi-stakeholder committee during the Water Use Planning process. Component specific feasibility studies, impact assessments, optimizations, and multi-stakeholder trade-off decisions remain for future investigation and consultation but it is assumed that the WUP process has already identified and considered the major elements of long term energy, social and environmental optimization of the system.

The leading concept for future impoundment of Carpenter Reservoir replaces the existing Terzaghi Dam with a new roller compacted concrete dam, located approximately 0.7km downstream from the current dam. A new dam would eliminate current risks associated with earthquake induced failure of Terzaghi Dam. It would also reduce risks associated with earthquake or static failure of La Joie Dam by withstanding the resulting overtopping flows and effectively reducing the downstream flood peak. An alternative concept for Terzaghi Dam is to refurbish the existing Terzaghi Dam and appurtenances. However, the technical feasibility of refurbishment has not been confirmed and trade-offs between cost and risk factor reduction for the refurbishment versus replacement concepts will need to be investigated.

Retaining the existing inter-basin diversion from Carpenter Reservoir to Seton Lake, refurbishing the existing BR2 penstocks and powerhouse, and constructing a new, underground BR1 powerhouse is the leading concept for future high head generation and for mitigating risks associated with the existing Bridge generating stations. Trade-offs between the BR1 replacement concept and the alternative concept of refurbishing the existing BR1 powerhouse should be further investigated. An option to install a 1000MW pumped storage facility at Bridge and an option to relocate the Bridge generating station to the Bridge/Fraser River confluence were also considered but compared to the leading concept these alternate configurations are less favorable.

La Joie project configurations ranging from decommissioning to full replacement to raising and rebuilding La Joie Dam were investigated. From an energy perspective, these storage variations were found to have relatively minor impacts on the operation and economics of the downstream projects. However, from a flow control perspective, decreasing the regulated storage volume at La Joie results in higher spill flows through the Seton project during the freshet. Thus decisions related to the configuration of the La Joie Project can be based primarily on the project specific costs, benefits and dam safety attributes but must consider the environmental impacts at both the La Joie and Seton projects.

Refurbishing La Joie Dam and generating station for continued operation of the existing generating assets at full reservoir elevation is the leading concept for future operation of the La Joie project. Refurbishing the dam for future operation at a reduced operating level is also attractive from economic and risk factor reduction perspectives. However, since the currently estimated levelized cost of energy of refurbishing the dam for full height is much less than the reference price forecast, the incremental capital investment in the full upgrade appears to be warranted.

From an integrated system perspective, the primary objective for the Seton project is the re-regulation of the Bridge GS outflows in a manner that minimizes the environmental impacts to the Seton River and thus permits the continued inter-basin diversion and peaking operation of the Bridge generating units. Seton is the only project with frequent occurrence of forced spill; however, from an average annual energy perspective the existing Seton GS discharge capacity is not a significant constraint on the total Bridge System generation. Concepts to increase Seton GS generating capacity were evaluated but were found on their own to be economically weak, even with consideration of the benefits of generation shaping across the system, the value of increased capacity, and system concept changes such as decommissioning

La Joie Dam. From an environmental perspective there may be benefits to increasing the discharge capacity at Seton GS as one means of mitigating the effects of spill events that are exacerbated by the inter-basin diversion.

The leading concepts for future operation at Seton Dam retain the project in its existing configuration and include foundation upgrades to the dam and rebuilding the left abutment dyke. Replacement of the gates at the inlet to the canal (HWOGs) and refurbishment of the canal/aqueduct is also included.

From the perspective of reducing the identified dominant risks, remedial works or a new dam at Terzaghi Dam appear to be the highest priority measure. Dependent on the acceptance of La Joie Dam interim risk management measures for the static condition, works at Seton are the next priority. Additional feasibility studies are required to better define the most sensible risk reduction prioritization.

Decisions relating to the upgrade or replacement of Terzaghi Dam can proceed independently of finalizing decisions for the configuration of the La Joie or Seton projects. Full optimization of the Bridge River System generation would benefit from finalizing decisions relating to the configuration of La Joie and Seton projects prior to initiating works that are specific to any major modification to the Bridge generating stations.

BRIDGE RIVER SYSTEM STUDY
ACTIVITY 3 - SUMMARY MEMO REPORT

1.0 INTRODUCTION

Many of BC Hydro's assets in the Bridge River system were constructed in the 1950's and 1960's and are in the late stages of their life cycle. Consequently, a number of large Dam Safety and Generation Asset Management capital projects will be initiated over the next 25 years at facilities in the Bridge River system. While every project will require management decisions concerning the timing and options for asset removal, refurbishment or replacement, there are many pitfalls in conducting the analyses on a project-by-project basis. Projects developed independently of others across the Bridge River system are limited in their ability to:

- assess the interactions between all active and planned projects;
- ensure that one project will not negatively impact the ability to achieve success in another;
- ensure that opportunities for addressing multiple risks with a single solution are not overlooked;
- ensure better risk reduction options involving scope beyond the boundaries of a single project are not overlooked; and
- ensure that opportunities (social, environmental, financial) that span beyond the scope of a single project are not overlooked.

A long term river system strategy would provide clarity and consistency for capital project planning. Consequently, the Bridge River System Study was launched to provide a long term strategy for risk reduction and investment in generation assets that is in alignment with BC Hydro's corporate objectives. This strategy will help to narrow the range of system configuration options to be considered but does leave some site-specific trade-offs for future analyses and stakeholder input.

The System Study was carried out in three Activities:

Activity 1: Determine requirements and existing system performance
Activity 2: Develop integrated river system concepts
Activity 3: Test river system concepts, analyse trade-offs and make recommendations

Separate reports have been produced for Activity 1 (Wong, 2013) and Activity 2 (Hatch, 2014). This memo report provides an overview of Activity 1 and Activity 2, in addition to documenting the methods and results of Activity 3. Conclusions and recommendations arising from the complete Bridge River System Study are presented.

2.0 PROCESS

This section provides an overview of the process of work carried out for the Bridge River System Study. The context of the study in terms of the overall process for Facility Asset Planning is first explained, followed by an overview of the process diagram for the System Study, the breakdown into three Activities, and the interconnections between Activity deliverables.

2.1 Facility Asset Planning Process

Coincident with Activity 1 of this study a Generation Asset Management planning process was completed for each facility (La Joie, Bridge River, and Seton) in the Bridge System. The focus of the Facility Asset plan is on life cycle and condition assessment of the existing assets and on the prioritization of works to reduce project operating risks and sustain the existing facility capabilities. The Facility Asset plans typically do not include consideration of significant modifications to the facility capabilities and configurations unless these are indicated by other studies. The Asset Plans are considered to be live documents and will be updated as required.

The process included identification of key issues, risks and opportunities at each facility, and compilation of this information into a Consolidated Facility Log. This information was then used to analyse high level scenarios and identify appropriate medium to long-term investments for consideration in both the Generation and Corporate capital planning process (BC Hydro, 2012).

The Asset Management process had scope overlap with this study; in particular the data gathering and internal stakeholder engagement initiatives were conducted jointly by representatives of the System Study team and the Asset Management team. Although the Facility Asset Plans needed to be finalized while Activity 2 of this study was still in progress, the Asset Plans were produced with foresight using the preliminary results of the System Study. Further, the two studies were guided by consistent philosophy with the Manager of Asset Management co-initiating the System Study with the Director of Dam Safety.

In the early part of the System Study, interviews with internal BC stakeholders were carried out jointly with Asset Management to highlight important issues in the river system and to uncover issues that are not currently documented. Interviews with a diverse group of BC Hydro parties were used to establish the state of available information and issues.

2.2 System Study Method

The System Study was carried out in three Activities:

Activity 1: Determine requirements and existing system performance
Activity 2: Develop integrated river system concepts
Activity 3: Test river system concepts, analyse trade-offs and make recommendations.

BC Hydro staff carried out the Activities 1 and 3 of this study, while Hatch Associates, a hydropower engineering consultant, was responsible for the deliverables of Activity 2, as well as review and input to Activity 1.

Figures 1 to 3 illustrate the components of the study process and the interconnections between each of the project Activities. While the general descriptions of task boxes of the process charts are the same from Activity 1 to 3, the details of work conducted in each Activity varied as discussed briefly below.

In Activity 1, the objective was to define and assess the performance of the existing system. As shown on Figure 1, this involved the following:

- Breakdown of the existing **Assets** to consider all the major parts with direct connection with the flow of water in the system (assets are lumped together with their sub-systems). In this case, assets were also considered more broadly at facility and river system levels;

- Listing of all the flow control **Functions** of each asset. Safe and efficient operation of the facilities requires the individual assets to function in accordance with their intended purpose and design. Each asset may have several functions.

- Consideration of **Hazards**, both internal (sub-system breakdown or failure of another asset, as well as failures from transportation or communication) and external (earthquakes, lightning) to the system, that may compromise the functions;

- Estimation of the consequences of functional failure and the frequency of the hazards to cause these consequences, together being a listing of system **Risks.** These risks may also be described as “physical risks” since human error and other organizational hazards were not considered**;**

- Identification of **Capability Requirements** which express BC Hydro’s performance expectations for the Bridge River System. Key Capability Requirements (KCRs) are the overarching requirements and they define what is considered essential if the study’s goals are to be met; and

- **Performance analysis**, comprising a comparison between the Requirements and the current capabilities of the system (**Functional Gaps**), as well as identification of the **Dominant Risks** in the system.

In Activity 2, the process detailed in Figure 2 was followed in an iterative way:

- The Dominant Risks and performance issues identified in Activity 1 (**Performance Analysis**) were used as a starting point by hydropower engineering consultant Hatch Associates

- **Concepts** were developed by Hatch for individual sites and for parts of the Bridge River system with the philosophy of reducing risks, solving issues and seeking opportunities. These concepts were focused primarily on physical improvements rather than operational changes. Measures to reduce risks by strengthening the organization or improving communication protocols were not considered. The concepts were categorized in the Activity 2 report (see Table 4.2 of Hatch, 2013) under the following families:

a. Do nothing
b. Reduce capability (includes concepts to **Remove** or **Reduce** assets or hazards such as reservoirs)
c. Upgrade current configuration (includes concepts to **Refurbish** or **Replace**)
d. **Re-configure** system (referred to as 'Blue Sky' alternatives in the Activity 2 Report.

- The concepts were **Filtered** to eliminate the least attractive concepts from the large number identified by assessing them against the Key Capability Requirements and the technical judgement of the Hatch subject matter experts;

- Concepts that were carried forward were combined with concepts for other sites to form a variety of **Integrated System Concepts.** These concepts are intended to represent the range of options to consider for the system as a whole.

- **Technical assessments** were conducted on promising Integrated System Concepts including preliminary flow and power modelling by BC Hydro as well as conceptual design and cost estimating by Hatch.

- Analysis of **gaps in performance** for the Integrated System Concepts was again conducted by comparisons with Key Capability Requirements and reduction or elimination of the dominant risks was confirmed.

In Activity 3, the process detailed in Figure 3 was followed:

- Variations of the **Integrated System Concepts** that emerged from Activity 2 were evaluated to assess the incremental system benefits of changes to the concepts at each facility (Section 5.1).

- Detailed **Technical Assessments** were conducted, including **Operations Modelling, Flood Modelling,** and **Downstream Consequence Modelling**. The latter was conducted for some scenarios to evaluate risk reduction effectiveness. This work is described in Sections 5.2 and 5.3.

- The **Functions, Hazards** and **Risks** analysed in the Activity 1 report were re-visited assuming that the Integrated Concepts are in place of the existing system; the output of this analysis was a list of **Residual Risks**.

- The analysis of **Performance and Functional Gaps** of the integrated system concepts also included overview assessment of **environmental and regulatory** issues and a detailed **economic comparison** of the incremental benefits of one facility concept over another.

- **Filtering** of the Activity 2 concepts was conducted on the basis of the performance analysis.

The work concluded by identifying the most promising integrated concepts at each site, the remaining alternatives and trade-offs to be considered in future studies, as well as outstanding information gaps (Section 6).

In Figures 1 to 3, the components with green circular borders are the primary deliverables of the Activity. Consistent with systems approaches the process is not linear and some of the other components may be regarded as outputs of the study as well as inputs to other parts of the process. Further information is provided in Sections 3, 4 and 5.

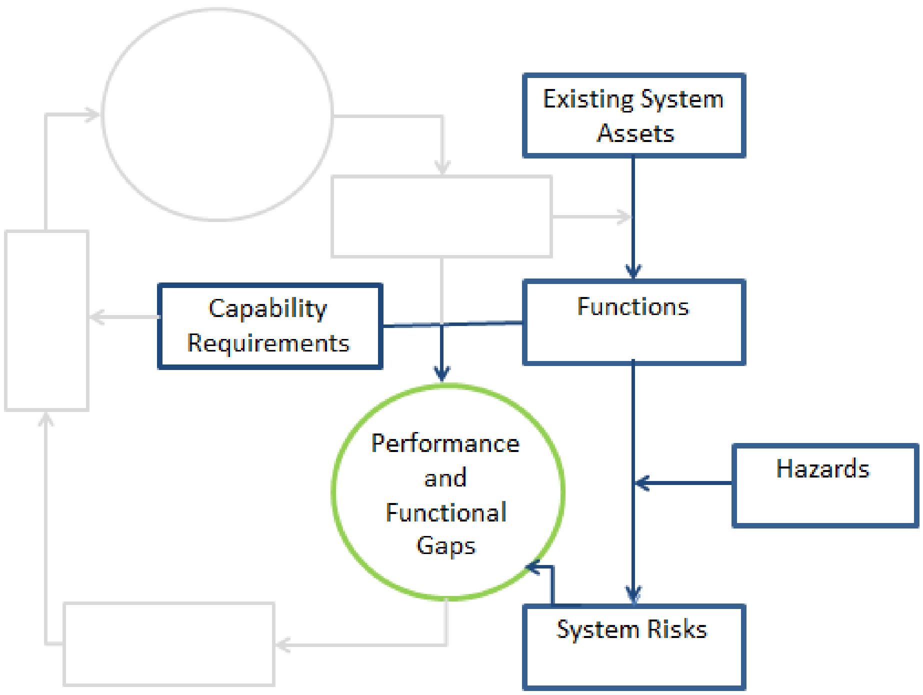


Figure 1. PROCESS DIAGRAM – ACTIVITY 1
Systematic Identification of Risks and Functional Gaps

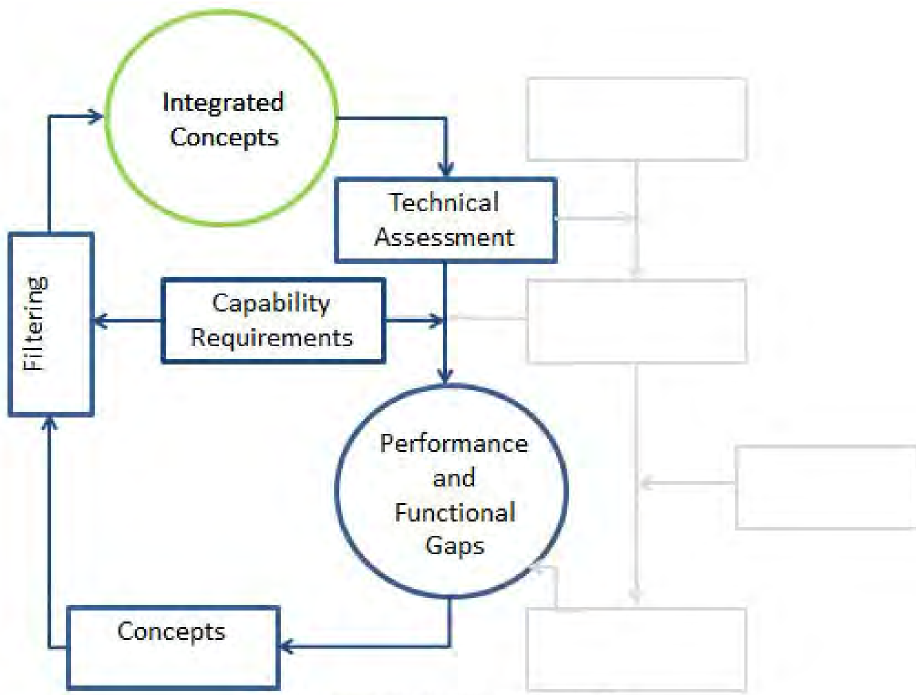


Figure 2. PROCESS DIAGRAM – ACTIVITY 2
Development and cost estimating for Integrated System Concepts (an iterative process)

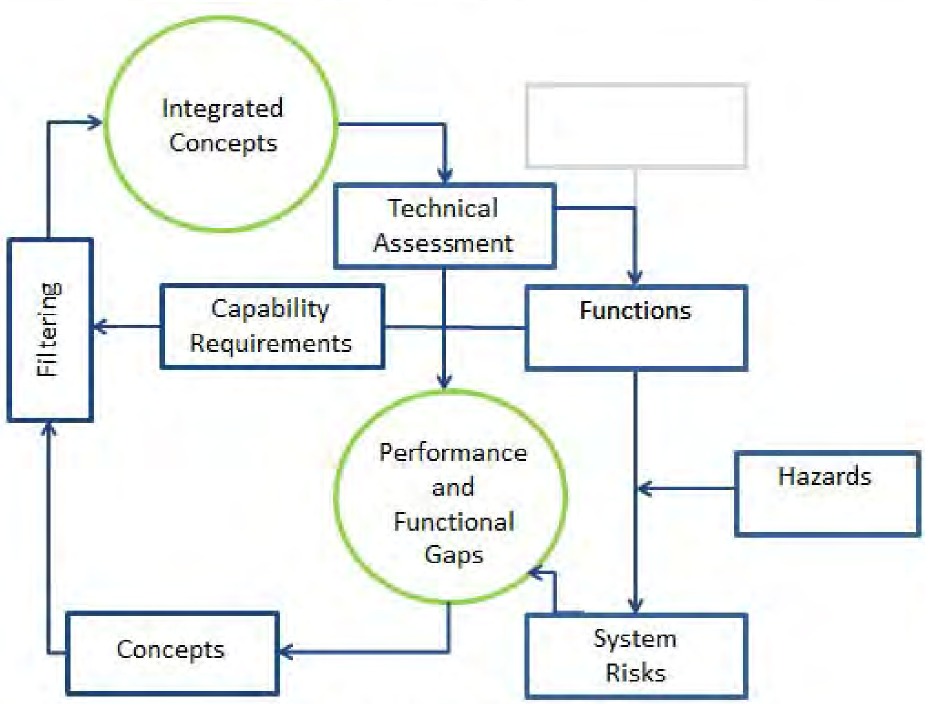


Figure 3. PROCESS DIAGRAM – ACTIVITY 3
Expanded Performance Comparisons for Integrated Concepts and Variations Thereof

3.0 ACTIVITY 1 FINDINGS

The key outputs of the Activity 1 Report include:

- a comprehensive **bibliography of the Bridge River System** pertaining to issues and risks. The documents in the bibliography were provided to the engineering consultant as background information for carrying out Activity 2 of the project, and furthermore serve as a useful reference for any studies within the Bridge System.

- a summary of the inferred **seismic withstands** for the major assets in the Bridge River system based on information available at the time of the Activity 1 study (2012/2013).

- A **System Diagram** which outlines the key assets which interface directly with the flow system and the capacities of each flow control structure.

- Fifty eight **Capability Requirements** were identified for the Bridge River system. The following six were identified as the **Key Capability Requirements,** with defined performance targets as detailed in the Activity 1 report:

  BC Hydro shall have the capability to:
  1. generate power from the Bridge River system.
  2. maintain reservoir levels within acceptable bounds under operation based loading and plant fault conditions.
  3. maintain downstream river flow within acceptable bounds under operation based loading conditions.
  4. be supported by the First Nations.
  5. maintain hydraulic control during floods.
  6. maintain hydraulic control post-earthquake.

- **Functional gaps** were identified where the stated capability requirements are not being met by the existing system. The analysis indicated that there are 12 capability requirements that are not met by the existing system, and a further 18 capability requirements that are considered to be at risk of not being met in the existing system. Many of these overlap with the identified risks and were used to inform the concept developed in Activity 2.

- **Risk scoring** and identification of a wide spectrum of system risks. Summary schematics were prepared that show key vulnerabilities of the system by hazard.

- Identification of the risks that are of highest concern to BC Hydro – the **dominant (Tier 1) and secondary (Tier 2) risks**. The identification of the risks of highest concern was informed by the risk scores assigned in the risk analysis but were not prioritized solely by the absolute value of the assigned risk scores. This is a reflection that the dominant risks were selected by a subjective process of consensus that brought together different perspectives of the risks and other factors that are not explicitly included in the initial 'likelihood' and 'severity' ratings such as the effectiveness of reactive measures or interim risk controls.

The dominant risks and secondary risks were agreed upon by a project consultative committee. A total of thirteen dominant risks (Tier 1) and ten secondary risks (Tier 2) were identified and are presented in Table 1.

4.0 ACTIVITY 2 FINDINGS

4.1 Activity 2 Outputs

The key outputs of the Activity 2 Report completed by Hatch include:

- A comprehensive **list of individual concepts** for addressing the risks and issues of the current Bridge River System and opportunities for re-configuration or redevelopment of the system.

- Documentation of each of the concepts by development of a concept "pro forma", a summary description that includes technical assessment of its advantages and disadvantages. The pro formae provide an **audit trail** for the elimination or retention of concepts including a check against the KCRs.

- A list of individual **concepts that address each of the dominant risks**, with the first concept listed as the preferred, most effective option (Table 4.2 in the Activity 2 Report).

- **Integration of the individual concepts** in a variety of ways to represent the range of potential for risk reduction and other benefits across the system, and an audit trail that provides record of filtering of these Integrated Concepts based on similar pro formas as the individual concepts.

- Presentation of **seven leading Integrated System Concepts**, for which the major elements are summarized below and the individual concepts that comprise each Integrated Concept are marked with an "x" in Table 2.

  Concept 0 (Base Case) includes the following:
  - LAJ Dam and intake tower are refurbished
  - TRZ Dam is replaced with new roller compacted concrete (RCC) dam on bedrock
  - Bridge River No. 1 (BR1) powerhouse is replaced with a new underground Powerhouse.
  - Major maintenance to BR2 plant equipment
  - SON Dam foundation, left abutment dyke and canal dyke are seismically upgraded.
  - SON headworks flap gates are replaced with new operating gates
  - Major maintenance and upgrades to SON turbine unit.

Concept 1A (New Higher TRZ): Base Case with the following modifications:
- o LAJ Dam, Intake Tower and Powerhouse are decommissioned; and
- o TRZ Dam is replaced with new RCC dam and the dam crest, spillway crest, reservoir rim road and maximum normal reservoir level are all raised by 10m.
- o New BR1 and BR2 intake shafts are constructed

Concept 1B (New Higher LAJ): Base Case with the following modifications:
- o LAJ Dam is replaced with new RCC dam on bedrock downstream of existing
- o structure and the dam crest, spillway crest, and maximum normal reservoir level are all raised by 10 m.
- o LAJ GS new powerhouse with two Kaplan turbine units (42 MW total).

Concept 1D (LAJ Reduced). Base Case with the following modifications
- o LAJ spillway crest is lowered from El.749.81 m to El. 730 m and the maximum normal reservoir level is also reduced to El. 730 m.

Concept 3 (TRZ Long Tunnel): Base Case with the following modifications:
- o Inter-basin diversion is decommissioned and replaced by a long tunnel from TRZ Dam to Bridge River Confluence with Fraser River.
- o A new underground powerhouse with capacity of 500 MW is constructed at the Fraser River.

Concept 4B (Pumped Storage): Base Case with the following modifications:
- o BR1 and BR2 powerhouses are replaced by a 1000 MW pumped storage facility located on SON reservoir.

Concept 5 (SON Tunnel): Base Case with the following modifications:
- o Seton Canal is replaced by a new tunnel from the Cayoosh Aqueduct to SON forebay.
- o SON GS replaced by a new facility with two Kaplan units (70 MW total).

- Capital **cost estimates** were developed for the seven leading Integrated River System Concepts to be carried forward for additional technical analyses. The fully loaded cost estimates for each of the Integrated Concepts were based on conceptual designs, industry information and Hatch's in-house data. These cost estimates are included in Appendix A. The line items are presented in a manner that allows total system costs for other combinations of the individual site concepts to be estimated.

- Demonstration that the seven Integrated System Concepts achieve **similar levels of risk reduction** but with varied costs, energy benefits, environmental and societal impacts, and alignment with the Key Capability Requirements. This will lead to trade-offs that will ultimately guide the asset management and redevelopment decisions.

- Comparisons of the Integrated System Concepts were made on the basis of a **Total Construction Cost Indicator** ($/kW), however it is acknowledged that further work is required to assess benefits and comparative economics.

In the course of the Activity 2 work, BC Hydro also conducted studies as needed to inform and test the work of Hatch. These studies include:

- A review of the impact of spills at Terzaghi Dam (discussed further in Section 5.4); and
- A due diligence review of the Hatch cost estimates (Le Couteur, 2013).

Preliminary power and flood routing studies were also carried out in Activity 2 as input to the concept development process. Further assessments were carried out in Activity 3 studies as presented in Section 5.

4.2 Activity 2 Conclusions

Noting that the Activity 2 Report needed to be supplemented by results of Activity 3 energy production and economic investigations for the principal integrated concepts, the following Activity 2 conclusions were made by Hatch (2013):

1. Hatch considered all reasonable concepts for configuring BC Hydro's assets in the Bridge River System and the general findings were that the integrated river system concept that best meets BC Hydro's Key Capability Requirements looks much like the current system with some replacements and upgrades.

2. All integrated concepts include replacement Terzaghi Dam with a roller compacted concrete (RCC) Dam founded on bedrock a short distance downstream from the existing structure.

3. The selection between integrated river system Concepts 0, 1A, 1B, 1D (which are all similar to the existing configuration) requires more detailed study; however,

   a. Concept 1B (LAJ Raise) is less attractive based on cost.
   b. Concept 1A (new higher TRZ RCC dam and decommission LAJ) is less attractive than a new RCC dam at the existing crest elevation due the added cost of Carpenter Lake road relocation.

4. While refurbishment of LAJ Dam (Concept 0 – Base Case) would appear to be the prudent course of direction, it is possible that the following options may have merit due to their lower cost indicators:

   a. Decommissioning of the LAJ Dam, but with TRZ Dam raise of 10m (Concept 1A); or
   b. Lowered LAJ Dam (Concept 1D), although this would result in reduced generation at LAJ, BR1, BR2 and SON.

5. In terms of sequencing future works, the replacement of TRZ Dam with a roller compacted concrete (RCC) structure may become a suitable solution for the initial capital expenditures as it would address the primary dominant risk of a "sunny day" breach of either the LAJ Dam or TRZ embankment dam. A concrete

gravity structure at TRZ could accommodate a flood or wave overtopping better than an embankment dam.

6. There remains the potential for the individual site concepts to be combined in different ways during the Activity 3 analyses, for example, the Seton Tunnel option could be included in other integrated river system concepts.

5.0 ACTIVITY 3

This section describes work conducted by BC Hydro to further compare the benefits and economics of the system concepts remaining at the conclusion of the Activity 2 work, and ultimately to narrow down the number of concepts for future consideration. The Activity 3 investigations included the following:

1. Variations on Integrated System Concepts (Section 5.1)

2. Operational performance (detailed in Section 5.2)
   - Energy generation;
   - Reservoir levels, flows, spills; and
   - Capability requirement gaps.

3. Risk reduction (Section 5.3)
   - Flood capacity;
   - Downstream consequence reduction;
   - Residual risks; and
   - Construction risks.

4. Environment and Regulatory Issues (Section 5.4)

5. Project economics (Section 5.5)

6. Activity 3 Summary (Section 5.6)

5.1 Variations on Integrated System Concepts

The Activity 2 Integrated System Concepts were derived to represent the range of possible long term configurations, with recognition that different combinations of the facility concepts that make up the system may ultimately be preferred. The analyses of Activity 3 included many variations of the Integrated System Concepts in order to tease apart the incremental benefits of one facility concept over another at the same facility when considered in the context of the total system.

The system variations were developed by combining elements of the Base Case (Concept 0) with the different combinations of the following site concepts:

LAJ Dam

- **Remove** (decommission)
- **Refurbish and lower dam**
- **Refurbish** dam to existing height
- **Replace** with new raised dam

LAJ Powerhouse

- **Refurbish** (25 MW)
- **Replace** with two unit powerhouse (44 MW, only with Replace dam)

Terzaghi Dam

- **Replace** with new RCC dam at existing crest elevation
- **Replace** with new 10 m higher RCC dam

Bridge River Powerhouses

- **Refurbish Intakes and BR2; Replace BR1** – for continued operation at existing water license flow capacity
- **Replace BR1 and BR2** with 1000 MW pumped storage plant located on Seton Lake.
- **Replace BR1 and BR2** with 500 MW plant fed by a power tunnel from Terzaghi to the Bridge/Fraser River confluence.

Seton Canal and Powerhouse

- **Refurbish** for existing plant flow capacity (126 cms)
- **Replace** canal with power tunnel and refurbish powerhouse (143 cms)
- **Re-configure** with new tunnel in addition to existing canal and replace powerhouse (250 cms)

The Activity 2 integrated concepts are compared across a variety of measures in Table 3. Variations in facility concepts at La Joie, Terzaghi, and Seton are compared in Tables 4 to 6 respectively.

Note also that in the Activity 2 Report, there are additional alternative concepts identified as “Carry Forward” that were not included in the Integrated System Concepts but have not been eliminated. These include:

- **Replace** La Joie Intake rather than **Refurbish** La Joie Intake
- **Refurbish** Terzaghi Dam rather than **Replace** Terzaghi Dam;
- **Rebuild** Seton Dam rather than **Refurbish** Seton Dam
- **Replace** Bridge Intake Towers rather **Refurbish** Bridge Intake Towers

These concepts are not included in the variations on the Integrated River System Concepts because there would be no change to the operational modelling. These alternatives remain for future trade-off investigations.

5.2 Operational Performance

Operations modelling was conducted for a variety of these Integrated System Concepts using the Operations Planning Tool (OPT) model. This is an optimization program that sequentially routes the 49 years of available historical daily inflows through the system in accordance with the specified concept physical configuration and operating constraints (hard constraints). Soft constraints (penalties) are added to guide reasonable operational behavior and introduce trade-offs in the model optimization. Generation is calculated at each plant and can be divided into heavy load and light load hours. The details of the model assumptions and inputs are presented in King (2013).

In total, fifteen variations of the remaining Integrated System Concepts (0, 1A, 1B, 1D, 3 and 5) were evaluated. All scenarios were modelled with assumed 365 day foresight, which allows the model to maximize generation and minimize spill and other operation penalties. This is acceptable for the purpose to compare the potential of different concepts but it does not realistically replicate the number of excursions from reservoir or spill targets that would occur. More detailed modelling with 15 day foresight was conducted for concepts that decommission or lower the La Joie reservoir to provide more realistic insight into potential for increased spilling at Terzaghi and Seton.

With the assumption that all of the Bridge system units will be upgraded to higher efficiency units over time, the project generation for the existing system configuration is represented by the Base Case (Concept 0) with approximately 190 GWh/year at La Joie, 2700 GWh/year at Bridge and 350 GWh/year at Seton. The total system generation (3240 GWh/year) is dominated by the high head at the Bridge Generating stations and thus intuitively minimizing spill at Terzaghi is a priority for maximizing system annual generation. Annual energy generated by each integrated concept (GWh/yr) is presented in Tables 3 to 6.

The results of the OPT modelling show that the existing La Joie, Bridge, and Seton projects are well sized from the perspective of regulating the available natural inflows for power generation. Taking into consideration the required non-power flow releases into the lower Bridge River and into Seton River there is relatively little forced spill/additional energy available to be captured by the various reconfigurations and upgrades to the existing system configuration.

Of the three projects, Seton is the only one with frequent occurrence of forced spill. The elimination of all Seton spill in excess of the minimum downstream flow requirements is accomplished by Concept 5i, which generates only 33 GWh/yr more than the Base Case (Concept 0). Concept 5i eliminates the existing annual volume limit for Seton generation and increases the Seton generating capacity to 250 m^3/s which exceeds the licensed diversion of 160 m^3/s from BR1 and BR2 with additional allowance for regulation of Seton local inflow. Therefore, from an average annual energy perspective the existing discharge capacity at Seton GS is not a significant constraint on the total Bridge System generation. Consideration of capital works at Seton to increase the discharge capacity of the generating station would not result in significant increases to system average annual energy and would need to be justified by other risk / economic drivers.

Increasing the height of La Joie Dam (Concept 1B) or Terzaghi Dam (Concept 1A0) by 10m at each site allows additional energy generation from the system, but only in the order of 48 GWh/yr and 69 GWh/yr respectively. The additional energy results primarily from the higher head at the upgraded facility with minor contribution from reduced system spill.

Decommissioning La Joie Dam (Concept 1Aii) or refurbishing a lower La Joie Dam (Concept 1D) result in decreases to system generation in the order of 236 GWh/year and 99 GWh/year respectively. These decreases result primarily from the direct reduction of generation at the La Joie project with minimal impact to Bridge Generation and a moderate impact at Seton. The Bridge system is capable of managing these relatively large changes to the operation of the La Joie storage by "flowing" these changes through the Bridge generating units with acceptance of resulting increases to Seton spilling.

Separating Bridge River and Seton River basins (Concept 3) causes a decrease in system generation of 145 GWh/year as the head that is present at the Seton location cannot be fully developed with a powerhouse located near the Bridge-Fraser confluence and there are additional head losses in the long tunnel from Terzaghi to the Fraser.

Concept 4, high capacity pumped storage, could not be simulated using the OPT platform. From an annual energy perspective, at best this option has the potential to eliminate all non-required Seton spill similar to Concept 5i. However, these energy gains would be offset by a loss of energy associated with any pumping cycles as the energy used to pump water to the upper reservoir exceeds the energy produced in the gravity flow phase of generation. Also, the reversible units have a slightly lower efficiency than conventional units in the gravity flow phase of generation. Overall it is anticipated that this concept would result in a net reduction to average annual system generation.

Overall, the various integrated configurations preserve the high head on the Bridge generating units and the capability to minimize spill at Terzaghi and thus the increases and decreases to system annual generation are relatively small when compared to the Base Case total system generation of 3240 GWh/yr.

The economic value of system generation results not just from the total annual energy but also from the magnitude of the installed capacity and the capability for daily and seasonal shaping of the annual generation. While these are significant project benefits, for the Bridge system the value of the capacity and shaping benefits attributable to the various system concepts are significantly lower than the value of the annual energy. The variations in capacity and shaping benefits are factored into the economic analysis presented in Section 5.5.

5.3 Risk Reduction

The risk reduction performance of the system concepts is compared below for flood capacity, reduction of downstream consequences, residual risks, and construction risks.

5.3.1 Flood Capacity

One of the key capability requirements of the river system (KCR5) is to be able to maintain hydraulic control during floods with associated performance target at the 10^{-4} risk level. A stochastic flood event modelling project is currently in progress for the Bridge River system and the results will be available soon. This will allow for comparison with the hazard annual exceedance target level.

In the absence of stochastic modelling for the various integrated river system concepts, the existing Probable Maximum Flood (PMF) estimates (LAJ was completed in 2013, TRZ in 1995, SON in 1988) were used as a benchmark of flood routing capability during the Activity 1 phase of identifying project risks. All three projects were considered to be capable of passing their existing design floods without overtopping based on those existing reports.

Further analysis of flood routing capability was performed as part of the Activity 2 and 3 investigations to allow for comparisons between system concepts. As noted above, the Probable Maximum Flood was updated in 2013 for La Joie Dam. Current estimates of the design flood for Terzaghi Dam are considered outdated. Therefore, to route the LAJ PMF through the system, two approaches were tested for estimating the concurrent TRZ inflow:

1. TRZ inflows scaled according to the LAJ 2013 PMF inflows; and
2. TRZ inflows from 1995 PMF study.

As documented in Finkenbine (2013), the results showed that both estimates of TRZ concurrent inflows, in combination with the LAJ PMF, would cause significant overtopping of the Terzaghi Dam. The flood hazard for Terzaghi Dam, therefore, needs to be confirmed and updated for the refurbishment or the replacement options for the dam.

Analysis of the Integrated System Concepts (Finkenbine, 2013) showed that the concepts that increase available flood storage at La Joie, including raise La Joie dam or reduce La Joie reservoir normal operating level, improve the capacity to handle floods more than decommissioning La Joie Dam with raised Terzaghi Dam. The modelling was conducted, though, assuming that a new spillway at Terzaghi would have a discharge versus normal maximum reservoir level rating curve similar to that for the existing project. If Terzaghi Dam is to be replaced with a new downstream RCC structure, the configuration of the spillway will be designed to provide increased discharge capacity. In any case, the La Joie decommissioning concept will result in greater likelihood of high magnitude discharges into the Lower Bridge River.

Additional flood modelling runs were made for the concept of lowering the reservoir level at La Joie to El. 734m and leaving the spillway crest at the current elevation. The flood routing performance of this concept was much improved, with no significant overtopping for the 1995 Terzaghi PMF inflows and lowered overtopping for the scaled 2013 TRZ inflows.

The Seton project is currently able to manage the Inflow Design Flood and the risk of flood induced failure of Seton Dam was comparatively low in the Functional Assessment of Activity 1.

5.3.2 Reduction in Downstream Consequences

Typically, the integrated concepts reduce system risks by reducing the likelihood that failure of any given component will occur. However, the concept for replacing Terzaghi Dam with a new concrete dam would, in addition to addressing the risks of failure of the dam on its own, also reduce the consequences of failure of La Joie Dam. It would do so providing that it allows for overtopping without failure of the dam thereby eliminating cascading failure of Terzaghi Dam and reducing the peak flows downstream. The effectiveness of this concept in reducing the consequences of La Joie Dam failure was modelled using the FloodSiMM inundation modelling platform as described in Section 5.1.3. The work is documented in Yusuf (2014).

FloodSiMM simulations were conducted for La Joie dam failure without cascading failure of Terzaghi Dam. Two scenarios combining high reservoir levels and high Fraser River flows were selected to provide insight into the most severe outcome expected for earthquake induced (sunny-day) failures.

The results showed that the Population at Risk would reduce from tens of thousands with the current risk of cascading failure to, in the vast majority of situations, only those in a few dwellings in Gold Bridge and possibly those in a camping area in Lillooet. For severe situations where the La Joie Dam fails at the same time as record high flows on the Fraser River, the population at risk would be in the hundreds due to inundation of settlements in low-lying areas downstream from Hope that are either not protected by dykes or behind inadequate dykes.

Although further analysis would be required to better estimate these numbers and loss of life risk, it is clear that the concept to replace Terzaghi Dam with a RCC structure not only provides risk reduction for the vulnerabilities of Terzaghi Dam, but also for La Joie Dam.

5.3.3 Residual Risks

The Integrated System Concepts all reduce the dominant (Tier 1 and Tier 2) risks effectively such that there is little differentiation between concepts on the basis of dominant risk reduction.

One risk for which the outcome does vary is for landslide wave risks at LAJ, which is eliminated by the concepts to decommission the dam and to rebuild the dam and largely eliminated by the concept to lower the reservoir, while some low risk would persist for the La Joie dam rebuild options.

In addition to looking at the performance of the concepts in reducing the dominant risks, all the risks that were identified in the Activity 1 functional analyses were reviewed for changes with the Integrated System Concepts in place. While a large proportion of the risks that were not included in the Tier 1 and Tier 2 risks were also eliminated, there were some that would persist after implementation of the Integrated System Concepts in the absence of other remedial works. Examples of these include:

- Vulnerability to a **landslide of Santa Clause Mountain** into Seton Reservoir. While moving the BR1 powerhouse underground would significantly reduce this risk, the only concept to eliminate the risk to BC Hydro personnel would be the construction of a long tunnel from Carpenter Reservoir to a new powerhouse located at the Fraser River.
- Concrete Alkali-Aggregate Reaction **(AAR) at Seton Dam** would continue to persist with the Base Case concept for foundation treatment. An alternative solution for Seton Dam that would address this problem is to construct a new downstream dam.
- Raising the height of a new Terzaghi Dam would potentially increase the likelihood of **landslides into Carpenter reservoir**, though the consequences would be lower with a new RCC dam being capable of withstanding overtopping.
- Failure mechanisms of the **Bridge Intake towers** and gates are not addressed explicitly in the Base Case, while the concept to build a new raised Terzaghi Dam does include costs to raise the towers.
- Risks of higher spills at Seton caused by prolonged outages due to **unreliability of the transmission system** are not addressed specifically by the generation system concepts.
- The environmental risk of collapse of **Cayoosh diversion tunnel** due to deterioration of corrugated steel is not addressed in any concept.
- **Seton power canal overtopping** caused by a landslide into the canal is addressed only by concepts to build a tunnel to replace the canal.
- The risk of **debris blockage** of the free crest spillway at LAJ or the gated spillway at SON is not addressed by the concepts.
- Risks arising from **deterioration of the Seton forebay and penstock** are not specifically addressed by the concepts.

Tables 3 to 6 highlight where there are noted differences in the residual risks left by each of the Integrated System Concepts.

5.3.4 Construction Risks

Some of the risks of construction are noted in Table 3. It is possible that the large construction projects of tunneling to the Fraser River and raising the reservoir level of Terzaghi Dam could have higher risk profiles than those for refurbishing assets in place.

However the projects are not well defined at this conceptual level and construction risks cannot be confidently evaluated in comparing concepts at this time.

5.4 Environment and Regulatory

Activity 3 included qualitative consideration of potential environmental and social impacts associated with the system concepts but did not include a detailed examination of these complex interactions. However, it was assumed that the future operation of the Bridge River System should continue to comply with general objectives and project operating constraints that were agreed to with input from a multi-stakeholder committee during the Water Use Planning process. Component specific feasibility studies, impact assessments, optimizations, and multi-stakeholder trade-off decisions remain for future investigation and consultation but it is assumed that the WUP process has already identified and considered the major elements of long term energy, social and environmental optimization of the system.

All concepts will raise some regulatory issues since changes are proposed to some facility footprints and some reservoir changes would require re-licensing. Tables 3 to 6 provide some of the main environmental and regulatory issues and opportunities with each concept; additional information follows:

General

- Changes to reservoir operations may trigger a review of the Bridge Water Use Plan for those affected components. The Water Use Plan is linked to the Bridge Fisheries Act Authorization and the St'at'imc –Hydro Agreement.

- The St'at'imc must be consulted if there are decisions to be made concerning any new operational water regime and elevation targets (flow, temperature, timing, habitat etc.). Joint Decision Making – the Water Use Plan and resulting new Water Licence - were key drivers for the St'at'imc-Hydro Agreement.

La Joie Reservoir Lowering

- At Downton, reservoir lowering would reduce fish habitat; increase potential for fish entrainment which would likely require an update to the *Fisheries Act* Authorization (FAA); alter grizzly bear habitat; and introduce the need for re-vegetation / dust mitigation.

- At Carpenter, spills greater than 20 m^3/s at TRZ would remain very infrequent but would increase in likelihood. Such spills could affect Chinook salmon spawning migration, egg incubation or juvenile rearing. Impacts could be mitigated by fish salvage and prudent ramping. (Gelchu, 2013).

- At Seton, spills during the freshet will increase with potential effect on salmon spawning migrations.

New Concrete Dam downstream from Terzaghi

- Up to 700 m of Bridge River habitat between the new dam and the existing dam would be inundated, however, the productive value of the habitat downstream from the new dam would increase because a newly designed outlet would allow for discharge of waters with appropriate temperature regime. The current low level outlet is a problem in that regard.
- There is a possibility that a new dam could include facilities to pass or transfer fish from the lower Bridge River to Carpenter Reservoir and further upstream. This would be of significant benefit, but would introduce new trade-offs for resident species upstream and introduce additional entrainment issues at the Bridge intakes.
- The concept to build the new dam to a higher elevation would impact the reservoir rim and inundate a reach of fish habitat in the middle Bridge River proportional to the raise.

Pumped Storage

- This concept to pump waters to Carpenter Reservoir from Seton Reservoir would introduce Seton water, at least in dilute ratios, into the lower Bridge River. This mixture could significantly impact fish migration.

Long Tunnel to Fraser River

- Although this concept would revert the Seton River system toward natural hydrology (with the exception of Cayoosh Creek diversion), the discharge of Bridge River waters directly into a new location in the Fraser could be highly disruptive to current migrations and would require extensive impact assessment.

5.5 Project Economics

A scoping level economic analysis of the Integrated System Concepts was conducted using the outputs from the models described in Section 5.2. The analysis was carried out for comparison of the various alternatives and assumes that capital works are required to achieve acceptable levels of residual risks i.e. they are either upgraded or they must be decommissioned. The avoided cost of decommissioning an existing component is therefore considered as a benefit in the economics of scenarios where the component is retained as an operating asset. The analysis does not consider detailed financial aspects of a specific project Business Case such as whether the works can be deferred or implemented in stages.

Present Values (PVs) of capital costs, annual operating costs and annual energy generation were calculated in consultation with BC Hydro's Reliability and Planning, Energy Planning, and Commercial Operations departments to ensure that the analysis was done in a manner that is consistent with others across the corporation. The value of daily (Heavy Load Hour/Low Load Hour) shaping and seasonal shaping of generation were also included in the PV calculations, in addition to the value of installed capacity (detailed in King, 2013). The capital cost breakdowns of the Activity 2 report were used to derive overall costs for each variation of the system concepts (King, 2013). Annual operating costs, water rentals, taxes and other expenses were approximated based on the historical costs for the existing system.

The present value calculations assumed that the capital costs for the scenario upgrades/replacements were fully implemented over a 5 year period at the start of the time period followed by 50 years of project operation (annual operating costs and generation benefits). Levelized costs of energy were computed for each system concept and can be compared to the current 50 year forecast Cost of New Energy reference values used for energy planning.

[redacted] However, the levelized cost of energy for the complete LAJ, BRR, SON systems is dominated by the very favourable economics of capital investment to retain the existing annual generation at Bridge/Terzaghi [redacted] compared to decommissioning that facility. The Terzaghi/Bridge system is retained in all of the proposed integrated systems and thus this concept masks the possible inclusion of other facility concepts that may not be economic. The incremental levelized costs of energy ($/MWh) for each facility concept were computed as detailed in King (2013). The results are described below with a "favourable" assessment indicating that the marginal cost of electricity associated with adopting an incremental capital expenditure is less than the current Cost of New Energy forecast provided by Energy Planning (i.e. the project increment is favourable compared to replacing the equivalent energy resource with energy purchased from another project).

La Joie

- Compared to decommissioning La Joie Dam, refurbishing the dam for operation at reduced reservoir level is very favourable.
- The incremental levelized cost of energy for refurbishing La Joie Dam to the existing height is also very favourable and provides greater system energy and flow control than the reduced reservoir operation.
- The cost of building a new La Joie Dam at raised elevation is not economic when compared with refurbishing the dam to the current elevation. The incremental levelized cost of energy for this project would be over $700/MWh.

Terzaghi

- If the existing Terzaghi Dam cannot be refurbished to an acceptable risk level, the economic basis for replacing Terzaghi dam with a new downstream dam is justifiable, with very high benefit/cost ratio and low levelized cost of energy.
- The incremental cost of rebuilding the dam to a higher elevation may also be economic and requires more thorough feasibility, impact assessment and cost estimating work.

- Compared to replacing/refurbishing the existing Bridge generating stations for power diversion to Seton Lake, the economic case to relocate the Bridge generating station to the Bridge/Fraser River confluence is very weak.
- Compared to replacing/refurbishing the existing Bridge generating stations with similar capacity conventional units, the economic case to install a 1000MW pumped storage facility is very weak.

Seton

- The economic case to build a new tunnel at Seton to replace or augment the existing canal is very weak. However, the increased discharge capacity would be beneficial in minimizing environmental impacts associated with periodic high spills at Seton and this may be considered in the event that risk reduction measures for the canal prove to be unsatisfactory.

5.6 Activity 3 Concept Filtering

The Activity 3 work has concentrated on analysing further the Integrated System Concepts that emerged from the Activity 2 report and identifying across multiple performance measures which of the site concepts appear to be the least attractive. These are summarized below along with the rationale for the judgements.

Decommission La Joie Dam
There is financial incentive to refurbish La Joie Dam and not to decommission the dam since the incremental levelized cost of energy for refurbishing the dam is much lower than for BC Hydro to purchase energy and capacity from the market or to replace this generation by developing an alternate domestic project. In addition, there are impacts across the system in terms of reduced ability to meet reservoir level and spill targets, even with storage compensation from a new higher dam at Terzaghi. The benefits realized are primarily the elimination of La Joie Dam seismic and static risks, but these benefits may also be met to an acceptable standard by refurbish options.

Refurbish and lower La Joie Dam
This project does not look as attractive as refurbishing the dam to the existing height because more energy, more capacity, and improved system water management is offered by the latter. Feasibility of the full refurbish option has been confirmed by recent investigations (KP 2013), however if the full refurbish option is for some reason not able to reduce risks acceptably then the option of a refurbished lower dam may be attractive as a permanent solution. Note that this lower dam solution would involve more capital work than lowering the reservoir, which is currently being considered as an interim measure.

Replace La Joie Dam with new higher RCC Dam
To raise the elevation of La Joie Dam, a new dam would have to be constructed. The Integrated System Concepts that include a new RCC Dam at a higher level do provide slightly more energy than the Base Case, but the incremental cost of this energy is not economic. The concept does not appear to be attractive, but the option for replacing the existing La Joie Dam with a new downstream dam may still be considered if the logistics and risk reduction for refurbishing the dam are not satisfactory.

Long Tunnel to Fraser River
The total cost of this concept is more than $1B more than the Base Case concept. System risks would be reduced in a manner similar to the Base Case, but additional risks of modifying fisheries migration patterns would be introduced. Separating Bridge River and Seton River basins causes a decrease in system generation as the head that is present at the Seton location cannot be fully developed with a powerhouse near the Bridge-Fraser confluence and there are additional head losses in the long tunnel from Terzaghi to the Fraser. The daily/seasonal generation shaping benefits associated with discharging directly into the Fraser River do not offset the additional costs and environmental studies may identify constraints on the assumed unfettered peaking operation for the scenario. Overall, this concept is not attractive for many reasons.

Development of Pumped Storage above capacity of BR1
The high capacity pumped storage option does not look attractive from an economic perspective. The total cost of this concept is more than $1B more than the Base Case concept. The qualitative assessment of this option considered the value of the additional capacity (~ 500MW more than the Base Case) and assumed very favourable daily and seasonal shaping benefits. Despite this optimistic view of the potential benefits, the incremental cost of the additional installed capacity is not favourable when compared to the current Cost of New Capacity forecast provided by Energy Planning. In addition, the concept of mixing Seton waters into the Bridge River system is of high regulatory and environmental risk. Pumped storage has been evaluated for Mica, a case without the added difficulties of inter-basin transfer, and was also found to be currently not attractive (Abdalla (2013), personal communication).

Construction of new tunnel at Seton
The economic case to build a new tunnel at Seton to replace or augment the existing canal is very weak. However, the increased capacity would be beneficial in minimizing environmental impacts associated with periodic high spills at Seton and this may be considered in the event that risk reduction measures for the canal prove to be unsatisfactory. As well, a new Seton tunnel is the only option that addresses the retained risk of Seton Canal overtopping due to a landslide.

Figure 4 shows all concepts included in the Activity 2 Integrated System Concepts. Red Xs are marked through the concepts noted above to indicate those that are least attractive, while single lines are drawn through those that are not as favourable as other concepts but may be considered further if the primary concept is not feasible or for other business drivers.

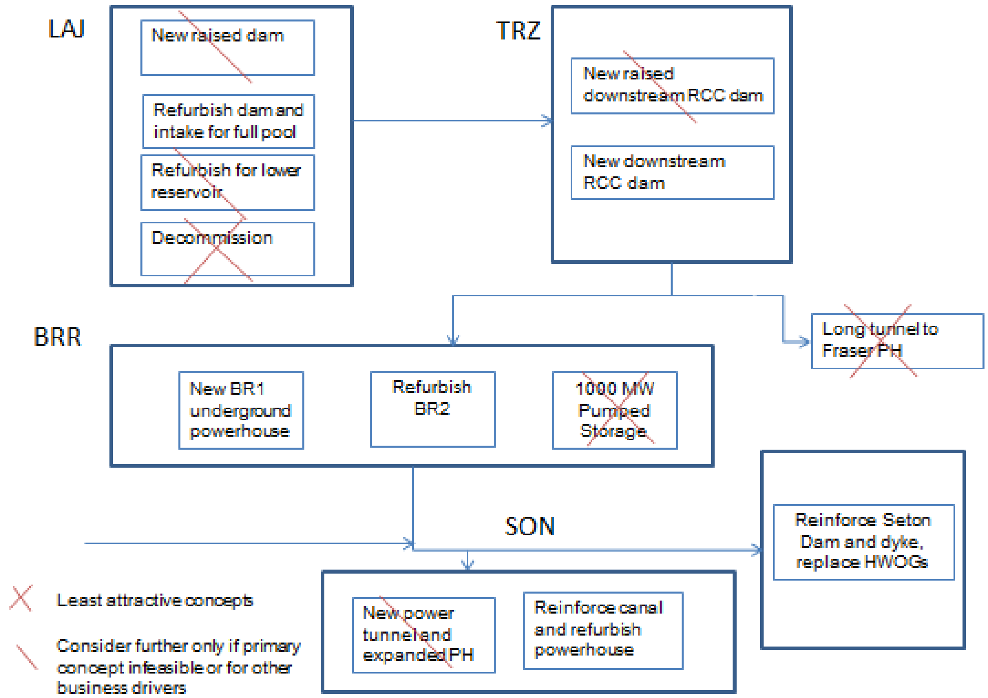


Figure 4: Filtering of site concepts included in the Activity 2 Integrated System Concepts

6.0 ALTERNATIVES, PRIORITIZATION, AND INFORMATION GAPS

6.1 Concept Alternatives

The findings from Activities 1 to 3 of the System Study have identified that the preferred configuration of the Bridge River System is to remain substantially the same as the existing, with no major re-configuration of the system.

Modifications to the existing assets are proposed that would:

- better meet BC Hydro's capability requirements for the river system, and in doing so improve management of the river system for other beneficial uses such as fisheries;
- reduce or eliminate the dominant risks; and
- increase generation revenue.

There remain, however, alternatives to the individual concepts that should be considered further in subsequent studies. As presented in Table 7, these alternatives are classified in two categories:

- 'Type 1', having the potential to offer effective risk reduction at lower cost than the primary concept, for which trade-off analyses are recommended; and
- 'Type 2' alternatives that offer solutions if the primary concept is not feasible or if decision making is driven by other business drivers.

The concepts that formed the Activity 2 Base Case along with the concept alternatives (Type 1) are presented in Figure 5.

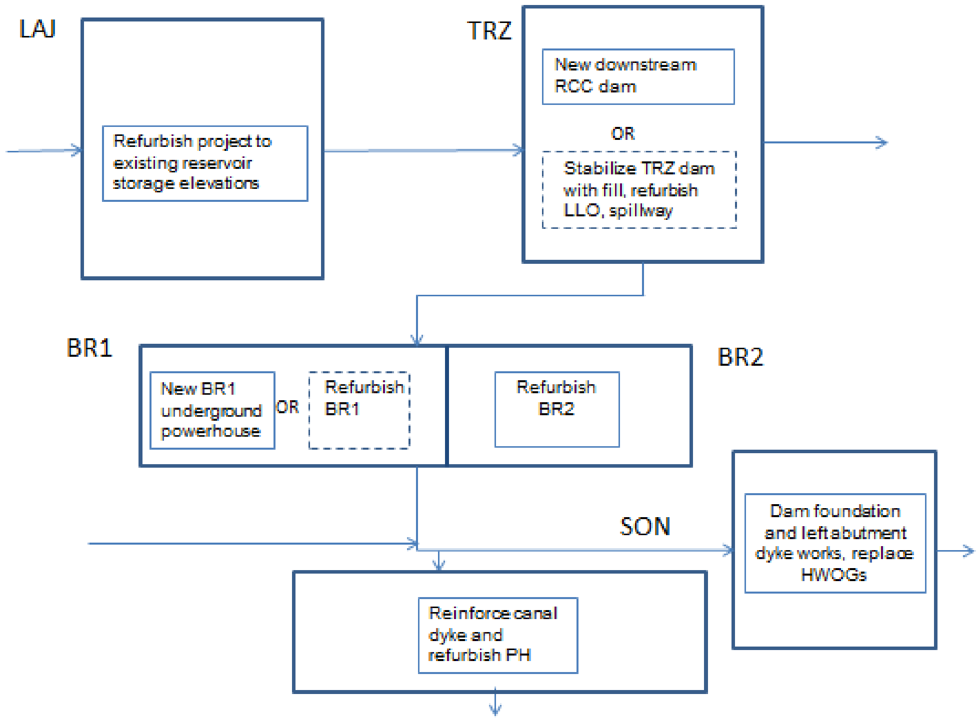


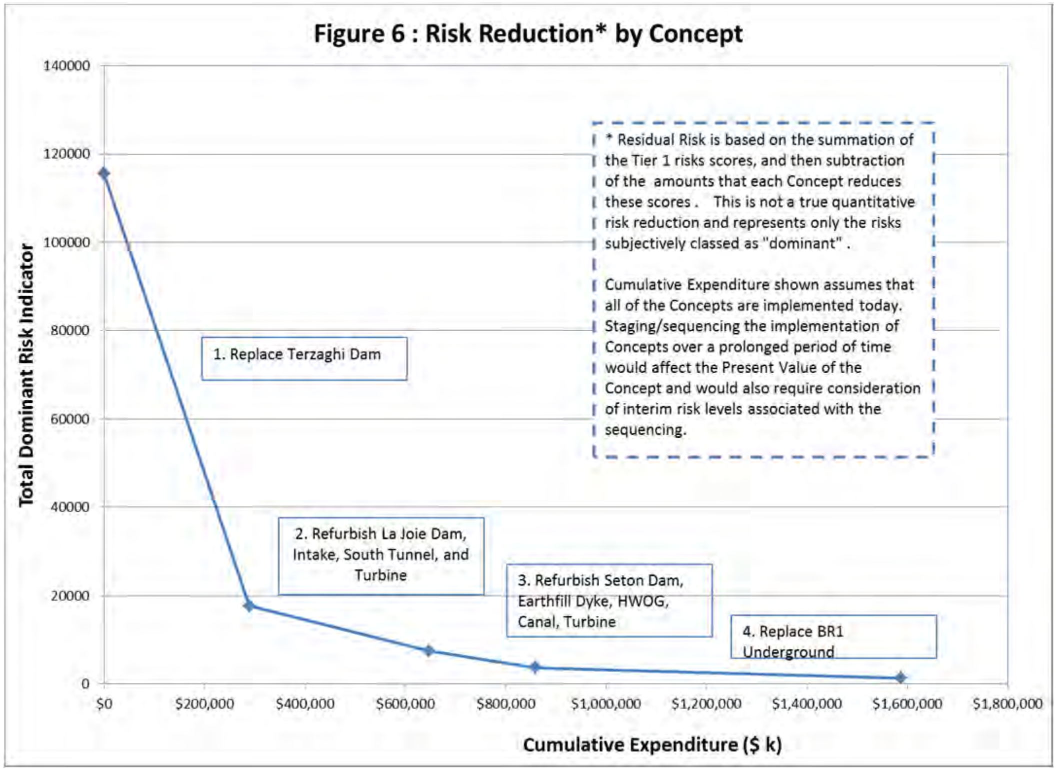
Figure 5 : Schematic of Leading Concepts (with alternatives Type 1 shown with dashed outlines)

6.2 Risk Reduction Prioritization

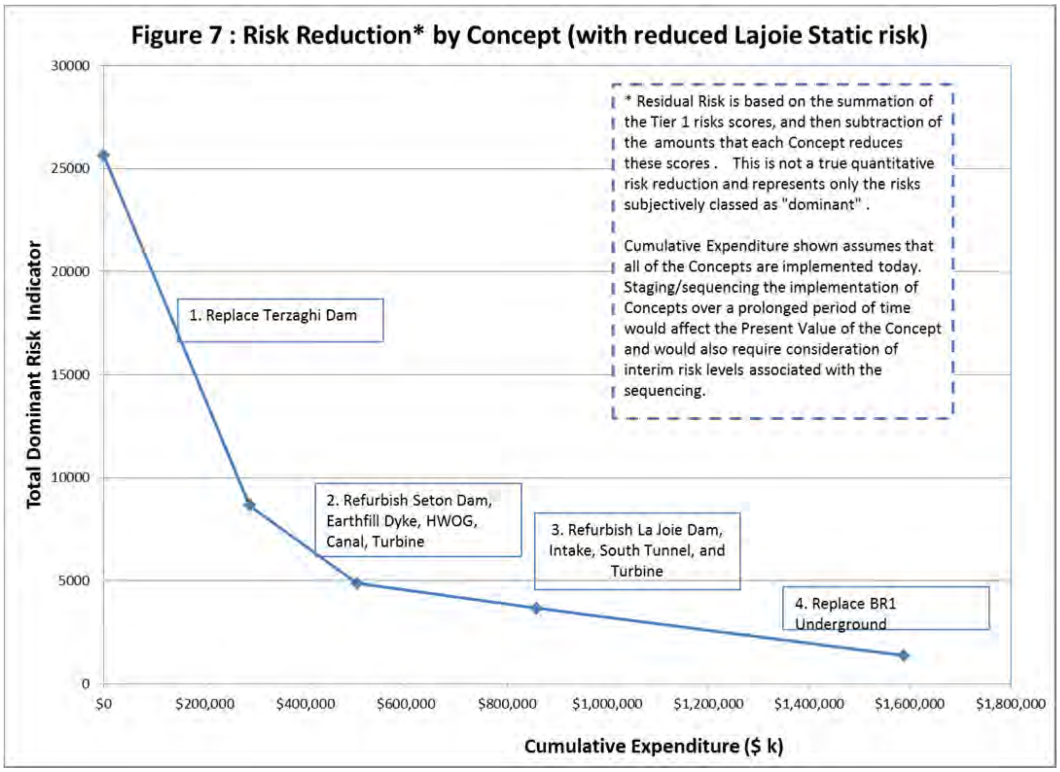
An analysis was carried out to compare the risk reduction cost effectiveness for the leading concepts. This was accomplished by the following method:

- The risk scores for the Dominant (Tier 1) risks, previously based on the methods of the Capital Investment Risk Analysis Guide (CIRAG), were converted to a numerical risk indicator by converting the Likelihood Score (on a scale of 1-9) to a probability based on the tables provided in the CIRAG. The Severity Scores (S), on a scale of 1-7 representing logarithmic increases in damages, were converted to a **consequence indicator** of 10^S. The **risk indicator** was computed as the probability times the consequence indicator.
- The total residual risk (for the Dominant risks only) was computed as a sum of all risk indicators.
- The effectiveness of the Primary Concepts in reducing the risks was extracted from the Activity 2 report, and converted to reduction in total risk indicator.
- Concepts were grouped by facility, and the order of implementation was adjusted until the most cost effective measures were apparent.

The results of this analysis showed that works to reduce identified dominant risks at Terzaghi Dam show the most promise for least cost compared to other sites, in part because the overtopping capability of a new concrete dam could reduce the consequences of a failure of La Joie Dam. Figure 6 below shows that following the implementation of Terzaghi Dam works the order of priority could be construction of physical works at La Joie, then Seton, and finally Bridge Powerhouse.



Interim risk reduction measures such as reducing the maximum normal reservoir level at Downton Lake Reservoir are currently under consideration by other projects as means of reducing the seismic and static risk of failure at La Joie Dam. Figure 7 below shows that if these measures are implemented and effectively reduce the static failure risk at La Joie Dam, then the risk reduction priorities may shift such that completion of risk reduction projects at Seton become the second priority after Terzaghi Dam upgrades.



It must be remembered that the analyses presented in Figures 6 and 7 were based only on the reduction of identified dominant physical risk factors and on capital costs. There are many more factors of existing asset life cycles and economic valuations that should also be considered. Further, Asset Management and risk reduction decisions need to be broken down by component rather than facility. At this time, the risk scores are considered to be too coarse to compare effectively between individual component remedial works; towards that goal further work is recommended below and in Section 8.

6.3 Remaining Information Gaps

The following present significant information gaps in making a fully informed assessment of the trade-offs and asset management / redevelopment decisions:

1. Seismic deficiency of the existing Terzaghi Dam and components compared to updated design criteria
   - o options for seismic remediation of the dam and appurtenant works including the LLO and spillway

2. The capacity of the current Terzaghi spillway
   - confirmation of the appropriate flood hazard criteria for the project
   - further investigation of the chute capacity and the vulnerability of the structure given the condition of the concrete

3. Feasibility of a new downstream dam at Terzaghi
   - Site suitability
   - Environmental impacts or benefits, including comparisons for existing maximum normal reservoir level as well as for concepts with higher reservoir levels
   - Concepts for low level outlet temperature control and possibly upstream fish passage should be developed
   - Regulatory and Aboriginal Relations input and consultation

4. Bridge Powerplant intake seismic and condition assessments and designs for refurbishment or replacement;

5. Stability of Bridge 1 Powerhouse and designs for remediation; and

6. Seismic performance of Seton canal embankment and options for remediation.

7.0 CONCLUSIONS

1. From the perspective of both maximizing energy benefits and minimizing contributions from identified dominant risk factors associated with dams, the highest objectives for the Bridge system configuration are to preserve and provide safe impoundment for Carpenter Reservoir storage, and to preserve the high head on the Bridge generating stations.

2. The findings from Activities 1 to 3 of the System Study have identified that the preferred configuration of the Bridge River System is to remain substantially the same as the existing, with no major re-configuration of the system. However, modifications are proposed that would:
   - better meet BC Hydro's capability requirements for the river system, and in doing so improve management of the river system for other beneficial uses such as fisheries;
   - reduce or eliminate the identified dominant physical risk factors; and
   - increase generation revenue.

3. The existing La Joie, Bridge, Seton projects are well sized from an average annual generation perspective. Taking into consideration the required non-power flow releases at Bridge and Seton there is proportionally little additional energy to be captured by reconfigurations to the existing system.

4. Concepts that remain for each site after the analyses of Activity 3 are presented in Table 7. This table includes primary and alternative concepts for each site, for which trade-offs will need to be investigated, as well as key considerations for concept optimization in further design studies.

5. The leading concept for future impoundment of Carpenter Reservoir replaces the existing Terzaghi Dam with a new roller compacted concrete dam, located approximately 0.7km downstream from the current dam. A new dam would eliminate current risks associated with earthquake induced failure of Terzaghi Dam. It would also reduce risks associated with earthquake or static failure of La Joie Dam by withstanding the resulting overtopping flows and effectively reducing the downstream flood peak. An alternative concept for Terzaghi Dam is to refurbish the existing Terzaghi Dam and appurtenances. However, the technical feasibility of refurbishment has not been confirmed and trade-offs between cost and risk factor reduction for the refurbishment versus replacement concepts will need to be investigated.

6. Retaining the existing inter-basin diversion from Carpenter Reservoir to Seton Lake, refurbishing the existing BR2 penstocks and powerhouse, and constructing a new, underground BR1 powerhouse is the leading concept for future high head generation and for mitigating risks associated with the existing Bridge generating stations. Trade-offs between the BR1 replacement concept and the alternative concept of refurbishing the existing BR1 powerhouse should be further investigated. An option to install a 1000 MW pumped storage facility at Bridge and an option to relocate the Bridge generating station to the Bridge/Fraser River confluence were also considered but compared to the leading concept these alternate configurations are less favourable.

7. La Joie project configurations ranging from decommissioning to full replacement to raising and rebuilding La Joie Dam were investigated. From an energy perspective, these storage variations were found to have relatively minor impacts on the operation and economics of the downstream projects. However, from a flow control perspective, decreasing the regulated storage volume at La Joie results in higher spill flows through the Seton project during the freshet. Thus decisions related to the configuration of the La Joie Project can be based primarily on the project specific costs, benefits and dam safety attributes but must consider the environmental impacts at both the La Joie and Seton projects.

8. Refurbishing La Joie Dam and generating station for continued operation of the existing generating assets at full reservoir elevation is the leading concept for future operation of the La Joie project. Refurbishing the dam for future operation at a reduced operating level is also attractive from economic and risk factor reduction perspectives. However, since the levelized cost of energy of refurbishing the dam for full height is much less than the current reference price forecast, the incremental capital investment in the full upgrade appears to be warranted.

9. From an integrated system perspective, the primary objective for the Seton project is the re-regulation of the Bridge GS outflows in a manner that minimizes the environmental impacts to the Seton River and thus permits the continued inter-basin diversion and peaking operation of the Bridge generating units. Seton is the only project with frequent occurrence of forced spill, however, from an average annual energy perspective the existing Seton GS discharge capacity is not a significant constraint on the total Bridge System generation. Concepts to increase Seton GS generating capacity were evaluated but were found on

their own to be economically weak, even with consideration of the benefits of generation shaping across the system, the value of increased capacity, and system concept changes such as decommissioning La Joie Dam. From an environmental perspective there may be benefits to increasing the discharge capacity at Seton GS as one means of mitigating the effects of spill events that are exacerbated by the inter-basin diversion.

10. The leading concepts for future operation at Seton Dam retain the project in its existing configuration and include foundation upgrades to the dam and rebuilding the left abutment dyke. Replacement of the gates at the inlet to the canal (HWOGs) and refurbishment of the canal/aqueduct is also included.

11. From the perspective of reducing the identified dominant risks only, remedial works or a new dam at Terzaghi Dam appear to be the highest priority measure. Dependent on the acceptance of La Joie Dam interim risk management measures for the static condition, works at Seton are the next priority. Additional feasibility studies are required to better define the most sensible risk reduction prioritization.

12. Decisions relating to the upgrade or replacement of Terzaghi Dam can proceed independently of finalizing decisions for the configuration of the La Joie or Seton projects. Full optimization of the Bridge River System generation would benefit from finalizing decisions relating to the configuration of La Joie and Seton projects prior to initiating works that are specific to any major modification to the Bridge generating stations.

8.0 RECOMMENDATIONS

1. It is recommended that the information gaps listed in Section 6.3 be investigated to inform the risk reduction effectiveness, trade-offs and feasibility of leading and alternative concepts.

2. It is recommended that Asset Management decisions for facility life cycle upgrades and replacements consider the river configuration emerging from this study and any potential modifications and alternatives as provided in Table 7.

3. Prioritization of risk reduction projects was assessed at a high level in this report by grouping assets at a facility level rather than breaking facilities further into components. It is recommended that risk reduction prioritization be refined to a component level using a harmonized Dam Safety and Asset Management methodology.

9.0 REFERENCES

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TABLES

Table 1: Dominant Risks (Tier 1) – from Activity 1 Report, MER2013-072

	#	Asset	Primary Hazard(s)	Failure Description	Likelihood Measures	Primary Severity Driver
LAJOIE	1	LAJ Dam	Construction Deficiencies and Material Ageing and Degradation	Degradation of shotcrete face and deformation over time under static load (dam over-steepened, not constructed according to design). Without timely intervention and reservoir lowering, seepage may increase at an accelerated rate to the point of rockfill failure. Further, maintenance may not mitigate risk from long term deformation of dam.	Return period for end of life of the existing upstream concrete facing under static conditions is between 10-100 yrs X 0.4 (probability of cascading TRZ dam failure) **L5**	Cascading failure of LAJ and TRZ Dams with associated flooding of inhabited areas down to the lower Fraser Valley. **S7 / safety**
			Earthquakes	Upstream shotcrete water barrier compromised to the extent that flow- through capacity of the rockfill exceeded.	Withstand is considered to have an AEP of up to 1/2475, but probability of failure could potentially be higher if a breach in the shotcrete were concentrated in one area. Probability = 0.4 that LAJ and TRZ reservoir levels are such that LAJ earthquake failure leads to overtopping and cascading TRZ dam failure. **L3**	Cascading failure of LAJ and TRZ Dams with associated flooding of inhabited areas down to the lower Fraser Valley. **S7 / safety**
	2	LAJ Intake Tower	Earthquakes	Seismic movement or damage to the intake tower or the conduits preventing safe discharge of water through the release facilities.	The functionality of the outlet facilities is expected to be maintained to at least 0.1g (1/1000). **L4**	Drying of the Middle Bridge River (with the exception of seepage through the dam, which post-seismic may increase) **S5 / environmental**
BRIDGE / TERZAGHI	3	TRZ Spillway Chute	Floods	Overtopping of the left wall of the spillway chute and potentially eroding the rockfill toe of the embankment dam. The capacity of the chute to pass high flows is in question.	Prob of 500 m^3/s spill event(~1/500 X 0.2 (assumed prob of failure due to overtopping of wall) **L3.5**	Failure of TRZ Dam with associated flooding of inhabited areas down to the lower Fraser Valley. **S7 / safety**
	4	TRZ Dam	Earthquakes	Deformation of the dam / loss of structural strength. Potential liquefaction leading to overtopping or seepage failure.	Dam has been assessed to withstand 0.15g earthquake (1/ 1750). **L3.5**	Failure of the dam and downstream consequences (Report H2804). **S7 / safety**
	5	TRZ LLO	Earthquakes	The post-seismic operability of the LLO is in question. If the dam slumps but does not breach, reservoir drawdown may be necessary to safeguard against piping failure.	LLO was not seismically upgraded as part of Gate Reliability Program. The capacity of the LLO to lower the reservoir also depends on the joint probability that LAJ will require drawdown in the same event. **L3**	Failure of the dam with associated downstream consequences (Report H2804). **S7 / safety**
	6	BRG1 and BRG2 Power System	Many possible hazards including earthquakes, landslides, transmission grid failures.	Extended forced outage (months) of water conveyance facilities including the powerhouse and transmission grid infrastructure leading to higher probability of TRZ spills.	The vulnerability of the transmission grid is amongst the most likely of hazards to lead to extended outages. Prob of extended outage assumed to be about 1/50 X prob of inflows causing significant spills during the outage period (assumed to be ½ of the year) **L5**	High spill discharges (>100 cms) to the Lower Bridge River downstream of TRZ would result in significant sediment movement and habitat impact. This can include fish stranding following conclusion of spill event. **S5 / environmental**
	7	BRG Penstocks	Earthquakes, Landslides, Material ageing and Degradation	Rupture of penstocks due to support failure and failure due to shock, impact and cyclic loading. Penstock slope failure due to mud/rock slides.	Penstocks have been assessed to withstand 1:1500 to 1:2475 X 0.5 (assumed probability of worker vulnerability). Probability of 1/30 for muck pile failure **L3 to L5**	Potential for worker fatalities in powerhouse (more so for BRG1). **S5 to S6 / safety**
	8	BR1 Power-house	Earthquakes, Flooding, Design and Construction	Differential settlement or deformations / artesian uplift from severe rainstorms or high spring runoff causing powerhouse to shift away from penstocks, rupturing it and losing flow control thereby compromising the powerhouse structure. Bleeder wells are used to reduce the high pressures. Control of pore pressures in the foundation may be inadequate. Infrastructure to maintain the stability of the BR1 Powerhouse may not work and the instrumentation to monitor the stability may be inadequate	The foundation of the powerhouse has been assessed to withstand ~0.14g to 0.2g (~ 1:1000 – 1:2475) X 0.5 (assumed probability of worker vulnerability) Structural stability of the powerhouse is questionable due to foundation issues. Due to artesian pressures, the powerhouse moves and the east end of the powerhouse is slowly sinking. **L3.5**	Potential for multiple worker fatalities in powerhouse. **S6 / safety**
SETON	9	SON Concrete Dam and Spillway	Earthquakes	Liquefaction of foundation soils leading to dam failure. Seton dam is not founded on bedrock. With liquefaction, the structure might undergo displacement downstream as well as some accompanying tilting (differential settlement) in both upstream and downstream and cross-valley direction.	Concrete dam foundation has about a 1:2500 withstand. (SON05DI 0.15g no expected liquefaction, 0.26g local liquefaction). **L3.5**	Population at risk is transient, and includes any workers in a downstream lumberyard. **S6 / safety**
	10	SON Left Bank Earthfill Dyke	Earthquakes	Slumping and overtopping failure.	Seismic withstand is estimated to be about 1:2475. **L3.5**	Failure of the dyke results in uncontrolled release of Seton Reservoir into Seton River. **S6 / safety**
	11	SON Canal	Earthquakes	Embankment / liner failure due to foundation liquefaction leading to sudden release of water.	Canal withstand assessed to be about 1:2,475 (0.15g) to 1:5000 (0.26g). (liquefiable assessment only). **L3 to L3.5**	If canal is breached upstream of the First Nation Band residences, there would be people at risk. **S7 / safety**
	12	SON HWOGs	Earthquakes	The HWOGs cannot be closed against flow; any embankment or fish flow release failure could lead to draining the SON reservoir and downstream impacts.	Likelihood unknown, assumed to be about 1:1,000. **L4**	Draining the reservoir to the sill of the HWOGs and resulting downstream environmental impacts to fisheries would be high profile. **S5 / reputation and environment**
	13	SON Power System	Many possible hazards	Outage of SON power facilities (even shorter term outages), including the powerhouse or transmission grid infrastructure, resulting in high spills at SON and at TRZ.	Forced outage (frequent occurrence) X (prob of local inflow + extended BRG plant flow exceeding total 200 cms) (nominally 1/50). **L5**	Severity rating is based on exceedance of 200 cms spill due to failure of a BC Hydro sub-system. High impact to fish habitat, loss of regulatory support. **S5 / environmental**

Table 2: Summary of Upgrade Features for Integrated River Concepts (from Hatch, 2013)

Feature	Integrated Concepts						
	0	1A	1B	1D	3	4	5
1. LAJ Facility							
a. Dam Embankment & Seismic Upgrade	x			x	x	x	x
b. Reinforce LAJ Intake Tower	x			x	x	x	x
c. Decommission LAJ Facility		x					
d. New RCC Dam (5 m higher)			x				
e. Reduced LAJ reservoir level & new spillway				x			
f. Refurbish penstock (South)	x			x	x	x	x
g. LAJ PH (Replace Exciter & other misc.	x			x	x	x	x
h. New Repositioned Powerhouse			x				
2. TRZ Facility							
a. New RCC Replacement Dam Downstream	x		x	x	x	x	x
b. New 10 m higher RCC replacement dam		x					
3. BRR Facility							
a. BRR bypass Facility	x	x	x	x			x
b. BR1 Pressure shaft (penstock)	x	x	x	x			x
c. BR1 Relocated Underground Powerhouse	x	x	x	x			x
d. BR1 Tailrace Tunnel	x	x	x	x			x
e. BR2 Powerhouse Equipment Overhauls	x	x	x	x			x
f. PIV #1 and #2 - Coating repairs	x	x	x	x			x
g. BR3 Long Tunnel (500 MW)					x		
h. BRR Pumped Storage (200 MW)						x	
i. BRR Pumped Storage (1000 MW)						x	
4. SON Facility							
a. SON Dam Foundation Treatment	x	x	x	x	x	x	x
b. Replace SON HWOGs	x	x	x	x	x	x	x
c. Rebuild SON Left Abutment Dyke	x	x	x	x	x	x	x
d. Rebuild SON Canal Dyke	x	x	x	x	x	x	
e. SON Power Plant – Major Maintenance	x	x	x	x	x	x	
f. SON Tunnel and 70 MW Power Plant							x
** "x" denotes high cost driver							

0	Base Case (Refurbish La Joie Dam, replace TRZ Dam with new downstream RCC dam, refurbish BR2, replace BR1 with new underground powerhouse, refurbish Seton)
1A	Decommission La Joie and build a new Terzaghi Dam 10 m higher
1B	Replace La Joie Dam with a new dam 5 m higher
1D	Refurbish and lower La Joie Dam
3	Replace BRR powerplants with new tunnel to powerplant on Fraser River
4	Replace BRR powerplants with new higher capacity pumped storage plant
5	Replace Seton Canal with tunnel and increase powerhouse capacity

Table 3: Comparison of Integrated Concepts from Activity 2 Report

Concept 0 used as Base Case. All comments are comparisons with Concept 0.

	Existing System	Concept 0	Concept 1A	Concept 3	Concept 4	Concept 5
LAJ	Existing Dam	Refurbished full height	Decommission			
TRZ	Existing Dam	RCC dam downstream	Higher RCC dam			
BRR	Existing Powerhouses	BR1 underground		Long tunnel to Fraser	Pumped storage	
SON	Existing Dam and Canal	Refurbished dam and canal				Power tunnel (142.8cms)
KCR Review	Does not meet KCR5 (Flood Hazard at TRZ) or KCR6 (Seismic Hazard)	Generally meets all KCRs	KCR1 not fully met (reduction in generation). KCR2 and 3 at risk (increased transgressions)	KCR1 not fully met (reduction in generation at SON)	Seton flow transfer to Bridge may not have First Nations support	Improvement for seismic hazards and reservoir control
Dominant risks	All dominant risks persist	Mitigates all Tier 1 and Tier 2 risks	+All LAJ risks eliminated	BRR tunnel and penstock risks mitigate	Similar to Concept 0	SON canal risks eliminated
Residual risks	All dominant risks persist	Many risks with score > 8 remain per Table _	+All LAJ residual risks eliminated	Risk of insufficient spill capacity at SON reduced	Environmental risks increase	Risk of insufficient spill capacity at SON reduced
Flood Capacity	Potential concerns at TRZ in 1:500	LAJ, SON meets IDF, TRZ built for new PMF (SEFM to come)	TRZ outflows during IDF will increase	Improved flood control at Seton, same at Terzaghi	May help with local Seton basin floods	Improved flood control
Key regulatory issues	Dam Safety guidelines not met for seismic hazard	Downstream dam at TRZ	Removal of Downton reservoir	BRR discharge into Fraser	Mixing Seton waters to Bridge	Modification to water license
Environmental footprint	Existing footprint	In lower Bridge, loss of 700m of habitat but gain temp control	Expanded Carpenter reservoir rim; increased spills at TRZ and SON	New powerhouse and Fraser R impacts	New tunnel bored from Carpenter	Tunnel inlet near Cayoosh River
TRZ spills	More frequent due to unreliable BRR and SON	> 20 cms 1 year in 25	Increase	Same as Concept 0	Same	Same
SON spills	More frequent due to unreliable SON	>200 cms 1 year in 10	Increase	Reduced	Reduced	Reduced
Generating Capacity (MW)		637	644	666	1070	644
Capital Cost ($B)	Low cost	1.26	1.27	2.07	2.55	1.56
Annual Energy (GWh)	3050	3242	3097	3096	Not modelled	3264
Construction risks	n/a	Base case construction risks (significant)	LAJ Decommissioning risks; Relocation of highway at Carpenter and intake relocation increase cost risks	Cost uncertainty in long tunnel construction	More significant underground excavation	Risks joining new tunnel to canal system

Subjective Ratings (Compared to Concept 0)

Base Case	++		Neutral	-	--	---

Table 4: Comparison of La Joie Variations on Integrated Concepts

Concept 0 used as Base Case. All comments are comparisons with Concept 0.

	Concept 0	Concept 1Aii	Concept 1B	Concept 1D
LAJ	Refurbished full height	Decommission	New higher RCC dam	Reduced reservoir
TRZ	RCC dam downstream			
BRR	BR1 underground			
SON	Refurbished dam and canal			
KCR Review	Generally meets all KCRs	KCR1 not met (reduction in generation). KCR2 and 3 at risk (more reservoir and spill transgressions)	KCR4 (First Nations territory would be flooded)	KCR1 not fully met (modest reduction in generation). KCR2 and 3 at risk (some transgressions)
Dominant risks	Mitigates all Tier 1 and Tier 2 risks	LAJ risks eliminated	LAJ risks eliminated	LAJ reservoir hazard reduced
Residual risks	Many risks with score > 8 remain	+All LAJ residual risks eliminated	New dam would allow residual risks to be minimized	Improved protection at LAJ for landslide induced waves
Flood Capacity	LAJ, SON meets IDF, TRZ built for new PMF (SEFM to come)	TRZ large magnitude spills will increase	Improved flood control	Improved flood control
Key regulatory issues	Downstream dam at TRZ	Removal of Downton reservoir	Raising Downton level	Modifications to WUP
Environmental footprint	In lower Bridge, loss of 700m of habitat but gain temp control	Naturalization of LAJ site but increased spills at TRZ and SON	Expanded LAJ site and Downton reservoir rim	Fish entrainment, minimum fish flows
TRZ spills	> 20 cms 1 year in 25	Increase	Reduced	Increase if LAJ spillway crest lowered
SON spills	>200 cms 1 year in 10	Increase	Reduced	Increase
Generating Capacity (MW)	637	607	643	632
Capital Cost ($B)	1.26	1.09	1.93	1.19
Annual Energy (GWh)	3242	3006	3290	3143
Construction risks	Base case construction risks (significant)	Risks during LAJ decommissioning	LAJ greenfield construction	Lower risks in LAJ remedial works

Subjective Ratings (Compared to Concept 0)

Base Case	++	+	Neutral	-	--	---

Table 5 : Comparison of Terzaghi Variations on Integrated Concepts

Concept 0 used as Base Case. All comments are comparisons with Concept 0.

	Concept 0	Concept 1A0
LAJ	Refurbished full height	
TRZ	RCC dam downstream	Higher RCC dam
BRR	BR1 underground	
SON	Refurbished dam and canal	
KCR Review	Generally meets all KCRs	Expanded Carpenter reservoir rim may not be supported by First Nations
Dominant risks	Mitigates all Tier 1 and Tier 2 risks	Same as Concept 0
Residual risks	Many risks with score > 8 remain per Table _	Risk of insufficient spill capacity at SON reduced
Flood Capacity	LAJ, SON meets IDF, TRZ built for new PMF (SEFM to come)	Improved flood control
Key regulatory issues	Downstream dam at TRZ	Modification to water license
Environmental footprint	In lower Bridge, loss of 700m of habitat but gain temp control	Expanded Carpenter reservoir rim; tunnel inlet near Cayoosh River
TRZ spills	> 20 cms 1 year in 25	Reduced
SON spills	>200 cms 1 year in 10	Reduced
Generating Capacity (MW)	637	661
Capital Cost ($B)	1.26	1.44
Annual Energy (GWh)	3242	3295
Construction risks	Base case construction risks (significant)	Relocation of highway at Carpenter and intake relocation increase cost risks

Subjective Ratings (Compared to Concept 0)

Base Case	++	+	Neutral	-	--	---

Table 6 : Comparison of Seton Variations on Integrated Concepts

Concept 0 used as Base Case. All comments are comparisons with Concept 0.

	Concept 0	Concept 5	Concept 5i	Concept 1A-5i	Concept 1Aii-5i	Concept 1D-5i
LAJ	Refurbished full height			Decommission	Decommission	Reduced reservoir
TRZ	RCC dam downstream			Higher RCC dam		
BRR	BR1 underground					
SON	Refurbished dam and canal	Power tunnel (142.8cms)	Power Tunnel and refurbished Canal (250cms)	Power Tunnel and refurbished Canal (250cms)	Power Tunnel and refurbished Canal (250cms)	Power Tunnel and refurbished Canal (250cms)
KCR Review	Generally meets all KCRs	Improved seismic withstand at SON (KCR6)	Better meets KCR1, Energy Generation Requirement	Trade-offs	Trade-offs	Trade-offs
Dominant risks	Mitigates all Tier 1 and Tier 2 risks	SON canal risks eliminated	SON canal risks eliminated	LAJ risks eliminated, SON canal risks eliminated	LAJ risks eliminated, SON canal risks eliminated	LAJ risks mitigated, SON canal risks eliminated
Residual risks	Many risks with score > 8 remain per Table _	Risk of insufficient spill capacity at SON reduced	Risk of insufficient spill capacity at SON reduced	+All LAJ residual risks eliminated	All LAJ risks eliminated; Risk of insufficient spill capacity at SON reduced	Improved protection at LAJ for landslide induced waves, risk of insufficient spill capacity at SON reduced
Flood Capacity	LAJ, SON meets IDF, TRZ built for new PMF (SEFM to come)	Improved flood control	Improved flood control	TRZ spills during extreme events higher, but SON spills reduced	TRZ spills during extreme events higher, but SON spills reduced	Improved flood control
Key regulatory issues	Downstream dam at TRZ	Modification to water license	Modification to water license	Removal of Downton reservoir, modification to water license	Removal of Downton reservoir, modification to water license	Modifications to WUP, water license
Environmental footprint	In lower Bridge, loss of 700m of habitat but gain temp control	Tunnel inlet near Cayoosh River	Tunnel inlet near Cayoosh River	Expanded Carpenter reservoir rim; tunnel inlet near Cayoosh River; increased spills at TRZ and SON	Tunnel inlet near Cayoosh River; increased spills at TRZ and SON	Fish entrainment, minimum fish flows; tunnel inlet near Cayoosh River
TRZ spills	> 20 cms 1 year in 25	Reduced	Reduced	Reduced	Increase	Increase
SON spills	>200 cms 1 year in 10	Reduced	Strongly Reduced	Reduced	Reduced	Reduced
Generating Capacity (MW)	637	644	688	696	659	683
Capital Cost ($B)	1.26	1.56	1.62	1.62	1.45	1.54
Annual Energy (GWh)	3242	3264	3274	3134	3054	3180
Construction risks	Base case construction risks (significant)	Risks joining new tunnel to canal system	Risks joining new tunnel to canal system	Relocation of highway at Carpenter and intake relocation increase cost risks; Risks joining new tunnel to canal system	LAJ Decommissioning risks; Risks joining new tunnel to canal system	Lower risks in LAJ remedial works; Risks joining new tunnel to canal system

Subjective Ratings (Compared to Concept 0)

Base Case	++	+	Neutral	-	--	---

Table 7: Bridge System Remaining Concepts by Site

	Leading Concepts (Base Case)	Alternative Concept(s) (Type 1,2)*	Key Considerations
La Joie Dam	***Refurbish*** to current elevation	***Reduce*** reservoir level and ***refurbish*** dam accordingly (2)	Spillway crest elevation
La Joie Powerhouse	Maintain / ***refurbish*** as required	***Replace*** with upgraded capacity (2)	Reservoir level / Hurley diversion
La Joie Intake Tower	***Refurbish***	***Replace*** control with downstream gate (2)	Maximum reservoir elevation
Terzaghi Dam	***Replace*** with new downstream dam	***Refurbish*** existing dam and appurtenant facilities (1)	Crest elevation / Maximum normal reservoir level / Spillway capacity
Bridge Intake Towers	***Refurbish*** for seismic	***Replace*** (2)	Maximum reservoir elevation
BR1 Powerhouse and Conveyance System	***Replace*** with new underground powerhouse	***Refurbish*** existing (1)	Generation capacity / Pumped storage potential
BR2 Powerhouse	Maintain / ***refurbish*** as required		Maximum Carpenter reservoir elevation
Seton Dam	***Refurbish*** with foundation treatment, rebuild left abutment dyke	***Replace*** with new downstream dam (2)	
Seton Canal	***Refurbish*** canal embankment, new HWOG	***Replace or re-configure*** with new parallel tunnel (2)	Flow capacity
Seton Powerhouse	Maintain / ***refurbish*** as required	***Refurbish and upgrade*** with additional unit (2)	Capacity depends on conveyance concept

*Alternative Types:
(1) requires trade-off investigations, potentially lower cost solution with acceptable risk
(2) consider pending feasibility studies of leading concept or on the basis of other business drivers

APPENDIX A
Cost Estimates for Integrated River System Concepts

Table 6.1 – Integrated River Concepts Cost Comparison Summary (2013 Bid Price Level $000)

#	Integrated Concept Description	0 Base Case	1A New Higher TRZ	1B New Higher LAJ	1D LAJ Reduced	3 TRZ Long	4 Pumped Storage	5 SON Tunnel
1.0	**La Joie Facilities Upgrade**							
1.1	Dam & Intake Seismic Upgrade	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
1.2	Lower Reservoir w/ new Spillway & Concrete line face	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
1.3	Decommission LAJ Facility	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
1.4	New RCC Dam (10m higher)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
1.5	a. Refurbish penstock (South)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
1.6	LAJ PH (Replace Exciter &other misc. equip.)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
1.7	New Repositioned Powerhouse	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
2.0	**Terzaghi Facilities Upgrade**	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
2.1	New RCC Replacement Dam Downstream	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
2.2	10-m higher RCC d/s dam	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
2.3	Relocate Carpenter Lake Road	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
3.0	**Bridge River Facilities Upgrade**	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
3.1	BRR by-pass Facility	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
3.2	BR1 Pressure shaft (penstock)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
3.3	BR1 Relocated Underground Powerhouse	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
3.4	BR1 Tailrace Tunnel	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
3.5	BR2 Powerhouse Equipment Overhauls	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
3.6	PIV #1 and #2 - Coating repairs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
3.7	BR3 Long Tunnel (500 MW)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
3.8	BRR Pumped Storage (1000 MW)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
4.0	**Seton Facilities Upgrade**	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
4.1	SON Dam Foundation Treatment	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
4.1	Replace SON Headworks Outlet Gate (HWOG)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
4.2	Rebuild SON Left Abutment Dike	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
4.3	Rebuild SON Canal Dyke	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
4.4	SON Power Plant – Major Maintenance	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
4.5	SON Tunnel and new 75 MW powerhouse	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	SUBTOTAL	$642,656	$644,634	$979,322	$602,846	$1,052,656	$1,298,731	$790,666
	Construction Management (7.5% of DCC)	$48,199	$48,348	$73,449	$45,213	$78,949	$97,255	$59,300
	Engineering & Owner Administration	$244,209	$244,961	$372,142	$229,082	$400,009	$492,758	$300,453
	PST (7% on 25% of DCC)	$11,246	$11,281	$17,138	$10,550	$18,421	$22,693	$13,837

HATCH™

BC Hydro - Bridge River System Study - Activity 2
Integrated River System Concepts

-- #	Integrated Concept Description	0 Base Case	1A New Higher TRZ	1B New Higher LAJ	1D LAJ Reduced	3 TRZ Long	4 Pumped Storage	5 SON Tunnel
	Contingencies (40% of DCC)	$257,062	$257,853	$391,729	$241,139	$421,063	$518,693	$316,267
	Contingencies (25% of E&OA)	$61,052	$61,240	$93,036	$57,270	$100,002	$123,189	$75,113
	Total Construction Cost	**$1,264,426**	**$1,268,317**	**$1,926,816**	**$1,186,100**	**$2,071,102**	**$2,551,319**	**$1,555,636**
	Inflation to 2018 In-service date	$123,957	$124,338	$188,894	$116,278	$203,039	$250,116	$152,505
	Capital Overhead (% on Inflated $)	$24,574	$24,650	$37,448	$23,052	$40,252	$49,585	$30,234
	Interest During Construction	$174,853	$175,391	$266,453	$164,022	$286,406	$352,814	$215,124
	Total Capital Project Costs	**$1,587,811**	**$1,592,696**	**$2,419,611**	**$1,489,453**	**$2,600,799**	**$3,203,835**	**$1,953,499**
	Retirement of Project Cost							
	Total Project Costs	**$1,587,811**	**$1,592,696**	**$2,419,611**	**$1,489,453**	**$2,600,799**	**$3,203,835**	**$1,953,499**
	Capacity MW	**544.0**	**519.0**	**561.0**	**541.0**	**573.0**	**1073.0**	**566.0**
	$/kW	**$2,920**	**$3,070**	**$4,310**	**$2,750**	**$4,540**	**$2,990**	**$3,450**

* The cost estimate provides an order of magnitude level of accuracy and is useful for indicating whether additional study or engineering is warranted. Thus, the stated accuracy is within +/- 30%."

Project Report

September 2013

BC Hydro

Bridge River System

Concept 2.2.1

Decommission Entire System

HATCH™

Notes:

1. **BRR SYS is used as an abbreviation for the 'Bridge River System'.**
2. **LAJ, TRZ and SON abbreviations used for Bridge River System's main dams.**
3. **Each Key Capability Requirement (KCR) has target performance levels.**

TOPIC	COMMENTS
Summary Description	Decommission and remove LAJ, TRZ and SON dams, returning Bridge River to a natural river complex. Remove all generating stations and artificial structures.
Ability to Meet KCRs	
KCR1 – Generate Power from BRR System	No. Generation would be lost.
KCR2 - Maintain Reservoir Levels Within Acceptable Bounds	No. Loss of all control.
KCR3 – Maintain Downstream River Flow Within Acceptable Bounds	No. Loss of all control.
KCR4 – Be Supported by First Nations	Yes, reintroduce anadromous fish to upper watersheds. And no, as increased flooding could result. Also, additional generation would be required to make up for lost power from BRR System. Other non-renewable sources may have to be developed that would be counter to societal interests.
KCR5- Maintain Hydraulic Control During Floods	No. Loss of all control.
KCR6- Maintain Hydraulic Control Post-Earthquake	Yes. No structures remaining.
Key Stakeholders	
References & Source	
Specialist Assessments	
Geotechnical Assessment	• x
Structural Assessment	• x
Hydrotechnical Assessment	• x
Environmental Assessment	• x
Mechanical Assessment	• x
Electrical Assessment	• x
Safety Implications	• x
Economic Implications	• x
Societal Implications	• x
Concept Assessment	
Benefits	• Risk of earthquake breach of dams and consequent flooding removed due to dam break. • Natural environment restored.

Disadvantages	• Decommissioning is a lengthy and expensive process. • Natural flooding will be unconstrained. • Loss of generation capacity. • Loss of recreation on the reservoirs. • Bridge River fish vulnerable to low water levels or sudden changes in level.
Covering Review	Fails to exploit or improve on the current infrastructure.
Recommendation	**Discard.**

September 2013

Annex C

Detailed Cost Estimate

Description	#0 Base Case	#1A New Higher TRZ	#1B New Higher LAJ	#1D LAJ Reduced	#3 TRZ Long	#4 Pumped Storage	#5 SON Tunnel
1.0 La Joie Facilities Upgrade							
1.1 Dam Embankment & Seismic Upgrade							
a. Replace LAJ Lining & Add U/S Embankment	[redacted]						
b. Reinforce LAJ Intake Tower							
c. Decommission LAJ Auxiliary Bypass Conduit							
1.2 Lower Reservoir w/ new Spillway & Concrete line face							
1.3 Decommission LAJ Facility							
1.4 New RCC Dam and Spillway (10m higher)							
1.5 a. Refurbish penstock (South)							
1.6 LAJ PH (Replace Exciter &other misc. equip.)							
1.7 New Repositioned Powerhouse							
a. PH Civil (incl. demo of existing PH & new Penstock)							
b. Turbine-Generator (incl TIV)							
c. PH Mechanical							
d. PH Electrical							
e. PH Auxiliaries							
f. PH Draft Tube Gates and Bridge Crane							
g. Protection, Controls & Comm.							
2.0 Terzaghi Facilities Upgrade							
2.1 New RCC Replacement Dam Downstream							
2.2 10-m higher RCC d/s dam							
2.3 Relocate Carpenter Lake Road							
3.0 Bridge River Facilities Upgrade							
3.1 BRR by-pass Facility							
3.2 BR1 Pressure shaft (penstock)							
3.3 BR1 Relocated Underground Powerhouse							
a. PH Civil							
b. Turbine-Generator (incl TIV)							
c. PH Mechanical							
d. PH Electrical							
e. PH Auxiliaries							
f. protection, controls & communication							
3.4 BR1 Tailrace Tunnel							
3.5 BR2 Powerhouse Equipment Overhauls							
a. Turbine Overhaul to Units #7 and $8							
b. Governor Replacement Units #6							
c. Paint & recoat scroll case Units #5 to #8							
d. TIV and Bypass recoating							
e. Replace #5 gen. stator & refurbish rotor							
3.6 PIV #1 and #2 - Coating repairs							
3.7 BR3 Long Tunnel (500 MW)	[redacted]						
a. New Intake Structure							
b. New Power Tunnel							
c. PH Civil (Underground)							
d. Turbine-Generator (incl TIV)							
e. PH Mechanical							
f. PH Electrical							
g. Tailrace tunnel							
3.8 BRR Pumped Storage (1000 MW)							
a. New Intake Structure							
b. New Power Tunnel							
c. PH Civil (including decomm.)							
d. Turbine-Generator (incl TIV)							
e. PH Mechanical							
f. PH Electrical							
g. Tailrace tunnel and Pump Intake structure							
h. Gate Shaft with Fixed Wheel Gate							
i. PH Auxiliaries							
j. Protection, controls & communication							
4.0 Seton Facilities Upgrade							
4.1 SON Dam Foundation Treatment							
4.1 Replace SON Headworks Outlet Gate (HWOG)							
4.2 Rebuild SON Left Abutment Dike							
4.3 Rebuild SON Canal Dyke							
4.4 SON Power Plant - Major Maintenance							
a. Turbine Upgrade	[redacted]						
4.5 SON Tunnel (75 MW)							
a. New Tunnel near Cayoosh Cr. Aqueduct							
b. New Penstock							
c. PH Facilities							
i. PH Civil							
ii. Turbine-generator							
iii. PH Mechanical							
iv. PH Electrical							
v. PH Auxiliaries							
vi. Protection, Controls & Comm.							
Subtotal	$642,656,083	$644,633,615	$979,322,115	$602,846,380	$1,052,656,468	$1,296,731,468	$790,666,253
Capacity MW							
$/kW							

Note that the above costs are construction costs w/o escalation, IDC, contingencies, engineering, etc.

Description	#0 Base Case	#1A New Higher TRZ	#1B New Higher LAJ	#1D LAJ Reduced	#3 TRZ Long	#4 Pumped Storage	#5 SON Tunnel
1.0 La Joie Facilities Upgrade							
1.1 Dam & Intake Seismic Upgrade	[redacted]						
1.2 Lower Reservoir w/ new Spillway & Concrete line face	[redacted]						
1.3 Decommission LAJ Facility	[redacted]						
1.4 New RCC Dam (10m higher)	[redacted]						
1.5 a. Refurbish penstock (South)	[redacted]						
1.6 LAJ PH (Replace Exciter &other misc. equip.)	[redacted]						
1.7 New Repositioned Powerhouse	[redacted]						
2.0 Terzaghi Facilities Upgrade	[redacted]						
2.1 New RCC Replacement Dam Downstream	[redacted]						
2.2 10-m higher RCC d/s dam	[redacted]						
2.3 Relocate Carpenter Lake Road	[redacted]						
3.0 Bridge River Facilities Upgrade	[redacted]						
3.1 BRR by-pass Facility	[redacted]						
3.2 BR1 Pressure shaft (penstock)	[redacted]						
3.3 BR1 Relocated Underground Powerhouse	[redacted]						
3.4 BB1 Tailrace Tunnel	[redacted]						
3.5 BR2 Powerhouse Equipment Overhauls	[redacted]						
3.6 PIV #1 and #2 - Coating repairs	[redacted]						
3.7 BR3 Long Tunnel (500 MW)	[redacted]						
3.8 BRR Pumped Storage (1000 MW)	[redacted]						
4.0 Seton Facilities Upgrade	[redacted]						
4.1 SON Dam Foundation Treatment	[redacted]						
4.1 Replace SON Headworks Outlet Gate (HWOG)	[redacted]						
4.2 Rebuild SON Left Abutment Dike	[redacted]						
4.3 Rebuild SON Canal Dyke	[redacted]						
4.4 SON Power Plant - Major Maintenance	[redacted]						
4.5 SON Tunnel and new 75 MW powerhouse	[redacted]						
SUBTOTAL	$642,656	$644,634	$979,322	$602,846	$1,052,656	$1,296,731	$790,666
Construction Management (7.5% of DCC)	$48,199	$48,348	$73,449	$45,213	$78,949	$97,255	$59,300
Engineering & Owner Administration	$244,209	$244,961	$372,142	$229,082	$400,009	$492,758	$300,453
PST (7% on 25% of DCC)	$11,246	$11,281	$17,138	$10,550	$18,421	$22,693	$13,837
Contingencies (40% of DCC)	$257,062	$257,853	$391,729	$241,139	$421,063	$518,693	$316,267
Contingencies (25% of E&OA)	$61,052	$61,240	$93,036	$57,270	$100,002	$123,189	$75,113
Total Construction Cost	**$1 264,426**	**$1 268 317**	**$1,926,816**	**$1,186,100**	**$2,071,102**	**$2,551,319**	**$1,555,636**
Inflation to 2018 In-service date	$123,957	$124,338	$188,894	$116,278	$203,039	$250,116	$152,505
Capital Overhead (% on Inflated $)	$24,574	$24,650	$37,448	$23,052	$40,252	$49,585	$30,234
Interest During Construction	$174,853	$175,391	$266,453	$164,022	$286,406	$352,814	$215,124
Total Capital Project Costs	**$1,587,811**	**$1,592 696**	**$2,419 611**	**$1,489,453**	**$2 600,799**	**$3,203,835**	**$1,953,499**
Retirement of Project Cost							
Total Project Costs	**$1,587,811**	**$1,592 696**	**$2,419 611**	**$1,489,453**	**$2 600,799**	**$3,203,835**	**$1,953,499**
Capacity MW	**544.0**	**519.0**	**561.0**	**541.0**	**573.0**	**1073.0**	**566.0**
$/kW	**$2,920**	**$3,070**	**$4 310**	**$2,750**	**$4,540**	**$2,990**	**$3,450**

Concept # 0, 1A, 1B, 3, 4, 5
Description: **Base Case - Upgrade existing system**

#	ITEM	UNIT	UNIT COST	QTY	TOTAL COST	Notes
			[redacted]			
1.1 a	**New Reinforced Concrete Face with a New US Slope**		[redacted]			
	Subtotal - reference separate tab	LS	[redacted]			Reference separate tab in this workbook "1.1a". Cost from C1.1 Knight Piesold cost estimate. Construction Services & Mgmt NIC.
	Camp Costs	%	[redacted]			Full camp: Assume labor 35% of civil works then assume camp costs are 33% of onsite labor costs.
			[redacted]			
1.1 b	**Refurbish LAJ Intake Tower**		[redacted]			Reference contractor submitted bid for intake tower retrofit in Washington state. Costs were from 2004 escalated to 2012 project was constructed; although certain costs were taken from KP 2009 study.
	Camp Costs	%	[redacted]			Full camp: Assume labor 35% of civil works then assume camp costs are 33% of onsite labor costs.
	Cofferdam and Dewatering System	LS	[redacted]			Escalate from Knight Piesold study on intake refurishment at 2009 price level.
	Remove / Reinstall Gatehouses and Equipment	LS	[redacted]			Escalate from Knight Piesold study on intake refurishment at 2009 price level.
	Anchors - supplied and installed	EA	[redacted]			BCH Strathcona Dam Intake Tower Seismic Upgrade escalated from 2008 size ratio 223/240
	Anchor Testing	LS	[redacted]			BCH Strathcona Dam Intake Tower Seismic Upgrade escalated from 2008 size ratio 223/240
	Supply Isolators (between top &bottom half of tower)	EA	[redacted]			BCH Strathcona Dam Intake Tower Seismic Upgrade escalated from 2008 size ratio 223/240
	Install Isolators	LS	[redacted]			BCH Strathcona Dam Intake Tower Seismic Upgrade escalated from 2008 size ratio 223/240
	Demo Intake Tower including saw cutting	ton	[redacted]			BCH Strathcona Dam Intake Tower Seismic Upgrade escalated from 2008 size ratio 223/240
	Demo Intake Tower Bridge	LS	[redacted]			BCH Strathcona Dam Intake Tower Seismic Upgrade escalated from 2008 size ratio 250/200
	Reconstruct Bridge	LS	[redacted]			BCH Strathcona Dam Intake Tower Seismic Upgrade escalated from 2008 size ratio 250/200
	Mobe	%	[redacted]			
			[redacted]			
1.4 a	**Refurbish penstock (South)**		[redacted]			
	Per estimate	LS	[redacted]			Per LAJ Equipment Health Rating (EHR) (2004 price level escalated to 2013). Costs include procurement and installation. EHR cost doubled per BCH comments.
	Camp Costs	%	[redacted]			
			[redacted]			
2.1	**New TRZ Dam DS (same height as existing)**		[redacted]			Existing dam to remain in place
	RCC for New TRZ Dam	m^3	[redacted]			Unit cost per reference study in BC Hatch compiled estimate. Adjusted unit cost for offsite aggregate source and smaller volume using empiracle formula.
	Excavation for New TRZ Dam	m^3	[redacted]			Assume 5 m depth at abutements and 10 m at base rock excavation. Unit cost per Campbell River JHT Power Conduit.
	Care of Water	LS	[redacted]			Existing dam serves as cofferdam only need to allow for bypass.
	Foundation and Curtain Grouting	%	[redacted]			Assume 3 drill rigs w/ crew of 4 drillers and 2 grout techs working for 80% of duration of the dam construc. If tota labour force on dam is 400 then drilling & grouting will amount to 3.6% of total cost of dam excl mobe and subsistence. (i.e. 3 rigs x 6 crew x 80% / 400 = 3.6%)
	Conventional concrete (Incl stilling basin and spillway)	m^3	[redacted]			Assumed to be double the ratio of conventional concrete volume to overall RCC volume as reference study located in BC. Unit price same as Strathcona LLO structure study.
	Rebar for Structural concrete @ 115kg/m3	kg	[redacted]			Unit price from Knight Piesold study escalated using USBR.
	Obermeyer gate -- (assume three 42m long x 3m high gates)	m	[redacted]			Derived from unit cost for project being constructed in BC $15 200/m. Separate actual construction cost from 2010 project in Washington state [redacted] .
	Low level conduits - excavation, reinf. Concrete, two 5m x 5m with underchute radial gates, intake bulkheads	LS	[redacted]			Cost is taken as 4 times Panama Hydro LLO with RCC design. Design is for two 5m x 5m conduits and energy dissipator. Costs include bulkhead intake slots underchute radial gates steel plate lining depth beneath dam crest = 28m. For TRZ depth of spillgates assumed to be deeper.
	Mobe	%	[redacted]			
	Subsistence in lieu of construction camp	%	[redacted]			No camp: Assume labor 35% of civil works then add compensation for travel time hotel etc @ 20% of onsite labor.
			[redacted]			
3.3 a	**New UG Powerhouse (215 MW)**		[redacted]			Peleton units x 2. Head same as other UG.
	Decommission Existing BR1		[redacted]			
	-Remove contaminated soil at switchyard	t	[redacted]			6 transformers 4.5 m^2 area required for decontamination 2.5 m depth of removal. Assume 2.2 t/m^3 per BCH.
	-Demo and remove surface penstock	m	[redacted]			Plug number. Penstock length per Google Earth imagery.
	-Powerhouse and Switchyard - Demolish and Remove Waste	LS	[redacted]			Cost from C6.1-1 Knight Piesold cost estimate. Includes USBR escalation. Scaled based on number of units at 50% o cost.
	-Environmental and Regulatory Costs	LS	[redacted]			Cost from C6.1-1 Knight Piesold cost estimate. Includes USBR escalation. Scaled based on % of total DCC for C6.1 o 19% of powerhouse demo.
			[redacted]			
	Adit tunnel - excavation	m^3	[redacted]			Unit costs per a similar Hatch project w/ underground powerhouse under construction.
	Powerhouse Excavation Incl. rock supports	m^3	[redacted]			Mica unit cost escalated.
	Dewatering	LS	[redacted]			Derived from 340 MW AK underground powerhouse cavern cost
	Concrete	m^3	[redacted]			Mica unit cost escalated.
	Rebar for Structural concrete @ 75kg/m3	kg	[redacted]			Unit price from Knight Piesold study escalated using USBR.
	Structural Steel and Misc. Metals	kg	[redacted]			Pro rated on 340 MW AK reference project.
	Architectural	LS	[redacted]			Pro rated on 340 MW AK reference project.
	Drilling	LS	[redacted]			Pro rated on 340 MW AK reference project.
	Portal Developments	LS	[redacted]			
	Cable and Access Tunnel - exavation	m^3	[redacted]			4.6 m dia horseshoe. Unit cost per USBR cost estimating material. Increased by 25% for surface transformer requirement.
	Cable and Access Tunnel - concrete liner	m^3	[redacted]			1.25' thick. Unit cost per Campbell River incl rebar. Increased by 25% for surface transformer requirement.
	Rebar for concrete @ 18kg/m3	kg	[redacted]			Unit price from Knight Piesold study escalated using USBR.

Concept # 0, 1A, 1B, 3, 4, 5
Description: **Base Case - Upgrade existing system**

#	ITEM	UNIT	UNIT COST	QTY	TOTAL COST	Notes
	Powerhouse Access Tunnel - excavation	m^3	[redacted]	[redacted]	[redacted]	7.6 m dia horseshoe plus overbreak
	Powerhouse Access Tunnel - concrete floor	m^3	[redacted]	[redacted]	[redacted]	.67m thick
	Rebar for concrete @ 60kg/m3	kg	[redacted]	[redacted]	[redacted]	Unit price from Knight Piesold study escalated using USBR.
	Valve Chamber		[redacted]	[redacted]	[redacted]	
	Excavation and Support	m^3	[redacted]	[redacted]	[redacted]	Pro rated on 340 MW AK reference project.
	Concrete	m^3	[redacted]	[redacted]	[redacted]	Pro rated on 340 MW AK reference project.
	Rebar for concrete @ 60kg/m3	kg	[redacted]	[redacted]	[redacted]	Unit price from Knight Piesold study escalated using USBR.
	Structural Steel and Misc. Metals	kg	[redacted]	[redacted]	[redacted]	Pro rated on 340 MW AK reference project.
	Mobe (civil works only)	%	[redacted]	[redacted]	[redacted]	
	Subsistence in lieu of construction camp	%	[redacted]	[redacted]	[redacted]	No camp: Assume labor 35% of civil works then add compensation for travel time hotel etc @ 20% of onsite labor.
3.3 b	Turbine-Generator (incl TIV)	EA	[redacted]	[redacted]	[redacted]	Powerhouse equipment proxy cost per Hatch internal database. Proxy was 225 MW BC project.
3.3 c	PH Mechanical	LS	[redacted]	[redacted]	[redacted]	Powerhouse equipment proxy cost per Hatch internal database. Proxy was 225 MW BC project.
3.3 d	PH Electrical	LS	[redacted]	[redacted]	[redacted]	Powerhouse equipment proxy cost per Hatch internal database. Proxy was 225 MW BC project.
3.3 e	PH Auxiliaries	LS	[redacted]	[redacted]	[redacted]	Powerhouse equipment proxy cost per Hatch internal database. Proxy was 225 MW BC project.
3.3 f	protection, controls & communication	LS	[redacted]	[redacted]	[redacted]	Powerhouse equipment proxy cost per Hatch internal database. Proxy was 225 MW BC project.
			[redacted]	[redacted]	[redacted]	
3.2	**BR1 Pressure Shafts (Penstock)**		[redacted]	[redacted]	[redacted]	
	Vertical shafts excavation - 3 m ID	m^3	[redacted]	[redacted]	[redacted]	360 m vertical section x 2. Assume V = 16 ft/s.
	Steel liner (incl trifurcation)	kg	[redacted]	[redacted]	[redacted]	Penstock and trifurcation branches are all steel lined. Unit cost per Campbell River JHT Power Conduit.
	Shaft - Concrete liner	m^3	[redacted]	[redacted]	[redacted]	Campbell River unit cost escalated to 2012.
	Rebar for concrete @ 18kg/m3	kg	[redacted]	[redacted]	[redacted]	Unit price from Knight Piesold study escalated using USBR.
	Plug existing 3.3 m m dia power tunnel DS of existing surge chamber	m^3	[redacted]	[redacted]	[redacted]	Plug is 40' in length. Unit cost per reference project under construction in AK adjusted for location.
	Plug existing 2.69 m dia power tunnel DS of existing surge chamber	m^3	[redacted]	[redacted]	[redacted]	Plug is 40' in length. Unit cost per reference project under construction in AK adjusted for location.
	Trifurcation excavation, 3 m ID each branch (one branch is bypass conduit)	m^3	[redacted]	[redacted]	[redacted]	
	Trifurcation - Concrete liner	m^3	[redacted]	[redacted]	[redacted]	Unit cost per Campbell River JHT Power Conduit.
	Rebar for Structural concrete @ 18kg/m3	kg	[redacted]	[redacted]	[redacted]	Unit price from Knight Piesold study escalated using USBR.
	Bypass conduit vault (incl spherical and dissipation valve)	LS	[redacted]	[redacted]	[redacted]	Required for addressing Dominant Risk of unit shutdown
	Mobe	%	[redacted]	[redacted]	[redacted]	
	Subsistence in lieu of construction camp	%	[redacted]	[redacted]	[redacted]	No camp: Assume labor 35% of civil works then add compensation for travel time hotel etc @ 20% of onsite labor.
			[redacted]	[redacted]	[redacted]	
3.4	**Tailrace Tunnel**		[redacted]	[redacted]	[redacted]	
	Concrete lining for tailrace	m^3	[redacted]	[redacted]	[redacted]	1' thick. Unit cost per Campbell River JHT Power Conduit.
	Rebar for concrete @ 18kg/m3	kg	[redacted]	[redacted]	[redacted]	Unit price from Knight Piesold study escalated using USBR.
	Excavation	m^3	[redacted]	[redacted]	[redacted]	Assume two tunnels each 5 m I.D. horseshoe.
	Mobe	%	[redacted]	[redacted]	[redacted]	
	Subsistence in lieu of construction camp	%	[redacted]	[redacted]	[redacted]	No camp: Assume labor 35% of civil works then add compensation for travel time hotel etc @ 20% of onsite labor.
			[redacted]	[redacted]	[redacted]	
4.1	**Replace SON Headworks Outlet Gate (HWOG)**		[redacted]	[redacted]	[redacted]	Chris May devised gate scheme at SON. Cost estimate per his email dated 10-2-2012 unit costs per mechanical cos database. Hydraulically driven gate 5 gates total.
	Diversion and Care of Water	LS	[redacted]	[redacted]	[redacted]	Assume existing bulkhead gates remain & HWOG's are installed behind the bulkheads
	Demolition and Enlargement of area for Gate/ Trans to Canal	LS	[redacted]	[redacted]	[redacted]	
	Concrete	m^3	[redacted]	[redacted]	[redacted]	Concrete structure to include lining transition. Campbell River study unit pricing.
	Rebar for concrete @ 115kg/m3	kg	[redacted]	[redacted]	[redacted]	Unit price from Knight Piesold study escalated using USBR.
	Foundation Piles	LS	[redacted]	[redacted]	[redacted]	
	Flaps (5 gates)	kg	[redacted]	[redacted]	[redacted]	Per Hatch internal database.
	Guides (5 gates)	kg	[redacted]	[redacted]	[redacted]	Per Hatch internal database.
	Hydraulic cylinders	EA	[redacted]	[redacted]	[redacted]	Per Hatch internal database.
	Common HPU	LS	[redacted]	[redacted]	[redacted]	Per Hatch internal database.
	Common Electrical & Common Systems	LS	[redacted]	[redacted]	[redacted]	Plug number.
	Installation	LS	[redacted]	[redacted]	[redacted]	
	Mobe	%	[redacted]	[redacted]	[redacted]	
	Subsistence in lieu of construction camp	%	[redacted]	[redacted]	[redacted]	No camp: Assume labor 35% of civil works then add reduced compensation for travel time hotel etc @ 8% of onsite labor.

Capital Cost Estimate - La Joie Project | **Concept 1.1a**

C1.1-1

Dam Remediation - New Reinforced Concrete Face on New Upstream Slope (Knight Piesold, VA103-216/1-1, 2009)

Feature	Item	Item Description	Unit	Unit Cost	Qty	Total Cost ($CAD 2009)	USBR (1) Cost Factor 2009	USBR (1) Cost Factor	Total Cost ($CAD 2013)
		Direct Construction Costs							
		Preliminary & General		[redacted]					
1	1	Mobilization / Demobilization	%						
		Construction Camp	included in						
		New RC Face on New Upstream Slope							
		Parapet Splash Wall							
2	1	Pre cast lock bolts - remove existing (upstream)	ea						
2	2	Concrete - demo and dispossal (splashwall footing)	m3						
2	3	Loose rockfill excavation	m3						
2	4	Concrete - rebar (parapet wall)	kg						
2	5	Waterstop	m						
2	6	Dowels (drill, install and grout)	ea						
2	7	Concrete - parapet wall	m3						
2	8	Concrete - rebar (footing)	kg						
2	9	Concrete - footings (DS footing)	m3						
2	10	Pre-cast lock blocks	ea						
2	11	Pre-cast lock blocks	ea						
2	12	Granular fill (structural)	m3						
2	13	Granular fill	m3						
		New Plinth							
2	14	Removal of debris from existing plinth	LS						
2	15	Overburden excavation	m3						
2	16	Detailed rock excavation (drill, blast, excavate)	m3						
2	17	Curtain grout in suspect locations	LS						
2	18	Rock anchors (drill, install, grout)	ea						
2	19	Concrete - rebar	kg						
2	20	Concrete - plinth	m3						
2	21	Mastic joint	m						
2	22	Waterstop	m						
		New US Slope for RC Face (1.4H:1V)							
2	23	Loose rockfill excavation	m3						
2	24	Rockfill (75mm minus)	m3						
		Face Slab							
2	25	Concrete - rebar	kg						
2	26	Concrete - face slab	m3						
2	27	Waterstop	m						
2	28	*Environmental and Regulatory Costs*	LS						

Capital Cost Estimate - La Joie Project

C1.1-2

Dam Remediation - New Reinforced Concrete Face on New Upstream Slope

Environmental Cost Estimate

Feature	Item	Item Description	Unit	Unit Cost	Qty	Total Cost ($CAD 2009)
		Direct Environmental Costs		[redacted]		
		Permits, Approvals and Licences				
2	11-2	Obtain all permits	LS			
		Reservoir Drawdown				
2	11-4	Fish salvage	$/year			
2	11-5	Screening or netting of intakes	LS			
2	11-6	Sediment control (In addition to basin revegetation)	LS			
		Construction Sediment Control				
2	11-7	Construction Sediment Control	%			
		Compensation and Mitigation				
2	11-17	Lake Basin - Revegetate (plant and seed)	ha			
2	11-15	Fish holding and restocking	LS			
		Monitoring				
2	11-16	Environmental monitoring	LS			
2	11	TOTAL ESTIMATED ENVIRONMENTAL COSTS				

(1) U.S. Bureau of Reclamation Construction Cost Trends

Concept # 1A
Description: Reconfigure storage from Downton to Carpenter

#	ITEM	UNIT	UNIT COST	QTY	TOTAL COST	Notes
			[redacted]			
1.2	**Decommission LAJ**					
	Decommission LAJ - reference separate tab	LS				Reference separate tab in this workbook "1.2". Const Svcs & Mgmt NIC. Per Knight Piesold cost est C6.1. Quantities updated.
	Camp Costs	%				Full camp: Assume labor 35% of civil works, then assume camp costs are 33% of onsite labor costs.
2.2	**New RCC TRZ Dam DS (+10 m higher)**					Changed to 10m raise from 15m raise during road inundation optimization exercise.
	RCC for new TRZ Dam	m^3				Unit cost per reference study in BC, Hatch estimate. Adjusted for offsite aggregate source and larger volume using empiracle formula.
	Excavation for New TRZ Dam	m^3				Assume 5 m depth at abutements and 10 m at base rock excavation required. Unit price per Campbell River JHT Power Tunnel.
	Care of Water	LS				Existing dam serves as cofferdam.
	Foundation and Curtain Grouting	%				Assume 3 drill rigs w/ crew of 4 drillers and 2 grout techs working for 80% of duration of the dam construc. If total labour force on dam is 400, then drilling & grouting will amount to 3.6% of total cost of dam excl mobe and subsistence. (i.e. 3 rigs x 6 crew x 80% / 400 = 3.6%)
	Conventional concrete (Incl stilling basin and spillway)	m^3				Same ratio of conventional concrete volume to overall RCC volume as reference study located in BC. Unit price same as Campbell River JHT Power Tunnel.
	Rebar for Structural concrete @ 115kg/m3	kg				Unit price from Knight Piesold study, escalated using USBR.
	Obermeyer gate -- assume three 42m long x 3m high gates)	m				Derived from unit cost for project being constructed in BC [redacted] Separate actual construction cost from 2010 project in Washington state, [redacted].
	Low level conduits - two 5m x 5m with underchute radial gates	LS				Cost is taken as 4 times Panama Hydro LLO with RCC design. Design is for two 5m x 5m conduits and energy dissipator. Costs include bulkhead intake slots, underchute radial gates, steel plate lining, depth beneath dam crest = 28m. For TRZ, depth of spillgates assumed to be deeper.
	Mobe	%				
	Subsistence in lieu of construction camp	%				No camp: Assume labor 35% of civil works, then add compensation for travel time, hotel, etc @ 20% of onsite labor.
2.3	**Relocate one-lane bridge west of Gold Bridge + Relocate road**					
	Relocate one-lane bridge west of Gold Bridge	m^2				
	Relocate road both sides of existing	km				40.5 km of road inundation for 667.5 m reservoir El (669.7 m dam crest El).
	Excavate New Access Tunnel	LS				This is a placeholder figure until further investigation by others.
	Relocate / Raise BR1 & BR2 Power Intakes	LS				This is a placeholder figure until further investigation by others. Placeholder cost increased to $20M from $5M per BCC comments. Then revised to $15M for 10m dam raise instead of 15m)
	Camp Costs	%				Full camp: Assume labor 35% of civil works, then assume camp costs are 33% of onsite labor costs.

Capital Cost Estimate - La Joie Project — Concept 1.2

C6.1

Decommissiong (Knight Piesold, VA103-216/1-1, 2009)

Feature	Item	Item Description	Unit	Unit Cost	Qty	Total Cost ($CAD 2009)	USBR (1) Cost Factor	USBR (1) Cost Factor	Total Cost ($CAD 2013)	
		Direct Construction Costs		[redacted]						
		Preliminary & General								
1	1	Mobilization / Demobilization (% of all construction activities)	%							
		Demolition								
2	1	Remove concrete diversion plugs	LS							
2	2	Shotcrete face (excavate, load, haul and dump)	m^3							
2	3	Retaining wall (Demolition, load, haul and dump)	m^3							emains in place
2	4	Intake tower (demolish and remove waste)	LS							
2	5	Powerhouse and switchyard (demolish and remove waste)	LS							ull amount of original e
		Earthworks								
2	6	Rockfill (Excavate, load, haul and dump) (including cofferdam)	m^3							ncludes 20 684 m3
2	7	Rockfill (Remove cofferdam)	m^3							r cofferdam
2	8	Dewatering (pumps and pipelines)	LS							
2	9	Channel (Prepare surface)	LS							
		Concrete Works								
2	10	Concrete plugs in tunnels	m^3							
2	11	*Environmental and Regulatory Costs*	LS							

Capital Cost Estimate - La Joie Project

C6.1

Decommissiong

Environmental Cost Estimate

Feature	Item	Item Description	Unit	Unit Cost	Qty	Total Cost ($CAD 2009)
		Direct Environmental Costs		[redacted]		
		Permits, Approvals and Licences				
2	11-1	BCEAA and/or CEAA	LS			
2	11-2	Obtain all additional permits	LS			
2	11-3	Develop new water use plan	LS			
		Reservoir Drawdown				
2	11-4	Fish salvage	$/year			
2	11-5	Screening or netting of intakes	LS			
2	11-6	Sediment control (In addition to basin revegetation)	LS			
		Construction Sediment Control				
2	11-7	Construction Sediment Control	%			
		Compensation and Mitigation				
2	11-8	Lake Basin - Revegetate riparian zone	m^2			
2	11-9	Lake Basin - Revegetate wetland zone	m^2			
2	11-10	Powerhouse (soil cover)	m^3			
2	11-11	Powerhouse (plant and seed)	ha			
2	11-12	Embankment and waste dump (soil cover)	m^3			
2	11-13	Embankment and waste dump (plant and seed, flat ground)	ha			
2	11-14	Embankment and waste dump (plant and seed, sloped ground)	ha			
2	11-15	Fish holding and restocking	LS			
		Monitoring				
2	11-16	Environmental monitoring	LS			
2	11	TOTAL ESTIMATED ENVIRONMENTAL COSTS				

(1) U.S. Bureau of Reclamation Construction Cost Trends

Concept # 1B
Description: **Increased Storage at LAJ**

#	ITEM	UNIT	UNIT COST	QTY	TOTAL COST	Notes
1.3	**Rebuild LAJ as RCC (+10 m higher) - Ungated Spillway**		[redacted]			Unit cost per reference project in BC, includes spillway and USBR escalation. 200 m DS of existing.
	RCC for New LAJ Dam	m^3				Unit cost per reference study in BC, Hatch estimate. Adjusted for offsite aggregate source and larger volume using empiracle formula.
	Excavation for New LAJ Dam	m^3				Assume 5 m depth at abutements and 10 m at base
	Care of Water and Cofferdam	LS				
	Foundation and Curtain Grouting	%				Assume 3 drill rigs w/ crew of 4 drillers and 2 grout techs working for 80% of duration of the dam construc. If total labour force on dam is 400, then drilling & grouting will amount to 3.6% of total cost of dam excl mobe and subsistence. (i.e. 3 rigs x 6 crew x 80% / 400 = 3.6%)
	Conventional concrete (Incl stilling basin and spillway)	m^3				Same ratio of conventional concrete volume to overall RCC volume as reference study located in BC. Unit price taken from Hatch Campbell River Study for Structural Concrete
	Rebar for Structural concrete @ 115kg/m3	kg				Unit price from Knight Piesold study, escalated using USBR.
	Obermeyer gate -- assume three 42m long x 3m high gates)	m				Derived from unit cost for project being constructed in BC, $15,200/m. Separate actual construction cost from 2010 project in Washington state, $29,650/m.
	Low level conduits - two 5m x 5m with underchute radial gates	LS				Cost is taken as 4 times Panama Hydro LLO with RCC design. Design is for two 5m x 5m conduits and energy dissipator. Costs include bulkhead intake slots, underchute radial gates, steel plate lining, depth beneath dam crest = 28m. For TRZ, depth of spillgates assumed to be deeper.
	Mobe	%				
	Camp Costs	%				Full camp: Assume labor 35% of civil works, then assume camp costs are 33% of onsite labor costs.
1.6 a	**Rebuild LAJ - PH Civil**					
	Construct Powerhouse	LS				Powerhouse proxy cost per Hatch internal database.
	Demolish LAJ Intake and Powerhouse					
	Intake tower (demolish and remove waste)	LS				Cost from tab "1.2" Knight Piesold cost estimate.
	Powerhouse and switchyard (demolish and remove waste)	LS				Cost from tab "1.2" Knight Piesold cost estimate.
	Environmental and Regulatory Costs	%				Cost from tab "1.2" Knight Piesold cost estimate.
	Penstock Structure	LS				Use of proxy project in Panama of similar Kaplan installation. Assumed cost to be 3 times higher to account for location adjustment
	New Intake	LS				Ditto for Panama proxy above.
	Mobe	%				
	Camp Costs	%				Full camp: Assume labor 35% of civil works, then assume camp costs are 33% of onsite labor costs.
1.6 b	Turbine-Generator (incl TIV)	LS				Powerhouse proxy cost per Hatch internal database. Assume 1.2 x Panama equipment proxy.
1.6 c	PH Mechanical	LS				Powerhouse proxy cost per Hatch internal database. Assume 1.2 x Panama equipment proxy.
1.6 d	PH Electrical	LS				Powerhouse proxy cost per Hatch internal database. Assume 1.2 x Panama equipment proxy.
1.6 e	PH Auxiliaries	LS				Powerhouse proxy cost per Hatch internal database. Assume 1.2 x Panama equipment proxy.
1.6 f	PH Gates and Controls	LS				Powerhouse proxy cost per Hatch internal database. Assume 1.2 x Panama equipment proxy.
1.6 g	Protection, Controls & Comm.	LS				Powerhouse proxy cost per Hatch internal database. Assume 1.2 x Panama equipment proxy.

Concept # 1D
Description: **Partial Storage at LAJ**

#	ITEM	UNIT	UNIT COST	QTY	TOTAL COST	Notes
			[redacted]			
1D	**1/2 LAJ**					
	Lower Elevation Spillway (Knight Piesold, VA103-216/1-1, 2009)	LS				Reference separate tab in this workbook "5.1". Cost from C5.1 Knight Piesold cost estimate. Construction Services & Mgmt NIC.
	Dam Remediation - New Reinforced Concrete Face on Existing Shotcrete (Knight Piesold, VA103-216/1-1, 2009)	LS				Cost from C1.2 Knight Piesold cost estimate. Construction Services & Mgmt NIC. Includes USBR escalation.
	Mobilization / Demobilization	%				Cost from C1.2 Knight Piesold cost estimate. Construction Services & Mgmt NIC. Includes USBR escalation.
	Concrete - rebar	kg				Cost from C1.2 Knight Piesold cost estimate. Construction Services & Mgmt NIC. Includes USBR escalation.
	Concrete - face slab	m^3				Cost from C1.2 Knight Piesold cost estimate. Construction Services & Mgmt NIC. Includes USBR escalation.
	Waterstop	m				Cost from C1.2 Knight Piesold cost estimate. Construction Services & Mgmt NIC. Includes USBR escalation.
	Environmental and Regulatory Costs	LS				Cost from C1.2 Knight Piesold cost estimate. Construction Services & Mgmt NIC. Includes USBR escalation.
	Camp Costs	%				Full camp: Assume labor 35% of civil works, then assume camp costs are 33% of onsite labor costs.

Capital Cost Estimate - La Joie Project — **Concept 1D**
C5.1
Lower Elevation Spillway (Knight Piesold, VA103-216/1-1, 2009)

Feature	Item	Item Description	Unit	Unit Cost	Qty	Total Cost ($CAD 2009)	USBR (1) Cost Factor 2009	USBR (1) Cost Factor 2012	Total Cost ($CAD 2013)
		Direct Construction Costs							
		Preliminary & General		[redacted]					
1	1	Mobilization / Demobilization	%						
		Demolition							
2	1	Pre-cast lock blocks - remove existing	ea						
2	2	Concrete - demo and disposal (splashwall footing)	m^3						
2	3	Saw cut concrete	m						
2	4	Concrete - demo and disposal (shotcrete)	m^3						
		Earthworks							
2	5	Topsoil organics excavation	m^2						
2	6	Overburden excavation	m^3						
2	7	Loose rockfill excavation	m^3						
2	8	Bulk rock excavation (drill and blast, excavate)	m^3						
		Concrete Works							
2	9	Concrete - Spillway walls / crest /slabs	m^3						
2	10	concrete - rebar	kg						
2	11	Rock anchors (drill, install and grout)	m						
2	12	*Environmental and Regulatory Costs*	LS						
		SUB TOTAL DIRECT CONSTRUCTION COST							

DCC Only
Incl

(1) U.S. Bureau of Reclamation Construction Cost Trends

Concept # 3
Description: **Separate River Basins - Long Tunnel Option**

#	ITEM	UNIT	UNIT COST	QTY	TOTAL COST	Notes
			[redacted]			
3.7 b	**Long Tunnel**		[redacted]			
	Drive Tunnel using TBM, 7 m diameter	m	[redacted]			Hatch Study on long TBM tunnel in AK with high rock cover through granetics. Costs include rock uppport and concrete lining where required. HMM provided estimate.
	Surge Chamber	LS	[redacted]			Hatch study on 340 MW project in Alaska (as noted above)
	Penstock	LS	[redacted]			Hatch study on 340 MW project in Alaska (as noted above)
	Mobe	%	[redacted]			
	Camp Costs	%	[redacted]			Full camp: Assume labor 35% of civil works then assume camp costs are 33% of onsite labor costs.
			[redacted]			
3.7 a	**Intake Strucutre**		[redacted]			
	Mobe	%	[redacted]			
	Intake Strucutre	LS	[redacted]			Cost equal to intake structure for 3.8
	Camp Costs	%	[redacted]			Full camp: Assume labor 35% of civil works then assume camp costs are 33% of onsite labor costs.
			[redacted]			
3.7 c	**Powerhouse Civil (Underground: 500 MW)**		[redacted]			Unit costs per reference study with underground powerhouse.
	Adit tunnel - excavation	m^3	[redacted]			Unit costs per a similar Hatch project w/ underground powerhouse under construction.
	Powerhouse Excavation Incl. rock supports	m^3	[redacted]			Mica unit cost escalated.
	Dewatering	LS	[redacted]			Derived from 340 MW AK underground powerhouse cavern cost
	Concrete	m^3	[redacted]			Mica unit cost escalated.
	Rebar for Structural concrete @ 75kg/m3	kg	[redacted]			Unit price from Knight Piesold study escalated using USBR.
	Structural Steel and Misc. Metals	kg	[redacted]			Pro rated on 340 MW AK reference project.
	Architectural	LS	[redacted]			Pro rated on 340 MW AK reference project.
	Drilling	LS	[redacted]			Pro rated on 340 MW AK reference project.
	Portal Developments	LS	[redacted]			
	Cable and Access Tunnel - exavation	m^3	[redacted]			4.6 m dia horseshoe. Unit cost per SH cost estimating notebook. Increased by 25% for surface ransformer requirement.
	Cable and Access Tunnel - concrete liner	m^3	[redacted]			1.25' thick. Unit cost per Campbell River. Increased by 25% for surface transformer requirement.
	Rebar for concrete @ 18kg/m3	kg	[redacted]			Unit price from Knight Piesold study escalated using USBR.
	Powerhouse Access Tunnel - excavation	m^3	[redacted]			7.6 m dia horseshoe plus overbreak
	Powerhouse Access Tunnel - concrete floor	m^3	[redacted]			67m thick
	Rebar for concrete @ 60kg/m3	kg	[redacted]			Unit price from Knight Piesold study escalated using USBR.
			[redacted]			
	Decommission Existing BR1		[redacted]			
	-Remove contaminated soil at switchyard	t	[redacted]			10 transformers 4.5 m^2 area required for decontamination 2.5 m depth of removal. Assume 2.2 /m^3 per BCH.
	-Demo and remove surface penstock	m	[redacted]			Plug number. Penstock length per Google Earth imagery.
	-Powerhouse and Switchyard - Demolish and Remov	LS	[redacted]			Cost from C6.1-1 Knight Piesold cost estimate. Includes USBR escalation. Scaled based on number of units at 50% of cost.
	-Environmental and Regulatory Costs	LS	[redacted]			Cost from C6.1-1 Knight Piesold cost estimate. Includes USBR escalation. Scaled based on % of otal DCC for C6.1 or 19% of powerhouse demo.
			[redacted]			
	Valve Chamber		[redacted]			
	Excavation and Support	m^3	[redacted]			pro rated on 340 AK reference project.
	Concrete	m^3	[redacted]			pro rated on 340 AK reference project.
	Rebar for Structural concrete @ 60kg/m3	kg	[redacted]			Unit price from Knight Piesold study escalated using USBR.
	Structural Steel and Misc. Metals	kg	[redacted]			pro rated on 340 AK reference project.
	Access Road	LS	[redacted]			Off of existing road
	Miscellaneous Itmes	LS	[redacted]			
	Mobe	%	[redacted]			
	Camp Costs	%	[redacted]			Full camp: Assume labor 35% of civil works then assume camp costs are 33% of onsite labor costs.
			[redacted]			
3.7 g	**Tailrace Tunnel**		[redacted]			
	Concrete	m^3	[redacted]			Reference 340 MW project in AK
	Rebar for Structural concrete @ 18kg/m3	kg	[redacted]			Unit price from Knight Piesold study escalated using USBR.
	Excavation & Rock Support - Tunnel	m^3	[redacted]			7.6 m dia horseshoe
	Portal and Outlet Structure	LS	[redacted]			Reference previous 1972 Study for 1000 MW pumped storage project in WA
			[redacted]			
	Mobe	%	[redacted]			
	Camp Costs	%	[redacted]			Full camp: Assume labor 35% of civil works then assume camp costs are 33% of onsite labor costs.

Concept # 4
Description: Pumped Storage

BRR Pumped Storage (1000 MW)	Lump Sum Cost
a. New Intake Structure	[redacted]
b. New Power Tunnel	
c. PH Civil	
d. Turbine-Generator (incl TIV)	
e. PH Mechanical	
f. PH Electrical	
g. Tailrace tunnel and Pump Intake structure	
h. Gate Shaft with Fixed Wheel Gate	
i. PH Auxiliaries	
j. Protection, controls & communication	
Total =	

Concept # 5
Description: **Minimize Seton Canal Risks (Canal Replacement)**

#	ITEM	UNIT	UNIT COST	QTY	TOTAL COST	Notes
4.5a	**Add Tunnel**		[redacted]			
	Lined Tunnel (Drill and Shoot) - Liner	m				7 m diameter. Unit cost Per cu m [redacted] similar to JHT Long tunnel concept in Campbell River study plus 3 years escalation
	Lined Tunnel (Drill and Shoot) - Excavation	m				7 m diameter. Unit cost Per cu m [redacted] similar to JHT Long tunnel concept in Campbell River study plus 3 years escalation
	Rock Supports	%				10% of excavation cost
	Mobe	%				
	Subsistence in lieu of construction camp	%				No camp: Assume labor 35% of civil works, then add reduced compensation for travel time, hotel, etc @ 8% of onsite labor.
4.5 c i	**SON Powerhouse Facilities - Civil**					
	Powerhouse Facilities	LS				Powerhouse proxy cost per Hatch internal database.
	Mobe	%				
	Subsistence in lieu of construction camp	%				No camp: Assume labor 35% of civil works, then add reduced compensation for travel time, hotel, etc @ 8% of onsite labor.
ii	Turbine-generator	LS				
iii	PH Mechanical	LS				
iv	PH Electrical	LS				
v	PH Auxiliaries	LS				
vi	Protection, Controls & Comm.	LS				
4.5 b	**New Penstock**					New 6 m penstock runs parallel to the existing
	Steel liner	kg				0.5" thick. Unit cost Campbell River JHT Power Tunnel unit cost @ [redacted]. Line 90 m of total length.
	Concrete lining	m^3				
	Rebar for concrete @ 18kg/m3	kg				Unit price from Knight Piesold study, escalated using USBR.
	Steel Pipe - two 3.7m diameter	kg				
	Thrust Block & Manifold	LS				Existing forebay used for surge protection
	Penstock Guard Valves	LS				Say two 3.7m valves plus builiding and equipment.
	Conduit connection to Forebay	kg				Steel pipe connection - say single 4m diameter pipe.
	Mobe	%				
	Subsistence in lieu of construction camp	%				No camp: Assume labor 35% of civil works, then add reduced compensation for travel time, hotel, etc @ 8% of onsite labor.

BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-2-2

2020 Bridge River System Update

PUBLIC

BC Hydro
Power smart

Bridge River System

2020 System Study Status Report

Prepared for: **Project Delivery — Capital Projects**

Prepared by:

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Revisions

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Executive Summary

The Bridge River generating system is comprised of a cascade of dams and encompasses two drainage basins. Given the age of the generating facilities and modernized design criteria, the existing facilities require numerous upgrades to reduce dominant risks, restore generating capacity and maintain operational reliability. As these facilities provide a sizable portion of BC Hydro's generating capacity and are in close proximity to the Lower Mainland, the facilities are considered key operating assets.

In 2014, a Bridge River System Study was performed to initiate steps for long term planning of this complex network of dams and generating stations. The 2014 System Study considered various concepts for each of the facilities ranging from decommissioning, upgrade, and new development. The focus of the Study was to minimize the dominant Dam Safety risks while recognizing other energy production, environmental and social requirements. Acknowledging that there were significant information gaps, the System Study identified leading concepts for each facility based on system level dominant risks and capital costs, and recommended follow-up studies to address the information gaps.

Based on a temporary lowering of the Downton reservoir to reduce dam safety risks in an interim with La Joie and Terzaghi dams, the System Study suggested the following potential risk reduction prioritization:

- Rebuild Terzaghi dam
- Upgrade the La Joie facilities
- Upgrade the Seton facilities
- Rebuild the BR1 and upgrade the BR2 facilities

BC Hydro subsequently prepared Facility Asset Plans with consideration of the asset life cycles and condition assessments at the component level while taking the overall Bridge River System risk reduction prioritization into consideration. This 2020 Bridge River System Status

Report provides a summary of the current Facility Asset Plans and of numerous completed and ongoing projects and studies that have resolved some of the information gaps identified in the 2014 System Study.

Notable observations from this Status Report include:

- To reduce dam safety risks associated with La Joie dam, Downton Lake reservoir surface elevation was reduced and will continue to be operated at this reduced level until upgrades to La Joie dam can be developed and implemented. While operating in this state does not substantially affect power generation, it does reduce operating flexibility to manage flows within the Water Use Plan (WUP) Order target flow schedule throughout the Bridge system and meet various core interests of the St’át’imc Nation.
- While the 2014 System Study identified that a Terzaghi dam replacement would provide the greatest safety risk reduction, subsequent studies assessing the seismic performance of Terzaghi dam have reduced the concerns over the existing seismic withstand of the dam. These subsequent studies have determined that the seismic performance of the dam can be enhanced by some modest upgrades, and dam replacement is not required.
- With the Dam Safety concerns at La Joie dam having been temporarily addressed through operating at an interim lowered reservoir elevation and acceptance of the existing seismic withstand of Terzaghi dam, the primary operational concern with the Bridge system is now focused at minimizing the risk of higher flows from Terzaghi dam into the Lower Bridge river.
- To enhance the ability to manage flows within the WUP Order target flow schedule, work is progressing to upgrade the Bridge River and Seton generating stations to improve their operating reliability.
- While the Bridge 1 powerhouse will be refurbished in the short to medium term, the concept to replace it with a new facility remains as a long-term option. Given some of the operational concerns with the existing Bridge 1 powerhouse, projects have been initiated to

reduce some of the residual risks associated with its continued operation.

- Work to design upgrades to the Seton generating equipment has been initiated. A conceptual design for constructing a flow bypass channel from the Seton power canal has been completed and will be assessed for feasibility. If constructed, this bypass channel would avoid the significant risk of higher flows to the Lower Bridge and Seton Rivers associated with a long duration outage at Seton and facilitate continue generation at Bridge 1 & 2 during the lengthy outage that will be required for the Seton generating equipment upgrade.
- Work is progressing to identify the preferred upgrade alternative for La Joie dam.

With the background information presented in this Bridge River System 2020 Status Memo, the table of dominant risks and the risk reduction prioritization figure provided in the 2014 report have been updated.

1 Introduction

The Bridge River System is a complex network of dams and hydroelectric generating facilities which include:

- La Joie dam and generating facility (LAJ)
- Terzaghi dam and discharge facilities (TRZ)
- Bridge generating facilities (BR1 and BR2)
- Seton dam, power canal, and generating facility (SON)

In managing the operation of these facilities, BC Hydro has endeavoured to strike a balance between maintaining reliable power generation for the people of British Columbia while minimizing the impact of their operations on the environment, salmon fishery, recreational impacts, local social / economic impacts, and the interests of Indigenous communities, primarily the St'át'imc Nation.

St'át'imc and BC Hydro have a series of agreements pertaining to historic impacts of these facilities, continued operations and mitigation activities. These agreements and the Water Use Plan (WUP) Order provides targets and priorities for how the facilities should operate to be aligned with the interests of the St'át'imc and other stakeholders.

Many of BC Hydro's assets in the Bridge River system were constructed in the 1950's and 1960's and are in the late stages of their life cycle. Consequently, a number of large Dam Safety and Generation Asset Management capital projects have been initiated or are planned in the next 20 years.

In 2014, a Bridge River System Study examined the risks associated with the facilities as a whole and considered concepts and configurations to minimize the dominant risk factors associated with the dams and to maximize energy and other societal benefits in alignment with the WUP goals. The identified concepts and configurations were prioritized based on dominant risk reduction and costs. In consideration of a list of information gaps, the 2014 System Study recommended studies on a number of issues to confirm or modify the suggested prioritization.

Following the 2014 System Study, facility level projects and Dam Safety Investigations were initiated and completed to address some of the information gaps identified in the System Study. Based on the results of these projects and additional studies, Generation Asset Management completed updates to the Facility Asset Plans (FAPs) for La Joie, Bridge River and Seton in 2016-2017 and 2019. The focus of these Facility Asset Plans is on the life cycle and condition assessment of the existing assets and on the prioritization of works to reduce operating risks and sustain the existing facility capabilities.

This 2020 Status Report summarizes new information which has changed the dominant risk reduction prioritization of projects in the Bridge River System since 2014, and the current strategies in the updated Facility Asset Plans to reduce the operating risks of these facilities.

1.1 Reissue

This report supersedes the previous Bridge River System Study — 2020 Status Report R0. This report 999-GER-00007 R1 comprises update to report title. All other content is unchanged.

1.2 Status Report Objectives

The key objectives of this System Study Status Report are to:

- Summarize the updated investment strategies from the latest Facility Asset Plans (2016-2019)
- Provide an update on relevant information gaps
- Outline the current prioritization of projects in the Bridge River System as outlined in the Facility Asset Plans.
- Summarize the rationale behind the changes from the original 2014 System Study.

2 Background

2.1 Project Description

The Bridge River System is a three hydroelectric project cascade located in the interior of British Columbia. The Bridge River is impounded by two dams (La Joie and Terzaghi) with the main flows diverted through Mission Mountain via tunnels to the Bridge River 1 (BR1) and Bridge River 2 (BR2) generating stations before discharging into Seton Lake. The Bridge generation stations are the largest of generating facilities on the Bridge River system. Natural inflow into Seton Lake and discharge from the Bridge stations is retained by Seton dam which diverts flow either to the Seton generating facility (SON) via the Seton Canal or into the Seton River. Both Seton River and SON discharge into the Fraser River. A brief description of the dominant risks identified in the 2014 Bridge River System Study associated to each facility is provided below. For reference, the complete list of the Tier 1 dominant risks from the Study is provided in Appendix A. Section 3.1 below describes the work that has occurred since the 2014 Study.

2.1.1 La Joie

La Joie (LAJ) is the upstream most of the three generating facilities in the Bridge River system. This facility is comprised of an 87 m high 1036 m long uncompacted shotcrete faced rockfill structure, which provides the impoundment for Downton Reservoir. The intake system consists of south conduit supplying flow to a generating unit, bypass valve and pressure regulating valve and a north conduit which supplies flow to two hollow cone valves. These two conduits are the only means to actively control the reservoir.

The uncompacted shotcrete faced rockfill dam has shotcrete panels on the upstream slope of the dam which act as a water barrier. The panels require ongoing repairs as they have deteriorated over several decades. Other dominant risks include the seismic withstand of the water barrier panels and the seismic movement or damage to the intake tower and conduits as a result of an earthquake which may prevent safe discharge of water through the release facilities. There are additional concerns over the upper portion of the upstream face constructed with a steeper (1:1) slope than is commonly used in current design. The Downton Reservoir has been lowered since January 2015 (Vazinkhoo, 2020) as an interim measure to manage the seismic vulnerability of the shotcrete face and the over-steepened section of the dam. Unfortunately, with the reduced storage capacity at La Joie dam, operational flexibility is limited which can lead to increased discharge through the Bridge River system. This could then exceed target discharge rates in the Lower Bridge or Seton Rivers depending on the operating situation at the Bridge and Seton plants.

2.1.2 Terzaghi

Terzaghi dam is a 60 m high 366 m long zoned earthfill dam which impounds Carpenter Reservoir. The original diversion dam was completed in 1948 for storage, with the present dam built over it in 1960 to create the current reservoir. Prior to the reduction in the La Joie operating level, Carpenter provided approximately 60% of the storage in the Bridge River system (with LAJ providing 40% and SON <1% of the total storage in the system).

The discharge facilities at Terzaghi consist of an overflow weir, a two gated spillway and a Low Level Outlet (LLO) with two operating gates. The LLO gates provide year round fish flows into the Lower Bridge River, enable drawdown of the reservoir, and help pass large floods. The two spillway gates are used to assist in passing larger flows, and the 106 m long free crest spillway further utilized to pass even larger floods.

The dominant risks at Terzaghi, identified during the 2014 System Study, include the water retention capability and seismic withstand of the dam, post-seismic operability of the LLO and the capacity of the spillway chute to pass high flood flows. Additional concerns over on-going rock slope stability above the spillway also remain.

2.1.3 Bridge River Generating Stations

Located on the banks of Seton Lake, BR1 and BR2 are the largest generating stations in the Bridge River System. These facilities provide over 85% of the system generation, which represents about 5% of BC Hydro's total hydroelectric generation capacity. BR1 and BR2 each have a free standing intake structure located 3 and 4 km upstream of Terzaghi dam, with 4.3 and 4.9 km long tunnels respectively through Mission Mountain. The intake structures have single intake operating gates which control the flows from Carpenter Reservoir to four penstocks at BR1 and two penstocks at BR2.

The Bridge powerhouses each contain 4 generating units with a total nameplate capacity of 460 MW. Prior to the unit upgrades initiated in 2018, five of the eight generators were de-rated reducing the total capacity to 396 MW due to deteriorating equipment and failures. As the generating facilities produce significant annual revenue, a greater level of investment has been proposed. Along with generation, water conveyance from Carpenter Reservoir through the Bridge generating facilities is necessary. This diversion is required to reduce the risk of higher flows being discharged through Terzaghi dam, to the Lower Bridge River which can negatively impact fish and fish habitat.

The facilities at Bridge River have several dominant risks which include maintaining the water conveyance through the BR1 and BR2 units, low seismic withstand of the BR1 powerhouse and of the BR1 and BR2 penstocks, and inability to close the penstock inlet valves in the event of a penstock rupture, stability of the BR1 powerhouse foundations, potential debris flow and slope failures impacting both the penstocks and the transmission grid infrastructure.

2.1.4 Seton

The Seton Generating station is the most downstream facility in the Bridge River system, located on the Fraser River about 1.5 km south of Lillooet. It receives its inflows from the Bridge River generating facilities, Walden North

Independent Power Producer (IPP) and local Seton Lake inflows. The Seton dam and canal intake are located on the Seton River approximately 500 m downstream of the natural outlet of Seton Lake. Seton Lake is impounded by Seton dam, a 13.7 m high concrete gravity dam which is comprised of a radial spill gate, five manually operated discharge siphons, a fish water release gate, and a fish ladder.

A 3.7 km concrete lined canal and steel penstock convey water from the Lake to the Seton single 44 MW unit generating station. The canal entrance is controlled by five headwork operating gates at the Seton dam, and a radial isolating gate is located near the end of the power canal. There are two siphons located along the power canal which divert water from the canal into two separate fish spawning channels located in between the canal and the Seton River.

Discharge rates at Terzaghi dam into the Lower Bridge River are defined by the Water Use Plan, but can be influenced by the various facilities on the Bridge System and particularly flow constraints on the Seton River. Into Seton Lake, Bridge 1 and 2 together pass 160 m^3/s at full load and the diversion from Walden North can contribute an additional 43 m^3/s. This is in addition to the natural inflow to Seton Lake. The turbine at Seton passes only 114 m^3/s at full load, and the Seton canal has a hydraulic limitation of 143 m^3/s. In addition, Seton Lake Reservoir has a narrow (<0.6 m) reservoir water surface operating range. Balancing natural and generator inflows into Seton Lake while maintaining target discharge in Seton River relies on the capability of SON.

The dominant risks at Seton include the seismic withstand of the dam, spillway, left bank earthfill dyke and canal embankment foundations; the inability of the canal operating gates to close under flow conditions; impacts to fish habitat; and loss of regulatory flows resulting from powerhouse and transmission grid infrastructure outages.

2.1.5 Bridge River Transmission

Bridge River generation is currently restricted by the limited transmission system capability during the summer periods (June – August). With the generation increase in the Bridge River area due to the addition of Independent Power Producers and BC Hydro's current and pending Bridge River unit replacements, upgrades to the transmission system are under review.

Work on BC Hydro's 2L90 transmission line to address rating defects, maintain operational reliability, and increase transfer capacity of the Bridge River Transmission System are being planned to accommodate the existing and future generation in the Bridge River area. This transmission line project is in the process of completing Conceptual Design, with a projected in-service date of October 2025.[1]

2.1.6 Watershed Considerations

As the Bridge River System is located entirely in St'át'imc traditional territory, BC Hydro has been working with St'át'imc Nation and St'át'imc communities for several decades regarding their interests and concerns related to the Bridge-Seton River System. This engagement has resulted in defining the operational and water conveyance conditions in the Bridge-Seton System that better reflect St'át'imc core values. The following narrative (Simpson, Cassleman, & Spencer, 2020) provides a brief history of the development of the operating rules for the Bridge River System to provide context to their necessity.

2.1.6.1 Water Use Planning

The Water Use Planning (WUP) consultative process began in June 1999 and was completed in December 2010. This process included development of the draft WUP in September 2003 and subsequent recommendations by the St'át'imc in 2009 and 2010. After acceptance of the WUP by the

[1] Personal communication with Transmission Project Manager Jason Lee, Capital Infrastructure Project Delivery, 2020-08-14.

Comptroller of Water Rights in March 2011, operational changes, monitoring studies and physical works recommended in the WUP were implemented through the issuance of an Order under Section 88 of the former *Water Act*. Some of the key priorities in the WUP Order related to fisheries values include:

1. Adherence to the Terzaghi target flow schedule;
2. Generation and spill at Seton in preference to spilling at Terzaghi dam in excess of the target flow schedule;
3. Seton Generation station shut downs for sockeye smolt out migration; and
4. Adherence to the Seton dam target flow schedule.

2.1.6.2 2011 Agreements

Through further negotiations, in 2011 BC Hydro, St'át'imc and the Province of British Columbia entered into a series of settlement agreements that provided St'át'imc's support of BC Hydro's facilities and settled claims for impacts to St'át'imc aboriginal title or rights relating to the Bridge River facilities. While many of the 2011 Agreements mirror the WUP Order, key fishery and environmental protection measures include:

- Average annual flows targeting between 3 m^3/s and 6 m^3/s at Lower Bridge River to simulate a naturalized hydrograph;
- Smolt mortality target = 5% to be achieved by modifying the Seton Generating station operations and monitoring the mortality rate for 10 years;
- Implementation of the Seton Lake erosion management plan (SLEMP) and monitoring of the SLEMP;
- Implementation of an adult fish passage monitoring program; and
- Implementation of the WUP Order.

2.1.6.3 February 2017 WUP Order Variance

Due to the lowering of the operational water level behind La Joie dam and further hindered by generation reliability at the Bridge River plants (described above), in 2016 BC Hydro requested a variance to the Bridge

River WUP Order to modify the annual average water budget from Terzaghi dam into the Lower Bridge River. This variance was granted in February 2017 and extended in February 2018, and authorizes BC Hydro to operate under a set of guiding principles and outside of the WUP ordered targets. These guiding principles were developed in collaboration with St'át'imc and regulators. While operating under the variance, BC Hydro is required to provide specified reporting and notifications, and BC Hydro is financially responsible for any effects to the WUP Ordered physical works (revegetation and erosion management) that may result.

3 Bridge River System Review Status

A Bridge River System Study was completed in 2014 to develop a comprehensive overview of the cascading facilities as a whole. This System Study was used to assist BC Hydro in determining a course of action to address numerous dam safety, operation, environmental, and maintenance concerns on this complex network of hydroelectric generating facilities. Following is a summary of this System Study, some additional facility projects and Dam Safety Investigations completed since the 2014 System Study, and the Facility Asset Plans.

3.1 2014 System Study

3.1.1 Objectives and Approach

With significant Dam Safety concerns having been identified at the La Joie and Terzaghi dams, and investment required to refurbish the deteriorating Bridge River generating facility, a Bridge River System Study was initiated in 2011 and completed in 2014. This system study examined the risks associated with operation of the entire La Joie, Terzaghi, Bridge River and Seton cascade of facilities and considered various concepts and configurations to minimize dominant risk factors (summarized in Appendix A) associated with the dams while seeking to provide energy production, protect the environment, and improve societal benefits.

The underlying goal of this study was to provide input on investment planning for the Bridge River system. Along with consideration into the generating capacity of the system and necessary dam safety upgrades, at a high level the study considered the system's impact to the environment, economics, and cultural impacts. These considerations were evaluated and used to assess different concepts. The System Study also considered overall concepts as to how a different hydro development might be implemented on the Bridge system to replace the existing one. This study consisted of three main activities:

Activity 1: Determine requirements and existing system performance (BC Hydro, 2013)

Activity 2: Develop integrated river system concepts (Hatch, 2014)

Activity 3: Test river system concepts, analyse trade-offs and make recommendations (Lang & Groves, 2014)

3.1.2 Study Results and Conclusions

Through the course of the 2014 Bridge River System Study, dominant risks associated with each facility and the whole system were identified and documented (Appendix A). Various concept options that could address these risks were then developed, with the leading options and their estimated risk reduction (Hatch, 2014), (Lang & Groves, 2014). The study also defined various criteria upon which these options were ranked. Along with economic viability and the provision of energy, criteria also included environmental, social and cultural impacts. In the subsequent development of concepts, the study assessed the potential impact of full decommissioning, as well as investigating alternative configurations of the system including a pumped storage scheme (between Seton and Carpenter Lakes), and reconfiguring the system so that Bridge generation flows went directly to the Fraser River. Ultimately, the following recommendations were derived:

- Carpenter Lake reservoir impoundment should be maintained with a new roller-compacted concrete dam immediately downstream of Terzaghi dam. However, refurbishment of Terzaghi dam may still be possible should further review of the existing facility's seismic withstand identify viable upgrade concepts.
- The inter-basin diversion from Carpenter to Seton should be retained. The recommended concepts include refurbishment of Bridge 2 facilities and replacement of the Bridge 1 plant including a new underground power tunnel. However, the potential for Bridge 1 refurbishment was still under review.

- A clear direction on the La Joie facility remains uncertain with concepts for decommission, refurbish, or replace identified for further consideration and consultation. Refurbishment of La Joie was highlighted as the leading concept.
- Through modeling of the hydrologic performance of the Bridge River System under various operating constraints, the 2014 System Study identified that operating the La Joie dam at the existing or lowered reservoir had minor impacts on the operation and economics of the Bridge generating facilities. However, flow control capability would be impacted by reducing or removing La Joie storage capacity (by lowering or decommissioning the dam).
- In its current configuration and fully operational, the analysis had shown that the existing La Joie, Bridge and Seton facilities were well sized for regulating available inflows with little forced spill required at Terzaghi. Seton however was shown to have the potential for forced spill (King, 2013).
- Seton plant is to be retained to safely regulate the BR1 and BR2 generation discharges without impacting the Seton River. Although Seton plant discharge is less than the Bridge discharge capacity, increasing Seton generation capacity to more closely match Bridge was not economically favourable. The leading concept was to retain and refurbish the existing Seton facility.

A qualitative assessment of risk relative to construction cost estimates was performed as part of the 2014 System Study to demonstrate potential strategies for ranking the priority of the various large cost components (Lang & Groves, 2014). The 2014 Study considered risks to the system with and without La Joie reservoir lowered. The figure below is based on a lowered La Joie reservoir. Figure 3-1 provides one such strategy based on the scenario where Downton reservoir is temporarily lowered. With Downton lowered, the Dam Safety risks at La Joie dam are reduced. This could enable the deferral of performing upgrades to La Joie while other issues within the Bridge System are addressed.

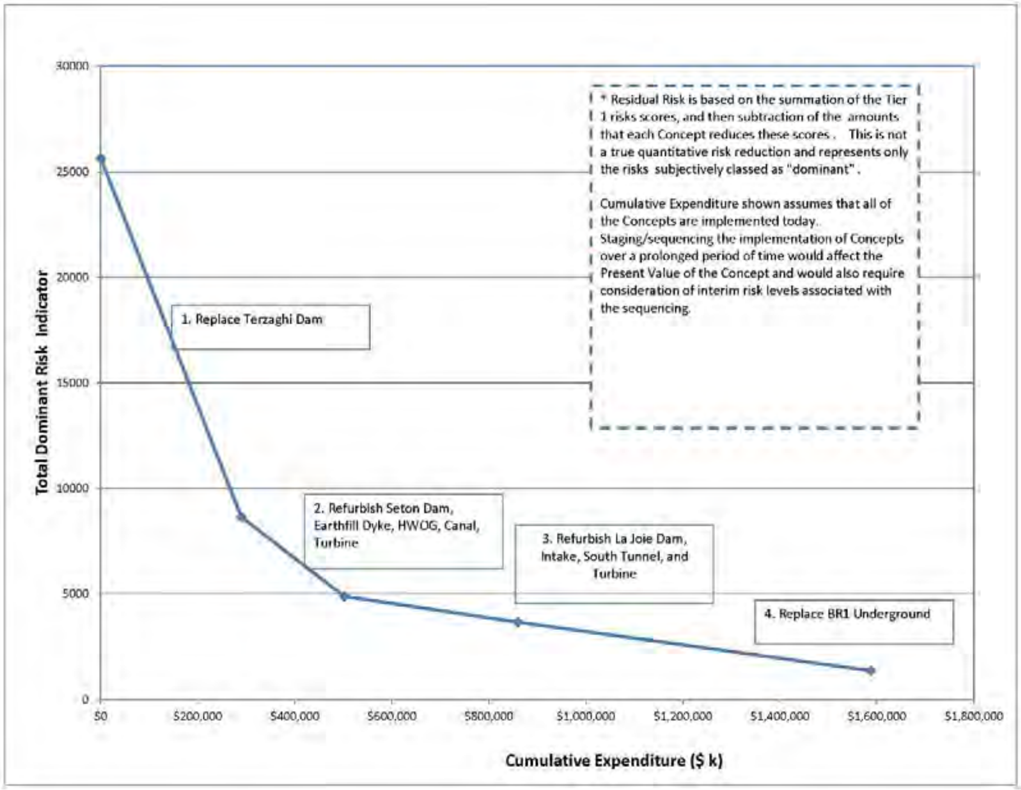

Figure 3-1: Risk Reduction* by Concept (with reduced La Joie static risk) (Lang & Groves, 2014)

Along with the safety concerns associated with the dams, given the magnitude and cost of the recommended works, performing the four key improvements described in Figure 3-1 will require planning and is expected to span several years. Time will be required to perform additional studies and engagement necessary for project decision making and acceptance prior to implementing the selected works. The engineering studies to assess the risks associated with the seismic withstand of Terzaghi dam and Bridge 1 Powerhouse have been ongoing since 2014. Following the results of these analyses, the design work to implement the proposed works can also take several years. The above Risk Reduction Concept was used to further prioritize these large construction projects as they could not all be funded simultaneously, with the collection of work expected to span decades. However, given the unknown seismic performance of Terzaghi dam at the time (2014), the benefits that could be provided with its replacement, and cost relative to the other required significant upgrades, upgrades to Terzaghi dam were highlighted as a potential high priority project subject to further studies and trade-off investigations.

3.1.3 Key Information Gaps

The key information gaps outlined in the 2014 Bridge River System Study which had a direct impact on the selection of the leading concepts included:

- Terzaghi dam and appurtenant facilities seismic withstand and flood control capabilities: The seismic response of the main dam and of the discharge components had been highlighted as vulnerable in a seismic event. In consideration of the combined dominant risk with the upstream La Joie dam, the 2014 System Study identified a new roller compacted concrete dam as the leading concept with a refurbishment concept cited as an alternative.
- Viable rehabilitation concepts for the La Joie facilities remain uncertain with alternatives for decommission, refurbish, or replace still under consideration.
- Component level equipment condition assessments and asset life cycle assessments at each Facility.
- Condition assessments of the BR1 and BR2 Intake structures: concerns remain for the existing intake structures which may hamper their ability to operate following a seismic event.
- Bridge River 1 powerhouse foundation stability. There are known issues with the foundation stability of the BR1 powerhouse since the initial construction. BR1 relies on a system of aquifer monitoring instrumentation and bleeder wells to maintain powerhouse stability. Issues regarding these systems are discussed in more detail in Section 3.2.5.
- Seton dam power canal seismic performance – if the Seton facility is to remain in its current location, further assessment to quantify the seismic performance of the canal is required.

The status of some of these key information gaps are discussed in the following section as new information has addressed some of these issues.

3.2 Additional Work Since the 2014 System Study

Below is a summary of key studies and reports on the Bridge River System that address some of the information gaps identified in the 2014 System Study. Additional studies have been performed which provide further understanding of the Bridge River System, and have helped to guide the decisions behind upgrade plans for the various components.

3.2.1 Terzaghi Seismic Performance Studies

Due to concerns regarding the seismic stability of Terzaghi dam, the System Study suggested a concept with a new roller-compacted concrete (RCC) dam downstream of the existing location. Another driver behind this suggestion was the seepage and seismic withstand risks at La Joie generating facilities upstream of Terzaghi, as failure of LAJ dam could cause overtopping and breach of Terzaghi embankment dam.

The System Study also identified gaps in the understanding of the seismic withstand of various Terzaghi dam components at the time. A subsequent seismic performance assessment of the embankment dam, spillway and low level outlets (KCB, 2015), (KCB, 2016) determined that:

- Terzaghi dam is expected to retain the reservoir with no uncontrolled release of water during and post Maximum Design Earthquake (MDE).
- Under the Maximum Design Earthquake (MDE), a localized failure and limited slope movement may occur at the downstream toe of the dam, however such failure and movement will not affect the dam stability and post MDE discharge from the Low Level Outlet (LLO).
- A remedial design has been proposed to improve seismic performance of the dam toe which has an estimated direct construction cost of [redacted].
- The stability of the spillway wall and its interface with the embankment dam were assessed and found to be stable with acceptable movements under the MDE. The impervious fill and fill/wall interface is not expected to maintain open cracks following the MDE.

- To improve confidence in the dam, a membrane could be attached to the spillway wall and founded on the impervious zone for an estimated construction cost of [redacted]. The wall could also be anchored with post-tensioned anchors for added confidence at an estimated construction cost of [redacted].
- Further analysis will be required to refine the proposed anchor design. The embankment-wall interaction should be modelled to consider the construction joints to obtain a more reasonable estimate on wall loads.
- The post-earthquake operability of the Terzaghi Low Level Outlet (LLO) gates remains an information gap.

Based on these seismic performance studies, the refurbishment concept is assessed as feasible, and the RCC replacement dam from the 2014 System Study is not required.

3.2.2 Terzaghi Dam Hydraulic Assessment

Dam Safety has released a project to perform a hydraulic assessment of the Terzaghi spillway and spillway chute in 2020. This analysis will review the capacity of the spillway chute to ensure it can pass design flows. Work will include development and testing of the spillway using Computational Fluid Dynamics (CFD), with the general scope described as:

1. Assess and investigate the following by considering fully and partially open gates over a range of reservoir levels:
   - approach flow conditions
   - discharge rating curve checks
   - water surface profiles through the spillway headworks and downstream chute (for example to assess the potential for wall overtopping)
   - pressure distributions (for example to assess the potential for cavitation)
   - flow patterns associated with asymmetrical gate operation
   - tailrace flow patterns

2. Investigate whether potential spillway structure deficiencies (e.g. Chute Invert slab offsets) would lead to cavitation and assess the potential impacts on operation and maintenance.
3. Document the findings and advise Dam Safety if the Dam Safety Issues Database should be updated.

The project will be initiated in 2020, with completion scheduled for end of calendar year 2022.

3.2.3 Stochastic Frequency Estimation

To provide some context to the flood risk exposure of the Bridge River facilities, a Stochastic Event Flood Model (SEFM) study was performed by BC Hydro (BC Hydro, 2014). This study provides a flood withstand annual exceedance probability (AEP) considering how all dams and discharge facilities would operate as a combined system during a flood emergency based on BC Hydro's operating rules without reduced operating level at Downton Reservoir. The risk of gate malfunction is also integrated into the flood withstand calculation. The following Table 3-1 summarizes the study results.

Currently, Terzaghi dam has been identified to be unable to pass the 2017 estimated Probable Maximum Flood (PMF) without overtopping (BC Hydro, 2018a). The PMF is the design flood standard commonly applied to dams classified as high or extreme consequence such as Terzaghi.

Large dam owners are beginning to consider basing the inflow design floods for high or extreme hazard dams on a risk informed decision, instead of using the deterministic Probable Maximum Flood. Should BC Hydro plan to adopt a risk informed approach, the flood risk design criteria could be based on a determined annual exceedance probability (AEP) for a large flood. Based on the "best estimate" AEP for Terzaghi from the SEFM study, depending on the selected risk tolerance, the existing dam design elevations could be adequate. Re-evaluation of the design flood for Seton may also be considered. However, given the broad confidence band in the

AEP estimates, the Bridge River projects may consider raising the existing design flood elevations when upgrading the facilities.

Table 3-1: Bridge River System AEP Estimates (BC Hydro, 2014)

Description	Elevation (m)	AEP Best Estimate	AEP Confidence Range	
			Lower	Upper
La Joie Crest	753.47	1:1,100,000	1:47,000	<1:100,000,000
La Joie Flood	754.60	1:50,000,000	1:270,000	<1:100,000,000
Terzaghi Core	653.81	1:147,000	1:20,000	1:19,000,000
Terzaghi Crest	654.71	1:600,000	1:32,000	1:47,000,000
Terzaghi Flood	655.80	1:3,900,000	1:77,000	<1:100,000,000
Seton Dyke Core	236.96	1:546,000	1:17,000	1:82,000,000
Seton Dyke Crest	237.86	1:4,500,000	1:71,000	<1:100,000,000
Seton Flood Wall	238.41	1:24,000,000	1:208,000	<1:100,000,000

3.2.4 Climate Change Assessment

Climate change may have an impact on the performance of the Bridge River system and should be taken into consideration. BC Hydro's Generation Resource Management prepared a review of the potential impacts of climate change (Jost, 2017).

The following provide a summary of the results. However, as noted in the document, uncertainty in the results exist as the outcomes are assessed using expert judgement and statistical analysis.

Temperature & Precipitation

- The warming trends observed in the past decades will continue.
- The mean annual precipitation will increase by 4% – 7% in 2050, and 7% – 10% by 2080.
- Winter, spring and fall will get wetter, summer will get drier.

Mean Annual Flows:

- Mean annual inflows to La Joie will be similar but with greater year-to-year variation including in drought and wet years.
- Carpenter, Seton & Cayoosh: 7% – 10% increase by 2050; 14% – 16% by 2080.

- Dry years for these catchments will be similar to the past, wet years will be wetter.

Seasonal Inflow:

- Loss of glaciers will impact La Joie inflows.
- La Joie peaks will be one month earlier; Carpenter, Seton & Cayoosh one month later.
- Summer flows will decrease, fall & winter flows will increase.

Work is being done through the La Joie dam upgrade project to assess if the climate change inflow estimates might alter how La Joie dam may perform both with the current interim lowered and normal reservoir levels. However, at the writing of this document, the work has not been completed.

3.2.5 Bridge 1 U1 - 4 Upgrade

The Bridge 1 Generating facility is currently in Preliminary Design stage for the unit upgrades. As summarized in the Bridge River Facility Asset Plan (BC Hydro, 2019a), the generating units have been identified to be in poor or unsatisfactory condition. With the turbines having been upgraded in 2002 – 2003 and the recent replacement or upgrade of major equipment such as transformers, switchgear and powerhouse balance of plant components, the generating units are now planned for upgrades as the generating units have been in operation for almost 70 years since original commissioning. Without intervention the units will continue to degrade.

The powerhouse foundation stability was assessed in more detail in the Bridge 1 Feasibility Geotechnical Design study (BC Hydro, 2018b). This study concluded that:

- The existing bleeder wells are heavily relied upon to maintain powerhouse stability under normal operation, and are under review by Dam Safety. Since the completion of the BR1 Geotechnical Design study, Dam Safety is implementing plans for installation of a second valve in the bleeder wells to provide a backup should one valve fail[2].

- The new generator design will need to consider the annual tilting cycle that the current powerhouse experiences, which can be performed using recently installed digital equipment.
- Removal of the existing generators and install of the new equipment will cause a change in the load distribution of the powerhouse. Monitoring and tracking of this movement will be required during construction.
- The weight of the new generating units should be designed to match the weight of the original units.
- The powerhouse and penstocks are susceptible to significant damage during a 1:475 – 1:1000 year earthquake. Damage to the foundation could also be induced by mechanisms other than seismic.
- The existing powerhouse will remain seismically deficient based on current design standards, and that future capital works or updates to the Bridge River Facility Asset Plan should take this into consideration.

Further discussion on the choice to upgrade the existing BR1 facility instead of replacing it with a new facility is discussed in Section 3.3.2. However, it is likely this geotechnical study was not available when the current Bridge Facility Asset Plan was developed.

3.2.6 Other Bridge Plant Upgrades

Recent works to improve the reliability of the existing Bridge River generating facilities have included (BC Hydro, 2019a):

- Bridge River 1 Unit Transformer Replacement (F2018)
- Bridge River 1 Electrical Protection Upgrade (F2018)
- Bridge River 1 Unit Switchgear Replacement (F2018)
- Bridge River 1 Powerhouse Pipe System Replacement (F2017)

2 Email communication between D.Sakamoto and C.Bray dated 2020 June 18 6:56am, Subject: RE: Bridge River powerhouse.

- Bridge River 1 Penstock Leakage Detection & Protection (described further below) (F2017)
- Bridge River 2 PIV Hydraulic Controls Upgrade (F2016)
- Bridge River Townsite Redevelopment (F2016)
- Bridge River U5 & 6 Upgrades (F2020)
- Bridge River U7 & 8 Upgrades (ongoing)
- Bridge River 2 Penstock 1 & 2 Interior Recoating (ongoing)
- Bridge River 1 Slope Drainage Improvement (ongoing)

3.2.7 Bridge River Penstocks

Beyond the recoating projects noted above, several projects have been initiated to alleviate problems identified with the Bridge River penstocks. Through implementation of these projects, many of the risks attributed to these problems have been reduced or eliminated.

3.2.7.1 Penstock Leakage Detection System

The Bridge River 1 Powerhouse is serviced by four penstocks that emerge from tunnels through Mission Mountain. Located on high steep slopes above Seton Lake, these penstocks could be damaged or ruptured due to seismic activity, slope movements, or differential movements between the penstocks and powerhouse. With only Penstock Inlet Valves (PIV) to control flow from Carpenter Lake into the penstocks, if the PIVs were to be open during a penstock rupture, the resulting uncontrolled release of water through the rupture could cause extensive damage on the penstock slopes, into the powerhouse, or impact other neighbouring infrastructure.

To address this risk, work has been completed to install a penstock leakage detection system at Bridge River Generating Station 1 (BC Hydro, 2019b), which has been in operation since 2016. Coupled with the PIVs being designed to close rapidly (in 20 seconds), the ability to identify and respond to a leakage in the penstock is available. The new system provides a more robust method for determining leakage than the system originally installed with the facility, which had been prone to freezing and sediment buildup, and had been taken out of service. However, multiple sensors on the new system are planned to be replaced to improve their operational reliability[3].

3.2.7.2 Surge Spill

To protect the penstocks from transient pressures caused by rapid gate closure, surge shafts were part of their original design. Through the development of the Penstock Leakage Detection System, analysis of hydraulic transients in the penstock indicated that numerous emergency gate closure scenarios could cause surges large enough to overtop the surge shafts and send an uncontrolled release of water down the penstock slopes. However, in selecting the design scenarios, the selected scenarios did not include rapid gate closure during a penstock rupture as the resulting rupture flows would be far more severe than the surge caused by the gate closure. Instead, several operational gate closure scenarios were identified. These operational scenarios could be where the PIV are inadvertently operated and cause a surge spill; or closure of the PIV during penstock leakage situations that are less than full rupture flow.

To alleviate the risks associated with these operational surge spill scenarios, various design options to contain or control the surge flow were assessed. The recommended alternative to be carried forward to feasibility design is to provide two containment structures below each of the existing surge shafts (BC Hydro, 2016a). BC Hydro initiated project GY-0248 in 2018 to develop these containment structures, with the project having completed its Preliminary Design (BC Hydro, 2020a) and now in early Implementation phase.

3.2.7.3 Penstock Inlet Valves

The penstock inlet valves (PIVs) remain a vital link to maintaining control of water at the head of the penstocks. The condition of the PIVs were assessed (BC Hydro, 2016b) to identify any further works that may be

[3] Personal conversation with Dam Safety Engineer Chris Bray (July 22, 2020)

required to improve the reliability and functionality of the PIVs. This analysis determined:

- The PIVs are capable of closing against rated unit flow of 18.1 m^3/s;
- The PIVs are likely to close against a maximum flow of 24 m^3/s. However, this depends on the accuracy of assumed dynamic torque coefficients used in the calculations;
- The PIVs are not capable of closing under flows greater than 24 m^3/s due to limitations of the existing valve actuating systems.
- Theoretical analysis predicts that the PIV hardware (casing, shaft, disc) are capable of withstanding the stresses and displacements during closure against the predicted maximum rupture flow of 74 m^3/s, provided these components are in a fault-free conditions (BC Hydro, 2016b).

There remains the concern that the PIVs cannot close under full penstock rupture. Since it has been shown that the PIV hardware should be capable of withstanding the stresses associated to closure under this flow, it remains feasible that the PIVs can be upgraded to close under full flow without extensive replacement of the existing valves. However, the gates remain operable only locally, which will decrease the ability to close the gates immediately upon leakage detection. A project to address issues with the PIVs is being planned, but as of May 2020 has not been initiated.

3.2.8 Penstock Recoating

Several recoating projects have been initiated to increase the longevity of the powerhouse penstocks.

- GM-0182: BR1 Strip and Recoat Penstocks 1 – 4 Interior
- GM-0011: BR2 Strip and Recoat Penstock 2 Interior

Several projects are also proposed:

- G001767: BR1 Surge Tower 1 Steel Liner Strip and Recoat
- G001768: BR1 Surge Tower 2 Steel Liner Strip and Recoat
- GM-0183: BR1 Tunnel Steel Linter Strip and Recoat
- G000491: BR2 Tunnel Steel Linter Strip and Recoat

3.2.9 La Joie Dam Upgrade Plan

A project to design improvements to La Joie dam is in Conceptual Design phase. Several alternatives to upgrade the La Joie facility will be assessed, including:

- Do nothing
- Decommission
- Rehabilitate to the full reservoir storage elevation (existing design)
- Rehabilitate to a reduced reservoir storage elevation

The Conceptual Design Plan (BC Hydro, 2019c) includes the following activities:

- Consultation and engagement with St'at'imc.
- Further assessment of the Bridge River system performance at the current reduced reservoir operating levels at La Joie to test the likelihood that this operating regime will cause increased risk of higher flows resulting in impacts to fish and fish habitat downstream;
- Refinement of operating procedures which may also reduce the risk or impact of embankment failures under the current reservoir operating regime.
- Further seismic assessment to clarify potential dam deformation, estimates of cracking to the dam facing, and estimate potential post-earthquake leakage as a result of this potential cracking.

Work is progressing, but no significant project decisions have been made at the time of preparation for this Status Report.

3.2.10 Seton Unit Upgrade

The unit upgrade work remains the highest priority for the Seton system, as meeting the WUP Order target flow schedule requires near continuous conveyance at the Seton facility to pass annual inflows from the Bridge-Seton system. Should the Seton facility be out of service due to forced outages or increased maintenance upgrades requirements in the aging facility, water must be stored in upstream reservoirs (Downton or Carpenter

Lakes), spilled through Seton dam into the Seton River, or spilled through Terzaghi dam to the Lower Bridge River.

To assist in the development of the Seton Unit upgrade project, additional work has been performed to identify potential methods to bypass flows from the canal past the Seton generating facility (BC Hydro, 2020b). The benefits of the bypass are to:

- Enable the continued passage of flows from the Bridge River generating facilities through the Seton system with minimal alteration to current operations when an extended outage of the Seton generating unit is required for maintenance or during replacement. This flow continuity avoids regulatory, reputational, and environmental risks associated with long duration outages at Seton.
- Provide the long term benefit of enabling the canal to operate when the Seton generating station has forced or planned outages. Currently, if the Seton station has a prolonged outage, the canal cannot be used to maintain flows into the two spawning channels during warmer summer months as the canal water feeding the spawning channels becomes too warm. This calls for the costly and environmentally risky need to maintain flow to these spawning channels with pumping.
- With a suitable design, the bypass may provide a secondary safe passage for downstream migrating fish when the powerhouse is not in operation. This aspect will be reviewed in the Feasibility Design of the bypass intended to start towards the end of 2020.

3.3 Facility Asset Plans

Prioritization of dominant risk reduction concepts and capital costs was assessed in the Bridge River System Study at a high level by grouping assets at a facility level rather than breaking facilities further into components. A risk reduction prioritization was subsequently refined to a component level in each of the Facility Asset Plans, as there are many more factors of existing asset life cycles and economic valuations that need to be considered.

The purpose of the Facility Asset Plans is to provide a robust understanding of the issues, risks and opportunities faced by a specific facility, and the proposed long term investment strategy that is believed to offer the best value solution.

The Facility Asset Plans are live documents, and have been updated with the current understanding of the dominant risks associated with each facility and the system. The updated Facility Asset Plans reflect the new information available since the completion of the System Study in 2014, and outline the current strategy for sustainment and risk reduction prioritization for each facility and the whole system.

3.3.1 La Joie Generating Facility

The Facility Asset Plan for the La Joie Generating Station was last updated in December 2017 (BC Hydro, 2017b).

Upgrade to LAJ dam may take many years to implement. To manage dam safety risks at La Joie dam, Downton Lake reservoir is currently being operated at an interim normal maximum elevation of 734.0 m (BC Hydro, 2015), while concepts to upgrade LAJ dam are being developed. The Bridge River System is consequently currently constrained with the loss of storage at Downton and the reduced water conveyance capability at the BR1 and BR2 Generating Stations. This increases the likelihood of higher flows at Terzaghi dam into the Lower Bridge River, exceeding the Water Use Plan Order target flows schedule.

The timing of the recommended investments consequently has to be coordinated in order to manage the flows in the Lower Bridge River. The general Bridge River system investment strategy is to restore the BR1 and BR2 water conveyance capability starting with Bridge 2 units (G5-8), followed with the Bridge 1 units (G1-4) while addressing the La Joie facility seismic and seepage risks to restore the full system storage capability.

The recommended investment strategy for La Joie in the 2017 Facility Asset Plan is to first address the pressing dam seepage and seismic issues through lowering of the reservoir coupled with short term investments to maintain reliability. There has already been some investment in the La Joie facility in recent years and five significant investments were identified over the next 20 years:

- Dam Seismic Upgrade
- Intake Tower Seismic Upgrade
- South Conduit Refurbishment
- Pressure Regulating Valve (PRV) Replacement
- Unit Upgrade (Generator, Governor, Exciter, Turbine End of Life Replacements)

Work to assess the upgrades to La Joie dam are currently ongoing, which will determine if the upgrades will enable the operation of La Joie at its original reservoir operating level as recommended in the 2014 System Study, or a new alternative can be identified.

3.3.2 Bridge River

The Facility Asset Plan for the Bridge River Generating Stations was last updated in March 2019 (BC Hydro, 2019a). Considering that it will not be possible to move the location of the BR1 powerhouse in the next 20 to 40 years given the complexities of such a project, it was recommended that investment continue in the BR1 and BR2 generating facilities. However, the various completed and ongoing efforts to understand and reduce the risks in operating the existing BR1 powerhouse have been outlined in Section 3.2 of this Status Report.

Much of the equipment at Bridge River is original, rated as either fair or poor condition. Having exceeded industrial life expectancy, the Bridge Facility will require short term investment between 2019 and 2026 to maintain operational reliability. This strategy also addresses the pressing issue to maintain water conveyance between Carpenter reservoir and Seton Lake. The Bridge River facilities will however retain some dominant risks which include low seismic withstand and foundation stability. Work has been performed to reduce this risk to penstock vulnerability and the foundation risks at BR1 as outlined in Section 3.2 above.

Concerns regarding the seismic stability of Terzaghi dam originally identified in past studies have since been alleviated with more detailed analysis of the dam. These studies discussed in Section 3.2.1 highlight how the previous concerns regarding the seismic withstand of the dam and spillway have been reduced.

Another dominant risk currently under review is the transmission grid infrastructure. Bridge River provides voltage support to the 69 kV system in the Cariboo Region, but output is restricted due to stability concerns whenever BR1 T3, T30, 2L19 or 60L21 is out of service. Local regional load (69 kV) is much less than Bridge River generation, and generation is severely constrained whenever the 69/230 kV interconnection at BR1 is unavailable.

The recommended investment strategy for Bridge River in the 2019 Facility Asset Plan is to address the pressing water conveyance/unit reliability issues while minimizing the risk of spill at Terzaghi dam. This strategy is built upon the basis that the Bridge River system will remain in its current configuration (Lang & Groves, 2014). The initial investments are focused on BR2 as they not only improve reliability but also provide the largest increase in generation and water conveyance per invested dollar. The following five significant investments were identified over the next 10 years:

- BR2 G5/6 unit upgrade to eliminate 36% derating (completed in 2019)
- BR2 G7/8 unit upgrade to eliminate 25% derating (planned for 2020)
- BR1 G1-4 unit upgrade – to eliminate 5% derating and improve reliability on some of the oldest generators in the BC Hydro system.
- BR1 and BR2 penstock recoating projects to be coordinated with the unit upgrades
- TRZ Low Level Outlet Reliability Upgrade

The investment strategy attempts to address the highest priority risks and issues at Bridge River. However, some retained risks will include:

- Santa Clause Mountain Potential Slide: potentially poses a threat to the Bridge River powerhouses, adjacent communities, and Seton dam. The consequences of this slide could have a high potential for loss of life. The risk continues to be managed through annual slope inspection surveys to monitor for movement.
- BR1 Powerhouse Foundation Soils (BC Hydro, 2018b): The BR1 powerhouse is situated on a soil foundation that could cause movement of the powerhouse under normal operation and during a seismic event. Currently the risks of foundation movements under normal operation are mitigated through monitoring of groundwater pressures and operation of bleeder wells, as discussed in Section 3.2.5. However, there are no current plans to address the risk of potential powerhouse foundation movements due to earthquake greater than 1/475 return period events.
- Terzaghi dam Spills: With reduced storage capacity at Downton Lake until issues at La Joie dam can be rectified, and powerhouse operating constraints at BR1/2 and SON until those facilities can be upgraded, the potential for increased spills at Terzaghi dam remains.
- Penstock Seismic Withstand (BC Hydro, 2018b): Penstock rupture at BR1 could lead to uncontrolled release of flow from Carpenter Lake into Seton Lake. Safety risks associated with damage to the penstocks and inlet gates are being mitigated through various projects which are described in Section 3.2.7. However, work is not being done to improve the actual seismic withstand of the penstocks, and the damage or loss of the penstocks following a seismic event are not being addressed.

3.3.3 Seton Generating Station

The Facility Asset Plan for the Seton Generating Station was last updated in March 2017 (BC Hydro, 2017a). A component by component strategy was proposed to upgrade/refurbish the existing equipment at end-of-life over the next 10 years. The facility is a mixture of old and new assets, and is expected to have considerable life left, meaning that decommissioning or re-development is not appropriate.

Seton Lake Reservoir level is controlled by load factoring the releases from the Bridge River plants and if necessary spilling at Seton dam. However, continued operation of the Seton facility is becoming challenging. Improvements to the Seton facility have been modest, mainly directed at addressing aging components, with the intent of preparation for a unit upgrade initially planned in the 2022 fiscal year, but likely delayed into 2027. Most of the generating equipment is approaching end of life and requires significant investment.

The recommended Investment Strategy for Seton outlined in the 2017 Facility Asset Plan is to invest in the unit related assets to ensure reliability of water conveyance and manage flows down the Seton River in accordance with the Water License Order target flow schedule. There has already been investment in the Seton facility in recent years to address the highest priority risks and four significant investments were identified over the next 10 years:

- Unit Upgrade (Generator, Governor, Turbine End of Life Replacements).
- Penstock Interior Recoating: to address concerns of internal corrosion.
- Headworks Operating Gates Upgrade: to provide reliability of closure during an emergency.
- Left Bank Dyke Upgrade: to address the risk of failure in a seismic event resulting in an uncontrolled release of flow into the Seton River.

Further works highlighted for resolution include:

- The aqueduct may fail in a seismic event causing an uncontrolled release of Seton Lake into Cayoosh Creek. Much of the aqueduct is built on loose granular soils which may be subject to liquefaction, which could result in a further uncontrolled release.

- Left dyke bank: there is a risk the left dyke bank could fail in a seismic event resulting in uncontrolled release of Seton Lake into the Seton River.
- Flood passage: there remains concern that the reliability of the discharge facilities is poor. All discharge facilities are manually operated and rely upon staff to be dispatched to operate them. Due to a slow progression of alkali aggregate reaction, the concrete around the Spillway Operating Gate continues to slowly "swell" with age reducing clearance and causes binding. Although the process is slow at Seton, it must be monitored to ensure gates remain functional. Additionally, during the design flood, the headwork gates to the power canal must be closed to prevent overtopping of the canal liner. Such overtopping could erode the embankment.

3.4 Status Update

Based on the new information developed since the completion of the 2014 Bridge River System Study, a reassessment of the key dominant risks can be performed using the new information summarized above. The original risk reduction prioritization chart copied into this report as Figure 3-1 showing the qualitative reduction of the dominant risks based on prioritization of the four key concepts for the four Bridge River facilities can be updated with the following new information:

- The assessed risk of a Terzaghi seismic dam failure has been reduced, and the dam can be refurbished instead of replaced.
- The upgrade costs to refurbish Terzaghi dam to provide seismic reliability are much less than the cost to rebuild the dam.
- The assumed dam breach risk reduction credit associated with a new Terzaghi RCC dam (which could withstand overtopping) are now applied to the plans to upgrade considerations for La Joie dam.
- Cost estimate updates for all projects (except BR1 Replacement) have been updated from the 2014 estimates based on the current BC Hydro Asset Management Capital Plan.

These changes have been implemented in Figure 3-2 below. For comparison, the original 2014 curve has been shown on the chart in green. The likelihood and severity rankings from 2014 and updated in 2020 are included in Appendix A, cost estimates from the Capital Plan as provided and summarized in Appendix B. The 2020 project cost estimates have been selected to correspond with the costs used in the commercial analysis for the Bridge projects (Cardno, 2020).

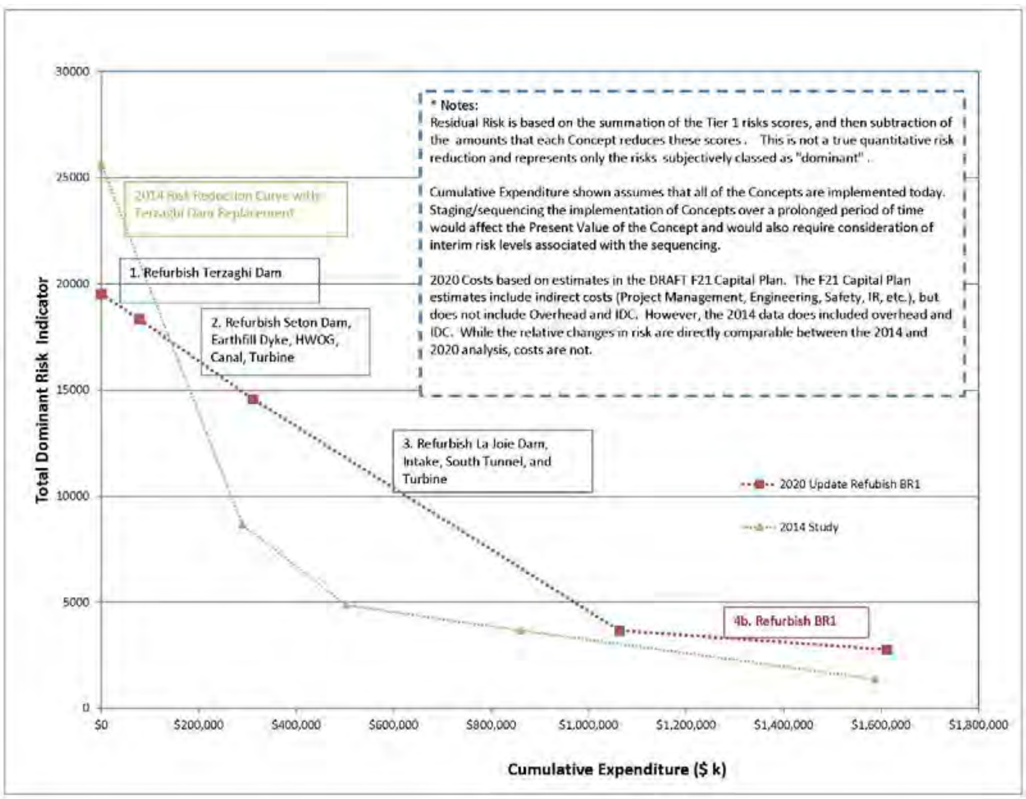

Figure 3-2: Updated Risk Reduction* by Concept (with reduced La Joie static risk)

While the 2014 estimates are all planning level estimates and included project overhead or interest during construction (IDC) (Le Couteur, 2013), the 2020 estimates are mix of planning level and more mature estimates, but do not include IDC or overhead. As a result, while the relative changes between the 2014 and 2020 dominant risk are comparable, the cost/risk slopes are not directly comparable.

It should be noted that the construction cost for the refurbishment of the Bridge 1 generation facility is based on the recent Feasibility Design estimate for that project (Toring, 2019), which is an estimate with higher confidence than some of the planning level estimates used to derive the Capital plan. Regarding the powerhouse estimates, as no further work has been performed to assess construction of a new Bridge 1 powerhouse since 2014, an updated cost estimate for that work is not available. The closest comparison for an update cost for a new Bridge 1 facility could be the recently installed John Hart powerhouse replacement project, which included a new underground 130MW powerhouse and tunnel, costing $1.1B. For the larger 200MW proposed BR1 replacement, cost would expected to be higher.

One difference between the 2014 and 2020 curve is that the total dominant risk value starts lower with the 2020 curve. This is because the assessed risk from seismic failure of Terzaghi has been reduced due to updated seismic analysis (KCB, 2015), (KCB, 2016).

With the reduction in cost for refurbishment of Terzaghi dam instead of replacement, the cost/risk reduction ratio for Terzaghi flattens. This redistribution of risk has coincidentally resulted in the improvements to Terzaghi having a similar slope (similar benefit) to the Seton and La Joie improvements on the cost/risk curve. For this reason, these projects are plotted in order of increasing project cost. However, based solely on Figure 3-2 these projects could be performed in any order. Caution is required when considering this ranking, as there are uncertainties in the risk characterization and scoring. The effort was also heavily weighted towards dam safety and environmental consideration, with less consideration to generating revenue.

If Terzaghi dam and its components are refurbished as recommended (KCB, 2016) instead of the 2014 leading concept to replace the dam with a new roller compacted concrete (RCC) dam, the potential for Terzaghi to fail due to overtopping remains a risk if nothing is done at La Joie. For this reason, the risk reduction attributed to the RCC dam alternative in 2014 is shifted in this assessment to La Joie. Regardless of which option is chosen for La Joie, as long as the project proceeds the risk of dam breach will be addressed. This 2020 update thus emphasizes the importance of completing the La Joie Dam upgrade.

While improvements to La Joie retain the greatest risk reduction potential for this collection of Bridge River upgrades, given its high cost and impacts to the overall operation to the system, the selection of these improvements will be done with careful consideration and engagement. Operating Downton Lake at its current lowered water surface elevation has helped to reduce the current dam failure risks. However, with the potential for increased forced outages due to the age of the generating facilities, the risk of spilling above target levels in the Lower Bridge and Seton rivers has increased. For this reason, a priority has been placed on improving the reliability of the Seton and Bridge generating facilities.

4 Conclusions

Building upon the 2014 Bridge River System Study, work has progressed to better understand the identified information deficiencies. This has included new studies to further the understanding of the concerns and operational risks with the facilities, investigate information deficiencies, and to inform risk reduction effectiveness on the selected options for asset management.

A key risk with the current configuration is associated with water management in the Bridge-Seton system which can result in higher flows into the Lower Bridge and Seton rivers, and resulting impacts to fish and fish habitat. This risk can be mitigated through storage of water at La Joie dam or maintenance of water conveyance through the Bridge / Seton generating facilities. However, due to dam safety concerns at La Joie dam, Downton reservoir is currently being operated at a lower elevation until the concerns at La Joie dam can be resolved. This latter concern has been compounded by decreasing reliability of the Bridge and Seton generating facilities due to age.

A further issue highlighted in the 2014 System Study was regarding seismic concerns at Terzaghi dam. The study identified uncertainty in the seismic withstand of the dam and post-seismic operation of the spillway which could lead to a potential dam failure. Given the high consequence associated with this scenario, subsequent work was performed to further assess the seismic withstand of the dam. These studies have since confirmed that the dam has a robust seismic withstand which can be further improved upon with modest civil works.

With the assessed likelihood of dam breach at Terzaghi dam greatly reduced, work has now focused on lowering the likelihood of higher flows in the Lower Bridge and Seton rivers. Upgrade work to the Bridge River and Seton Powerhouses and development work to determine a suitable path for La Joie dam upgrades have been prioritized to meet this goal.

The following is a summary of observations that can be made from the review of material compiled in this 2020 Status Report:

1. Alternatives to upgrade La Joie dam will be investigated in project GM-0246. While retention of a dam at the current elevation is BC Hydro's current preferred upgrade concept, the La Joie project will develop alternatives through a consultative process with St'at'imc and other key stakeholders within the Bridge River System. The dominant risk associated with excessive seepage through the dam has been temporarily mitigated with periodic repairs and by lowering of the Downton reservoir.
2. Updated seismic assessments of the Terzaghi dam indicate that initial seismic concerns can be addressed with a refurbishment concept with much lower cost of about [redacted] direct planning level costs in 2016 dollars (KCB, 2016) as compared to a new dam, if all proposed improvements are implemented. However, the extent of Terzaghi dam refurbishment may be impacted by the results of the pending Computational Fluid Dynamics analysis of spillway capacity and further assessment of the Low Level Outlet.
3. While the BR1 underground powerhouse concept should be retained in long-term facility optioneering, the current Facility Asset Plan indicates this major investment has been deferred to address the pressing risks associated with maintaining water conveyance and generation reliability. Current investments will prolong the service life of the BR1 generation facility, however residual risks regarding seismic vulnerability of the penstock and powerhouse will remain.
4. Work to progress the upgrades to the Seton generating units continues. Upgrades to the dam components of the Seton generating facility are planned to follow upgrading of the generating units.
5. To facilitate the upgrades to the Seton generating units, conceptual design of a bypass flow system from the power canal into the Fraser River has been completed. A bypass would maintain continuity of

flow through the Seton system during the prolonged Seton plant outages required during its refurbishment and future maintenance.

6. Considerations need to be made on the potential impacts of climate change. Based on some initial climate projections:
    a. Warming trends will continue and winter precipitation will increase. As a result, summers will become warmer and drier but winters will become wetter.
    b. La Joie will see a greater variation in flows with drier and wetter years. For Carpenter, Seton and Cayoosh, drier years will be similar but wetter years will be wetter.
7. While work progresses to remove them, many of the dominant risks outlined in the 2014 System Study remain (as outlined in Appendix A). The only exceptions are the risks associated with the seismic concerns at Terzaghi dam and power systems at Bridge 2. Based on the refined seismic assessment, the concerns associated with a potential TRZ dam withstand under the Maximum Design Earthquake have been reduced.

The Bridge River system facilities are interdependent and establishing priorities for investment is complex. The system is currently constrained with the loss of storage at Downton and the reduced water conveyance capability at the BR1 and BR2 Generating Stations. This increases the risk of releases at Terzaghi dam into the lower Bridge River, exceeding the Water Use Plan Order targeted flows.

The timing of the upgrades consequently has to be coordinated in order to manage the flows in the Lower Bridge and Seton Rivers. As outlined in the current Facility Asset Plan, the general Bridge River system investment strategy is to maintain the BR1, BR2 and Seton generation conveyance capability. Having already started with upgrades to the BR2 units with BR1 and SON being planned, work to address the La Joie facility seismic and seepage risks to restore the full system storage capability is underway. The updated information and risks in this report are in general alignment with the current investment strategy for the Bridge River system.

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Appendix A
Bridge River System Dominant Risks

Dominant Risks (Tier 1) – Table 1 from MER2014-032

	#	Asset	Primary Hazard	Failure Description	Likelihood Measures	Primary Severity Driver
LA JOIE	1	La Joie Dam	Construction Deficiencies and Material Ageing and Degradation	Degradation of shotcrete face and deformation over time under static load (dam over-steepened, not constructed according to design). Without timely intervention and reservoir lowering, seepage may increase at an accelerated rate to the point of rockfill failure. Further, maintenance may not mitigate risk from long term deformation of dam.	Return period for end of life of the existing upstream concrete facing under static conditions is between 10-100 yrs. X 0.4 (probability of cascading TRZ dam failure) **L5**	Cascading failure of LAJ and TRZ Dams with associated flooding of inhabited areas down to the lower Fraser Valley. **S7 / safety**
			Earthquakes	Upstream shotcrete water barrier compromised to the extent that flow-through capacity of the rockfill exceeded.	Withstand is considered to have an AEP of up to 1/2475, but probability of failure could potentially be higher if a breach in the shotcrete were concentrated in one area. Probability = 0.4 that LAJ and TRZ reservoir levels are such that LAJ earthquake failure leads to overtopping and cascading TRZ dam failure. **L3**	Cascading failure of LAJ and TRZ Dams with associated flooding of inhabited areas down to the lower Fraser Valley. **S7 / safety**
	2	La Joie Intake Tower	Earthquakes	Seismic movement or damage to the intake tower or the conduits preventing safe discharge of water through the release facilities.	The functionality of the outlet facilities is expected to be maintained to at least 0.1g (1/1000). **L4**	Drying of the Middle Bridge River (with the exception of seepage through the dam, which post-seismic may increase) **S5 / environmental**
BRIDGE / TERZAGHI	3	TRZ Spillway Chute	Floods	Overtopping of the left wall of the spillway chute and potentially eroding the rockfill toe of the embankment dam. The capacity of the chute to pass high flows is in question.	Prob of 500 m^3/s spill event(~1/500 X 0.2 (assumed prob of failure due to overtopping of wall) **L3.5**	Failure of TRZ Dam with associated flooding of inhabited areas down to the lower Fraser Valley. **S7 / safety**
	4	TRZ Dam	Earthquakes	Deformation of the dam / loss of structural strength. Potential liquefaction leading to overtopping or seepage failure.	Dam has been assessed to withstand 0.15g earthquake (1/ 1750). **L3.5**	Failure of the dam and downstream consequences (Report H2804). **S7 / safety**

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Dominant Risks (Tier 1) – Table 1 from MER2014-032

	#	Asset	Primary Hazard	Failure Description	Likelihood Measures	Primary Severity Driver
	5	TRZ LLO	Earthquakes	The post-seismic operability of the LLO is in question. If the dam slumps but does not breach, reservoir drawdown may be necessary to safeguard against piping failure.	LLO was not seismically upgraded as part of Gate Reliability Program. The capacity of the LLO to lower the reservoir also depends on the joint probability that LAJ will require drawdown in the same event. **L3**	Failure of the dam with associated downstream consequences (Report H2804). **S7 / safety**
	6	BRG1 and BRG2 Power System	Many possible hazards including earthquakes, landslides, transmission grid failures	Extended forced outage (months) of water conveyance facilities including the powerhouse and transmission grid infrastructure leading to higher probability of TRZ spills.	The vulnerability of the transmission grid is amongst the most likely of hazards to lead to extended outages. Prob of extended outage assumed to be about 1/50 X prob of inflows causing significant spills during the outage period (assumed to be ½ of the year) **L5**	High spill discharges (>100 m^3/s) to the Lower Bridge River downstream of TRZ would result in significant sediment movement and habitat impact. This can include fish stranding following conclusion of spill event. **S5 / environmental**
	7	BRG Penstocks	Earthquakes, landslides, material ageing and degradation	Rupture of penstocks due to support failure and failure due to shock, impact and cyclic loading. Penstock slope failure due to mud/rock slides.	Penstocks have been assessed to withstand 1:1500 to 1:2475 X 0.5 (assumed probability of worker vulnerability). Probability of 1/30 for muck pile failure **L3 to L5**	Potential for worker fatalities in powerhouse (more so for BRG1). **S5 to S6 / Safety**
	8	BR1 Powerhouse	Earthquakes, flooding, design and construction	Differential settlement or deformations / artesian uplift from severe rainstorms or high spring runoff causing powerhouse to shift away from penstocks, rupturing it and losing flow control thereby compromising the powerhouse structure. Bleeder wells are used to reduce the high pressures. Control of pore pressures in the foundation may be inadequate. Infrastructure to maintain the stability of the BR1 Powerhouse may not work and the instrumentation to monitor the stability may be inadequate	The foundation of the powerhouse has been assessed to withstand ~0.14g to 0.2g (~ 1:1000 – 1:2475) X 0.5 (assumed probability of worker vulnerability) Structural stability of the powerhouse is questionable due to foundation issues. Due to artesian pressures, the powerhouse moves and the east end of the powerhouse is slowly sinking. **L3.5**	Potential for multiple worker fatalities in powerhouse. **S6 / Safety**

Dominant Risks (Tier 1) – Table 1 from MER2014-032

	#	Asset	Primary Hazard	Failure Description	Likelihood Measures	Primary Severity Driver
SETON	9	SON Concrete Dam and Spillway	Earthquakes	Liquefaction of foundation soils leading to dam failure. Seton dam is not founded on bedrock. With liquefaction, the structure might undergo displacement downstream as well as some accompanying tilting (differential settlement) in both upstream and downstream and cross-valley direction.	Concrete dam foundation has about a 1:2500 withstand. (SON05DI 0.15g no expected liquefaction, 0.26g local liquefaction). **L3.5**	Population at risk is transient, and includes any workers in a downstream lumberyard. **S6 / safety**
	10	SON Left Bank Earthfill Dyke	Earthquakes	Slumping and overtopping failure.	Seismic withstand is estimated to be about 1:2475. **L3.5**	Failure of the dyke results in uncontrolled release of Seton Reservoir into Seton River. **S6 / safety**
	11	SON Canal	Earthquakes	Embankment / liner failure due to foundation liquefaction leading to sudden release of water.	Canal withstand assessed to be about 1:2,475 (0.15g) to 1:5000 (0.26g). (liquefiable assessment only). **L3 to 3.5**	If canal is breached upstream of the First Nation Band residences, there would be people at risk. **S7 / safety**
	12	SON HWOGs	Earthquakes	The HWOGs cannot be closed against flow; any embankment or fish flow release failure could lead to draining the SON reservoir and downstream impacts.	Likelihood unknown, assumed to be about 1:1,000. **L4**	Draining the reservoir to the sill of the HWOGs and resulting downstream environmental impacts to fisheries would be high profile. **S5 / reputation and environment**
	13	SON Power System	Many possible hazards	Outage of SON power facilities (even shorter term outages), including the powerhouse or transmission grid infrastructure, resulting in high spills at SON and at TRZ.	Forced outage (frequent occurrence) X (prob of local inflow + extended BRG plant flow exceeding total 200 cms) (nominally 1/50). **L5**	Severity rating is based on exceedance of 200 cms spill due to failure of a BC Hydro sub-system. High impact to fish habitat, loss of regulatory support. **S5 / environmental**

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Updated Dominant Risks Summary

		Asset	Failure Description	Likelihood				Severity			
				Before		After		Before		After	
				2014	2020	2014	2020	2014	2020	2014	2020
LA JOIE	1	La Joie Dam	Degradation of shotcrete face and deformation over time under static load (dam over-steepened, not constructed according to design). Without timely intervention and reservoir lowering, seepage may increase at an accelerated rate to the point of rockfill failure. Further, maintenance may not mitigate risk from long term deformation of dam.	L4 (with reduced water level)	L4 (with reduced water level)	L2	L2	S7	S7	S7	S7
			Upstream shotcrete water barrier compromised to the extent that flow- through capacity of the rockfill exceeded.	L3	L3	L2	L2	S7	S7	S7	S7
	2	La Joie Intake Tower	Seismic movement or damage to the intake tower or the conduits preventing safe discharge of water through the release facilities.	L4	L4	L2	L2	S5	S5	S5	S5
TERZAGHI	3	TRZ Spillway Chute	Overtopping of the left wall of the spillway chute and potentially eroding the rockfill toe of the embankment dam. The capacity of the chute to pass high flows is in question.	L3.5	**L2**	L1	L1	S7	S7	S7	S7
	4	TRZ Dam	Deformation of the dam / loss of structural strength. Potential liquefaction leading to overtopping or seepage failure.	L3.5	**L2**	L1	L1	S7	S7	S7	S7
	5	TRZ LLO	The post-seismic operability of the LLO is in question. If the dam slumps but does not breach, reservoir drawdown may be necessary to safeguard against piping failure.	L3	L3	L2	L2	S7	S7	S5	S5
	6	BRG1 and BRG2 Power System	Extended forced outage (months) of water conveyance facilities including the powerhouse and transmission grid infrastructure leading to higher probability of TRZ spills.	L5	L5	L5	L5	S5	S5	S3	S3 (replace) **S5** **(rehab)**
	7	BRG Penstocks	Rupture of penstocks due to support failure and failure due to shock, impact and cyclic loading. Penstock slope failure due to mud/rock slides.	L3-L5	L3-L5	L2 (replace)	L2 (replace) **L4.5** **(rehab)**	S5-S6	S5	S5	S5

		Asset	Failure Description	Likelihood				Severity			
				Before		After		Before		After	
				2014	2020	2014	2020	2014	2020	2014	2020
	8	BR1 Powerhouse	Differential settlement or deformations / artesian uplift from severe rainstorms or high spring runoff causing powerhouse to shift away from penstocks, rupturing it and losing flow control thereby compromising the powerhouse structure. Bleeder wells are used to reduce the high pressures. Control of pore pressures in the foundation may be inadequate. Infrastructure to maintain the stability of the BR1 Powerhouse may not work and the instrumentation to monitor the stability may be inadequate	L3.5	L3.5	L2 (replace)	L2 (replace) **L3** **(rehab)**	S6	S6	S6	S6
SETON	9	SON Concrete Dam and Spillway	Liquefaction of foundation soils leading to dam failure. Seton dam is not founded on bedrock. With liquefaction, the structure might undergo displacement downstream as well as some accompanying tilting (differential settlement) in both upstream and downstream and cross-valley direction.	L3.5	L3.5	L2	L2	S6	S6	S6	S6
SETON	10	SON Left Bank Earthfill Dyke	Slumping and overtopping failure.	L3.5	L3.5	L2	L2	S6	S6	S6	S6
SETON	11	SON Canal	Embankment / liner failure due to foundation liquefaction leading to sudden release of water.	L3-L3.5	L3-L3.5	L2	L2	S7	S7	S7	S7
SETON	12	SON HWOGs	The HWOGs cannot be closed against flow; any embankment or fish flow release failure could lead to draining the SON reservoir and downstream impacts.	L4	L4	L2	L2	S5	S5	S5	S5
SETON	13	SON Power System	Outage of SON power facilities (even shorter term outages), including the powerhouse or transmission grid infrastructure, resulting in high spills at SON and at TRZ.	L5	L5	L5	L5	S5	S5	S5	S5

Appendix B
Project Cost Summary

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Asset Management DRAFT Capital Plan Project Costs (extracted Aug 2020)

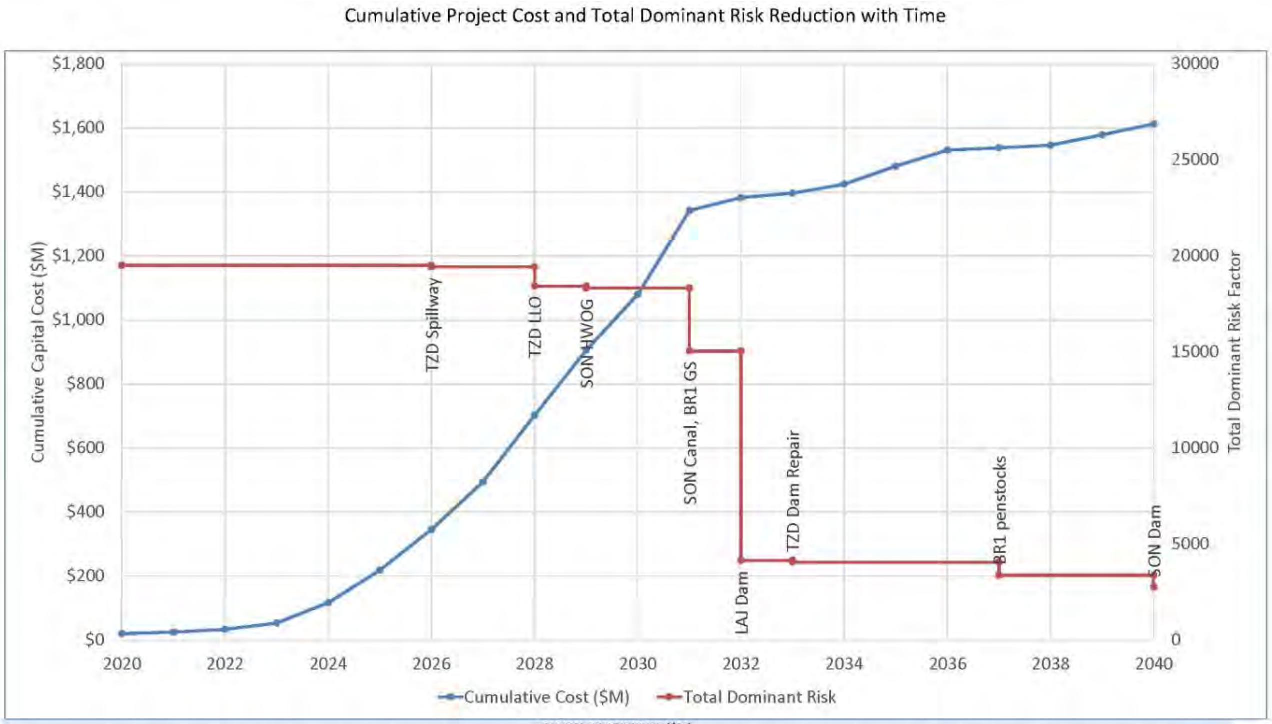
Project Code	SAP Code	Project Name	Project Stage	Start Year	Total
BRIDGE RIVER 1					[redacted]
G000474	GM-0085	Bridge River – Intake Seismic Withstand Improvements	Proposed	2030	[redacted]
G000776	GY-0239	Bridge River 1 Replace Units 1-4 Generators / Governors	Definition	2015	[redacted]
G000485	GM-0182	Bridge River 1 - Strip and Recoat Penstocks 1-4 Interior	Identification	2018	[redacted]
G003467	GY-0150	Bridge River 1 Improve Slope Drainage	Identification	2016	[redacted]
G000661	GY-0124	BR1 - Replace Unit Circuit Breakers	In-Service	2013	[redacted]
G004327	TBD	Bridge River 1 - Penstock Concrete Foundation Refurbishment	Proposed	2022	[redacted]
G003685	GM-0302	Bridge River 1 - U1 - U4 Penstock Inlet Valves Replacement	Proposed	2029	[redacted]
G000477	GM-0008	Bridge River 1 - U1 - U4 Penstocks Exterior Refurbishment	Proposed	2030	[redacted]
Total Facility					[redacted]
BRIDGE RIVER 2					[redacted]
G000489	GM-0011	Bridge River 2 - Strip and Recoat Penstock 2 Interior	Definition	2018	[redacted]
G000493	GY-0345	Bridge River 2 Upgrade Units 7 and 8	Implementation	2016	[redacted]
G000492	GY-0143	Bridge River 2 Upgrade Units 5 and 6	In-Service	2013	[redacted]
G000490	TBD	Bridge River 2 - Penstock Inlet Valves 1 and 2 Replacement	Proposed	2030	[redacted]
G003785	TBD	Bridge River 2 - U7 and U8 Runner Replacement	Proposed	2029	[redacted]
Total Facility					[redacted]
LA JOIE					[redacted]
G000459	GM-0246	Lajoie - Dam Improvements	Identification	2018	[redacted]
G002326	GM-0323	LaJoie - Governor Pressure Regulating Valve Replacement	Proposed	2022	[redacted]
G000463	GM-0144	LaJoie - Unit Upgrade	Proposed	2025	[redacted]
Total Facility					[redacted]

Asset Management DRAFT Capital Plan Project Costs (extracted Aug 2020)

Project Code	SAP Code	Project Name	Project Stage	Start Year	Total
SETON					[redacted]
G003026	GM-0076	Seton - Upgrade Unit	Identification	2018	
G000542	GM-0342	Seton - Aqueduct Seismic Withstand Upgrade	Proposed	2028	
G000543	GM-0119	Seton - Canal Flow Control Structure Upgrade	Proposed	2023	
G003238	TBD	Seton - Canal Refurbishment	Proposed	2024	
G002663	TBD	Seton - Dam Seismic Upgrade	Proposed	2034	
Total Facility					
TERZAGHI					
G000467	GM-0343	Terzaghi - Spillway Chute Access Improvement	Identification	2019	
G001045	GM-0123	Terzaghi - Dam Upstream Cut-off Upgrade	Proposed	2028	
G000468	GM-0120	Terzaghi - Low Level Discharge Reliability Improvement	Proposed	2022	
Total Facility					

Project Cost Comparison ($M)

Component	2014	2020
Replace Terzaghi Dam (RCC)	[redacted]	-
Refurbish Terzaghi Dam	-	[redacted]
Refurbish La Joie Dam + Intake	[redacted]	[redacted]
Refurbish Seton Canal + HWOGs + Turbine	[redacted]	[redacted]
Refurbish Seton Dam + Left Dyke	[redacted]	[redacted]
Replace BR1 underground	[redacted]	-
Refurbish BR1 (including penstocks)	-	[redacted]
Total	[redacted]	[redacted]



CAPITAL EXPENDITURE ($M)

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	TOTAL
TZD spillway	[redacted]																					
TZD dam																						
TZD LLO																						
LAJ Dam																						
LAJ PH																						
SON canal																						
SON HWOG																						
SON dam																						
SON PH																						
BR1 units																						
BR1 penstocks																						
TOTAL	$ 20	$ 4	$ 9	$ 20	$ 63	$ 102	$ 127	$ 149	$ 208	$ 204	$ 175	$ 262	$ 40	$ 13	$ 28	$ 56	$ 51	$ 7	$ 8	$ 33	$ 33	
CUMM.TOTAL	$ 20	$ 24	$ 33	$ 53	$ 116	$ 218	$ 344	$ 493	$ 702	$ 905	$ 1,080	$ 1,341	$ 1,382	$ 1,395	$ 1,424	$ 1,480	$ 1,530	$ 1,537	$ 1,545	$ 1,578	$ 1,612	

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BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-2-3

2020 Bridge River System Economic Analysis and Financial Model

PUBLIC

CONFIDENTIAL APPENDIX

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BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-3

Facility Asset Plans

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FACILITY ASSET PLAN

BRIDGE RIVER

MARCH 2019

REVIEWED BY

Senior Field Manager: [signature] on behalf of Morgan McLennan

Director, Stations Asset Planning: [signature]

Director, Dam Safety: [signature]

Senior Vice-President, Integrated Planning: [signature]

PREPARED BY

Generation Asset Management: Alan Pattinson

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1. INTRODUCTION

The purpose of the Facility Asset Plan is to provide a robust understanding of the issues, risks and opportunities faced by a specific facility, and the proposed long-term investment strategy that is believed to offer the best value. Facility Asset Plans are key inputs to the fleet planning process. The investment strategies that are proposed in discrete facility asset plans will be reviewed collectively, and prioritized to provide the most appropriate suite of investments across the fleet given resource and financial constraints, outage planning and other considerations. As a result, lower priority investments will be deferred and considered in future planning.

1.1. The Facility Planning Process

The Facility Asset Planning process provides stakeholders with a transparent methodology for producing a documented strategy. It is a structured process to identify key issues and risks, and prioritize investment decisions for a specific facility or system. Data is consolidated from multiple parties throughout BC Hydro, including Station Field Operations, Dam Safety, Safety, Generation System Operations and Environmental. Key risks, issues and opportunities at a facility are identified, and compiled in the asset investment planning tool. The data is reviewed to consider factors such as the facility's strategic role, performance targets, risks and growth opportunities. The consequences and frequency of issues and risks are assessed through the lens of the Corporate Risk Matrix and Capital Investment Analysis Guide. Appropriate medium to long-term investments are identified for consideration in both the Generation and Corporate capital planning process.

1.2. The Facility Asset Plan

The Facility Asset Plan document is a concise record of the outcome of the Facility Asset Planning process. The primary audiences are Stations Asset Planning, Dam Safety, Station Field Operations and the Executive Management Team. Its primary intention is to provide:

- Current facility configuration, value and obligations
- Significant known issues, risks and opportunities
- Contextual performance and recent investments, based on last complete fiscal year
- High level scenarios considered to address issues, risks and opportunities
- Proposed investments aligned to the expected planning cycles of the business

By signing the Facility Asset Plan, management is agreeing that, to the best of their knowledge, the content is complete and accurate. In addition, that the proposed investment strategy reflects the best interests of BC Hydro at the facility level and is consistent with goals and objectives outlined in the Generation Strategic Asset Plan. The signature of the Senior Vice-President of Integrated Planning does not represent endorsement of the technical content, but confirms that the planning process has been appropriately followed, the right stakeholders engaged and broad agreement on the strategy for the facility has been reached.

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Once approved, the Facility Asset Plan's investment strategy will become an input for the Generation Fleet-Wide Planning process. This will determine whether the investments proposed in the Facility Asset Plan are optimal at a fleet level, or whether changes to the facility strategy are required.

The asset investment planning tool will be updated regularly to capture emerging issues, risks or opportunities, or changes to existing ones. The Facility Asset Plan will be updated as per the Stations Asset Management Manual (SAMM) or whenever new information leads to a significant change in the strategy for a facility.

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2. Facility Overview

Bridge River System Background

The four Unit Bridge River 1 and the four unit Bridge River 2 Generating Stations are located approximately 60km West of Lillooet and forms part of the cascading Bridge River system with La Joie Generating Station and the Seton Generating Station located upstream and downstream respectively. The entire river system is impounded by three dams. The most upstream dam is La Joie Dam which retains water in Downton Reservoir. Water then passes through the La Joie Dam and Generating Station to Carpenter Reservoir which is impounded by Terzaghi Dam. Terzaghi Dam is an earth-filled dam with two low-level outlet gates that allow minimum flows to go down the environmentally sensitive Lower Bridge River. Two spillway gates and a free crest overflow spillway are available for flood control. Carpenter Reservoir is the largest storage reservoir in the Bridge River system. Water is diverted from Carpenter to Bridge River 1 and Bridge River 2 via two 4 km long tunnels. Downstream of the Bridge River Generating Stations is Seton Dam which retains water in Seton Lake. Seton Lake is operated within a 0.6 m range which means that there is limited storage for water passing through Bridge River 1 and Bridge River 2. Water from Seton Lake flows into the Fraser River through the Seton Generating Station or down the Seton River.

The Bridge River Facility consists of:

- Carpenter Lake Reservoir
- Terzaghi Dam, which was completed in 1960
- The four unit, 200MW Bridge River 1 Generating Station, which was commissioned in 1954
- The four unit, 300MW Bridge River 2 Generating Station, which was commissioned in 1960

Bridge River generation is connected to the BC Hydro grid and stepped up to 230/360 kV at the Bridge River Terminal switchyard. The generation capability from Bridge River represents 5% of BC Hydro's total hydroelectric generation. For asset management purposes, Bridge River is classified as a "Key" facility. From 2012 to 2016 the facility produced between [redacted]n in annual revenue. However, five of the eight generators have been derated due to failures and deteriorating equipment resulting in a loss of 104MW or 21% of Bridge River's capacity from historic levels.

The overriding concern in the Bridge River System is that of water management and operating in accordance with the water licenses. The system is currently heavily constrained with limited allowable flows past Terzaghi Dam into the Lower Bridge River. At present, the generating capacities of all four units at Bridge River 2, and one unit at Bridge River 1 have been derated due to degrading equipment, reducing the flow of water that can be routed through the Generating Stations and hindering BC Hydro's ability to prevent excessive flows in the Lower Bridge River. System storage and flexibility is also impacted by the drawdown of the Downton Reservoir behind La Joie Dam which has been drawn down to manage dam safety risks and has reduced the storage buffer/flexibility of the Bridge River system.

The facility produces significant annual revenue and a greater level of investment is proposed within the next twenty years. The investment strategy is to avoid extended outages and a loss of generation from the facility while mitigating the risk of spills at Terzaghi Dam into the environmentally-sensitive Lower Bridge River.

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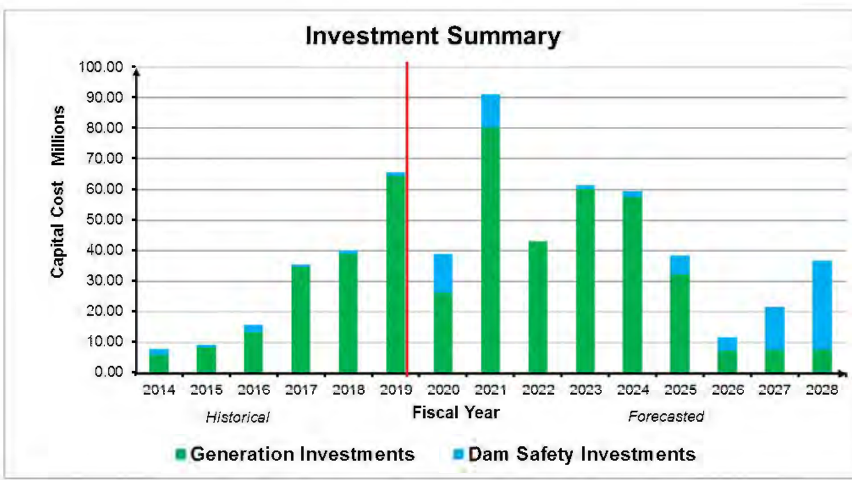
The following table summarizes key facility data:

Facility Name	Bridge River
Asset Classification	Key
Dam Classification	Extreme
Original In-Service Date(s)	BR1: 1948-1954 BR2: 1959-1960
Annual Revenue Range (F2012 to F2016)	[redacted]
Plant Maximum MW Rating	460/396MW[1]
Historic Annual Average Plant Generation	2479 GWh

[1] Nameplate: BR1 (4 x 50MW), BR2 (4 x 65MW). Current (derated) Operating Capacity: BR1 (3 x 50MW + 40MW), BR2 (3 x 48MW + 1 x 62MW). Historical Operating Capacity: BR1 (4 x 50MW), BR2 (4 x 75MW)

The following summarizes recent and proposed investments in Bridge River:



The most significant issues and risks that are being addressed with ongoing projects or projects proposed to start within the next ten years are listed below. More detailed information can be found in Section 5.

[2] Proxy for revenue attributed to the facility.

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High Risk (risk score >9.5)

Bridge River 1

- Interior and exterior penstock coatings for Units 1-4 have failed.
- Units 1 to 4 Generators, Governors and Protection have poor and unsatisfactory equipment health ratings.
- A sudden stop of all four units could cause the surge tower to be overtopped mobilizing debris down the mountain.
- There is a risk of mobilizations of the ground/banks under and around the penstocks due to a high water or seismic event.

Bridge River 2

- Units 5 and 6 Generators, Governors, Exciter and Circuit breakers have poor and unsatisfactory equipment health ratings.
- The interior penstock coating on Penstock 1 (Units 5 and 6) has failed
- Units 7 and 8 Generator, Circuit Breakers and Turbines have poor and unsatisfactory equipment health ratings.
- The interior penstock coatings on Penstock 2 (Units 7 and 8) have failed.

Terzaghi Dam

- The spillway chute has a rock fall hazard that has not allowed full access for crews to do inspections or repairs.
- The post-seismic operability of the Low-Level Outlets and gates has not been assessed.
- Insufficient instrumentation to monitor the potential development of the internal erosion in the dam.
- Potential post-seismic deformation of downstream slope toe and the embankment abutted against the spillway wall.
- Terzaghi Dam Spills - The Bridge River units derating reduces the operating capability to divert water and hence increases the likelihood and magnitude of spills from Terzaghi Dam to the Lower Bridge River. The increased volume and frequency of the spilling from Terzaghi Dam poses environmental risks downstream of the Terzaghi Dam, with First Nations and regulatory implications.

Based on the recommended investment strategy, it is recognized that for at least the next ten years there will be a number of retained risks at the facility. Key retained risks are listed below with more detailed information provided in Section 6.3.

- Santa Claus Mountain Potential Slide – poses a threat to the Bridge River Powerhouses, Seton Dam and adjacent communities.
- Bridge #1 Powerhouse Foundation Soils – Bridge River 1 Powerhouse is situated on an artesian aquifer.
- Bridge # 1 Powerhouse seismic risk – Bridge River 1 Powerhouse is at increased risk of flooding due to a rupture of the penstocks in a seismic event.
- Bridge # 1 Penstock Inlet Valves (PIVs) – Work has been done to detect the penstocks leaks and allow for closure of the PIVs, however, the PIVs are unable to close under the rupture flows.

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- Failure of the powerhouse after a seismic event (>1/2,000).

2.1. Performance Overview

The facility has become increasing vulnerable to forced outages. The largest outage was in F2016 when a bus fault resulted in damage to the stator and circuit breaker (13CB8) for Unit 8. Lack of spare parts for the circuit breaker exacerbated the outage.

Average/Unit	F14	F15	F16	F17	F18
Availability Factor	79.7	89.0	80.6	90.0	80.0
Forced Outages (count)	11	13	12	7	8
Duration of Forced Outages (hours)	105	592	4,414	847	933
Forced Outage Factor	.6	.9	6.25	1.21	1.33

EHR Ratings for Equipment as of May 2019.

Equipment Health Rating	Generator	Turbine	Circuit Breaker	Governor	Exciter	Transformer
Unit 1	P	F	G	P	F	G
Unit 2	U	G	G	P	F	
Unit 3	P	G	G	P	F	G
Unit 4	U	F	G	P	F	
Unit 5	U	F	P	P	P	F
Unit 6	U	F	P	P	P	F
Unit 7	P	P	P	F	G	G
Unit 8	U	P	F	F	G	G

Good	Fair	Poor	Unsatisfactory

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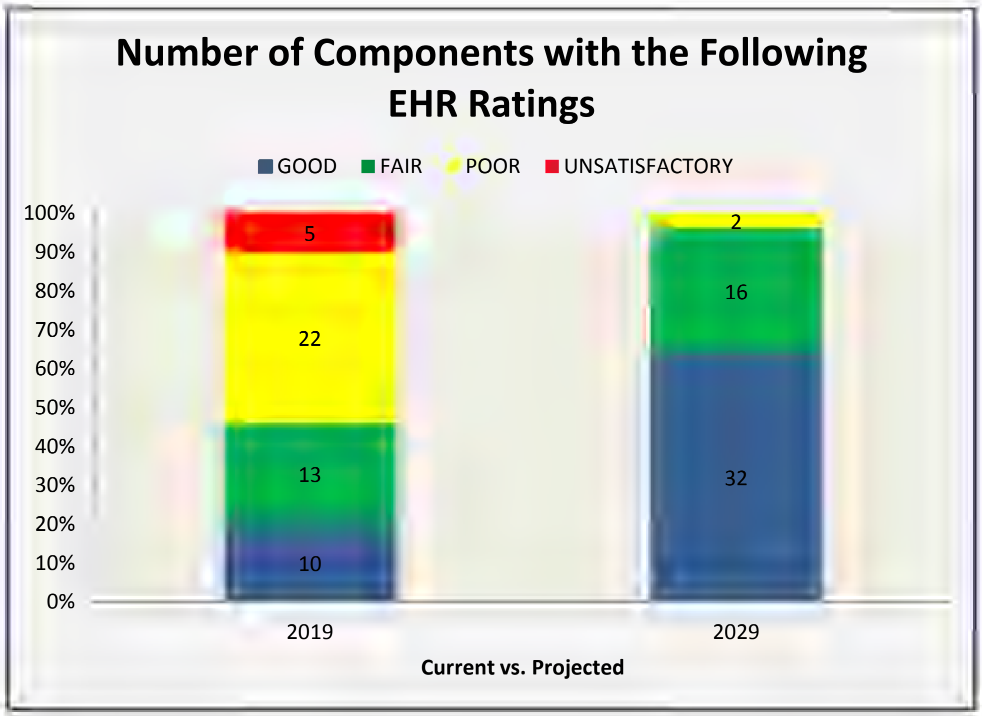
The following graph shows the expected change in equipment condition following the recommended strategy proposed in this plan. EHR equipment rated POOR or UNSATISFACTORY will be addressed or started to be addressed in the next ten years.



2.2. Other Relevant Information

Bridge River provides voltage support to the 69 kV systems in the Cariboo Region. However, local load is much less than the Bridge River generation capability so output is restricted due to stability concerns whenever components (T3, T30, 2L19 or 60L21) of the Bridge River 69 to 230 kV interconnection are out of service.

The Bridge River facility is unique in its design in that the only way to move water from Carpenter Reservoir to Seton Lake (the preferred water flow) is through the two powerhouses. Spilling at Terzaghi Dam down the lower Bridge River is limited by the Water Use Plan Order. Bridge River 1 and Bridge River 2 pass 160 cms at full load. The turbine at Seton passes only 114 cms at full load. In addition, Seton Lake has a narrow (<0.6 m) operating range. The Bridge River units are capable of putting more water into Seton Lake than can be passed by the downstream Seton Generating Station. Because of this, the Bridge River Generating Stations act as peaking plants, allowing the stations to generate at high load hours then back off or go into synchronous condense at low-load hours. With upstream storage at Carpenter and Downton unrestricted at 749.8 m (currently at 734.0 m) combined with fully-functioning Units at the Bridge River Generating Stations, the system is considered to be in hydraulic balance.

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2.3. Investment Summary

Since the last Bridge River Facility Asset Plan issued in 2016, Bridge River has benefited from a number of capital investments to mitigate known safety, dam safety, equipment and reliability risks/issues. The following outlines key investments made, or ongoing in the last five years:

COMPLETED PROJECTS

- **Bridge River 1 Unit Transformer Replacement (F2018)** – Replaced two aging and deteriorating sets of three single-phase transformers with two new three-phase transformers to address reliability risks.
- **Bridge River 1 Electrical Protection Upgrade (F2018)** – Replaced the existing electro-mechanical relays with digital relays for the four generators, two unit transformers and associated 13.8 kV station service.
- **Bridge River 1 Unit Switchgear Replacement (F2018)** – Replaced all 13.8 kV switchgear in their entirety; including enclosures, circuit breaker, current transformers and voltage transformers, cabling and terminal equipment.
- **Bridge River 1 Replace Powerhouse Pipe System (F2017)** – Replaced the water pipe systems and ancillaries for: penstock dewatering, turbine inlet valve (TIV) bypass, penstock inlet valve (PIV) bypass and drains, unit cooling water and service water.
- **Bridge River 1 Penstock Leak Detection and Protection (F2017)** – Design and installation of a penstock leak detection system and auto closure including logistics and communication for monitoring and potential control. Although complete, this project is currently manually activated and will not put the autoclose system into service until the Surge Spill Hazard project is complete (see below).
- **Bridge River 2 PIV Hydraulic Controls Upgrade (F2016)** – Upgrade the outdated and faulty PIV hydraulic system, bypass valve and electrical controls.
- **Terzaghi Dam Spillway Gate Upgrade (F2016)** – Replaced both spillway gates and all ancillary equipment.
- **Bridge River Townsite Redevelopment (F2016)** – Redevelop the townsite buildings and infrastructure to include ten single story fourplexes and one family house plus water supply, septic, road and electrical distribution

ONGOING PROJECTS

- **Bridge River 2 Unit 5 and 6 Upgrade Project** – The Bridge River 2, Unit 5 and 6 generators are in “Unsatisfactory” condition and the exciters, governors and circuit breakers are in “Poor” condition. Stator winding failures in the past have resulted in the units being de-rated. The unit derating has resulted in the reduced operating capability to divert water and has increased the likelihood and magnitude of spills from Terzaghi Dam to the Lower Bridge River. The project is replacing the generator, exciters, governors and circuit breakers.

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- **Bridge River 2 Strip and Recoat Penstock 1 Interior**– Penstock 1 interior coating is rated as being in “Unsatisfactory” condition. It is recommended to strip and recoat the interior of the penstock to preserve the metal thickness and structural integrity of the pipe. Failure to address the active corrosion will result in loss of metal thickness and could lead to more expensive repairs or eventual penstock replacement.

- **Bridge River 2 Unit 7 and 8 Unit Upgrade Project** – The Bridge River 2, Unit 7 and 8 generators are in “Poor” and “Unsatisfactory” condition, the breakers are in “Poor” and “Fair” condition and the turbines are in “Poor” condition. Stator winding failures in the past have resulted in the units being de-rated. The unit deratings have resulted in the reduced operating capability to divert water and have increased the likelihood and magnitude of spills from Terzaghi Dam to the Lower Bridge River. The project is replacing the generator and circuit breakers, and overhauling the turbines.

- **Bridge River 2 Strip and Recoat Penstock 2 interior** - Penstock 2 interior coating is rated as being in “Unsatisfactory” condition. It is recommended to strip and recoat the interior of the penstock to preserve the metal thickness and structural integrity of the pipe. Failure to address the active corrosion will result in loss of metal thickness and could lead to more expensive repairs or eventual penstock replacement.

- **Bridge River 1 Slope Drainage Improvement** – Mobilization of the slope as well as the tunnel construction spoil pile after a seismic or heavy rain event could impact the facilities and public properties near the base of the slope. This project will implement slope drainage improvements and debris flow mitigation for School Creek and Town Creek.

- **Bridge River 1 Mitigate Surge Spill Hazard** - A Penstock Leak Detection System (PLDS) was installed at Bridge River 1 station which, upon detecting a leak, can send an alarm to Fraser Valley Office (FVO) and the Bridge River 1 control room. Under certain PIV closure conditions and plant operations there is a risk that water level in the surge shafts could overtop. There is a possibility that a large spill surge volume could cause extensive damage and potential loss of life. This project will address the surge spill risk.

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3. OPERATIONS AND HYDROLOGY

3.1. Facility Components

The Bridge River facility is part of the larger Bridge River system which stores and diverts the flows of the Bridge River into Seton Lake and eventually the Fraser River. Bridge River, located near Shalalth, is the largest of the three facilities in the Bridge River system. The Bridge River facility consists of Terzaghi Dam, Carpenter Reservoir, Bridge River 1 and 2 intakes, Bridge River 1 Generating Station, Bridge River 2 Generating Station and the Bridge River townsite.

The Terzaghi Dam, Carpenter Reservoir and Intakes

Terzaghi Dam is an Extreme Consequence dam, located on the Bridge River and provides impoundment for Carpenter Reservoir. It is a zoned earth-filled dam and is 60m high by 366m long. The original diversion dam was completed in 1948 for storage, and in 1960 the present dam was built over it raising Carpenter reservoir to its present elevation. Today the reservoir provides over 60% of the storage in the Bridge River system. The reservoir is located in the South Interior climatic region. The watershed includes the Bridge River as well as a number of smaller tributaries. Snowmelt is the primary contributor to flows in the Bridge River Basin. The main mechanisms for water to exit Carpenter Reservoir are:

- **Low-Level Outlet Gates**

The two low-level operating gates (LLOG) provide year round fish flows (1.5 – 15 cms) into the Lower Bridge River. Combined the LLOGs can discharge 350 cms of water and are the preferred method of passing water in high flow events. The gate sill elevation is 599.7 m.

- **Spillway Operating Gates**

Terzaghi dam has two spillway operating gates (SPOGs) which discharge excess water from Carpenter Reservoir into the Lower Bridge River. Combined, the two spillway gates can discharge 479 cms and would be used in times of flood or high-inflow events. The SPOGs can only be operated in local manual control. This requires dispatching crews from the Bridge River Generating Stations, who would travel to the dam to operate the spillway operating gates. The SPOGs were rebuilt and put in-service on April 30, 2010. The SPOGs can be powered from three redundant power sources; the BC Hydro power system, a backup diesel generator and an uninterruptable power supply (UPS). The UPS feed is designed with sufficient battery power to raise and lower each gate one time. Discharge from the SPOGs is conveyed downstream via a spillway chute to the downstream deflector and then into the plunge pool. The gate sill elevation is 641.7 m.

- **Free Crest Spillway**

The free crest spillway is located along the curved left side of the chute, roughly perpendicular to the spillway operating gates. It is 106m long with a capacity 1400 cms at 655.0 m and discharges water into the same spillway chute as the SPOGs. The sill elevation of the free crest spillway is 651.08 m.

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- **Bridge River 1 and 2 Intakes**

A free-standing intake structure located 3 km upstream of the dam diverts up to the licensed inflow of 65 cms to the Bridge 1 powerhouse via a 4 km long, 4.3 m diameter concrete-lined tunnel. The intake consists of a single Intake Operating Gate (sill elevation 600.6 m).
A free-standing intake structure located 4 km upstream of the dam diverts up to the licensed inflow of 95 cms to the Bridge 2 powerhouse via a 4 km long, 4.9 m diameter concrete-lined tunnel. The intake consists of a single Intake Operating Gate (sill elevation 599.5 m)

Bridge 1 and 2 Generating Stations

For power dispatch purposes, the two Bridge River powerhouses are treated as a single facility. The powerhouses discharge into the Seton Lake Reservoir. It should be noted that the only way to move water from Carpenter Reservoir to Seton Lake Reservoir is through the units in the powerhouses. They consist of the following water passage components:

Bridge 1 Powerhouse (Contains Four Units: G1-4)

- The 4.3 m diameter concrete-lined power tunnel splits into four water passages at the valve house.
- Each water passage contains a 1.8 m diameter Penstock Inlet Valve (PIV)
- Each PIV supplies a 1.5 m diameter surface steel penstock which vary in length from 682 m to 758 m
- Each penstock contains a 1.4 m diameter Turbine Inlet Valve (TIV) in the powerhouse
- Each TIV supplies a 58.6MW (nominal) turbine
- Each Generator is rated a 50MVA is capable of discharging 16cms of water.

Bridge 2 Powerhouse (Contains Four Units: G5-8)

- The 4.9 m diameter concrete-lined tunnel splits into two water passages at the valve house
- Each water passage contains a 3.05 m diameter PIV
- Each PIV supplies a 2.9 m diameter 1327 m long surface steel penstock
- Each penstock bifurcates into 2 m diameter steel penstocks
- Each penstock contains a 1.5 m diameter TIV in the powerhouse
- TIV 5 and 6 supplies a 75MW (nominal) Turbine, and TIV 6 and 8 supplies a 61.2MW turbine
- Each Generator is rated is rated at 65MVA but have historicaly ran higher

The diagram on the following page illustrates the key system components of the facilities.

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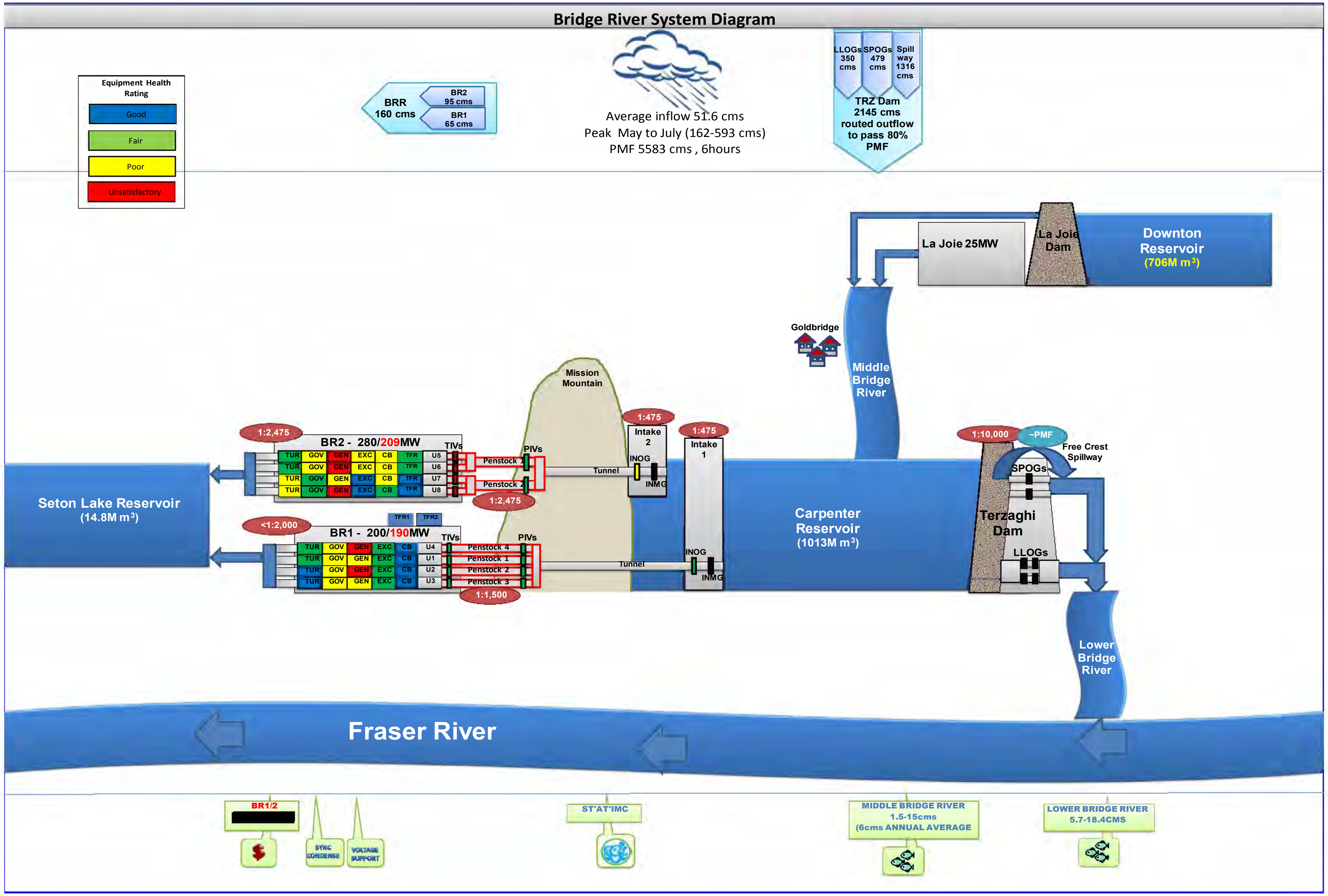

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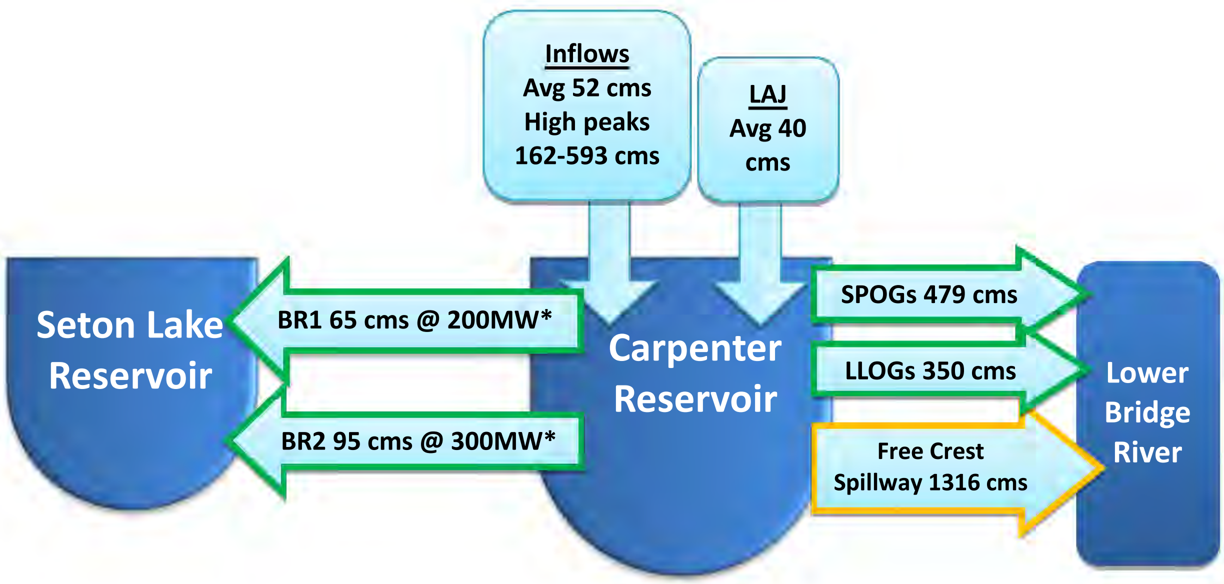
3.2. Hydrology – System Inputs and Outputs

The Bridge River basin inflows consist mainly of snowmelt runoff and glacial melt occurring from June to August for Downton and May to July for Carpenter. The Bridge River Generating Stations are primarily operated as a single generating station and as a load shaping and peaking plant. Generation is typically step loaded over heavy load and light load hours, or synchronous condensed at night. Seton Generating Station moderates the flow of the Bridge River generating stations before entering the Fraser River and within the operating limitations of storage in Seton Lake. Spills at Terzaghi Dam into the Lower Bridge River are limited by the Water Use Plan.

The Carpenter Reservoir storage capacity moderates the inflows of the middle Bridge River and La Joie Generating Station. The La Joie Generating Station provides a steady flow into Carpenter Reservoir via the generator, pressure regulating or hollow cone valves. The Carpenter Reservoir provides over 60% of the storage in the Bridge River system.

The diagram below shows the main components under BC Hydro control. The arrows outlined in green represent active controls, while those outlined in orange represent passive free crest spillways.



*BR1 and 2 are currently derated to 190MW and 206MW respectively, which has reduced their flow capacity by 21%

Carpenter Reservoir
Carpenter Reservoir is impounded by Terzaghi Dam and captures all of the outflows from La Joie Dam along with three other major tributaries (Hurley River, Gun Creek, and Tyaughton Creek). Water from Carpenter Lake is diverted through two tunnels to Bridge River 1 (BR1) and Bridge River 2 (BR2) Generating Stations located near the community of Shalalth on the north bank of

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Seton Lake. Water from Carpenter Reservoir also passes Terzaghi Dam via the Spillway (gated and emergency overflow) and the Low-Level Outlet. The Spillway Operating Gates (SPOGs) and Low-Level Outlet Gates (LLOGs) are manually operated while the overflow spillway is unregulated.

The maximum operating level of Carpenter Reservoir is El. 651.08 m but the end of freshet target is El. 648.00 m to try and avoid large spills in the Lower Bridge River due to potential environmental and economic impacts.

Downton Reservoir (La Joie)
Downton Reservoir is the upstream reservoir to Carpenter Reservoir. Its maximum operating level has been reduced to mitigate dam seismic withstand concerns. This has reduced the effective storage of Downton by almost 50% and put more pressure on the Carpenter Reservoir to moderate the inflows of the Bridge River system. Unit deratings resulting from deterioration and winding failures have reduced the generation (i.e. discharge) capacities at Bridge 1 and 2 generating stations. This has reduced the ability to pass water from Carpenter Reservoir to Seton Lake thus increasing the likelihood of increased spills at Terzaghi Dam.

Terzaghi Dam Release Variance
Annual discharge from Terzaghi Dam during the capital programs may exceed the 6 cms annual average water budget identified in the Water Use Plan. As a result, BC Hydro has requested a variance to exceed the 6 cms annual average hydrograph target flows. The actual annual average discharge will be subject to the volume and timing of inflows received in the year and timing of capital work.

3.3. Facility Operations

The Power intakes divert water from Carpenter Lake over an operating elevation range of 606.55 m to 651.08 m. Historically all Bridge River 1 units (1-4) and Bridge River 2 units (5-8) typically run in continuous generation during the day and in synchronous condense mode during the night. This practice supports the load during the day and the system voltage during the night, while keeping Bridge River 1 and Bridge River 2 in hydraulic balance with Seton Generating station. Due to planned outages, unit derating and the need to keep Downton Reservoir below 734 m, the Bridge River 1 and 2 units have been operating more frequently to manage water conveyance in the Bridge River System resulting in sub-optimal economic dispatch.

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4. Value, Benefits and Obligations

The Bridge River Facilities provides a number of financial, reliability and environmental benefits.

Generation of Electricity and Revenue
Bridge River provides 4% of the capacity and 5% of the energy to BC Hydro's system. It is also a significant contributor to revenue in the BC Hydro fleet. In recent history it has contributed between $245 million and $290 million in annual generation revenue (proxy).

Ancillary Services
Ancillary services provided by Bridge River Generating Stations include: voltage support and sync- condense operation. These help to support the surrounding transmission system.
"Voltage support" means maintaining an acceptable level of voltage to meet electrical system reliability and stability requirements.
"Sync-condense" means a unit is operated in synchronous condense mode. In this mode, the unit can respond to voltage changes more quickly and dynamically than most other voltage control devices, making them very valuable tools for maintaining reliability of the transmission system.

Water Passage, Flood Mitigation and Erosion Control
The Terzaghi Dam is one of two dams on the Bridge River that are used to store and manage the inflows for the purpose of electricity generation at the Bridge 1 and 2 Generating Stations. Carpenter Reservoir provides over 60% of the storage in the Bridge River system and enables additional energy to be generated at Seton Generating Station. In addition, the storage provides operating flexibility at the Bridge River plants allowing load factoring and mitigates flows that could result in damaging spills down the Lower Bridge River.

Lower Bridge River Flows
The Water Use Planning process established year-round target flows between 1.5 – 15 cms, with an annual average of 6 cms in the Lower Bridge River from Terzaghi Dam. Variances of more than +/-5% from the targeted flows (+/-0.25 cms of target flows when flow is <5 cms) require BC Hydro to inform the St'at'imc First Nations, fisheries agencies and the Comptroller of Water Rights. Due to environmental sensitivities in the Lower Bridge River downstream of Terzaghi Dam, Carpenter Reservoir is managed to mitigate spills.

St'at'imc First Nations Agreement
BC Hydro has signed a historic agreement with the St'at'imc First Nation. The Bridge River System lies in their traditional territory. As part of the agreement, BC Hydro agrees to work with the St'at'imc First Nation and explore economic opportunities. The agreement also commits BC Hydro to operate the system consistent with the signed Water Use Plan, and any deviations from the operating regime require notification of the St'at'imc First Nation. The certainty protocols also mean if there are any material changes to the facilities themselves (additions, reconstruction, etc.) that require a change to BC Hydro's Water License, BC Hydro will consult with the St'at'imc First Nation.

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5. Issues, Risks and Opportunities

There are a number of issues, risks and opportunities associated with the assets in the Bridge River Facility. The key risks are described in the following section, which include:

- A brief description of the key issue, risk or opportunity.
- The expected impact of a failure.
- The risk score, based on the Corporate Risk Matrix. Risk scores range from 0 to 16, with 16 representing the highest level of risk. Risks not proposed for mitigation in the ten-year planning window may not have a cost forecast and/or risk score.
- A planning allowance to mitigate, if known. Planning allowances are subject to change. Project-level estimates are developed in the identification and definition phases.

More detailed information on less significant issues, risks and opportunities is documented in the Consolidated Facility Log. The details of the investment strategy addressing the following risks can be found in Section 6.0.

5.1. Generating Equipment

There are a number of different components that contribute to the reliability of the facility. The conceptual diagram below shows where key components are estimated to be in their lifecycle, coupled with the condition of the equipment (if known) based on the Equipment Health Rating (EHR). The x-axis represents the lifecycle associated with each component illustrated. Not all components have the same expected lifecycle. The y-axis represents the performance risk which can be expressed in terms of condition assessment, reliability/availability, probability of failure, etc. Typically, maintenance costs associated with newly-installed equipment should be expected to be higher, given that additional work may be required to eliminate any construction deficiencies, and to perform increased inspections in the first few years of life (often in support of equipment warranty). Equipment towards the end of lifecycle is expected to be a higher performance risk and is also likely to require increased maintenance. This may progress to a point where either the component is no longer maintainable, or the best value decision is to replace or refurbish the equipment (i.e. its end of life).

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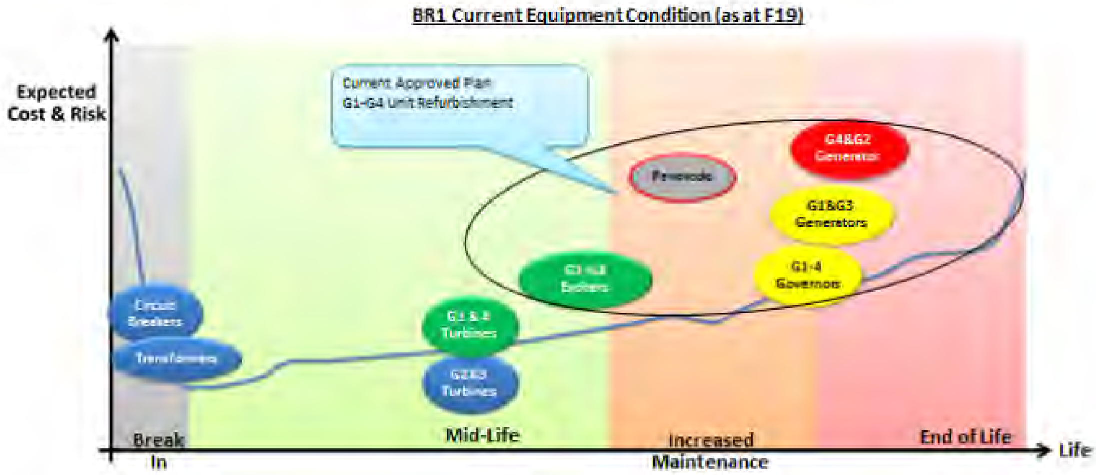

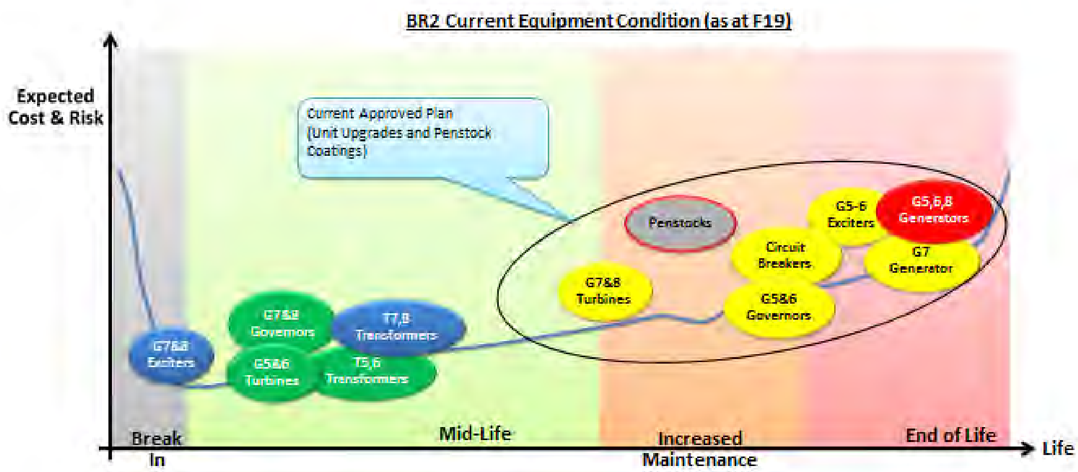

The majority of the equipment at Bridge River is original and has exceeded its industry life expectancy. According to EHR, the equipment is rated as "Poor" or "Unsatisfactory" due to age, decreasing reliability and deterioration. In addition, technical support and parts are no longer readily available which further impacts reliability. Two generator windings (G2 and G4) were replaced over 25 years ago but are deteriorating and are rated as "Unsatisfactory". In the past twenty five years the Bridge River 1 exciters, Bridge River 1 unit transformers, Bridge River 1 unit breakers, Bridge River 2 unit transformers, G1-G6 runners were replaced, and G7 and G8 governors and exciters were replaced to address reliability issues. Currently, there are ongoing projects to upgrade Bridge River 2 units 5 and 6 (generators, governors, circuit breakers, exciters and protection and control) as well as the coating on Penstock 1. These upgrades will go in effect

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in calendar year 2019 (F2020). Upgrade to Bridge River 2 units G7 and G8 generator and unit breakers are ongoing and will be completed in F2022.

The water management challenge with Bridge River system is to keep water moving from Carpenter Reservoir to Seton Lake while maintaining target discharges from Terzaghi Dam in the Lower Bridge River. The only way to do this is through the generating units in the Bridge River 1 and Bridge River 2 powerhouses.

Bridge River is entering a critical time of reinvestment in the next ten years. These investments will require lengthy outages to implement, further complicating the water management challenge in the system. The risk during a long capital-driven outage is that another long-duration unit failure could occur which would most likely result in a large spill at Terzaghi Dam, outside of current Water Use Plan targets.

Bridge River 1 G1-4 Exciter Controls – Reliability Risk (Risk Score 9.5 Ongoing) – Estimated Mitigation [redacted]

Due to the age, obsolescence and lack of Original Equipment Manufacturer (OEM) support of the Bridge River R1 static exciters, there is a risk of failure which would lead to a long forced outage. The Bridge River 1 G1-4 static exciters were installed in 1992/3 to replace the failing rotary exciters. The exciters are rated “Fair” in EHR, due to age and lack of OEM support. The Bridge River 1 exciters are the single largest source of forced outages (by count) in Bridge River. Support is no longer available from the OEM, and the new owner (Andritz) does not support the older technology. The main electrical components can still be supported on a discrete basis. The control modules cannot be refurbished and will require replacement in the next five years. There is an ongoing Bridge River 1 units replacement project that will address this risk. The decision to replace the exciter controls will be reviewed by the unit upgrade projects as the existing exciters may not support the potential increase in capacity.

Bridge River 1 Generators – Reliability Risk (Risk Score 10.5 Ongoing) – Estimated Mitigation [redacted]

Due to the age and general deterioration of the Bridge River 1 generators, there is a risk of failure which would lead to a forced outage. Two of the generators (G1 and G3) are original and have exceeded their industrial life expectancy. Two other generators (G2 and G4) were rewound over twenty five years ago. Generators G1and G3 are rated “Poor” due to age, poor test results, leaking asphalt, corona-winding damage and core waves and chevrons at the core split. The G2 and G4 generators are rated “Unsatisfactory” due to poor test results. G4 had a winding failure which led to a cutout coil and a derating of the unit. G2 has stator core deficiencies. There are various unit upgrade projects proposed in the next ten years to address the generator reliability issues. There is also an opportunity to modestly increase the unit capacity.

Bridge River 1 Governors – Reliability Risk (Risk Score 10.5 Ongoing) – Estimated Mitigation [redacted]

Due to age and general wear of the Bridge River 1 governors, there is a risk of failure which could lead to a long forced outage. The governors are rated “Poor” due to age, poor unit response as

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shown in WECC testing, high external oil leakage and lack of spare parts. Failure of the governor can cause a unit to go into over speed causing significant damage if not corrected in time. G4 went into over speed in 1992 but quick action by plant staff prevented serious damage. Over speed is a dangerous situation that could cause significant damage to the unit and powerhouse, and seriously injure anyone nearby. There are various unit upgrade projects proposed in the next ten years to address the governor reliability issues.

Bridge River 1 Penstocks 1-4 External Condition – Financial Risk (Risk Score 10) – Estimated Mitigation [redacted]

Due to the failure of the exterior coating on the penstocks, there is a risk corrosion will compromise the structural integrity of the steel which will lead to replacement of the penstock. According to EHR the Bridge River 1 Penstock Exterior Coatings are "Unsatisfactory". The penstock exterior coating is original and starting to fail with localized corrosion. A strip and recoat is recommended. Protective coatings prevent corrosion on steel penstocks. Corrosion leads to metal loss and loss of strength. If not prevented by application of coatings then the strength will be compromised to the point that the penstock will have to be taken out of service to prevent failure. The Bridge River Penstocks are one of the highest pressure (600psi) penstocks in BC Hydro. Failure of a penstock would disrupt the CN railway line, public access road, Bridge River 1 powerhouse and switchyard. Even a small leak could compromise slope stability. Taking a penstock out of service will also take out a generating unit with corresponding loss in generation/revenue but more importantly, the ability to pass flows through the Bridge River system down to Seton GS.

Bridge River 1 Penstocks 1-4 Interior Condition – Financial Risk (Risk Score 10 Ongoing) – Estimated Mitigation [redacted]

Due to the failure of the interior coating in the penstocks, there is a risk corrosion will compromise the structural integrity of the steel which will lead to replacement of the penstock. According to EHR, the Bridge River 1 Penstock Interior Coatings are "Unsatisfactory". The penstock interior coatings are original and have failed with localized corrosion. The 2011 internal penstock inspection report (N3339 by Klohn Crippen Berger) identified the penstocks as a good candidate for strip and recoat. Failed coatings lead to corrosion, metal loss and loss of strength. If not prevented (by application of coatings) then the strength will be compromised to the point the penstock will have to be taken out of service to prevent failure. The Bridge River Penstocks are one of the highest pressure (600psi) penstocks in BC Hydro. Failure of the penstock would disrupt the CN railway line, public access road, Bridge River 1 powerhouse and switchyard. Even a small leak could compromise slope stability. Taking a penstock out of service will also take out a generating unit with corresponding loss in generation/revenue but more importantly, the ability to pass flows through the Bridge River system down to Seton GS.

Various penstock interior recoat projects are proposed in the next ten years. These are coordinated with the proposed unit upgrades as they both require lengthy outages to implement.

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Bridge River 1 Tunnel 1 Steel Liner Coating – Financial Risk (Risk Score 9.5) – Estimated Mitigation [redacted]

Due to the failure of the interior coating on the tunnel steel liner, there is a risk corrosion will compromise the structural integrity of the liner which will lead to the replacement of the liner. According to EHR the Bridge River 1 Tunnel Liner Interior Coating is "Unsatisfactory". The tunnel steel liner interior coating is original and has failed with localized corrosion. The 2011 internal penstock inspection report N3339 characterized the metal loss as not structurally significant. A strip and recoat is recommended. Protective coatings prevent corrosion on steel liners. Corrosion leads to metal loss and loss of strength. If not prevented by application of coatings then the strength will be compromised to the point the tunnel will have to be taken out of service to prevent failure. The steel liner is an integral structural component of the tunnel to prevent a tunnel blowout where the bedrock cover reduces to zero as the penstock leaves the bedrock tunnel. Failure of the tunnel liner could result in slope instability threatening the penstocks, public road and CN railway tracks. Taking the tunnel out of service will also take out all of Bridge River 1 generating station with corresponding loss in generation/revenue but more importantly the ability to pass flows through the Bridge River system down to Seton GS.

Bridge River 2 Generators – Reliability Risk (Risk Score 11 Ongoing) – Estimated Mitigation [redacted]

Due to the deteriorated condition of the generator windings, there is a risk of failure which could lead to a long forced outage. All the generators at Bridge River 2 are original and have exceeded their industrial life expectancy. The units have historically run at a 15% above nameplate. They are rated “Poor” to “Unsatisfactory” by EHR due to age, failures, declining reliability and poor test results. Three of the four generators have experienced winding failures which led to cutout coils and a 25% derating of the units. In addition, analysis of the stator windings has indicated severe degradation of the insulation system which has resulted in a further 15% derating of all Bridge River 2 generator units. There is a high probability the next failure could result in permanent shutdown as it is not possible to cut out further coils.

There are various ongoing unit replacement projects to replace the generators as well as other related unit components to restore unit capacity and reliability.

Bridge River 2 G5/6 Governors – Reliability Risk (Risk Score 10 Ongoing) – Estimated Mitigation [redacted]

Due to age and obsolescence there is a risk that Bridge River 2 G5 and 6 governors could fail which would lead to a forced outage. Both governors are original (1959), and have exceeded their industrial life expectancy. They are rated “Fair” to “Poor” by EHR due to age, declining reliability, poor test results, lack of spare parts and manufacturer support. Poor governor response means the Bridge River 2 units are unable to contribute to regional stability and reliability.

There is an ongoing unit upgrade project to replace the governors as well as other related unit components to restore unit capacity and reliability.

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Bridge River 2 G5/6 Exciters – Reliability risk (risk score 10 ongoing) – Estimated mitigation [redacted]

Due to age and obsolescence, there is a risk that Bridge River 2 G5 and 6 exciters could fail resulting in a forced outage. Both exciters are original (1959), and have exceeded their industrial life expectancy. The major components are rated "Unsatisfactory" by EHR due to age, failures, declining reliability, poor test results, lack of spare parts and manufacturer support. Similar exciters on G7 and 8 experienced failures that resulted in fires and lengthy outages. They have since been replaced with digital exciters.

There is an ongoing unit upgrade project to replace the exciters as well as other related unit components to restore unit capacity and reliability.

Bridge River 2 Circuit Breakers – Reliability Risk (Risk Score 10 Ongoing) – Estimated Mitigation [redacted]

Due to age and obsolescence there is a risk that Bridge River 2 circuit breakers could fail resulting in a forced outage. All of the circuit breakers are original and have exceeded their industrial life expectancy. They are rated "Poor" by EHR due to age, failures, declining reliability, lack of spare parts and manufacturer support. Recently, as a result of the G8 failure, difficulty in obtaining circuit breaker parts caused the longest delay in repairing the unit so it could be returned to service.

There are ongoing unit upgrade project to replace the circuit breakers as well as other related unit components to restore unit capacity and reliability.

Bridge River 2 G7/8 Turbines – Reliability Risk (Risk Score 10 Ongoing) – Estimated Mitigation [redacted]

Due to wear on G7 and 8 turbine components there is a risk the unit will not stop on a shutdown which could lead to mechanical damage such as a wiped bearing. Units 7 and 8 were commissioned in 1960 and have had some recent capital investments to improve their reliability. The turbines are original and have exceeded their industrial life expectancy. They are rated "Poor" by EHR due to age, declining reliability and excessive leakage due to wear. The G7 and 8 runners are the only original runners left in Bridge River, the other six being replaced in 2001/2. While having exceeded their industrial life expectancy, they are efficient and only show minor cavitation which can addressed through maintenance. However, the turbines are in need of an overhaul to address wear on major components as the leakage is so excessive that recently G8 had to have its runner removed to permit work on the unit without the risk of it turning.

Bridge River 2 Penstocks 1 and 2 Interior Coating – Financial Risk (Risk Score 10 Ongoing) – [redacted]

Due to the failed interior penstocks coating, there is risk corrosion will compromise the structural integrity of the penstocks which will lead to the replacement of the penstocks. According to EHR, the BR2 Penstock Interior Coatings are "Unsatisfactory". The penstock interior coating is original and has failed with localized corrosion. The penstock exterior has been recoated. The Bridge River Generating Station 2 (BR2) - Inspection of Surge Shaft, Tunnel Liner and Penstock 1 and 2

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Report (E685, February 2009) characterized the metal loss as not structurally significant at this time. A strip and recoat is recommended. Protective coatings prevent corrosion on steel penstocks. Corrosion leads to metal loss and loss of strength. If not prevented by application of coatings then the strength will be compromised to the point the penstock will have to be taken out of service to prevent failure. The Bridge River Penstocks are one of the highest-pressure (600psi) penstocks in BC Hydro. Failure of a penstock could disrupt the CN railway line, public access road and the Bridge Terminal switchyard depending on where it was to occur. Taking a penstock out of service will also take out two BR2 generating units with corresponding loss in generation/revenue but more importantly, the ability to pass flows through the BRR system down to Seton GS.

Bridge River 2 Tunnel 2 Steel Liner Interior Coating – Reliability Risk (risk score 9.5) – Estimated [redacted]

Due to the failure of the interior coating on the tunnel steel liner there is risk corrosion will compromise the structural integrity of the liner which will lead to the replacement of the liner. According to EHR, the BR2 Tunnel Liner Interior Coating is "Unsatisfactory". The tunnel steel liner interior coating is original and has failed with localized corrosion. The 2009 internal penstock inspection report E685 characterized the metal loss as not structurally significant at this time. A strip and recoat is recommended. Protective coatings prevent corrosion on steel penstocks. Corrosion leads to metal loss and loss of strength. If not prevented (by application of coatings) then the strength will be compromised to the point the tunnel will have to be taken out of service to prevent failure. Failure of the tunnel liner could disrupt the CN railway line, public access road and the Bridge Terminal switchyard. Taking the tunnel out of service will also take out all of BR2 generating station with corresponding loss in generation/revenue but more importantly the ability to pass flows through the BRR system down to Seton GS.

5.2. Dam and Ancillary Facilities

5.2.1. Dam Performance and Infrastructure

Terzaghi Dam Upstream Cut-off Upgrade - Safety (Risk Score 10.5) [redacted]

There is potential for failure of the dam due to internal erosion as a result of seepage through the cut-off wall bedrock contact. A total of eighteen (18) sinkholes have been located and treated since the dam was built, with the most recent occurring in 2010. The sinkholes predominantly occur in the vicinity of the sheet pile cut-off wall adjacent to the right abutment. The majority of the sinkholes are considered to form as a result of leakage between the bedrock and improperly-seated sheet piles. The leaks erode material causing a collapse of the material above which results in a sinkhole on the surface about 30 meters above the rock surface. By preventing water from leaking past the cut-off wall, internal erosion of the granular material would be halted and periodic sinkholes repairs would no longer be necessary.

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Terzaghi Dam- Provide Safe Access to Spillway Chute and Spillway Chute Improvement – Safety (Risk Score 11 ongoing) Estimate Mitigation [redacted]

The spillway chute has not been fully inspected for at least fifteen years. All recent inspections have been from the outside of the spillway due to rock fall hazard from the adjacent rock slope. Prior to any access to the spillway chute area, a means must be provided to protect workers from rock falls from the bluff above the right (south) side of the spillway. Safe access to the spillway chute must be available to allow for maintenance work and any potential future upgrades of the chute structure.

Terzaghi Dam- Upgrade Dam Instrumentation – Safety Risk (Risk Score 9.5) - Estimated Mitigation [redacted]

Adequate seepage measurement is key information to confirm that dam performance is adequate. Terzaghi Dam is not in compliance with accepted seepage monitoring practices for embankment dams as currently there is inadequate instrumentation to detect progression of internal erosion/piping within the foundation. The dam has experienced recurring sink holes observed during low reservoir-level inspections. Instrumentation upgrade is required to detect/monitor the development of potential erosion/piping within the dam and its foundation.

5.2.2. Flood

The maximum reservoir-level target at the end of freshet is set at El. 648.00 m to avoid spill from Terzaghi Dam due to potential environmental and economic impacts. The buffer is sufficient to capture the moderate inflow events which have been experienced historically; however, it may not be sufficient to prevent overtopping of Terzaghi Dam during passage of the Probable Maximum Flood (PMF).

In order to pass the full estimated PMF through Terzaghi without overtopping the dam, the Carpenter Reservoir level would need to be initially at El. 641.1 m; this is about 7 m below the current target maximum end-of-freshet elevation.

Low-Level Outlet Gates (LLOGs) Reliability – Safety Risk (Risk Score 10) - [redacted]

The largest contributor to flood risks that have been identified at Terzaghi Dam is the reliability of the low-level outlet gates (LLOGs). Due to the age and condition of the LLOGs, there is a risk that they may not operate during a flood event resulting in the overtopping of the Terzaghi earthfill dam, leading to dam failure, property damage and potentially loss of life. All discharge facilities are required to pass the Inflow Design Flood (IDF = PMF). Therefore, reliability of the LLOGs is required on an ongoing basis. There are no stoplogs in place to enable inspections and maintenance of the LLOGs. In addition, the LLOGs are also used to pass the targeted environmental flows downstream of Terzaghi Dam into the lower Bridge River.

5.2.3. Seismic

Terzaghi Dam is classified as an Extreme Consequence dam, required to withstand the 1/10,000 (AEP) seismic event (Maximum Design Earthquake or MDE) without an uncontrolled release of the reservoir. Dam Safety investigations carried out in 2015 and 2016 indicated that the Terzaghi

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Dam is sufficiently stable to withstand the MDE event. The elevation of the post-MDE settled core would be above the current normal maximum reservoir level and the crest of the spillway overflow section, i.e. there will be no uncontrolled release of the reservoir. However, the study identified some potential residual seismic deficiencies with the chute wall, and with the embankment downstream slope toe.

While an uncontrolled release of the reservoir is not expected, damage induced by the earthquake could lead to a required drawdown of the reservoir. A reservoir drawdown at Terzaghi Dam would require the use of the spillway, the Low-Level Outlet Gates (LLOGs) and the Bridge 1 and 2 units. Post-MDE operability of the spillway gates and LLOGs is not currently assured. In addition, the Bridge River 1 penstocks and powerhouse are particularly vulnerable to a seismic event, as the penstocks could rupture and the powerhouse could shift. Both the Bridge River 1 and Bridge River 2 intake structures would likely be damaged and possibly inoperable in a seismic event.

Terzaghi Dam Downstream Infill Berm – Safety (Risk Score 9) [redacted]

The embankment downstream slope has been shown to be stable post-MDE. However, given the complex geometry (both surficial and bedrock topography) and the inherent uncertainties in assessing the seismic performances, this project will ensure adequate post-seismic performance of the dam. Seismically-induced movement of the spillway wall retaining the embankment dam is expected to be relatively small. There is a risk, however, that an open crack at the wall-fill contact would remain open only during the earthquake. This project will improve the confidence in the performance of the embankment by implementing the appropriate remedial measures.

Bridge River 1 and 2 Intake Seismic Stability – Financial Risk (Risk Score 9) – Estimated Mitigation [redacted]

The Bridge River 1 and Bridge River 2 intake towers will not withstand the maximum design earthquake (MDE). The collapse of the towers places a risk on the post-earthquake management of water, as the main means of moving water through the Bridge River 1 and Bridge River 2 powerhouses may not be available.

If an intake structure fails with its gate closed, flows into the power tunnel and downstream to the generating units would be blocked, resulting in the loss of generation and revenue. It would moreover result in large spills downstream of Terzaghi Dam in the lower Bridge River with potential environmental consequences.

More critical is the case where an intake structure fails with its gate open. Considering the vulnerability of the penstocks and BR1 powerhouse to failure in an earthquake, and further considering that the downstream Penstock Inlet Valves (PIVs) are unable to close under rupture flows, a significant earthquake could result in uncontrolled flow from Carpenter Lake out of a breached penstock with no means available to stem the flow. This could result in significant—possibly catastrophic—damage to the powerhouses and possible loss of life. Damage and flooding downstream impacts at Seton Canal would also be likely.

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The objective of this project is to increase the seismic withstand of both the Bridge River 1 and Bridge River 2 intake towers and to provide assurance of post-earthquake reservoir control.

5.3. Other

Bridge River 1 Penstock Surge Spill Hazard – Safety Risk (Risk Score 10 Ongoing) – Estimated Mitigation [redacted]

The hydraulic transient studies showed that water level in the surge shafts can rise above the top of the surge shafts under certain plant operation and PIV closure conditions. Water flowing from the surge shafts will travel overland and may spill over-steep slope onto the area of PIV valve houses, and if people are working in the area they can be swept away. A water surge could impact the tunnel spoil pile located east of Penstock 4, immediately downslope of the Valve House Road, and any loose rock lying on the slopes and in and near the trenches alongside the penstocks could be mobilized creating a debris flow causing damage to facilities and possibly endangering the life of BC Hydro employees and public.

Bridge River 1 Slope Drainage Improvements – Safety Risk (Risk Score 11 Ongoing) – Estimated Mitigation [redacted]

Due to the soils supporting the BR1 penstocks, there is a risk that movement could cause a rupture leading to property damage and potentially loss of life. There are concerns Bridge River 1 penstocks are vulnerable to a seismic event, slope instability powerhouse movement or failure due to corrosion.

This project will provide slope drainage improvement at Town Creek and School Creek. The current slope drainage system is undersized. Large precipitation events could cause debris flows and erosion at these two creeks resulting in potential impacts to infrastructure and personnel located near the base of the slope.

Bridge River 1 Powerhouse Foundation Soils – Bridge River 1 powerhouse is situated on a soil foundation underlain by an artesian aquifer. Artesian pressures can cause the powerhouse to move and settle. This was discovered during construction and limited the size of the Bridge River 1 powerhouse. Further development was limited until ten years later when Bridge River 2 powerhouse was constructed on solid rock.

There is a risk the Bridge River 1 powerhouse could slide into Seton Lake Reservoir or move enough to rupture the penstocks or disrupt the generators to a point where they no longer function. To mitigate these risks, a tailrace berm (the island) was constructed to stabilize the foundation under static conditions, and bleeder wells were placed in the foundation to manage the artesian pressure. In 2018 an instrumentation project was completed to monitor the movement of the powerhouse. The Bridge River System Study recommended replacing the BR1 powerhouse as the only long-term solution to mitigate this risk. However, this recommendation was ranked last on the priority list of dominant risks to address in the Bridge River System and is not proposed in the next forty years.

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Santa Claus Mountain Potential Slide – located on the south side of Seton Lake 16 km upstream of Seton Dam directly across from the Bridge River powerhouses. The Santa Claus Mountain slope has been exhibiting progressive downward creep and has potentially unstable areas. It poses a direct threat to the Bridge River powerhouses, adjacent communities, shoreline development, Seton Dam and downstream areas. In the event of a slope failure, the potential for loss of life would be high. A slope inspection survey is required annually to monitor the situation.

5.4. Key Opportunities

The Resource Smart Inventory Study (E356) in 2005 and the Bridge River System Study (MER No 2014-032) did not identify any capacity increases for the Bridge River powerhouses. The current setup is well matched to the available water in the Bridge River system. In the early 2000’s, 6 of 8 runners (1-4, 5 and 6) were upgraded, resulting in increased capacity and efficiency. Therefore, there is an opportunity to make full use of existing runner capability through equipment investments. System output is currently constrained by equipment deficiencies causing deratings in 5 of 8 units. For example: the new runners at Bridge River 1 are rated at 58MW, compared to the current generator output of 50MW; Bridge River 2 5 and 6 runners are capable of 75MW while the units 7 and 8 are rated at 62MW. If these capabilities are coordinated with proposed capital investments it may be possible to modestly increase unit and plant output.

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6. Facility Strategy

A system study was last completed in 2014. This study examined the risks associated with operations of the entire La Joie, Terzaghi and Seton projects, and considered concepts and configuration to minimize identified dominant risk factors associated with the dams as well as maximizing energy and other social benefits.

The Facility Asset Plan reflects the recommendations of the system study. The Carpenter reservoir and downstream flow through the Bridge River plants are already optimized. The Bridge River 1 powerhouse is exposed to some retained risks given the ground condition and its location, but there are no plans to the move the powerhouse in the next forty years.

From the perspective of both maximizing energy benefits and minimizing contributions from risk factors associated with the dams, the highest objective of the Bridge system configuration is to preserve and provide safe impoundment for Carpenter Reservoir storage and to preserve the high head on the Bridge Generating Stations.

Having identified the key issues, risks and opportunities in the Bridge River facility, a component by component strategy has been proposed to upgrade/refurbish existing equipment at end-of-life over the next twenty years. This strategy addresses the most pressing issues to restore plant capability and improve reliability.

6.1. Recommended Investment Strategy

The proposed strategy for Bridge River is to address the pressing water conveyance/unit reliability issues through focused capital and Operations, Maintenance and Administration investments in the short term while minimizing the risk of spill at Terzaghi Dam. The investments will be focused on Bridge River 2 first, specifically units 5 and 6, then units 7 and 8 as this will not only improve reliability and water conveyance but also provide the largest increase in capacity per invested dollar. Bridge River 1 equipment investments are aligned with future needs and optimized water conveyance. There is also the opportunity to modestly increase generating capacity which should be taken into consideration during the unit investments. None of the proposed upgrades would impact the existing water license, although they would allow for increased unit flexibility.

There have already been some investments in the Bridge River facility in recent years and six significant investments were identified over the next ten years;

- Bridge River 2 G5 and G6 Unit upgrade – to eliminate 36% derating from historic
- Bridge River 2 G7 and G8 Unit upgrade – to eliminate 27% derating from historic
- Bridge River 1 G1-G4 Unit upgrade – to eliminate 20% derating on G4, address G1 the oldest generator winding in the Bridge River system and improve reliability of units.
- Terzaghi Dam Low-Level Outlet Reliability Upgrade

In addition, there are numerous penstock recoating projects identified and ideally they should be coordinated with the unit upgrades to take advantage of the long outage windows. Several other less material sustainment investments that are recommended. The timing and materiality of the recommended investments are shown in the following section.

All proposed projects will be risk assessed from the fleet perspective, and will consider constraints such as budgets and resources. The highest priority items will be included, while lower priority will be deferred for consideration in future planning cycles.

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6.2. Investment Prioritization

This Facility Asset Plan is an input for the 10-year Generation Capital Forecast. Capital expenditures are approved as part of the 10-year corporate capital planning process which guides the timing of investments, associated with the near-term (one to three years) planning window, which forms the basis of BC Hydro's BCUC Revenue Requirements Application. Investments beyond the 10 years facilitate Generation Asset Management's strategic planning process.

The Strategy at a Glance on the next page illustrates the recommended investments for Bridge River Generating Station and their timelines.

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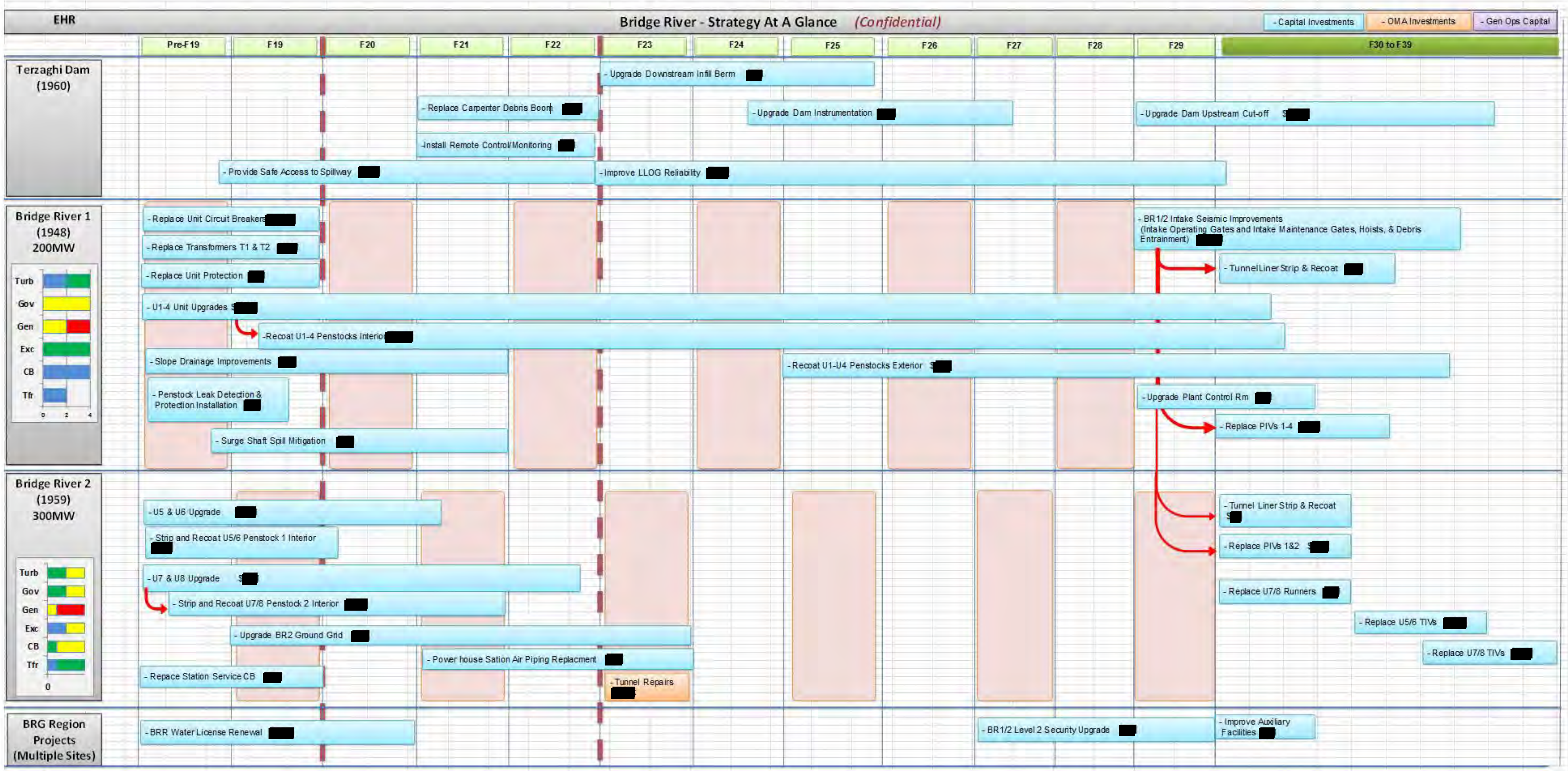

Notes:
For asset management purposes, a planning cost allowance is shown for proposed projects. Planning allowances have a high degree of uncertainty, and therefore should not be interpreted as a cost estimate. The first engineering cost estimate or cost estimate range is available at the end of the Identification Phase of the project lifecycle.

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6.3. Retained Risks

The 10-year investment strategy details projects to address the highest-priority risks and issues at Bridge River. It is important to consider that Bridge River is one of many generating facilities, and efforts are made to prioritize investments across the entire fleet over the 10-year window. Key retained issues and risks include:

Santa Claus Mountain Potential Slide – This slide poses a direct threat to the Bridge River powerhouses, adjacent communities, shoreline development, Seton Dam and downstream areas. In the event of a slope failure, the potential for loss of life would be high. The risk is presently managed through surveillance; a slope inspection survey is undertaken annually to monitor the situation. There are no plans to further address the risk through physical works such as drainage or slope stabilization at this time.

Bridge River 1 Powerhouse Foundation Soils – Bridge River 1 powerhouse is situated on an artesian aquifer that can cause movement of the powerhouse, especially during a seismic event. There are no plans to directly address this risk at this time due to other higher-priority risks in the system. However, there are a number to measures that can be taken to mitigate this risk. Foundation bleeder wells and piezometers are monitored and maintained to ensure stability of the powerhouse, offices will moved out of the powerhouse and the penstock leak detection project will help mitigate the impact of a ruptured penstock caused by powerhouse movement.

Terzaghi Dam Spills - The increased volume and frequency of the spilling downstream of the Terzaghi Dam poses environmental risks with First Nations and regulatory implications. Normal operation of Bridge River 1 and 2 units provides a hydraulic balance between the Seton and Terzaghi Dams so that minimum flows go down the environmentally-sensitive Lower Bridge River. The planned and unplanned unit outages and the interim lowered Downton Reservoir elevation (< 734 m) would result in large spills downstream of Terzaghi Dam in the lower Bridge River with potential environmental consequences. The Water Use Planning has established year-round target flows between 1.5 – 15 cms with an annual average of 6 cms in the Lower Bridge River from Terzaghi Dam. Variances of more than +/-5% from the targeted flows (+/-0.25 cms of target flows when flow is <5 cms) require BC Hydro to inform the St'at'imc First Nations, fisheries agencies and the Comptroller of Water Rights. The actual required spilling at Terzaghi Dam would depend on the volume and timing of the inflows received in the year, and the timing and duration of Bridge River 1 and 2 unit outages.

Penstocks Seismic Withstand Risk - Penstock rupture during a seismic event may lead to slope failures and flooding of the powerhouses. A significant earthquake could result in uncontrolled flow from Carpenter Lake out of a breached penstock with currently no means available to stem the flow. This could result in significant—possibly catastrophic—damage to the powerhouses and possible loss of life. Damage and flooding downstream impacts at Seton Canal would also be likely.

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Penstock Inlet Valves – The Bridge River 1 Penstock Inlet Valves (PIVs) are unable to close under rupture flows. Considering the vulnerability of the penstocks, intake structure and Bridge River 1 powerhouse to failure in an earthquake, and further considering that the PIVs are unable to close under rupture flows, a significant earthquake could result in uncontrolled flow from Carpenter Lake out of a breached penstock with currently no means available to stem the flow. This could result in significant—possibly catastrophic—damage to the powerhouses and possible loss of life. Damage and flooding downstream impacts at Seton Canal would also be likely.

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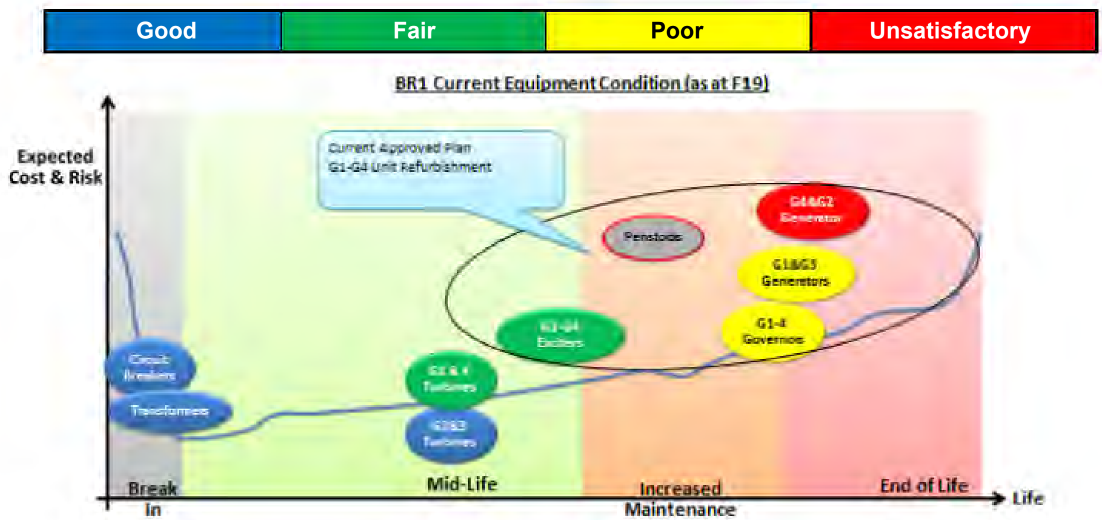
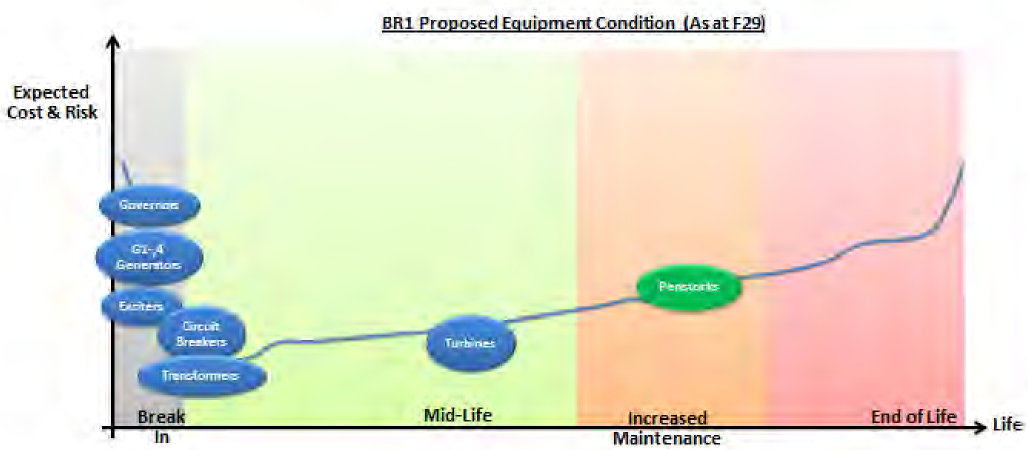
7. Expected Results

Assuming that the proposed series of investments outlined in the previous section are implemented, the following results should be expected.

7.1. Bathtub Curve – Current and Future State

The Equipment Health Rating of the major system components is shown on the following bathtub curves to provide a visual depiction of not only condition but also lifecycle stage. The two diagrams show the current state at F2019 and the likely state at the end of the ten years assuming that the proposed suite of investments outlined in section 6.2 are implemented as expected.





The equipment investments recommended for Bridge River 1 in the current planning cycle (F20-21) are focused on high-risk aging plant equipment such as generators, governors and exciters. At the end of ten years (F2029), the Unit 1-4 generators, Governors and Exciters will have been replaced, moving them all to “Good” condition (shown in Blue), and the Penstocks would have

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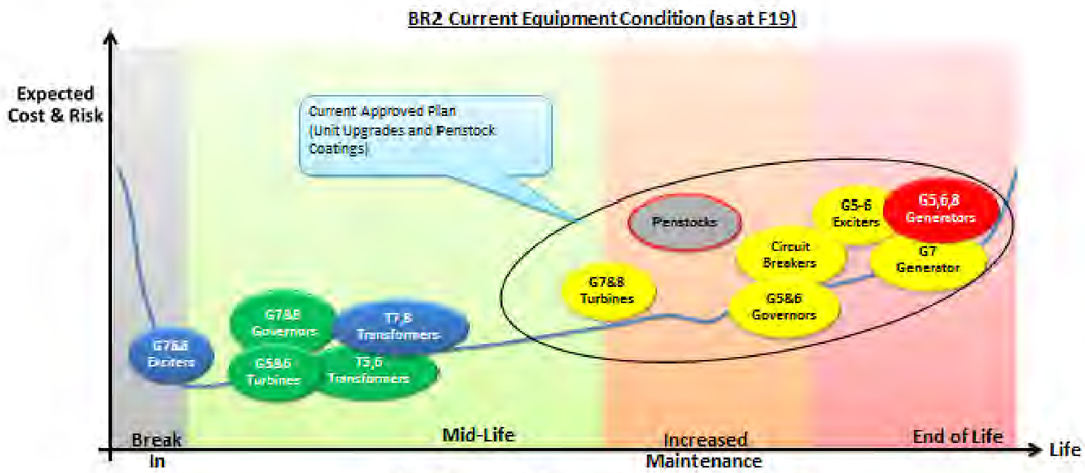
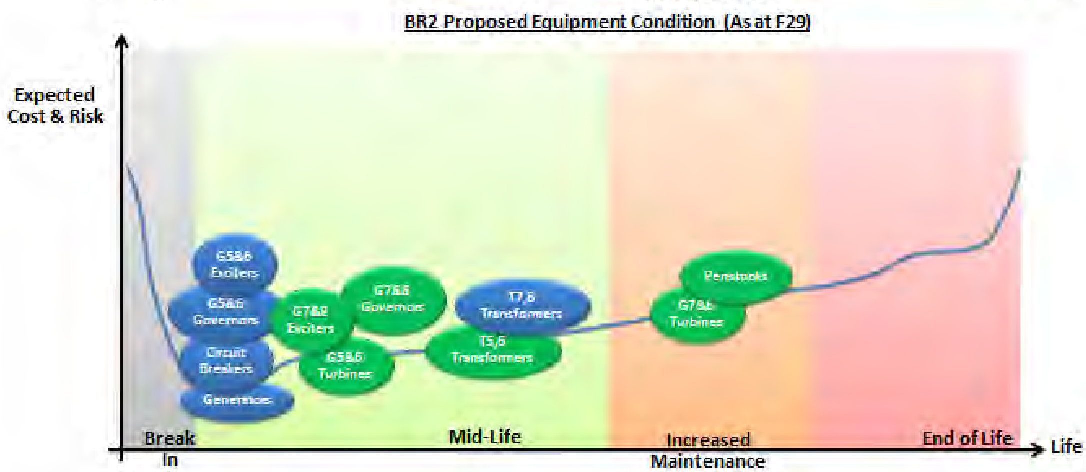
been recoated moving them to "Fair" condition (show in Green). Additional turbine work included in the capital refurbishment projects are anticipated to bring G1 and 4 to "Good" condition rating.





The equipment investments recommended for Bridge River 2 in the current planning cycle (F20-21) are focused on high-risk aging plant equipment such as generator, governor, exciter and governor replacements to improve reliability and restore lost capacity. At the end of ten years (F2029), most Bridge River 2 generating equipment should be restored to "Good" (shown in blue) or "Fair" condition. There will be some aging of components.

7.2. Strategic Outlook

If the investments are completed, as proposed in this Facility Asset Plan, many of the generating equipment risks will have been mitigated resulting in more reliable and efficient generating equipment with a modest increase in capacity. In the next ten to twenty years, investments will

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focus on major civil assets and gates and valves. These investments will focus on mitigating seismic risks and civil repairs to the dam and other water passage infrastructure.

In addition, it can be expected that targeted investments will be required to replace aging electronics in equipment replaced in the 2000's as the life cycle of these components is much shorter than the original electro-mechanical components they replaced.

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8. Data References

The following is a list of data references used in this Facility Asset Plan. All data is for the last complete fiscal year unless stated otherwise.

Annual Revenue (proxy) – facility revenue (proxy) is expressed as a range (highest, lowest) of values calculated for the last five years. These values are available for each facility in a spreadsheet on the GAM J: Drive. The revenue data is provided by GSO and is only a proxy for revenue attributed to each facility.

Maximum Sustained Generating Capacity – is available from the facility Hydroweb page and the values are provided by GOO 1J-08.

Historic Annual Average Plant Generation – is available from the facility Hydroweb page and the values are provided by GSO.

Investment Summary – this graph is generated from a spreadsheet on the GAM J:Drive. The historical capital spend is retrieved from the GCCR/CCR reports. The forecast capital spend is taken from the asset investment planning tool.

Performance Data (Availability Factor, Forced Outage Count, Forced Outage Duration, Forced Outage Factor) – is available from the GAM Monthly Report. This data is extracted from the USR report maintained by GSO.

EHR Equipment Ratings – are available from the GAM Monthly report. This data is extracted from EHR and is usually for the most recent month the FAP is prepared.

EHR Forecast Ratings – this is available from the EHR Forecast spreadsheet on the GAM J:Drive. The spreadsheet uses a combination of current EHR rating, historical trends for equipment ageing and proposed investments to predict the future EHR rating of equipment. Some judgment is required and discussion with other GAM members may help come to a consensus.

Completed and Ongoing Projects – these projects are available from previous fiscal GCCRs/CCR reports.

Dam, Spillway and Water Passages – description, dimensions, ratings and capacities of these components comes from a number of sources; Dam Safety's Operation, Maintenance and Surveillance (OMS) Manual, GSOs Generation Operating Orders (GOOs) and Generation Operations Local Operating Orders (LOOs). All three should be aligned but if discrepancies are discovered then a discussion with the various parties will be necessary. Generally, LOOs must conform to GOOs and the system is operated via the GOO/LOO as they are easier to update to reflect new information.

Hydrology – similar to dams, spillway and water passages above there are various sources of information OMS, GOO and LOO. In addition, GSO will provide inflow data.

Seismic Withstand – these values are available from Dam Safety to ensure the latest values are used as they are constantly being updated.

Probable Maximum Flood (PMF) – these values are available from Dam Safety or the OMS.

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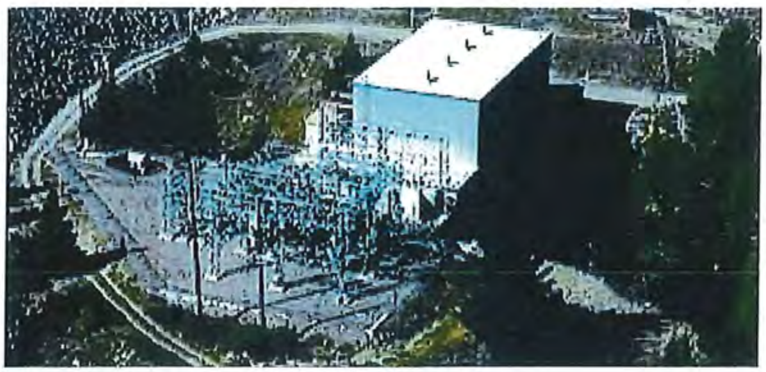
FACILITY ASSET PLAN

LA JOIE GENERATING STATION

DECEMBER 2017



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1. INTRODUCTION

The purpose of the Facility Asset Plan is to provide a robust understanding of the issues, risks and opportunities faced by a specific facility, and the proposed long term investment strategy that is believed to offer the best value. Facility Asset Plans are key inputs to the fleet planning process. The investment strategies that are proposed in discrete facility asset plans will be reviewed collectively, and prioritized to provide the most appropriate suite of investments across the fleet given resource and financial constraints, outage planning, and other considerations. As a result, lower priority investments will be deferred and considered in future planning.

1.1. The Facility Planning Process

The Facility Asset Planning process provides stakeholders with a transparent methodology for producing a documented strategy. It is a structured process to identify key issues and risks, and prioritize investment decisions for a specific facility or system. Data is consolidated from multiple parties throughout Generation, including Generation Operations, Dam Safety, Safety, Generation System Operations and Environmental Risk Management. Key risks, issues and opportunities at a facility are identified, and compiled in the Copperleaf C55 asset management tool. The data is reviewed to consider factors such as the facility's strategic role, performance targets, risks and growth opportunities. The consequences and frequency of issues and risks are assessed through the lens of the Corporate Risk Matrix and Capital Investment Analysis Guide. Appropriate medium to long term investments are identified for consideration in both the Generation and Corporate capital planning process.

1.2. The Facility Asset Plan

The Facility Asset Plan document is a concise record of the outcome of the Facility Asset Planning process. The primary audiences are Generation Asset Management, Dam Safety, Generation Operations, and the Generation Executive Management Team. Its primary intention is to provide:

- Current facility configuration, value and obligations;
- Significant known issues, risks, and opportunities;
- Contextual performance and recent investments, based on last complete fiscal year;
- High level scenarios considered to address issues, risks and opportunities;
- Proposed investments aligned to the expected planning cycles of the business

By signing the Facility Asset Plan, management are agreeing that, to the best of their knowledge, the content is complete and accurate, and that the proposed investment strategy reflects the best interests of BC Hydro (BCH) at the facility level and is consistent with goals and objectives outlined in the Generation Strategic Asset Plan. The signature of the Senior Vice-President of Integrated Planning does not represent endorsement of the technical content, but confirms that the planning process has been appropriately followed, the right stakeholders engaged, and broad agreement on the strategy for the facility has been reached.

Once approved, the Facility Asset Plan's investment strategy will become an input for the Generation Fleet Wide Planning process. This will determine whether the investments proposed in the Facility Asset Plan are optimal at a fleet level, or whether changes to the Facility strategy are required.

The Copperleaf C55 asset management tool will be updated regularly to capture emerging issues, risks or opportunities, or changes to existing ones. The Facility Asset Plan will be updated as per Generations Strategic Asset Management Manual (SAMM) or whenever new information leads to a significant change in the strategy for a facility.

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2. Facility Overview

La Joie is an Extreme Consequence facility located on the Bridge River near the Village of Goldbridge approximately 100 km west of Lillooet. The facility is comprised of an uncompacted rockfill dam with an intake structure and a free crest overflow spillway section, Downton Reservoir and a single 25 MW unit powerhouse. A 69 kV transmission line (60L22) connects La Joie to the BC Hydro grid at Bridge River 1 switchyard.

La Joie is the most upstream of three generating facilities in the Bridge River system. The Bridge River is impounded by two dams (La Joie and Terzaghi), diverted through Mission Mountain via tunnels and Bridge 1 and 2 powerhouses into Seton Lake, and finally enters the Fraser River via the Seton Generating Station and Dam.

The La Joie basin inflows consist mainly of snowmelt runoff occurring from June to August. The facility is primarily operated as a baseload plant for much of the year. Powerhouse discharges are adjusted to manage downstream flow targets, Downton Reservoir levels and maximize Bridge River system generation. La Joie provides support to the local 69 kV transmission system and on occasion, during 60L22 outages, operates islanded to supply the local Goldbridge and Bralorne load. The local load is relatively small, only 1.5 MW, and the plant requires constant staffing during 60L22 outages to maintain frequency and voltage control.

On average, the generation capability from La Joie represents less than 1% of BC Hydro's total hydroelectric generation capacity. For asset management purposes, La Joie is classified as a Strategic facility. From 2012 to 2016 the facility produced annual revenue between $9 million to $14.6 million per year.

The dam was originally commissioned in 1951 for storage and in 1955 it was raised to its present height and the generating unit was added. La Joie Dam is an 87m high 1036m long uncompacted rockfill structure and provides impoundment for Downton Reservoir. The intake consists of a North and South Conduit that direct water to the powerhouse via two 180m long, 2.74m diameter steel conduits. The South Conduit supplies the generating unit, an Auxiliary Bypass Valve (not in-service) and a Pressure Regulating Valve (PRV) which discharges into the tailrace. The PRV operates in conjunction with the generator following any type of load rejection or can be operated independently if the generator is not running. The North Conduit supplies two Hollow Cone Valves (HCVs) which also discharge into the tailrace to manage the reservoir level. The two Conduits and the associated discharge components represent the only means to actively control the reservoir levels.

The design of the uncompacted rockfill dam presents a number of challenges. The shotcrete face of the La Joie dam acts as the water barrier and is deteriorating. Expansion joints are eroding, shotcrete panels are buckling and cracking, which leads to increased leakage each year unless repairs are undertaken. It is only due to ongoing repair/replacement of these panels and joints and

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managing the reservoir level that keeps the leakage under control. Additionally, the dam does not meet the seismic performance criteria of an Extreme Consequence dam.

The following table summarizes key facility data:

Facility Name	La Joie
Asset Classification	Strategic
Dam Classification	Extreme
Original In-Service Date(s)	Dam: 1951 Powerhouse: 1955
Annual Revenue Range (F2011 to F2016)	[redacted] [1]
Plant Maximum MW Rating	25 MW
Historic Annual Average Plant Generation	162 GWh*

*Lower Downton reservoir operating level will reduce these by 30% over historical values

Equipment, such as the transformer and circuit breaker, has been replaced in the last 10 – 15 years. The generator, governor, exciter and turbine are original and replacements are proposed to start in the next 10 years. In addition, the water passages and discharge facilities have received recent investments to ensure continued reliable operation and active management of the reservoir levels.

The La Joie Dam Capital Improvement Project was initiated in F28 for the La Joie Dam which is focused on improvements in the dam's seismic performance, reducing the static leakage and addressing water conveyance issues. In 2015 the Downton Reservoir Maximum Normal Operating Level was reduced from El. 749.8m to El. 734.0m to help mitigate the seismic risk. This project is broad in scope and represents a significant future investment. The timing of the implementation of this project is dependent on the successful completion of the Bridge 1 and 2 unit replacement projects Work on the Bridge River units should be completed first, to mitigate water management issues that may otherwise arise during construction work on the La Joie dam.

La Joie generates moderate annual revenue and a greater level of investment is proposed within the next 20 years to proactively mitigate the reliability risks and avoid extended outages and a loss of generation from the facility. A component by component risk reduction strategy is recommended. The strategy would mitigate dam risks and then followed by unit reliability. There is also the opportunity to modestly increase the capacity of the generating station which should be taken into consideration during the equipment investments.

[1] Proxy for revenue attributed to facility

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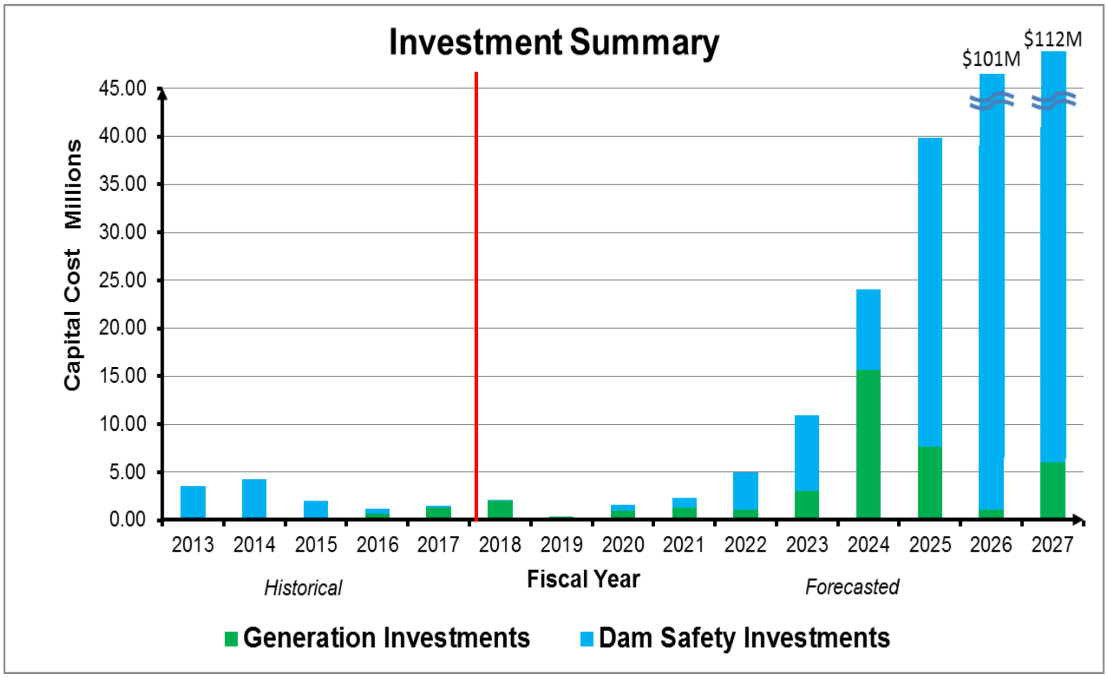

*(It is recognized that there is a high degree of variability and uncertainty associated with the context and cost of capital investments proposed for consideration beyond F22)

Investments in the past have been relatively modest to address the reliability concerns with the discharge facilities (gates, valves and conduits). These modest investments will continue to address conduit, governor and water conveyance reliability concerns. Near the end of the 10 year window, investments will ramp up to address the dam seismic withstand and static leakage risks and end of life equipment replacements such as generator, exciter, governor and turbine.

The most significant issues and risks that are proposed for resolution or are well underway within 10 years are listed below. More detailed information can be found in Section 5.

- La Joie Dam static seepage and seismic risks (started)
- Intake tower Alkali-Aggregate Reaction (AAR) and seismic risks (started)
- South Conduit corrosion and seismic risks
- Pressure Regulating Valve (PRV) reliability/maintainability issues

Targeted OMA investments are recommended to enable continued reliable operation and support appropriate capital investments. The most significant OMA items include:

- Dam Upstream Face Shotcrete repairs
- Pressure Regulating Valve (PRV) weld repairs

These investments are in addition to the regular annual OMA activities planned for the facility.

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Based on the recommended investment strategy, it is recognized that for at least the next 10 years there will be a number of retained risks at the facility. Key retained risks are listed below with more detailed information provided in Section 6.3. For some of these risks a project to address them may be started in the next 10 years, but not completed.

- Wedge Drop Mountain Potential Slide
- Generator Reliability
- Exciter Reliability
- Turbine Reliability

2.1. Performance Overview

The last 5 years shows a trend of decreasing reliability and increasing maintenance at LAJ. F13 and F14 saw long planned outages as a result of the capital project to improve discharge reliability. F14 also saw forced outages due to problems with the System Control Center and turbine instrumentation. In F15 there were a few short duration forced outages but there were a number of long planned maintenance outages for Intake concrete repairs and replacing the failed PRV discharge tunnel. In F16 there were two forced outages due to a broken shear pin and a bearing temperature trip. Governor problems also forced a maintenance outage extension. More recently F17 availability was impacted when a wiped bearing and extensive cavitation damage on the PRV had to be addressed, extending the planned outages.

Average/Unit	F13	F14	F15	F16	F17
Availability Factor	87.7	51.5	65.6	65.9	58.5
Forced Outages (count)	1.0	2.0	3.0	2.0	0.0
Duration of Forced Outages (hours)	0.4	200.6	4.3	1904.6	1659.0
Forced Outage Factor	0.0	2.3	0.1	21.7	18.9

EHR Ratings for Equipment (as of September 2017)

Equipment Health Rating	Generator	Turbine	Circuit Breaker	Governor	Exciter	Transformer
Unit 1	P	P	G	P	P	F

Good	Fair	Poor	Unsatisfactory

The following graph shows the expected change in equipment condition following the recommended strategy proposed in this plan.

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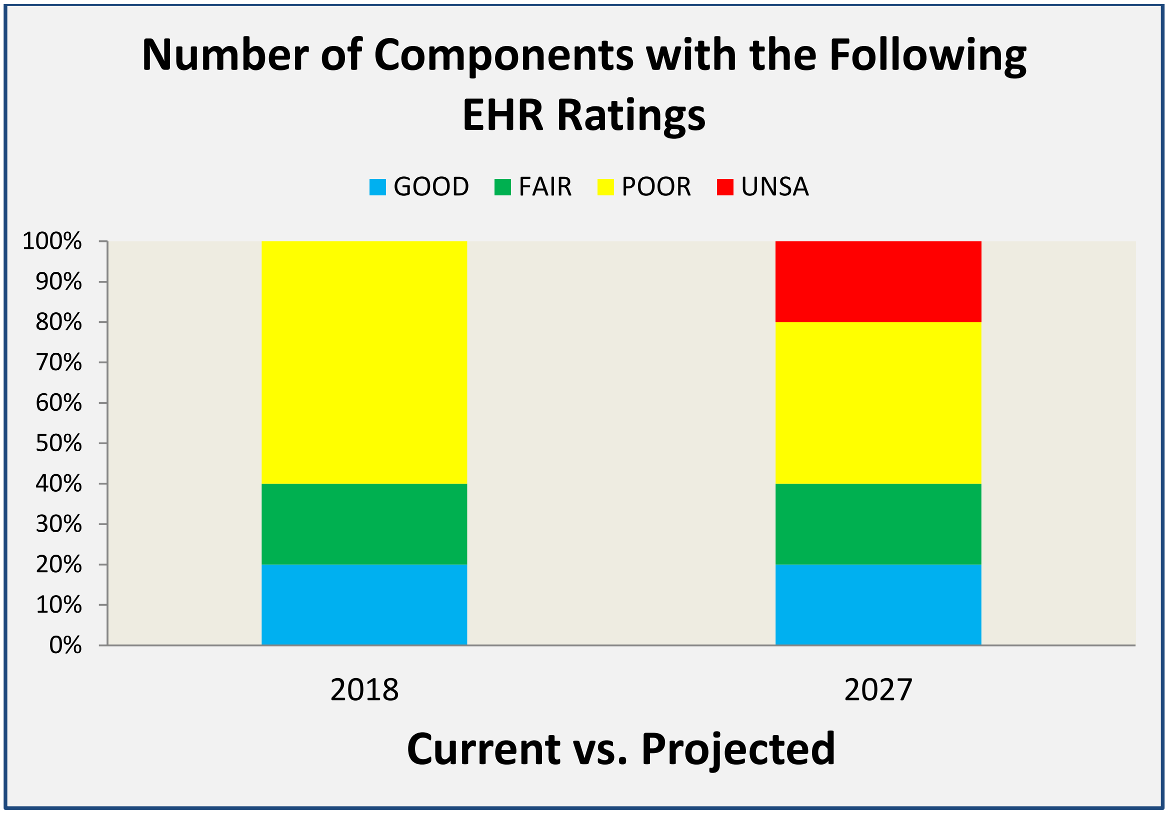

2.2. Other Relevant Information

La Joie provides voltage support to the 69 kV system in the Cariboo Region but output is restricted due to stability concerns whenever BR1 T3, 2L19 or 60L21 is out of service. Local regional load is much less than local generation and the 69 kV transmission system is old and has many constraints without the aid of the 230/360 kV transmission system. A new 24MW Independent Power Producer in Goldbridge went into service in 2013 sharing 60L22 with LAJ which has resulted in constraints on 60L21 during the summer months. A new 60/230 kV transformer (T30) was installed at BR1 however; this transformer (T30) will not alleviate any of the 69kV transmission constraints in the area.

The La Joie facility is unique in its design in that all discharge facilities that can be used to actively manage the Downton Reservoir are located in the common intake and powerhouse. The free crest overflow spillway cannot safely manage high inflows on its own. Historically, safe passage of high inflows requires the use of discharge facilities to manage the reservoir to the rule curve. A rule curve specifies reservoir level targets for certain times of the year based on snowpack levels so that there is adequate storage and discharge facility capacity to manage the inflows. However, now that the reservoir is being operated to a lower maximum operating level the rule curve is not required as there is adequate buffer within the reservoir to manage unforeseen inflow events.

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2.3. Investment Summary

In the past 5 years, La Joie has benefited from a number of capital investments. These have been to mitigate known water conveyance reliability risks. The following outlines key investments made or ongoing in the last 5 years:

COMPLETED PROJECTS

- **Dam Water Passage Reliable Discharge (F16)** – This project was in response to a number of concerns regarding the water passages at LAJ. The project certified the intake gantry crane, SDI certification of the Intake Operating Gates (INOGs) 1&2, Intake Stoplogs (INSLs) and the Low Level Operating Gate (LLOG) by replacing the INSLs and LLOG, replaced the Hollow Cone Valves (HCVs), repaired the Pressure Regulating Valve (PRV) and PRV discharge conduit, and provided a number of misc. improvements to make it easier to maintain the water passage components.
- **Generator Stator Radiators (F16)** – the generators coolers were original (1950s). The suffered from corrosion, obstruction in the tubes and leaks. They were no longer effectively cooling the unit in the summer months and were at risk causing a generator fault. New coolers were installed.
- **Replace Unit Cooling Water and Station Service Water Piping (F18)** – the station piping is original (1950s) and suffers from corrosion, leaks from thinning walls, and obstructions to filters and small passages due to rust scale. This project will replace the station water piping and drainage piping, including lead paint and asbestos insulation, to ensure reliable operation, reduced maintenance costs and increase worker safety.
- **Upgrade Intake Access Bridge (F18)** – the intake tower is accessed via a suspension bridge from the dam crest. This bridge is original and does not have a documented safe load rating or as-built drawings. This project will assess the bridge, refurbish it as required and provide engineering drawings and a safe load rating to ensure worker safety.
- **Powerhouse Roof Replacement (F18)** – this project replaced the old roof membrane to address leaks and preserve the underlying structure and powerhouse equipment.

ONGOING PROJECTS

- **Upgrade Unit Protection and Control (F20)** – The unit protection and control (P&C) system is original, obsolete, difficult to maintain and requires increased maintenance to identify hidden failures. This project will update the unit electrical P&C systems with a modern digital system that will increase reliability and reduce maintenance.
- **La Joie Dam Capital Improvements (F29)** –This project will address the seismic vulnerability of the dam and intake tower and dam seepage. In addition, it will look at mitigating a number of intake deficiencies such as concrete repairs, intake gate reliability and stoplog constraints.

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3. OPERATIONS AND HYDROLOGY

3.1. Facility Components

The La Joie facility is part of the larger Bridge River system which stores and diverts the flows of the Bridge River into Seton Lake and eventually the Fraser River. La Joie is the smallest generating station and first of three facilities in the Bridge River system, located near Goldbridge, and historically provided 40% of the storage in the Bridge River System. However, a new lower maximum operating level for the Downton reservoir (established in 2015) has reduced this storage capacity to about 25% of the Bridge River system. The Downton Maximum Normal Operating Level was reduced from El. 749.8m to El. 734.0m in 2015 to help mitigate risks under both seismic and static conditions until future remediation project are completed. The La Joie facility consists of La Joie Dam and Intake, La Joie Generating Station, and Downton Reservoir.

The La Joie Dam, Intake and Downton Reservoir

The La Joie Dam is a 1036m long, 87m high sluiced rockfill structure with a shotcrete membrane on the upstream face which impounds the upper Bridge River to form Downton Reservoir. The reservoir is located in the South Interior climatic region. The watershed includes the Bridge River as well as a number of smaller tributaries. Snowmelt is the primary contributor to flows in the Bridge River Basin.

The runoff regime is characterized by high flows in the late spring to early summer resulting from snowmelt followed by a recession period during the drier summer and winter months. The main mechanisms for water to exit Downton Reservoir are:

- A steel South Conduit [2]connects the free standing intake structure to the Powerhouse. The inlet consists of two Intake Operating Gates (sill elevation 697.4m) and a Low Level Operating Gate (sill elevation 688.5m).
- A steel North Conduit connects the free standing intake structure to the Powerhouse. The inlet consists of two Intake Operating Gates (sill elevation 697.4m)
- A 102m U-shaped free crest spillway (capacity 900 cms at IDF El. 753.1m) which discharges excess water in Downton Reservoir starting at elevation 749.8m into a dry channel that connects to the Middle Bridge River

La Joie Generating Station

The La Joie Generating Station discharges into the Middle Bridge River. It consists of the following discharge components:

1) South Steel Conduit 2.74m in diameter trifurcates into three water passages:

[2] At the La Joie facility the penstock is referred to as a conduit. The terms conduit and penstock may be used interchangeably in this Facility Asset Plan.

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- A 3.7m Turbine Inlet Valve (TIV) and a single 25MW generating unit (preferred discharge)
- A 2.4m Pressure Regulating Valve (PRV) opens on unit trips to reduce water hammer in the steel conduit and maintain flows in the middle Bridge River.
- A 1.9m Auxiliary By-Pass Valve (ABPV) (not in service)

2) North Steel Conduit 2.74m in diameter bifurcates into two water passages:

- Two 1.2m Hollow Cone Valves (HCV) to help regulate the reservoir level

The diagram on the following page illustrates the key system components of the La Joie facility and the Bridger River System.

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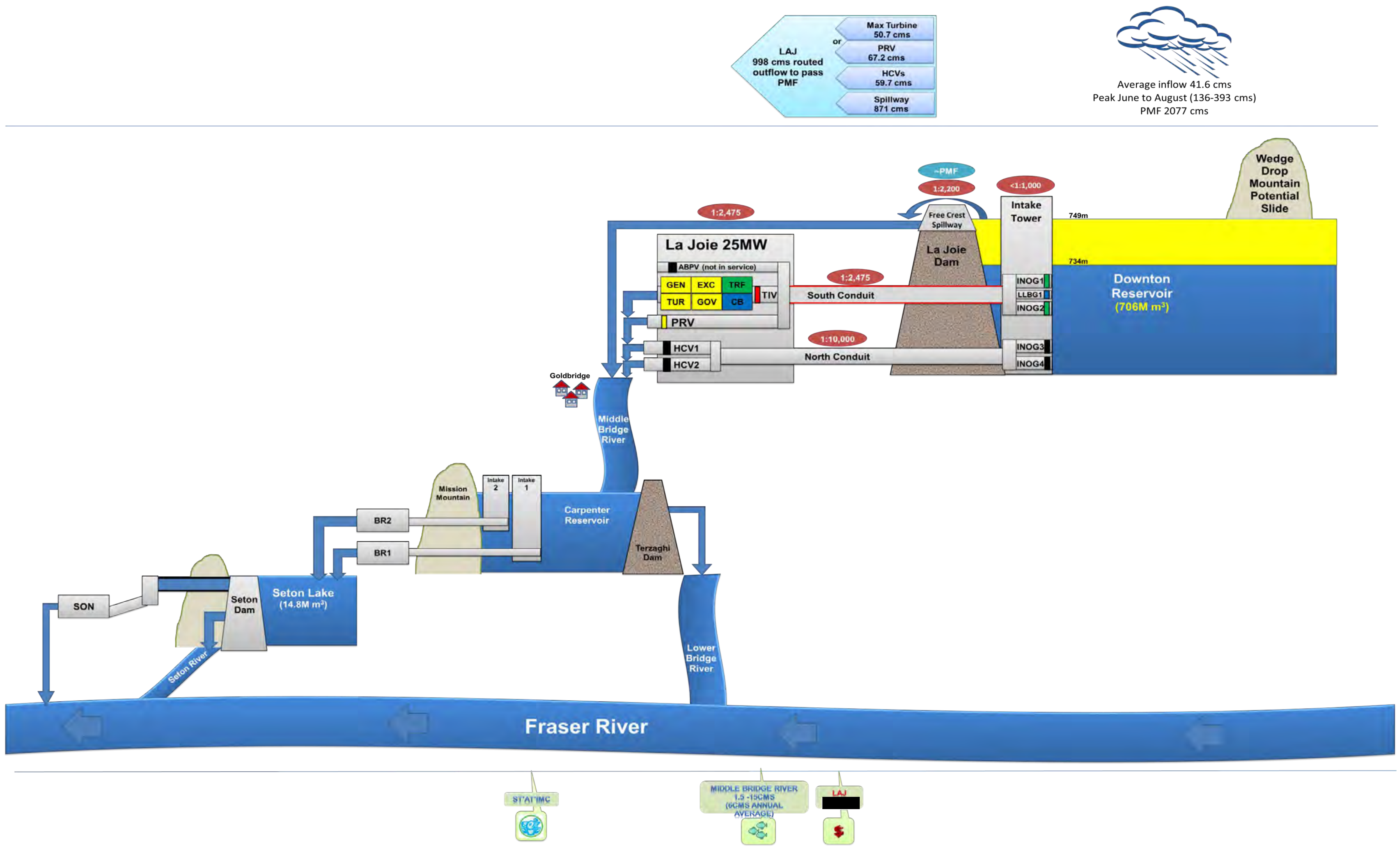
La Joie Generating Station System Diagram



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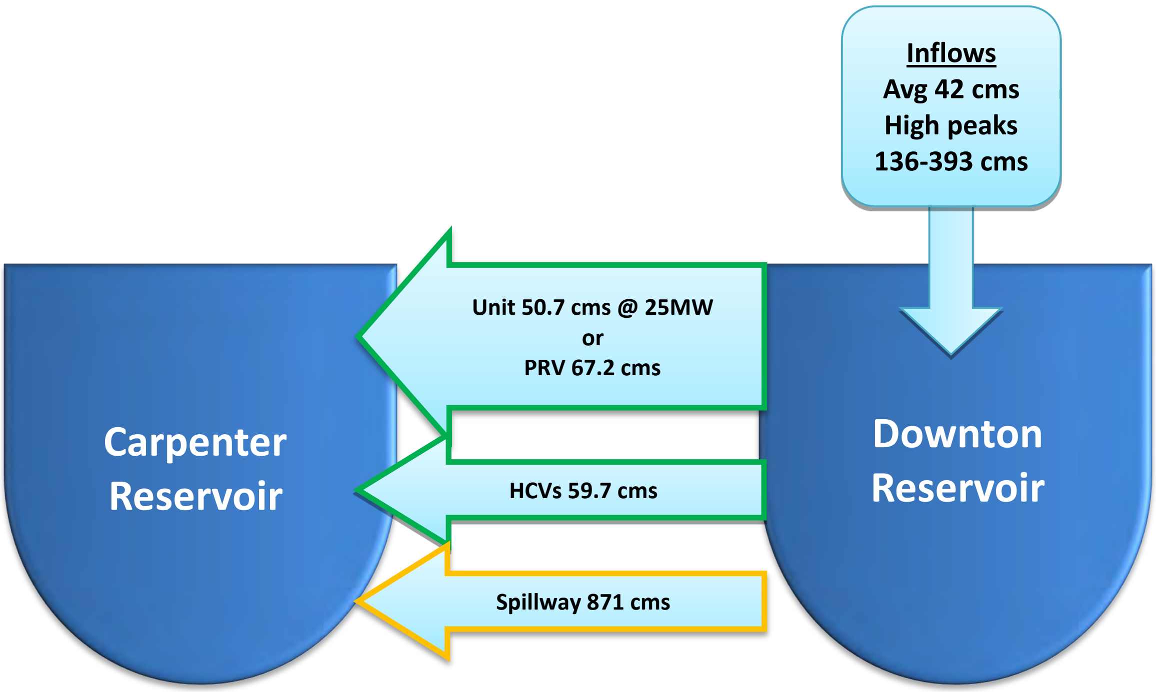
3.2. Hydrology – System Inputs and Outputs

The La Joie facility can be viewed as a series of inputs and outputs that must be well balanced for the facility to run effectively. The diagram below shows the main components under BC Hydro control. The arrows outlined in green represent active controls, while those outlined in orange represent passive free crest spillways.



Downton Reservoir: All discharge facilities are required to pass the Probable Maximum Flood (PMF). The Inflow Design Flood (IDF) = Probable Maximum Flood (PMF). The discharge facilities capacity of 1029 cms meets the routed discharge requirements to pass the 6 hour IDF of 2165 cms. The Downton Reservoir Maximum Normal Operating Level has been reduced from El. 749.8m to El. 734.0m to help mitigate risks under both seismic and static conditions.

3.3. Facility Operations

La Joie is primarily operated as a base load plant. The Downton Reservoir storage capacity moderates the inflows of the upper Bridge River. The La Joie Powerhouse provides a steady flow into Carpenter Reservoir via the generator or PRV and HCVs. The PRV works in conjunction with the unit to moderate pressure transients in the conduit. A target flow is set; generations is maximized and if the unit trips flows are transferred to the PRV as it opens automatically. This also maintains flows uninterrupted in the Middle Bridge River during unit interruptions. The generator / PRV can be operated remotely from the BC Hydro control center in the Lower Mainland, the HCVs

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are manually operated locally in the powerhouse while the overflow spillway is unregulated. The generating unit or PRV and the HCVs are the only way to actively manage the Downton Reservoir levels.

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4. Value, Benefits & Obligations

The La Joie facility provides a number of financial, reliability and environmental benefits. In addition BC Hydro has a number of obligations in the area.

Generation of Electricity and Revenue

The 25 MW LAJ generating facility generates an average of 162 GWh annually and has recently contributed between [redacted] in annual proxy for revenue. However, with the new lower Downton maximum reservoir operating level the generation and associated revenue is expected to be reduced by 30% from historical averages.

The La Joie Dam is one of two dams on the Bridge River that are used to store and manage the inflows for the purpose of electricity generation at the Bridge #1 and #2 generating stations on Seton Lake. Downton Reservoir historically provides 40% of the storage in the Bridge River system which allows for additional energy to be generated at downstream plants. However, to manage risks under both seismic and static conditions the new lower Downton Reservoir level has reduced the system storage by about 25%. The Downton storage provides operating flexibility at the Bridge River plants, allowing load factoring and mitigating flow fluctuations that could otherwise result in spills above the target hydrograph at Terzaghi Dam down the Bridge River.

Water Passage, Flood Mitigation and Erosion Control

Middle Bridge River Flows: The Water Use Plan Order establishes year round target flows (5.7-18 cms) in the Middle Bridge River from the La Joie Generating Station. Variances of more than +/-10% from the targeted flows or flows expected to go below 11.3 cms require BC Hydro to inform the St'at'imc First Nations, fisheries agencies and the Comptroller of Water Rights. In addition, ramp rates have been established to limit river stage changes to <2.5cm/hr and <15cm/24hrs.

Social

St'at'imc First Nations Agreement – BC Hydro and St'at'imc First Nation signed a number of agreements in 2011 to address the historical impacts of the Bridge–Seton System facilities. The Bridge-Seton System lies within their traditional territory. As part of the agreements BC Hydro agrees to work with the St'at'imc First Nation and explore economic opportunities. At the same time the agreements commit BC Hydro to operating the system consistent with our Water Licenses and Orders. Any deviations from the operating regime require notification of the St'at'imc First Nation. The certainty protocols also mean that if there are any material changes to the facilities themselves (e.g. additions, reconstruction, etc) that require a change to BC Hydro's Water License, BC Hydro will consult with the St'at'imc First Nation.

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5. Issues, Risks and Opportunities

There are a number of issues, risks and opportunities associated with the assets in the LAJ Facility. The key risks are described in the following section, including:

- A brief description of the key issue, risk or opportunity
- The expected impact of a failure
- The risk score, which is based on the Corporate Risk Matrix. Risk scores range from 0 to 16, with 16 representing the highest level of risk. Risks not proposed for mitigation in the 10 year planning window may not have a risk score.
- A planning allowance to mitigate, if known
- Issues and risks proposed outside of the 10 year window may not have a developed cost forecast or risk score.

More detailed information on less significant issues, risks and opportunities are located in Generation Asset Management's online capital planning tool (C55).

The seismic issues and flood risks have been included in the facility diagram in Section 3.1, where issues or risks are known to exist. Seismic withstand capabilities are shown in the red ovals, and flood withstand capabilities in the blue ovals.

The investment strategy to address the risks discussed below is detailed in Section 6.0. Facility Strategy.

5.1. Generating Equipment

There are a number of different components that contribute to the reliability of the facility. The conceptual diagram below shows where key components are estimated to be in their lifecycle, coupled with the condition of the equipment (if known) based on EHR. The x-axis represents the life-cycle associated with each component illustrated. Not all components have the same expected life cycle. The y-axis represents the performance risk which can be expressed in terms of condition assessment, reliability/availability, probability of failure, etc. Typically, maintenance costs associated with newly installed equipment should be expected to be higher, given that additional work may be required to eliminate any construction deficiencies, and to perform increased inspections in the first few years of life (often in support of equipment warranty). Equipment towards the end of lifecycle is expected to be a higher performance risk and is likely to require an increased level of maintenance. This may progress to a point where either the component is no longer maintainable, or the best value decision is to replace or refurbish the equipment (i.e. it is at its end of life).

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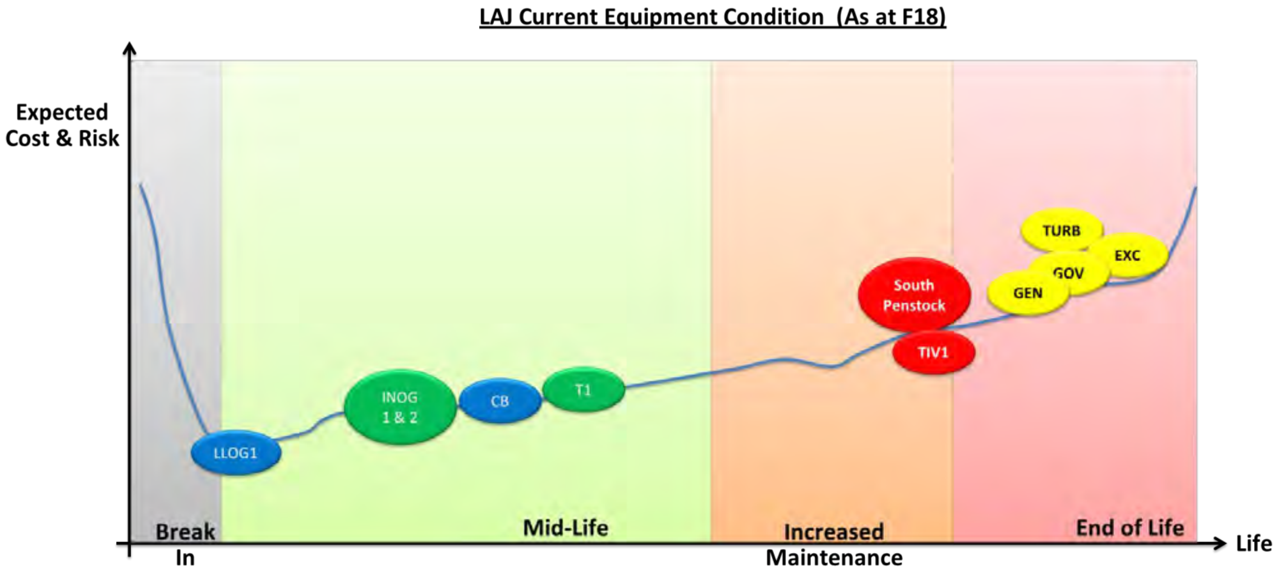

The main generating components are a mix of old and new assets, and based on EHR, are rated as GOOD to POOR. The transformer and circuit breaker are relatively new, having been installed in the last 10-15 years. The rest of the equipment is original and rated POOR and at 60 years are at the end of expected industry life. La Joie is a single unit plant so equipment outages result in loss of generation. The water passage has seen significant investment in the past few years to assess condition and address known deficiencies. The Intake Operating Gates (INOG1&2) and Low Level Operating Gate (LLOG1) are relatively new. Generally, water passage components are in GOOD to FAIR condition, however, the South Conduit and TIV have been rated as UNSATISFACTORY, due to coatings failure and active corrosion.

Generator Stator Degradation – Reliability risk (risk score 10) – Estimated mitigation [redacted]

Due to the age, condition and poor test result of the generator stator there is a risk of a fault which would lead to a long forced outage and a loss of generation. The generator is original and has exceeded its industrial life expectancy. The generator has an EHR rating of POOR due to poor test results, age, leaking asphalt from windings, corona winding damage and core waves and chevrons at the core split. There are only four windings of this type (manufactured by Canadian General Electric) and vintage (1952 to 1956) in BC Hydro. The stator winding at the Wahleach facility was rewound in 1992. The La Joie winding was reversed in 1994 as a short term life extension. Experience at other facilities, such as John Hart, has shown winding reversals are no longer effective and have resulted in ground faults.

There is a LAJ unit upgrade project proposed to address this risk.

Turbine Runner Wear – Reliability Risk (risk score 8.5) – Estimated mitigation [redacted]

Due to age and wear on the turbine components there is a risk the runner will fail, which would lead to a long forced outage resulting in a loss of generation. The turbine is rated as POOR due to age,

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low efficiency, moderate cavitation, excessive wicket gate leakage and concerns with wicket gate bearing and seals resulting in broken shear pins. Forced outage performance has deteriorated due to issues with broken shear pins. The runner has already exceeded its industrial life expectancy and is expected to require replacement in the next 20 years. However, as long as it remains structurally sound it can continue to operate at lower efficiencies with higher maintenance costs, for a long time. This assumes a major overhaul is performed to address the other wear parts in the turbine (wicket gate seals, bearings, regulating ring, shaft seals) every 20 – 30 years. A major turbine overhaul would extend the life of the unit until such time a case can be made for replacing the runner with a more efficient one or it starts to crack due to the welding repairs. There is only a finite amount of welding that can be done before the built up stresses lead to cracks and more frequent repairs. BC Hydro's past experience with cracking runners have led to some extensive outages at the Lake Buntzen 1 and GM Shrum facilities.

Governor Performance – Reliability risk (risk score 10) – Estimated mitigation [redacted]

Due to age, decreasing reliability and a lack of OEM support and spare parts there is a risk the governor could fail which would lead to a long forced outage and a loss of generation. The governor is original and has exceeded its industrial life expectancy. The governor has an EHR rating of POOR due to reliability performance, leakage and lack of spare parts. Manufacturer support is no longer available. As the governor wears and degrades it becomes increasingly difficult to control the generating unit speed and output, stable operation and proper shutdown of the unit during forced outage events. While connected to the system these have a minor impact, however during 60L22 outages, when La Joie is islanded and is required to run to support local load, it is difficult for the unit to maintain the appropriate frequency and requires daily adjustment by local staff. The La Joie governor is unique as it also controls the PRV. A governor failure may also make the PRV inoperable. In the worst case, this could result in a ruptured conduit however; the likelihood of a conduit rupture is low. Both the unit or PRV and the HCV's are required to manage the Downton Reservoir and keep it below the lower Maximum Operating Level imposed as an interim risk mitigation measure until the Dam deficiencies are addressed.

Exciter Performance – Reliability risk (risk score 9.5) – Estimated mitigation [redacted]

Due to age, poor performance and test results there is a risk the exciter could fail which would lead to a medium length forced outage and a loss off generation. The exciter is original and has exceeded its industrial life expectancy. The exciter has an EHR rating of POOR due to age, poor test results, operating performance and maintenance costs. The exciter represents voltage control and impacts voltage and stable operation of the unit during system disturbances. While connected to the system these are minor irritants, however during 60L22 outages La Joie is islanded and is required to run to support local load, it is difficult for the unit to maintain the appropriate voltage and requires constant staffing. There is a unit upgrade project proposed to address this risk.

South Conduit Corrosion – Safety Risk (risk score 10.5) – Estimated mitigation [redacted]

Due to coating failure, design and the presence of active corrosion there is a risk the structural integrity of the conduit will become too weak. This would lead to it being taken out of service resulting in a long forced outage, a loss of generation and limiting our ability to manage the Downton Reservoir level. Two conduits connect the intake to the powerhouse; one directing water

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to the generating unit (south) and other discharge valves (north). The South Conduit lower portion is imbedded in concrete for support. The concrete to steel interface is not sealed and allows water to ingress. This interface shows extensive corrosion. Test results have confirmed extensive corrosion on the conduit external surface that is imbedded in concrete. Repairs were made internally in the conduit however, the corrosion continues. This is a concern as the South Conduit is already thin as it was originally designed to supply two slow operating discharge valves and not a generating unit. That is why La Joie has a PRV controlled by the governor to minimize water pressure transients due to rapid wicket gate movement. Corrosion left unaddressed will compromise the structural integrity of the conduit and result not only in the shutdown of the unit and loss of revenue but the loss of active control of the Downton Reservoir. With the reduced maximum reservoir operating level it is important to maintain discharge reliability and maintain the lower reservoir level.

Pressure Regulating Valve Deterioration – Safety Risk (risk score 10) – Estimated mitigation [redacted]

Due to the deteriorated condition of the PRV there is a risk it may fail which would lead to a long force outage, a loss of generation and limit our ability to manage the Downton Reservoir. The (PRV) is connected to the turbine through governor linkages. It minimizes over pressure transients in the South Conduit caused by rapid wicket gate movements (such as a unit trip) by opening the PRV as the wicket gates close. In addition, the PRV helps maintain uninterrupted flows in the tailrace and Middle Bridge River for environmental reasons. The PRV is a butterfly valve and is not well suited in an application that requires regulation and partial openings. As a result it is in poor condition and requires extensive welding on a regular basis to maintain its structural integrity. The PRV is critical to the operation of the unit.

Turbine Inlet Valve Leakage – Financial Risk (risk score 9.5) – Estimated mitigation [redacted]

Due to excessive leakage from the Turbine Inlet Valve (TIV) it is not possible to certify it as a Single Device Isolation (SDI) point which would lead to additional isolation requirements resulting in longer outages and a loss of generation. Inspections indicate the valve is in fair condition but due to excessive leakage obtaining SDI may not be possible. The TIV isolates the turbine from the conduit and is located downstream from where the South Conduit splits into three water passages: 1) to the TIV and unit, 2) to the PRV thus allowing flows to be maintained while the unit is down for maintenance and 3) to the Auxiliary Bypass Valve which is not in-service. The TIV provides a number of functions: unit isolation and unit emergency shutdown in the event of a governor (runaway unit) or headcover failure. The TIV has never had SDI due to the unique situation at LAJ where it is possible to provide double block (INOG1&2/LLOG1 and TIV1) and full size bleed (PRV) to isolate the turbine thus not requiring SDI. INOGs 1&2 and a new LLOG combined with new intake stoplogs (INSLs) now allow safe isolation of the water passage for maintenance purposes. However, this comes at a cost of additional time and labour required to isolate/drain the conduit and fill/de-isolate the conduit. The valve has exceeded its industrial life expectancy but as long as it is in sound mechanical condition and does not present a hazard to the unit, it can continue to operate in the medium term.

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5.2. Seismic

It is certain that a number of facility components would not be able to meet the requirements for a dam that is rated as Extreme Consequence. Of concern is the seismic performance of the Dam, Intake structure and Powerhouse. La Joie is unique in that the only discharge facilities that can be used to actively manage the reservoir are located in the powerhouse.

The seismic risk at La Joie has been under study for some time to better understand the nature of the risks and the interdependencies of the various systems and how they support the safe management of the reservoir before, during and after a seismic event. A comprehensive project is proposed that intends to address a number of risks at La Joie such as structural deficiencies in the dam, intake structure and water conduits. In addition, it will address reliability issues with gates, hoists and controls. As part of the interim risk management plan, a new lower maximum reservoir operating level for Downton Reservoir has been implemented which reduces the risk.

Dam Seismic Withstand – Safety Risk (risk score 10) – Estimated mitigation [redacted]

Due to the construction type of the dam (uncompacted rockfill with a shotcrete membrane) during an earthquake, the dam could move and settle disrupting the membrane leading to leakage. Excessive leakage through the dam would wash out the toe material resulting in dam failure and an uncontrolled release of the reservoir. There is a 40% chance that there would be insufficient storage downstream in Carpenter Reservoir resulting in overtopping of the Terzaghi earthfilled dam. This would lead to a cascading dam failure and seriously impact communities downstream on the Bridge and Fraser Rivers.

In 2014, a decision was made to lower the Downton maximum normal reservoir operating level from El. 749.8m to El. 734.0m to mitigate the risk of a dam failure in the event of a seismic event and to minimize the impacts downstream. This is a temporary measure until a permanent solution can be implemented. The loss in storage at Downton compounded with the loss in capability at the Bridge 1 and 2 Generating Stations contributes to the water management challenges in the Bridge River system. There is an ongoing capital project to address the Dam Seismic risk.

Intake Tower Seismic Withstand – Safety Risk (risk score 10.5) – Estimated mitigation [redacted]

Due to the design and deteriorated condition there is a risk a seismic event of sufficient magnitude (~1:1000) could cause the intake tower to collapse which could result in an uncontrolled rise in the reservoir level leading to overtopping of the dam. Successful passage of high flows to avoid dam overtopping requires the use of all discharge facilities to manage the reservoir. All of the active discharge facilities are located in the powerhouse supplied by the intake tower. In addition, a large seismic event would also impact the dam requiring a reservoir drawdown to mitigate the risk of dam failure. See previous Dam Seismic Withstand risk description.

There is an ongoing Dam Seismic Upgrade project to address this risk.

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Powerhouse Seismic Withstand – Safety Risk (risk score 10) – Estimate to mitigate TBD[3]

Due to the seismic withstand of the powerhouse there is a risk a seismic event could cause the powerhouse to collapse which could result in an uncontrolled rise in the reservoir level resulting in spills from the free overflow spillway. A simplified stability analysis indicated that the seismic withstand of the powerhouse would be 1:2475. Successful passage of high flows to avoid dam overtopping requires the use of all discharge facilities to manage the reservoir. All of the active discharge facilities are located in the powerhouse supplied by the intake tower. In addition, a large seismic event would also impact the dam requiring a reservoir drawdown to mitigate the risk of dam failure. See previous Dam Seismic Withstand risk description.

5.3. Flood

La Joie Dam meets the flood routing criteria for an Extreme Consequence dam. It has the ability to pass the Inflow Design Flood (IDF), which is equal to the Probable Maximum Flood (PMF). The unit and PRV discharge can be set remotely by FVO while the HCVs are manually operated and rely upon staff being dispatched from the Bridge River Headquarters (2 hours away).

The reservoir level is primarily managed by generation or PRV discharges and assisted by the HCVs as necessary. During the PMF both the PRV and HCVs are required to be fully open.

5.4. Other

The previous sections focused on the most significant issues and risks that **directly** impact the performance of the overall facility and the impact that La Joie performance has on the facilities downstream on the same river system. However, there may be other issues and risks that need to be considered, which are generally associated with discrete components or pieces of equipment. These may not directly impact the performance of the overall facility, but are considered to be important enough to warrant further consideration.

The La Joie facility impounds water and then gradually releases it for the purposes of generating electricity in the Bridge River system. It does this in a safe, environmentally and socially responsible manner. For the La Joie facility to operate efficiently it relies upon a number of inter-dependent systems and components. If any one of these does not perform as required it does not have an immediate impact on the others but if not addressed in a timely manner the risks build up until the whole operation is at risk.

A number of risks are presented below discretely but to understand their importance one must understand how they are related and impact the overall operation of the facility.

1. To safely manage the water level in the reservoir the discharge facilities (unit, PRV, HCVs and associated conduits) must be functional and reliable.
2. To ensure functionality of the discharge facilities, the isolating devices (TIV, INOG and INSLs) must be functional and have Single Device Isolation (SDI) certification.

[3] Issues and risks proposed outside of the 10 year window may not have a developed cost forecast or risk score.

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3. To ensure the isolating devices are functional and have SDI, there must be a way to install the Intake Stoplogs (INSL).
4. Installation of the INSLs requires an intake gantry crane and the reservoir level to be below 727m.
5. A functioning intake gantry crane requires access to the intake (via a bridge) and to ensure a reservoir level below 727m requires functioning discharge facilities (see 1. Above).

Intake Gantry Crane – Reliability Risk (risk score 9) – Estimated to mitigate [redacted]

Due to the age and condition of the intake gantry crane there is a risk it may be taken out of service which will make it difficult to inspect and maintain the water passages and related equipment. The intake gantry crane is original and used to raise/lower the intake stoplogs (INSL) for isolating everything downstream in the water passage such as the intake operating gates (INOGs), conduits, HCVs, TIV etc. This is required approximately once per year depending on the condition of the other isolating devices. In addition, the gantry crane is used to remove the INOGs for major inspection (SDI), repairs or replacement. This is performed every 5 years to recertify INOGs 1&2. The crane also used to operate the Low Level Outlet Gate (LLOG). The crane was recently refurbished and recertified to 27 tons. While it is functional, it does have a number of deficiencies and is difficult to maintain. The crane will eventually require replacement and as experience has shown is essential to the maintenance of the water passages.

Intake Operating Gates 3 and 4 – Reliability Risk (risk score 9) – Estimate to mitigate TBD

Due to the age and condition of INOGs 3 and 4 there is a risk we may not be able to isolate the North Conduit in an emergency, which could lead to the loss of the Hollow Cone Valves and make managing the Downton Reservoir difficult. The INOGs are used to dewater the water passages. INOGs 3 and 4 on the North Conduit are original, past their life expectancy and do not have SDI. INOGs 1 and 2 on the South Conduit were replaced in 1999/2000 because they were no longer structurally suitable for isolation. SDI of the existing INOGs 3 and 4 is unlikely and therefore they cannot be used for isolation. Instead, the INSLs (see above) must be used for isolation of the North Conduit and for any work on the HCVs. The INSLs have a constrained safe operating range and limit when the North Conduit and HCVs can be isolated for inspection or repairs. The HCVs are new. According to an engineering assessment, in their current condition the INOGs would unlikely close under flow in the event of a North Conduit failure or HCV failure to close. There are no plans to address INOGs 3 and 4 in the short term and their long term operational requirements for the North Conduit need to be resolved.

Auxiliary By-Pass Valve – Reliability Risk (risk score 8) – Estimate to mitigate TBD

Due to the age and condition of the Auxiliary By-Pass Valve (ABPV) there is a risk this valve could fail resulting in the uncontrolled release of water and a forced outage of the South Conduit leading to a loss of generation and water conveyance. At the powerhouse end, the South Conduit splits into three branches; to the generator turbine (preferred), the PRV (alternate flow) and to the ABPV (not in service). The ABPV is a 1.9m butterfly valve and was used for additional drawdown capacity when the reservoir was below elevation 714.5m and the turbine was not operating. However, there were problems with its operation resulting in tailrace erosion on the right bank. The valve has not been opened in recent memory; the valve operator was removed and the valve has been blocked

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closed. There are no plans to use the valve for operations. Recent inspections indicate the valve is in fair condition. An inspection/monitoring program is recommended to ensure the integrity of the valve.

Dam Static Seepage – Safety Risk (risk score 10) – Estimated mitigation [redacted] annually

Due to the design and condition of the upstream face of the La Joie Dam there is a risk that increased seepage could wash away toe materials and destabilize the dam if not addressed in time. La Joie was originally constructed as a timber-faced rockfill dam in the early 1950's to allow for settlement in the early years of dam life. Leakage was great in the initial years (up to 24cms) and was managed by dumping lava ash down the upstream dam face. In 1972, the timber-face was replaced by a 3-inch nominally thick shotcrete face, the lowest cost option at that time. It performed well until 1984, when leakage rates through the dam began to noticeably increase. Repair work to the upper shotcrete face (i.e. above about El 718 m) was carried out for the first time in 1985 and then again in more than 15 subsequent years most recently in 2017. Since 1999, the repair work has apparently been less effective in reducing the total leakage through the dam. The shotcrete face which is now 40 years old is quickly reaching end of life. This is evident by the rate of deterioration observed across the dam face which has been increasing in the last few years. Typically, loosely dumped rockfill dams as is the case with La Joie will continue to deform throughout their life. In the deep canyon section at La Joie, vertical settlement progresses at a regular pace of about 8mm/year, while the horizontal deformation evolves at about 4mm/year. Such movements induce tensions and strains in the brittle shotcrete face which manifests itself as face cracks, spalling, bulging or buckling of panels and holes along construction joints. The shotcrete repair programs have been successful in maintaining leakage flows through the dam to acceptable levels and they must be continued to extend the life of the shotcrete face until the permanent remedial measures are constructed. The current program is revealing significant damage to the sealant along the construction joints which will need to be addressed in these current and upcoming programs. However, to enable these repairs the reservoir needs to be drawn down in the spring by the discharge facilities. The lower Downton Maximum Normal Operating Level has helped reduce the seepage.

There is an ongoing LAJ Dam Upgrade project to address this risk.

Unit Electrical Protection – Reliability Risk (risk score 9.5) – [redacted]

Due to the age, obsolescence and condition of the electrical protection there is a risk it may fail to detect and operate during a fault which would lead to more extensive damage, costlier repairs, longer forced outage and a loss of generation. According to BC Hydro Engineering Report #E1114, the unit electrical protection scheme at LAJ is in poor condition and should be replaced due to age, obsolescence, and condition of the existing electromechanical relays and the difficulty in sourcing appropriate quality spare parts. LAJ as a single unit generating station and was identified as the third highest priority strategic station by the engineering report. As the unit ages the risk of failure by major components (generator, exciter) increases, thus the need for a reliable protection scheme is critical in minimizing the damage caused by a fault.

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Intake Stoplog Concrete Constraints – Safety Risk – Estimate to mitigate TBD

Due to structural limitations with the intake concrete there is a risk that in an emergency it would not be possible to isolate the water passage components to make repairs which could lead to the Downton Reservoir exceeding its maximum reservoir level and lead to excessive static seepage from the dam. The breast wall the intake stoplogs seal against can only withstand reservoir levels up to El. 727m. This limits the available window in which to isolate the North Conduit and the HCVs as INOGs 3&4 are not suitable for SDI. It would also limit the window in which INOGs 1&2 could be isolated for SDI recertification. With careful planning it is possible to work around this restriction but there are times of the year when the reservoir will be above 727m and it is not possible to draw it down using the Unit/PRV and HCVs because inflows exceed their combined discharge capability.

5.5. Key Opportunities

Turbine Upgrade

The Resource Smart Inventory Study (E356) in 2005 identified a number of potential upgrades for La Joie which involved the diversion of the Hurley or Gun Creeks. However, none of these were deemed economical and are not recommended at this time. The study did indicate that a turbine upgrade would result in a modest (1.1MW/13GWh) increase. The economics would have to be reassessed to reflect current value of energy and capacity and the reduced maximum reservoir operating level. La Joie is reasonably well balanced and without more inflows a significant increase in generation is not warranted. This modest increase can be realized cost effectively as the various components (i.e. Generator, Exciter, and Turbine) are replaced at their end of life.

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6. Facility Strategy

Having identified the key issues, risks and opportunities in the La Joie generating facility, a number of high level strategic alternatives were reviewed to identify the best value course of action for the development of this FAP.

1. De-commission the facility / system in the event of a significant equipment failure
2. Redevelopment of the existing facility / system
3. Continue to maintain and invest in existing facility.

De-commission Alternative

De-commissioning of La Joie was not considered as part of this Facility Asset Planning process. The Bridge River System Study (2014) concluded that decommissioning the facility was not the best long term solution. At a high level, La Joie's cash flow is positive and requires a moderate level of investment to maintain its current output reliably. However, a number of significant Dam Safety risks remain and depending on how they are quantified, the costs to mitigate need to be carefully weighed against the value the facility provides to the Bridge River System as a whole.

Re-development Alternative

A large scale re-development of La Joie was not considered as the generation is well balanced with the inflows and reservoir storage. Redevelopment would only be considered if that was the only way to mitigate the risks associated with the dam.

Maintain and Invest Alternative

A component by component strategy has been proposed to upgrade/refurbish existing equipment at end-of-life over the next 20 years. This strategy addresses the most pressing issues to maintain existing facility capability and restores the full storage capacity of Downton Reservoir. An NPV analysis was not included as part of the development of this FAP.

6.1. Recommended Investment Strategy

The Bridge River System Study concluded the leading concept for the La Joie facility was to refurbish the Dam and Powerhouse for continued operation at full reservoir elevation. However, the study also identified higher risks in the region that should be addressed first and proposed to address the pressing dam seepage and seismic issues through lowering of the reservoir coupled with focused OMA investments in the short term. There has already been some investment in the La Joie facility in recent years and five significant investments were identified over the next 20 years;

- Dam Seismic Upgrade
- Intake Tower Seismic Upgrade
- South Conduit Refurbishment
- Pressure Regulating Valve (PRV) Replacement
- Unit Upgrade (Generator, Governor, Exciter, Turbine End of Life Replacements),

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There are several other less material sustainment investments that are recommended. The timing and materiality of the recommended investments are shown in the following section.

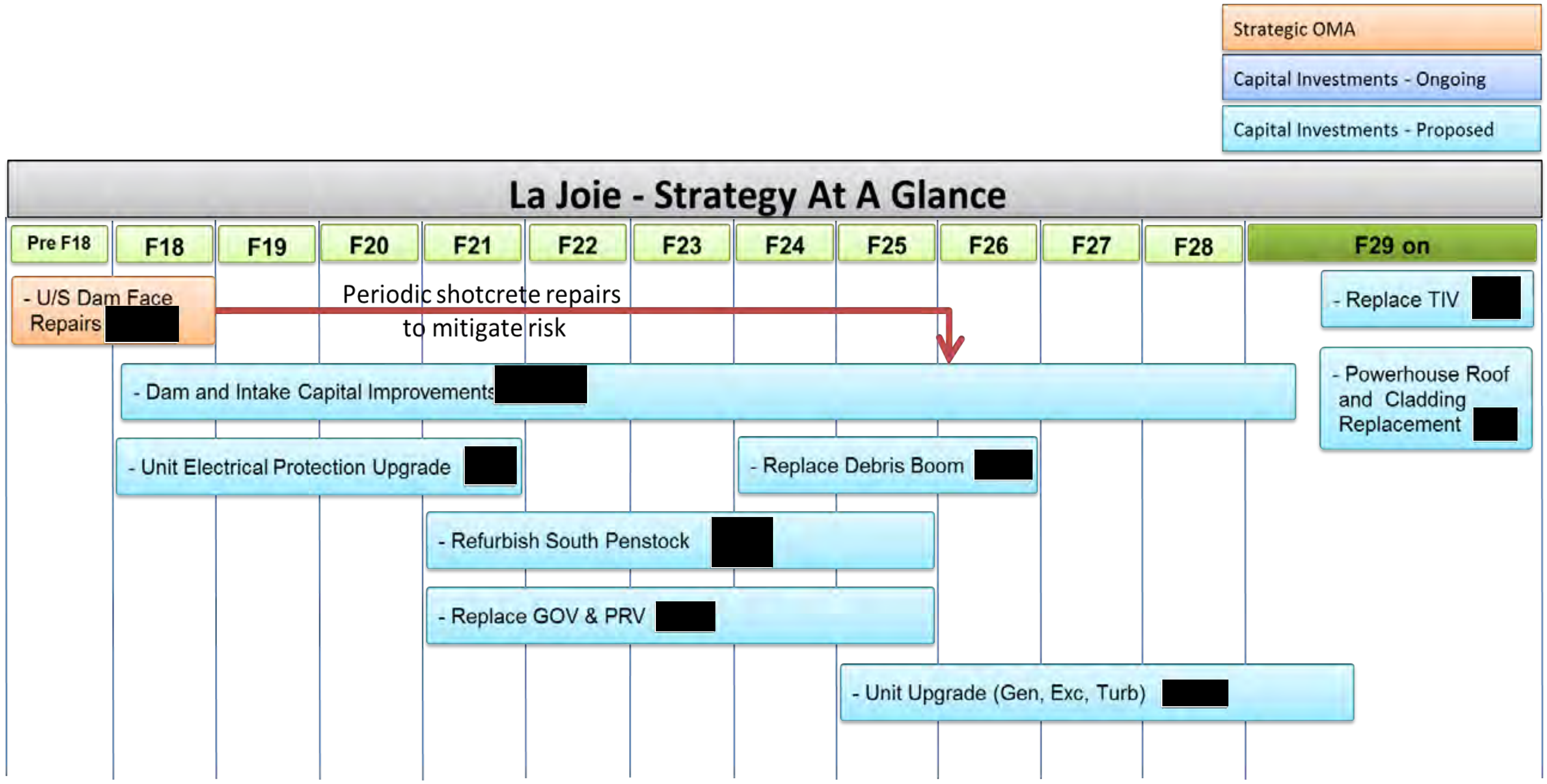
The Bridge River system facilities are interdependent. The system is currently constrained with the loss of storage at Downton and the reduced capability at the Bridge 1 and 2 Generating Stations. This increases the risk of releases at Terzaghi dam into the lower Bridge River, exceeding the Water Use Plan Order targeted flows. Therefore the timing of the recommended investments has to be coordinated in order to manage the flows in the lower Bridge River. The general Bridge River system investment strategy is to restore the Bridge 1 and 2 conveyance capability, starting with Bridge 2 units, and then address the La Joie facility seismic and seepage risks to restore the full system storage capability.

All proposed projects will be risk assessed from the fleet perspective, and will consider constraints such as budgets and resources. The highest priority items will be included, while lower priority will be deferred for consideration in future planning cycles.

6.2. Investment Prioritization

This Facility Asset Plan is an input for the 10 year Generation Capital Forecast. Capital expenditures are approved as part of the 10 year corporate capital planning process which guides the timing of investments, associated with the near term (1-3 years) planning window, which forms the basis of BC Hydro's BCUC Revenue Requirements Application. Investments beyond the 10 years facilitate Generation Asset Management's strategic planning process.

The Strategy at a Glance on the next page illustrates the recommended investments for La Joie and their timelines.



Notes:

1) For asset management purposes, a planning cost allowance is shown for proposed projects. Planning allowances have a high degree of uncertainty, and therefore should not be interpreted as a cost estimate. The first engineering cost estimate or cost estimate range is available at the end of the Identification Phase of the project lifecycle.

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6.3. Retained Risks

The 10 year investment strategy details projects to address the highest priority risks and issues at La Joie. It is important to consider that La Joie is one of many generating facilities, and efforts are made to prioritize investments across the entire fleet over the 10 year window. Key retained issues and risks include

Wedge Drop Mountain Potential Slide – Due to the presence of a large failing rock mass on Wedge Drop Mountain there is a risk it may fail and fall into Downton Reservoir which would generate a large wave and lead to over topping and potentially failure of La Joie Dam. Wedge Drop Mountain is located on the south side of Downton Reservoir 12km upstream of La Joie Dam. There are large wedge-shaped masses of rock failing downslope towards the reservoir. A 1999 to 2003 Deficiency Investigation (DI) summarized a 1993 geological assessment of Wedge Drop (Report H2468) and concluded that a rapid failure of the potential slide was unlikely, but possible, under extreme rainfall and/or seismic events. During this investigation a simple numerical simulation implied that there is the potential for a landslide generated wave to impact the dam justifying the annual monitoring and observation of this estimated 100 to 300 million cubic meters potential slide. Monitoring to date shows some movement, it is felt that remedial measures are not required at this time. The new lower Downton Maximum Normal Operating Level reduces this risk to some extent. Currently, annual monitoring and site observations indicate remedial measures are not required at this time.

Dam Seismic Deficiency – There is an ongoing project to address this risk. However, the risk will not be fully addressed in the 10 year window. Project completion is forecasted in F29+.

Intake Structure Seismic and AAR Deficiency – The plan to mitigate this risk is linked to the timing of the dam seismic upgrades. Therefore, this risk is unlikely to be addressed in the 10 year window.

Intake Stoplog Slots – While serviceable, they limit the window to isolate the water passages (in particular the North). However, the North water passage has recently been inspected and upgraded and is in relatively good condition. Therefore, no long outages are required on the North Conduit. By careful planning Operations can work around this limitation. The weakness in the concrete is not easy to address and it would be more cost effective to replace INOGs 3 and 4 to provide year round isolation of the North Conduit. The stoplogs were replaced in 2013 and as long as they are maintained, stored properly and protected from the elements they will continue to provide years of service. There are no plans in the 20 year capital plan to address the operating limitation at this time. However, it may be addressed by the Dam Upgrade project depending on the final solution to address the intake seismic risk.

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7. Expected Results

Assuming that the proposed series of investments outlined in the previous section are implemented, the following results should be expected.

7.1. Bathtub Curve – Current and Future State

The Equipment Health Rating of the major system components is shown on the following bathtub curves to provide a visual depiction of not only condition but also lifecycle stage. The two diagrams show the current state (F18) and the likely state at the end of the 10 years assuming that the proposed suite of investments outlined in section 6.2 are implemented as expected.

At the end of 10 years (F27), the reliable water conveyance via the South Conduit will have been restored by refurbishing the South Conduit and upgrading the governor and PRV. This will enable the Dam Upgrade project work to proceed reliably. The Dam Upgrade and Unit Upgrade projects will be well underway at the end of 10 years. Other assets will age normally moving from GOOD (blue) condition to FAIR (green) as they approach mid-life.

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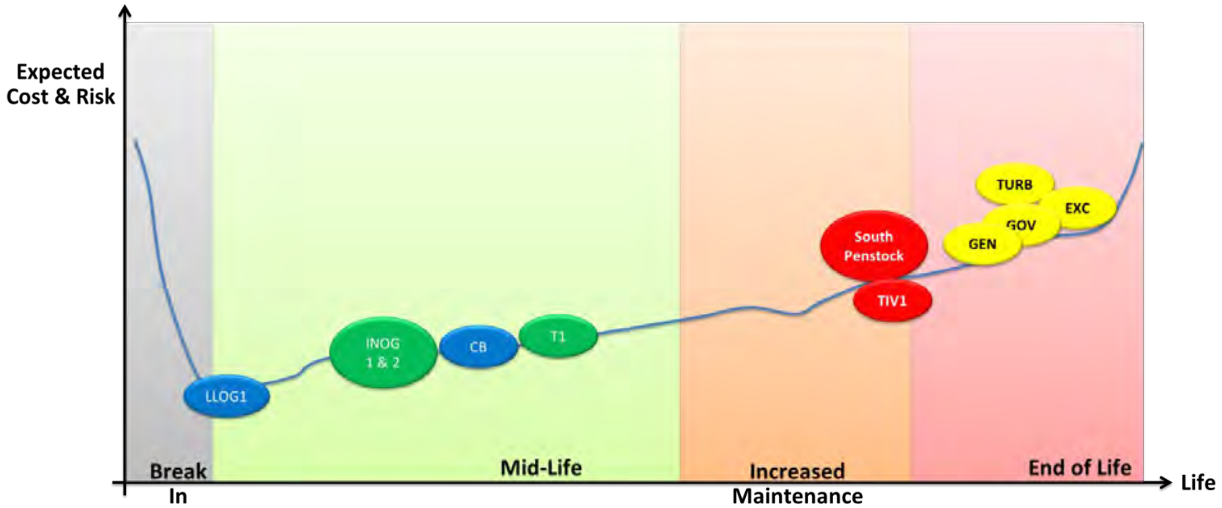
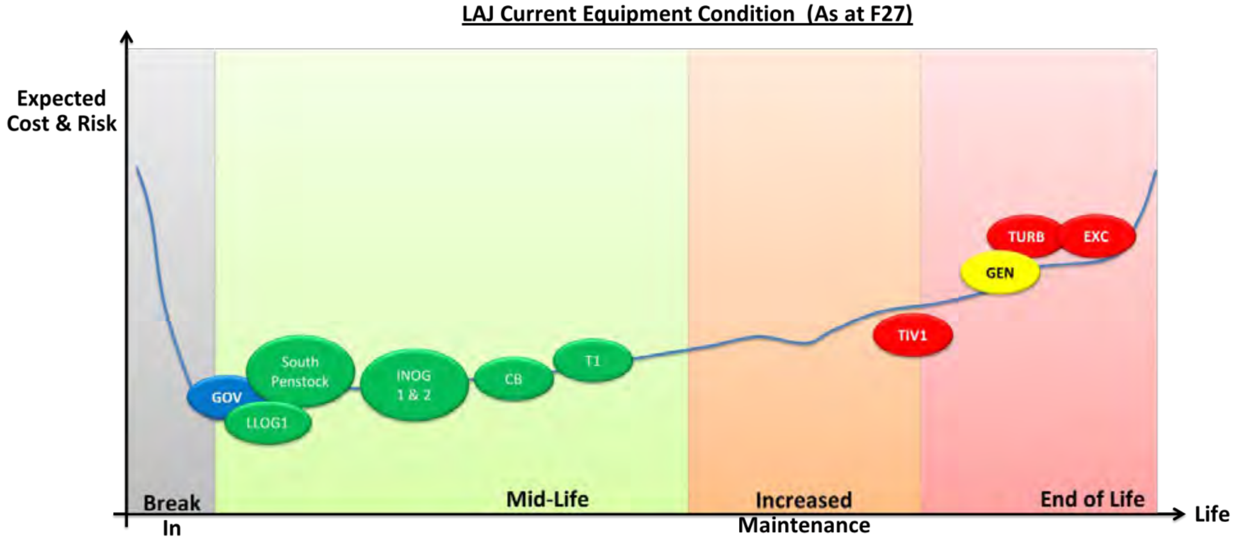
Good	Fair	Poor	Unsatisfactory

LAJ Current Equipment Condition (As at F18)



LAJ Current Equipment Condition (As at F27)



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7.2. Strategic Outlook

If the investments are completed, as proposed in this Facility Asset Plan, many of the water conveyance equipment risks will have been mitigated resulting in more reliable reservoir control. It is anticipated a number of components will be requiring investment in the next 10-20 year window. A project to address a number of seismic risks will have been started and will be well under way in the 10 year window. It is anticipated investment in the dam and intake will continue in the next 10-20 year window. In addition, investments in improving unit reliability will be well underway which present an opportunity to modestly increase capacity and energy through efficiency gains, but only once all components are upgraded.

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8. Data References

The following is a list of data references used in this Facility Asset Plan. All data is for the last complete fiscal year unless stated otherwise.

Annual Revenue (proxy) – facility revenue is expressed as a range (highest, lowest) of values calculated for the last 5 years. These values are available for each facility in a spreadsheet on the GAM J:Drive. The revenue data is provided by GSO and is only a proxy for revenue attributed to each facility.

Maximum Sustained Generating Capacity – is available from the facility Hydro Web page and the values are provided by either GOO 1J-08.

Historic Annual Average Plant Generation – is available from the facility Hydro Web page and the values are provided by GSO.

Investment Summary – this graph is generated from a spreadsheet on the GAM J:Drive. The historical capital spend is retrieved from the GCCR/CCR reports. The forecast capital spend is taken from C55.

Performance Data (Availability Factor, Forced Outage Count, Forced Outage Duration, Forced Outage Factor) – is available from the GAM Monthly Report. This data is extracted from the USR report maintained by GSO.

EHR Equipment Ratings – are available from the GAM Monthly report. This data is extracted from EHR and is usually for the most recent month the FAP is prepared.

EHR Forecast Ratings – this is available from the EHR Forecast spreadsheet on the GAM J:Drive. The spreadsheet uses a combination of current EHR rating, historical trends for equipment ageing and proposed investments to predict the future EHR rating of equipment. Some judgment is required and discussion with other GAM members may help come to a consensus.

Completed and Ongoing Projects – these projects are available from previous fiscal GCCRs/CCRs.

Dam, Spillway and Water Passages – description, dimensions, ratings and capacities of these components comes from a number of sources; Dam Safety's Operation, Maintenance and Surveillance (OMS) Manual, GSOs Generation Operating Orders (GOOs) and Generation Operations Local Operating Orders (LOOs). All three should be aligned but if discrepancies are discovered then a discussion with the various parties will be necessary. Generally, LOOs must conform to GOOs and the system is operated via the GOO/LOO as they are easier to update to reflect new information.

Hydrology – similar to dams, spillway and water passages above there are various sources of information OMS, GOO and LOO. In addition, GSO will provide inflow data.

Seismic Withstand – these values are available from Dam Safety to ensure the latest values are used as they are constantly being updated.

Probable Maximum Flood (PMF) – these values are available from Dam Safety or the OMS.

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FACILITY ASSET PLAN

SETON GENERATING STATION

MARCH 2017

REVIEWED BY

Plant / Area Manager:

Regional Manager, Generation Operations:

Manager, Asset Management:

Director, Dam Safety:

Senior Vice President, ~~Generation~~ Integrated Planning:

PREPARED BY

Generation Asset Management:

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1. INTRODUCTION

The purpose of the Facility Asset Plan is to provide a robust understanding of the issues, risks and opportunities faced by a specific facility, and the proposed long term investment strategy that is believed to offer the best value. Facility Asset Plans are key inputs to the fleet planning process. The investment strategies that are proposed in discrete facility asset plans will be reviewed collectively, and prioritized to provide the most appropriate suite of investments across the fleet given resource and financial constraints, outage planning, and other considerations. As a result, lower priority investments will be deferred and considered in future planning.

1.1. The Facility Planning Process

The Facility Asset Planning process provides stakeholders with a transparent methodology for producing a documented strategy. It is a structured process to identify key issues and risks, and prioritize investment decisions for a specific facility or system. Data is consolidated from multiple parties throughout Generation, including Generation Operations, Dam Safety, Safety, Generation Resource Management and Environmental Risk Management. Key risks, issues and opportunities at a facility are identified, and compiled in the Copperleaf C55 asset management tool. The data is reviewed to consider factors such as the facility's strategic role, performance targets, risks and growth opportunities. The consequences and frequency of issues and risks are assessed through the lens of the Corporate Risk Matrix and Capital Investment Analysis Guide. Appropriate medium to long term investments are identified for consideration in both the Generation and Corporate capital planning process.

1.2. The Facility Asset Plan

The Facility Asset Plan document is a concise record of the outcome of the Facility Asset Planning process. The primary audiences are Generation Asset Management, Dam Safety, Generation Operations, and the Generation Executive Management Team. Its primary intention is to provide:

- Current facility configuration, value and obligations;
- Significant known issues, risks, and opportunities;
- Contextual performance and recent investments, based on last complete fiscal year;
- High level scenarios considered to address issues, risks and opportunities;
- Proposed investments aligned to the expected planning cycles of the business

By signing the Facility Asset Plan, management are agreeing that, to the best of their knowledge, the content is complete and accurate, and that the proposed investment strategy reflects the best interests of BC Hydro (BCH) at the facility level and is consistent with goals and objectives outlined in the Generation Strategic Asset Plan.

Once approved, the Facility Asset Plan's investment strategy will become an input for the Generation Fleet Wide Planning process. This will determine whether the investments proposed in

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the Facility Asset Plan are optimal at a fleet level, or whether changes to the Facility strategy are required.

The Copperleaf C55 asset management tool will be updated regularly to capture emerging issues, risks or opportunities, or changes to existing ones. The Facility Asset Plan will be updated as per Generations Strategic Asset Management Manual (SAMM) or whenever new information leads to a significant change in the strategy for a facility.

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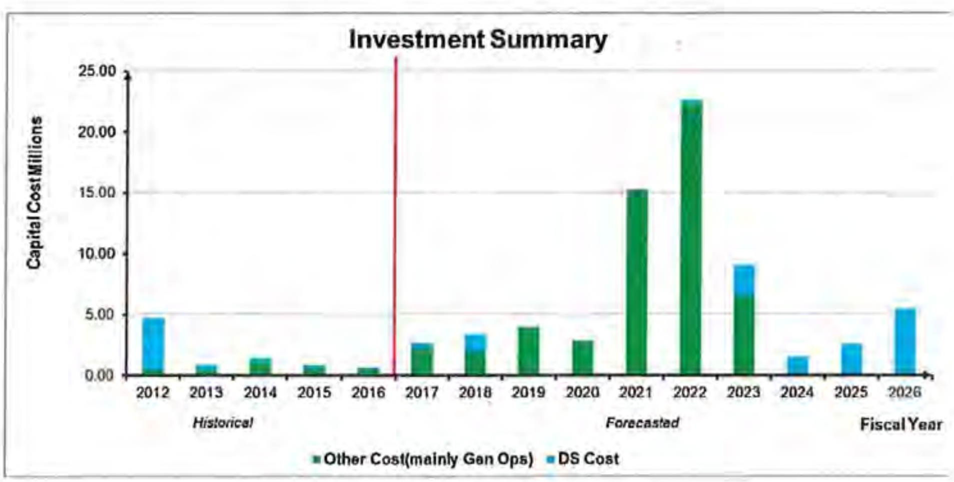
2. Facility Overview

The Seton facility consists of Seton Generating Station, Canal and Aqueduct, Dam and Left Bank Dyke, Cayoosh Diversion Tunnel and Seton Lake. The single unit Seton generating station at the outlet of Seton Lake is located approximately 5 km south of the Village of Lillooet. Seton Dam is a 13.7 m high by 76.5m long concrete gravity dam and provides impoundment for Seton Lake. The water is directed to the powerhouse via a 3.7 km long concrete lined power canal. Besides natural inflows, water is diverted into Seton Lake from Cayoosh Creek (via a tunnel) and the Bridge River via tunnels through Mission Mountain and the Bridge River powerhouses. On average, the generation capability from Seton represents less than 1% of BC Hydro's total hydroelectric generation capacity.

The following table summarizes key facility data:

Facility Name	Seton Generating Station
Asset Classification	Strategic
Dam Classification	High
Original In-Service Date(s)	1956
Annual Revenue Range (F2011 to F2016)	[redacted]
Plant Maximum MW Rating	44MW
Historic Annual Average Plant Generation	309 GWh

The following chart summarizes recent and proposed investments in Seton Generating Station:



[1] Proxy for revenue attributed to facility

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Recent investments at the Seton facility have been modest addressing aging ancillary components to mitigate risk and prepare for the unit upgrade planned for F22. Most of the equipment is approaching end of life requiring significant investment. Some equipment, such as the exciter, transformer, and circuit breaker, have been replaced in the last 10 – 15 years while the generator and governor are original and will require investments in the next 5 – 10 years. The turbine was replaced in 1977 and requires at least a major overhaul. Investment in the next few years will increase to focus on unit related risks leading up to the unit upgrade in F22. After that, the focus will be on seismic risks to the civil assets. Given that Seton is a single unit facility that generates significant annual revenue, a level of investment is proposed within the next 10 years to proactively mitigate the reliability risks and avoid extended outages and a loss of generation from the facility.

A component by component risk reduction strategy is recommended, with Capital investments being deferred as long as practical. This is based on recommendations in key Technical Prescriptions, indicating that large expenditures in equipment such as the Generators, Governors and Turbine may reasonably be required in the next 5 to 10 years. There is also the opportunity to increase the capacity of the generating station which should be taken into consideration during the equipment investments.

It is recognized that there is a high degree of variability and uncertainty associated with the context and cost of capital investments proposed for consideration beyond F22.

The most significant issues and risks that are proposed for resolution within 10 years are listed below. More detailed information can be found in Section 5.

- Power Canal and Aqueduct cracks and deteriorated concrete
- Generator age and deterioration
- Left dyke bank
- Inability to shut-off flow in the event of a canal failure

Based on the recommended investment strategy, it is recognized that for at least the next 10 years there will be a number of retained risks at the facility. Key retained risks are listed below with more detailed information provided in Section 6.3.

- Santa Clause Mountain potential slide
- Dam Alkali Aggregate Reaction (AAR) and slow concrete deterioration
- Dam seismic vulnerability
- Canal/Aqueduct/Forebay seismic vulnerability
- Single Unit Plant/No Bypass
- Spawning channel water supply

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2.1. Performance Overview

The last 5 years shows a trend of slightly decreasing reliability at Seton Generating Station, however performance is still better than the Strategic facility average reliability in terms of Forced Outage Factor and Availability Factor. Seton maintenance outages are taken every other year which result in lower availability in odd fiscal years. Outages are increasing but are generally short in duration and can mostly be attributed to the governor and turbine.

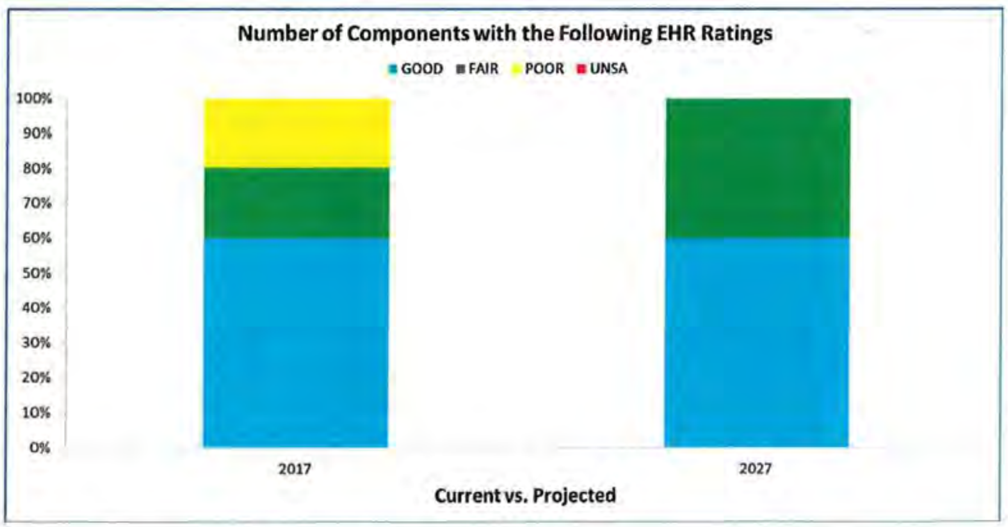
Average/Unit	F12	F13	F14	F15	F16
Availability Factor	98.0	92.3	99.1	77.9	98.5
Forced Outages (count)	2.0	0.0	3.0	4.0	3.0
Duration of Forced Outages (hours)	27.5	0.0	13.7	58.8	35.0
Forced Outage Factor	0.31	0.00	0.16	0.67	0.40

EHR Ratings for Equipment (as of March 2017)

Equipment Health Rating	Generator	Turbine	Circuit Breaker	Governor	Exciter	Transformer
Unit 1	P	P	G	F	G	G

Good	Fair	Poor	Unsatisfactory

The following graph shows the expected change in equipment condition following the recommended strategy proposed in this plan.



Other Relevant Information

Seton is the most downstream facility on the Bridge River System. The Bridge 1 and 2 powerhouses can pass 160 cms at full load and the local IPP (Walden North) is capable of

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contributing an additional 43 cms. The turbine at Seton passes 114 cms at full load and the Seton power canal has a hydraulic limitation of 143 cms. Seton Lake has a narrow (<0.6m) operating range. Seton is operated around the clock, except for fisheries and maintenance requirements, and the Seton Lake level is controlled by load factoring the releases from the upstream Bridge River plants and if necessary spilling at Seton Dam.

Seton provides voltage support to the 60 kV system in the Cariboo Region. Whenever BR1 T3, 2L19 or 60L21 is out of service, the output of Seton, LaJoie and Walden North (an independent power producer) is restricted to 35MW, due to stability concerns. In addition, Seton has black start capability to supply local 60 kV load and can provide station service to the Bridge River generating stations. Local load is minimal and the transmission system is old and has several constraints. Capacity increases greater than 6MW to Seton would require improvements to the transmission system.

2.3. Investment Summary

In the past few years, Seton has benefited from a number of capital investments. These have been to mitigate known safety, Dam Safety, equipment and reliability risks/issues. The following outlines key investments made or ongoing in the last 5 years:

COMPLETED PROJECTS

- **Seton Dam Spillway Gate (SPOG) Upgrade (F12)** – as part of the Dam Safety Spillway Gate Reliability Program the spillway operating gate (SPOG) components were upgraded to improve reliability. The radial gate itself is still original.
- **Powerhouse Crane Upgrade (F12)** – the powerhouse crane was upgrade to address safety and reliability issues.
- **Draft Tube Maintenance Gate Hoist Replacement (F14)** – the project addressed the reliability and safety issues associated with the draft tube maintenance gate hoist.
- **Powerhouse Unwatering and Drainage Pumps Replacement (F15)** – the station dewatering and drainage pumps were replaced to reduce the risk of powerhouse flooding from high Fraser River levels.

ONGOING PROJECTS

- **Canal Refurbishment (F18 phase)** – The power canal concrete has localized spalling and cracks at the construction joints. A refurbishment program has been initiated to address these areas which will require ongoing outages in future years to implement.
- **Unit Governor and Protection Upgrade (F20)** – this project will replace the aging electro-mechanical protection and control system with a modern digital system, to improve reliability and trouble shooting. The governor will also be replaced as it is integral to the unit control system and suffers from hunting and instability problems.

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3. Operations and Hydrology

3.1. Facility Components

The Seton facility is part of the larger Bridge River system which stores and diverts the flows of the Bridge River into Seton Lake. Seton is an important asset, as it is the third and final facility in the Bridge River system and the facility regulates the flow from the Bridge 1 and 2 powerhouses. The Seton facility consists of Seton Generating Station, Power Canal and Aqueduct, Dam, Cayoosh Diversion Tunnel and Seton Lake.

The Seton Lake, Seton Dam and Cayoosh Creek Diversion

The main mechanisms for water to exit Seton Lake are:

- A 3.7 km open canal to the Seton Generating Station which discharges (up to 114 cms) into the Fraser River
- 5 siphons (120cms) which pass excess water and help maintain fish flows in the Seton River
- A spillway operating gate (SPOG) (286cms @IDF) which pass excess water into the Seton River
- A fish ladder which passes nominal flows enabling the upstream and downstream migration of fish
- A fish water release valve which maintains minimum fish flows (11 to 36cms) in the Seton River

Seton Power Canal

The 3.7 km Seton Power Canal directs water from Seton Lake to the Seton Generating Station. It consists of the following components:

- Headworks structure at the entrance to the canal consisting of five headworks operating gates.
- A 3.3 km open trapezoidal canal
- A 50 m long rectangular concrete aqueduct crossing over Cayoosh Creek
- A 137 m long open trapezoidal/rectangular culvert
- A forebay intake (radial) gate
- A 122 m penstock forebay
- An intake structure
- A 113 m long surface penstock connects the intake structure to the powerhouse.

Seton Generating Station

The Seton Generating Station has a single 44 MW unit that discharges directly into the Fraser River.

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The diagram on the next page visually shows the key system components located throughout the Seton Generating Facility and the Bridge River System.

The seismic issues and flood risks have been included in the facility diagram, where issues or risks are known to exist. Seismic withstand capabilities are shown in the red ovals, and flood withstand capabilities in the blue ovals.

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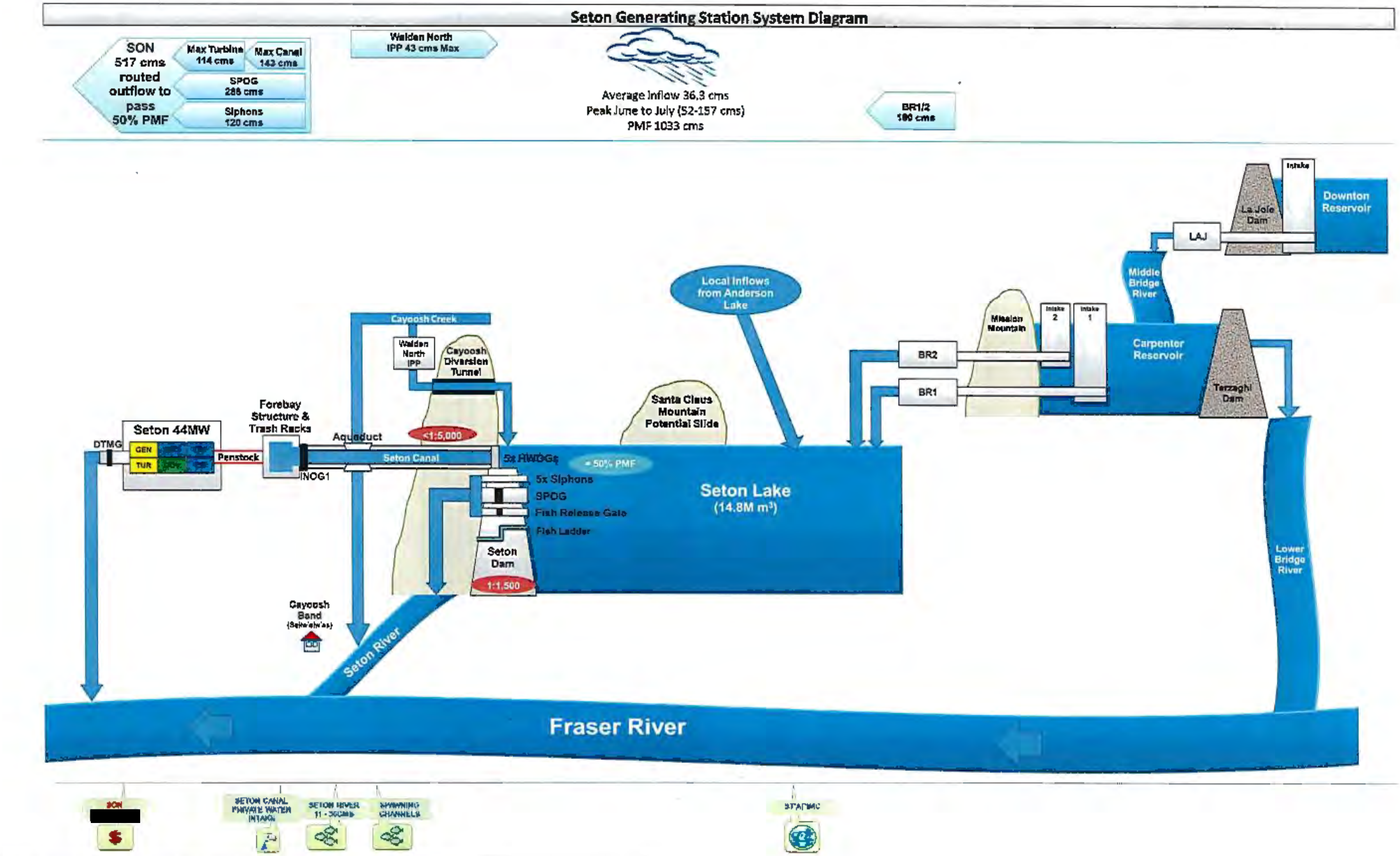
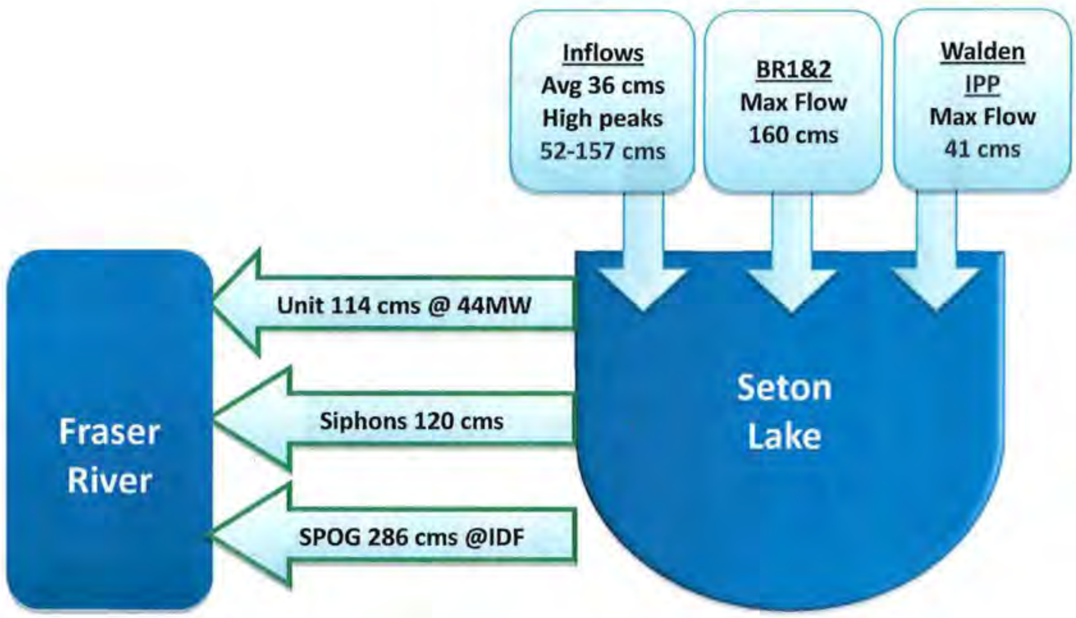


3.2. Hydrology – System Inputs and Outputs

The Seton Lake drains an area located in the South Interior climatic region. The watershed includes the Seton River, Anderson Lake as well as a number of smaller tributaries to the lakes. In addition, Cayoosh Creek is diverted by an IPP (Walden North) into Seton Lake and the Bridge River system is diverted into Seton Lake via Terzaghi dam and associated tunnels. Snowmelt is the primary contributor to flows in the Seton and Bridge River Basin.

The runoff regime is characterized by high flows in the late spring to early summer resulting from snowmelt followed by a recession period during the drier summer and winter months.

The green arrows represent active controls while orange arrows represent passive controls.



Seton Lake: All discharge facilities are required to pass the Inflow Design Flood (IDF) which is 50% of the Probably Maximum Flood (PMF = 1033cms). The discharge facilities capacity meets the routed discharge requirements to pass the 6 hour IDF (Inflow Design Flood) of 517 cms. The SPOG and the 5 siphons are operated manually.

3.3. Facility Operations

Seton is an unmanned station. It is primarily operated as a base load plant, as it modulates the discharge from the Bridge River 1 and 2 powerhouses. Seton Lake has limited storage capacity

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and inflows have to be carefully balanced often requiring generation at Bridge 1 and 2 to be reduced to avoid excessive spills. However, given the various environmental consideration in the overall system, generally spilling occurs at Seton Dam into the Seton River before at Terzaghi Dam into the Lower Bridge River.

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4. VALUE, BENEFITS & OBLIGATIONS

The Seton facility provides a number of financial, reliability and environmental benefits. In addition, BC Hydro has a number of obligations in the area.

Generation of Electricity and Revenue

The original benefit of the Seton facility was to provide electricity to customers locally and in the Lower Mainland. Over time, other facilities have been added to the BC Hydro System, and while still an important contributor to the system, the relative importance of Seton generating capacity and energy to the overall fleet has decreased. The 44 MW Seton generating facility generates an average of 309 GWh annually and has over the past 5 years contributed between [redacted]

Black Start Capability: according to Generation Operating Order 2G-43 Seton, as a Group 2 generator, Seton has the ability to black start and restore area load, but does not have the capacity for restoration of the Bulk Power System. Seton would also be able to provide station service to the upstream Bridge River generating stations.

Water Passage, Flood Mitigation and Erosion Control

Seton River Flows: The Water Use Plan Order establishes year round target flows (11-36 cms) in the Seton River from the Seton Dam. Variances of more than +/-25% from the targeted flows for more than one week require BC Hydro to inform the St'at'imc First Nations, fisheries agencies and the Comptroller of Water Rights. In addition, a maximum ramp down rate of 2.5 cm/hr or 15cm/24hr is specified by the Order.

Environmental

Fish Spawning Channels in Seton River: The Seton River is an important salmon spawning river and contains two spawning channels. Each spawning channel is provided with water via a siphon from the power canal. It is important that these siphons are kept operational from September to May, but are normally operated year round.

Salmon Migration past the Seton Dam: The Seton Dam is equipped with a fish ladder and a fish water control gate to aid in the passage of Salmon past the Dam onto the upstream tributaries flowing into Seton Lake and Anderson Lake. The specific requirements vary depending in which species, sockeye or pink, is migrating. In addition, operational changes aid in the downstream outmigration of smolts. Generation Operating Order SON 4G-39 outlines the operational details.

Lower Fraser River Levels: During the winter months (November 15 to Fraser River freshet) when flow at the WSC Hope gauge is below 700cms, BC Hydro will make best efforts to not load

[2] Proxy for Revenue attributed to facility

factor, shutdown or undertake maintenance outages. This is to reduce the potential impact to fish in the lower Fraser that are spawning, incubating, emerging and/or rearing during low winter flows.

Social

St'at'imc First Nations Agreement – BC Hydro and St'at'imc First Nation signed a number of agreements in 2011 to address the historical impacts of the Bridge–Seton System facilities. The Bridge-Seton System lies within their traditional territory. As part of the agreements BC Hydro agrees to work with the St'at'imc First Nation and explore economic opportunities. At the same time the agreements commit BC Hydro to operating the system consistent with our Water Licenses and Orders. Any deviations from the operating regime require notification of the St'at'imc First Nation. The certainty protocols also mean that if there are any material changes to the facilities themselves (e.g. additions, reconstruction, etc) that require a change to BC Hydro's Water License, BC Hydro will consult with the St'at'imc First Nation.

Domestic Water Supply – there are 3 irrigation water supply siphons in the power canal for the Cayoose Band and one in the forebay structure for the Rochard Farm. Users need to be notified if the power canal is drained or when the forebay is drained for more than 24 hours from April 1 – September 30.

Recreation

Recreation Facilities and residences on Seton Lake: Seton Lake has private residences and a BC Hydro owned recreation site which is managed by the local St'at'imc First Nations. Since the water levels in the lake have a narrow operating range (0.6m) changing water levels are not usually an issue.

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5. Issues, Risks and Opportunities

There are a number of issues, risks and opportunities associated with the assets in the Seton Facility. The key risks are described in the following section, including:

- A brief description of the key issue, risk or opportunity
- The expected impact of a failure
- The risk score, which is based on the Corporate Risk Matrix. Risk scores range from 0 to 16, with 16 representing the highest level of risk

More detailed information on less significant issues, risks and opportunities are located in Generation Asset Management's online capital planning tool (C55).

The investment strategy to address the risks discussed below is detailed in Section 6.0. Facility Strategy.

5.1. Generating Equipment

There are a number of different components that contribute to the reliability of the facility. The conceptual diagram below shows where key components are estimated to be in their lifecycle, coupled with the condition of the equipment (if known) based on EHR. The x-axis represents the life-cycle associated with each component illustrated. Not all components have the same expected life cycle. The y-axis represents the performance risk which can be expressed in terms of condition assessment, reliability/availability, probability of failure, etc. Typically, maintenance costs associated with newly installed equipment should be expected to be higher, given that additional work may be required to eliminate any construction deficiencies, and to perform increased inspections in the first few years of life (often in support of equipment warranty). Equipment towards the end of lifecycle is expected to be a higher performance risk and is likely to require an increased level of maintenance. This may progress to a point where either the component is no longer maintainable, or the best value decision is to replace or refurbish the equipment (i.e. it is at its end of life).

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SON Proposed Equipment Condition (as at F16)

Penstock Interior Coating Financial risk (risk score 9.5) – Estimated mitigation [redacted]

Due to the failed interior coating of the penstock there is a risk corrosion will reduce the structural strength of the penstock leading to replacement. According to EHR TP ID 5899 the penstock interior coating has failed and is recommended for a strip and recoat. The exterior has been recoated in the past 10 years. Coatings protect the structural steel from corrosion, loss of metal and preserve the structural integrity of the penstock.

Turbine Reliability Risk (risk score 9.5) – Estimated mitigation (included in Opportunity)

Due to the age and condition of the turbine there is a risk that the runner could suffer from excessive cracking or lose a piece of a blade leading to a long outage. According to EHR TP ID 5748, the turbine at SON is in "Poor" condition as a result of age, low efficiency and excessive leakage from the wicket gates. The wicket gates experience a significant amount of leakage due to worn bushings, which can only be addressed through a unit overhaul. The SON powerhouse crane cannot lift the rotor and the process of removing the runner for an overhaul is complex and time consuming as it requires more dismantling of the unit (rotor) than other units in the BC Hydro system. A significant amount of welding has been undertaken to address cavitation in the runner and as a result the runner is less efficient than designed. However, as long as regular cavitation welding is performed, the runner should operate reliably as it approaches its industrial life expectancy in the next 15 years. Replacement of the runner would provide an opportunity to upgrade the unit capacity at Seton. See Section 5.5 Key Opportunities.

Governor Reliability risk (risk score 9.5) – Estimated mitigation [redacted]

Due to age and condition of governor there is a risk it may fail to properly control the unit leading to a long outage or in the worst case significant damage to the unit if the unit goes into an overspeed situation. According to EHR HAS ID 3678, the governor is rated "Fair". However, the governor is original and has exceeded its industrial life expectancy, and has performance issues and a lack of spare parts. OEM support is no longer available though it is possible to reverse engineer some of

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the mechanical parts. The governor has shown intermittent instability in recent years and efforts to correct this have been unsuccessful.

Generator Reliability risk (risk score 10) – Estimated mitigation [redacted]

Due to the age and condition of the generator winding there is an elevated risk that it could fail, leading to a long outage. According to EHR HAS ID 3624 the generator is rated as POOR due to age, visual degradation, poor test results and similar windings at Bridge River 2 have faulted resulting in cut-out coils and unit de-ratings. The generator winding is original and has exceeded its industrial life expectancy. Similar to the BR2 units, SON has a history of being overloaded to pass more water. Seton is a single unit plant and a generator outage would be lengthy and costly. It would also result in high flows down the Seton River which could impact the fishery values as there is no unit bypass.

5.2. Seismic

It is uncertain whether the components would be able to withstand the requirements for a dam that is rated as High consequence. For a High consequence dam the expectation is that the water retaining structures will have a seismic withstand of 1:2475. Of concern is the seismic performance of the power canal and aqueduct and the potential inability to close the headworks in the event of a breach.

Headworks Operating Gates (HWOG) Safety Risk (risk score 10.5) – Estimated mitigation [redacted]

There are concerns the aqueduct would not meet the seismic expectations for a 'High' consequence dam and could fail during a seismic event, resulting in an uncontrolled release of water from Seton Lake, and requiring the emergency closure of the HWOGs. Due to the design of the HWOGs, there is a risk they would not be able to close in an emergency. Having emergency closure of the HWOG would assist in mitigating this risk. In addition, the retained risk of seismic damage to the canal lining could result in a breach that would endanger nearby residences.

Canal, Aqueduct and Forebay Safety Risk (risk score 10) – Estimated mitigation [redacted]

Due to the uncertain seismic withstand capabilities of the aqueduct there is a risk it could fail in a seismic event, which would lead to an uncontrolled release of Seton Lake into Cayoosh Creek. The aqueduct concrete structure is built on loose granular soils which may be subject to 'liquefaction" during a seismic event. This could result in environmental damage to fish interests, erosion and property damage.

Dam Seismic and Left Dyke Safety Risk (risk score 10) – Estimated mitigation [redacted]

Due to the uncertain seismic withstand of the dam, there is a risk it could fail which would lead to the uncontrolled release of Seton Lake. This would cause environmental damage to fish interests in the Seton River, erosion and property damage to homes and culturally sensitive areas.

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5.3. Flood

Seton Dam meets the flood routing criteria for a High consequence dam, and is able to pass the Inflow Design Flood (IDF), which is 50% of the Probably Maximum Flood (PMF). The largest flood risks that have been identified at Seton are the reliability of the single Spillway Operating (radial) Gate (SPOG) and the overtopping of the aqueduct. All gates and siphons are manually operated and rely upon staff being dispatched from the Bridge River Headquarters. The SPOG will likely continue to have issues in the future as the radial gate arms will have a tendency to bind on the concrete wall slot wall due to a slow progression of Alkali Aggregate Reaction (AAR), where the concrete 'swells' with age reducing clearances and causing binding. The process is slow at Seton Dam but needs to be monitored and addressed to ensure it does not adversely impact the operation of the dam.

To safely pass the IDF the HWOGs must be closed to isolate the canal from Seton Lake. This is to prevent overtopping at the aqueduct and the concrete canal liner. Overtopping of the canal liner could wash away the embankment leading to failure of the canal and inundation of local residences.

5.4. Other

The previous sections focused on the most significant issues and risks that **directly** impact the performance of the overall facility and the impact that Seton performance has on the facilities downstream on the same river system. However, there may be other issues and risks that need to be considered, which are generally associated with discrete components or pieces of equipment. These may not directly impact the performance of the overall facility, but are considered to be important enough to warrant further consideration.

60kV Transmission Constraints Reliability risk (no risk score) – no estimate.[3]

Due to the age and configuration of the local bulk 60kV transmission system there is a risk that it can become overloaded or unstable resulting in restrictions on SON output. The local 60kV transmission system is old and mainly supplies the local regional load and its capacity is limited. The local generation (Seton, LaJoie and Walden North IPP) exceed the local load. Therefore the main route for local generation is via the 230kV system at BR1 and BRT Substation. BR1 T3, 2L19 and 60L21 outages significantly restrict generation due to stability concerns and do so a number of times each year due to forced outages or planned maintenance. T3 has recently been replaced and T31 has been installed to improve reliability.

Power Canal Concrete Safety Risk (score 10) – Estimated mitigation [redacted]

Due to age and deterioration of the power canal concrete there is a risk that excessive seepage may increase the likelihood of a failure of the canal which could lead to property damage. The Seton power canal is showing normal aging and wear for a 50 year old concrete structure. Regular inspection, monitoring and refurbishment are required to preserve the integrity of the structure over time. Due to fishery concerns the annual work window is not very large and will require ongoing outages to implement the refurbishment. This will be an ongoing effort.

[3] Issues and risks proposed outside of the 10 year window may not have a developed cost forecast or risk score.

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Spawning Channel Water Supply Environmental/Reputational Risk (no risk score) – no estimate[4]

Due to there being one siphon to provide water for each spawning channel there is a risk that the water supply could be interrupted which may have an adverse impact on incubating salmon eggs. The siphons have failed in the past. The upper spawning channel siphon has an alarm but the lower spawning channel does not. In addition, ongoing maintenance of the power canal and proposed investments in the facility may impact the ability to provide a continuous water supply at the appropriate temperature to the spawning channels.

Unit Protection and Control Reliability Risk (score 9 ongoing) – Estimated mitigation [redacted]

Due to age and deterioration of the protection and control components there is a risk the equipment may fail to detect a fault, which could lead to extensive damage to the unit. An engineering assessment (Report E1114) of protection and control systems for Strategic facilities identified Seton as the highest risk in the fleet due to the age of components, a lack of spare parts and being a single unit facility.

Dam Concrete Safety Risk (no risk score) – no estimate

Due to the presence of Alkali Aggregate Reaction or AAR in the concrete there is a risk it could lead to jamming of the spillway gate making it inoperable. AAR causes the concrete to 'swell' which can result in slow deterioration and cracking. In addition, moving components can bind. At some point in the future the dam will require refurbishment including cracks/joints, coatings/re-surfacing etc. If the leaning of the spillway walls impacts the operation of the spillway gate the walls will have to be addressed.

Excessive Seton River Spill Environmental/Reputation Risk (no risk score) – no estimate

Due to the design of the Seton Generating Station there is a risk that a long outage could lead to high flows down the Seton River, impacting fish values if this was to occur during more sensitive times of the year. Seton is a single unit facility with no bypass provision, meaning that in the event of an outage, water that would have otherwise flowed through the facility will be directed down the Seton River. Seton is a mix of old and new components. A failure of a critical component, such as the generator, could lead to a long unplanned outage. While there are proposed projects to address these risks, they may require long planned outages to install equipment. In addition, when Fraser River flows are low in the winter months, outages at Seton can affect water levels in the lower Fraser which can potentially impact fish spawning, incubating emerging and/or rearing.

Santa Claus Mountain Potential Slide Safety Risk (no risk score) – no estimate

Due to the presence of unstable ground on Santa Claus Mountain there is a risk it could fail falling into Seton Lake which would lead to a large wave being generated and causing widespread damage along the lake shore and loss of life. Santa Claus Mountain is located on the south side of Seton Lake 16km upstream of Seton Dam directly across from the Bridge River powerhouses. The

[4] Issues and risks proposed outside of the 10 year window may not have a developed cost forecast or risk score.

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slope has been exhibiting progressive downward creep and has potentially unstable areas. It poses a direct threat to the Bridge River powerhouses, adjacent communities, shoreline development, Seton Dam and downstream areas. In the event of a slope failure, the potential for loss of life would be high. A slope inspection is performed annually to monitor the situation.

5.5. Key Opportunities

Unit Capacity Increase

The Generator has a nameplate capacity of 42MVA and had been historically operated at 44MW. According to Engineering report E356 (2005) and MEP68 (1997) Seton has the most potential for increased capacity in the Bridge River System. Hydraulically, the power canal is capable of supporting up to 60MW which would put it in almost hydraulic balance with Bridge River plants. However, this would also require costly transmission upgrades to accept this capacity. Given the transmission limitations it was recommended a 50MW unit would be more economical as that was the maximum the transmission system could handle. MEP68 recommended a component by component replacement with a 50MW unit in mind. Over the years various components (exciter, transformer, and circuit breaker) have been replaced with increased capacity to support a 50MW generator. With the proposed replacement of the Generator in the near future (with increased capacity) there is an opportunity to upgrade the rest of the unit (turbine and ancillaries) to ensure reliable water to wires 50MW of generation. However, this may require changes to the Seton Water license and consideration would need to be given to the provisions in the St'at'imc agreements.

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6. Facility Strategy

Having identified the key issues, risks and opportunities in the Seton generating facility, a number of high level strategic alternatives were reviewed to identify the best value course of action for the development of this FAP.

1. De-commission the facility / system in the event of a significant equipment failure
2. Redevelopment of the existing facility / system
3. Continue to maintain and invest in existing facility.

De-commissioning

De-commissioning of Seton is not a practical alternative at this time given that the facility is required to pass water for regulatory requirements and moderate upstream generation at Bridge 1 and 2 Generating Stations.

Large Scale Re-development

A large scale re-development of Seton is not a practical alternative at this time given that the facility, the equipment, and the heavy civil assets are in reasonably good condition. While the potential exists to increase Seton generating capacity by almost 25%, there are higher priorities in the Bridge River system that needs to be addressed first. Large scale rehabilitation of the major concrete structures may be required beyond 20 years to address the AAR condition.

Maintain and invest in Existing Facility

A component by component strategy has been proposed to upgrade/refurbish existing equipment at end-of-life over the next 10 years. The facility is a mixture of old and new assets, and is expected to have considerable life left, meaning that decommissioning or re-development are not appropriate. An NPV analysis was not included as part of the development of this FAP considering that the future investments proposed at this facility are relatively low in comparison to the annual revenue generated. Proposed projects will usually undergo a financial evaluation as part of the project lifecycle. The financial and system value that this facility provides to the BC Hydro system is positive.

6.1. Recommended Investment Strategy

The proposed strategy for Seton is to invest in the unit related assets to ensure reliability water conveyance and manage flows down the Seton River in accordance with the Water License Order target hydrograph. There has already been investment in the Seton facility in recent years to address the highest priority risks and four significant investments were identified over the next 10 years;

- Unit Upgrade (Generator, Governor, Turbine End of Life Replacements),
- Penstock Interior Recoating
- Headworks Operating Gates Upgrade

- Left Bank Dyke Upgrade

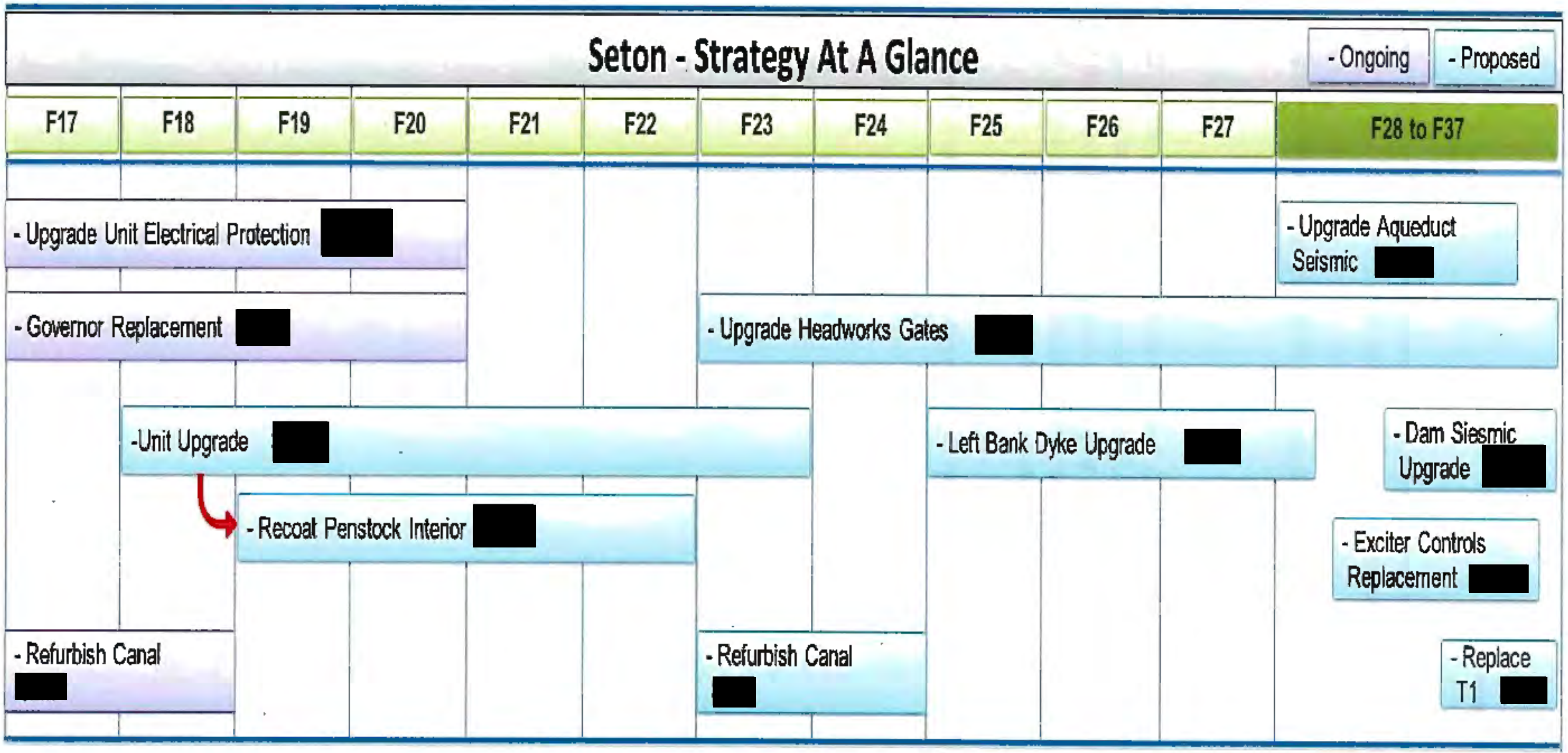
There are several other less material sustainment investments that are recommended. The timing and materiality of the recommended investments are shown in the following section.

All proposed projects will be risk assessed from the fleet perspective, and will consider constraints such as budgets and resources.

6.2. Investment Prioritization

This Facility Asset Plan is an input for the 10 year Generation Capital Forecast. Capital expenditures are approved as part of the 10 year corporate capital planning process which guides the timing of investments, associated with the near term (1-3 years) planning window, which forms the basis of BC Hydro's BCUC Revenue Requirements Application. Investments beyond the 10 years facilitate Generation Asset Management's strategic planning process.

The Strategy at a Glance on the next page illustrates the recommended investments for Seton and their timelines.



Notes:

1) For asset management purposes, a planning cost allowance is shown for proposed projects. Planning allowances have a high degree of uncertainty, and therefore should not be interpreted as a cost estimate. The first engineering cost estimate or cost estimate range is available at the end of the Identification Phase of the project lifecycle.

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6.3. Retained Risks

The 10 year investment strategy details projects to address the highest priority risks and issues at Seton. It is important to consider that Seton is one of many generating facilities, and efforts are made to prioritize investments across the entire fleet over the 10 year window. Key issues that will not be addressed in the 10 year investment strategy:

Santa Clause Mountain Potential Slide – The slide poses a direct threat to the Bridge River powerhouses, adjacent communities, shoreline development, Seton Dam and downstream areas. In the event of a slope failure, the potential for loss of life would be high. A slope inspection is required annually to monitor the situation. There is little that can be done to address this risk through investment.

Dam AAR – the aggregate in the concrete of the Dam 'swells' over time. This is a slow process at Seton Dam. Eventually the dam will have to be refurbished. The dam is inspected regularly and this phenomenon is monitored. There are no plans to address this risk at this time.

Dam Seismic – The seismic performance of the dam to meet the criteria for a High consequence dam is uncertain at this time. There are no plans to address this risk in the next 10 years. However, a Dam Safety Investigation is planned to investigate the seismic performance of various civil assets at the Seton facility and there are plans to address this risk in the next 10-20 year timeframe.

Canal, Aqueduct and Forebay Seismic – The canal, aqueduct and forebay are not expected to meet the criteria for a High consequence dam. There are no plans to address this risk in the next 10 years. However, a Dam Safety Investigation is planned to investigate the seismic performance of various civil assets at the Seton facility and there are plans to address this risk in the next 10-20 year timeframe.

Single Unit Plant/No Bypass – Seton has operated as a single unit facility for 60 years. Through timely investments and carefully planned implementation, high flows down the Seton River at sensitive times of the year can be avoided. However, this is becoming a greater concern with local communities and the window to take long unit outages for refurbishment work is getting smaller. There are no plans to address this risk at this time.

Spawning Channel Water Supply – The requirement to provide appropriate water flow and at a suitable temperature to the spawning channels is important and presents a constraint on maintenance and capital investments activities that stop the flow through the plant. This is mitigated through careful planning and operational controls.

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7. Expected Results

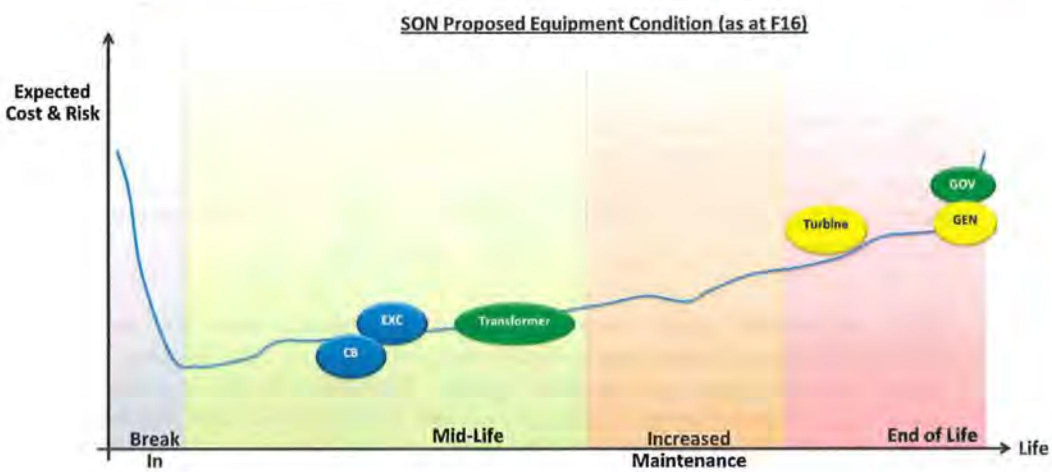
Assuming that the proposed series of investments outlined in the previous section are implemented, the following results should be expected.

7.1. Bathtub Curve – Current and Future State

The Equipment Health Rating of the major system components is shown on the following bathtub curves to provide a visual depiction of not only condition but also lifecycle stage. The two diagrams show the current state (F16), and the likely state at the end of the 10 years assuming that the proposed suite of investments outlined in section 6.2 are implemented as expected.

At the end of 10 years (F27), the remaining unit original equipment, and the risks associated with it, will have been replaced leaving a relative modern reliable unit at Seton. As a single unit plant, it is important that the generating unit remain reliable to pass flows at sensitive times of the year for environmental reasons. Should the flows through the plant be interrupted, the flows would be diverted through the spillway into the Seton River to the detriment of fish values.

Good	Fair	Poor	Unsatisfactory



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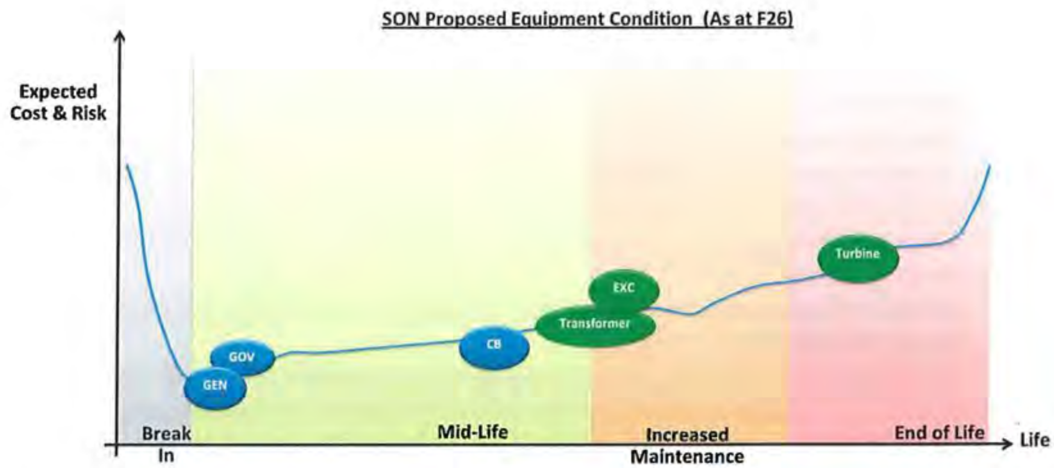

7.2. Strategic Outlook

If the investments are completed, as proposed in this Facility Asset Plan, many of the generating equipment risks will have been mitigated resulting in a more reliable and efficient generator with potentially a modest increase in capacity. A number of civil risks will have been started and will be well under way in the 10 year window. It is anticipated investment in civil assets will continue in the next 10-20 year window. These investments will focus on mitigating seismic risks at the dam and power canal.

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8. DATA REFERENCES

The following is a list of data references used in this Facility Asset Plan. All data is for the last complete fiscal year unless stated otherwise.

Annual Revenue – facility revenue is expressed as a range (highest, lowest) of values calculated for the last 5 years. These values are available for each facility in a spreadsheet on the GAM J:Drive. The data is provided by GRM and is only a proxy for revenue attributed to each facility.

Maximum Sustained Generating Capacity – is available from the facility Hydro Web page and the values are provided by GOO 1J-08.

Historic Annual Average Plant Generation – is available from the facility Hydro Web page and the values are provided by GRM.

Investment Summary – this graph is generated from a spreadsheet on the GAM J:Drive. The historical capital spend is retrieved from the GCCR/CCR reports. The forecast capital spend is taken from C55.

Performance Data (Availability Factor, Forced Outage Count, Forced Outage Duration, Forced Outage Factor) – is available from the GAM Monthly Report. This data is extracted from the USR report maintained by GRM.

EHR Equipment Ratings – are available from the GAM Monthly report. This data is extracted from EHR and is usually for the most recent month the FAP is prepared.

EHR Forecast Ratings – this is available from the EHR Forecast spreadsheet on the GAM J:Drive. The spreadsheet uses a combination of current EHR rating, historical trends for equipment ageing and proposed investments to predict the future EHR rating of equipment. Some judgment is required and discussion with other GAM members may help come to a consensus.

Completed and Ongoing Projects – these projects are available from previous fiscal GCCRs/CCRs.

Dam, Spillway and Water Passages – description, dimensions, ratings and capacities of these components comes from a number of sources; Dam Safety's Operation, Maintenance and Surveillance (OMS) Manual, GRMs Generation Operating Orders (GOOs) and Generation Operations Local Operating Orders (LOOs). All three should be aligned but if discrepancies are discovered then a discussion with the various parties will be necessary. Generally, LOOs must conform to GOOs and the system is operated via the GOO/LOO as they are easier to update to reflect new information.

Hydrology – similar to dams, spillway and water passages above there are various sources of information OMS, GOO and LOO. In addition, GRM will provide inflow data.

Seismic Withstand – these values are available from Dam Safety to ensure the latest values are used as they are constantly being updated.

Probable Maximum Flood (PMF) – these values are available from Dam Safety or the OMS.

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BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-4

Bridge River Facility Water Licences

Bridge River Generating Station 1 Water Licences

License/ Permit	Purpose	Licenced Amount	Date of Precedence	Expiry Date	Total Licenced Right	Portion of Total Licenced Right
FWL 126080	Diversion from Carpenter Reservoir to Bridge River Generating Station BR1	2.7 m3/s	Jan 18, 2011	Mar 30, 2051	2.7 m3/s	4%
FWL 126287	Diversion from Carpenter Reservoir to Bridge River Generating Station BR1	42.5 m3/s	Dec 26, 1912	Apr 1, 2019[1]	42.5 m3/s	65%
FWL 126288	Diversion from Carpenter Reservoir to Bridge River Generating Station BR1	19.8 m3/s	Apr 27, 1954	Apr 1, 2019[1]	19.8 m3/s	31%

1. BC Hydro has applied to renew these water licenses. The water licenses remain valid pending a decision by the BC Water Comptroller.

BRITISH COLUMBIA
The Best Place on Earth

Province of British Columbia
Water Act

FINAL WATER LICENCE

British Columbia Hydro and Power Authority is hereby authorized to divert and use water as follows:

a) The stream on which the rights are granted is Bridge River.

b) The point of diversion is PD 47063 and the point of rediversion is PD 47061 located as shown on the attached plan.

c) The date from which this licence shall have precedence is January 18, 2011.

d) The purpose for which this licence is issued is power, which is to be generated at Bridge River generating station BR1.

e) The maximum rate at which water may be diverted and used under this licence is 2.7 cubic metres per second.

f) The water may be diverted and used throughout the whole year.

g) This licence is appurtenant to the undertaking of the British Columbia Hydro and Power Authority to generate power from Bridge River generating station BR1 situated on Block B in the Slosh Indian Reserve No. 1, District Lot 7141 and District Lot 951, Lillooet District.

h) The authorized works are a dam, low level outlet (PD 47063), intake (PD 47061), tunnel, penstock, powerhouse as shown on the attached plan, and ancillary works associated with the operation of the dam and powerhouse.

i) The licensee must operate the works authorized in h) above in accordance with an order of the Comptroller that:

  i) Sets values for parameters and procedures for the operation of the works which are based on the Bridge River Water Use Plan dated March 17, 2011;

  ii) Requires a monitoring program to evaluate the effectiveness of the regulation of the works as ordered in i) i) above, and which program is based on the Bridge River Water Use Plan dated March 17, 2011; and

  iii) Amends the parameters and procedures ordered in i) i) above in consideration of the results of the monitoring program and any subsequent Bridge River Water Use Plans.

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j) This licence or any licences issued in substitution thereof shall expire on March 30, 2051.

Glen Davidson P.Eng.
Comptroller of Water Rights

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Province of British Columbia
Water Act

FINAL WATER LICENCE

British Columbia Hydro and Power Authority is hereby authorized to divert and use water as follows:

a) The stream on which the rights are granted is Bridge River.

b) The point of diversion is PD 47063 and the point of rediversion is PD 47061 located as shown on the attached plan.

c) The date from which this licence shall have precedence is December 26, 1912.

d) The purpose for which this licence is issued is power, which is to be generated at Bridge River generating station BR1.

e) The maximum rate at which water may be diverted and used under this licence is 42.5 cubic metres per second.

f) The water may be diverted and used throughout the whole year.

g) This licence is appurtenant to the undertaking of the British Columbia Hydro and Power Authority to generate power from Bridge River generating station BR1 situated on Block B in the Slosh Indian Reserve No. 1, District Lot 7141 and District Lot 951, Lillooet District.

h) The authorized works are a dam, low level outlet (PD 47063), intake (PD 47061), tunnel, penstock, powerhouse as shown on the attached plan, and ancillary works associated with the operation of the dam and powerhouse.

i) This licence or any licences issued in substitution thereof shall expire on April 1, 2019.

j) This licence is issued in substitution of Conditional Water licence 9264.

Glen Davidson P.Eng.
Comptroller of Water Rights

File No. 0265200 **Date Issued: March 30, 2011** **Final Licence No.: F126287** *Page 1 of 1*

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Water Act

FINAL WATER LICENCE

British Columbia Hydro and Power Authority is hereby authorized to divert and use water as follows:

a) The stream on which the rights are granted is Bridge River.

b) The point of diversion is PD 47063 and the point of rediversion is PD 47061 located as shown on the attached plan.

c) The date from which this licence shall have precedence is April 27, 1954.

d) The purpose for which this licence is issued is power, which is to be generated at Bridge River generating station BR1.

e) The maximum rate at which water may be diverted and used under this licence is 19.8 cubic metres per second.

f) The water may be diverted and used throughout the whole year.

g) This licence is appurtenant to the undertaking of the British Columbia Hydro and Power Authority to generate power from Bridge River generating station BR1 situated on Block B in the Slosh Indian Reserve No. 1, District Lot 7141 and District Lot 951, Lillooet District.

h) The authorized works are a dam, low level outlet (PD 47063), intake (PD 47061), tunnel, penstock, powerhouse as shown on the attached plan, and ancillary works associated with the operation of the dam and powerhouse.

i) This licence or any licences issued in substitution thereof shall expire on April 1, 2019.

j) This licence is issued in substitution of Conditional Water licence 22129.

Glen Davidson P.Eng.
Comptroller of Water Rights

File No. 0202694 **Date Issued: March 30, 2011** **Final Licence No.: F126288** *Page 1 of 1*

BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-5

BR1 Alternative Assessment Financial Model

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BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-6

BR1 Summary of Power Benefits Study

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Summary of Power Benefits Study for Bridge River 1 Unit 1 to 4 Generators and Plant Equipment Replacement

Introduction

This appendix summarizes studies carried out to inform the business case for upgrading the generators and plant equipment on the units at Bridge River 1. Four generator rating alternatives were selected as follows:

- Baseline: 4 units @ 50 MW each;
- Alternative No. 1: 3 units @ 50 MW each and 1 unit @ 40 MW;
- Alternative No. 2: 4 units @ 54 MW each; and
- Alternative No. 3: 4 units @ 57 MW each.

In all cases, Bridge River 2's units are assumed to be rated at 75 MW each and that operations continue under the existing BR1 and BR2 water licenses.

Deliverables

1. For the three alternatives compared to the baseline:
    - Incremental dependable capacity in MW;
    - Incremental annual power benefit in $/year;
    - Incremental shaping benefit in $/year; and
    - Incremental annual system energy in GWh/year
2. Sensitivity analysis to determine the values in 1 for Alternative No. 3 only, for alternate assumptions on the maximum forebay at La Joie Dam and on the rating of the generator at Seton Generating Station.
3. For all cases, the modeled maximum power output of BR1.

Studies

The studies follow Resource Planning and Coordination's typical modelling procedure used to evaluate operating alternatives and estimate operational effects. This involves sequential use of the hydro simulation model (**HYSIM**) and the generalized optimization model (**GOM**). The studies are:

- Three HYSIM studies, one for the base analysis and two more for the sensitivity analyses. These studies establish monthly operating regimes for Williston, Kinbasket, Arrow Lake, and the Bridge River system that maximize system operating value including electricity trade; and
- Eight GOM studies, one each for the base four unit rating alternatives and four more for sensitivity analyses.

Modelling Process

In Resource Planning & Coordination's typical modelling process, HYSIM is used first to simulate the monthly operation of BC Hydro's generation system, including the detailed operation of the major storage projects, namely Williston, Kinbasket, and Arrow Lake. GOM is subsequently used to optimize the hourly operation of the hydropower system, guided by the month-end storage targets and fixed year-end storage targets produced by HYSIM. The two models are described in more detail in the next two sections.

HYSIM

The HYSIM model is a monthly simulation model of the integrated BC Hydro generation system with limited foresight. It includes detailed hydraulic modelling of the hydro system as well as operating rules derived under the Columbia River Treaty operating plans. For a given load and resource portfolio (including contracts), the model will determine the most economic dispatch of the generating system subject to fixed operating constraints (e.g., dam safety, physical capability, flood control, regulatory requirements, third-party agreements) across an historical sequence of inflows and subject to external market opportunities. The external markets are represented with both heavy- and light-load hour import prices, export prices and tie-line limitations.

As a monthly time-step model, HYSIM can be used only to accurately address constraints on monthly resolutions. The outputs from the model include end-of-month reservoir elevations and storage contents, monthly average energy production, project discharges, and trade, and do not reflect any variability within the month.

GOM

GOM is a medium-term system optimization model that uses deterministic linear programming techniques to solve for optimal operating conditions subject to constraints. GOM meets BC Hydro electrical system load while maximizing the operational value of the generating resources subject to generator capability limits, regulatory/licensing requirements, third-party agreements, inflow sequences, intertie limits on electricity trade, etc. GOM has perfect foresight of parameters such as load, price, and inflows for the time period being modelled but its ability to shift water from month to month is guided by month-end reservoir storage targets from HYSIM. Furthermore, the reservoir storage contents of are fixed to those that came from the corresponding HYSIM study at the start and end of each water year. This limits GOM's perfect foresight to one water year.

Typically, GOM is run with an hourly time step, for one water year at a time, to capture the variability in inflows, load, and prices within months and days. Inputs include the domestic load; available generating resources along with their operating characteristics (operating and flow constraints, efficiency curves, etc.); and market prices of electricity.

GOM determines optimal reservoir elevations, plant discharges, and energy trade. These data are not wholly representative of how actual operations would occur because the effects of forced generation and transmission outages, forecast uncertainty, and electricity market liquidity, among other things, are not explicitly modelled. As a result, GOM results are a proxy for hydro system operations and can indicate the incremental value and incremental operating impact between two scenarios.

Study Assumptions

Study Period

- The study year used for the resource portfolio, load forecasts, and price forecasts is October 1, 2036 through September 30, 2037.

Load and Resources

- Resources are from the resource plan that was presented in the Fiscal 2020 to Fiscal 2021 Revenue Requirements Application evidentiary update.
- Load energy and peak demand are based "June 2019 Load Resource Balance" (with existing, committed, and planned DSM; with LNG)" issued by Load & Market Forecast.

Prices

- Electricity prices for the study are based on the March 2020 Mid-C BC Hydro corporate price forecast. The prices are in 2019 C$ and average [redacted].
- Wheeling charges are added to or subtracted from Mid-C to determine import and export prices at the B.C. border.
- The electricity prices are adjusted for each month to reflect the impact of: regional stream flow conditions as measured at The Dalles; natural gas prices at Sumas; and temperatures in Washington State, California, and B.C.

- Gas prices are the Sumas price which corresponds to the electricity price scenario described above.

Plant Data and Operational Constraints

Peace and Columbia Systems**:**

- Unit ratings as existing or based on planned work scheduled to be complete by the study year;
- Reservoir and flow limits as per water licenses and associated orders and/or Columbia River Treaty requirements; and
- Flows for Site C to meet nominal ice control requirements in December to March.

Bridge System**:**

- Lajoie Unit 1 as existing – 24 MW;
- Bridge River 1 Units 1 to 4 as per alternatives described above;
- Bridge River 2 Units 5 to 8 assumed at 75 MW each;
- Seton Unit 1 at 50 MW (44 MW in the sensitivity analysis); and
- Reservoir & flow limits as per water licenses and associated orders:
  - ▶ Downton Reservoir limited to 734 m (749 m in the sensitivity analysis)

Miscellaneous

- Generic outage schedules are used to represent typical planned outage requirements for each plant including planned unit additions.
- Columbia River Treaty operations are based on Assured Operating Plan 2022.

Generator Rating Scenario Results

The following table summarizes the additional benefits for each of the unit rating alternatives compared to the baseline of four units at 50 MW each.

Table 1 Change in benefit from the Baseline

BR1 U1-4 Scenario	Dependable Capacity change (MW)	Annual System Benefit change ($/yr)	Annual Shaping Benefit change ($/yr)	Annual System Energy change (GWh)	Max Absolute Generation (MW)
Alt. 1 (3x50+1x40)	(10)[1]	(295,644)	(141,789)	(3.619)	1901
Baseline (4x50)	-	-	-	-	2001
Alt. 2 (4x54)	161	214,911	166,336	1.143	2161
Alt. 3 (4x57)	16[2]	237,641	181,392	1.323	221[3]

The dependable capacity for BR1 for the baseline (4x50) is 200 MW. As the dependable capacity is calculated based on the hydraulic head in the winter months (December, January and February), the increase in dependable capacity may be less than the increase in generator rating as the available head and/or the water license may be the limiting element. Any reasons for limitations are footnoted.

The annual system benefit presented is the total benefit of any additional energy produced and any change in energy trading activity (shaping). The shaping benefit is estimated as the total benefit less the annual energy increase multiplied by the annual average export price of [redacted].

The maximum absolute generation presented in Table 1 is the maximum value of the BR1 plant output in the model runs (and respects the water license limit). Note that this value is not the difference from the baseline and hence is presented for all alternatives.

1 Limited by the generator rating.
2 Limited by the water license and the winter hydraulic head.
3 Limited by the water license (value occurs at maximum expected head).

Sensitivity Analysis

The results presented in Table 1 are obtained under the assumptions that the maximum possible reservoir elevation for Downtown reservoir is 734 m and that the Seton plant has a capacity of 50 MW. Sensitivity analysis was conducted for Alt. 3 by altering these two assumptions one at a time as follows:

- Downton Reservoir Elevation @ 749 m; and
- SON GS @ 44 MW.

Table 2 summarizes the results of the sensitivity analysis. The table shows the updated incremental benefits and max absolute generation when both the baseline (4x50) and Alt. 3 (4x57) are run under the modified assumptions described above. Any reasons for limitations on the MW values are the same as in Table 1.

Table 2 Change in benefit of Alt. 3 from the Baseline under varying assumptions

BR1 U1-4 Scenario	Dependable Capacity change (MW)	Annual System Benefit change ($/yr)	Annual Shaping Benefit change ($/yr)	Annual System Energy change (GWh)	Max Absolute Generation (MW)
Baseline: LAJ @ 749	-	-	-	-	200
Alt 3: LAJ @ 749	16	204,940	187,769	0.40	221
Baseline: SON @ 44	-	-	-	-	200
Alt 3: SON @ 44	16	224,787	187,099	0.89	221

Glossary

Some terms which may not be familiar to all readers are described below.

Dependable Capacity is an estimate of the capacity which can be counted on to be available in winter when BC Hydro's load peaks. It is the capacity value which is used by BC Hydro in the Capacity LRBs which guide the acquisition of new capacity resources.

Incremental Annual System Benefit is the difference in the GOM objective function value between two alternatives and as such represents the change in all power-related benefits modeled in GOM in dollar terms. As such, it includes the benefits of both any additional energy produced and any change in energy trading activity (shaping).

Incremental Shaping Benefit is an estimate of the portion of Incremental Annual System Benefit which is arises due to a change in energy trading activity.

Heavy Load Hours is an industry standard definition for the hours of 6 a.m. to 10 p.m. daily, excluding Sundays and NERC holidays. Broadly speaking, these are the hours when electricity loads are highest.

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Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-7

BR1 Preliminary Design Report

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BRIDGE RIVER 1 GENERATING STATION

UNITS 1 TO 4 UPGRADE PROJECT

PRELIMINARY DESIGN REPORT

Prepared for: Project Delivery

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2021 Feb 03

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Title:	Project Engineer
Reviewed by:	Bob Stewart P. Eng.
Title:	Principal Engineer
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Revisions

Revision Number	Date	Description
Revision 0	2021/01/29	

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Appendix F:	621-GER-00008 Preliminary Design Report for Control System R1
Appendix G:	BR120-05.10-IOM-GY0239 High Bay Design Memo
Appendix H:	621-GEM-00011 BR1-U1-4 Turbine Preliminary Design Memo R0
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Appendix M:	BR1-SIS-2019-02-07 Final Interconnection System Impact Study
Appendix N:	621-GER-00002 BR1 Generator Control and Excitation System Condition Assessment R1
Appendix O:	5585256-004000-47-ERA-0002-R01 BBA Exciter System Condition Assessment

Tables

Figures

Acronyms

The following are acronyms used in this report.

BR	Bridge River
BRT	Bridge River Terminal
CIP	Critical Infrastructure Protection
CPCN	Certificate of Public Convenience and Necessity
CS	BC Hydro Construction Services
CT	Current Transformer
DAS	Data Acquisition System
ESFR	Early Suppression Fast Response
FVO	Fraser Valley Office
GCC	Governor Control Console
GS	Generator Supplier
EHR	Equipment Health Rating
GOAAL	Generation Operation Asset Architecture Logic
HPOIS	High Pressure Oil Injection System
LAJ	La Joie
MCC	Motor Control Centre
NERC	North American Electric Reliability Council
OEM	Original Equipment Manufacturer
OI	Operational Information
OTSS	Operational Technical Support Services
PAM	Protection, Alarm and Metering
PIO	PAM Remote IO

PSS	Power System Stabilizer
RFP	Request for Proposals
RTD	Resistance Temperature Detector
SbD	Safety by Design
SCR	Short-Circuit Ratio
SIP	Signal Interface Panel
SIS	System Impact Study
TRZ	Terzaghi
UCC	Unit Control Console
TEDD	Turbine Energy Dissipation Device

Executive Summary

This report summarizes and consolidates the Preliminary-level design activities performed as of September 28, 2020, and presents the Preliminary level design information, cost estimate and recommendations to proceed for the Bridge River One (BR1) Generator Replacement Project (GY-0239).

Bridge River One Generator Replacement was initiated to address reliability issues with the generating equipment installed in the powerhouse including: generators, excitation systems, governors, protection and control (P&C) system, and additional systems and components.

Based on the project activities performed at the Conceptual and the Feasibility stage, the project scope includes replacement of the major generating equipment in all four units as summarized below:

- Generator and generator terminal equipment replacement
- Governor replacement
- Excitation System replacement
- P&C System
- Miscellaneous Balance of Plant equipment
- Additional activities to improve reliability of the generation units

In addition, the project scope of work includes supply of the turbine energy dissipation device and minor refurbishment of the turbine components subject to their condition assessment by the generator supplier.

The complete scope of the work is included in Appendix A of this report.

This report summarizes the engineering activities performed at the Preliminary design stage.

The scope of the performed activities was focused on:

- Validation of the selected design solutions including major parameters of the equipment
- Supporting development of the cost estimate for the project scope of the work

- Constructability evaluation for the defined scope of the work
- Further development of the Safety by Design (SbD) register for the project work

Based on the performed activities, the engineering team has confirmed validity of the project scope and selected engineering solutions. The team will proceed with finalizing the Preliminary design activities.

1 INTRODUCTION

This report describes the objectives, methodology and results of the Definition Phase, Preliminary Design for the Bridge River One (BR1), Units 1 to 4 Upgrade Project.

1.1 Current Conditions

The Bridge River Generation Area is within the Coastal Generation Region and includes the La Joie, Bridge River 1 and 2, and Seton generation stations. The system consists of two main storage dams on the Bridge River: La Joie (LAJ) and Terzaghi (TRZ). These create two reservoirs, respectively: Downton and Carpenter. Water from Carpenter Reservoir is diverted through tunnels and penstocks to the two Bridge River powerhouses (Bridge River 1 (BR1) and Bridge River 2 (BR2)), each with four generating units, located on the Seton Lake Reservoir. The system layout is such that the only way to move water from Carpenter Reservoir into Seton Lake Reservoir is through the Bridge River generating units. Unavailability of the Bridge River generating units creates a risk of having to spill more than targeted discharge rates from TRZ into the upper Bridge River. It is therefore very important to the Bridge River system that the Bridge River generating units are available and reliable.

The primary driver of this project is the poor and unsatisfactory condition of the generators, and the need to restore lost water conveyance capacity within the Bridge River system to gain greater efficiency and reliability, and to manage the risk of not being able to meet the target water levels and water flows at the Terzaghi Dam. After upgrade, generators will match the turbine capability and achieve a modest increase in dependable plant capacity.

This project involves the replacement of the Bridge River 1, Units 1 - 4 generators, governors, unit controls and excitation systems, as well as work on the auxiliary systems and the turbines.

1.2 Related Projects

Related projects include the Unit 5 and Unit 6 upgrade at Bridge River Two (BR2).

1.3 Project Setting

The Bridge River powerhouses are located on Seton Lake Reservoir, approximately 20 km West of Lillooet BC. The primary access is via the Mission Mountain Road (Hwy 40). Secondary access is available over the Highline Road; however, this will not be recommended as a transportation route for this project. The site is also accessible by rail, and water access may be possible, though there are currently no barge landings at the power station or in Lillooet. Figure 1 below is a BC Hydro access map which shows the location of the Bridge River Powerhouses in the context of the Bridge River System.

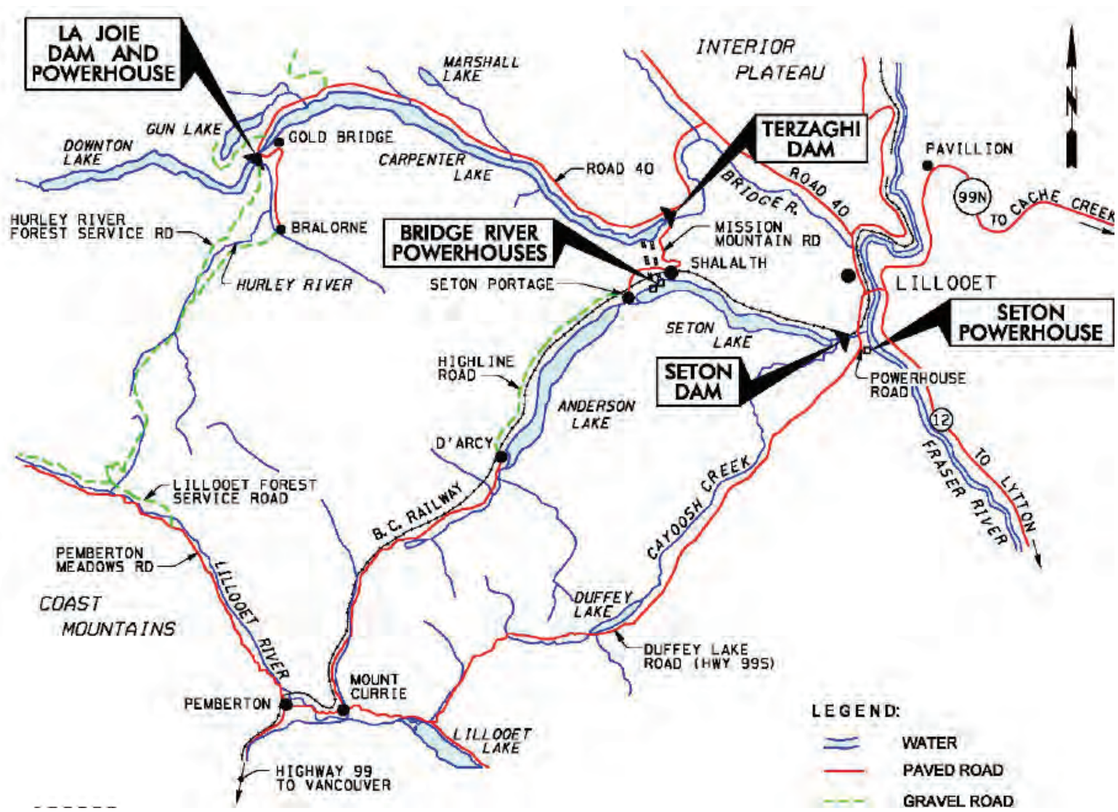

Figure 1: Bridge River System Access Map

2 PRELIMINARY DESIGN OVERVIEW

The design objectives and methodology of this phase are discussed in detail in the project's Preliminary Design Plan; however, a high-level overview is presented below.

2.1 Design Objectives

The overall design objectives for this phase of the project were to:

1. Complete field investigations and preliminary design of the following end-feature systems:
    - New Generator
    - Assembly bay floor slab capacity assessment
    - Crane assessment
    - Exciters and exciter transformers (excitation system)
    - Generator terminal equipment
    - Generator foundation assessment
    - Governors
    - Grounding and bonding within the powerhouse
    - Fire Protection System in the High Bay area
    - Mechanical Balance of Plant equipment assessment
    - Turbine nozzle and deflector refurbishments
    - Turbine Energy Dissipation Device
2. Refine the definition of the project's physical scope and equipment interfaces.
    - Provide sufficient detail and supporting design information to support a +30%/-15% project cost estimate to support the Certificate of Public Convenience and Necessity (CPCN) application.
    - Add definition of responsibilities (i.e., design, supply, installation, commissioning) for each item in support of the project's design and procurement planning.

3. Investigate the impact of the generator upgrade on the transmission system
4. Identify design-related project risks and mitigations.
5. Update and add to the project's understanding of safety hazards to be addressed through Safety by Design.

2.2 Methodology

2.2.1 General

The design of each system included in the project scope based on the initial statement of objectives has been based on the following stages:

1. Conceptual design stage. Conceptual design stage included an extensive condition assessment based on the Equipment Health Rating (EHR) methodology and additional factors. Based on the review of the gathered information, the project team has defined the viable options and the leading alternative, summarized in the conceptual design report.
2. Feasibility design stage. At this stage, the project team refined the project scope and confirmed feasibility of the leading alternative and validated the leading alternative as the preferred alternative. The engineering activities performed at the Feasibility stage are summarized in the feasibility design report.
3. Preliminary design stage. This is the current stage in which the preferred alternative for each system is further developed to culminate in preparation of the contract specifications and to be issued for RFP drawings. Constructability and Safety by Design aspects are confirmed and optimized. More detailed results of the work performed at the current stage are included in Section 5 of this report and the engineering reports and memos included in the appendices.

2.2.2 Key Assumptions

Key assumptions that affect the project's Preliminary Design are listed below. For a more complete listing of design assumptions, please refer to the Design Basis section in this report.

- The generator work will be performed based on the competitive RFP process.
- The generator supplier will also perform the required turbine refurbishment activities and interface activities between the new governor system and the turbine.
- Installation of other equipment will be performed by BC Hydro Construction Services.
- Each unit will be allocated a one-year outage window.
- The required design life for the major equipment is 50 years.
- No major civil work is required.
- No significant fatigue or corrosion will be found in the existing generator structural supports after the generator is removed.
- BC Hydro internal design resources are and will continue to be available as needed for this project.
- BC Hydro Operations will allow sufficient outages for the removal and installation of each unit in a single outage.

2.2.3 Generator

The condition of the original generators installed in 1948 and 1949 is rated "unsatisfactory" in the EHR system based on the performed tests, inspections and known issues. Additional evaluation performed by the project team confirmed the original assessment.

In the end of the Conceptual stage, replacement of the existing generator was determined to be a leading alternative.

At the Feasibility stage, the project team selected a new generator nameplate rating of 60 MVA/0.9 PF based on factors such as existing water license, turbine capacity, historical operation characteristics and the limitations of the existing powerhouse structure.

The procurement strategy for the generator replacement is based on issuing an RFP attracting as many potential qualified participants as possible.

In the current stage, the engineering activities are focused on the further refinement of the preferred alternative focusing on constructability and detailed design requirements.

In addition, market sounding will be performed to determine the level of interest and to identify additional potential suppliers worldwide

The detailed information on the engineering activities covering the generator in the definition stage are included in the engineering memos included in Appendices C and D.

At the end of this stage as a part of the partial implementation stage, the engineering team will produce the engineering specifications to be integrated in the procurement package for the competitive bid.

2.2.4 Crane Assessment

The crane was manufactured by Provincial Engineering in 1948 and consists of a 175 short ton main hoist and a 25 short ton auxiliary hoist. A 5 metric tonne tertiary hoist was recently installed and commissioned in January 2017.

A major refurbishment project was completed on the crane in 2011, including new motors, brakes, variable frequency drive control and other features common to modern cranes. The commissioning of the refurbished crane involved a load test to 125% of its capacity.

A July 2016 inspection report revealed no major deficiencies, as expected for a recently upgraded crane. Based on this information, it is expected the crane will not require any significant work for the project.

The crane's rated capacity is less than the weight of the existing generator rotor. To minimize outage length and improve the safety and quality of the rotor disassembly / installation, a consultant study was performed to assess the feasibility of performing engineered lifts for the rotor. The study confirmed that it is feasible to perform rotor engineered lifts.

2.2.5 Excitation Systems

The detailed information on the engineering activities in the definition stage covering the excitation system is included in the engineering report Appendix E.

While the original Equipment Health Rating indicated that the excitation systems in all units were marginally above poor condition, additional condition assessment performed by the independent engineering consultant (BBA) and by the BC Hydro subject matter experts lead to the conclusion that the excitation systems need to be replaced based on the following systemic factors:

1. The static excitation system currently installed at Bridge River 1 is undersized compared to the needs of both the new generator nameplate and the historical operating range of the existing generator.
2. Non-compliance with North American Electric Reliability Council (NERC) requirements
3. Lack of spare parts
4. The excitation system is well past the vendor's life expectancy and there is foreseeable increased operation and maintenance cost as the equipment ages.
5. Limited vendor support – The Supplier (GE) does not have technical expertise to support the installed excitation systems including implementation of the requirements included in NERC standards.
6. Limited in-house expertise – BC Hydro has limited site staff knowledge on these excitation systems in BR1.

Excitation system replacement in all four units is a preferable alternative that will be implemented based on the existing blanket contract.

Both condition assessment reports are provided in Appendices N and O.

At the end of this stage, as a part of the partial implementation stage, the engineering team will produce the engineering specifications in the draft form to be integrated in the procurement package to issue the order based on the blanket contract.

2.2.6 Protection and Controls

BR1 Units 1-4 control systems were installed in 1989 and the unit control equipment is past the 30 years life expectancy. As reviewed during Conceptual stage, system reliability and availability are significantly reduced due to aged component failures and lack of self-diagnostics capability.

During the feasibility study of replacing the BR1 generators, unit control equipment was also evaluated by BBA to use risk level methodologies which resulted into the recommendation on the detailed scope of the preferred alternative.

Control system replacement in all four units is a preferable alternative that will be implemented based on the existing blanket contract.

The detailed information on the engineering activities covering the excitation system replacement in the definition stage are included in the engineering memo included in Appendix G.

At the end of this stage as a part of the partial implementation stage, the engineering team will produce the engineering package to order the new P&C system.

2.2.7 Generator Terminal Equipment

A neutral transformer and other terminal equipment (disconnect switch and resistors) were installed in 1987. Two sets of neutral Current Transformers (CT) and one set of split-phase CTs are mounted in the generator terminal cabinet. The existing generator CTs were reviewed as part of the Unit Protection Replacement project in 2014 and are not considered for replacement as part of the protection upgrade due to uncertainty of the generator upgrade planning.

The terminal equipment will be more than 40 years old in 2025 and represents a reliability issue in the upgraded unit.

In addition, the new generators increased rating could accelerate the equipment aging.

Based on the engineering evaluation, replacement of the existing terminal equipment was concluded to be the best course of action.

2.2.8 Generator Foundation Assessment

Preliminary structural assessment on the existing generator foundations was conducted to determine the existing foundation's ability to withstand the larger magnitude foundation loads from the uprated generator.

The scope of the assessment included both the site inspection performed by Structural Engineering in 2017, and an analytical evaluation based on a 3D finite element model of the existing generator foundation to calculate the stresses in the foundation under the uprated generator loads recommended by the project engineering team.

It was found that the allowable tensile stress limit is exceeded under the synchronization failure load case, and the shear stress limit of the existing stator soleplate foundation anchors are also exceeded under electrical fault load cases.

To address the found issue, a solution of adding eight new stator soleplate foundation anchors per unit was evaluated and found to be effective.

Based on the performed assessment, designing and installing additional foundation anchors have been included in the project scope.

The generator specifications will require the generator supply proposals to include foundation forces due to electrical faults. This will ensure no generator foundation work will be required except adding anchors.

2.2.9 Turbine Energy Dissipation Device (TEDD)

The detailed information on the engineering activities in the definition stage covering TEDD is included in the engineering report provide in Appendix J.

The extended outage required to complete upgrade of one generation unit combined with the poor reliability of the existing generators introduce the risk of concurrent shutdown of two or more generating units.

To mitigate the risk of unacceptable spill to the Lower Bridge River, the project team has developed a mitigation plan based on design and installation of a turbine energy dissipation device (TEDD) to allow water flow in one shutdown unit.

The final decision on design and supply of TEDD will be taken by the end of the current stage of project activities.

2.2.10 Governors

The engineering assessment performed during the Conceptual stage concluded that the governors rated POOR based on the EHR methodology have an expected remaining life of less than 10 years.

During the Feasibility stage, it was concluded that replacement of the existing governor system with a new high-pressure governor system operating at approximately a 1750 psig with a digital control system is the preferred solution.

PLC-based digital controls for each unit will be located in a separate governor control cabinet (GCC).

The detailed information on the engineering activities in the definition stage covering the governors is included in the engineering report Appendix K.

2.2.11 Grounding and Bonding Within the Powerhouse

To confirm if a Powerhouse grounding system required any upgrade to support replacement of the major equipment in the powerhouse, the existing grounding and bonding connections for all the relevant indicated equipment has been reviewed and inspected.

It was determined that the conductor sizes of existing bonding and grounding connections meet the latest BC Hydro engineering standard ES44-Z1010 requirement and the new equipment grounding and bonding conductors can be connected to the existing grounding and bonding system.

2.2.12 Station Service Air Supply System

The project has undertaken to review the station service air system to determine if the scope of the work included in the preferred alternative could require system modification. It has been concluded that the existing system does not require any modification based on the design review performed.

2.2.13 Station Service Water Supply System

The project has reviewed the station water supply system to determine if the scope of the work included in the preferred alternative could require system modification. It has been concluded that the existing system does not require any modification based on the performed design review.

2.2.14 Fire Protection System

Portions of the BR1 Fire Protection System were substantially upgraded in 2007. The generator deluge valve stations and deluge rings were not replaced at that time and their replacement will be included in the Generator scope of supply.

The existing generator deluge panel was determined to be suitable for reuse.

To mitigate the risk of fire in the designated area of the powerhouse that could lead to the complete loss of the BR1 generating it was decided to add an automatic fire suppression system protecting the project work area.

2.2.15 Turbine Minor Refurbishments

The additional evaluation of the turbines concluded that the assessment of U1-4 turbines performed at the project Feasibility stage is still valid, and the turbines are suitable for continued long-term operation.

This project provides an opportunity to further assess the condition of some turbine components such as guide bearing and deflector stem bushings, which were not included in the turbine upgrade work performed in 2002-2003. Such assessment will be included in the scope of the work to be assigned to the generator Original Equipment Manufacturer (OEM).

Based on the experience gained from upgrading the BR2 Units 5-6, it is likely that the deflector stem bushings will need to be replaced.

The generator replacement may potentially introduce a risk of nozzle-runner misalignment that may impact the normal operation of the unit. To mitigate this risk the generator supplier will verify the nozzle to runner alignment before and after the new generator installation. If required, realignment of the runner will be performed to meet the tolerances requirements stipulated in the contract specification based on the CEATI Erection Guide.

2.2.16 Assembly Bay Floor Assessment

The BR1 Generator Floor structural assessment was performed in 2018 (Appendix L).

Structural analysis was supplemented with a visual inspection undertaken to evaluate the capacity of the Generator Floor to carry the loads associated with the unit's replacement. The allowable uniformly-distributed live load based on the existing concrete slabs and the existing steel beam capacities was evaluated for the entire Generator Floor.

Based on the allowable uniformly-distributed live load, the Generator Floor requires mitigation measures to support the New Stator combined with the New Upper Bracket. These equipment components could be placed onto a new designed steel platform system above the Generator Floor that would sit on precisely positioned support points.

The new rotor and existing rotor will need to be handled on a new steel platform to distribute the rotor mass directly on the existing steel posts and column.

The platform design will be included in the generator supplier scope.

2.2.17 System Impact Study

As a part of engineering work for the project planning activities, plus for the identification of any impact to the power system network and transmission equipment, a system interconnection feasibility and

System Impact Study (SIS) was performed by BC Hydro system and station planning groups to assess the impact of the interconnection of this project on the BC Hydro Transmission System to identify constraints and suggest power system network upgrade options in order to obtain adequate performance for the reliable operation of the Transmission System.

The SIS concluded that no transmission network upgrade for the related equipment, protection, control, revenue metering and telecommunication work is required as a part of the BR1 to 4 Generator project.

All known constraints in the transmission capacity from the BR generation area that includes BR1 and BR2 generation stations are expected to be addressed by the capital project that are being developed by Transmission business group.

The SIS has also concluded that no station work is required, and therefore no related cost on the transmission system for the BR1 switchyard and Bridge River Terminal (BRT) substation has been identified.

The new generators' associated protection and control system review and setting update, which is not in the scope of the SIS, will be covered as a part of the BR1 Units 1 to 4 Generator Replacement project scope. The power system stabilizer (PSS) modeling and fine tuning will be performed by the BC Hydro Performance Planning group during the Implementation stage of the BR1 project, based on the final generator parameters provided by the generator supplier.

The additional information on the system impact study is included in the engineering report Appendix C.

2.2.18 Safety by Design

Safety by Design (SbD) was integrated throughout Preliminary Design. Specific activities included reviewing and updating the SbD Hazard Log (Appendix B) and comparing this against the design deliverables to ensure that the hazards are being addressed. The next step for most of the hazards will be to incorporate their mitigation into design specifications, which will flow from preliminary design.

3 DESIGN BASIS (DB)

3.1 General Information

The Bridge River system consists of two main storage dams on the Bridge River: La Joie (LAJ) and Terzaghi (TRZ). These create two reservoirs, respectively Downton and Carpenter. Water from Carpenter Reservoir is diverted through tunnels and penstocks to the two Bridge River powerhouses (Bridge River 1 and Bridge River 2), each with four generating units, located on Seton Lake Reservoir. The Bridge River 1 (BR1) powerhouse, which houses Units 1 to 4, was completed in the 1950s with a total design capacity of 200 MVA. Most of the generating equipment is original and, at more than 60 years of age, nearing or at the end of its design life as confirmed based on the performed condition assessment.

The Bridge River system is unique in its layout in that the only way to move water from Carpenter Reservoir into Seton Lake Reservoir is through the Bridge River generating units.

The water conveyance challenge is to manage these flows to maximize the value of generation, while maintaining targeted discharges from the TRZ dam in the Lower Bridge River. It is therefore very important to the Bridge River system that the Bridge River generating units are available and reliable.

The Bridge River 1 Powerhouse is founded on a thick soil stratum, which contains compressible soils. These ground conditions resulted in settlement of the Powerhouse from the time it was put into service. In addition, subsurface artesian pressures are present in the area surrounding the Powerhouse which have resulted in stability issues with the Powerhouse prior to 1974. The artesian pressures are currently regulated by three bleeder wells installed in 1975/76 and the settlement has been monitored over the last 60 years with most settlement occurring prior to the 1970s.

3.2 Generators

3.2.1 Original Equipment Health Rating

The original generators have Unsatisfactory health rating in all four units.

Health Assessment Summary List — First | Previous | Showing 1 - 4 of 4 | Next | Last

HAS ID	Facility	Unit	Div	System	Equip Type	Equip No	Comp Type	Comp No	UTC	MA	Assessed By	Assessment Date	Status	LG	Action
4656	BR1	UNIT01	BRG	NA	GEN	SYSTEM			745460	GEN	M. Albinto, I. Chichkin	2020-03-12	Active	U	Manage TPs
4657	BR1	UNIT04	BRG	NA	GEN	SYSTEM			745463	GEN	M. Albinto	2020-03-12	Active	U	Manage TPs
4658	BR1	UNIT02	BRG	NA	GEN	SYSTEM			745461	GEN	ILiu; IChichkin	2020-03-16	Active	U	Manage TPs
4659	BR1	UNIT03	BRG	NA	GEN	SYSTEM			745462	GEN	ILiu; IChichkin	2020-03-16	Active	U	Manage TPs

3.2.2 Design Objectives

The project scope includes replacement of the existing generators in Units 1 to 4

3.2.3 Design Requirements

- The Generator will be an alternating current, synchronous, salient pole, and vertical axis type suitable for direct coupling to the Turbine.
- The Generator will be a robust design and will provide reliable operation over the expected minimum Design Service Life of 50 years.
- The Generator will be designed to fulfil the operating condition of the BR1 power plant as determined by the power system requirement, to withstand the ambient conditions and meet the technical requirements with conservative safety margins.
- The Generator design will minimize hazards and maximize safe and ergonomic access for inspections, maintenance, testing and repair.
- The Generator design will incorporate Safety by Design practices, provide ease of access and ease of isolation, inspection, maintenance and repair.
- The four new Generators will be of identical design and installation.

- The total mass of the new generator rotor lifting assembly must be no more than that of the powerhouse crane capacity.
- The Generator design will not lead to detrimental dynamic behaviour and/or structural strength of the existing turbine components.

3.2.4 Major Parameters

Based on the major design requirement, the key parameters of the generator are listed in Table 1 below.

Table 1: Generator Key Parameters

Discipline	Description	Value	U/M	Notes
Generator	Nameplate Rating	60	MVA	
	Power Factor (lagging)	0.9		
	Rated Voltage	13.8	kV	
	Frequency	60	Hz	
	Minimum Efficiency	>98.4	%	At Nameplate Rating
Mechanical	Rated Speed	300	rpm	To match Turbine
	Maximum Runaway Speed	550	rpm	To match Turbine
	Critical Speed	>= 660	rpm	20% above runaway speed
	Stored Energy Constant (H)	>=2.55	kWs/KVA	For generator part only
	Rotor Weight Assembly	158.8	metric tons	Powerhouse bridge crane main hoist capacity.
Seismic	Design to BC Hydro Horizontal	1:2475 AEF FDS with 5% damping ratio		BCH Horizontal 1:2475 AEF return period FDS defined in the SPS1.5.7
	Design to BC Hydro Vertical	1:2475 AEF FDS with 5% damping ratio		BCH Vertical 1:2475 AEF return period FDS defined in the SPS1.5.7
Electrical	Synch Reactance (unsat) Xd	<1	pu	Based on 60MVA and 13.8kV
	Direct Axis Transient Reactance(saturated) X'd	<0.29	pu	Based on 60MVA and 13.8kV
	Direct Axis Sub-Transient Reactance(saturated)X "d	>0.22	pu	Based on 60MVA and 13.8kV
	Short-Circuit Ratio (SCR)	>1.2		
	X" q/X"d Ratio (unsat) .	<1.35		
	Stator Groundwall Insulation Voltage Stress Level	<2.5	kV/mm	For multiple-turns coil for the sided of the coils only

Discipline	Description	Value	U/M	Notes
	Stator Groundwall Insulation Voltage Stress Level	<2.75	kV	For Roebel bar
	Current Transformer (CT) Ratio	3000-5	A	For differential protection purposes, on neutral side
		2500-5	A	For metering purpose
	CT Voltage Class/BIL	15/110	kV	
	CT Accuracy Class for Protection Purposes	5L1200	V	
	CT Class	TPS		
	CT Accuracy Class for Metering Purposes	0.15B1.8		

3.2.5 Acceptance Criteria

a. **Electrical**

The generator and the integration will be accepted as per the applicable standards and requirement. The criteria include that the design outcomes, lab test, factory test and online testing result will comply with:

- ANSI/IEEE, CSA, CEATI, etc. standards listed in the Design Standards section
- BC Hydro ES 44/47 and ES 45/48 Engineering standards listed in the specification parameter requirement in Table 1.

b. **Mechanical**

To confirm stress levels, a Finite Element Analysis (FEA) will be performed on Generator components such as stator frame, rotor spider, rotor rim, rotor pole, rotor fans, shaft, bearing brackets and rotor and stator lifting devices.

Mesh sensitivity analysis will be performed as part of each FEA for high secondary or peak stress area. Alternative methods may be used only after prior acceptance by Hydro’s Representative.

For this allowable stress and safety factor section, “yield strength” will be interpreted as the minimum yield strength of the material, and "tensile strength" the minimum tensile strength of the material.

c. **Plate Steel, Steel Shape and Forgings**

For plate steel, steel shapes and forgings used in the generator, the maximum stress values will not exceed the limits defined in Table 2 except as allowed in the footnotes of this table. Primary Stress, Secondary Stress, and Peak Stress in the following table are von Mises equivalent stresses defined in ASME Boiler and Pressure Vessel Code VIII Division 2 Part 5. A summary of these definitions is included in the footnotes of the following table for reference.

Table 2: Maximum stress values for plate steel, steel shapes and forgings

Condition	Primary Stress[1]	Primary Plus Secondary Plus Peak Stresses[2, 3]	Primary Plus Secondary Plus Peak Stresses - Limits for Rotor Only[4]
Normal operation and standstill	1/3 of yield strength	0.6 of yield strength	Yield strength or 3/4 of tensile strength, whichever is less
Standstill – compression due to rim shrink[5]	1/2 of yield strength	3/4 of yield strength	n/a
Runaway speed	2/3 of yield strength	1.5 times of yield strength	2.5 times yield strength or 2 times tensile strength, whichever is less
Worst of short circuits or synchronization failure	3/4 of yield strength		

Notes for the table:

1. Primary stress is defined as the stress developed by the imposed loading which is necessary to satisfy the laws of equilibrium of external and internal forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses which considerably exceed the yield strength will result in failure or at least in gross distortion.
2. Secondary stress is the self-equilibrating stress necessary to satisfy continuity of structure. It is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur and failure from one application of this stress is not to be expected. Peak stress is the incremental stress added to the primary or secondary stress by a stress concentration. It does not cause any noticeable distortion and is objectionable only as a possible source of a fatigue crack or a brittle fracture. The secondary stress and peak stress are to be calculated from FEA method based on elastic material law. Use of analytical method for rare cases is subject to prior acceptance by Hydro's Representative.

3. If any value specified in this column is exceeded, a fatigue analysis covering all applicable load cases is mandatory. Fatigue analysis will be per ASME Boiler and Pressure Vessel Code VIII Division 2. Use of other recognized international standard or guideline will be subject to prior acceptance by Hydro's Representative.
4. This column applies to rotating components only. Limits in this column are not to be exceeded for rotating components regardless of the results of fatigue analysis.
5. Compression stress limits apply for standstill conditions after the rim slippage due to the clearance between rim studs and punchings.

(a) Stresses in cast steel will be limited to 80% of the allowable stresses for plate steel in the above table.

(b) The Generator will be constructed so that it will withstand the Maximum Runaway Speed of the generating unit without mechanical damage.

d. Other Materials

Primary stresses in cast irons, if used in the generator, when subject to worst operating conditions, including runaway, short circuits, and faulty synchronization, will not exceed 14 MPa for tension and 69 MPa for compression.

The maximum primary stress in normal operating and runway condition will not exceed 60 MPa in copper parts heated or relieved in the fabrication or installation process.

3.2.6 Interface Information

The major interface points for the new generator and its integration system are included in Table 3:

Table 3: Interface information

	Interface circuit	**Connecting from** (generator work)	**Link**	**Connecting** (by generator work) **to** (other's)	**Isolation point by means**
1	Generator winding line leads	Generator leads in generator terminal cubicle	Flexible link	Existing RIP main bus in the terminal cubicle	At both ends of flexible link by bolted connection
2	Groundings and Bonding	Generator and all electrical equipment supplied	Copper wires	Powerhouse existing grounding grid	
3	Power supply to EXC Transformer	Generator leads in generator terminal cubicle	HV cable	Termination HV side of EXC transformer	EXC transformer termination
4	Generator field input	Gen brushgear	DC cable	Exciter panel DC	Exciter panel DC output by Exciter circuit breaker
5	LV Power supply	Generator terminal box or panel	LV power cable	Generator Unit MCC	MCC panel by circuit breakers in the MCC

6	P&C interface	Generator instrumentation Terminal box/panel	P&C cables	PAM	
7	Civil interface	Generator terminal equipment	Anchor bolts	Steel base frame	
8	Civil interface	Stator Frame	Anchor bolts	Soleplates	
9	Mechanical	Rotor shaft	Bolted connection	Shaft coupling flange	

3.2.7 Design Standards

the Generators specification will conform to the requirements of the following standards:

ASME B1.1	Unified Inch Screw Threads
ASME B1.13M	Metric Screw Threads – M profile
ASME BPVC.VIII.2	Boiler and Pressure Vessel Code; Rules for Construction of Pressure Vessels; Alternative Rules
ASTM D1868	Detection and Measurement of partial-Discharge (Corona) Pulses in Evaluation of Insulation Systems
CEATI	Hydroelectric Turbine–Generator Units Guide for Erection Tolerances and Shaft System Alignment, Parts I and IV
IEC 60034-2-1 /2	Method for Determining Losses and Efficiency for Rotating Electrical Machinery from Tests
IEEE 1	Recommended Practice-General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation
IEEE 43	Recommended Practice for Testing Insulation Resistance of Rotating Machinery
IEEE 95	Guide for Insulation Testing of Large AC Rotating Machinery with High Direct Voltage
IEEE 98	Standard for the Preparation of Test Procedures for the Thermal Evaluation of Solid Electrical Insulating Materials
IEEE 99	Recommended Practice for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment
IEEE 115	Test Procedures for Synchronous Machines
IEEE 286	Recommended Practice for Measurement of Power-Factor Tip-up of Rotating Machinery Stator Coil Insulation
IEEE 492	Guide for Operation and Maintenance of Hydro-Generators
IEEE 522	Testing Turn-to-Turn Insulation on Form Wound Stator Coil for AC Rotating Electric Machines
IEEE 810	Standard for Hydraulic Turbine and Generator Integrally Forged Shaft Couplings and Shaft Run Out Tolerances
IEEE 1043	Recommended Practice for Voltage–Endurance Testing of Form-Wound Bars and Coils

IEEE 1310	Recommended Practice for Thermal Cycle Testing of Form-Wound Stator Bars and Coils for Large Rotating Machines
IEEE 1434	Guide for the Measurement of Partial Discharges in AC Electric Machinery
IEEE 1553	Standard for Voltage–Endurance Testing of Form-Wound Coils and Bars for Hydro generators
IEEE 1799	Recommended Practice for Quality Control Testing of External Discharges on Stator Coils, Bars and Windings
IEEE C37.102	Guide for AC Generator Protection
IEEE C37.110	Guide for Application of Current Transformers used for Protective Relaying Purposes
IEEE C50.12	Requirements for Salient-Pole Synchronous Generators and Generator/Motors for Hydraulic Turbine Applications
IEEE 1248	Guide for the Commissioning of Electrical Systems in Hydroelectric Power Plants
IEEE 1434	IEEE Guide for the Measurement of Partial Discharges in AC Electric Machinery
ISO 20816-5	Mechanical Vibration – Measurement and evaluation of Machine Vibration – Part 5: Machine sets in hydraulic power generating and pump-storage plants
ISO 21940	Mechanical vibration – Rotor balancing
CEATI	Hydroelectric turbine-generator units. Guide for erection tolerances and shaft system alignment. Part IV: Vertical shaft units with impulse turbines.
BCH ES 44 - A0151	
BCH ES 44 - A0201	
BCH ES 44 – C0051	
BCH ES 44 – C0052	
BCH ES 47 – C0050	

3.3 Generator Terminal Cubicle

3.3.1 Original Equipment Health Rating

Generator Terminal Cubicle rating is rated Unsatisfactory as a part of the generator rating.

3.3.2 Design Objectives

The new generator terminal cubicle will be designed, supplied, and installed in Units 1 to 4 of BR1 to contain the current transformers, other reactive equipment and to provide the interface between the generator and the generator bus and the excitation system.

3.3.3 Design Requirements

The detailed requirements for the generator terminal cabinet are provided in the Preliminary Design Report (Appendix C).

3.3.4 Major Parameters

Minimum short circuit withstand (rms symmetrical) will be 40 kA, 3 Seconds.

Temperature rise of the equipment will not exceed that specified in IEEE C37.20.4.

3.3.5 Acceptance Criteria

All major parameters will be validated during the site commissioning activities.

3.3.6 Major Interface Information

The major interfaces between the generator neutral grounding system and the unit are as follows:

a. Existing Generator bus

b. AC cable from the excitation system

3.4 Generator Neutral Grounding System

3.4.1 Original Equipment Health Rating

The original system health rating is included in the generator system health rating determined as unsatisfactory.

3.4.2 Design Objectives

New neutral grounding systems will be designed, supplied, and installed in Units 1 to 4 of BR1 to provide high impedance grounding for the new generators.

3.4.3 Design Requirements

The detailed requirements for the generator neutral grounding system are provided in Appendix C.

3.4.4 Major Parameters

Rated Maximum Voltage: 15 kV.

Power frequency withstanding voltage: ≥36 kV.

Basic Insulation Level (BIL): 95 kV.

Rated Continuous Current: 600 A.

3.4.5 Acceptance Criteria

All major parameters will be validated during the site commissioning activities.

3.4.6 Major Interface Information

The major interfaces between the generator neutral grounding system and the unit are as follows:

a. P&C Interface

b. Generator Neutral Point

3.4.7 Design Standards

The generator neutral grounding system will conform to the requirements of the following standards:

IEEE C57.32

IEEE C62.92.2

BCH ES 44-Z0320 Generator Neutral Grounding Equipment Design.

3.5 Generator Cooling Water System

3.5.1 Design Objectives

The project scope includes replacement of the portions of the unit cooling water system inside the generator enclosure for BR1 Units 1 to 4.

3.5.2 Design Requirements

The generator cooling system will be designed to perform the following functions:

1. Cool generator stator and rotor.
2. Cool generator bearing.
3. The minimum system design life will be 50 years.

4. Withstand Design Basis Earthquake will match the generator requirements based on the methodology included in the BC Hydro standard ES47-C0050.

3.5.3 Major Parameters

Final determination of the major parameters will be completed based on the supplier generator data.

Preliminary values of the major parameters are provided below:

Table 4: Major parameters and features

#	Parameter	Unit	
1	Minimum CW inlet temperature	C	0.5
2	Maximum CW inlet temperature	C	18
3	CW nominal pressure at pump discharge (see pump curve)	50	psig

3.5.4 Acceptance Criteria

The major acceptance criteria are included in the table below:

Table 5: Major acceptance criteria

#	What is tested	Activity	Acceptance criteria
1	Compliance with the contractual requirements	Design Report	Reported adequate cooling.
2	Quality of fabrication	Off-Site ITPs	Specific to test, in compliance with ASME B31.1.
3	Quality of installation	On-Site ITPs	Specific to test, in compliance with ASME B31.1.

3.5.5 Major Interface Information

The major interface points for the generator cooling water system are included in the table below:

Table 6: Interface information

	Interface	System connection	Link	Isolation point	How
1	Cooling water system inlet on upstream wall of generator enclosure.	Facility cooling water supply (pumped)	Flanged connection.	Existing upstream valve.	Flanged connection.
2	Cooling water system outlet on upstream wall of generator enclosure.	Unit cooling water drain	Flanged connection.	None.	Flanged connection.

3.5.6 Design Standards

The cooling water system will conform to the requirements of the following standards:

ANSI/UL Standard 467	Grounding and Bonding Equipment
API 598	Valve Inspection and Testing
ASME BPVC	Boiler and Pressure Vessel Code (Section VIII, Division 1)
ASME B16.5	Pipe Flanges and Flanged Fittings
ASME B16.10	Face-to-Face and End-to-End Dimensions of Valves
ASME B16.34	Valves-Flanged, Threaded, and Welding End
ASME B31.1	Power Piping
ASME B31.Ea	Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems
ASME PCC-1	Guidelines for Pressure Boundary Bolted Flange Joint Assembly
BCBC	British Columbia Building Code
BCH ES	BC Hydro Engineering Standards

3.6 Generator Bearing Oil Fill and Drain System

3.6.1 Design Objectives

The project scope includes provision of a system to fill and drain oil to/from the generator bearing(s) for BR1 Units 1 to 4.

3.6.2 Design Requirements

The new system will perform the following functions to ensure the generator operation:

1. Move oil from oil barrels located on linkage floor to generator bearings.

2. Move oil from generator bearings to oil barrels located on linkage floor.
3. Provide oil filtration.
4. Meter quantity of oil moved.
5. Reliable operation over the expected minimum Design Service Life of 50 years.
6. Withstand Design Basis Earthquake given in Generator DB based on the methodology included in the BC Hydro standard ES47-C0050.

3.6.3 Major Parameters

The design parameters will be determined by the generator supplier and reviewed by the project engineering team.

3.6.4 Acceptance Criteria

The major acceptance criteria are included in the table below:

Table 7: Major acceptance criteria

#	What is tested	Activity	Acceptance criteria
1	Compliance with the contractual requirements	Design Report	Adequate flow rate (proposed by supplier).
2	Quality of fabrication	Off-Site ITPs	Specific to test, in compliance with ASME B31.1.
3	Quality of installation	On-Site ITPs	Specific to test, in compliance with ASME B31.1.

3.6.5 Major Interface Information

The major interface points for the generator cooling water system are included in the table below:

Table 8: Interface information

	Interface	System connection	Link	Isolation point	How
1	Hose connection to oil barrel.	Oil barrel used for oil storage	Hose.	Ball valve	N/A.

3.6.6 Design Standards

The generator bearing oil fill and drain system will conform to the requirements of the following standards:

ANSI/UL 467	Grounding and Bonding Equipment Standard
API 598	Valve Inspection and Testing
ASME BPVC	Boiler and Pressure Vessel Code (Section VIII, Division 1)
ASME B16.5	Pipe Flanges and Flanged Fittings
ASME B16.10	Face-to-Face and End-to-End Dimensions of Valves
ASME B16.34	Valves-Flanged, Threaded, and Welding End
ASME B31.1	Power Piping
ASME B31.Ea	Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems
ASME PCC-1	Guidelines for Pressure Boundary Bolted Flange Joint Assembly
BCBC	British Columbia Building Code
BCH ES	BC Hydro Engineering Standards

3.7 Generator Bearing High Pressure Oil Injection System

3.7.1 Design Objectives

The project scope includes high pressure oil injection system to lift the rotating components during normal unit starting and stopping for BR1 Units 1 to 4.

3.7.2 Design Requirements

The new system will perform the following functions to ensure the generator operation:

1. Lift rotating components.
2. Operate reliably over the expected minimum Design Service Life of 50 years.
3. Withstand Design Basis Earthquake given in Generator DB

3.7.3 Major Parameters

The design parameters will be determined by the generator supplier and reviewed by the project engineering team.

3.7.4 Acceptance Criteria

The major acceptance criteria are included in the table below:

Table 9: Major acceptance criteria

#	What is tested	Activity	Acceptance criteria
1	Compliance with the contractual requirements	Design Report	Adequate flow/pressure to provide needed lift.
2	Quality of fabrication	Off-Site ITPs	Specific to test, in compliance with ASME B31.1.
3	Quality of installation	On-Site ITPs	Specific to test, in compliance with ASME B31.1.

3.7.5 Major Interface Information

There will be no interface points external to generator supplier’s scope.

3.7.6 Design Standards

The generator bearing high pressure oil injection system will conform to the requirements of the following standards:

ANSI/UL	Grounding and Bonding Equipment Standard 467
API 598	Valve Inspection and Testing
ASME BPVC	Boiler and Pressure Vessel Code (Section VIII, Division 1)
ASME B16.5	Pipe Flanges and Flanged Fittings
ASME B16.10	Face-to-Face and End-to-End Dimensions of Valves
ASME B16.34	Valves-Flanged, Threaded, and Welding End
ASME B31.1	Power Piping
ASME B31.Ea	Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems
ASME PCC-1	Guidelines for Pressure Boundary Bolted Flange Joint Assembly
BCBC	British Columbia Building Code
BCH ES	BC Hydro Engineering Standards

3.8 Generator Brake and Jack System

3.8.1 Design Objectives

The project scope includes pneumatic braking function to reduce stopping time of generator and hydraulic jacking function to enable maintenance for BR1 Units 1 to 4.

3.8.2 Design Requirements

The new system will perform the following functions to ensure the generator operation:

1. Stop rotating component rotation

2. Jack rotating components.
3. Operate reliably over the Design Service Life of 50 years.
4. Withstand Design Basis Earthquake given in Generator DB

3.8.3 Major Parameters

Final determination of the major parameters will be completed based on the generator supplier generator data.

Preliminary values of the major parameters are provided below:

Table 10: Major parameters and features

#	Parameter	Unit	
1	Brake air nominal gauge pressure, drawn from existing service air compressor system. Note that brakes will be capable of normal operation with air pressure variation of +/- 25% of nominal gauge operating pressure.	100	psig

Jacking parameters will be determined by the generator supplier.

3.8.4 Acceptance Criteria

The major acceptance criteria are included in the table below:

Table 11: Major acceptance criteria

#	What is tested	Activity	Acceptance criteria
1	Compliance with the contractual requirements	Design Report	Reported adequate cooling.
2	Quality of fabrication	Off-Site ITPs	Specific to test, in compliance with ASME B31.1.
3	Quality of installation	On-Site ITPs	Specific to test, in compliance with ASME B31.1.

3.8.5 Major Interface Information

No interface points external to generator supplier’s scope.

3.8.6 Design Standards

The generator brake and jack system will conform to the requirements of the following standards:

ANSI/UL Standard 467	Grounding and Bonding Equipment
API 598	Valve Inspection and Testing
ASME BPVC	Boiler and Pressure Vessel Code (Section VIII, Division 1)
ASME B16.5	Pipe Flanges and Flanged Fittings

ASME B16.10	Face-to-Face and End-to-End Dimensions of Valves
ASME B16.34	Valves-Flanged, Threaded, and Welding End
ASME B31.1	Power Piping
ASME B31.Ea	Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems
ASME PCC-1	Guidelines for Pressure Boundary Bolted Flange Joint Assembly
BCBC	British Columbia Building Code
BCH ES	BC Hydro Engineering Standards

3.9 Generator Rotor Turning System

3.9.1 Design Objectives

The project scope includes provision of rotor turning devices for BR1 Units 1 to 4.

3.9.2 Design Requirements

1. Reliable operation over the expected minimum Design Service Life of 50 years.
2. Withstand Design Basis Earthquake given in Generator DB

3.9.3 Acceptance Criteria

The major acceptance criteria are included in the table below:

Table 12: Major acceptance criteria

#	What is tested	Activity	Acceptance criteria
1	Compliance with the contractual requirements	Design Report	Adequate flow/pressure to achieve desired speed of rotation.
2	Quality of fabrication	Off-Site ITPs	Specific to test, in compliance with ASME B31.1.
3	Quality of installation	On-Site ITPs	Specific to test, in compliance with ASME B31.1.

3.9.4 Major Interface Information

No interface points external to generator supplier’s scope.

3.9.5 Design Standards

The generator rotor turning system will conform to the requirements of the following standards:

ANSI/UL	Grounding and Bonding Equipment Standard 467
API 598	Valve Inspection and Testing

ASME BPVC	Boiler and Pressure Vessel Code (Section VIII, Division 1)
ASME B16.5	Pipe Flanges and Flanged Fittings
ASME B16.10	Face-to-Face and End-to-End Dimensions of Valves
ASME B16.34	Valves-Flanged, Threaded, and Welding End
ASME B31.1	Power Piping
ASME B31.Ea	Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems
ASME PCC-1	Guidelines for Pressure Boundary Bolted Flange Joint Assembly
BCBC	British Columbia Building Code
BCH ES	BC Hydro Engineering Standards

3.10 Governor System

3.10.1 Original Equipment Health Rating

All four original existing Woodward and Pelton electromechanical-type governors are rated as Poor per the most recent Health Assessments provided through the EHR program.

3.10.2 Design Objectives

The new governor systems will be designed, supplied, and installed in Units 1 to 4 of BR1 to support operation of the generating units at the new generator rating.

Replace governor controls and cabinet with GOAAL standard component digital governor controller.

Replace speed sensor and position measurement transducers.

3.10.3 Design Requirements

The Unit 1-4 governors will be as similar as possible to those of BR2 Unit 5-8 governors (installed in 2005 and 2018) for consistency of operation and maintenance, and for common spare parts.

The governor mechanical equipment, including accumulator sizing and capacity, and sizing of hydraulic piping, will be in accordance with IEEE 125.

Servomotor sizing for the BR1 needles and deflectors will be calculated by the turbine supplier.

The needle sequencing program, similar or the same as used on BR2 5 and 6 and Wahleach GS, will be implemented for efficiency gains.

Based on Generation Maintenance evaluation, the needles, deflectors, rock shafts and linkages will be reused.

The servomotor needle springs will be replaced.

3.10.4 Major Parameters

The needle and deflector timing, neglecting any cushioning effects, will be as follows:

- Needle Closing: 120 seconds (unchanged for the turbine OEM design)
- Needle Opening: 170 seconds (based on the hydrotechnical study and report recommendations, the turbine OEM design was 120 seconds)
- Deflector Closing: 4 seconds (unchanged from the turbine OEM design)
- Deflector Opening: 8 seconds (unchanged from the turbine OEM design)

3.10.5 Acceptance Criteria

The governor systems will be tested to verify that the major parameters of the installed systems match the requirements detailed in sections 4.3.3 and 4.3.4.

The major tests included in the commissioning program are:

a. Mechanical Inspection
b. Electrical Tests
c. Efficiency testing performed by BC Hydro to update the efficiency curve for unit dispatch and operation

3.10.6 Major Interface information

The major interfaces between the governor and the unit are as follows:

- Hard-wired interconnections between the Unit Control Console (UCC) and Governor Control Console (GCC) are provided for start/stop; raise/lower of turbine speed, power, etc.; governor discreet speed switch output; alarm conditions; and other critical I/Os. Data (Ethernet) connections are provided for non-critical monitoring.

- Governor tooth wheel is mounted on the generator shaft, with adjacent speed sensing devices mounted within the generator enclosure.
- The deflector servomotor is mechanically connected to the deflector linkage system to control the position of the deflector cutting edges relative to the jets.
- Needle servomotors are connected to the needle stems to control turbine flow by opening and closing the needles.

3.10.7 Design Standards

The governor system will conform to the requirements of the following standards:

- IEEE 125 Recommended Practice for Preparation of Equipment Specifications for Speed-Governing of Hydraulic Turbines Intended to Drive Electric Generators
- IEEE 1207 Guide for the Application of Turbine Governing Systems for Hydroelectric Generating Units
- ASME 31.1 Power Piping
- ASME BPVC Boiler and Pressure Vessel Code

3.11 Excitation System

3.11.1 Design Objectives

The project scope includes replacement of the existing excitation systems in units 1 to 4 with GOAAL standard component with redundant controller and thyristor bridges.

3.11.2 Major Design Requirements

The new excitations system will meet the following requirements:

1. Support operation of the new generator
2. Comply with the relevant NERC requirements
3. Meet the GOAAL architecture requirements

4. Design life to exceed 30 years

3.11.3 Major Parameters

Final determination of the major parameters will be completed based on the new generator data provided by the supplier.

Preliminary values of the major parameters are provided in Table 13.

Table 13: Major parameters and features

#	Parameter	Unit	
1	Continuous AC Current	A	1000
2	Continuous DC Current		
3	Nominal Voltage	V	250
4	Ceiling Voltage	VDC	TBD
5	Ceiling Voltage	VDC	
6	Excitation transformer rating	MVA	
7	Exc transformer LV	V	580
8	Exc Tr Arc flash resistant enclosure		2B

3.11.4 Acceptance Criteria and Their Validation

The major acceptance criteria will be determined based on the detailed design of the generator system by the generator supplier

3.11.5 Interface Information

The major interface points for the new excitation system are included in the table below.

Table 14: Interface information

	Interface circuit	Connecting from	Link	Connecting to	Isolation point by means
1	AC Power supply to EXC transformer	Generator leads in generator terminal cubicle	HV cable	Termination HV side of EXC transformer	EXC transformer termination
2	DC Generator field input	Gen brushgear	DC cable	Exciter panel DC Busbar	DC reverse busbar in Exciter panel
3	LV Power supply	Powerhouse MCC	LV power cable	Exciter Cabinet	MCC panel by circuit breakers in the MCC
4	Control Signal	UCC cabinet	Control cable	Exciter Control	Terminal Block
5	Alarm	PAM	Control cable	Exciter Control	Terminal Block

6	Civil interface	Excitation system frame	Anchor bolts	Powerhouse floor	n/a

3.11.6 Design Standards

The excitation system will comply with the following standards:

- ANSI/CSA IEEE C73.20.7
- BCH DP 45 Z0002 GENERATION ENGINEERING GOAAL ARCHITECTURE
- BCH ES 44-B2600
- BCH ES 44-B3000

3.12 P&C System

3.12.1 Design Objectives

a. **Units 1-4 Controls**

Replace existing unit control cabinet built with hardwired relay logic with GOAAL standard component Unit Control Console (UCC),

Replace existing Data Acquisition System (DAS) panel and analogue meters with digital Non-Electrical Protection, Alarm and Metering (PAM), PAM Remote IO (PIO)

Replace the existing common synchronization system with standalone devices

Add vibration and air gap monitoring system built in Auxiliary Panel (AUX)

b. **Station Remote Controls**

Replace existing RTU with new RTUs for remote communication. Add GOAAL standard component SIP to communicate with Fraser Valley Office (FVO).

c. **Plant Network**

Upgrade network panels for new network backbone per guidance from Operational Technical Support Services (OTSS). Plant LAN topology will be with up-to-date North American

Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP) practices.

d. **Station Common System**

Replace the station common control and annunciation system with new GOAAL Station PAM for all powerhouse common alarms.

e. **Protection System**

Coordinate the plant protection system with the new generator, exciter, governor and other updated facility elements.

3.12.2 Design Requirements

Design will be based on BC Hydro GOAAL concept. To the extent practical, GOAAL major standard components will be utilized. Where justified, modifications to standard software will require approval from the P&C Principal Engineer.

The control room operator user interface will include as a minimum the same control functionality and alarm, status and metering data as what is provided to FVO/SIO operators. BR1 customized displays will be developed as required for U1-4 to meet the user requirement and align with the new control room HMI standard.

3.12.3 Acceptance Criteria

All common P&C system will be commissioned with the first unit of work

3.12.4 Interface Information

The diagram below shows internal interfaces for the P&C system

The major external interfaces are with

a. Generator P&C system
b. Turbine P&C system
c. Governor
d. Excitation system

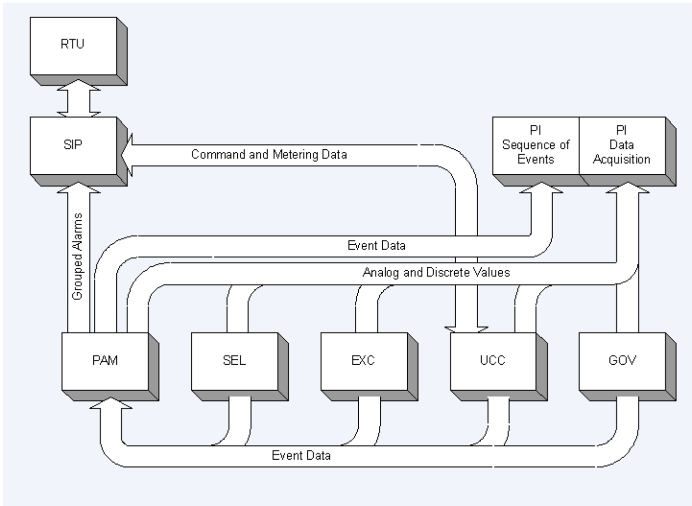

Figure 2: Interface diagram for the new P&C system

3.12.5 Design Standards

The new P&C system will conform to the requirements of the following standards:

ES 44-Z0330	Air gap monitoring system design
ES 44-Z0510	Current and Voltage Transformers
ES 45-A0065	CT and VT Winding Designation
ES 45-A0084	Device Function Designations
ES 45-E0184	Conservator tank oil level device
ES 45-L0821	VTJBs for Outdoor and Indoor Installations
ES 45-L0822	Typical wiring and components for vt circuits in metal-enclosed switchgear
ES 45-L0825	Wiring Diagrams and Junction Boxes for Bus-Type CTs
ES 45-U0041	Colour Code for Low Voltage Cables and Wires
ES 45-U0093	Grounding and bonding associated with P&C modular type panels
ES 45-U0094	Grounding and Bonding Associated with Major Equipment Control Cabinets

ES 45-U0096	Grounding of Shields on Spirally Shielded Control Cables
ES 45-U0123	Securing Facility for Low Voltage Cables Entering Switchboards, Cubicles, etc.
ES 45-U0342	Grounding of CT secondary circuits
ES 45-U0511	Painting for indoor equipment
ES 45-U0541	Name plating for switchboards, cubicles, etc.
ES 45-V0371	Sectional Rail Mounted Terminal Blocks (600V) and Related Accessories
ES 45-W0010	Software Charge Control and Archiving for P&C Field Devices
ES 45-X0010	Isolation and Test Facilities
ES 45-X0011	Isolation and Test Facilities Within P&C Panels
ES 45-X0071	P&C Circuit Supervision
ES 45-Z0004	P&C Cable & Wire Selection Guide
ES 48-A0005	Preferred Drawing Number and File Name
ES 48-C0001 R3	Auxiliary Control Panel (AUX)
ES 48-C0002 R0	Unit Control Cabinet (UCC)
ES 48-E0001 R3	Application of Surge Suppression on P&C Equipment
ES 48-F0001	Generator Engineering GOAAL Architecture
ES 48-F0002	GOAAL Architecture Recommended Sequence
ES 48-F0011	Reliability Principles for P&C and Telecom Systems Inspection and Testing
ES 48-I0001R5	Unit Instrumentation
ES 48-M0001	125VDC sub distribution and 24VDC distribution
ES 48-R0001	Plant LAN Overview
ES 48-V0001	P&C Panel and Inter-Panel wiring requirements
ES 48-V0003	P&C panel wiring naming convention
ES 48-W0001	Software Development

ES 48-X0001	Hydroelectric Unit Protection Trip Sequences and Faults Detection Elements Overview
ES 48-X0002	Unit Electrical Protection (PN)
ES 48-X0005	Protection(non-electrical). Alarm and Metering (PAM)
ES 48-X0010	Integration of Fire Detection Into Unit Protection
ES 48-X0008	High risk RTD termination

3.13 High Bay Fire Protection Sprinkler System

3.13.1 Design Objectives

The design objective is to extend the sprinkler system over the high bay area.

3.13.2 Design Requirements

The total area to be covered by this extension is 11000 ft2 over Ordinary Hazard (Group 1) occupancy based on NFPA 13 classification.

3.13.3 Major Parameters

Design density of this extension will be minimum 0.20 gpm/ft2 (8.2 (L/min)/m2) over design area.

Sprinkler heads will be Early Suppression Fast Response (ESFR) type with 74 DEG C (165°F) operating temperature.

3.13.4 Acceptance Criteria

New high bay sprinkler system will be commissioned based on the requirements included in the NFPA 13 standard.

3.13.5 Interface Information

New high bay sprinkler system will be integrated with the existing BR1 fire protection system

3.13.6 Design Standards

The new P&C system will conform to the requirements of the following standards:

NFPA 13	Standard for the Installation of Sprinkler Systems
NFPA 72	National Fire Alarm Code

4 DEFINITION OF SCOPE

This section provides details on the design requirements and is focused on the design requirements that are important for the equipment safe operation, maintenance and testing.

4.1 Generators

The detailed information on the generator is provided in the design reports GY-0239-DEF 621-GEM-00014 and GY-0239-DEF 621-GER-00006.

The information below summarizes the design requirements focusing on the maintainability and Safety by Design implementation.

4.1.1 Design

The nameplate rating of the generator is 60 MVA at 0.9 Power factor.

The mechanical design of the new generators is based on the plan to reuse the existing civil structures and to ensure the rotor assembly weight will not exceed the nameplate capacity of the powerhouse crane.

The major features of the new design are:

1. Elimination of the lower guide bearing and use of a single combined thrust and guiding bearing
2. Maximum weight of the rotor assembly with the lifting device to be less than the crane rated capacity
3. Minimum inertia constant of 2.55 kWs/kVA
4. Implementation of the Safety by Design features detailed in this section

a. Stator Frame Design Features

The supplier will design the new frame to allow radial and vertical adjustment of the frame.

The stator frame will be designed to allow removal of the generator coolers without need to disassemble any components installed inside the generator. The design will ensure accessibility for the generator inspections and maintenance activities.

Accesses for maintenance personnel to inspect, maintain and repair will be provided at the back, bottom and top of the stator and all around the outer stator diameter.

b. Stator Core Design

The stator core will be designed as a single continuous assembly.

The generator will be designed to operate without overheating at 110% of rated voltage under full load for the time period that this overvoltage is required.

The maximum core temperature, as measured by stator core RTDs, will be no more than 100°C.

Each core lamination will be coated on both sides with an insulating varnish or other insulating material to minimize eddy current losses.

BC Hydro will request having a core clamping system with core studs through the stator core, also known as a floating clamping system.

Core studs passing through laminations will be insulated so that no current can pass between the core and the studs.

During stacking, to minimize the potential for core buckling, the stator core will be pressed uniformly at intervals.

c. Stator Winding

BC Hydro will allow design based either on stator bars or a coil system.

Either coils or bars will undergo intensive prototype lab testing

The main phase leads will be phase segregated and suitable for connection to a segregated or insulated bus by means of flexible, removable links.

The links, when removed, will provide an open clearance of metal-to-metal not less than 200 mm.

The main leads will be arranged to allow for attachment of portable safety grounds using a hot stick (6 ft.) complying with the latest BC Hydro Limit of Approach.

Ground ball studs will be installed on both sides of the flexible links.

Permanent barrier(s) or guard(s) will be designed and installed for the main leads inside the air casing to comply with the Limit of Approach-based clearances for the maintenance crew. The barrier(s) or guard(s) need to be removable during maintenance.

d. Rotor Design

The rotor will be arranged for ease of removal and placement of the rotor in the Generator.

The generator supplier will provide any special tools, lifting apparatus, and rotor support pedestal required for the removal and placement of the rotor on the Service Bay Floor.

The generator supplier will supply a rotor turning device as specified to facilitates rotating the rotor for inspection, maintenance, testing and repair in accordance with BC Hydro standard safe work procedures.

The generator supplier will provide a new device for lifting the complete rotor assembly, including all poles.

The rotor lifting device will allow the rotor, while coupled or attached to the generator shaft, to pass over the other operating generators.

e. Rotor Poles Design

It will be possible to remove individual field poles with the rotor in the pit to provide access to the stator in the generator housing for maintenance and inspections.

A pole lifting device will be provided by the generator supplier.

It will be possible to remove poles from the rotor in-situ, without removing the complete rotor.

The rotor poles will be removable without removing the upper bracket.

The design of the pole stop blocks will allows easy adjustment of the pole elevation for alignment to the rotor magnetic centre.

The rotor poles will be equipped with an amortisseur winding

All field bus connections will be of bolted design with provisions for the connections to be opened and bus sections removed with the rotor in place.

f. Bearing Design

The generator will be provided with one combined thrust and guide bearing located above the rotor.

Alternatively, the generator supplier can propose a lower guide bearing, in a double bearing configuration generator design.

A safe means of installation and removal of the thrust collar from the Generator shaft will be provided. This means will not use the Powerhouse Crane for any load greater than the dead load of the collar and rigging.

A safe means of de-stressing and removing the retaining ring above the thrust collar will be provided.

A clear line indicating the pole one location will be scribed onto the thrust collar.

The thrust collar will have a shrunk fit to the generator shaft that allows reliable operation of the generator and easy removal of the thrust collar during maintenance.

The thrust and guide bearing parts will be capable of being ergonomically accessed and removed by personnel, without removing the rotor. All bearing seals will be adjustable without the removal of the main covers.

The bearing support brackets and all associated components will be designed to permit easy removal and installation.

There will be provision for easy measurements of the guide bearing clearances and the thrust bearing support levelness.

The bearing parts will be capable of being removed without removing the generator rotor.

The bearing will be designed to allow removal of the thrust bearing pads without the removal of the thrust collar, unless the Supplier demonstrates that this requirement negatively impacts the design and functionality of other components.

The bearing design will have provisions for maintenance staff to perform hydrostatic testing on the bearing heat exchangers with minimal disassembly.

g. Brushgear Design

The collector rings and brushes will be mounted to allow safe and practical inspection in the operating unit.

The design will prevent the circulation of brush (carbon) dust within the generator ventilation system and the escape of brush (carbon) dust into the Powerhouse.

There will be provisions to adjust (increasing or decreasing) the ventilation to vary slip ring and brush operating temperature during commissioning or future outages.

The brushes will be of sufficient length and grade to remain in continuous operation for a period of at least twenty-four months without brush replacement and without reducing any insulation resistance.

The collector ring and brushes will be at standing elevation to allow for easy cleaning and maintenance.

The collector rings temperature and the air temperature in the brushgear enclosure will be monitored by installing infrared sensors and RTD respectively.

The design will allow for infrared inspection of the brushgear while the unit is running.

A carbon dust collection system will be supplied.

Humidity monitoring inside brushgear enclosure will be provided.

h. **Generator Cooling Water System**

The generator supplier will optimize design of the cooling water piping inside the generator enclosure to enhance existing air coolers removal.

i. **Generator Soleplates**

The generator supplier will inspect the existing stator soleplates and determine if the existing soleplates can be reused.

If needed, the scope of the work will be based on the replacement of the existing soleplates.

Soleplates will allow radial movement of the stator frame while simultaneously limiting any tangential or vertical movement.

4.1.2 Supply Scope

Supply scope is based on supply of four complete generators of identical design.

Supply of the generator enclosures is included in the base scope however BC Hydro will be willing to review alternative proposals based on the reuse of the refurbished original enclosures.

Reuse of the existing generator coolers is included in the base scope and supply of the new the generator coolers is optional based on the supplier evaluation of the existing coolers.

The generator supplier will also disassemble, remove and dispose of the old generators.

Below is the summary of supply scope for the new generators

a. **Stators**

New frames, windings, cores, brackets, circuit rings and Current Transformers (CT) will be supplied. The stator sole plates and structural supports will be replaced or refurbished based on the supplier condition assessment and design verification of compatibility with the new loads. Allowance for radial expansion will be added.

b. **Rotors**

The rotors will be replaced entirely, including the shaft, turbine coupling, spiders, rims, rotor poles and inter-polar connections. New coil brackets, field leads and cables, collectors and brushes will also be provided.

c. **Other Generator Systems**

The thrust bearings and upper guide bearings will be replaced, as will the lubricating systems including: oil reservoirs, high pressure oil injection systems, oil coolers and piping.

d. **Fire Protection System**

The generator deluge systems, including all mechanical and electrical components downstream of the upstream flange of the manual and pneumatic deluge valves will be replaced entirely.

The mechanical scope includes the provision of pipe, valves, joints, fittings and supports for the deluge valve station. It also includes supply and drain piping, deluge solenoid, pressure and tamper switches, and deluge rings complete with supports and water spray nozzles.

The electrical scope includes provision of heat detectors, smoke detectors and all associated supports and cabling to terminal boxes, fire alarm panels and P&C control boards. The generator deluge panels, cabling between the deluge panels and terminal boxes, and cabling to the P&C control board will be reused.

4.1.3 Interfaces with the Other Systems

a. **Electrical Interface**

Information on the electrical interface is included in Table 3 of section 3.2.6.

b. **Mechanical Interface**

The generator shaft will be connected the turbine shaft and the supplier will be responsible the generator shaft coupling flange with the coupling flange of the existing turbine.

c. **P&C Interface**

The information on the P&C Interface is included in Table 3 of section 3.2.6.

d. **Fire Protection Interface**

The fire protection generator deluge system scope for the generator replacement project begins at the downstream flange of the manual and pneumatic deluge valves.

e. **Civil Interface**

The existing stator soleplate ring will be assessed and modified to allow connection of the new frame to the soleplates.

4.1.4 Removal of the Existing Equipment

The generator supplier will be responsible for removal and disposal of the existing generators.

Removal of the existing rotors is the critical operation in the process of removal of the old generators.

The generator supplier will confirm the floor capacity to support removal of the existing rotors.

The existing rotors will be lifted from the generator in the complete assembly and placed on the multi-axle truck close to Unit 4 and then tilted to a near horizontal position before being removed from the powerhouse.

The generator supplier will be given an option to develop the plan of the work based on removal of a few rotor poles to avoid the need for the engineering lift of the existing rotors.

4.1.5 Installation Information

The assembly process requires careful evaluation of the generator floor capacity and the existing powerhouse crane.

The generator supplier will confirm the floor capacity to support all construction activities

Subject to confirmation by the supplier, it is expected that the supplier erection activities will take place between Units 1 and 2.

It is assumed that that the weight of the complete rotor assembly will be below the rated capacity of the powerhouse crane.

4.1.6 Test and Commissioning Scope

The generator supplier will perform a comprehensive test and commissioning program based on the IEEE and BC Hydro standards.

The program will encompass all stages of manufacturing, installation and commissioning.

Some of the salient activities ae described below

a. **Stator Assembly**

Prior to installation of the stator winding, the complete stator core will be tested for lamination and assembly quality.

Each coil/bar will be tested prior, during and after installation, including a high potential test.

b. **Overspeed Tests**

A mechanical test will include overspeed tests, in steps, to 110%, 130%, 150% and 160%, to monitor bearing temperatures, vibrations and general behaviour of the unit.

c. **Rotor Rim Separation Speed Test**

During the overspeed tests, rotor rim separation of the first unit will be monitored and separation speed will be verified using proximity probes.

d. **Load Rejection Test**

Load rejection tests will be performed on each generator in steps of 25%, 50%, 75%, and 100% of rated load.

Vibration, governor on-line gain performance, pressure (in the penstock and manifold), needle and deflector timing and position, speed rise, and voltage rise will be measured and recorded for each test;

e. **Sudden Short Circuit Tests**

Sudden short circuit tests will be performed on the first unit of work to ensure the mechanical integrity of the generator.

f. **Heat Run Test**

Heat run tests will be performed on each generator to determine the absolute temperature and temperature rise of the various parts of the generator, including generator terminal equipment, and to confirm the generator Nameplate Rating.

g. **Generator Losses**

Generator total losses will be measured in accordance with IEEE standard 115.

h. **WECC Model Validation Tests**

BC Hydro, with the support by the generator supplier will perform the tests required to confirm that the new generators, exciters and governors meet the requirements of Western Electricity Coordinating Council (WECC) Test Guidelines for Synchronous Unit Dynamic Testing and Model Validation.

4.1.7 Specific Safety by Design Measures

Below is the list of the SbD measures included in the generator scope of the work.

- The new/refurbished generator enclosures will include noise suppression measures.
- The generator design will allow for generator cooler removal without removal of other generator components except the generator covers.
- The generator design will allow generator cooler inspection inside the enclosures.
- Grounding studs will be mounted on both sides of the flexible links to facilitate the isolation activities.

- A Brake/Jack dismantling device will be supplied to facilitate removal of the brakes/jacks.
- New rotor dismantling device will be supplied with one mobile hydraulic unit and a hydraulic roller installed on each rotor.
- The design will allow ergonomic access to the generator rotor from the top and from underneath the unit to perform routine maintenance activities such as rotor poles removal, rim inspections, etc.
- The design of the lower bracket, upper bracket, and combined bearing assembly will be optimized to ensure ergonomic access.
- The brushgear housing design will allow proper ventilation and access to the brushes.
- The brushes will be located at a level that avoids working in the awkward position while replacing the brushes.
- The brushgear housing will be furnished with at least four anchor points for attaching the fall arrest gear and personal rescue equipment.
- The filters will be removable from the outside.
- The floor inside the brushgear housing will be smooth.
- The surface on top of the generator covers will be without steps and protruding parts/hardware.
- Lifting points will be added to the bottom of the lower bracket.
- A lifting beam will be added along the turbine pit entrance.

4.2 Generator Auxiliary Systems

The list of the generator auxiliary equipment includes the following sub-systems and components for G1 to G4 generators:

a. High Pressure Oil Injection System (HPOIS)

b. Brake System

c. Jacking System

d. Brake Dust Collector System

e. Oil Fill and Drain System

f. Slip Ring Ventilation System

g. Generator Anti-Condensation System

h. Lighting System

i. Flux Density Monitor

j. PD monitoring system

4.2.1 Design

Design of all auxiliary system will be included in the generator supplier scope of the work.

4.2.2 Supply Scope

a. High Pressure Oil Injection System (HPOIS)

The generator supplier will supply a complete HPOIS.

The HPOIS scope of supply will include:

- electric motor-powered lift pump, complete with control panel
- The oil reservoir with access doors
- A pressure gauge and 4-20 mA temperature compensated pressure transducer
- Pressure relief valve

The piping to the pressure gauge, pressure transducer and pressure switches connected to a common standard manifold.

b. Generator Bearing Coolers

The generator supplier will supply a generator bearing heat exchanger, piping and instrumentation required to install and operate the generator heat exchangers.

c. Generator Cooling Water System

The generator supplier will supply a complete generator cooling water system, including:

- Generator air coolers

- Generator bearing heat exchanger (internal or external)
- RTDs for measuring inlet cooling water temperature
- RTDs for measure cooling water temperature downstream of each generator air cooler and downstream of the generator bearing heat exchanger
- Pressure gauges upstream and downstream of each generator air cooler and the generator bearing heat exchanger to enable balancing
- Piping and valving to connect to heat exchanger's and air coolers to existing cooling water supply and return tie-in points

d. Braking System

The generator supplier will supply a complete pneumatically-actuated brake system to bring the rotating parts to rest.

The braking system supply will include:

- The brakes capable of being used for braking and jacking
- Piping from BC Hydro tie-in points
- Isolating and check valves
- Brake transducers and brake limit switches

e. Jacking System

The generator supplier will supply a complete, hydraulically-actuated jacking system to lift the rotating parts.

The jacking system supply will include:

- A jacking pump cart shared by all units
- Manually-operated valves
- Blocking devices to hold the rotating parts in the raised position

f. Brake Dust Collector System

The generator supplier will supply a self-contained, fireproof brake dust vacuum removal and collection system to eliminate brake dust contamination of the generator pit and winding.

The generator supplier will supply:

- A control panel,
- The dust collection hood or enclosure,
- The ductwork,
- Filters,
- A pressure gauge to indicate the filter clogging

g. Oil Fill and Drain System

The generator supplier will supply a complete fill and drain system.

The system supply will include:

- Drain oil pump
- Piping
- Isolating valves
- Filters

h. Generator anti-condensation system

The generator supplier will supply a complete system to prevent condensation on the generator components during the generator shutdowns.

The system supply will include:

- Electric heaters
- Heater control system mounted in the control panel
- Thermostatic switch
- Cables to connect the system to the existing power supply and the P&C system

i. Lighting system

The generator supplier will supply a complete lighting system inside the generator enclosure to facilitate inspections, testing, repairs and maintenance. The lighting system supply will include:

- Lighting fixtures
- Lighting Control

- Low voltage cables
- Cable trays
- Emergency lighting units
- Receptacles and switches
- Distribution transformer and lighting panels (if required based on the generator supplier design)

j. PD Monitoring system

An on-line continuous partial discharge monitoring system (PDMS), manufactured by IRIS Power Engineering will be supplied, installed, tested, and verified in accordance with BC Hydro's Standard 01.20.SPEC.02 for each generating unit. The system supply will include:

- Capacitive couplers installed on the stator winding
- Continuous on-line partial discharge monitoring system (PDMS) panel

k. Flux Density Monitoring

The generator supplier will install flux monitoring probes connected to the terminals in the PDMS panel.

4.2.3 Interfaces with the Other Systems

a. Air supply

Air supply for the new braking system will be supplied from the existing air supply system.

b. Oil supply

Supply interface information is provided in section 3.6.5

c. Power supply

Power supply for heaters, lightings and pumps will be fed from the unit MCC and Common MCC.

d. Water supply

Water supply interface information is provided in section 3.5.5.

4.2.4 Removal of the Existing Equipment

All existing auxiliary equipment will be removed by the generator supplier.

4.2.5 Installation Information

All auxiliary system described in section 4.2 will be installed by the generator supplier.

4.3 Governors

The detailed information on the generator is provided on the design memo GY0239-DEF-PDR (Appendix L).

Additional information is included in the Design Basis section 3.3 included in this report.

Summarized information on the governor system scope is provided below.

4.3.1 Design

a. Governor Controls

Control System will be based on the PLC-based digital controls for each unit located in a separate governor control cabinet (GCC).

b. HPU/Mechanical Cabinet

The governor HPU is based on a high-pressure design for each unit (expected to be around 120 bar), and will include the oil reservoir, pumps, filters, and fluid controls as well as pump motor starters.

As with the GCC, the governor HPU/mechanical cabinet is expected to be of a design that will be identical to BR2 Units 5-8, with minor variations in equipment size due to the slightly smaller BR1 servomotor capacity.

Sizing of governor oil pumps and sump capacity will be performed on a similar basis to BR2 Units 5-8.

c. Accumulator System

A new high pressure N2/oil accumulator system will be provided for each unit, consisting of N2/oil accumulators and N2 pressure bottles arranged in one or more complete equipment skids for each unit, and including additional oil filtration equipment, pressure controls, isolation valves, etc. – similar in design to those provided for BR2 Units 5 through 8. For improved reliability purposes, the BR1 governors will utilize piston-type accumulators per current BC Hydro standards, rather than rubber bladder-type accumulators as previously used elsewhere in the BC Hydro system for high pressure governors. Otherwise, the governor accumulator system design will be functionally identical to the BR2 design and will provide similar deflector/needle servomotor stroke stored oil capacity.

d. Servomotors

New deflector and needle servomotors of a high-pressure design will be provided, and each will include electronic servomotor position sensors.

Interface components to allow connection of the new servomotors with existing needles and deflector mechanism will be provided with the new servomotors.

The servomotors will be specified to utilize a robust, reliable sealing system of a proven design for high pressure, hydro governor equipment.

e. Governor Piping

New stainless-steel tubing will be provided and installed for the supply of governor oil from the new HPU cabinet to the needle and deflector servomotors, as well as between the accumulator equipment and the HPU cabinet.

Generator brake air piping connected to equipment located in the governor cabinet will be replaced.

f. Generator Brake Controls

New governor brake air controls will be provided with the new governor to replace the existing brake air controls located within the current governor mechanical cabinet.

g. Speed Sensing

New tooth wheels and speed sensing transducers provided by the governor vendor will be installed on the new generators. As with other governor equipment previously described, this equipment will be very similar to that of BR2 Units 5-8.

h. Governor Oil

New governor oil will be provided (Mobil DTE 25), which will be hydraulic oil of the same type used in all BR2 governors.

4.3.2 Supply Scope

Complete governor systems, including all systems and components described in this section, will be purchased based on the existing blanket contract with L&S.

4.3.3 Construction Scope

All governor construction work, including demolition and disposal of existing equipment, and installation of new governor equipment (including field piping, electrical cables, and control wiring) will be performed by BC Hydro Construction Services (CS). Very similar types of governor installation projects have recently been performed by CS (BR2 Units 5 and 6, Seton U1, etc.)

4.3.4 Interfaces with the Other Systems

a. Mechanical Interface

The information is provided in section 4.3.6 of this report

b. P&C Interface

The information is provided in section 4.3.6 of this report

c. Civil Interface

The governor vendor will also provide equipment floor anchor hardware designed according to the project seismic design criteria.

d. Electrical Interface

Power supply for the new governor system will be fed from the unit MCC.

4.3.5 Removal of the Existing Equipment

The existing governor actuator cabinet, along with all existing governor electrical controls, mechanical controls (proportional speed control mechanism with dashpot damping), oil pumps, and all other equipment within the cabinet will be removed.

Existing deflector servomotors, needle servomotors, needle controllers and controller linkages to/from the deflector mechanism, needles, and existing governor mechanical cabinet, will be fully removed.

Floor and linkage room wall penetrations for control linkages will be filled.

The existing low-pressure air/oil accumulators will be removed, as well as all governor compressed air equipment.

Existing deflector servomotors, needle servomotors, needle controllers, and controller linkages to/from the deflector mechanism, needles, and existing governor mechanical cabinet, will be fully removed.

All existing exposed carbon steel governor oil piping and pipe supports will be completely removed, along with governor compressed air piping.

Governor permanent magnet generators currently installed at the top of the existing generators will be permanently removed as part of the generator replacements as the new governors will not use this equipment.

Oil used within the existing governors (Terresso 46) is turbine oil, which will be removed and disposed of.

4.3.6 Installation Information and the Equipment Layout

Due to additional space requirements for generator exciter equipment on the generator floor area, the existing location of the governor mechanical cabinets for Units 1 through 4 will no longer be available for the governors.

Layout of the governor HPU and GCC equipment on the turbine bearing/linkage floor was identified as the favoured arrangement during Feasibility Design stage as it allows all governor equipment to be located in close proximity.

The main advantage of this arrangement is that the governor equipment will be close to the turbine deflector and needle servomotors and instrumentation – which makes governor setup/commissioning and maintenance activities more convenient. However, available space in this area is limited compared to the generator floor above.

A review of floor loading was performed for the turbine bearing/linkage floor layout option during Feasibility Design, and it was determined that the existing floor structure is adequate for support of the governor HPU and GCC equipment.

(a) Governor Layout

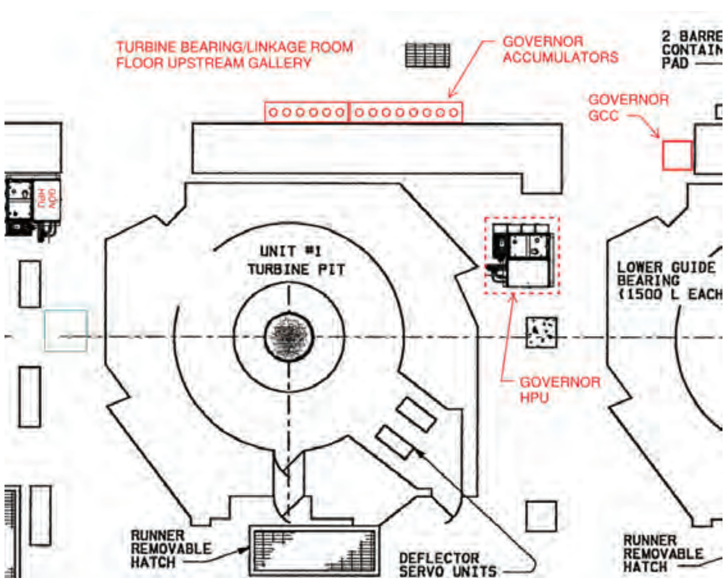

Figure 3: G4 Governor Arrangement, Turbine Bearing/Linkage Room Floor (G1 - G3 Similar).

4.3.7 Commissioning Scope

Tests will be included in the commissioning activities to confirm that the new governor system meets the project requirements, including various offline dry and wet tests, and online tests.

BC Hydro Site Engineering Acceptance and Commissioning will be responsible for the commissioning of the governors with technical direction provided by the governor vendor.

4.3.8 Specific Safety by Design Measures

Below is the list of the SbD measures included in the governor scope of the work:

- Governor equipment will be designed to limit any increase in existing powerhouse ambient noise levels.
- Accumulator double valve and drain isolation will be provided between the accumulator systems and connecting equipment to allow safe access to the governor and turbine without the need to depressurize the accumulator system.
- Needle and deflector servomotors will be provided with full force blocking for isolation safety as well as maintenance convenience.
- During Detailed Design, further review and consideration of Safety by Design will be performed, and additional design considerations to improve safety will be incorporated as appropriate.

4.3.9 Outstanding Activities

A site trip is required to confirm the suitability of the proposed layout and confirm there are no conflicts with the existing equipment.

Some modification of the favoured arrangement would be expected during detailed design based on the actual sizing of the governor systems.

Andritz as the turbine OEM will complete the engineering study to determine:

- Servomotor force requirements design information will be provided to the governor vendor for sizing of servomotor components.
- Confirmation that a higher loading in the closing direction on the needle and nozzle seat/tip (buckling considerations, contact stresses, etc.) as a result of the new high-pressure servomotor design is acceptable.
- Needle/deflector relationship curves
- Recommended speed ramping rates for start-up from standstill to speed-no-load (both with and without high-pressure bearing lift pump operation)
- Impact on the turbine due to needle sequencing, and recommendation of the optimal needle sequencing control scheme

4.4 Excitation Systems

4.4.1 Design

The new excitation system will be designed to meet the latest NERC requirements and to support operation of the new generators.

4.4.2 Supply Scope

The new excitation system will be supplied based on the blanket contract with ABB to include:

a. Excitation transformer

b. Excitation control system

4.4.3 Interfaces with the Other Systems

A 15kV AC cable will connect the HV side of the excitation transformer to the generator leads located in the terminal cabinet.

A DC field cable will be installed to connect the excitation system DC output to the generator sliprings.

Both cables are not included in the scope of the supply by ABB.

The cables will be supplied and installed by the generator supplier.

4.4.4 Removal of the Existing Equipment

The complete old excitation system will be removed by the team responsible for installation of the new excitation system.

4.4.5 Installation Information

The existing exciter will be removed before any installation work starts.

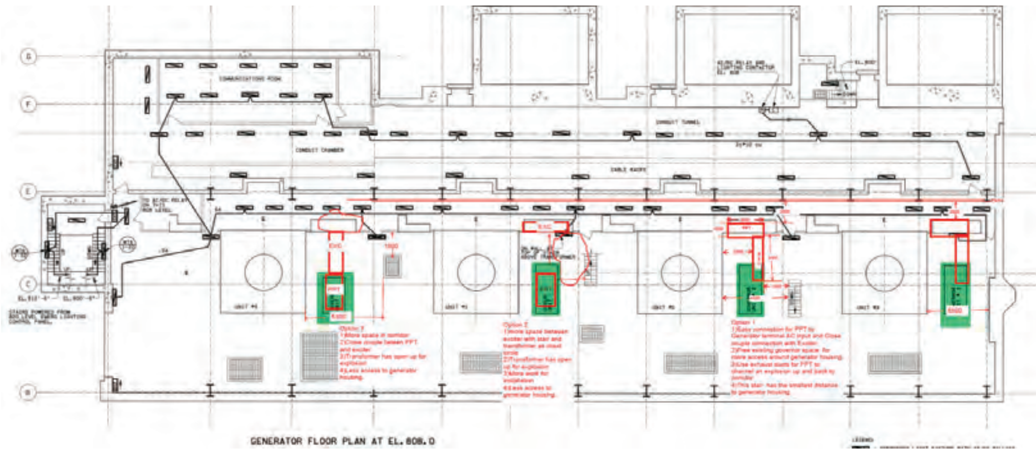

Figure 4: Excitation System layout

4.4.6 Commissioning Scope

The excitation systems will be subjected to the standard off-le and online tests including:

- Electrical tests
- Exciter off line optimization
- Exciter o line optimization

4.5 Electrical Station Service System

4.5.1 Design

The existing station service system is based two common MCC and unitized MCCs.

Based on the engineering review of the existing station service system and the load study, it was concluded that the existing station service transformers SS1 and SS2 installed in 2007 do not require any upgrade.

The station system will require adding the circuits for both the 480V and 120V loads of the new generator auxiliary according to the preliminary loads list.

The existing 480V loads connected to the Unit MCC are identical for each unit.

Six additional 480V circuits in each unitized MCC and common MCC are needed for the expected new 480V loads. Available spare circuits and spare locations will be used to add the additional circuits.

For the 120V new loads, more than 10 circuits will need to be added for each unit.

Based on the consultation with the plant team, the preferred design is based on rearrangement of the existing 120V load connections from each Unit MCC to Common MCC to accommodate the new loads. Thus, no addition or modification on the existing 120V panel itself is required.

4.5.2 Supply Scope

The interconnection design and all new circuits and cables for the power supplies (AC 480V and 120V) will be a part of the generator supplier's scope.

4.5.3 Interfaces with the Other Systems

Additional loads from the new generators listed in the table below will be added to Common MCC 1 and 2, and each unitized MCC.

The final verification of the design interfaces will be made during detailed design based on the generator supplier's design of the generator auxiliary system.

Table 15: Common MCC

Equipment Name	Location	Existing Breaker	Required Breaker	Load Type / Operation
G1 Anti Condensation System	Common 1 – G1 Heating Panel	Spare	20 A	Continuous, only during unit outage
G2 Anti Condensation System	Common 2 – G2 Heating Panel	Spare	15 A	Continuous, only during unit outage

G3 Anti Condensation System	Common 2 – G3 Heating Panel	Spare	15 A	Continuous, only during unit outage
G4 Anti Condensation System	Common 1 – G4 Heating Panel	Space	15 A	Continuous, only during unit outage
Jacking System - Pump	Common 1	70 A	15 A	Non Continuous
Rotor Turning Device - Motor	Common 2	70 A	15 A	Non Continuous

Table 16: Unit MCC

Component Name	Unit Cell	Existing Breaker	Required Breaker	Load Type
Lift Pump	F2CR	15 A	20 A	Non Continuous
Brake Dust Collector System	F1BR	Spare	15 A	Non Continuous
Oil Mist Recovery System	F2BL	Spare	15 A	Continuous
Slip Ring Vent System	F1ER	Empty Space	15 A	Continuous
Combined Oil fill and Drain	F2ER	Empty Space	15 A	Continuous
Governor Oil Pump #2	F1CR	40 A	40A (TBD)	Continuous

Table 17: Interconnections

Interface circuit	**Connecting from** (generator work)	**Link**	**Connecting** (by generator work) **to** MCC	**Isolation point by means**
LV Power supply	Generator auxiliary terminal box or panel	LV power cable	Generator Unit or common MCC	MCC panel by circuit breakers in the MCC

4.5.4 Removal of the Existing Equipment

Existing cables not scheduled to be reused will be removed by the general contractor.

4.5.5 Installation Information

Each unit outage involves a modification of the existing generator MCCs and common MCCs to connect the additional generator auxiliary equipment. Existing components from the Generator Unit 120V Lighting Panels will be relocated to the 120V AC Station Service Panels within Common MCCs 1 and 2. For these common 120V panels, no shutdown of the common MCC will be required to complete the installation. Local isolations will be in place.

4.5.6 Commissioning Scope

All new cables and circuits will be subjected to the standard testing program.

4.5.7 Specific Safety by Design Measures

The work will follow the BC Hydro WPP lockout requirement.

4.6 Generator Neutral Grounding System

4.6.1 Design

The grounding transformer, the disconnect switch and the grounding resistor will be installed in a free standing NEMA 2 type enclosure compliant with the requirements of the standards ANSI C37.22 and IEEE C37.20.4.

4.6.2 Supply Scope

Supply of the system includes: neutral grounding transformer, neutral grounding resistor, disconnect switch and all parts to complete the system.

4.6.3 Interfaces with the Other Systems

The generator stator neutral point will be connected to the grounding disconnect with a single conductor cable.

4.6.4 Removal of the Existing Equipment

All existing equipment will be replaced by the generator supplier.

4.6.5 Installation Information

Installation of the new system is included in the base scope of the generator supplier.

4.6.6 Commissioning Scope

All generator terminal equipment will subject to a Hi-Pot test to ensure it meets the required voltage BIL rating.

4.6.7 Specific Safety by Design Measures

Ground ball studs will be installed on the primary bus in a location where portable grounds can be conveniently applied.

The enclosure will be so constructed that panels can be removed from top, bottom and sides to provide easy maintenance access.

At least one explosion-proof viewing window for inspection of the status of the disconnect switch, grounding transformer and grounding resistor from outside the neutral grounding cubicle will be provided.

4.7 Station Grounding and Bonding

The engineering evaluation performed by the project team confirmed that the existing powerhouse grounding system does not require any upgrades.

The conductor sizes of existing bonding and grounding connections meet the latest BC Hydro engineering standard ES44-Z1010 requirement, which suggests the conductor sizes are not less than #2/0 for the generator terminal equipment, including the exciter system, and not less than #4/0 for generator frame. In accordance with BC Hydro grounding standard, the new equipment will be grounded and bonded based on the manufacturer's recommendations.

4.8 Instrumentation, Protection and Control

4.8.1 Design

All system design activities will be executed by BC Hydro engineering team.

4.8.2 Supply Scope

The new unit control system consists of:

- Unit Control Cabinet (UCC),
- Protection (non-electrical), Alarm and Metering (PAM) for each unit
- Auxiliary Control Panel (AUX) for each unit
- Common control Signal Interface Processor (SIP) for the whole plant

4.8.3 Interfaces with the Other Systems

The diagram below represents interface between the new protect panels and the rest of the plant data and communication systems.

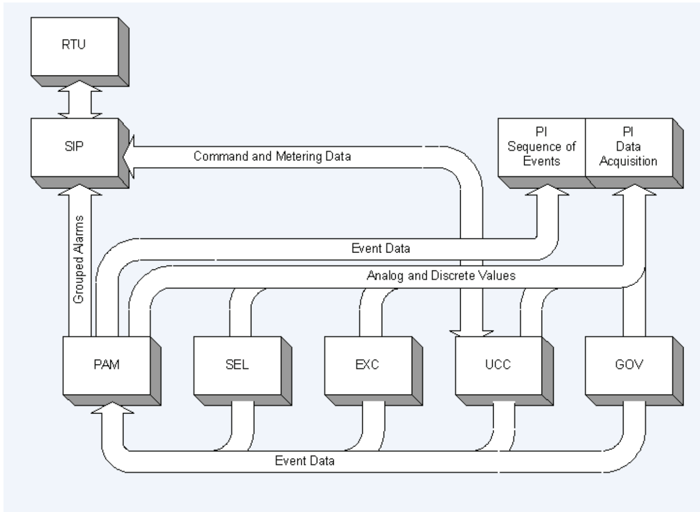

Figure 5: Interface diagram for the new P&C system

4.8.4 Removal of the Existing Equipment

The existing P&C panels that will be removed are shown below in green. The removal of the existing panels will be staged based on the unit outages.

4.8.5 Installation Information

The new P&C panels will be installed in the control room as shown in Fig. 6 in red. The installation of the new P&C panels will be staged based on the unit outages.

4.8.6 Commissioning Scope

The commissioning program will be based on the BC Hydro GOALL standards and will include

- UCC testing
- PAM testing
- Interface verification

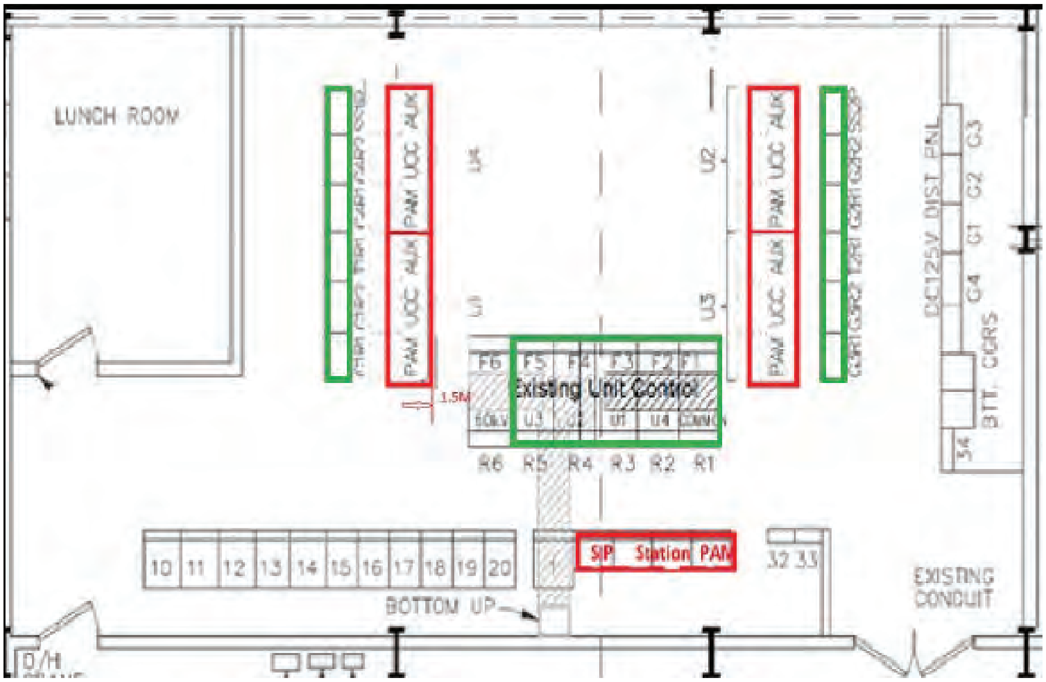

Figure 6: P&C System Layout

4.9 Turbines Scope

This work is minor and comprises of:

- The turbine guide bearing inspection and refurbish work if required
- Inspection of the needle and deflector bushings supplemented with the refurbishment activities based on the inspection findings

4.10 High Bay Sprinkler System

4.10.1 Design

The sprinkler system extension over the high bay area at BR1 will be installed to manage a risk of losing the entire facility due to a fire event during upcoming major work for a replacement of all four generating units at BR1.

4.10.2 Supply Scope

The work for this extension will include design, supply and installation of:

• Connection to the existing fire protection water supply

- Pre-action valve station c/w isolation valve
- Provision for pre-action system test without filing the system riser
- System riser up to the Powerhouse ceiling level
- Main(s) and branch lines over the protected area
- Seismic bracing
- Grounding of the system metal parts
- Fire stopping of the created or modified openings

4.10.3 Interfaces with the Other Systems

The new system will be integrated with the with the station fire alarm system.

4.10.4 Installation Information

Work will be performed by a contractor specializing in this kind of work such as VIKING Fire Protection, GISBORNE Group or TYCO Integrated Fire & Security.

4.10.5 Commissioning Scope

Commissioning activities will be performed by the specialized contractor in accordance with the requirements included in NFPA 13, 14, 15, 20, and 25 including

- Hydrostatic test
- Functional verification

4.11 Generator Foundations

The preliminary structural assessment on the existing generator foundations was conducted to determine the existing foundation's ability to withstand the larger magnitude foundation loads from the uprated generator. Based on the uprated generator loads recommended by the project engineering team, it was found that the allowable tensile stress limit of the concrete in the existing generator foundation is exceeded under the electrical fault load cases.

To address the found issue, a solution of adding eight new stator soleplate foundation anchors per unit was evaluated and found effective to address the issues.

The generator specifications will require the generator supply proposals to include foundation forces due to electrical faults to ensure no generator foundation work will be required except adding new stator soleplate anchors.

The generator supplier will be asked to propose new generator equipment with less mass based on the powerhouse crane nameplate rating. The lesser mass of the new generator equipment will cause lesser reaction forces to the generator's foundation structures under normal operation and seismic event, which are beneficial to the aged existing foundation structures.

4.12 Constructability Review

The intent of the constructability review by the engineering team is to ensure efficient application of the knowledge and experience to mitigate various types of risk inherent during the construction stage of such a complex project.

The project engineering team, in cooperation with the Generation Operations, has performed a preliminary constructability review of the preferred alternative to identify risk factors that could negatively affect the safety, cost and schedule during the construction activities. The results of the performed constructability review are summarized below.

A comprehensive constructability review will be conducted in the implementation phase during the Detailed Design stage to further identify any issues that could impact design, construction, and operation of the new equipment

4.12.1 Powerhouse Assembly Bay

Based on the evaluation performed by the engineering team, the generator assembly activities will be performed in the Powerhouse assembly bay located between G1 and G2.

The work comprises of three stages:

a. Pre-outage activities

b. Disassembly and removal of the existing generator

c. Assembly of the new generator in the generator pit

Based on the estimated weight of the new rotor and the new stator, the rated capacity of the generator floor will be exceeded.

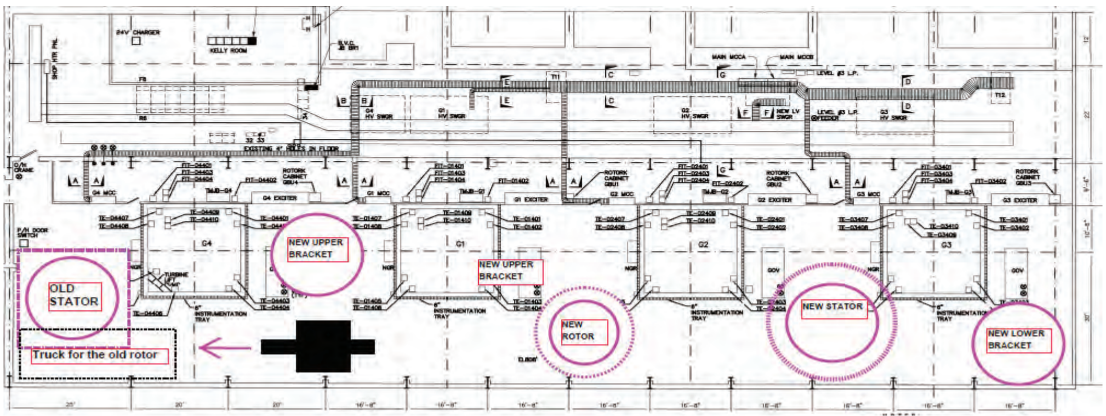

Figure 7: Assembly Bay – Generator Activities

4.12.2 Powerhouse Crane Availability

Generator supplier (GS) ability to successfully implement the engineering lift will be scrutinized during the RFP process and on-site activities related to facilitating the engineering lift of the existing rotor will be monitored.

4.12.3 Quality of the Supplied Equipment/Parts/Components

All leading generator suppliers base manufacturing of the major components world-wide, and this poses an additional challenge with ensuring that the materials/parts/components meet the contractual engineering requirements. The project engineering team will participate in development of the rigorous QA plan to ensure that the materials/parts/components are delivered to the site non-deficient.

Experience indicates the following parts are prone to issues:

a. Stator laminations

b. Stator coils

c. Stator wedges

4.12.4 Interface with the Existing Systems

Special attention will be given to the verification of the interface points between the existing systems and the new equipment.

The example of such interface is alignment between the new generator leads and the existing generator bus. More detailed information on the interface point is provided in Section 4 of this report.

4.12.5 Non-conformance with the Engineering Documents

Non-adherence to the installation procedures is potentially the major source of issues with the quality of the new generators. The GS procedures will be reviewed to ensure clarity, appropriate level of details and compliance with the contract requirements.

Experience indicates the following critical activities are prone to issues:

a. Stator core assembly
b. Stator winding assembly
c. Installation of the stator wedges
d. Rotor poles installation
e. Meeting tolerance requirements in the assembled unit
f. Meeting the vibration limits
g. Oil leaks

4.12.6 Removal of the Existing Equipment

Removal of the existing rotor assembly is a critical operation due to the insufficient rated capacity of the powerhouse crane.

It is critical to ensure that the GS is ready to the scenarios when partial disassembly of the rotor is required.

4.13 Station Service Air

Based on the engineering evaluation performed by the engineering team, the existing service air system does not require any modification.

The generator supplier will be responsible to ensure that the generator air supply is coordinated with the existing service air tie in points

4.14 Powerhouse Crane Assessment

The BR1 powerhouse crane is a double-girder, overhead travelling crane, manufactured in 1948 and installed in the BR1 Powerhouse during construction. The crane has a main hoist of 158.8 metric ton capacity, an auxiliary hoist of 22.7 metric ton. A tertiary hoist of five metric ton was added in 2017.

The crane was overhauled and upgraded in 2011 and successfully load tested with 125% load corresponding to 198.5 metric ton on completion of the upgrade.

The estimated weight of the existing rotor including the rotor lifting device is 179.5 metric ton and it exceeds the crane's load capacity (13%).

The generator specification will specify the weight of the new rotor assembly with the lifting device to be below the crane rated-capacity of 175 metric ton.

Still there is a risk that the generator supplier will not be able to propose a design meeting such requirements.

The project team has considered two approaches to handle of the generator rotors with the weight exceeding the crane rated capacity:

a. Option A

The generator supplier can propose a planned engineered lift procedure to remove the existing rotors from the pit and truck them out of the powerhouse. The generator supplier will be responsible to apply to WorkSafeBC for an engineered lift variance to allow the engineered lift of the existing generator rotors, including all required preparatory works such as powerhouse crane and runway inspection, justification report, engineered lift procedure, related critical lift plans (in particular tilting the rotor and placing it on transport vehicle), transport vehicle specification and the rotor laydown location. BC Hydro will include in the construction specifications detailed requirements to cover the engineered lift application and its implementation but will take no responsibility for the outcome of the generator supplier's application.

b. Option B

The generator supplier can propose removal of some of the rotor components in order to bring the rotor lifting assembly weight within the crane capacity to exclude an engineered lift; or use this option as a backup plan in case a variance application for an engineered lift is not accepted by WorkSafeBC BC (when Option A is the selected option); and then truck the partially-disassembled rotor out of the powerhouse.

A detailed assessment of the crane runways and supporting structures was conducted to assess feasibility of the engineering lift process.

The assessment was based on use of the crane with 158.8 metric ton capacity to lift a 179.5 rotor assembly over a modified range of motion and two specific load paths.

The analysis results show that the crane runways can safely support the specified lifted loads requested provided the loads stay within the prescribed ranges of movement.

No modifications or upgrades to the crane runway are required.

4.15 Generator Disassembly Tools

All lifting devices and tools for handling of existing and new generator rotors will be designed and supplied by generator.

The generator specification will require a below-the-hook-lifting device to be designed in compliance with ASME B30.20, which recommends load testing of lifting devices. BC Hydro will stipulate performing load testing by the Supplier as a part of the base scope.

This requirement may be waived if the Supplier will be able to provide acceptable justification stipulated in the contract for why load testing should not be performed. The Supplier should stipulate what justification is acceptable to BC Hydro.

The Supplier should provide the cost breakdown for load testing each device.

4.15.1 Rotor Lifting Device

Since the existing rotor lifting device is rated at 136 metric ton which is significantly less than the weight of the old rotor assembly the scope of the generator supplier supply will include supply of the new rotor lifting device suitable for lifting of both the old and the new rotor assemblies.

The rotor lifting device will allow the rotor, while coupled or attached to the generator shaft, to pass over the other operating generators.

4.15.2 Rotor Pole Lifting Device

A new rotor pole lifting device will be provided for installing and removing the new poles.

To address the potential need for removal of the existing rotor poles the generator supplier will be asked to evaluate removal of the existing rotor poles and submit the work procedure.

4.15.3 Stator Lifting Device

The existing stator will be removed using the upper bracket as the lifting device.

A new stator lifting device will be provided for installing and removing the stator as a single assembly.

The stator lifting device will be designed to allow the stator to pass over the other operating generators.

5 SAFETY BY DESIGN

BC Hydro's Safety by Design process was followed throughout all stages of design. The design team discussed safety with site personnel.

Key hazards were identified for each system included in the project scope. System-specific Safety by Design provisions and solutions are described in section 4 of this report.

The full Safety by Design Hazard Log is included in Appendix B.

In all instances, the contract specifications will include detailed requirements stipulating design measures to implement the SbD solution in the specific system.

The contractors awarded the contracts will receive this Hazard Log and will follow BC Hydro's Safety by Design process or their own equivalent process, if acceptable to BC Hydro.

6 ENGINEERING RISKS – GENERAL DISCUSSION

Table 18 below summarises the risks and mitigations related to the design that have been identified up to completion of this version of the Preliminary Design Report. These will also be recorded in the Project's Risk Register by the end of the current design stage.

Table 18: Design risks and mitigations

#	Risk	Mitigation	Specification Reference
1	Powerhouse assembly bay floor capacity is inadequate to be used for the assembly/disassembly work	The generator supplier (GS) will design, supply and install new platforms to achieve proper weight distribution.	TBD
2	Certified lifting devices are not available for assembly and disassembly	The GS will design, supply and install all lifting devices required for assembly and disassembly.	TBD
3	Crane and runway inspection by the generator supplier prior to engineered and/or critical lift application indicates that repairs are necessary	- Consider contingency based on past crane yearly overhaul costs. - Stipulate in the Contract an early start for the WorkSafeBC engineered lift application with adequate duration and float. - Determine in the Contract who is responsible for crane inspection (BCH or generator supplier). Either way, inspection and repair can be performed by a crane inspection specialist company and reasonable cost estimates can be agreed prior to Contract signing.	TBD
4	Failure to Obtain Engineered Lift permit	- Include Option B in the specifications and request cost/duration estimate for Option B bid documents. - Start WorkSafeBC Engineered Lift Application early into the project, consider adequate duration and float.	TBD

5	Failure to remove the rotor poles	- The preliminary plan for option B will be available and agreed by all parties as part of the generator supplier scope of the work. - Long lead activity/supplies within Option B will be addressed in advance.	TBD
6	Crane component failure during heavy lifting works (existing/new rotor lifting)	- Perform crane and runway inspections and do the required repairs if necessary. - Prepare and follow the engineered and critical lift plans. - For heavy lifts, always start with a trial short height lift, and do inspections to ensure no abnormalities exist with crane components or lifting device before continuing with lifting operation (to be considered in engineered and/or critical lift plans by the supplier). - Consider additional safety measures for engineered/critical lifts (e.g. slow speed, continuous alarms monitoring)	TBD
7	Incomplete removal operation of existing rotor (due to reasons other than powerhouse crane component failure).	- Detailed rotor removal procedure as well as tight supervision and control will be implemented. - Strict adherence to engineered and critical lift plans - If the issue persists twice, Option B is to be followed.	TBD
8	As found condition of the concrete in the generator area is worse than expected	The contractor will be requested to conduct site inspection on the existing soleplates and the concrete foundation of each unit to confirm the existing condition of the concrete foundation	TBD
9	Prototype testing of the stator coils fails	BC Hydro Engineering will witness the testing process	TBD

10	Factory QA issues with the stator laminations	BC Hydro will ensure tight QA control of the lamination manufacturing using a combination of the local QA representatives and BC Hydro engineering to witness the production especially first laminations.	TBD
11	It is not feasible to design the new rotor assembly to keep the weight below the crane capacity.	The generator supplier will be required to develop the mitigation plan as a part of the RFP submission	TBD
12	Weight of the new rotor assembly with the lifting device exceeds the crane capacity because of a design error	The generator supplier will provide detailed calculations for the weight of the major components. The factory ITP will include verification of the weight.	TBD
13	Failure to meet new CIP requirements	P&C engineering will identify all applicable standards with the BC Hydro experts	TBD
14	The new governor system fails to operate smoothly with the existing turbine.	Andritz will provide the design calculations to specify the new servomotors buy the end of the Preliminary design stage	TBD
15	The Generator supplier fails to meet inertia requirements.	The generator supplier will submit a detailed calculation report to confirm.	TBD
16	Generator losses as measured exceed the contractual requirements.	The generator supplier will submit a detailed calculation report to confirm.	TBD
17	Generator air gap does not meet the design criteria.	The generator supplier will submit a detailed calculation report to confirm.	TBD
18	Brush wear exceeds the contractual requirements.	Will be discussed with the generator supplier early to share the lessons learned in BC Hydro based on the recently completed generator replacements and upgrades.	TBD

19	The new generator fails the sudden short circuit test.	The test will be performed on the first generator to mitigate the risk	TBD
20	The generator noise exceeds the contractual requirements.	The test points will be identified in the specification.	TBD
21	The OEM fails to design the Split Phase protection.	BC Hydro will request a detailed report with the Split phase Protection calculations	TBD
22	Generator OEM fails to design mechanical interfaces	The generator supplier will submit the report with the interface information	TBD
23	Generator OEM fails to design electrical interfaces	Detailed verification of the existing bus bars will be stipulated in SPG	TBD
24	Quality of the P&C design by the Generator OEM is poor	The P&C design will be discussed in detail in the beginning of the project. The P&C lead qualifications will be included in the specification.	TBD
25	Generator OEM provides poor commissioning support	BCH to appoint an overall commissioning lead with the contract award	TBD
26	Inadequate civil design for the new governor systems	The governor contract will include the option for the seismic design of the new governor installation.	TBD
27	Inadequate civil design for the new excitation system	The exciter contract will include the option for the seismic design of the new governor installation.	TBD
28	Stator winding is poorly assembled on site	Qualified BC Hydro field engineer will be assigned to monitor the installation	TBD
29	Stator wedges are poorly installed	The generator specification will stipulate 100% testing of the installed stator wedges using the modern testing equipment.	TBD
30	Drawing issue process is slow and inefficient	Stipulate digital sign and seal process in the generator contract	TBD
31	Work in the control room to replace the unit P&C panels can cause forced outage of the	Special attention will be given to avoid forced outage due to the work in the control room. This includes use of the low	TBD

	units in operation potentially leading to excessive spilling	impact tools and development of the detailed staging plan.	

7 COST ESTIMATE

At the time of finalizing this report, the total project cost, as described in the most up-to-date draft of the Preliminary Cost Estimate Memo is estimated at $244.9 Million. The following estimate summary table is taken directly from that memo.

Table 19: Cost estimate summary

Description	Expected Amount	Authorized Amount
Total Construction Cost (IMP)	[redacted]	
Removal/Dismantle Cost (IMP)		
Contingency (IMP)		
Loadings (IMP) - Inflation, Capital Overhead (CO) and Interest During Construction (IDC) (*No CO and IDC on Removal/Dismantle Cost)		
P-IMP Costs loadings (from end of DEF to project In-Service Date (ISD))		
DEF Costs loadings (from end of DEF to project ISD)		
E-DEF Costs loadings (from end of DEF to project ISD		
IDN Feasibility Costs loadings (from end of DEF to project In-Service Date (ISD))		
Special Reserve IMP (loaded)		
Total Cost requested for Implementation Phase without Sunk Costs (loaded + reserves) (+19%/-15%)		
P-IMP Actuals and Forecast to end of P-IMP	[redacted]	
DEF Actuals and Forecast to end of DEF		
E-DEF Sunk Costs		
IDN Feasibility Sunk Costs		
Total Project Cost loaded with DEF and IDN Feasibility Sunk Cost	**$228.7M**	**$304.9M**
IDN Conceptual & Needs Sunk Cost Non-Capital/Operating, Maintenance and Administrative (OMA)	$0.9M	
Total Project Cost loaded with IDN Conceptual Sunk Cost	**$229.6M**	**$305.8M**
Previous estimate (Feasibility)	$244.9M $340.4M ~ $209.4M	N/A

8 CONCLUSIONS AND RECOMMENDATIONS

Preliminary Design activities confirmed that the alternatives recommended in Identification phase are valid.

The project's equipment scope has been clearly identified and detailed to the extent required to initiate preparation of the detailed technical specifications. From a design point of view, it is recommended that this project complete the Preliminary Implementation activities leading to Implementation phase and Detailed Design.

9 REFERENCES

1.	Project Statement of Objectives
2.	Project User Requirements

Appendix A: GY0239-IDN Master Scope List

Appendix B: Safety by Design Hazard Log

Appendix C: 621-GER-00006 Preliminary Design Report-Electrical Design R1

Appendix D: 621-GEM-00014 BR1 U1-4 Definition Design Memo Generator Mechanica

Appendix E: 621-GER-00007 Preliminary Design Report - Excitation System R0

Appendix F: 621-GER-00008 Preliminary Design Report for Control System R1

Appendix G: BR120-05.10-IOM-GY0239 High Bay Design Memo

Appendix H: 621-GEM-00011 BR1-U1-4 Turbine Preliminary Design Memo R0

Appendix I: GY-0239-DEF Preliminary Design Memo Mechanical Auxiliary R0

Appendix J: 621-GEM-00010 BR1 U1-4 Preliminary Design Memo Energy Dissipation Device R0

Appendix K: GY0239-DEF-PDR Preliminary Design Memo Governor R0

Appendix L: 200244-0000-DD20-RPT-0001

Wood Structural Assessment Report R0

Appendix M: BR1-SIS-2019-02-07 Final Interconnection System Impact Study

Appendix N: 621-GER-00002 BR1 Generator Control and Excitation System Condition Assessment R1

Appendix O: 5585256-004000-47-ERA-0002-R01 BBA Exciter System Condition Assessment

BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-8

BR1 Project Procurement Decision

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BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-9

BR1 Preliminary Cost Estimate

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BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-10

BR1 Project Expenditure Breakdown by Year

PUBLIC

GY-0239 BR1 U1-4 Generator Replacement
Cashflow by Fiscal Year at April 2021

	Actual Cost/ Prior Years	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027	FY2028	FY2029	FY2030	FY2031	FY2032	Total
Pre-Full Implementation Phase Costs													
Actual Cost (IDN, DEF Phases)	$ 6,904,064												$ 6,904,064
Pre-Full IMP Phase (Remaining DEF Phase)		$ 3,963,275	$ 1,691,475	$ 875,308									$ 6,530,058
Total Pre-Full Implementation Phase Costs:													**$ 13,434,122**
Direct Construction Costs				[redacted]									
Generator 1st Unit													
Generator 2nd Unit													
Generator 3rd Unit													
Generator 4th Unit													
Governor-all units													
Exciter-all units													
Controls-all units													
Balance of Plant													
Total Direct Construction Costs:													
Indirect Construction Costs	[redacted]												
Project Management													
Engineering & Design													
Indigenous Relations													
Environment, Stakeholders & Properties													
Procurement & QA (incl P-IMP Phase)													
Legal													
Total Indirect Construction Costs:													
Implementation Costs													[redacted]
Before Contingency & Loadings:													
Contingency	[redacted]												
Capital Overhead													
Interest During Construction (IDC)													
BC Hydro Expected Amount:													**$ 243,397,300**
Project Reserves												$ 82,884,483	$ 82,884,483
BC Hydro Authorised Amount:													**$ 326,281,783**
Fiscal Year totals:	[redacted]												

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BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-11

BR1 Rate Impact Models

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BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

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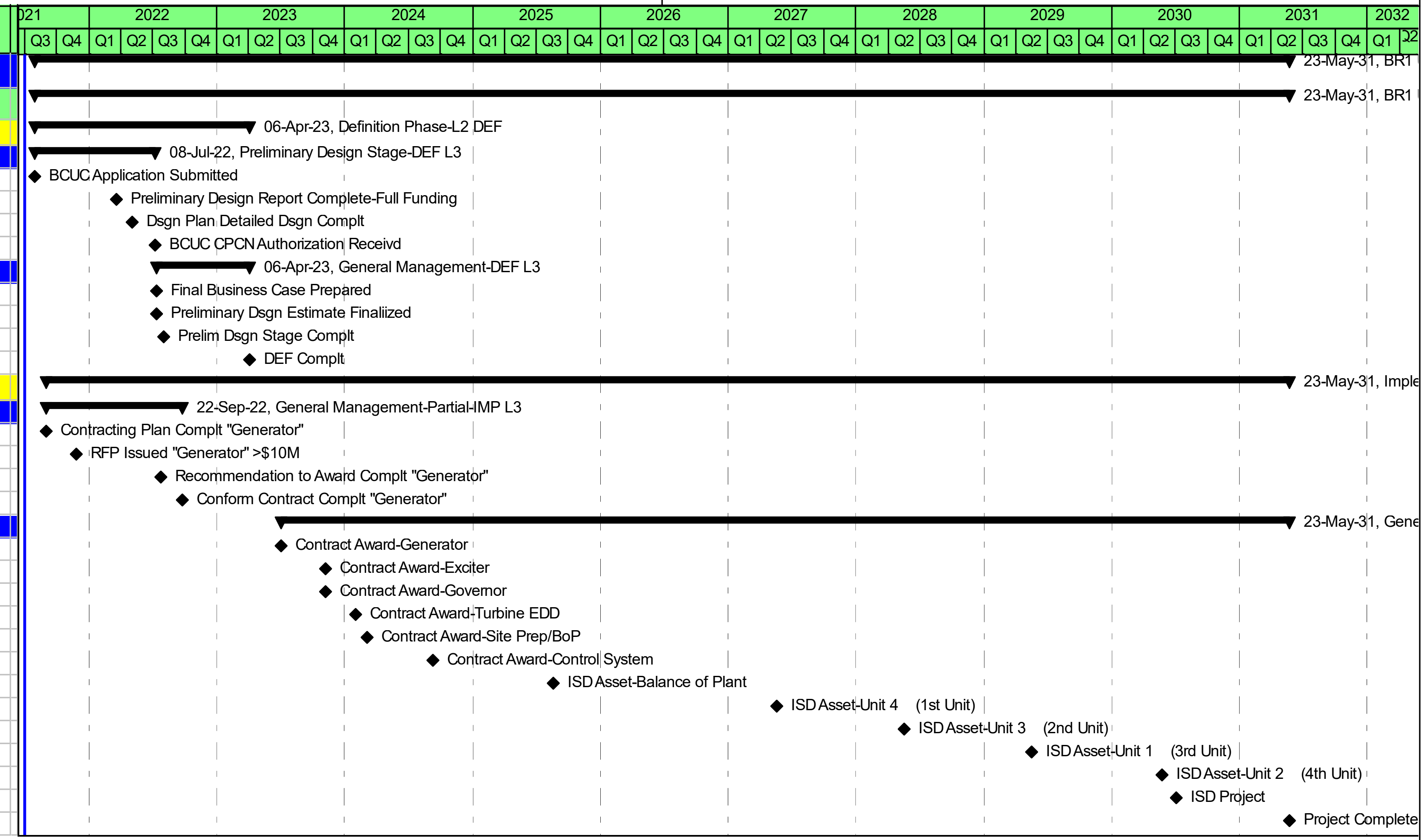
BR1 Project Schedule

Project:BR1 Units 1 to 4 Generator Replacement | KB_Gantt Chart with Waterfall | Printed On:20-Jul-21 Data Date:01-Jul-21

Activity ID	PPM Milestor	Activity Name	Start	Finish
BR1 Units 1 to 4 Generator Replacement			30-Jul-21	23-May-31
BR1 Units 1 to 4 Generator Replacement			30-Jul-21	23-May-31
Definition Phase-L2 DEF			30-Jul-21	06-Apr-23
Preliminary Design Stage-DEF L3			30-Jul-21	08-Jul-22
GY0239-6495	3.38	BCUC Application Submitted		30-Jul-21
GY0239-7980	3.03	Preliminary Design Report Complete-Full Fundir		18-Mar-22
GY0239-8050	4.26	Dsgn Plan Detailed Dsgn Complt		03-May-22
GY0239-6515	4.04	BCUC CPCN Authorization Receivd		08-Jul-22
General Management-DEF L3			11-Jul-22	06-Apr-23
GY0239-7060	4.30	Final Business Case Prepared		11-Jul-22
GY0239-7150	4.06	Preliminary Dsgn Estimate Finalized		11-Jul-22
GY0239-6880	3.11	Prelim Dsgn Stage Complt		02-Aug-22
GY0239-1030	2.02	DEF Complt		06-Apr-23
Implementation Phase-L2 IMP			31-Aug-21	23-May-31
General Management-Partial-IMP L3			31-Aug-21	22-Sep-22
GY0239-9380	4.69	Contracting Plan Complt "Generator"		31-Aug-21
GY0239-9550	4.09	RFP Issued "Generator" >$10M		25-Nov-21
GY0239-9680	4.49	Recommendation to Award Complt "Generator"		26-Jul-22
GY0239-9710	5.63	Conform Contract Complt "Generator"		22-Sep-22
General Management - IMP L3			05-Jul-23	23-May-31
GY0239-BK20	4.10	Contract Award-Generator		05-Jul-23
GY0239-BL90	4.10	Contract Award-Exciter		06-Nov-23
GY0239-BN20	4.10	Contract Award-Governor		06-Nov-23
GY0239-BP60	4.10	Contract Award-Turbine EDD		02-Feb-24
GY0239-BS30	4.10	Contract Award-Site Prep/BoP		04-Mar-24
GY0239-BQ90	4.10	Contract Award-Control System		10-Sep-24
GY0239-1140	3.10	ISD Asset-Balance of Plant		20-Aug-25
GY0239-1170	3.10	ISD Asset-Unit 4 (1st Unit)		19-May-27
GY0239-1150	3.10	ISD Asset-Unit 3 (2nd Unit)		19-May-28
GY0239-1160	3.10	ISD Asset-Unit 1 (3rd Unit)		16-May-29
GY0239-AA90	3.10	ISD Asset-Unit 2 (4th Unit)		22-May-30
GY0239-1050	1.01	ISD Project		04-Jul-30
GY0239-1070	3.08	Project Complete		23-May-31



BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-13

BR1 Environmental Impact Statement

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Hemmera
An Ausenco Company

Bridge River 1 Unit Replacement Environmental Impact Statement

Photo Credit: BC Hydro

Photo Credit: BC Hydro

Prepared for:

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February 26, 2021

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APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
BC	British Columbia
BCUC	British Columbia Utilities Commission
BRGMON	Bridge River WUP monitoring program
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CMP	Construction Management Plan
DNA	deoxyribonucleic acid
LAA	Local Assessment Area
PAR	photosynthetically active radiation
PC	Pathway Component
RAA	Regional Assessment Area
RV	Recreational Vehicle
SLRD	Squamish Lillooet Regional District
VC	Valued Component
WUP	Water Use Plan

LIST OF SYMBOLS AND UNITS OF MEASURE

Symbol / Unit of Measure	Definition
km	kilometre
m	metre
m^3/s	cubic metres per second
masl	metres above sea level
mg dry wt/m^2	milligrams of dry weight per square metre
mm	millimetre
MW	megawatt
µg/L	microgram per litre

1.0 INTRODUCTION

BC Hydro is proposing to replace four aging generators, governors, exciters and control systems at Bridge River 1 Generating Station (the Project) located adjacent to Seton Lake, British Columbia (BC). Completion of the replacement project will improve reliability, restore licenced flow capacity and increase the operating flexibility.

This report has been prepared to support an application for an order from the British Columbia Utilities Commission (BCUC), pursuant to Section 44.2(1)(b) of the *Utilities Commission Act* and demonstrates BC Hydro's consideration of environmental and social effects of the Project. The scope of the report encompasses baseline information, identification of potential social and environmental Project effects, and recommendation of mitigation measures to address potential Project effects.

1.1 Project Background

The Bridge River System is in the Coast Mountains of southern B.C., northeast of Pemberton and west of Lillooet. The Bridge River System, built between 1950 and 1960, is a cascading system that includes three facilities: the La Joie facility, the Bridge River facility, and the Seton facility, which collectively contribute on average approximately 6 per cent of BC Hydro's total hydroelectric generation.

The Bridge River is a mid-size river, approximately 120 km long, and is divided into Upper Bridge River (upstream of Downton Reservoir), Middle Bridge River (downstream of the La Joie Dam and Generating Station), and Lower Bridge River (downstream of Terzaghi Dam). The Bridge River basin inflows consist mainly of snowmelt runoff and glacial melt occurring from June to August for Downton Reservoir and from May to July for Carpenter Reservoir and Seton Lake. Water is diverted from Carpenter Reservoir to the Bridge River 1 and 2 Generating Stations via two parallel four-kilometre tunnels.

The Bridge River generating stations, Bridge River 1 and 2, are the largest facilities in the Bridge River System and are located at the west end of Seton Lake near Shalalth. The Bridge River 1 Generating Station was commissioned in 1954 with four generating units and a plant capacity rating of 200 MW (current plant capacity rating is 190 MW due to a de-rated generator). At the maximum licenced flow capacity, Bridge River 1 Generating Station can pass 65 m^3/s of water.

The Bridge River 1, Unit 1 to 4 generators, governors, exciters, and control systems are in poor or unsatisfactory condition. The replacement of the aging equipment will improve reliability, restore licenced flow capacity, and increase operating flexibility of the Bridge River 1 Generating Station. These changes will enhance the ability to manage flows within the Water Use Plan (WUP) Order target flow schedule.

BC Hydro undertook a similar project in 2018 with the Bridge River 2, Units 5 and 6 Replacement Project and is currently undertaking work to replace the Bridge River 2 Units 7 and 8.

1.2 Project Description

The Project involves replacing the Unit 1 to 4 generators, Unit 1 to 4 governors, Unit 1 to 4 exciters, and the associated Unit 1 to 4 control systems at the Bridge River 1 Generating Station. In addition, the Project scope includes the refurbishment of other generator and turbine components to improve the functioning of the generating units; the supply and installation of a fire protection system on the generator floor; and supply of a turbine energy dissipation device. Implementation of the generator replacements is expected to commence after contract award in 2022, with a project in-service date of June 2029. Works are being undertaken within the existing footprint of the Bridge River 1 Generating Station and existing ancillary areas (e.g., parking lots, laydown areas previously used for the replacement of generating equipment at the Bridge River 2 powerhouse). No new infrastructure is required to support this replacement Project, and no clearing or ground disturbance is currently planned.

The units will be replaced sequentially starting with Unit 4 (**Table 1.1**). Construction for each unit will start with 4 to 5 months of pre-assembly to build the rotor and stator. Each unit will then be taken out of service for disassembly, assembly and commissioning.

Table 1.1 Construction Schedule for Unit 1 to 4

Bridge River 1 Unit	Pre-Assembly	Assembly/Commissioning	In-service Date
Unit 4	Mar to July 2025	Aug 2025 to Mar 2026	Apr 2026
Unit 3	Mar to July 2026	Aug 2026 to Mar 2027	Apr 2027
Unit 1	Mar to July 2027	Aug 2027 to Mar 2028	Apr 2028
Unit 2	Mar to July 2028	Aug 2028 to Mar 2029	Apr 2029

The construction phase of the Project is anticipated to last approximately 5 years. Construction will require a labour force of approximately 40 to 50 workers, with a peak of 56 during the assembly of each unit. The types of employment will range from project management to skilled trades and general labour.

The Project is adjacent to the St’át’imc community of Tsal’álh, and approximately 7 km east of the community of Seton Portage. The labour force is expected to be housed in and around Seton Portage, and will travel back and forth to the site each day.

2.0 SCOPE OF THE ASSESSMENT

2.1 Scope of Issues and Valued Components

Valued components (VCs) are environmental, social, cultural, or economic elements deemed important or valuable and are therefore assessed for potential project-related effects. For the Project, VCs were selected based on Project team's experience with similar-sized hydroelectric developments and informed by years of engagement with St'át'imc Nation to understand critical issues. Other factors considered include public engagement, knowledge and review of existing government standards and guidelines, legislation, and regulations, and input from BC Hydro. Both presence in the Project area and the potential for Project-related effects are required for an element to be considered a VC.

A Pathway component (PC) is defined as a component of a dynamic system that supports one or more VCs as part of a larger pathway of effect. PCs are intermediate components of the pathway of effect and are therefore integral to understanding potential effects on end receptors (i.e., VCs).

2.2 Spatial Boundaries

Local and regional spatial boundaries were determined for the effects assessment based on the characteristics of each VC and their anticipated interactions with the proposed Project. Spatial boundaries were identified through a review of the spatial extent of the environmental and socio-economic resources potentially affected by the Project. Local and regional assessment areas are defined below.

Local Assessment Area (LAA): the spatial area within which there is a reasonable potential for the Project or Project-related activities to cause effects during the Project (i.e., within close proximity to the action where direct and indirect effects are anticipated).

Regional Assessment Area (RAA): an area beyond the LAA, for which information may provide context for assessing the effects of the Project.

Local assessment areas and RAAs (if applicable) for each VC are identified and presented (including the provision of maps where appropriate) in **Section 3.0 Environmental Assessment** and **Section 4.0 Socio-Economic Assessment**. A description of the rationale used to define the boundaries is also provided.

2.3 Temporal Boundaries

Temporal boundaries are defined based on the timing and duration of Project activities that could induce environmental or socio-economic effects. Temporal boundaries for the proposed Project were based on a construction and commissioning schedule, including removal of temporary construction-related facilities and restoration of disturbed areas. Currently unit replacements are planned to occur between March 2025 to April 2029, with unit replacements occurring sequentially starting with Unit 4.

At the end of construction and commissioning, the Project will return to service as per existing conditions with improved reliability and operational certainty. Operations and maintenance of the Project will continue to be provided by BC Hydro's staff, who will continue to perform routine inspection and maintenance and equipment repairs. Operations activities will result in no additional interactions with the biological or socio-economic environment and will be undetectable from baseline conditions; therefore, the operation phase is not considered further in this analysis.

2.4 Environmental Assessment Methodology

Environmental assessments are tools used to examine potential project-related effects and benefits during the planning stages of a project, allowing for refinements in project design and development of appropriate measures to mitigate potential adverse effects.

An assessment of potential direct and indirect effects related to the proposed Project was conducted through completion of the following steps:

- Describe existing conditions for each selected VC.
- Identify the potential for an interaction between Project activities and each VC.
- Describe potential effects from Project-VC interactions.
- Describe mitigation measure(s) to avoid, minimize, or reduce potential adverse effects; propose mitigation measure(s) to enhance positive effects.

3.0 ENVIRONMENT ASSESSMENT

This section describes existing environmental conditions in the vicinity of the proposed Project, including a rationale for the selection of the environmental VCs. The potential for Project-related interactions is considered, potential effects are identified and mitigation measures are proposed.

3.1 Issues Scoping

The purpose of Issues Scoping is to focus the assessment on key issues that have the potential to affect environmental components in proximity to the Project. These key issues were determined through the identification of the potential interactions of the Project components and activities with the biophysical environment, past projects of similar size and scope, engagement with St'át'imc Nation, input from key stakeholders, and use of professional judgement and scientific and regulatory considerations.

A list of candidate VCs that were identified for the Project is provided in **Table 3.1**. The table also describes the rationale for selection and subsequent inclusion or exclusion of the candidate VC in the effects assessment. For those VCs carried forward in the assessment, indicators are provided.

Candidate VCs considered, but excluded from the assessment, include Heritage Resources, Water Quality, Wildlife and Wildlife Habitat, and Vegetation. These components were excluded because they are not anticipated to interact with proposed Project activities. Specifically, no ground disturbance or vegetation removal is required for the Project because BC Hydro plans to make use of pre-existing laydown areas, access roads, and parking lots. Further, although the accidental release of hazardous substances could occur during Project activities, these are generally preventable and will be mitigated through the application of Best Management Practices and spill-response actions outlined in the Project's Environmental Management Plan and Environmental Protection Plan.

Table 3.1 Rationale for Selection of Environmental Valued Components

Candidate VC	Rationale	Indicators
Heritage Resources	Project activities will occur within the existing footprint of the Bridge River 1 powerhouse and ancillary areas (e.g., parking lots and existing laydown areas). No ground disturbance or vegetation removal is anticipated. **Excluded**	N/A
Water Quality	Project activities associated with the replacement of the four generating units are not anticipated to affect the water quality in Carpenter Reservoir or Seton Lake. The accidental release of hazardous substances (e.g., fuel and oil) during Project construction has the potential to change surface water quality in watercourses in close proximity to the Bridge River 1 powerhouse and ancillary areas. Spills are generally preventable, and if they do occur, they are expected to be localized in nature and promptly reported and responded to with appropriate spill-response actions as per the specifications outlined in the Project's Environmental Management Plan and Environmental Protection Plan. **Excluded.**	N/A

Candidate VC	Rationale	Indicators
Water Quantity	Outages associated with the replacement of generating units has the potential to affect surface water quantity in Carpenter Reservoir, and Seton Lake, with subsequent impacts on Lower Bridge River. Changes to water quantity primarily represent a pathway through which other environmental components (e.g., fish and fish habitat) will be affected. Potential interactions related to changes in water quantity will be considered in the assessment of these VCs. **Included as Pathway Component**	Fluctuating water levels in Carpenter Reservoir, Seton Lake, and Lower Bridge River.
Fish and Fish Habitat	Changes in surface water quantity associated with outages for the replacement of generating units have the potential to affect fish and fish habitat present in Carpenter Reservoir and Lower Bridge River, with subsequent impacts on Lower Bridge River. **Included as Valued Component**	Changes in aquatic habitat quality and connectivity. Changes in species abundance, diversity, and distribution.
Wildlife and Wildlife Habitat Vegetation	Project activities will occur within the existing footprint of the Bridge River 1 powerhouse and ancillary areas (e.g., parking lots and existing laydown areas). No ground disturbance or vegetation removal is anticipated. **Excluded**	N/A

3.2 Assessment Boundaries

The proposed LAA for Water Quantity and Fish and Fish Habitat is defined as the full supply level of both Carpenter Reservoir and Seton Lake, and encompasses the area where the Project is expected to interact with and potentially create direct or indirect effects on the aquatic environment, such as fluctuating water levels.

To provide regional context for the assessment, the proposed RAA for Water Quality and Fish and Fish Habitat is defined as the Bridge River and Seton River watersheds combined.

Temporal boundaries are defined as the approximately 5-year construction and commissioning schedule for the proposed Project.

3.3 Water Quantity

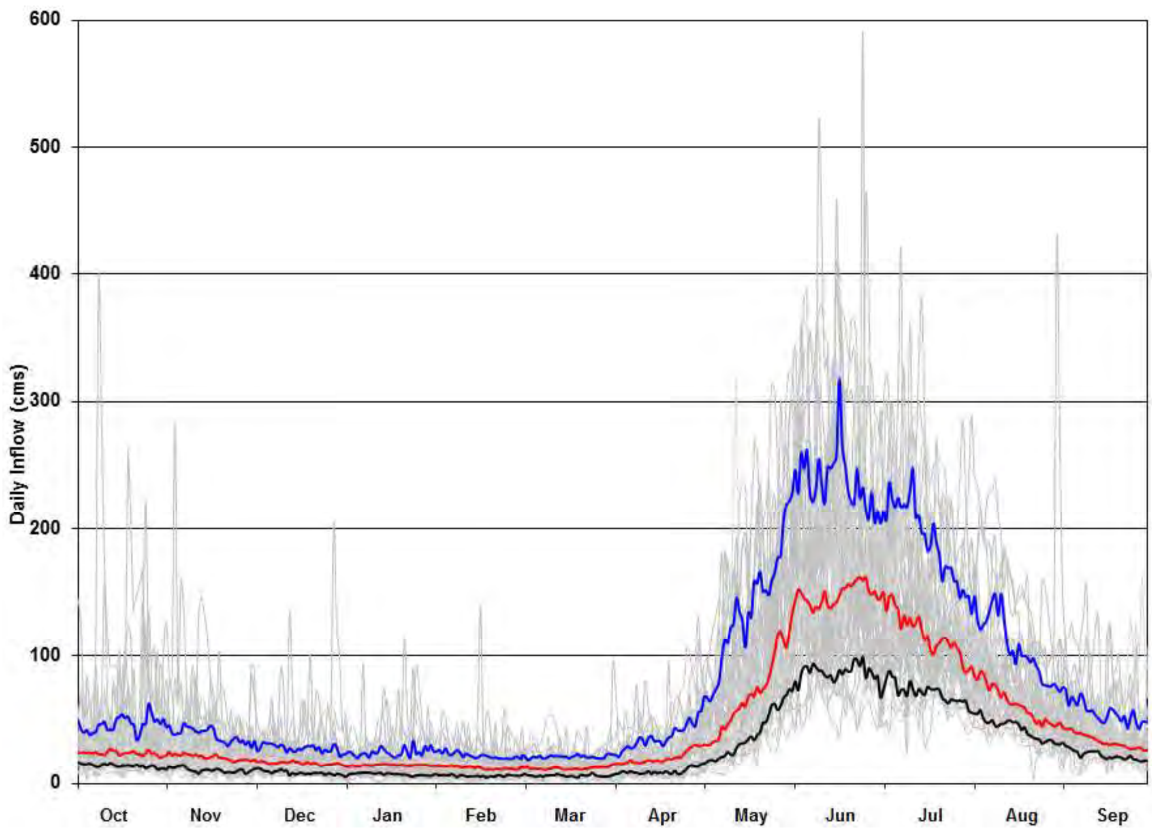
This section describes existing conditions related to Water Quantity in the RAA and LAA. The description of existing conditions is based on available information identified through a review of available studies and reports in the area. Other sources of information reviewed include federal, provincial, regional and local government websites, First Nations including St'át'imc representatives on the Joint Planning Forum, BC Hydro staff knowledgeable about the Bridge River System, and publicly available reports related to the RAA and LAA.

As a Pathway Component, Project-related effects to Water Quantity are considered in terms of their potential to cause effects to the Fish and Fish Habitat VC (i.e., end receptor).

Regional Assessment Area – Carpenter Basin

Carpenter Basin is the largest basin in the Bridge River region and is bounded to the northwest by the Shulaps Range and to the southeast by Mission Ridge, Bendor Range, and the Cadwallader Range. The basin has a glacial extent that covers approximately 2% of the drainage area, resulting in less glacial inflows later in the summer compared to the La Joie Basin. The elevation range is from 649 metres above sea level (masl) to 2,902 masl with a median El. 1,809 masl (Weston 2017). The basin is characterized by large, vertical elevation range; high median basin elevation; and moderately rugged topography. Four major streams discharge into Carpenter Reservoir: the Middle Bridge River (regulated discharge from La Joie Dam), Hurley River, Gun Creek, and Tyaughton Creek.

Carpenter Reservoir follows a nival, or snowmelt-dominated, regime and the basin has a mean annual precipitation of 975 mm. Precipitation in Carpenter Basin is less than in other surrounding watersheds due to the rain-shadow effect of the Coast Mountains. Low flows occur in the winter as snowpack accumulates. The freshet begins in late April and reaches its peak in June (**Figure 3.1**). Annual maximum peak flows are primarily generated during the spring freshet as a result of intense snowmelt or rainfall-runoff (Weston 2017).



Note: The 10th, 50th, and 90th percentile non-exceedance inflows are shown in bold black, red, and blue lines, respectively.

Source: Weston 2017, page 20

Figure 3.1 Historical Daily Local, Unregulated Inflows to Carpenter Reservoir (1964 to 2013)

Mean annual inflow into Carpenter Reservoir is 51 m^3/s, with a mean annual runoff of 586 mm. Mostly due its large drainage area, Carpenter Reservoir receives the highest inflows compared to the other surrounding watersheds (**Table 3.2**), with the exception of August and September, when Downton Reservoir is higher due to inputs from glacial melt.

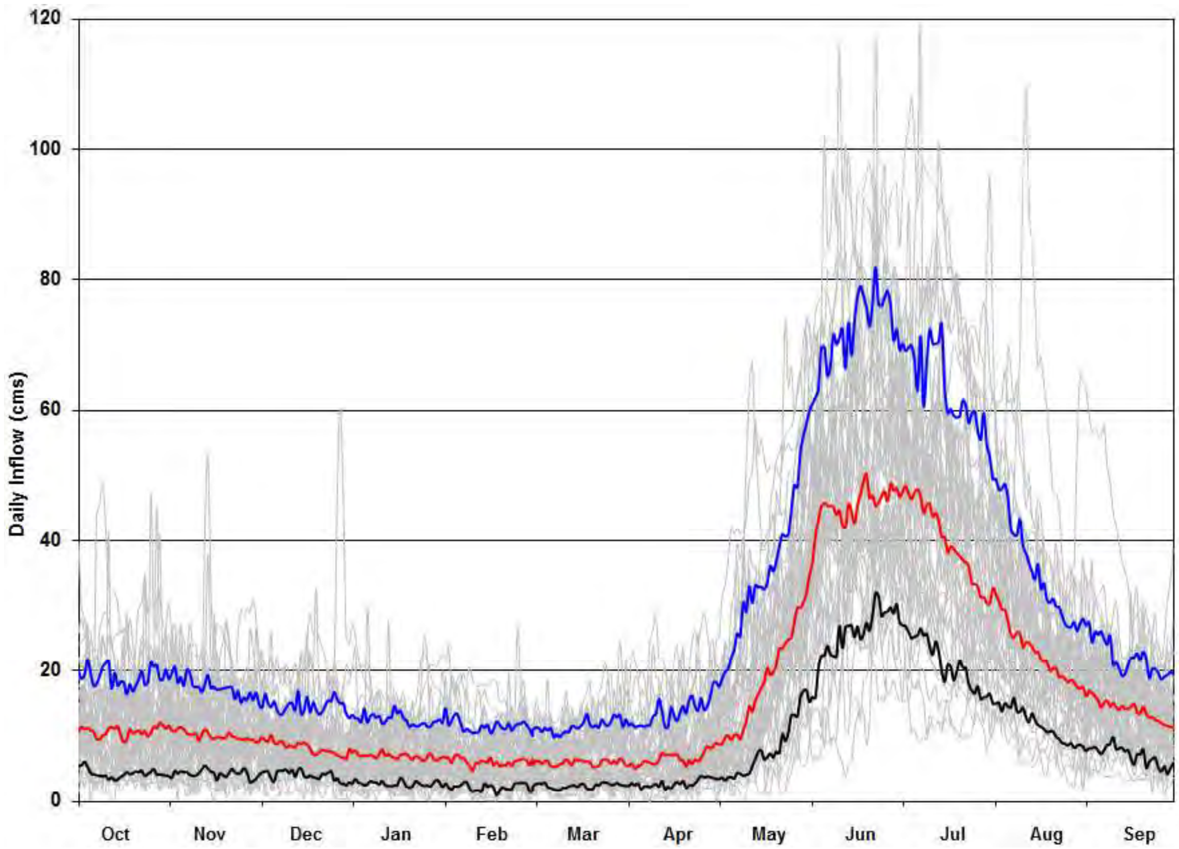
Table 3.2 Monthly Distribution of Daily Local, Unregulated Carpenter Basin Inflows in Cubic Metres per Second (1964 to 2013)

Month	5%	30%	50%	70%	95%	Min	Max	Mean
October	11	19	23	30	61	4	394	29
November	7	16	20	26	48	1	283	23
December	6	12	15	19	34	1	204	17
January	5	11	14	17	32	<1	115	15
February	4	9	12	15	27	<1	139	13
March	5	9	12	15	24	1	54	13
April	6	14	18	24	45	<1	132	21
May	18	43	65	91	181	7	326	77
June	70	120	149	183	292	35	591	159
July	60	94	118	148	230	23	419	128
August	34	51	62	78	139	3	428	71
September	18	28	33	41	72	6	165	37
Annual	**7**	**16**	**25**	**52**	**174**	**<1**	**591**	**51**

Regional Assessment Area – Seton Basin

Seton Basin is separated from the Carpenter Basin to the north by Mission Ridge and the Bendor Range. The elevation of the basin ranges from 219 masl to 2,914 masl, with a median EL. 1,533 masl. The basin is characterized by rugged topography and has a glacier extent less than 1% of the total drainage area (Weston 2017).

Seton Lake follows a nival regime, and the mean annual precipitation in Seton Basin is 919 mm. Low flows occur in the winter as snowpack accumulates, and the freshet begins in late April and reaches its peak in June (**Figure 3.2**).



Note: The 10th, 50th, and 90th percentile non-exceedance inflows are shown in bold black, red, and blue lines, respectively.

Source: Weston 2017, page 20

Figure 3.2 Historical Daily Local, Unregulated Inflows to Seton Lake (1964 to 2013)

Mean annual inflow into Seton Lake is 17 m^3/s, with a mean annual runoff of 535 mm. Seton Lake receives the lowest unregulated inflows compared to the other basins in the Bridge River System (**Table 3.3**). The hydrograph for inflows into Seton Lake are similar to Carpenter Reservoir, with higher inflows in the summer months (**Figure 3.2**). This unregulated flow makes up only 16% of the inflow to Seton Lake. Flows diverted through the Bridge River 1 and 2 generating stations represent 78% of inflow to Seton Lake. Cayoosh Creek, a tributary that flows into Seton River but has been partially diverted to Seton Lake and provides the remaining 6% of inflow (Roscoe 2009, FWCP 2011).

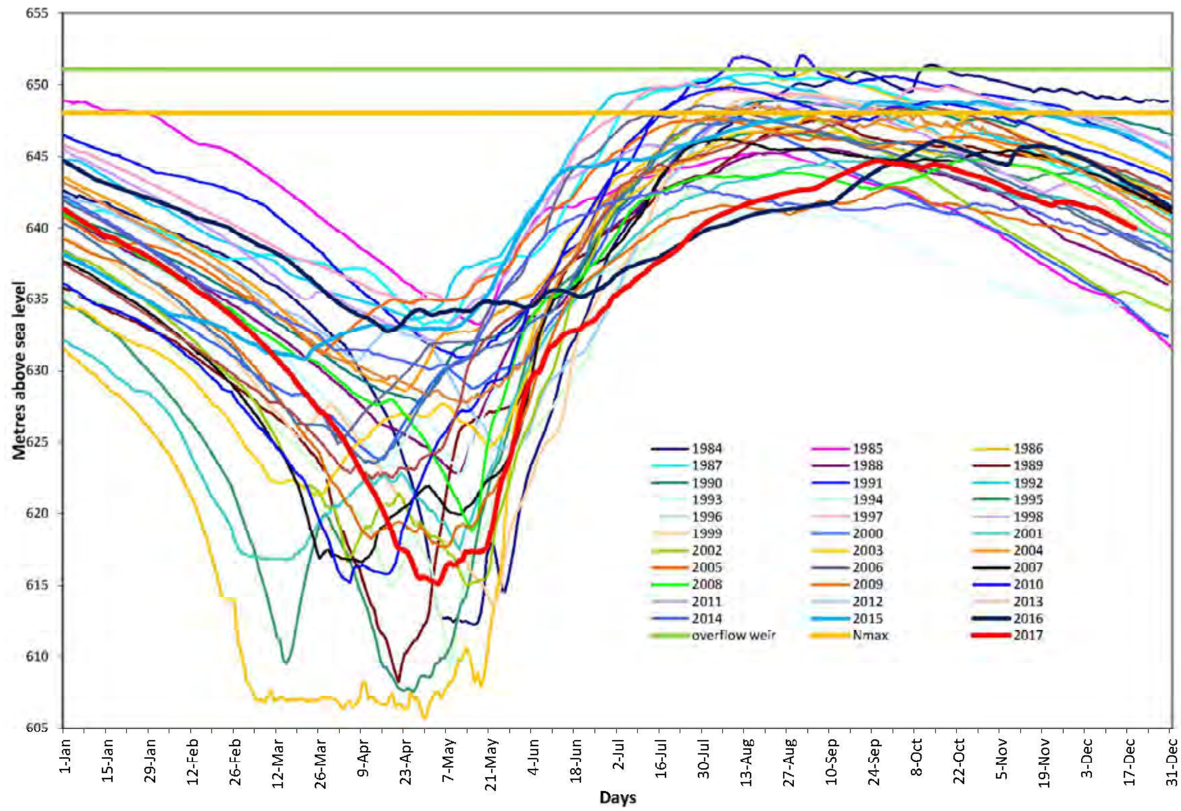
Table 3.3 Monthly Distribution of Daily Local, Unregulated Seton Basin Inflows in Cubic Metres per Second (1964 to 2013)

Month	5%	30%	50%	70%	95%	Min	Max	Mean
October	3	8	11	14	23	<1	49	11
November	3	7	10	12	21	<1	53	10
December	2	6	8	10	17	<1	60	9
January	2	5	7	10	15	<1	30	8
February	1	4	6	8	14	<1	27	7
March	2	4	6	9	13	<1	25	7
April	2	4	7	9	17	<1	29	8
May	4	11	17	25	46	<1	74	20
June	19	37	45	56	80	4	117	47
July	16	30	40	50	74	8	118	42
August	9	17	22	28	46	2	109	24
September	5	11	14	17	26	1	63	15
Annual	3	7	11	18	54	<1	118	17

Local Assessment Area – Carpenter Reservoir

Carpenter Reservoir is approximately 50 km long and has a maximum water depth of 55 m at full pool. It is downstream of Downton Reservoir and Middle Bridge River, Gun Creek, Hurley River, and Tyaughton Creek are the major streams that discharge into Carpenter Reservoir. Surface elevations in the reservoir are seasonal, with lowest elevations occurring in spring (April to May) and highest from August to November (Scholz et al. 2016) (**Figure 3.3**). Annual surface elevation does not mimic seasonality of unregulated inflow (**Figure 3.1**). For example, the highest unregulated inflows occur in June (**Figure 3.1**), while the highest reservoir surface elevations occur from August to November (**Figure 3.3**). The reservoir is generally operated between 606.55 masl and 651.08 masl for the purposes of power generation but can be drafted as low as 599.54 masl for maintenance activities (BC Hydro 2011). Drawdowns in the reservoir can be as large as 52 m. Carpenter Reservoir can store approximately 60% of its local annual inflow within the licence storage limits (Weston 2017).

Approximately 26.7% of water inflow to Carpenter Reservoir comes from the La Joie Basin, 20.5% from Tyaughton Creek, and 18.2% from Hurley River. The remaining 34.6% comes from other tributaries, including Gun and Marshall Creeks.



Source: BC Hydro

Figure 3.3 Elevation of Water Level in Carpenter Reservoir (2000 to 2014)

Local Assessment Area – Seton Lake

Located in the Seton Basin, Seton Lake is approximately 20 km long, with a surface area of 24.3 km2 and a mean depth of 85 m (Moreira and Taylor 2015). Seton Lake has very little storage, equivalent to approximately 2% of its local annual inflow (Weston 2017). The majority (approximately 78%) of inflow Seton Lake is the result of diversion from Carpenter Reservoir. The remaining inflow primarily comes from Cayoosh and Portage Creeks (Roscoe 2009, FWCP 2011).

Bridge River 1 has four generating units with an estimated total maximum discharge of 65.0 m^3/s. Bridge River 2 has four generating units with an estimated total maximum discharge of 95.0 m^3/s (BC Hydro 2011). Most of the flow from Carpenter Reservoir discharges into Seton Lake through Bridge River 1 and 2, with the remaining volume discharging through Terzaghi Dam into the Lower Bridge River. The flow is highest through the winter, with another peak near August-September (Perrin et al. 2016) (**Figure 3.4** and **Figure 3.5**). There are no ramp rate restrictions for Bridge River 1 and 2 (BC Hydro 2011). Unregulated inflows into Seton Lake (**Figure 3.2**) are somewhat offset by the total discharge from both Bridge River 1 and 2. For example, the 50th percentile unregulated inflow into Seton Lake begins to increase in May, peaking in June and July (**Figure 3.2**), while the 50th percentile discharge from Bridge River 1 decreases to approximately 15 m^3/s in May, compared to 45 m^3/s in the winter months. Similarly, the 50th percentile discharge from Bridge River 2 decreases to 35 m^3/s in June, compared to 65 m^3/s in January.

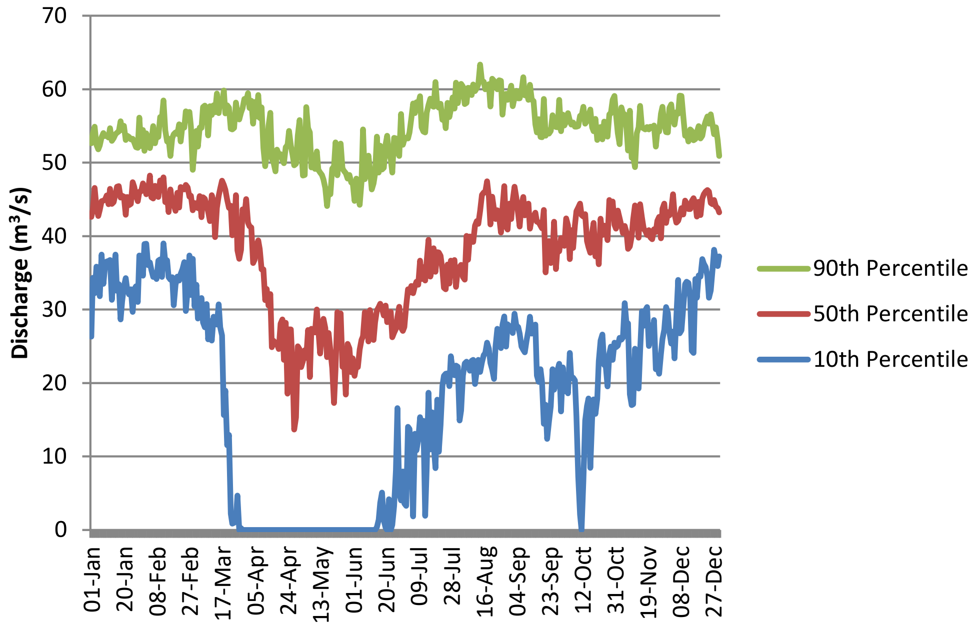


Figure 3.4 **Average Daily Discharge from Bridge River Generating Station 1 into Seton Lake (1984 to 2017)**

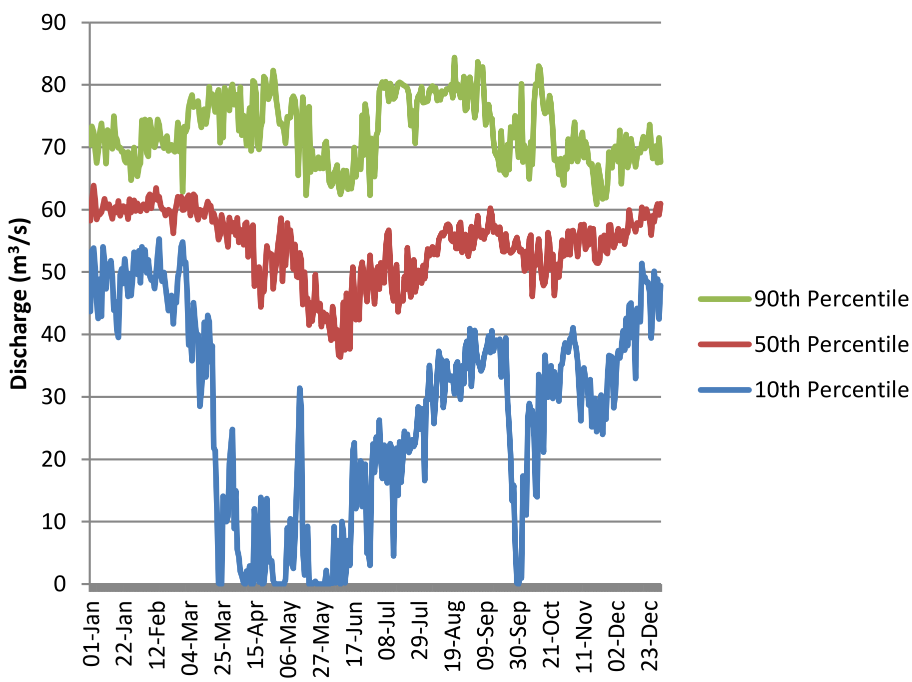


Figure 3.5 **Average Daily Discharge from Bridge River Generating Station 2 into Seton Lake (1984 to 2017)**

The magnitude and timing of changes in water levels are what distinguishes most reservoirs from natural lakes (e.g., Furey et al. 2004). In the Bridge River System, reservoir elevations and instream flows were recommended during the Water Use Planning process in consideration of finding a better balance between competing uses of water such as domestic water supply, fish and wildlife, recreation, heritage and electrical power needs. In Carpenter Reservoir, large inflows occur during the freshet from June to July, whereas there is very little inflow from November to May. In contrast, the outflow releases from the reservoir tend to be relatively stable. As a result, the water elevations in Carpenter Reservoir fluctuate substantially, recurrently exposing and flooding large areas within the drawdown zones annually. In contrast, Seton Lake is managed so that there is very little drawdown (less than 3 m).

3.4 Fish and Fish Habitat

Resident Salmonids, Anadromous Salmonids, and Instream Fish Habitat were selected as Key Indicators for the Fish and Fish Habitat VC as both resident and anadromous salmonids reside in the assessment area for all or part of their life cycle and in-stream fish habitat is important in sustaining fish populations.

This section assesses potential effects of the Project on the Fish and Fish Habitat VC, including a description of the existing conditions in the LAA. This section also identifies potential interactions with Fish and Fish Habitat during Project construction, identifies potential Project effects and proposes mitigation measures to address potential Project-related effects.

3.4.1 Existing Conditions

This section defines the Key Indicators of the Fish and Fish Habitat VC and describes their existing conditions in the RAA and LAA. The description of existing conditions is based on available information identified through and a review of available studies and reports in the area. Sources of information reviewed included federal, provincial, regional and local government websites, First Nations including St’át’imc representatives on the Joint Planning Forum, BC Hydro staff knowledgeable about the Bridge River System, and publicly available reports related to the RAA and LAA, including reports generated from relevant WUP monitoring programs (BRGMON).

Resident Salmonids

Resident salmonid fish species are those that reside in freshwater for their entire lifecycle; most of these species spawn more than once in their lifecycle. Rainbow Trout (*Oncorhynchus mykiss*), Bull Trout (*Salvelinus confluentus*), Mountain Whitefish (*Prosopium williamsoni*), and Kokanee (*Oncorhynchus nerka*) are species of resident salmonids present in the LAA.

<u>Rainbow Trout</u>

Rainbow Trout can have both freshwater and anadromous (steelhead) populations. Resident Rainbow Trout are native and common to the RAA and LAA. They are not listed under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and are provincially listed as Yellow (apparently secure) (CDC 2020).

Based on preliminary capture data obtained in 2013 to 2017 during general index sampling in Carpenter Reservoir, Rainbow Trout were present in lower densities than other salmonids (e.g., Bull Trout, Mountain Whitefish [*Prosopium williamsoni*]) (Tisdale 2013, Putt et al. 2018). These low densities could be a result of inaccurate population estimates due to index sampling being hindered by turbidity (Putt et al. 2018). Lower densities of Rainbow Trout may also be a result of Bull Trout predation on fry and/or a result of a large portion of the Rainbow Trout population possibly recruiting from Tyaughton and Marshall Lakes, which drain into Carpenter Reservoir (Putt et al. 2018). Reservoir elevations and lacustrine habitat areas were lower in 2016 and 2017 relative to previous monitoring years, which suggests that reservoir elevation significantly affects the distribution and condition of fish in Carpenter Reservoir (Putt et al. 2018). Of the Rainbow Trout captured during the study, high numbers were found in the deeper portions of the lake in the vicinity of the Bridge River 1 and 2 diversion tunnels. In the 2016 and 2017 study years, fish densities generally shifted east toward the contracted lacustrine habitat (Putt et al. 2018).

Drawdown exposes large areas of littoral mudflats in Carpenter Reservoir (Azimuth 2015, Perrin et al. 2018). Coarser substrate materials (i.e., sand, gravel, and cobble) are sometimes found near alluvial fans, such as that of Gun Creek. At least half of the tributaries to Carpenter Reservoir have suitable spawning habitat near their outlets to the reservoir. Rainbow Trout are known to spawn in Jones, Marshall, Girl, McDonald, and Truax creeks in the months of May and June, with peak numbers occurring in mid-June (Putt et al. 2018).

Rainbow Trout occur in all parts of the Seton River watershed (FWCP 2020, BCMOE 2017); however, specific information on populations and their habitat is limited. In Seton Lake, during a random index sampling survey conducted in 2013 and 2014, only 45 Rainbow Trout ranging in size from 100 mm to 480 mm were captured by boat electrofishing (Sneep 2015). Since 2015, sampling for the resident fish population index survey has been conducted by gill netting in both nearshore and offshore habitats (Sneep 2019). A total of 18 Rainbow Trout were captured in 2017, ranging from 117 mm to 348 mm in size. Low capture rates were thought to be due to Rainbow Trout populating deep parts of the lake that cannot be effectively sampled through boat electrofishing. Large adfluvial (spawned and reared in streams) Rainbow Trout have been reported spawning in Portage and Gates creeks; little is known about their life history (Webb et al. 2001), but they are likely Seton Lake residents. The combination of Rainbow Trout life history characteristics and a small population size in Seton Lake, makes this species less suitable for trend monitoring and linking observed population characteristics to operations, relative to Gwenish (Kokanee) and Bull Trout (Sneep 2019).

<u>Bull Trout</u>

Bull Trout are a provincially Blue-listed (Special Concern) species, because they are highly temperature-sensitive and sensitive to changes in habitat (CDC 2020). They are also listed under COSEWIC as a species of Special Concern because of characteristics that make them sensitive to human activities (CDC 2020). Land-use practices, invasion of aquatic species, and harvesting may be contributing factors in the decline of Bull Trout populations (Rieman and McIntyre 1993). They are listed as a Priority Species under the *Bridge-Seton Watershed Action Plan* (FWCP 2020).

In Carpenter Reservoir, previous fish inventories conducted in 1999 and 2000 (Chamberlain et al. 2001) suggest that the majority of Bull Trout spawning and rearing occurs within the Gun Creek and Tyaughton Creek sub-watershed, with smaller spawning populations in some of the southern tributaries, including Nosebag, Keary, and Tommy creeks. Data suggest that mature Bull Trout within Carpenter Reservoir are adfluvial and migrate into the headwaters of cold glacial tributaries in late summer and early fall (Chamberlain et al. 2001). Based on age data, it is thought that juvenile Bull Trout leave tributaries at around two years of age, and that Carpenter Reservoir Bull Trout rear in the Carpenter Reservoir and Middle Bridge

River until they reach sexual maturity at age six or seven years (Chamberlain et al. 2001). Because there were no small fish (under 225 mm) captured in 2000, it appears that Middle Bridge River is used for rearing only (Chamberlain et al. 2001).

The BRGMON-4 program, which started in 2012, conducted Bull Trout inventory and movements investigations over five years using radio telemetry to tag Bull Trout in Carpenter Reservoir and Middle Bridge River (BC Hydro 2011). Initial data from this work suggest that the fish community in Carpenter Reservoir is dominated by Bull Trout (Putt et al. 2018). A total of 642 Bull Trout (mean fork length 364 mm) were captured in the Year 1 and 2 monitoring field seasons. The 164 Bull Trout captured in 2000 in the Middle Bridge River had a mean fork length of 425 mm. More recently, a total of 317 Bull Trout (mean fork length 390.8 mm) were captured in the Year 5 (2017) monitoring field season. The fixed capture probability model estimated Year 5 adult Bull Trout abundance in Carpenter Reservoir to be 1,237 individuals (Putt et al. 2018).

As part of BRGMON-8, random index sampling was conducted in the lake to determine basic biological characteristics of the resident fish population. Sampling started in 2013, and the first five years of data of the 10-year study is currently available. During the first two years of the survey, only 13 Bull Trout ranging from 345 mm to 577 mm in size were captured by boat electrofishing (Sneep 2015). Sampling by boat electrofishing is difficult in lakes and can bias capture results; consequently, gill net sampling was adopted as the sampling method from 2015 onward (Sneep 2018). In 2017, a total of 45 Bull Trout were captured, ranging from 268 mm to 680 mm in size, with a mean fork length of approximately 454 mm. It is thought that the Bull Trout population in Seton Lake is adfluvial, likely spawning in the headwaters of the Seton River watershed (FWCP 2011). Although there is little information available on Bull Trout movements in Seton Lake, a Bull Trout tagged in Seton River as part of the BRGMON-9 studies was later recorded in Gates Creek, indicating that Bull Trout potentially move extensively through the Seton River watershed (Ramos-Espinoza et al. 2015).

Mountain Whitefish

Mountain Whitefish are native and common in the LAA. The species is provincially Yellow-listed (apparently secure) and has no status under COSEWIC (CDC 2020). Mountain Whitefish are not a priority species under the *Bridge-Seton Watershed Action Plan* (FWCP 2020).

In Carpenter Reservoir, Mountain Whitefish move between the reservoir and spawning habitat in Middle Bridge River (Tisdale 2013, Putt et al. 2018). During the BRGMON-4 program, a total of 560 Mountain Whitefish were captured in Carpenter Reservoir in 2013 and 2014, with a mean fork length of 226 mm (Putt et al. 2018). In Year 5 (2017), a total of 255 Mountain Whitefish were captured in Carpenter Reservoir, with a mean fork length of 260 mm.

In Seton Lake, during the BRGMON-8 random index sampling survey, only 10 Mountain Whitefish were captured in 2013 and 38 were captured in 2014 by boat electrofishing (Sneep 2015). In 2017, 16 individuals were captured by gill netting nearshore and offshore habitats (Sneep 2019). As with Bull Trout and Rainbow Trout, the use of boat electrofishing in lake habitat may result in low capture efficiencies; gill net sets were implemented from 2015 onwards as the sampling method (Sneep 2019). Mountain Whitefish can exhibit different life history patterns and are fall spawners (October and November) and most lake populations migrate into the streams to spawn (Sneep 2019).

Kokanee

Kokanee are the freshwater resident form of Sockeye Salmon (*Oncorhynchus nerka*) and are common in the LAA (McPhail 2007). Kokanee are identified as a priority species under the *Bridge-Seton Watershed Action Plan* (FWCP 2020).

Kokanee were stocked by the BC Government in Carpenter Reservoir between 1970 and 1973 (Chamberlain et al. 2001). Kokanee spawning surveys have been conducted over two years (2012 and 2013) in Carpenter Reservoir as part of BRGMON-4 (BC Hydro 2011). They are known to spawn in McDonald, Sucker, Girl, Truax, and Marshall Creeks, starting in mid-August and lasting until mid-September, with peak numbers at the end of August or beginning of September (Putt et al. 2016).

The Kokanee population in Seton Lake is a unique variant called Gwenish. Their skin colour turns black as they mature to spawning condition (Limnotek 2015). Unlike typical Kokanee, Gwenish in Seton Lake spawn in deep water at 20 m to 70 m, typically in November (Moreira 2014, Moreira and Taylor 2015, and Limnotek 2015). It is estimated that age at maturity for Kokanee in Seton Lake is two years (Morris and Caverly 2004).

Based on a littoral survey conducted in 2003, areas of unconsolidated-cobble and gravel beaches typically exhibiting lower gradient bottom slopes appeared to yield higher numbers of Gwenish than areas of steep rocky-rubble or rocky bedrock substrate (G3 Consulting 2003). Gill net surveys conducted in 2003 by Morris and Caverly (2004) confirmed Gwenish habitat at two locations in the middle of the north shore of Seton Lake, opposite Machute Creek at approximately 20 m in depth. Substrates at these sites were small gravels with some fines (Morris and Caverly 2004).

During the BRGMON-8 random index sampling survey conducted in 2013 and 2014, 24 Gwenish or Sockeye Salmon juveniles were captured by boat electrofishing in 2013, but none were captured in 2014 (Sneep 2015). Given the previously described difficulty in sampling lakes via boat electrofishing, gill netting was used as the sampling method of choice from 2015 onward. A total of 419 Gwenish individuals were captured in 2017. Gwenish were the most abundant species in the 2015, 2016, and 2017 annual resident fish sampling event and were therefore identified as being a well-suited target species for monitoring (Sneep 2019). Gwenish in Seton Lake ranged from age 1 to 3 years and Gwenish in Anderson Lake had a maximum age of 4 years, which is similar to the typical spawning age of Sockeye Salmon (Sneep 2019). According to the assessment, all *Oncorhynchus.nerka* greater than 75 mm but less than or equal to 130 mm in size were identified as Gwenish (Limnotek 2015, Sneep 2019). One estimate indicated a population of 67,700 for all life stages (FWCP 2011) and the adult population size has been estimated at approximately 5,000 (Moreira and Taylor 2015). Based on Deoxyribonucleic acid (DNA) analysis of trawl captures completed during BRGMON-6 surveys of outmigrating Sockeye Salmon fry from Anderson Lake to Seton Lake, Gwenish comprise 11% of the age zero population in Seton Lake (Limnotek 2015). Gwenish continues to be the favoured resident species in trend monitoring in Seton Lake due to their ecological and social value, their entire life cycle is carried out within the lake, and their potential for response to diversion effects. Additionally, the Seton and Anderson populations may not mix such that the indices of abundance and size, may specifically link to the conditions within the respective lake in which the population resides (Sneep 2019).

Anadromous Salmonids

Anadromous fish species are those that spawn in freshwater and out-migrate to the ocean as juveniles, living most of their adult lives in the ocean, before returning to freshwater to spawn. There are no anadromous fish species in Carpenter Reservoir because the Terzaghi Dam prevents upstream migration of anadromous fish from Lower Bridge River. Fish passage at Seton Dam provides anadromous fish access to Seton Lake from Seton River. Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*Oncorhynchus kisutch*), Sockeye Salmon (*Oncorhynchus nerka*), Pink Salmon (*Oncorhynchus gorbuscha*) and Steelhead (*Oncorhynchus mykiss*) are species of anadromous salmonids present in the Seton Lake portion of the RAA and LAA.

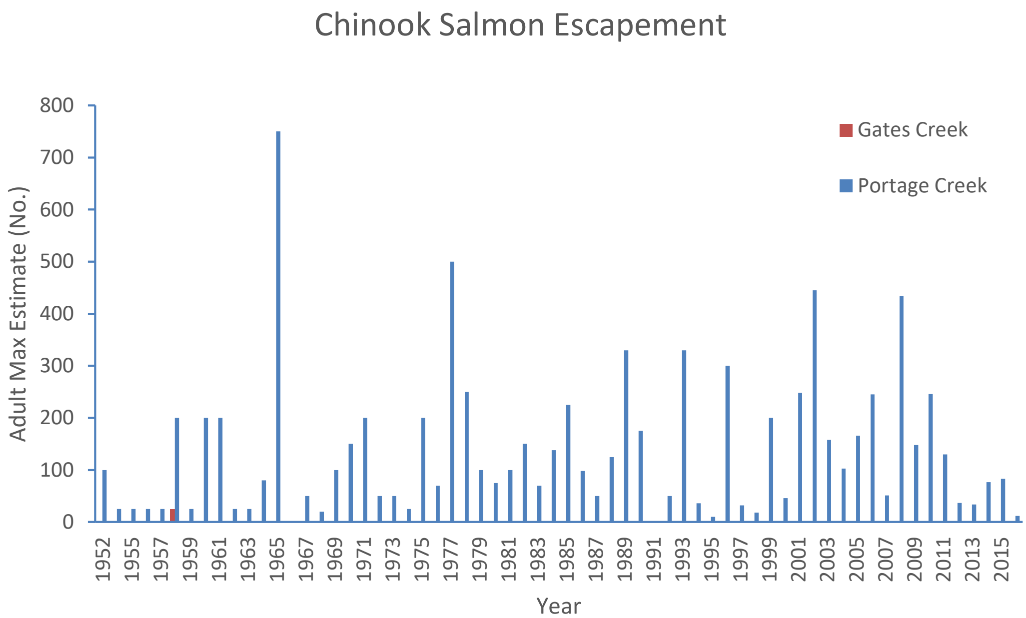
<u>Chinook Salmon</u>

Chinook Salmon are a provincially Yellow-listed species and under COSEWIC Middle Fraser, fall and spring populations are designated as Endangered and Threatened, respectively (COSEWIC 2018). Chinook Salmon are a high priority under the *Bridge-Seton Watershed Action Plan* (FWCP 2020).

Chinook Salmon in the Bridge and Seton river watersheds are classified as stream-type (DFO 2011). Following emergence, stream-type Chinook Salmon spend one or more years as juveniles in fresh water, typically in streams and rivers (DFO 2011). Their use of habitat in lakes is not well documented, although juvenile Chinook Salmon have been captured near the surface in some BC lakes (Roberge e al. 2001).

The Chinook Salmon population in the Seton River watershed is small compared to the population of the other anadromous fish species (BC Hydro 1995). Chinook Salmon spawning in Portage Creek migrate through Seton Lake between July 15 and August 31 (FWCP 2011, Komori 1997). Chinook Salmon were transplanted to Gates Creek in the 1940s, but the population does not appear to be viable (FWCP 2011). Recent studies in Gates Creek have not captured any juvenile Chinook Salmon or observed any spawning adults, suggesting this population no longer exists (Hillaby 2012, Lingard et al. 2013, Lingard et al. 2016). Escapement trends in Gates and Portage creeks are provided in **Figure 3.6**; however, not all years were sampled and observer efficiency may vary between years. Chinook Salmon ascend the fishway at Seton Dam, although there is some evidence that adult Chinook Salmon have difficulty with ascending the fishway (FWCP 2011, Pon et al. 2006). This population of fall run chinook spawning in Seton and Anderson watersheds has declined to very low levels and declines are anticipated to continue (COSEWIC 2018).

During the BRGMON-8 random index sampling survey conducted in 2013, three juvenile Chinook Salmon were captured by boat electrofishing in Seton Lake (Sneep 2015). No Chinook Salmon were captured by gill netting from 2015 onward (Sneep 2019). Based on the life history characteristics of Chinook Salmon, the low capture numbers are not unexpected, and there is no evidence of Chinook Salmon rearing within Seton Lake.



Source: DFO 2017

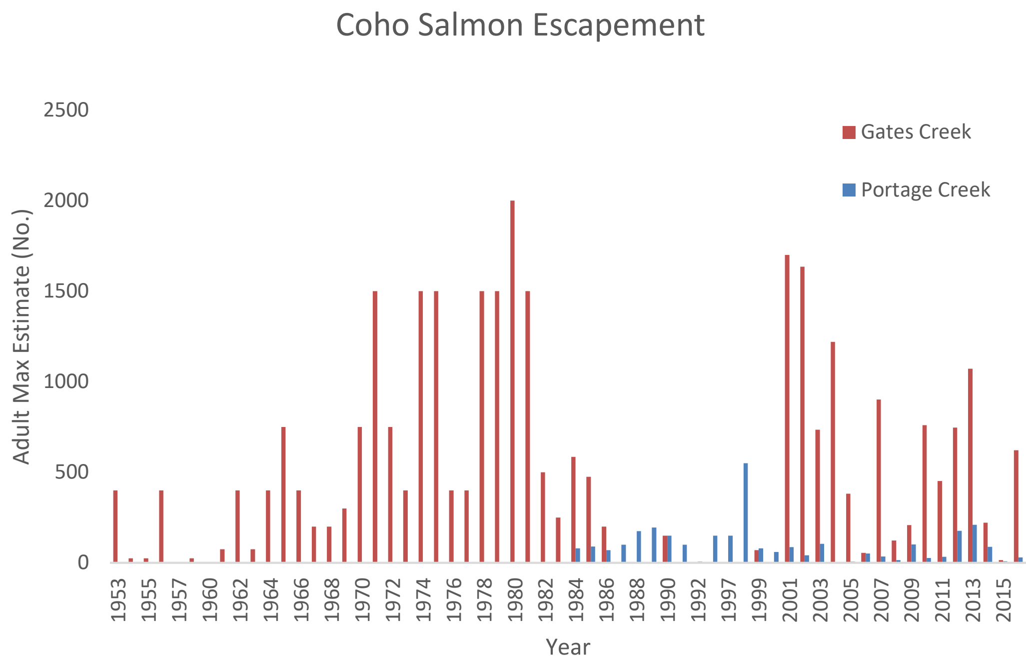
Figure 3.6 Chinook Salmon Escapement Trends

Coho Salmon

Coho Salmon in the LAA are considered Threatened, as they are part of the Interior Fraser River Population (pop. 7) and are genetically distinct from fish in the lower Fraser River (COSEWIC 2016). They are considered a high priority under the *Bridge-Seton Watershed Action Plan* (FWCP 2020).

Coho Salmon spawn throughout Gates Creek and downstream of Gates Lake, to the confluence with Anderson Lake. Spawning also takes place in some low-gradient tributaries to Anderson Lake, including D'Arcy Creek (Komori 1997). Rearing occurs along the entire length of Gates Creek and the foreshore of Anderson Lake near the confluence with Gates Creek (Hillaby 2012). Coho Salmon also spawn in Portage Creek, although in lower numbers than in Gates Creek (**Figure 3.7**, DFO 2017). Information on rearing within Portage Creek is limited.

During the BRGMON-8 random index sampling survey conducted in 2013, only five juvenile Coho Salmon were captured by boat electrofishing in Seton Lake (Sneep 2015). Gill netting was implemented from 2015 onward as the sampling method in Seton Lake and Anderson Lake. No Coho Salmon individuals were captured or reported as of 2017 (Sneep 2019). Coho Salmon do not use lake habitat extensively, except for upstream migration to spawning sites as adults and downstream outmigration in the spring (Groot and Margolis 1991). There is evidence of Coho Salmon rearing in the foreshore of Anderson Lake (Hillaby 2012), but this may be localized. There is no evidence of Coho Salmon rearing in Seton Lake. Coho Salmon escapement trends in the Gates and Portage Creeks are provided in **Figure 3.7**; however, not all years were sampled and observer efficiency and effort may vary between years.



Source: DFO 2017

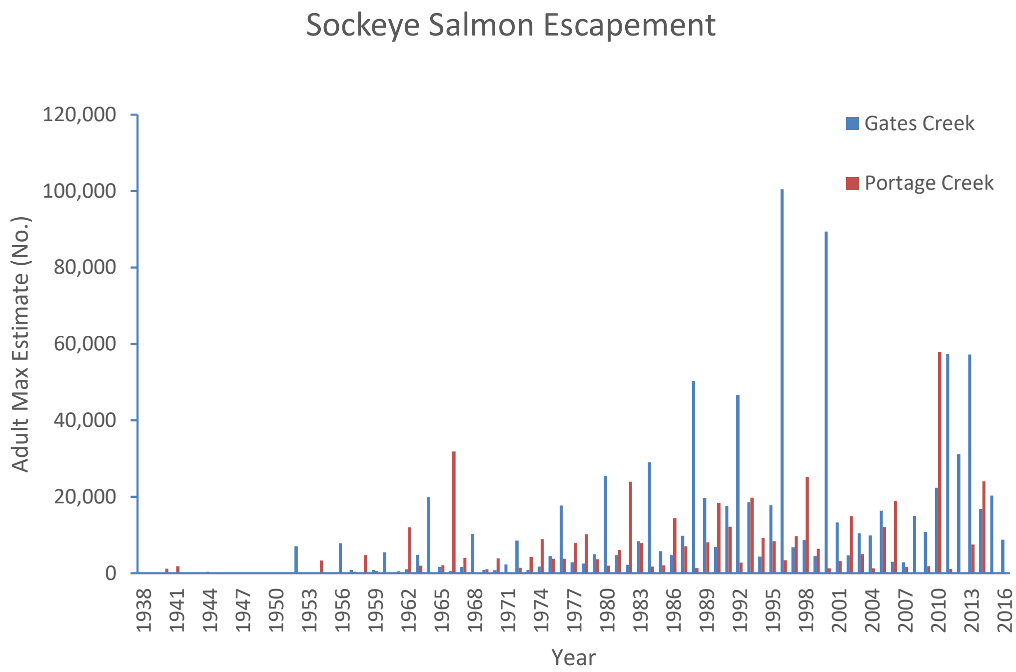
Figure 3.7 Coho Salmon Escapement Trends

Sockeye Salmon

Sockeye Salmon are not ranked provincially and the Seton Lake population (pop. 22) is designated as Endangered under COSEWIC (COSEWIC 2017). They are considered a high priority under the *Bridge-Seton Watershed Action Plan* (FWCP 2020).

There are two genetically distinct populations of Sockeye Salmon in Seton Lake, referring to the location where each population spawns. The Gates Creek population is an early summer run (based on timing through the lower Fraser River) with spawners migrating through Seton Lake and entering Gates Creek from late July to early September (Komori 1997). The Portage Creek population is a late summer run, with adults migrating through Seton Lake and entering Portage Creek from early September to late November (Komori 1997, Hopkins et al. 2015, Moreira and Taylor 2015). In Seton Lake, smolt outmigration occurs from mid-April until the end of May (Hopkins et al. 2015).

Sockeye Salmon are the most abundant anadromous fish species in the Seton River watershed (Golder 2002). A Sockeye Salmon spawning channel was constructed in Gates Creek in 1968 to enhance the Sockeye Salmon population in the Seton River watershed. Since then, a gravel replacement project in the spawning channel has been completed by DFO and FWCP to increase egg-to-fry survival (FWCP 2020). Future works in this spawning channel is considered a high priority under the *Bridge-Seton Watershed Action Plan* (FWCP 2020). The Portage Creek population is less abundant (Geen and Andrew 1961). Sockeye Salmon escapement trends in Gates and Portage creeks are provided in **Figure 3.8**; however, not all years were sampled and efficiency may not be equal between years.



Source: DFO 2017

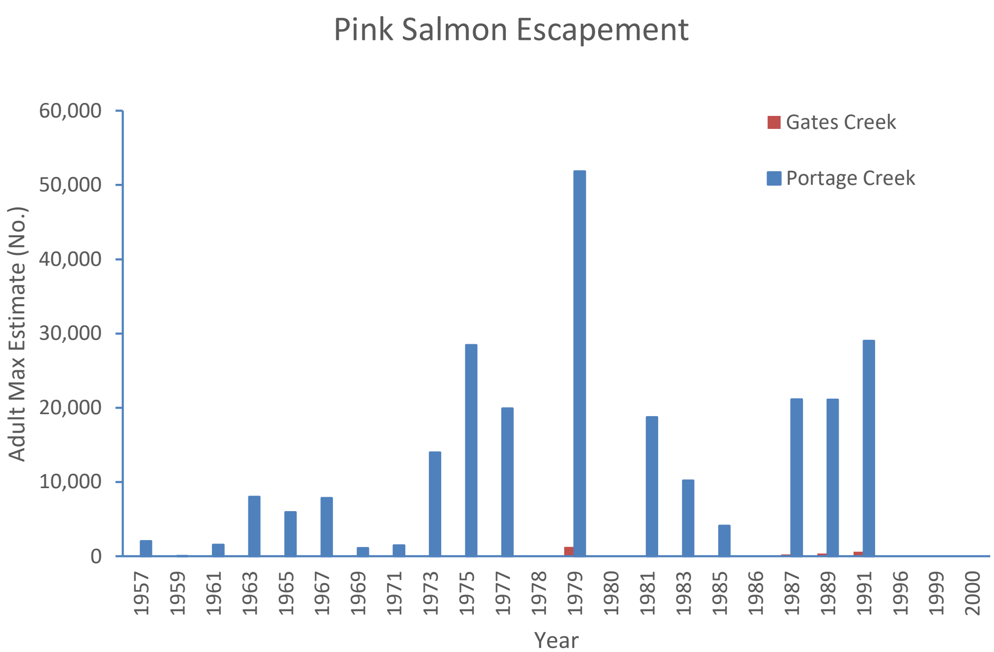
Figure 3.8 Sockeye Salmon Escapement Trends

Sockeye Salmon fry from the Portage Creek spawning populations move downstream to rear in Seton Lake shortly after emergence. A substantial portion of Sockeye Salmon fry from the Gates Creek spawning population migrate through Anderson Lake and also rear in Seton Lake (Moreira and Taylor 2015). Most Sockeye Salmon fry migrate to Seton Lake to rear for one year before they out-migrate to the ocean as age one smolts (Bell 1985, Limnotek 2015), although a small number out-migrate as young-of-the-year and age two smolts. DNA analysis of Sockeye Salmon from the summer trawl found that Gates Creek sockeye represent 56% of the juvenile fish captured in Seton Lake, while Portage Creek constitute 33%. The remaining 11% are juvenile Gwenish (Kokanee) (Limnotek 2015). Sockeye numbers have been declining since the late-1990s and abundance is considered close to the historical minimum (COSEWIC 2017).

Pink Salmon

Pink Salmon are not considered a management priority under the *Bridge-Seton Watershed Action Plan* (FWCP 2020) and have no status provincially or under COSEWIC (CDC 2020).

Pink Salmon in the Seton River watershed are an odd-year population that primarily spawn in large numbers in habitat located below the Seton Dam (BC Hydro 1995). Pink Salmon also spawn in Gates Creek, although the species is not considered abundant in the stream. The spawning distribution in Gates Creek is not well known, but carcasses have been observed at least 1.3 km upstream of the confluence with Anderson Lake (Lingard et al. 2016, Hillaby 2012). Pink Salmon also spawn extensively in Portage Creek (Golder 2002, Ramos-Espinoza et al. 2015). Escapement trends in Gates and Portage creeks are provided in **Figure 3.9**; however, not all years were sampled and efficiency between years may differ. An overview study of downstream fish passage conducted by BC Hydro in 1995 estimated that Pink Salmon escapement from above Seton Dam (Portage Creek) was 50,000 to 53,000 adults. In 2013, the BRGMON-14 estimated that 87,032 Pink Salmon migrated through the Seton Dam (Casselman et al. 2016).



Source: DFO 2017

Figure 3.9 Pink Salmon Escapement Trends

Based on its life-history characteristics, Pink Salmon only use Seton Lake while migrating to spawning grounds upstream of Seton Lake or as fry during outmigration. Consequently, Pink Salmon are only present in Seton Lake for a short period each year. No Pink Salmon were captured in Seton Lake during the BRGMON-8 random index sampling survey in either June or September 2013 (Sneep 2015). No Pink Salmon were captured in Seton Lake during BRGMON-8 gill netting sampling from 2015 to 2017 (Sneep 2019). The lack of capture during the two sampling events is consistent with the life history characteristics of this species.

Steelhead

Steelhead in the Bridge and Seton River watersheds belong to the interior Fraser River group (McPhail 2007, Webb et al. 2001). They are considered a priority species by the BC Government under the *Bridge-Seton Watershed Action Plan* (FWCP 2020). COSEWIC undertook an emergency assessment of the Interior steelhead trout population in January 2018, because of an imminent threat to the survival of the species. This assessment resulted in a COSEWIC status of Endangered for both the Thompson and Chilcotin River populations but did not include steelhead in the Bridge and Seton rivers. This Steelhead population is currently provincially Yellow-listed and has no COSEWIC status (CDC 2020). The decline in steelhead populations may be linked to reduced ocean survival and adult by-catch in salmon fisheries, although habitat degradation, increased water temperatures, and reduced flows may all play a part in the population reduction (Levy and Parkinson 2014, Kendall et al. 2017).

Steelhead spawning is known to occur downstream of Seton Dam, mostly in the Cayoosh Creek compensation channel (a man-made channel near the powerhouse on Cayoosh Creek) and in Seton River (Webb et al. 2001). Steelhead have moved upstream through the fishway at Seton Dam and into the power canal, where they have been captured during trash rack maintenance. In addition, a single steelhead smolt was captured in the Seton power canal in 1999 (R.L. and L. Environmental Services Ltd. 1999). No steelhead have been documented spawning in the Seton River watershed upstream of the dam (Webb et al. 2001).

Fish Habitat

Fish habitat includes physical habitat for rearing, adult holding and feeding, overwintering, and spawning, as well as other measures of fish habitat including food availability, measured as productivity (e.g., phytoplankton and zooplankton), and water quality parameters (e.g., water temperature, total dissolved gas). Information on locations of important fish habitat, habitat quality, productivity, and water quality in the LAA is provided below.

<u>Habitat Availability</u>

Tributaries within the full-pool area of Carpenter Reservoir provide spawning habitat for Kokanee, Rainbow Trout, and Mountain Whitefish (Putt et al. 2018). Habitat investigations concluded that most tributaries have limited stream lengths accessible to fish due to steep gradient and barriers, limited spawning gravels substrates, and lack of cover due to reservoir drawdown (Perrin et al. 2016). Spawning habitat for Mountain Whitefish may also be present in the reservoir, although no known areas of Mountain Whitefish spawning have been identified. No other salmonid species likely spawn in the reservoir.

Carpenter Reservoir provides rearing habitat for a number of salmonids, including Mountain Whitefish, Kokanee, and Rainbow Trout (Putt et al. 2018). The reservoir provides adult feeding and holding habitat for Mountain Whitefish, Kokanee, and Rainbow Trout, and Bull Trout (Putt et al. 2018). Mountain Whitefish juveniles and adults as well as Rainbow Trout juveniles from tributaries may use the reservoir for overwintering habitat. Resident fish may move through the reservoir upstream to spawn in tributaries, but Terzaghi Dam is an impassable barrier between Carpenter Reservoir and the Lower Bridge River.

Seton Lake provides spawning habitat for Gwenish (Kokanee) (Moreira 2014). Gwenish spawn in the deeper parts of the lake, although little is known about the exact nature of the spawning substrate or location (Moreira 2014). Although suitable shore spawning areas for Sockeye Salmon may be available in Seton Lake, Sockeye Salmon shore spawning has not been observed in the lake. No other salmonid is known to use habitat in Seton Lake for spawning.

Seton Lake provides rearing habitat for Sockeye Salmon, Gwenish, Rainbow Trout, and sub-adult Bull Trout (rearing for several years likely occurs in tributary streams) (Sneep 2015). Adult Bull Trout, Kokanee, Rainbow Trout, and Mountain Whitefish all use habitat within the lake for feeding and holding (Sneep 2015). Sockeye Salmon juveniles from Anderson Lake appear to move into Seton Lake to overwinter prior to smoltification and outmigration in the following spring (Geen and Andrew 1961). The proportion of Anderson Lake Sockeye Salmon that undertake this overwintering migration is not known.

Seton Lake provides an important migration corridor for a number of salmonid species. Sockeye, Coho, Chinook, and Pink Salmon all move through Seton Lake as part of spawning migrations as adults and smolt outmigration (Geen and Andrew 1961, Komori 1997). Bull Trout and steelhead may also migrate through the lake to upstream areas, but the extent is unknown (Webb et al. 2001).

Productivity and Food Availability

Phytoplankton and zooplankton communities vary according to physical and chemical parameters such as light, temperature, and nutrient regime (Wetzel 1983). Zooplankton feed on phytoplankton, and zooplankton communities are fed upon by fishes including salmonids. Changes in reservoir residence times or water retention time (the amount of water stored divided by the rate of inflow or outflow) can increase or decrease the growing period for zooplankton in the reservoir (Perrin et al. 2016). Longer reservoir residence times can provide more time for growth that would increase the productivity of the reservoir and food availability for fish.

Water temperature, turbidity, and dissolved inorganic nitrogen are the significant determinants of periphyton and zooplankton production in Carpenter Reservoir (Perrin et al. 2016). Warmer water with low turbidity favours zooplankton but is limited to the top 10 m of the water column from May through September (Perrin et al. 2016). Rising water temperature in late summer favours zooplankton, despite rising turbidity in the reservoir. Fall is the optimum time for biological production in Carpenter Reservoir when suitable water temperatures and rising nutrient concentrations drive metabolic activity (Perrin et al. 2016). Zooplankton populations are dominated by cladocerans, mostly *Daphnia* spp. Periphyton chlorophytes are predominantly *Spirogyra* spp. Periphyton biomass (chlorophyll-a) is higher in areas with greater accumulations of photosynthetically active radiation (PAR), warmer water, and higher concentrations of dissolved inorganic nitrogen (Perrin et al. 2016). The short growing season in fall and limited light due to turbid water may limit food production for fish. Combined with a short water retention time in the reservoir, primary and secondary productivity in the Carpenter Reservoir may be limiting fish production (Griffith 1999).

Seton Lake has lower productivity and lower plankton density than observed upstream in Anderson Lake (Geen and Andrew 1961, Limnotek 2015, Moreira 2014, Moreira and Taylor 2015). The average chlorophyll concentration in Seton Lake was 1.49 µg/L during a study conducted in 2000 (Shortreed et al. 2001). In the littoral zone, a shift in periphyton composition occurs between spring and summer when chlorophytes (*Spirogyra* spp.) become more abundant (Perrin et al. 2016). The average zooplankton biomass in Seton Lake is 422 mg dry wt/m^2, which is considered lower than in most other rearing lakes of Fraser River Sockeye Salmon (Shortreed et al. 2001, Limnotek 2015). The majority of the zooplankton community in May is comprised of cyclopoids (85% or more) but shifts to 70% or more Cladocerans (*Daphnia* sp.) later in the season (Shortreed et al. 2001, Perrin et al. 2016). Despite the lower productivity in Seton Lake, juvenile Sockeye Salmon are larger than those in Anderson Lake (Geen and Andrew 1961, Limnotek 2015).

Water Quality

Water quality, including water temperature, is important for survival and productivity of salmonids. Each salmonid species has a preferred optimal temperature range that varies with life stage (BCMOE 2001). Exposure to temperatures higher than optimal levels can reduce reproductive success and growth, and ultimately lead to death (BCMOE 2001). Water temperatures in the Bridge River System are primarily determined by glaciers originating in the La Joie Basin but can be changed through operations activities such as low reservoir elevations or flow releases. For example, flow release from the La Joie Dam can reduce seasonal temperature variation, which results in a relatively uniform water temperature. Surface water temperature in the reservoirs can exceed the optimal rearing temperature ranges for both Rainbow Trout and Bull Trout in the summer months. In Carpenter Reservoir and Seton Lake, summer maximum surface water temperatures have been recorded as high as 18°C, 20°C, and 22°C, respectively. This makes deeper, cooler water in the reservoirs an important refuge for fish in the summer months.

3.4.2 Effects Assessment

The Project has the potential to affect Fish and Fish Habitat in the LAA resulting from reduced water conveyance capacity through Bridge River 1 during the unit outages. To understand the potential effects, BC Hydro undertook two modelling studies to determine the likelihood of higher flows on Lower Bridge River and Seton River impacting fish and fish habitat. The likelihood was determined by calculating the percentage of years where a specified threshold would be exceeded out of 53 years of inflow data. Specified thresholds were determined considering:

- Season: specific time periods relevant for the fish species present in Lower Bridge River and Seton River.
- Threshold: flow velocities known to affect fish species present in Lower Bridge River and Seton River and their habitats.

Each outage scenario was compared to baseline conditions (likelihood of higher flows with no outage), to determine if the outage would result in an increased likelihood of higher flows (increased risk).

Planned Outages

To manage potential effects to Fish and Fish Habitat through changes in Water Quantity, the unit replacements will be sequenced (i.e., take one unit out at a time) starting with the least reliable unit. To quantify the potential effects of a single unit outage, several outage durations were modelled, including the [redacted] outage durations to represent potential schedule delays. The results of the analysis demonstrate that potential impacts to Water Quantity and Fish and Fish Habitat associated with the Project outage are negligible, with the likelihood calculated for all options approximating the baseline (**Appendix A; Table 3.4**).

Table 3.4 Percentage of Years with High Impact Flows on the Lower Bridge River and Seton River During 8-, 10-, or 12- Month Project Outages

River	Season	Threshold Flow (m^3/s)	Baseline	Planned Outage Duration		
				8-month Outage	10-month Outage	12-month Outage
Lower Bridge River	Winter (Jan 1 - Mar 31)	>15	0%	0%	0%	0%
	Spring (Apr 1 - May 31)	>60	0%	0%	0%	0%
	Spring-Summer (Jun 1 - Jul 31)	>60	0%	0%	0%	1%
	Summer-Fall (Aug 1 - Sep 30)	>30	0%	1%	1%	2%
	Fall-Winter (Oct 1 - Dec 31)	>15	0%	1%	0%	0%
Seton River	Winter (Nov 16 - Apr 14)	>60	0%	0%	0%	0%
	Spring (Apr 15 - May 31)	>100	6%	6%	5%	4%
	Spring-Summer (Jun 1 - Jul 31)	>120	5%	5%	5%	6%
	Summer-Fall (Aug 1 - Nov 15)	>60	19%	18%	18%	19%

Once completed, the Project will result in environmental benefits associated with improved reliability and increased flexibility in water conveyance from Carpenter Reservoir to Seton Lake. Specifically, the increased total potential capacity of the new units provides flexibility in the event that one unit is out of service. In this situation, BC Hydro can transfer lost generating capacity from the one unit to the three remaining units to maintain water conveyance. BC Hydro would only use the increased capacity in the event of a unit outage as total diversion rate is limited by the three existing water licences associated with the generating station. The flexibility in water conveyance and the increased reliability of the new equipment improves the ability to maintain water conveyance and reduces the likelihood of higher flows from Terzaghi to the Lower Bridge River.

Forced Outages

If during the planned outage additional units fail and are forced out of service, further changes to Water Quantity could result. To quantify the potential effects of multiple unit outages, additional modelling was undertaken to review scenarios where more than one unit is forced out of service during the [redacted] outage. Scenarios considered were: Generic (no units out of service); Alternative 1 (one unit out of service; planned outage); Alternative 2 (two units out of service; planned outage and one additional unit); Alternative 3 (three units out of service; planned outage and two additional units); and Alternative 4 (four units out of service; planned outage and three additional units).

The results of the analysis demonstrate that potential effects to Water Quantity and Fish and Fish Habitat increase as additional units are taken out of service (**Table 3.5**). The results indicate that the increased likelihood of higher flows to Lower Bridge River is nominal with one and two units out of service (0% to 8% for all seasons). However, with three and four units out of service the likelihood of higher flows to Lower Bridge River after [redacted] increases by 11% to 17% and 32% to 39%, respectively. This analysis highlights the need to address the aging generating equipment to reduce the risk of concurrent forced outages.

Table 3.5 Percentage of Years with Flows that Exceed the WUP Order Target Flow Schedule During Forced Outages.

River	Season	Criteria (m^3/s)	Baseline	Alternative: Number of Units Out of Service			
				1	2	3	4
Lower Bridge River	Winter (Jan 1 - Mar 31)	>3	0%	0%	0%	2%	4%
	Spring (Apr 1 - May 31)	>14	0%	0%	0%	2%	2%
	Spring-Summer (Jun 1 - Jul 31)	>15	0%	0%	0%	2%	2%
	Summer-Fall (Aug 1 - Sep 30)	>12.9	4%	6%	9%	21%	43%
	Fall-Winter (Oct 1 - Dec 31)	>1.5	0%	4%	8%	11%	32%
Seton River	Winter (Nov 16 - Apr 14)	>32	30%	38%	42%	32%	72%
	Spring (Apr 15 - May 31)	> 32	70%	75%	75%	83%	85%
	Spring-Summer (Jun 1 - Jul 31)	>36	79%	81%	81%	87%	87%
	Summer-Fall (Aug 1 - Nov 15)	>26	45%	42%	49%	42%	47%

4.0 SOCIO-ECONOMIC ASSESSMENT

This section describes existing socio-economic conditions in the vicinity of the proposed Project, including a rationale for the selection of the socio-economic VCs. The potential for Project-related interactions is considered, potential effects are identified, and mitigation measures are proposed.

A separate baseline report has been prepared describing the existing conditions and priority areas for Indigenous and non-Indigenous communities near the Project area (**Appendix B**). This section presents a summary of relevant baseline information as it pertains to each VC. Additional details on existing conditions and full community profiles can be found in **Appendix B**.

The information provided in this section was gathered through ongoing engagement with St'át'imc Nation, from publicly available sources, and from the Project's Construction Management Plan (BC Hydro 2019a). For each community, there is a variable amount of publicly available information; therefore, some of the sections below have more information than others, and additional context may be gathered through community review and further engagement. In addition, Statistics Canada supresses data for small populations to protect anonymity. Communities with larger populations also typically have more community service organizations that publish reports and receive more attention in regional reports, creating more access to information.

4.1 Issues Scoping

The purpose of Issues Scoping is to focus the assessment on key issues that have the potential to affect the socio-economic environment of communities and populations in proximity to the Project. These key issues were determined through the identification of the potential interactions of the Project components and activities with the socio-economic environment, input received from St'át'imc Nation on similar past BC Hydro projects and use of professional judgement and scientific and regulatory considerations.

BC Hydro has been working with the St'át'imc Nation and the St'át'imc communities for several decades in regard to their interests and concerns related to the Bridge River System. BC Hydro undertook a similar project in 2018 with the Bridge River 2, Units 5 and 6 Replacement Project and is currently undertaking work to replace Unit 7 and 8. Interests and concerns were raised by St'át'imc with regard to the construction phase of these projects, in addition to the long history of in-depth discussions about the Bridge River system. Specifically, the St'át'imc community of Tsal̓álh, adjacent to the Bridge River Generating Station, raised concerns related to workers coming into the local area, including inappropriate and illegal activities, cultural insensitivity, and traffic safety. These safety concerns also extend to other St'át'imc communities and Lillooet. With the recent COVID-19 pandemic, there are additional concerns related to an influx of workers and potential impacts on community health. This background has informed the understanding of issues and concerns and what the potential socio-economic impacts of this project may be.

The Project construction and operations is anticipated to create employment and procurement opportunities for local residents and businesses but will also require workers from outside the study area, which would create a temporary influx of workers to the local communities. This influx of workers may, in turn, increase the pressure on local services and infrastructure, such as temporary accommodation, health services and policing and emergency services. The presence of non-local workers may also interfere with cultural practices and community wellbeing should their presence have a negative influence on community activities. In addition, Project transportation activities may create additional vehicle traffic and additional demand on regional transportation infrastructure. Project-related hazards may also increase pressure on local emergency services, including fire, ambulance, and police if accidents occur.

Table 4.1 summarizes the potential effects identified for each VC.

Table 4.1 Rationale for Selection of Socio-Economic Valued Components

Candidate VC	Rationale	Indicators
Labour Force	Construction of the Project is expected to provide employment and procurement opportunities for local workers and businesses, but also to require workers from outside the local area. Local employment and procurement are community benefits arising from the Project. The presence of non-local workers can, in turn, have negative effects as discussed in community safety and wellbeing. Local stakeholders and St'át'imc Nation have expressed interest in employment opportunities from the Project. **Included as Valued Component**	Changes in demand for local labor Changes in demand for non-local labor
Housing and Accommodation	Non-local workers will require temporary accommodation while working on the Project. Increase demand for accommodation could affect rental prices and or availability of temporary accommodation (e.g. hotel, motel, rental accommodation). **Included as Valued Component**	Changes in demand for local accommodation Changes in local accommodation availability
Community Safety and Wellbeing	The influx of non-local workers has the potential to affect local community sense of safety and wellbeing by potentially interfering with cultural activities or by increasing negative social behaviors (e.g., substance abuse, etc.). This could result in additional harm to already vulnerable populations. The influx of non-local worker can also have negative effects on community services (e.g. emergency, health, and policing). Local stakeholders and the St'át'imc Nation have raised concerns related to workers coming into the local area, including inappropriate and illegal activities and cultural insensitivity. **Included as Valued Component**	Influx of non-local workers Changes in community safety and wellbeing Change in demand for local emergency, health, and policing services
Transportation and Traffic	Transportation of workers, equipment and materials could create additional traffic on highways and local roads and increase congestion and the potential for motor vehicle accidents. Increase in traffic during construction activities, and associated effects on road safety, were raised as a concern by local stakeholders and the St'át'imc Nation. **Included as Valued Component**	Changes in traffic volumes

4.2 Assessment Boundaries

BC Hydro's Bridge River System is located entirely in St'át'imc Territory and in the Squamish Lillooet Regional District (SLRD).

The proposed LAA for the Project is defined as the St'át'imc Nation communities of Tsal'álh, T'it'qet, Sekw'el'was, Xwísten and N'Quatqua; the unincorporated community of Seton Portage; and the District of Lillooet, and encompasses the area where the Project is expected to interact with and potentially create direct or indirect effects on socio-economic conditions, such as demand for employment and accommodation.

The proposed RAA for the Project is defined as Electoral Areas A, B and C of the Squamish – Lillooet Regional District, including Seton Portage and the District of Lillooet; and includes the identified St'át'imc communities of Tsal'álh, T'it'qet, Xwísten, Sekw'el'was and N'Quatqua. Electoral Areas A B, and C sit within the broader St'át'imc Nation territory.

Temporal boundaries are defined as the approximately 5-year construction and commissioning schedule for the proposed Project.

4.3 Labour Force

The Project has the potential to interact with socio-economic conditions in those communities most likely affected by Project construction activities. The Project will require a construction workforce as well as the procurement of goods and services, which may create employment and business opportunities in the region. Project labour demands would also require bringing workers form outside the local area, which may create an influx of non-local residents to the LAA.

This section assesses potential effects of the Project on the Labour Force VC, including a description of the existing labour force conditions in the LAA and RAA. This section also identifies potential interactions with the labour force during Project construction, identifies potential effects and proposes mitigation measures to address potential Project-related effects.

4.3.1 Existing Conditions

Population

The Project is located in the St'át'imc Territory and in the rural Electoral area B of the SLRD, immediately adjacent to Tsal'álh and seven km east of the community of Seton Portage. Seton Portage is a small rural community located between Anderson Lake and Seton Lake, approximately 7 km south-west of Slosh IR, with a mix of permanent residents and seasonal homes. The District of Lillooet is the largest population centre in the LAA and is the economic and services hub for the communities in SLRD Areas A and B and is located approximately 65 km east of Project via Lillooet Pioneer Road 40.

Tsal'álh (formerly known as Seton Lake Band) is located adjacent to the Bridge River 1 Generating station and has nine reserves (IR): Mission 5, Necait 6, Nzaw't 4A, Seton Lake 5A, Seton Lake 7, Silicon 2 and Slosh 1, Slosh 1A and Whitecap 1 (INAC 2020a). The main populated reserve of the Tsal'álh is Slosh 1 and data availability on Statistics Canada is limited to the Slosh 1, and therefore only Slosh 1 is used in the tables below.

T’it’q’et (formerly known as Lillooet Indian Band) is located near Lillooet and has seven reserves in the Lillooet area, Kilchult 3, Lillooet 1, Lillooet 1A, McCartney’s Flat 4, Riley Creek 1B, Seton Lake 5, and Towinock 2 (First Nations Land Management Resource Centre 2020, INAC 2020b). The main populated reserve of the T’it’q’et community is Lillooet 1 IR. Data availability on Statistics Canada is limited to the Lillooet 1 IR, and therefore only Lillooet 1 IR is used in the tables below.

Xwísten (formerly Bridge River Indian Band) is located approximately 9km northwest of the town of Lillooet. Xwísten have three reserves, Bridge River 1, Bridge River 2, and Lillooet 1A (shared with T’it’q’et) (INAC 2020c). The main reserve of the Xwísten is the Bridge River 1 IR.

N’Quatqua is located near D’Arcy, a small unincorporated St’át’imc and non-Indigenous community situated at the head of Anderson Lake, approximately 43 km northeast of Pemberton and 36 km southwest of Bridge River 1. N’Quatqua has six reserves, Anderson Lake 5, Nequatque 1, Nequatque 2, Nequatque 3, Nequatque 3A and Nequatque 4 (INAC 2020d). Of these six reserves, Nequatque 1, Nequatque 2, and Nequatque 3A, are represented in Statistics Canada data together. The data for the Nequatque reserves will be used in the tables below because of its focus on the D’Arcy area.

Sekw’el’was (formerly Cayoosh Creek Indian Band) is located near to Lillooet and has three reserves in the Lillooet area, Cayoosh Creek 1, Pashilqua 2 and Pashilqua 2A. The main community is Cayoosh Creek 1 which services the three Sekw’el’was reserves (Stl’atl’imx Tribal Police Service 2020). For Sekw’el’was, data from Cayoosh Creek 1 reserve is the only data available on Statistics Canada and was used to inform the tables below.

Population data for the communities in the LAA and RAA are summarized in **Table 4.2**

Table 4.2 Population of Communities in the Local and Regional Study Areas

Community	Population (2016 Canadian Census)	Percent Change (2011 to 2016)	Percentage of Indigenous Population
Slosh 1 IR (Tsal̓álh)	177	-20.6	95.5
Lillooet 1 IR (T’it’qet)	243	9.5	95.2
McCartney’s Flat 4 IR (T’it’qet)	26	NA	NA
Bridge River 1 IR (Xwísten)	241	+2.1	97.9
Nequatque 1, 2, 3A IR (N’Quatqua)	132	-54.8	92.6
Cayoosh Creek 1 IR (Sekw’el’was)	66	+22.2	76.9
Seton Portage, Unincorporated Community/Shalath	46	-17.9	44.4
District of Lillooet	2,275	-1.02	25.8
Squamish Lillooet Regional District	42,665	+11.8	12.2

Source: Statistics Canada 2017

Labour Force Characteristics

Labour force participation in the LAA communities ranges from 47.8% in Nequatque to 57% in Lillooet; these values are below the provincial average of 63.9%. In general, unemployment rates in the LAA communities are higher than those in the overall regional district or in the province. Unemployment rates in the St’át’imc communities tend to be higher than in Lillooet and in BC.

The main areas of employment in the St’át’imc communities are public administration, educational services, health care and social assistance, and agriculture, forestry, fishing, and hunting. Lillooet has a more diverse range of industries in which residents work. In Lillooet approximately, 14.8% of the population works in retail trade, 11.4% works in transportation and warehousing, and 11.4% works in health care and social assistance. Education, agriculture, forestry, fishing, and hunting, manufacturing, public administration, and accommodation and food services are other common industries in Lillooet (Statistics Canada 2017). Because of data suppression the full range of industries of employment for Indigenous communities is likely not fully represented by Statistics Canada data.

According to an SLRD economic report, communities in Electoral Areas A and B (e.g., Lillooet, Seton Portage, and Shalalth) are increasingly challenged in attempting to grow their economies. Northern communities have been severely affected by the decline in logging and sawmill industries over the last few decades. This has contributed to economic hardship in the northern areas of the SLRD along with a trend of younger community members moving away to find work (Squamish Lillooet Regional District 2012). Labour force characteristics of the LAA and RAA communities are summarized in **Table 4.3**.

Table 4.3 Labour Force Characteristics, 2016

Community	Main Industries of Employment	Participation Rate[1]	Unemployment Rate[2]
Slosh 1 IR (Tsal̓álh)	Public administration – 26.7% Educational service – 26.7% Construction – 13.3%	53.6%	13.3
Lillooet 1 IR (T’it’qet)	Public administration – 26.7% Health care and social assistance – 13.3% Construction – 13.3% Retail and trade – 13.3%	47.2%	29.4
Bridge River 1 IR (Xwísten)	Public administration – 27.8% Health care and social assistance – 16.7% Agriculture, forestry, fishing, and hunting – 11.1% Construction – 11.1% Retail Trade – 11.1%;	52.8%	26.3
Nequatque 1, 2, 3A IR (N’Quatqua)	Public administration – 27.3% Health care and social assistance – 18.2% Agriculture, forestry, fishing, and hunting – 18.2% Retail and trade – 18.2%	47.8%	18.2
Cayoosh Creek 1 IR (Sekw’el’was)	Health care and social assistance – 40% Retail trade – 40%	50%	n/a

Community	Main Industries of Employment	Participation Rate[1]	Unemployment Rate[2]
Seton Portage, Unincorporated Community/Shalath	Utilities; Retail trade; Transportation and warehousing; and Public administration	50%	0%
District of Lillooet	Retail trade - 14.8% Transportation and warehousing – 11.4% Health care and social assistance – 11.4%. Education Services – 9.0% Public administration – 8.1% Accommodation and food services – 7.6% Agriculture, forestry, fishing, and hunting - 7.6% Manufacturing – 5.2%	57.7%	10%
Squamish Lillooet Regional District	-	75.7	6.1%
British Columbia	-	63.9	6.7%

Note: (1) "Participation Rate" refers to the number of people in the labour force in the week prior to Census Day, as a percentage of the population 15 years and over.
(2) "Unemployment Rate" refers to the number of people unemployed in the week prior to Census Day expressed as a percentage of the labour force.

Source: Statistics Canada 2017

To identify the potential for local labour integration in Project activities, available information on Educational attainment is also summarized in **Table 4.4.** Statistics Canada data shows that relative to the Province, residents of the LAA are more likely to have incomplete high school education and are less likely to have post secondary degrees. The percentage of the adult population (15 years and older) with no certificate, diploma or degree ranged from 33.3% for adults on the Bridge River 1 reserve to 21.5% of adults in Lillooet, compared to 15.5% for adults in BC. A detailed baseline account for each community is included in **Appendix B**.

Table 4.4 Highest Educational Attainment (percent of population 15 years and over)

Community	No Certificate, Diploma or Degree	Secondary School Diploma or Equivalency Certificate	Apprenticeship or Trades Certificate	Post Secondary Certificate, Diploma, or Degree
Slosh 1 IR (Tsal'álh)	28.6	28.6	11.4	28.6
Lillooet 1 IR (T'it'qet)	31	28.6	11.9	28.6
Bridge River 1 IR (Xwísten)	33.3	36.1	5.5	25
Nequatque 1, 2, 3A IR (N'Quatqua)*	27.3	54.5	13.6	22.7
Cayoosh Creek 1 IR (Sekw'el'was)	41.7	25	16.7	16.7
Seton Portage / Shalalth*	62.5	25	0	25
District of Lillooet*	21.5	29.9	13.9	34.9
BC	15.5	29.4	8.8	46.3

Note: *Totals do not add up to 100% due to rounding at the source.

Source: Statistics Canada 2017

4.3.2 Effects Assessment

The Project will require a labour force comprised of a range of tradespeople, engineers, heavy equipment operators, labourers, and others. Filling the labour-force requirements arising from the Project presents an opportunity to create employment and business opportunities for local communities. The ability of local residents and St'át'imc members to benefit from these opportunities would depend on their skills and occupational training, as well as ongoing engagement between BC Hydro and St'át'imc to identify opportunities.

The construction phase of the Project is anticipated to commence in 2025 and to last approximately 5 years. The facilities have not seen major upgrades since they were built between 1948 and 1960. The Bridge River 1 Generating Station was commissioned in 1954. The replacement of the aging equipment will improve reliability, restore licenced flow capacity, and increase operating flexibility of the Bridge River 1 Generating Station. The type and degree of specialization of skills required vary across Project activities.

At this definition stage, detailed labour and cost information was not available for all Project activities. However, based on past unit upgrades, the anticipated labour force requirements will be approximately 56 workers at the peak of construction during unit assembly, with typical monthly numbers of approximately 40-50 workers on-site (BC Hydro 2019a).

In addition to direct jobs, other indirect and induced jobs would be created in local supplier industries (e.g. equipment rentals, fuel suppliers, transportation services, accommodation etc.) and as a result of increased consumer spending.

It is expected that BC Hydro will define specific work packages and contract out the majority of the work during the construction phase either through a public tendering process or direct awards to St'át'imc designated businesses through an agreed process (BC Hydro, 2019). Personnel hiring decisions would ultimately rest with the contractors; however, BC Hydro will work closely with contractors and local communities to identify local hire opportunities.

The LAA has a relatively limited labour force that would not meet all the needs of the Project, so it is anticipated that many workers will come from outside the LAA. The overall effects of the Project on local employment and businesses are anticipated to be positive, but small. While mitigation is not required, BC Hydro will enhance local benefits by identifying opportunities to increase employment and procurement from local suppliers. BC Hydro recognizes commitments in the 2011 Settlement Agreements and the 2019 High Flow Settlement Agreement between BC Hydro and St'át'imc Nation, and will continue working on their implementation, including by supporting information sharing and collaboration on business, employment, education and training opportunities.

4.4 Housing and Accommodation

As discussed in the previous section, most of the labour force is expected to be sourced from communities outside of the LAA and, therefore, will require local accommodation while working on the Project. Given the duration of the construction activities and the rotation schedules in the construction industry, it is not anticipated that workers would bring their families or relocate to the study area permanently. Instead, non-local contractors are expected to use temporary accommodations (e.g. hotels, motels, guesthouses) and rental accommodations (e.g. apartments) in the LAA.

This section assesses potential effects of the Project on the Housing and Accommodation VC, including a description of the existing conditions in the LAA. This section also identifies potential interactions with the housing and accommodation market during Project construction, identifies potential Project effects and proposes mitigation measures to address potential Project-related effects.

4.4.1 Existing Conditions

Temporary accommodation in the LAA includes hotels, motels, bed-and-breakfasts, as well as campgrounds and recreational vehicle (RV) sites. Temporary accommodation serves the tourism industry, but also short-term housing needs of business travellers.

Generally, the smaller LAA communities have limited temporary accommodation capacity. Accommodation for visitors is available in Seton Portage at Lil'tem Mountain Hotel and Crane's Landing Recreational Vehicle (RV) park with rental RVs available, both owned and operated by Tsal̓álh Development Corp. The local area of Seton Portage has approximately 92 self-contained units available for rent. The accommodation is generally of good quality and units typically contain a TV and landline, have access to internet, and many have kitchenettes. There are also eight rental houses in Shalalth (BC Hydro 2019a).

BC Hydro regularly utilizes Lil'tem Mountain Hotel and works closely with the hotel to ensure capacity for its projects and other staff. If this accommodation is full, BC Hydro tries to maximize the accommodation in Seton Portage, and then looks to accommodation in Lillooet (BC Hydro 2019a).

The larger centre of Lillooet has the greatest capacity for accommodating out-of-town workers, however is less accessible to the project site at Bridge River Generation Station. Lillooet has approximately 150 hotel rooms and a limited number of private residences available for rent for visitors to the community. Generally, the accommodations have good internet, landline, and television services (BC Hydro 2019a). A detailed baseline description of housing and accommodation capacity in each community is included in **Appendix B**.

4.4.2 Effects Assessment

A large portion of the construction workers are anticipated to be sourced from communities outside the LAA and therefore will require local accommodation while working on the Project.

BC Hydro encourages the use of local facilities to accommodate workers and typically requires contractors to use the Lil'tem Mountain Hotel in order to gain full utilization of the agreement between BC Hydro and Tsal̓álh Development Corporation.

Given the limited number of workers who will require accommodation (up to 56 people at peak construction) increased demand is not expected to result in considerable strain on existing vacancy and availability of short-term accommodation in the study area. The local area of Seton Portage can accommodate up to 92 temporary workers between a combination of hotels, RVs, and rental houses. In addition, there are approximately 150 hotel rooms in Lillooet that could accommodate non-local workers during peak times, if necessary.

The vacancy rate in Seton Portage is usually very high, as BC Hydro's contractors are the main customers requiring temporary housing. For efficiency and safety reasons and to support local businesses, BC Hydro will encourage contractors to exhaust all of Seton Portage's accommodation resources before seeking accommodation elsewhere.

The arrival of up to 56 workers will create an increase in the demand for temporary accommodation that is within the existing capacity of the LAA. Local accommodations in Seton Portage have been sufficient in housing workers for recent projects, including the Bridge River 1 Unit 5-6 Replacement Project and Unit 7-8 Replacement Project. BC Hydro will assist contractors to the greatest extend possible to achieve efficient booking and use of available accommodation. If shortages of accommodation occur in the Seton Portage area, BC Hydro will plan ahead and assist in locating suitable accommodation or suggest alternative solutions such as split shifts and/or schedule extension where possible to minimize interference with local communities.

While staying in the local area, workers and contractors will be required to follow the *Bridge River Contract Worker Conduct Requirements* to ensure respectful behaviors and minimize conflicts with local residents. Refer to **Section 4.5** for additional analysis on Community Safety and Wellbeing.

4.5 Community Safety and Wellbeing

The influx of temporary workers to the project area has the potential to affect the community's sense of safety, wellbeing, and privacy. In the past, some communities affected by BC Hydro projects have expressed their concern with the conduct of the workers staying in or travelling through their communities. Specifically, the St'át'imc community of Tsal̓álh, adjacent to the Bridge River Generating Station, raised concerns related to workers coming into the local area, including inappropriate and illegal activities, cultural insensitivity, and traffic safety. These safety concerns also extend to other St'át'imc communities and Lillooet. With the recent COVID-19 pandemic, there are additional concerns related to an influx of workers and potential impacts on community health.

Large construction projects in remote, rural areas of BC are often found to result in adverse social and cultural effects on local communities and disproportionately affect Indigenous communities. The final reports of the Truth and Reconciliation Commission of Canada and of the National Inquiry into Missing and Murdered Indigenous Women and Girls (NIMMIWG) documented adverse effects on Indigenous communities from land and resource development activities. Indigenous communities in remote areas of BC may be socio-economically disadvantaged and therefore vulnerable to the effects of temporary population increases from project workforces (Truth and Reconciliation Commission 2015, NIMMIWG 2019). The NIMMIWG report included specific Calls for Extractive and Development Industries, one of which was to consider the safety of Indigenous women and girls (NIMMIWG 2019). The report also included calls for equitable benefits from development, and for gender-based socio-economic assessment of proposed development projects.

This section assesses potential effects of the Project on the Community Safety and Wellbeing VC, including a description of the existing conditions, identification of potential project effects, and proposes mitigation measures to address potential Project-related effects. A detailed baseline account is included in **Appendix B**.

4.5.1 Existing Conditions

The understanding of safety and wellbeing on the LAA and RAA draws from available indicators of health and safety service provision and local perspectives about community safety.

In general, Shalalth and Seton Portage are safe places to live and visit. The communities are remote, and residents know and rely on each other. Crime rates are low, and people generally go about their lives unencumbered by worries that may affect more populated or urbanized areas. A serious incident did occur in 2018 when a homicide was committed at a residence on the Highline Road, close to Shalalth and Seton Portage. At the time, the RCMP reported that the incident did not pose a threat to others in the community, but the occurrence was alarming for the population (CFJC Today 2018).

Previous BC Hydro projects at the Bridge River site have resulted in concerns related to community safety and wellbeing for local residents, particularly for the community of Tsal'álh. Concerns include reports of disruptive parties in Seton Portage, allegations of illicit drug use and possible drug dealing, and inappropriate and offensive behaviour, including racism, towards local residents. Tsal'álh and St'át'imc leadership raised these concerns with BC Hydro. The issues indicated a general sense of unease and fear as a result of the temporary workforce staying in the community. An increase in partying and associated negative behaviour can lead to a culture change that has lasting negative effects after the temporary workers leave (BC Hydro 2019a).

There is little public information available on community safety and wellbeing for St'át'imc communities. Crime rate is generally used as an indicator for evaluating community safety. The crime rates observed in Stl'atl'imx Tribal Police jurisdiction are recorded by the Government of BC. In recent years, Stl'atl'imx jurisdictions have seen a decrease in crime rates. The crime rate based on total criminal code offences per 1,000 people (including property, violent, and other crimes) recorded for 2018 was 44% less than the number recorded for 2009 (BC 2019).

Similarly, in recent years, Lillooet has experienced a drop in crime. Total criminal code offences per 1,000 people (including property, violent, and other crimes) recorded for 2018 was 57% less than the number recorded for 2009 (BC 2019).

In terms of overall socio-economic wellbeing, the SLRD was ranked 8th out of 26 regions in BC's 2015 socio-economic indicators index. The socio-economic index summarizes key social and economic information for all areas of BC and indicates that SLRD compares well to other regions (Squamish-Lillooet Regional District 2015).

Policing Services

Policing Services in the LAA and RAA are generally provided by Stl'atl'imx Tribal Police or the local RCMP detachments.

There are RCMP detachments located in Pemberton and in Lillooet. The Lillooet RCMP services Seton Portage and surrounding rural area. The Stl'atl'imx Tribal Police services Indigenous lands in Mount Currie, Lillooet, and Shalalth, out of their offices in Lillooet (T'it'q'et) or Mount Currie (Lil'wat). Lillooet is policed both by the RCMP and Stl'atl'imx Tribal Police, depending on the area of town. First Nations territory in Lillooet is managed by the Tribal Police (BC Hydro 2019a). The Whistler RCMP detachment services D'Arcy (BC Hydro 2019a, BC211 2020, Stl'atl'imx Tribal Police 2020).

There is no cell phone service in Shalalth and Seton Portage; therefore, calling for emergency help requires a landline, but a satellite phone or communication device such as InReach can also be used. Locals are accustomed to using these devices for emergency communication (BC Hydro 2019a).

Health Services

The main health facility in the LAA is in Lillooet. Lillooet has a hospital and health centre that offers a wide range of services, including 24-hour emergency service. The hospital and health centre is classified as a Community Level 1 Hospital and is the smallest type of hospital in the Interior Health Region (Interior Health 2020). The hospital serves a local health area that encompasses Shalalth and Seton Portage, and includes a population of 4,564. Of all hospitalizations, 85% come from the Lillooet area, suggesting that this facility is not hugely burdened with providing care to people from other areas (Interior Health 2020, Provincial Health Services Authority 2019).

St'át'imc Outreach Health Services delivers primary health services to Indigenous peoples on and off reserve in Northern St'át'imc Territory, providing both mental health and wellness services (St'át'imc Outreach Health Services 2020).

Emergency Services

Many of the LAA communities have limited capacity to accommodate emergencies. Instead, the larger district provides centralized emergency services for the surrounding communities. In the Northern area, fire emergency services are dispatched by the Surrey Fire Communications Centre to Lillooet and Seton Valley, among other locations. Fire Services for the south are dispatched by Emergency Communications for British Columbia Incorporated (ECOMM) to Pemberton, Whistler, and Squamish, among other locations (BC Hydro 2019a).

Helicopter companies (e.g., Caribou Chilcotin Helicopters) based out of Lillooet are used for emergency search and rescue services as well as for transportation to remote locations (BC Hydro 2019a).

Table 4.5 summarizes the Emergency, Health and Policing Services available in the LAA and RAA communities.

Table 4.5 Emergency, Health and Policing Services by Community

Community	Policing	Health Services	Fire Department	Other safety considerations
Tsal'álh	Stl'atl'imx Tribal Police Services	-	-	• Nearest office is located in Lillooet • There is no cell phone service in Shalalth and Seton Portage
T'it'qet	Stl'atl'imx Tribal Police Services	-	-	• Nearest office is located in Lillooet
Sekw'el'was	Stl'atl'imx Tribal Police Services	-	-	• Nearest office is located in Lillooet
N'Quatqua (Nequatque)	Stl'atl'imx Tribal Police Service	-	-	• The closest office is the headquarters located in Mount Currie
Xwísten	RCMP	-	-	• Nearest office is located in Lillooet
Shalalth/Seton Portage, Unincorporated Community	Stl'atl'imx Tribal Police Services		-	• Nearest office is located in Lillooet • There is no cell phone service in Shalalth and Seton Portage
District of Lillooet	RCMP Stl'atl'imx Tribal Police	Hospital and health centre with 24-hour emergency service -	-	• Seven officers assigned to the detachment • First Nations territory in Lillooet is managed by the Tribal Police
Squamish Lillooet Regional District	RCMP Stl'atl'imx Tribal Police	-	Two volunteer fire department	• The Lillooet RCMP services Seton Portage. The Stl'atl'imx Tribal Police services Indigenous lands in Mount Currie, Lillooet, and Shalalth. The Whistler RCMP detachment services D'Arcy.

4.5.2 Effects Assessment

The Project may influence community safety and wellbeing through multiple pathways including the influx of workers to temporary accommodation in Seton Portage, potential strain on healthcare and emergency services, and potential increase in traffic and road accidents. Project-related traffic safety aspects are discussed in **Section 4.6**.

The influx of temporary workers to the LAA has the potential to affect the population's sense of safety, wellbeing, and community if external workers are involved in negative social behaviors (e.g., substance abuse, illegal practices) or are disrespectful of the local ways. This effect is often exacerbated by high disposable income, which can lead to socially irresponsible or reckless behaviours and thereby increase demands on health, social and policing services.

The presence of temporary, non-local workers may also place strain on local emergency services if non-local workers need access to medical services during their stay in the local communities as they may use the emergency facility for basic medical attention.

BC Hydro recognises that their relationship with St’át’imc is integral to the ongoing operations of their facilities in St’át’imc Territory and are committed to developing a collaborative and respectful working relationship with St’át’imc Nation.

BC Hydro and St’át’imc have jointly developed the *Bridge River Contract Worker Conduct Requirements* (BC Hydro 2019b) for contractors working on the Bridge River System. These requirements were developed together, in response to specific concerns raised by the St’át’imc community of Tsal’slh and include specific requirements for workers while in the Bridge River area, including when offsite or outside of working hours.

The *Bridge River Contract Worker Conduct Requirements* apply to all contractors working on the Bridge River projects and will be implemented for this Project alongside focused efforts to improve cultural awareness and sensitivity of the Bridge River workforce throughout the St’át’imc Territory. These requirements note that the work is taking place in St’át’imc Territory and supplement the *Contractor Standards for Ethical Conduct* that each contractor is required to comply with at all times by their contract with BC Hydro.

Specific mitigation measures included in the *Bridge River Contract Worker Conduct Requirements* include:

- **Travel requirements –** outlines compliance with applicable laws, speed limits, school zone restrictions, prohibition of alcohol or drug consumption, etc.
- **Workers Accommodation Requirements –** outlines unacceptable behaviours such as illicit drugs use or possession, disrespectful behaviour, theft, vandalism, violence, unruly parties, unlawful behavior, failure to respect personal privacy of residents, etc.
- **Worker Recreation Requirements –** outlines requirements for workers if taking part in recreational activities, such as obeying road and property restrictions, follow local restrictions, obtaining licenses, not hunting, fishing of harvesting on St’át’imc reserve lands, etc.

BC Hydro will work with contractors to ensure compliance with the *Bridge River Contract Worker Conduct Requirements* and other contractual obligations. Each worker will be required to complete the Project orientation and cultural awareness training, as well as confirming in writing their commitment to the Worker Conduct Requirements. Workers who fail to comply with the *Bridge River Contract Worker Conduct Requirements* may be removed from the Project. If BC Hydro receives a complaint or reports of damage, the BC Hydro Representative will initiate an investigation into the complaint or report. Each complaint will be managed on a case-by-case basis and the outcome will be determined by the relevant code, law or act, as applicable. BC Hydro will not tolerate any criminal behaviour or activities. Contractor employees who engage in criminal behaviour will be directed off site and will not be permitted to work at any other BC Hydro facilities.

BC Hydro will maintain ongoing communication with local policing and emergency service providers to ensure adequate provision of services to the local area.

To mitigate any effects on the provision of local health services, First Aid is provided on site. The Bridge River area is equipped with First Aid Facilities, Level 3 First Aid Attendants, and transportation services such as industrial ambulances and emergency transport vehicles. In the event of an accident, patients will be transported to Lillooet Hospital. It is anticipated that Lillooet Hospital has the capacity to serve emergency situations. The Project Construction Management Plan (CMP) will include an Emergency Response Plan that outlines the planned response, equipment needed, and action plan for medical emergencies, fire or natural hazard events, and environmental spills.

4.6 Transportation, Traffic and Road Safety

Project activities (including transportation of construction materials, as well as the work-related and casual travel of workers) will rely on several local roads. Transportation and Traffic was selected as a VC to assess the capacity of local roads to accommodate the increased volume of traffic derived from project activities.

This section assesses potential effects of the Project on the Transportation and Traffic VC, including a description of the existing conditions present in the vicinity of the Project. This section also identifies potential interactions with the surrounding road network during Project construction, identifies potential Project effects and proposes mitigation measures to address potential Project-related effects.

4.6.1 Existing Conditions

The Project is accessible from Kamloops to the north and from the Lower Mainland to the south:

Access from the North

- Via Highway 97 to just north of Cache Creek and then Highway 99 west to Lillooet

Access from the South

- Via the Trans Canada Highway to Lytton then Highway 12 to Lillooet
- Via the Duffy Lake Road to Lillooet then Highway 40 to Shalalth
- Via the Highline Service Road (seasonal) from D'arcy to Shalalth

The road from Shalalth to Seton Portage is fully paved and maintained by Dawson Road Maintenance through a highway maintenance agreement with the BC Government (Dawson Road Maintenance 2020). The road is approximately 7 km long and consists of winding sections and a few switchbacks. There is a public school located on the route, which has a school zone speed restriction of 30 km/hr (BC Hydro 2019a). The road is unmarked so travellers frequently cross over the centre line.

Additionally, T'it'q'et communities are accessed from Highway 99, though are not situated on the highway. Highway 99 also travels through Cayoosh Creek 1.

N'Quatqua is accessed via Pemberton Portage Rd when travelling from Pemberton. N'Quatqua is also connected to the Project as well as Shalalth and Seton portage via Highline Rd. which was declared a provincial highway in 2013 and is maintained by Dawson Road Maintenance (Question 2013, Dawson Road Maintenance 2020). Contractors and BC Hydro crews travelling to the site often utilize the Highline Rd, particularly in the summer months, which increases traffic through N'Quatqua.

There are difficult driving conditions between some of the communities in the LAA, specifically between Lillooet and Shalalth. The drive is approximately 65 km and 1.5 hours long. The road is a mix of gravel and paved surfaces, has windy sections, steep climbs and descents and tight passages. Potholes, washboard texture, and large rocks are common. It is also common to encounter logging trucks while driving. It is possible to travel by boat between Lillooet and Shalalth. The distance by boat is about 20 km and takes about 25 minutes, depending on the watercraft. It is about a 10 km drive from the dock at the end of Seton Lake into downtown Lillooet (BC Hydro 2019a).

4.6.2 Effects Assessment

The Project will use main highways and secondary roads for the transport of equipment, materials, and workers to and from the Project construction site, which could increase road traffic and the risk of motor vehicle accidents. All roads to Bridge River are maintained by the Ministry of Transportation. The Project site is remote with difficult road access over steep mountain terrain with unstable slope conditions.

In addition, BC Hydro has 3 small vessels used to transport crews on Seton Lake from Bridge River to Lillooet with capacity of 11 passengers per vessel. This mode of transportation may be used at peak times if the worker forecast requires people to stay in Lillooet, and to minimize traffic and ensure safety. However, current forecasts indicate that all workers will be housed locally, and boat transportation will not be required.

During Project construction, there is expected to be a temporary increase in highway and secondary road traffic delivering materials and personnel to and from the construction site. Transportation will be a combination of light trucks for personnel and heavy trucks for equipment and materials.

Increases in traffic volumes could affect road and traffic conditions and potentially the safety of road users. Complaints received during previous projects in the area included speeding, specifically in the school zone between Shalalth and Seton Portage, and driving on the wrong side of the road, particularly on Mission Mountain.

To reduce traffic in the area and reduce parking requirements at site, BC Hydro will require contractors to use carpooling or shuttle services. This is expected to provide employment opportunities to the local community and to reduce congestion on-site and off-site.

To minimize the risk of accidents and risk to public safety, appropriate traffic control measures and signage will be implemented according to WorkSafeBC's Operational Health and Safety Regulation and BC Hydro safety management policies. The Project CMP also considers safety protocols and incident management (e.g. Owners Safety Plan, Occupational Hazards Identification Risk Assessment, Environmental Management Plan, Travel to Site Protocol, Emergency Evacuation Protocols, and Accidents protocols) that contractors will be required to comply with at all times.

All workers and contractors will be required to follow the BC Hydro Travel Code of Conduct to ensure compliance with a basic set of rules created to maintain minimum safety requirements and respectful and lawful behaviour. In addition to the Travel Code of Conduct, the general Bridge River Contract Worker Conduct Requirements must also be followed which outlines unacceptable behaviour such as illegal drug use, racism, drinking, theft of any item, and any activity that could impede the operator's ability to operate a vehicle or vessel safely.

Further, all workers will be required to follow the applicable laws, including the *Motor Vehicle Act*, Domestic Vessel Regulatory Oversight and Boating Safety, and the Small Vessel Compliance Program. Any worker found to be violating these laws will be held accountable by the respective law or act.

BC Hydro will create a code of conduct review committee that will review code of conduct violations and road incidents. If BC Hydro receives any motor vehicle complaint, BC Hydro will commission an investigation into the complaint. Each complaint will be managed on a case-by-case basis and the outcome will be determined by the applicable code, law or act.

5.0 CLOSURE

We sincerely appreciate the opportunity to have assisted you with this project and if there are any questions, please do not hesitate to contact the undersigned by phone at 604.669.0424.

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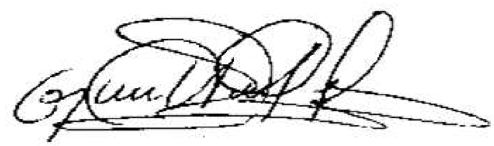

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APPENDIX A

Bridge River System – Water Management Fact Sheet

Bridge River System – Water Management Fact Sheet

Date: Sept 25, 2020

Project: GY0239 – Bridge River 1 Unit 1 to 4 Generator Replacement Project

Project Manager: John Fitzgibbon

Project Description:

The Bridge River generating stations, Bridge River 1 and 2, are the largest facilities in the Bridge River System and are located at the west end of Seton Lake near Shalalth. The Bridge River 1 Generating Station was commissioned in 1954 with four generators, each with a nameplate rating of 50MVA (currently the unit 4 generator has been de-rated to 40 MVA). At the maximum licenced flow capacity, Bridge River 1 Generating Station can pass 65 m^3/s of water (Figure 1).

The Bridge River 1, Unit 1 to 4 generators, governors, exciters, and control systems are in poor or unsatisfactory condition and replacement of the aging equipment is required to improve reliability, restore licenced flow capacity, and increase operating flexibility. These changes will enhance the ability to manage flows within the Bridge River Water Use Plan Order target flow schedule.

The Bridge River 1 Unit 1 to 4 Generator Replacement Project (or "Project") was initiated to address the poor reliability of the units. Construction for each unit will start with 4 to 5 months of pre-assembly to build the rotor and stator. Each unit will then be taken out of service for [redacted] for disassembly, assembly and commissioning (the "Project Outage").

Modelling was undertaken to consider different schedules and durations for the Project Outage and determine the potential for higher flows and associated impacts to fish and fish habitat. This modelling is predictive of what may occur, however, actual reservoir elevations and the likelihood of spills during the Project Outages will depend on real-time hydrologic conditions and may not be reflective of the results presented herein.

Outage Duration:

Four separate [redacted] outages are required to complete the replacement project starting in [redacted] To determine the potential effect of a delay in the Project schedule, [redacted] and [redacted] outages were also modelled.

Outage Schedule:

The project has developed a detailed outage schedule with the preferred outage from [redacted] (**Table 1**). [redacted] start ensures water conveyance during the critical spring-summer freshet, providing the most flexibility for water management. Other outages considered for comparison include [redacted].

Prior to the start of construction, the suitability of this schedule will be confirmed in consideration of current water supply forecasts and other maintenance outages required in the Bridge-Seton System.

Table 1. Current Construction Schedule for Unit 1 to 4 Replacement.

Bridge River 1 Unit	Pre-Assembly	Outage (assembly and commissioning)	In-service Date
Unit 4	[redacted]		
Unit 3			
Unit 1			
Unit 2			

Assumptions:

- Operations continue under the existing water licenses;
- Downton Reservoir does not exceed el. 734 m under planned operations;
- Maintaining WUP schedule flow targets at Terzaghi is prioritized over Seton following the Guiding Principles;
- There are no transmission restrictions;
- Only routine preventative maintenance will occur at La Joie, Seton and Bridge River 2 during the Project Outages; and
- Reservoirs can be returned to the desired target levels in the period between consecutive outages.

Methods:

The following three options for schedule were analysed for the Project Outage, including:

[redacted]

In addition, the following two options for schedule were analysed for the Project Outage, including:

[redacted]

Each option was compared to the baseline which represents outflows with all units at Bridge River 1 and 2 generating station operating at their designed capacity (no unit outages).

The potential impacts associated with each outage option was assessed by determining how many years, out of 53 years of historical inflow data (1961 to 2012), would have resulted in higher flows, where higher flows are defined as flows above the WUP Order target flow schedule. Each option (start time and duration) was modelled and the number of years with higher flows was determined for both the Lower Bridge River and the Seton River. Low, moderate and high impacts to fish and fish habitat are reported for each season (**Attachment 1 and 2**) and the likelihood of high impacts to fish and fish habitat is summarized below (**Table 2**).

Potential impacts to fish and fish habitat were characterized based on results of the Bridge River Water Use Plan monitoring programs, other scientific research and professional judgement. This information was used to qualify the level of impact considering specific time periods (seasons) relevant for fish species present in the Lower Bridge River and Seton River and flow velocities known to affect those species and their habitats. Impacts were characterized as low, moderate and high for specific flow velocities (threshold) in each season in both the Lower Bridge River (**Attachment 3a**) and the Seton River (**Attachment 3b**).

Impacts to Flows:

For the five planned outage options considered, the percentage of years with low to high impact flows on Lower Bridge River ranged from 0% to 2% greater than expected under baseline conditions (**Table 2, Attachment 1 and 2**). An increase in the likelihood of high flow up to 5% over baseline is considered negligible. For Seton River, the percentage of years with low to high impact flows ranged from 0 to 3% greater than expected under baseline conditions, with one exception. The percentage of years with moderate and high impact flows increased over the baseline by 9% and 6%, respectively for Option 1b (**Table 2, Attachment 1 and 2**).

Table 2. The likelihood* of high impact flows on the Lower Bridge River and Seton River considering different schedules and durations for the Project outage.

River	Season	Threshold (cms)**	Baseline	Planned Outage - Schedule			Planned Outage - Duration	
				Option 1a	Option 1b	Option 1c	Option 1d	Option 1e
				[redacted]				
Lower Bridge River	Winter (Jan 1 - Mar 31)	>15	0%	0%	0%	0%	0%	0%
	Spring (April 1 - May 31)	>60	0%	0%	0%	0%	0%	0%
	Spring-Summer (June 1 - July 31)	>60	0%	0%	0%	0%	0%	1%
	Summer-Fall (August 1 - Sept 30)	>30	0%	1%	2%	1%	1%	2%
	Fall-Winter (Oct 1 - Dec 31)	>15	0%	1%	0%	0%	0%	0%
Seton River	Winter (Nov 16 - April 14)	>60	0%	0%	0%	0%	0%	0%
	Spring (April 15 - May 31)	>100	6%	6%	5%	5%	5%	4%
	Spring-Summer (June 1 - July 31)	>120	5%	5%	8%	5%	5%	6%
	Summer-Fall (August 1 - Nov 15)	>60	19%	18%	25%	19%	18%	19%

*likelihood of high flow events expressed as a percent of years predicted to have high flows using 53 years of historical inflow data; **thresholds are defined in Attachment 3a and 3b; Colours defined in Attachment 1 (darker represents higher risk).

Environmental Impacts:

This analysis demonstrates that the WUP target flow schedule is expected to be maintained on the Lower Bridge River and the Seton River in nearly all options, with two exceptions. This demonstrates that there is a low likelihood that incremental impacts to fish and fish habitat will result from the Project Outage.

Option 1b results in a 6% increase over the baseline in the likelihood of high impact flows during the Summer-Fall. High impact flows during this period can impact upstream migration of adult salmon, strand adult Pink Salmon and redds on Seton river and reduce the availability of juvenile rearing habitat on Seton River.

Recommendation

This analysis indicates that all scheduling options are feasible with a negligible to small increase in the likelihood of higher flows resulting from the Project Outage. Option 1b ([redacted]) is less desirable because there is an increased likelihood of high impact flows in the Summer-Fall, which is considered a high risk period due to migrating salmon. Similarly, this analysis indicates that increasing the outage duration to [redacted] would have negligible impacts on flows, assuming reservoirs can be returned to the desired target levels between consecutive outages.

Additional Mitigation:

No additional mitigation is proposed at this time.

Authorization:

Name	Position	Signature	Date
John Fitzgibbon	Project Manager		

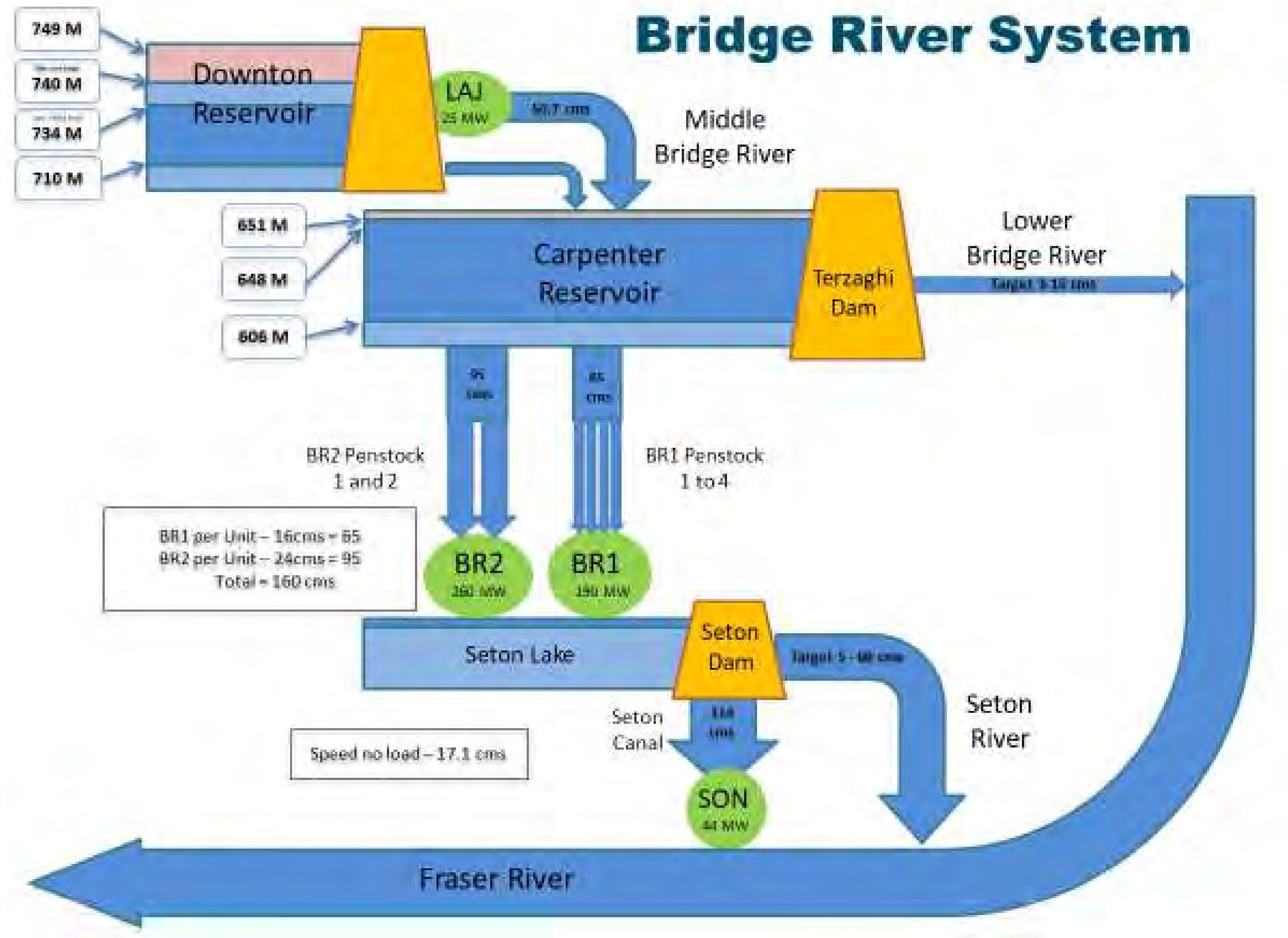


Figure 1. Bridge-Seton System Overview

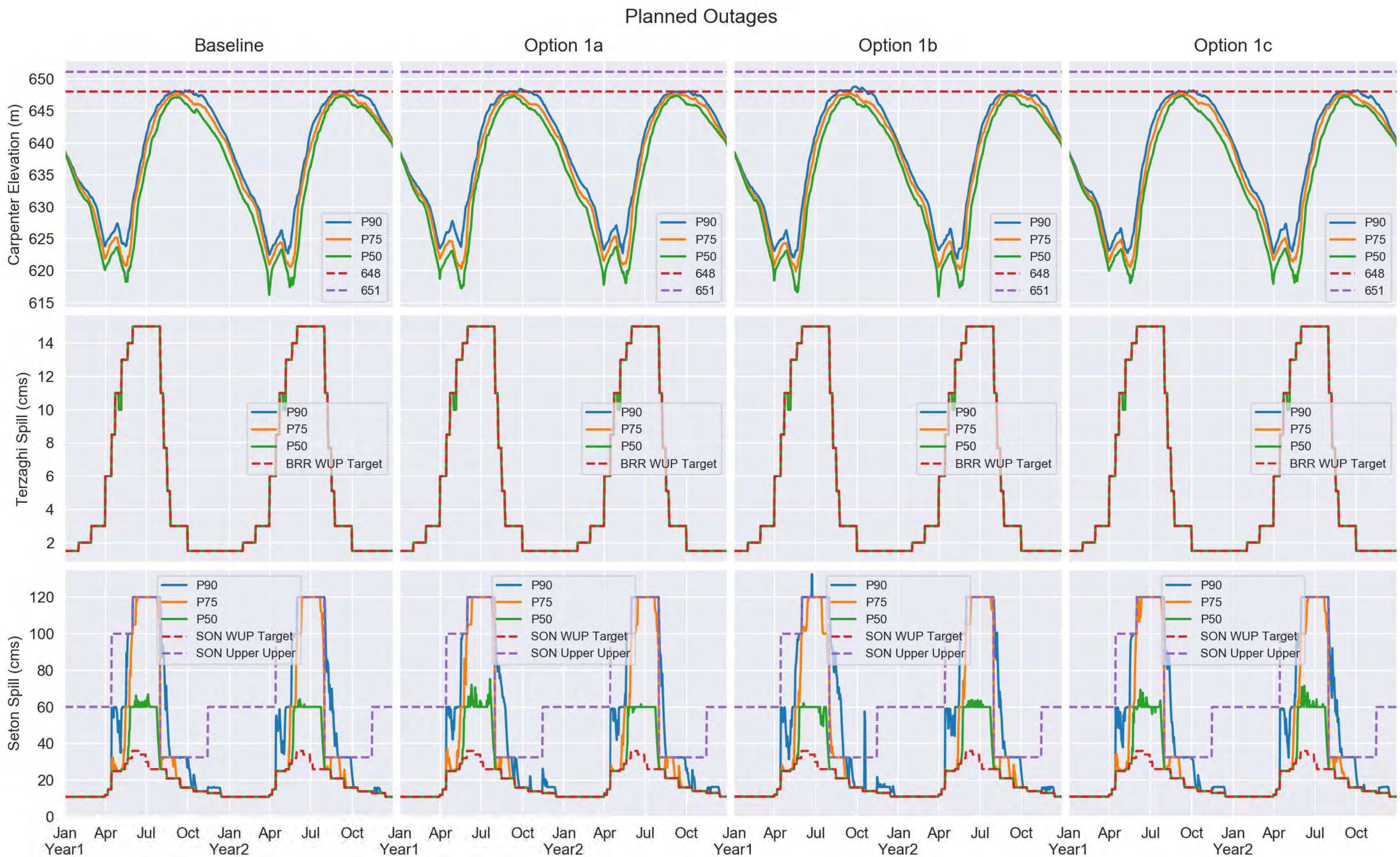
Attachment 1. Percentage of years with low, moderate and high impact flows at Lower Bridge or Seton River during the Unit 1-4 Project Outage.

Characterization of Impacts to Fish and Fish Habitat					Planned Outage - Schedule			Planned Outage - Duration	
Location	Period	Threshold (cms)	Impact	Baseline	Option 1a [redacted]	Option 1b [redacted]	Option 1c [redacted]	Option 1d [redacted]	Option 1e [redacted]
Lower Bridge River	Winter (Jan 1 - Mar 31)	>WUP	Low	0%	0%	0%	0%	0%	0%
		>7.5 cms	Moderate	0%	0%	0%	0%	0%	0%
		>15 cms	High	0%	0%	0%	0%	0%	0%
	Spring (April 1 - May 31)	>WUP	Low	0%	0%	0%	0%	0%	1%
		>32.5	Moderate	0%	0%	0%	0%	0%	0%
		>60	High	0%	0%	0%	0%	0%	0%
	Spring-Summer (June 1 - July 31)	>WUP	Low	0%	0%	0%	0%	0%	1%
		>32.5	Moderate	0%	0%	0%	0%	0%	1%
		>60	High	0%	0%	0%	0%	0%	1%
	Summer-Fall (August 1 - Sept 30)	>WUP	Low	3%	3%	5%	3%	3%	5%
		>15	Moderate	0%	2%	2%	1%	2%	4%
		>30	High	0%	1%	2%	1%	1%	2%
	Fall-Winter (Oct 1 - Dec 31)	>WUP	Low	0%	1%	1%	2%	1%	2%
		>3	Moderate	0%	1%	1%	2%	1%	2%
		>15	High	0%	1%	0%	0%	0%	0%
Seton River	Winter (Nov 16 - April 14)	>15	Low	20%	30%	25%	25%	24%	22%
		>33	Moderate	2%	3%	2%	1%	3%	2%
		>60	High	0%	0%	0%	0%	0%	0%
	Spring (April 15 - May 31)	>32	Low	70%	72%	69%	69%	68%	69%
		>60	Moderate	28%	28%	32%	28%	28%	29%
		>100	High	6%	6%	5%	5%	5%	4%
	Spring-Summer (June 1 - July 31)	>36	Low	75%	74%	72%	70%	69%	69%
		>60	Moderate	59%	58%	58%	58%	53%	55%
		>120	High	5%	5%	8%	5%	5%	6%

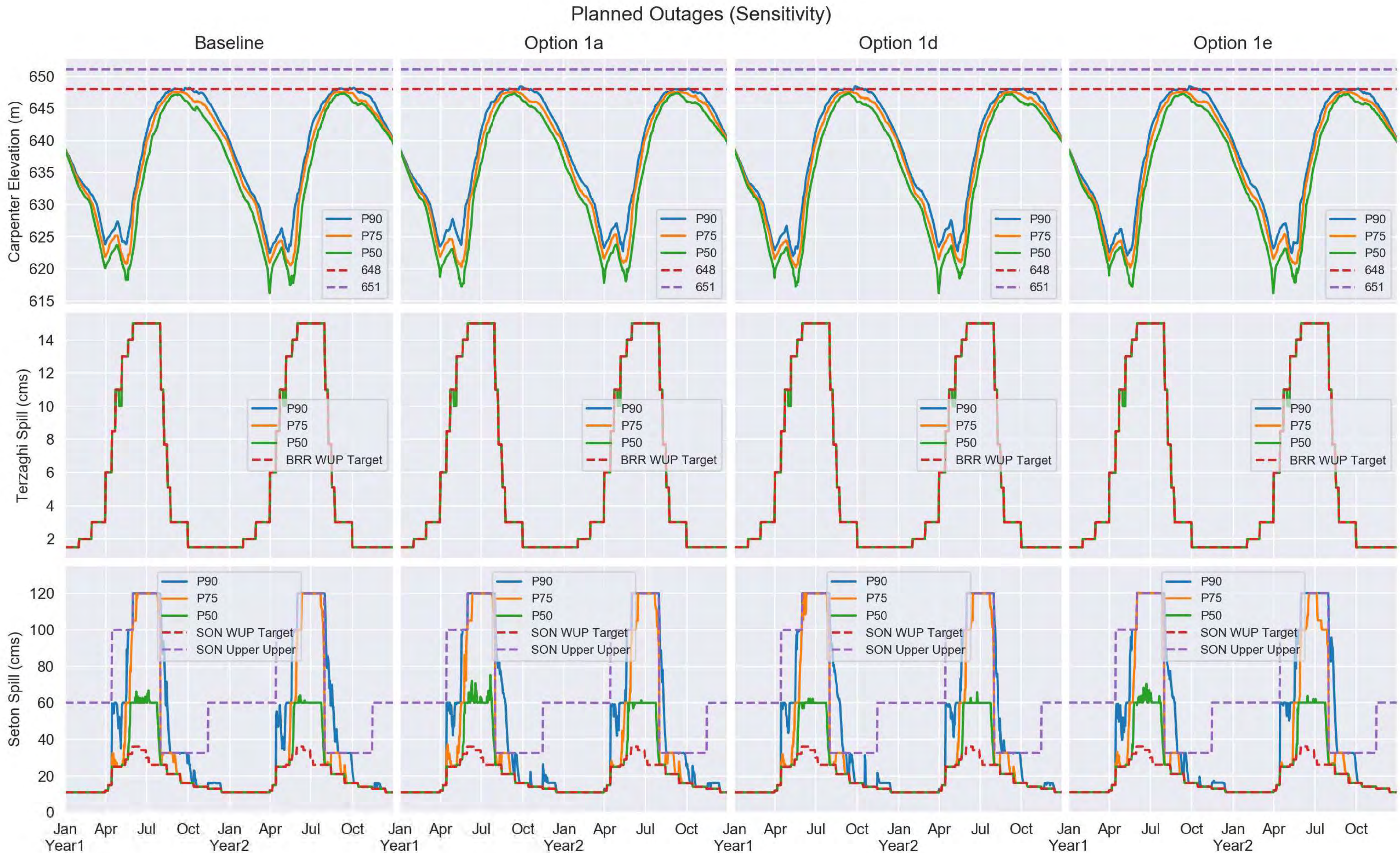
	Summer-Fall (August 1 - Nov 15)	**>26**	**Low**	40%	41%	43%	41%		42%	35%
		>33	**Moderate**	21%	20%	30%	22%		21%	20%
		>60	**High**	19%	18%	25%	19%		18%	19%

Absolute Increase In Risk	>50%	100%	
	>30%	50%	
	>15%	30%	
	>5%	15%	
Base Case (+/- 5%)		5%	
	No difference	**0%**	
		-5%	
Absolute Decrease in Risk	<-5%	-15%	
	<-15%	-30%	
	<-30%	-50%	
	<-50%	-99%	

Attachment 2. Hydrographs representing the planned Unit 1-4 Project Outage options.



Attachment 2b. Hydrographs During the Unit 1-4 Project Outage - Duration



Attachment 3a. Summary of Water Discharge Thresholds and Environmental Impact to Fish and Fish Habitat for Lower Bridge River.

Lower Bridge River			
Season and WUP Hydrograph Benefits	**Threshold**	**Impact Level**	**Impacts of Flows Exceeding Threshold** **Low Impact (-) / Moderate Impact (--) / High Impact (---)**
Winter (January 1 to March 31) **WUP flows: 1.5-3 cms** **Key WUP hydrograph benefits:** **- Stable, cold, low flows for salmon egg/alevin incubation** **- Stable low flows and overwintering habitat for juvenile salmon and resident fish**	>WUP	Low	- Maintained low flows for incubating eggs & alevin, potential for increased temperatures (-) - Minor decrease in overwintering habitat (-) - Risk of fry stranding during ramp down (-)
	>7.5 cms	Moderate	- Decrease in overwintering habitat and potential displacement of hatched fry up to 15 cms (--) - Moderate risk of stranding fry or resident fish if flows ramp down, salvage is not possible (--) - Some potential for redd scour (-); risk of increased water temperature accelerating incubation rates (--)
	>15 cms	High	- Decrease in overwintering habitat and risk displacement of hatched fry above 15 cms (---) - High risk of stranding fry or resident fish if flows ramp down; salvage is not possible (---) - High likelihood of redd scour (---) and increased temperatures throughout Reach 1-4 (---)
Spring (April 1 to May 31) **WUP flows: 6-15 cms** **Key WUP hydrograph benefits:** **- Good availability of nursery habitat for emergent salmon fry** **- Abundant rearing habitat for juvenile salmon and resident fish** **- Suitable flows for spawning steelhead and rainbow trout**	>WUP	Low	- Decrease in fry refugia habitat and increasing risk of displacing emerged fry (--) - Decrease in rearing habitat and increasing risk of fry displacement with greater discharge (--) - Potential for reduced steelhead spawning habitat (-) - Potential for gravel mobilization near 30 cms (-)
	>33 cms	Moderate	- Minimal refugia habitat available for emerged fry, high displacement risk (---) - Continued decrease in juvenile fish habitat and moderate-high displacement risk (---) - Increased risk to steelhead spawning success and potential for redd dewatering (--) - Gravel mobilization in some areas, increasing with discharge (--)
	>60 cms	High	- Minimal/no fry refugia habitat and high displacement risk (---) - Significant decrease in juvenile rearing habitat with high risk of displacement (---) - Limited steelhead spawning habitat (---) - Widespread gravel mobilization and bank erosion, high likelihood of redd scour (---)
Spring-Summer (June 1 to July 31) **WUP flows: 15 cms** **Key WUP hydrograph benefits:** **- Steelhead and rainbow trout egg/alevin incubation flows and fry nursery habitat** **- Abundant rearing habitat for juvenile salmon and resident fish**	>WUP	Low	- Decrease in fry refugia habitat and increasing risk of displacing emerged fry (-) - Decrease in rearing habitat and increasing risk of fry displacement with greater discharge (--)
	>33 cms	Moderate	- Minimal refugia habitat available for emerged fry, high displacement risk (---) - Continued decrease in juvenile fish habitat and moderate-high displacement risk (---) - Gravel mobilization in some areas, increasing with discharge (--)
	> 60 cms	High	- Decrease in fry refugia habitat and high displacement risk (---) - Significant decrease in juvenile rearing habitat with high risk of displacement (---) - Widespread gravel mobilization and bank erosion, high likelihood of redd scour (---)
Summer-Fall (August 1 to September 30) **WUP flows: 15-3 cms ramp downs (August); 3 cms (September)** **Key WUP hydrograph benefits:** **- Abundant summer rearing habitat for juvenile salmon, trout, and resident fish** **- Low risk during August ramp down, migrated through ramp rates and salvage** **- Suitable flows for spawning adult Chinook and pink salmon (odd years)**	>WUP	Low-Moderate	- No change in juvenile rearing habitat, increased stranding risk during ramp down (--) - Reduction in Chinook spawning habitat and risk of redd stranding during ramp down (-) - Loss of pink spawning habitat and high risk of redd stranding (---)
	>15 cms	Moderate-High	- Significant decrease in juvenile rearing habitat (---) and additional stranding risk (--) - High risk of adult Chinook redd stranding during ramp down (---) - High risk to adult pink salmon migration, spawning and adult/redd stranding (---)
	>30 cms	Very High	- Decrease in juvenile rearing habitat, additional stranding risk, and moderate-high displacement risk (---) - Very high risk to adult Chinook spawning success with high risk of redd stranding (---) - Very high risk to adult pink salmon migration, spawning and very high risk of redd stranding (---)
Fall-Winter (October 1 to December 31) **WUP flows: 1.5 cms** **Key WUP hydrograph benefits:** **- Stable flows for spawning Coho Salmon** **- Stable, cold low flows for salmon egg incubation** **- Stable low flows for overwintering juvenile salmon and resident fish**	>WUP (>1.5-3 cms)	Low	- Maintained low flows for incubating eggs & alevin (+/-) - Potential for Coho to spawn in shallows and redd dewatering during ramp down (-) - Decrease in overwintering habitat (-)
	>3 cms (3-15 cms)	Moderate-High	- High potential for redd dewatering and juvenile/adult stranding on ramp down (--) - Decrease in overwintering habitat and potential displacement of juveniles up to 15 cms (--) - Decrease in spawning habitat for Coho (--)
	>15 cms	High	- High risk of Coho redd dewatering and juvenile/adult stranding on ramp down (---). - Continued decrease in overwintering habitat and displacement of juveniles above 15 cms (---) - Further decrease in spawning habitat for Coho (---)

Attachment 3b. Summary of Water Discharge Thresholds and Environmental Impact to Fish and Fish Habitat for Seton River.

Seton River			
Season and Hydrograph Benefits	**Threshold**	**Impact Level**	**Impacts of Flows Exceeding Threshold** **Low Impact (-) / Moderate Impact (--) / High Impact (---) / Benefit (+)**
Fall/Winter (November 15 to April 15) WUP Target Flows 11-15 cms throughout winter Key WUP Hydrograph Benefits - Stable, cold, low flows for salmon egg/alevin incubation (pink salmon in odd years) - Stable low flows and overwintering habitat for juvenile salmon and resident fish	>WUP	Low	- Stable low flows for incubating pink salmon eggs & alevin (odd years) - Minor decrease in of overwintering habitat for juvenile salmon and resident fish (-)
	>33 cms	Moderate	- Some potential pink salmon redd scour (odd years) (-) - Decrease in overwintering habitat up to 60 cms, potential displacement of fish (--)
	>60 cms	High	- Decrease in overwintering habitat and displacement of juvenile salmon and resident fish (---) - Gravel mobilization and scouring of pink salmon redds (--)
Spring-Summer (April 15 to May 31) WUP Target Flows 25-32 cms ramp up across April and May Key WUP Hydrograph Benefits - Flows for migrating and spawning steelhead and rainbow trout - Nursery habitat for emergent salmon fry - Rearing habitat for juvenile salmon and resident fish - Partial diverison of outmigrating sockeye salmon smolts to Seton River	>WUP	Low	- Increased diversion of out-migrating salmon smolts to Seton River (+) - Decrease in salmon fry nursery habitat and increased displacement risk up to 60 cms (-) - Decrease in juvenile salmon rearing habitat up to 60 cms (-) - Low-Moderate risk to adult steelhead migration and spawning (-)
	>60 cms	Moderate	- Increased diversion of out-migrating salmon smolts to Seton River (+) - Low availability of salmon fry nursery habitat; moderate displacement risk (--) - Increased risk to adult Steelhead migration and spawning (--) - Gravel mobilization in spawning areas (--)
	>100 cms	High	- Increased diversion of out-migrating salmon smolts to Seton River (+) - Minimal/no fry nursery habitat and high displacement risk (---) - Impacts to adult Steelhead migration and spawning (---) - Gravel mobilization in spawning areas (---)
Summer (June 1 to July 31) WUP Target Flows 36 cms peak (June 1-15); 36-26 cms ramp downs (June 15 to July 31) Key WUP Hydrograph Benefits - Summer rearing habitat for juvenile salmon, Steelhead Trout, and resident fish - Partial diversion of out-migrating Coho/Chinook smolts to Seton River - Low stranding risk during all ramp downs	>WUP	Low	- Decrease in Steelhead fry nursery habitat and increased displacement risk (--) - Decrease in juvenile salmon summer rearing habitat up to 60 cms (--) - Low risk of Steelhead redd scour (-) - Increased diversion of out-migrating Coho and Chinook smolts to Seton River (+)
	>60 cms	Moderate	- Minimal Steelhead fry nursery habitat, moderate displacement risk (---) - Moderate-High decrease in juvenile salmon summer rearing habitat (--) - Potential for Steelhead redd scour; gravel mobilization in spawning areas (--) - Increase in diversion of Coho/Chinook smolts to Seton River (+)
	>120 cms	High	- Minimal/no Steelhead fry nursery habitat; high displacement risk (---) - Juvenile summer rearing habitat at minimum availability (---) - Potential for Steelhead redd scour, gravel mobilization in spawning areas (---) - Increase in diversion of Coho/Chinook smolts to Seton River (+)
Summer-Fall (August 1 to November 15) WUP Target Flows 26 - 21 cms (August 1 to September 15); 16 - 14 cms (September 15 to November 15) Key WUP Hydrograph Benefits - Summer rearing habitat for juvenile salmon, trout, and resident fish - Migration flows for Gates Creek sockeye (August 1 to September 15) - Spawning flows for pink salmon (September 1 to October 1 - odd years) - Migration flows for Portage Creek sockeye (September 15 to November 1) - Migration flows for Bull Trout, Coho, and Portage Chinook (October 1 to November 15) - Low stranding risk during all ramp downs	>WUP	Low – Moderate	August to September - Improved migration conditions for Gates Creek sockeye at Seton Dam using Siphon 4 (+) - Decrease in juvenile rearing habitat up to 35 cms (-) September to November - Decrease in pink salmon spawning habitat in Seton River (-) - Moderate-High risk to Portage Creek sockeye, Coho, and Chinook upstream migration (--)
	>35 cms	Moderate-High	- Moderate-High risk to adult Gates sockeye upstream migration success (--) - Moderate-High risk to adult pink salmon spawning and potential redd stranding (--) - High risk to Portage Creek sockeye, Coho, and Chinook upstream migration (---) - Increased loss of juvenile rearing habitat (--)
	>60 cms	Very High	- High risk to the upstream migration success of all adult salmon species (---) - High risk of pink salmon spawning and redd stranding in Seton River (---) - Large decrease in juvenile salmon/trout summer rearing habitat (---)

APPENDIX B

Bridge River 1 Unit Replacement
Socio-Economic Baseline

Hemmera
An Ausenco Company

Bridge River 1 Unit Replacement Socio-Economic Baseline

Prepared for:

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October 8, 2020

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1.0 INTRODUCTION

Bridge River 1 (BR1) is a four-unit 180 MW generating station that was completed in 1954. The generating station equipment is in poor to unsatisfactory condition overall, and most of the major equipment for Generators 1 to 4 are original and are nearing or at the end of their design life. Due to the age and condition of the BR1 generating equipment, there is a risk of major failure leading to loss of generation and extended outages. BC Hydro is proposing to replace the aging generating equipment in BR1 (the Project) to maximize reliability of the equipment, avoid extended outages, and prevent higher flows down the Lower Bridge River. The scope of the Project is to design, procure, install and commission an upgrade of the BR1 generating equipment including, Generator, Governor, Excitation and Controls equipment.

Hemmera Envirochem Inc. (Hemmera) was retained by BC Hydro to assemble socio-economic baseline information for the Project. This report will be used to support discussions with St’át’imc and other stakeholders to assist with the further scoping of a socio-economic effects assessment.

Replacement of the generating equipment will need a construction workforce of up to 56 workers, requiring accommodation in the local area during construction. The influx of workers to temporary accommodation in Seton Portage for previous work at Bridge River 2 Generating Station created concerns from the local Indigenous community regarding worker conduct. Large construction projects in remote, rural areas of BC are often found to result in adverse social and cultural effects on local communities and disproportionately affect adjacent Indigenous communities.

The final reports of the Truth and Reconciliation Commission of Canada and of the National Inquiry into Missing and Murdered Indigenous Women and Girls (NIMMIWG) included descriptions of adverse effects on Indigenous communities from land and resource development activities. Indigenous communities in remote areas of BC may be socio-economically disadvantaged and therefore vulnerable to the effects of temporary population increases from project workforces (Truth and Reconciliation Commission 2015, NIMMIWG 2019). The NIMMIWG report included specific Calls for Extractive and Development Industries, one of which was to consider the safety of Indigenous women and girls with respect to resource extraction and development industries (NIMMIWG 2019). The report also included calls for equitable benefits from development, and for gender-based socio-economic assessment of proposed development projects.

2.0 BACKGROUND

BC Hydro has been working with the St’át’imc Nation and the St’át’imc communities for several decades in regard to their interests and concerns related to the Bridge River System. The construction and operation of BC Hydro’s facilities comprising the Bridge River System caused significant impacts to the environment and the St’át’imc cultural way of life in their Territory. In May 2011, after 17 years of negotiations, the St’át’imc Nation, BC Hydro and the Government of B.C. signed a historic and comprehensive set of agreements, which settled the past, present and future impacts of the existing facilities and operations. These agreements include: the St’át’imc (Participating Communities) Settlement Agreement; the Certainty Provisions Agreement; and the Relations Agreements (collectively referred to as the 2011 Agreements).

A cornerstone of the 2011 Agreements is the Relations Agreement. This is a “living agreement” that is intended to evolve over time. It sets out a framework for an ongoing collaborative and enduring relationship and includes, among other things:

- Information sharing on BC Hydro’s long-term plans
- Information sharing through an Annual Operations Update, which includes updates on capital project work such as those contemplated by the unit replacements of this Project
- Sharing of Environmental Management Plans
- Certain notifications related to ground disturbance that could impact St’át’imc cultural heritage, work on reserve, environmental incidents
- Information sharing and collaboration on business, employment, education and training opportunities.

BC Hydro undertook a project similar in scope to this Project in 2018 with the Bridge River 2, Units 5 and 6 Replacement Project. Interests and concerns were raised by St’át’imc with regard to the construction phase of that project, in addition to the long history of in-depth discussions about the Bridge River system. Specifically, the St’át’imc community of Tsal’álh, adjacent to the Bridge River Generating Station, raised concerns related to workers coming into the local area, including inappropriate and illegal activities, cultural insensitivity and traffic safety. These safety concerns also extend to other St’át’imc communities and Lillooet. With the recent COVID-19 pandemic, there are additional concerns related to an influx of workers and potential impacts on community health. This background has informed our understanding of what the potential socio-economic impacts of this project may be and have informed how the socio-economic baseline study has been developed.

3.0 SCOPING OF EXISTING CONDITIONS

This section describes the scoping of existing socio-economic conditions and priority areas of interest for Indigenous and non-Indigenous communities located near the Project. To set the initial parameters for the socio-economic baseline research, potentially affected communities located near BR1 were identified. BC Hydro's Bridge River System is located entirely in St'át'imc Territory and in the Squamish Lillooet Regional District (SLRD). Existing conditions are described for potentially affected communities, including:

- St'át'imc Nation communities of Tsal'álh, T'it'qet, Sekw'el'was, Xwísten and N'Quatqua
- Unincorporated community of Seton Portage
- District of Lillooet

The proposed Local Study Area (LSA) for the Project is defined as the communities listed above (**Figure 3.1**), and encompasses the area where the Project is expected to interact with and potentially create direct or indirect effects on socio-economic conditions, such as demand for employment and accommodation.

The proposed Regional Study Area (RSA) for the Project is defined as Electoral Areas A, B and C of the Squamish – Lillooet Regional District, including Seton Portage and the District of Lillooet; and includes the identified St'át'imc communities of Tsal'álh, T'it'qet, Xwísten, Sekw'el'was and N'Quatqua. Electoral Areas A B, and C sit within the broader St'át'imc Nation territory. BC Hydro recognizes commitments in the 2011 Settlement Agreements between BC Hydro and St'át'imc Nation, and for that reason have included a broader St'át'imc Nation profile in **Section 5.1** for additional context.

Reference to conditions in SLRD Electoral Areas A and B are made throughout the community profiles to provide regional context**.** The Project is located in Electoral Area B of the SLRD and contains the unincorporated community of Seton Portage and the St'át'imc Nation communities of Tsal'álh, T'it'qet, Xwísten, and Sekw'el'was. Electoral Area A contains Mission Mountain Road that will be used to access the Project. N'Quatqua is located in Electoral Area C. An overview of existing regional socio-economic conditions in Electoral Areas A and B of the SLRD is provided in **Section 5.2**. **Appendix A** contains further regional information for of the entire SLRD.

Baseline information provided for the LSA consists of community profiles, which provide context and understanding of community characteristics, including demographics, labour force, and economy. In addition, information is provided on topics of interest that have been identified by St'át'imc Nation (correspondence with BC Hydro March 2020). The profile information and topics of interest were used to organize the description of socio-economic conditions for each community (**Section 4.0**) as well as St'át'imc Nation (**Section 5.1**).

The information provided in this report was obtained from publicly available sources and from the Project's Construction Management Plan (BC Hydro 2019). For each community there is a very different amount of publicly available information; therefore, some of the sections below have more information than others. In addition, Statistics Canada supresses data for small populations to protect anonymity. Communities with larger populations also typically have more community service organizations that publish reports publicly and receive more attention in regional reports, also creating an increased amount of information. Through ongoing engagement with St'át'imc Nation, additional information to build out the baseline conditions would be sought to support the assessment of impacts.

Bridge River Generating Station
Unit 1-4 CPCN
Shalath, BC

Local Study Area for BR1 Project

Legend

- Bridge River 1 Generating Station
- Populated Place
- First Nations Community
- First Nations Reserve
- Park or Protected Area
- Highway
- Road

Notes

1. All mapped features are approximate and should be used for discussion purposes only.
2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Contains information licensed under the Open Government Licence(s) - British Columbia
- Basemap: ESRI World Topo Base
- Inset Basemap: ESRI World Topographic Map

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4.0 COMMUNITY PROFILES

4.1 Tsal̓ál̓h and Seton Portage

Members of Tsal̓ál̓h (Seton Lake Band) reside in Slosh Indian Reserve (IR), adjacent to BR1 and Seton Lake. Slosh IR contains the Shalalth and Ohin subdivisions (Academic 2020). Seton Portage is a small rural community located between Anderson Lake and Seton Lake, approximately 7 km south-west of Slosh IR, with a mix of permanent residents and seasonal homes.

Shalalth and Seton Portage are often grouped in data, such as the data from Statistics Canada. However, it is important to note that the data grouping of Shalalth and Seton Portage does not accurately represent the population of the Shalalth subdivision of Slosh IR. In the sections below, data is described for Slosh IR, as well as for Seton Portage and Shalalth to attempt to provide a complete picture of the population in communities adjacent to BR1.

4.1.1 Demographics

The population of Slosh IR was reported by Statistics Canada to be 177 in 2016, decreasing 20.6% from the 2011 population (Statistics Canada 2016a). The population of Tsal̓ál̓h was recorded as 220 by Statistics Canada in 2016 (Statistics Canada 2016b) indicating that, of those members of Tsal̓ál̓h who participated in the 2016 Census, many live on the Slosh IR. The combined population of Shalalth and Seton Portage was reported by Statistics Canada as 46 in 2016, representing a decrease of 10 people from 2011 (Statistics Canada 2016c).[1]

The median age of the population in Slosh IR based on Statistics Canada's count was 43.2 (Statistics Canada 2016a, 2016b). This is notably younger than the recorded median age of Shalalth and Seton Portage, 63.5, however, similar to the British Columbia (BC) average of 43 (Statistics Canada 2016d, 2016c, 2016a). The population of Seton Portage experiences a seasonal population increase during warmer months with the influx of seasonal residents and visitors.

4.1.2 Labour Force Characteristics

The 2016 labour force participation rate for Slosh IR was 53.6% in 2016. For Shalalth and Seton Portage, the 2016 labour force participation rate, based on the population count of 46 from 2016, was approximately 50% (Statistics Canada 2016c). Approximately 26.7% of the people of Slosh IR work in public administration, and 26.7% work in educational services. Additionally, people of Slosh IR work in utilities, construction, professional, scientific and technical services, administration and support, waste management and remediation services. People in Shalalth and Seton Portage work in retail trade, transportation and warehousing, and public administration (Statistics Canada 2016c). Because of data suppression the full range of industries in which individuals work in Slosh IR and in Shalalth and Seton Portage is likely not fully represented by Statistics Canada data.

[1] Data suppression and random rounding are used by Statistics Canada to protect individuals of small populations and result in many details from Statistics Canada being irrelevant to small populations.

Education conditions are generally described using educational attainment, which is defiend as the highest level of education completed. The percentage of the labour force without a secondary school diploma or equivalent on the Slosh IR, Shalalth and Seton Portage was lower than the BC average as presented in **Table 4.1**. However, random rounding likely affects the accuracy of the data for the small populations.

Table 4.1 Highest Educational Attainment for Slosh IR and Shalalth and Seton Portage (percent of labour force)

Community	No Certificate, Diploma or Degree	Secondary School Diploma or Equivalency Certificate	Post Secondary Certificate, Diploma, or Degree
Slosh IR	25.0	29.6	50.0
Shalalth and Seton Portage	33.0	33.0	33.0
BC	15.5	29.4	55.1

Statistics Canada 2016

Median after-tax income of individuals is not available for Slosh IR, Shalalth and Seton Portage. Household data for each community reveals that the median after-tax income of households was $25,920 on Slosh IR and $53,888 in Seton Portage (Statistics Canada 2016b). The median after-tax income of households on Slosh IR is notably lower than in Shalalth and Seton Portage and lower than the BC average of $61,280 (Statistics Canada 2016d, 2016c).

4.1.3 Housing and Accommodation

There were approximately 75 occupied private dwellings on Slosh IR and 25 occupied private dwellings in Shalalth and Seton Portage recorded in the 2016 census. In Slosh IR, the majority of the dwellings were built in 1981 or more recently, whereas in Shalalth and Seton Portage, many of the dwellings were built prior to 1980 (Statistics Canada 2016c). BC Hydro noted that very few accommodations are available to temporary workers in this area (BC Hydro 2019).

Accommodation for visitors to Seton Portage is available at Lil'tem Mountain Hotel and Crane's Landing Recreational Vehicle (RV) park with rental RVs available, both owned and operated by Tsal̓álh Development Corp., and available seasonal rentals. The local area of Seton Portage has approximately 92 self-contained units available for rent. The accommodation is generally of good quality and units typically contain a TV and landline, have access to internet, and many have kitchenettes. There are also eight rental houses in Shalalth (BC Hydro 2019).

BC Hydro regularly utilizes Lil'tem Mountain Hotel and works closely with the hotel to ensure capacity for its projects and other staff. If this accommodation is full, BC Hydro tries to maximize the accommodation in Seton Portage, and then looks to accommodation in Lillooet (BC Hydro 2019).

4.1.4 Community Safety, Wellbeing, and Services

In general, Shalalth and Seton Portage are safe places to live and visit. They are remote, and residents know and rely on each other. Crime rates are low, and people generally go about their lives unencumbered by worries that may affect more populated or urbanized areas. A serious incident did occur in 2018 when a homicide was committed at a residence on the Highline Road, close to Shalalth and Seton Portage. At the time, the Royal Canadian Mounted Police (RCMP) reported that the incident did not pose a threat to others in the community, but the occurrence was alarming for the population (CFJC Today 2018).

Previous BC Hydro projects at the Bridge River site have resulted in issues and concerns from local residents specific to community safety and wellbeing, particularly in the community of Tsal̓álh. Concerns include reports of disruptive parties in Seton Portage, allegations of illicit drug use and possible drug dealing, and inappropriate and offensive behaviour, including racism, towards local residents. Tsal̓álh and St'át'imc leadership raised these concerns with BC Hydro. The issues indicated a general sense of unease and fear as a result of the temporary workforce staying in the community. An increase in partying and associated negative behaviour can lead to a culture change that has lasting negative effects after the temporary workers leave (BC Hydro 2019).

With respect to community recreational services, there are historic sites, lake access in both communities, a playing field at the Sk'il Mountain Community School, and Shalalth has the Bridge River Library (BC Parks 2020a, Lillooet Area Library Association 2020, BC Hydro 2019).

Seton Portage has one grocery store and one restaurant that, as noted by BC Hydro, cannot stock for the additional demand brought on by temporary workers. For community members to have continued access to the groceries and dining they are accustomed to, BC Hydro workers have to bring their own food, as they have done for previous work in the area (BC Hydro 2019).

4.1.5 Emergency, Health and Policing Services

Slosh IR is policed by the Stl'atl'imx Tribal Police Services and the nearest office is located in Lillooet approximately 64 km east of Shalalth. The surrounding area, including Seton Portage and rural Bridge River, is in the jurisdiction of the RCMP, with the nearest office in Lillooet (BC Hydro 2019).

There is no cell phone service in Shalalth and Seton Portage; therefore, calling for emergency help requires a satellite phone or communication device such as InReach. Locals are accustomed to using these devices for emergency communication (BC Hydro 2019).

4.1.6 Transportation and Traffic

The road from Shalalth to Seton Portage is fully paved and maintained by Dawson Road Maintenance through a highway maintenance agreement with the BC Government (Dawson Road Maintenance 2020). The road consists of winding sections and a few switchbacks. There is a public school located on the route, which has a school zone speed restriction of 30 km/hr (BC Hydro 2019). The Kaoham Shuttle provides passenger car train service between Seton Portage and Lillooet and is managed by a partnership between St'át'imc and CN Rail. More recently, service has been intermittent and is subject to cancellation due to limited operator availability. The community of Tsal̓álh is very interested in reviving the shuttle car service to support the community and its tourism plans (BC Hydro. 2019).

4.2 T'it'q'et

T'it'q'et (formerly known as Lillooet Indian Band) is located near Lillooet and has seven reserves in the Lillooet area, Kilchult 3, Lillooet 1, Lillooet 1A, McCartney's Flat 4, Riley Creek 1B, Seton Lake 5, and Townock 2 (First Nations Land Management Resource Centre 2020). Data availability on Statistics Canada is limited to four out of the seven reserves, Lillooet 1 (population 243), McCartney's Flat 4 (population 26), Seton Lake 5 (population 0), and Townock 2 (population 5) (Statistics Canada 2016e). There is also an Aboriginal Population Profile on Lillooet Tribal Council, which has six member St'át'imc communities that use Lillooet as a service centre. Of the reserves with recorded data on Statistics Canada website, the recorded populations are quite small and the resulting Statistics Canada data is of poor quality due to data suppression. Lillooet 1 Reserve has a larger population and therefore data is less affected by random rounding and data suppression. The data from Lillooet Reserve 1 and the Aboriginal Population Profile will be used in the section below, along with additional sources.

4.2.1 Demographics

The population of Lillooet Tribal Council as recorded by Statistics Canada is 1,260 (Statistics Canada 2016e). The population living on Lillooet Reserve 1 is 243, however, it is expected that a larger amount of the population lives on reserve than is demonstrated through Statistics Canada data (Statistics Canada 2016e). The median age of the population is 38.2, notably lower than the Electoral Area B average of 55.8 (Statistics Canada 2016e, 2016g).

4.2.2 Labour Force Characteristics

The labour force participation rate for Lillooet Tribal Council membership is 54.5% (Statistics Canada 2016e). On Lillooet Reserve 1 the labour force participation rate is slightly lower at 47.2% (Statistics Canada 2016f). These labour force participation rates are higher than that of Area B, 44.4%, but lower than the BC average of 63.9% (Statistics Canada 2016f, 2016d). Data for the Lillooet Tribal Council show the breakdown of types of work that people are involved in to be public administration (20.6%), health care and social assistance (12.7%), agriculture, forestry, fishing, and hunting (7.8%), retail and trade (7.8%), and a diverse array of other industries (Statistics Canada 2016e). People living on Lillooet Reserve 1 work in public administration (26.7%), as well as in construction, manufacturing, retail trade, professional, scientific, and technical services, and health care and social assistance (Statistics Canada 2016f).

Educational attainment recorded for the Lillooet Tribal Council membership is similar to that on Lillooet Reserve 1. Approximately 31.7% have no certificate diploma or degree and 28.6% have a secondary school diploma or equivalency certificate, 10.6% have an apprenticeship or trades certificate, 18.1% have college, or other non-university certificate or diploma, and 7.5% have a university certificate or diploma below bachelor level, and 3.5% have a university certificate, diploma or degree at the bachelor level or above (Statistics Canada 2016e, 2016f).

Median after-tax income recorded for individuals in 2015 was $17,003 for Lillooet Tribal Council members (Statistics Canada 2016e). This data point is suppressed for the population of Lillooet Reserve 1. The median after-tax household income for Lillooet Reserve 1 was $31,104 (Statistics Canada 2016f). The median after-tax income for individuals is similar to that found in Electoral Area B where the median after-tax income for individuals was $23,424, however, the median after-tax household income is lower than that in Electoral Area B where it is $43,264 (Statistics Canada 2016g). These values are lower than BC averages where the median after-tax income for individuals in 2015 was $29,783 and the median after-tax household income was $61,280 (Statistics Canada 2016d).

4.2.3 Housing and Accommodation

There are approximately 103 houses on T’it’q’et reserves, as recorded in the T’it’q’et Annual Report 2017-2018 (T’it’q’et 2018). On Lillooet Reserve 1 there are 85 private households as recorded by Statistics Canada (Statistics Canada 2016f). During previous BC Hydro projects at the Bridge River Station, concerns have been raised with respect to impacts on the rental housing market due to contractors taking up available rentals and increasing rental rates.

T'it'q'et own and operate the Retasket Lodge and RV Park Ltd in Lillooet (St'át'imc 2020).

4.2.4 Community Safety, Wellbeing, and Services

There is little public information available on community safety and wellbeing, however, T'it'q'et has many community services aimed at increasing community safety and wellbeing. These services include: T'it'q'et Community Health Centre and T'it'q'et Daycare and preschool in addition to community initiatives with local and regional partners that include housing and environmental initiatives, as well as social and economic development (St'át'imc 2020a, T'it'q'et 2018). In general, the presence of temporary construction workers is known to influence community members' sense of safety and wellbeing (Gibson et al. 2017).

4.2.5 Emergency, Health and Policing Services

The T'it'q'et reserves are policed by the Stl'atl'imx Tribal Police Services and the nearest office is located in Lillooet (Stl'atl'imx Tribal Police Service 2020). The remaining areas in Lillooet are within the jurisdiction of the RCMP that has a regional detachment located in Lillooet (BC Hydro 2019).

4.2.6 Transportation and Traffic

T'it'q'et communities are accessed from Highway 99, though are not situated on the highway. CN Rail runs adjacent to Lillooet Reserve 1.

4.3 Sekw'el'was

Sekw'el'was (formerly Cayoosh Creek band) is located near to Lillooet and has three reserves in the Lillooet area. The main community is Cayoosh Creek 1 which services the three Sekw'el'was reserves (Stl'atl'imx Tribal Police Service 2020). For Sekw'el'was, data from Cayoosh Creek 1 reserve is the only data available on Statistics Canada and was used to inform the sections below.

4.3.1 Demographics

The population of Cayoosh Creek 1 was reported by Statistics Canada as 65 in 2016. The median age of the population based on Statistics Canada's recorded population was 55.8, older than the BC average of 43 (Statistics Canada 2016d, 2016h).

4.3.2 Labour Force Characteristics

The 2016 labour force participation rate for Cayoosh Creek 1 was 50.0 based on the population count of 65 in 2016 (Statistics Canada 2016h). Due to random rounding, the industries in which the people of Cayoosh Creek work are not accurately represented in Statistics Canada data.

Educational attainment of Cayoosh Creek 1 is reported by Statistics Canada as lower than the BC average (see **Table 4.1**); however, not substantially different than the educational attainment found in surrounding communities. Approximately 27.8% have no certificate diploma or degree, 16.7% have a secondary school diploma or equivalency certificate, 11.1% have an apprenticeship or trades certificate or diploma, and 11.1% have a university certificate or diploma below bachelor level (Statistics Canada 2016d, 2016h). Random rounding likely affects this data due to the small reported population on Statistics Canada.

Income data is not available for Cayoosh Creek 1.

4.3.3 Housing and Accommodation

There were approximately 35 occupied private dwellings in Cayoosh Creek 1 in 2016 according to Statistics Canada, however Sekw'el'was reports on their website that there are 26 individually owned homes in the community, 12 social housing units for rent, and two additional rentals (Statistics Canada 2016h, Sekw'el'was 2020a). Many of these dwellings were built prior to 2000, and the majority only require regular maintenance or require minor repairs (Statistics Canada 2016h). For accommodation, Bonnie and Trev's Rentals and Accommodation is locally owned by a Sekw'el'was member (St'át'imc 2020a).

During previous BC Hydro projects at the Bridge River Station, concerns have been raised with respect to impacts on the rental housing market due to contractors taking up available rentals and increasing rental rates.

4.3.4 Community Safety and Wellbeing

There is little public information available on community safety and wellbeing for Sekw'el'was. The Sekw'el'was website explains the community-based safety and wellbeing services offered by the First Nation include: community wildfire protection program, education and funding for post-secondary education and skills training, community health program and home care aid, housing, and social development programs (Sekw'el'was 2020b). In general, the presence of temporary construction workers are known to influence community members' sense of safety and wellbeing (Gibson et al. 2017).

4.3.5 Emergency, Health and Policing Services

Sekw'el'was community is policed by the Stl'atl'imx Tribal Police Services and the nearest office is in Lillooet (Stl'atl'imx Tribal Police Service 2020).

4.3.6 Transportation and Traffic

Highway 99 travels through Cayoosh Creek 1.

4.4 Xwísten

Xwísten (formerly Bridge River Indian band) is located approximately 9km northwest of the town of Lillooet. Xwísten have three reserves, Bridge River IR 1, Bridge River IR 2, and Lillooet IR 1A (Xwísten 2013). Recorded by Statistics Canada for Xwísten, there is a Bridge River Aboriginal Population Profile as well as a census profile for Bridge River 1 reserve (Statistics Canada 2016i). These profiles were reviewed and represent nearly the same population size and show the same data. The Bridge River 1 data was used in the below sections.

4.4.1 Demographics

In 2016, the population of Bridge River 1 was reported by Statistics Canada as 241, increasing by 2.1% since 2011 (Statistics Canada 2016i). The median age of the population is 33.9, younger than the BC average of 43 (Statistics Canada 2016d, 2016i). In 2013, there were approximately 424 registered members of Xwísten, with 37% living on reserve and the remainder of the population living off reserve. The number of members living on reserve declined from 2000 when the split of members living on and off reserve was almost equal (Xwísten 2013).

4.4.2 Labour Force Characteristics

The 2016 labour force participation rate for Bridge River 1 was 52.8% (Statistics Canada 2016i). The people of Bridge River 1 work in diverse industries. Approximately 27.8% work in public administration, 16.7% work in health care and social assistance, and other common industries include transportation and warehousing, retail trade, construction, and agriculture, forestry, fishing, and hunting (Statistics Canada 2016i).

The highest educational attainment of the population of Bridge River 1 is reported by Statistics Canada and differs from BC averages as they are presented in **Table 4.1**. Approximately 33.3% have no certificate diploma or degree, 36.1% have a secondary school diploma or equivalency certificate, and 30.6% have a post-secondary certificate, diploma, or degree (Statistics Canada 2016i).

Median after-tax household income was $34,219, notably lower than the BC average of $61,280 (Statistics Canada 2016d, 2016i).

4.4.3 Housing and Accommodation

In 2013 there were 90 dwellings on reserve according to the Xwísten community profile (Xwísten 2013). This aligns with Statistics Canada data that also recorded 90 houses on reserve in 2016 (Statistics Canada 2016i). Of these dwellings, 38.9% were built prior to 1990, 61.1% were built between 1991 and 2005, and 11.1% are newer than 2000. The housing is a mix of Canadian Mortgage and Housing Corporation Homes, band-owned rental units, and homes owned by members (Xwísten 2013).

4.4.4 Community Safety and Wellbeing

There is little public information available on community safety and wellbeing for Xwísten. The Xwísten website explains the safety and wellbeing services offered by the First Nation include: a women's healing circle, community dinners, youth groups and educational groups, post-secondary funding, day care, health care, and housing (Xwísten 2020).

In general, the presence of temporary construction workers are known to influence community members sense of safety and wellbeing (Gibson et al. 2017).

4.4.5 Emergency, Health and Policing Services

Xwísten is policed by the RCMP.

4.4.6 Transportation and Traffic

Lillooet Pioneer Rd 40, the road travelled to access the Project, travels through Bridge River 1.

4.5 N'Quatqua

N'Quatqua is located in D'Arcy, a small unincorporated community situated at the head of Anderson Lake, approximately 43 km northeast of Pemberton and 36 km southwest of BR1. N'Quatqua has five reserves, Anderson Lake 5, Nequatque 1, Nequatque 2, Nequatque 3, and Nequatque 4 (AANDC 2008). Of these five reserves, Nequatque 1, Nequatque 2, and Nequatque 3A, are represented in Statistics Canada data together as Nequatque IRs. N'Quatqua First Nation also has an Aboriginal population profile on Statistics Canada, however, the data for the Nequatque reserves will be used in the sections below because of its focus on the D'Arcy area.

4.5.1 Demographics

In 2016, the population of the Nequatque IRs was reported by Statistics Canada as 132, decreasing from 54.8% from 2011 (Statistics Canada 2016j). However, N'Quatqua reported in 2015 that they had 356 registered members with 164 members living in the community and 42 members living in other First Nations communities, and 151 living off reserve. N'Quatqua reports that over the 20 years before 2015, their population grew by 48% (N'Quatqua 2015). The median age of the reported population was 39.5 in 2016 (Statistics Canada 2016j).

4.5.2 Labour Force Characteristics and Economy

The 2016 labour force participation rate for Nequatque was 47.8% (Statistics Canada 2016j). The people of Nequatque work in public administration, health care and social assistance, retail trade, and agriculture, forestry, fishing, and hunting (Statistics Canada 2016j). Because of the small population represented in the industry statistics, this data does not fully represent the range of industries in which the people of N'Quatqua work.

Educational attainment of N'Quatqua as reported by Statistics Canada is lower than BC averages as they are presented in **Table 4.1**. Approximately 27.3% have no certificate diploma or degree which is higher than the BC average of 15.5%. Approximately 54.5% have a secondary school diploma or equivalency certificate which is higher than the BC average of 29.4%. Approximately and 22.7% have a post secondary certificate, diploma, or degree as their highest level of educational attainment, which is notably lower than the BC average of 55.1% (Statistics Canada 2016j, 2016d).

Median after-tax household income was $30,784 in 2015 notably lower than the BC average of $61,280 and also notably lower than the Statistics Canada reported median after-tax household income of D'Arcy ($58,624) (Statistics Canada 2016k, 2016d, 2016j).

Local businesses in D'Arcy and N'Quatqua include a gas station, convenience store, and community centre. The majority of local businesses are owned and operated by N'Quatqua (Pemberton and District Chamber 2020a).

4.5.3 Housing and Accommodation

As of the 2016 census, there were 50 occupied private dwellings in Nequatque (Statistics Canada 2016j). The majority of the houses were built prior to 2000 and the majority are in good repair requiring only regular maintenance or minor repairs (Statistics Canada 2016j).

4.5.4 Community Safety and Wellbeing

N'Quatqua offers community safety and wellbeing services, though little public information is available on community safety and wellbeing. N'Quatqua safety and wellbeing services include family support, community health, social development, education, housing, and economic development (N'Quatqua 2015). Contractors and BC Hydro crews often travel through N'Quatqua on their way to Bridge River, and this may influence the community's sense of safety and wellbeing.

4.5.5 Emergency, Health and Policing Services

The Stl'alt'imx Tribal Police Service police Nequatque and their closest office is their headquarters located in Mount Currie, a little less than 40km from Nequatque (Stl'atl'imx Tribal Police Service 2020). The remainder of D'Arcy is policed by the RCMP.

4.5.6 Transportation and Traffic

N'Quatqua is accessed via Pemberton Portage Rd when travelling from Pemberton. N'Quatqua is also connected to the Project as well as Shalalth and Seton Portage via Highline Rd. which was declared a provincial highway in 2013 and is maintained by Dawson Road Maintenance (Question 2013, Dawson Road Maintenance 2020). Contractors and BC Hydro crews travelling to the site often utilize the Highline Road, particularly in the summer months, which increases traffic through N'Quatqua.

4.6 Lillooet

The District of Lillooet is the economic and services hub for the communities in SLRD Areas A and B and is located approximately 65 km east of Bridge River Generating Station via Lillooet Pioneer Road 40.

4.6.1 Demographics

The population of Lillooet was reported as 2,275 in the 2016 Canadian census, which represented a slight decrease from 2011 when the population was reported as 2,321 (Statistics Canada 2016l). The population has been experiencing declines for the last thirty years but is projected to stabilize at current levels (Interior Health 2018).

Lillooet has an older population than BC's median age. In 2016, the median age of the population in Lillooet was 51.1, compared with the BC median age of 43. The greater median age in Lillooet was in part due to the portion of the population that was aged 65 and older, which was 23.5% in Lillooet compared to 18.3% in all of BC. Lillooet had slightly fewer residents aged 0-14 than all of BC (13.0% in Lillooet compared to 14.9% in all of BC) and also slightly fewer residents aged 15-64 (63.3% in Lillooet compared to 66.9% in all of BC). Approximately 25.8% of the Lillooet population self-identified as Aboriginal (Statistics Canada 2016d, 2016l).

4.6.2 Labour Force Characteristics

Of the population aged 15 and over, the labour force participation rate in Lillooet was 57% in 2016, which was lower than the labour force participation rate in BC overall (63.9%). Lillooet had a 10% unemployment rate compared to a 6.7% unemployment rate in BC overall. However, Lillooet's unemployment rate has decreased since 2011 when it was 17.3%, partially due to a replacement of jobs that were lost in the downturn of the forestry industry at that time (Statistics Canada 2016d, 2016l, Squamish Lillooet Regional District 2012).

Lillooet has a diverse range of industries in which residents work. Approximately, 14.7% of the population works in retail trade, 11% works in transportation and warehousing, and 11% works in health care and social assistance. Education, agriculture, forestry, fishing, and hunting, manufacturing, public administration, and accommodation and food services are other common industries in Lillooet (Statistics Canada 2016l).

Educational attainment of the Lillooet labour force in 2016 was similar to BC, although the percentage of people with no certificate, diploma, or degree was higher than the BC average (approximately 21.5% versus 15.5% respectively). Approximately 29.9% had secondary school or equivalent certificate as their highest level of attainment (about the same as the BC average, 29.4%) and 48.8% had a post-secondary certificate, diploma, or degree (slightly less than the provincial average of 55.1%) (Statistics Canada 2016d, 2016l)

The median household income in Lillooet is below the levels found in BC overall. Household income in 2015 was $53,077 in Lillooet and $69,995 in all of BC. Median after tax income for individuals was $25,621 in Lillooet compared to $29,783 in all of BC (Statistics Canada 2016d, 2016l).

When compared with the provincial average, Lillooet has a higher prevalence of low-income individuals and a larger portion of the population collecting government transfers. In 2016, 66.2% of income for Lillooet residents was from employment income, while 18.6% of income was from government transfers (which includes pensions, employment insurance and child benefits, among other sources), compared to 70.8% and 11.1% in BC, respectively. Considering the higher median age of people in Lillooet, a large portion of the government transfers are likely to be pension income and may indicate that the retired population relies more heavily on government transfers as opposed to other retirement savings plans (Statistics Canada 2016d, 2016l).

4.6.3 Economy

In recent years, Lillooet has been challenged with facilitating economic growth. The economy has been greatly affected by decades of forestry industry downturns, the pine beetle infestation, and provincial government cutbacks. In 2001 forestry accounted for 20% of jobs in the Lillooet area, and now accounts for less than 10% of jobs (Squamish Lillooet Regional District 2008c, Statistics Canada 2016l). The SLRD reported that the local economy is impeded by infrastructure constraints such as transportation links, poor road conditions, and limited commercial attractions and amenities. Recently, Lillooet and St'át'imc Nation local government have joined together to discuss community economic development and to create an action plan (Squamish Lillooet Regional District 2015).

Current economic development drivers in Lillooet include the emerging wine industry, specialized agricultural crops (such as hops for brewing beer), expanded operations at the Bralorne Mine, the developing arts, culture and heritage sector, and progressive initiatives by area First Nations (Squamish-Lillooet Regional District 2008a).

4.6.4 Housing and Accommodation

Lillooet has 1,207 private dwellings according to the 2016 census; composed of a mix of housing types. Approximately 63.7% of the dwellings are single detached houses, 15.8% are attached dwellings such as semi-attached houses, row houses and apartment buildings, and 20% are movable dwellings. Of the private dwellings, 133 were not occupied by usual residents in 2016, indicating that there may be an excess supply of housing. Approximately 59.3% of the dwellings were built prior to 1980, 19.1% were built from 1981 to 1990, 13.0% were built from 1991 to 2000, and 9.3% of the houses are built from 2001 to 2016. Despite the older age of the houses in Lillooet, a small percentage (11.6%) are in need a major repair, with the others reporting only regular maintenance or minor repairs needed (Statistics Canada 2016l).

Lillooet has approximately 150 hotel rooms and a limited number of private residences available for rent for visitors to the community. Generally, the accommodations have good internet, landline, and television services (BC Hydro 2019).

4.6.5 Community Safety and Wellbeing

The RCMP division in Lillooet services a population of 3,429 people, which extends beyond Lillooet and includes Seton Portage. There are seven officers assigned to the detachment (BC 2019a). In recent years, Lillooet has experienced a drop in crime. The crime rate based on total criminal code offences per 1,000 people (including property, violent, and other crimes) recorded for 2018 was 57% less than the number recorded for 2009 (BC 2019b).

Lillooet has a range of recreational opportunities. Opportunities for free and small-fee activities are provided at the Lillooet Recreation, Education, and Cultural Centre as well as at the Lillooet and District Library (Lillooet 2020a). Lillooet belongs to the Health Service Area of Thompson Cariboo Shuswap, and 75.4% of people (aged 12 and up) have reported a somewhat strong or very strong sense of belonging to their local community (Provincial Health Services Authority 2019).

Access to health care information is available for Lillooet where it is not for the other communities. Provincial Health Services reported that approximately 25.8% of the population is Indigenous, 0.4% are new immigrants, and 4.5% are visible minorities in 2019. This substantial portion (approximately 30%) of the population may have unique challenges in sustaining health and wellness. Income levels also greatly affect health because of resultant effects on housing conditions and the ability to make healthy choices. A greater number of people with higher income in Lillooet have reported that they are in very good or excellent health compared to people with lower incomes. For example, 49.0% of low-income individuals report they are in very good or excellent health compared to 67.6% of high-income individuals (Provincial Health Services Authority 2019).

4.6.6 Emergency, Health and Policing Services

Lillooet has a hospital and health centre that offers a wide range of services, including 24-hour emergency service. The hospital and health centre is classified as a Community Level 1 Hospital and is the smallest type of hospital in the interior health region (Interior Health 2020). The hospital serves a local health area that encompasses Shalalth and Seton Portage, and includes a population of 4,564. Of all hospitalizations, 85% come from the Lillooet area, demonstrating that this facility is not hugely burdened with providing care to people from other areas (Interior Health 2018, Provincial Health Services Authority 2019).

Lillooet is policed both by the RCMP and Stl'atl'imx Tribal Police, depending on the area of town. First Nations territory in Lillooet is managed by the Tribal Police (BC Hydro 2019).

4.6.7 Transportation and Traffic

In addition to regional transportation and traffic information (**Section 5.2.5**), there is a passenger train service available between Lillooet and D'Arcy with capacity for 20 passengers. There are also helicopter companies (e.g., Caribou Chilcotin Helicopters) based out of Lillooet that are used for emergency search and rescue services as well as for transportation to remote locations (BC Hydro 2019).

5.0 REGIONAL CONTEXT

5.1 St’át’imc Nation

St’át’imc peoples have lived in the Bridge River region since time immemorial, but their territory extends much further and is made up of 11 St’át’imc communities. They describe their territory as:

> *“…the territory which extends north to Churn Creek and to South French Bar; northwest to the headwaters of Bridge River; north and east toward Hat Creek Valley; east to the Big Slide; south to the island on Harrison Lake and west of the Fraser River to the headwaters of Lillooet River, Ryan River and Black Tusk” (St’át’imc 2020).*

The Lillooet Tribal Council serves the six northern St’át’imc communities: Sekw'el'was, T'ít'q'et, Ts'xw'aylaxw, Xaxl’ip, Xwísten, and Tsal̓álh. The Lower Stl’atl’imx Tribal Council serves the five southern St’át’imc communities: Líl'wat, N'Quatqua, Samahquam, Skatin, Xa'xtsa (St’át’imc 2020a, Squamish Lillooet Regional District 2020b). The Lillooet Tribal Council and the Lower Stl’atl’imx Tribal Council have Aboriginal population profiles on Statistics Canada, which were used to provide community profile information for this report. Additional St’át’imc sources were used where information was available.

5.1.1 Demographics

Reports produced by St’át’imc Nation place total membership at more than 6,900, with over 4,700 of the members residing within St’át’imc communities (St’át’imc 2015). Information from Statistics Canada indicate that the Lillooet Tribal Council had a population of 2,180 in 2016 and the Lower Stl’atl’imx Tribal Council had a population of 1,795 (Statistics Canada 2016e, 2016m). Statistics Canada notes that many Indigenous populations were likely to be incompletely enumerated in the 2016 census (Statistics Canada 2016e).

The median age of Lillooet Tribal Council members was 38.2 in 2016, compared to the median age of Lower Stl’atl’imx Tribal Council members, which was 33.4. The median ages of both groups were lower than the median age of 43 for the entire BC population (Statistics Canada 2016e, 2016m, 2016d).

5.1.2 Labour Force Characteristics

Lillooet Tribal Council and Lower Stl’atl’imx Tribal Council labour force participation rate in 2016 was 54.5% and 41.8%, respectively, both of which were lower than the provincial average of 63.9%. The unemployment rate for both tribal councils in 2016 was notably higher than the provincial average; 24.1% for Lillooet Tribal Council, 18.8% for Lower Stl’atl’imx Tribal Council, and 6.7% for residents of BC overall (Statistics Canada 2016e, 2016m, 2016d).

As of 2016, the Lillooet Tribal Council labour force was involved in diverse industries with the most common industries being public administration (20.5% of workforce), health care and social assistance (12.1% of workforce), and manufacturing (8.4% of workforce). Retail and trade; and agriculture, forestry, fishing and hunting also each employ about 7.4% of the Lillooet Tribal Council workforce. The Lower Stl’atl’imx Tribal Council workforce was also spread through diverse industries, similar to the Lillooet Tribal Council labour force (Statistics Canada 2016e, 2016m).

Approximately 28.6% of the Lillooet Tribal Council population in 2016 had attained a high school diploma or equivalent as their highest educational attainment, which was similar to the provincial average of 29.4%. In comparison, approximately 49.6% of Lower Stl'atl'imx Tribal Council members had attained a high school diploma or equivalent. Approximately 22.6% of Lillooet Tribal Council members and 25.3% of Lower Stl'atl'imx Tribal Council members have a postsecondary diploma, degree, or certificate, which is notably lower than the provincial average of approximately 55.0%. Approximately 32.0% of the Lillooet Tribal Council population and 24.6% of the Lower Stl'atl'imx Tribal Council population had no diploma, certificate or degree, compared to the BC average of 9.6% (Statistics Canada 2016e, 2016m, 2016d).

The Lillooet Tribal Council and the Lower Stl'atl'imx Tribal Council median after tax income in 2015 was close to half the provincial average: $17,003 for Lillooet Tribal Council members and $17,024 for Lower Stl'atl'imx Tribal Council members, compared to $31,585 for all of BC (Statistics Canada 2016e, 2016m, 2016d).

St'át'imc Nation has been working to maximize local employment and economic development opportunities for their membership. St'át'imc has identified that many of their communities are not located near centres of employment which results in weak connections to the local job market. St'át'imc has worked to promote skills training and learning opportunities and have created partnerships with training and academic institutions to support the delivery of trades training (St'át'imc 2015).

5.1.3 Housing and Accommodation

Lillooet Tribal Council members had 490 private dwellings in 2016. Approximately 53.1% of dwellings were owned, 17.3% were rented, and 29.5% were band housing. Approximately 47.9% of the private dwellings were constructed prior to 1990, 28.5% were constructed between 1991 and 2000, and 23.4% were constructed in 2001 or more recently. Approximately 27.2% of the private dwellings were reported as in need of major repairs (Statistics Canada 2016e).

Lower Stl'atl'imx Tribal Council members had 595 private dwellings in 2016. Approximately 62.1% were owned, 15.9% were rented, and 22.6% were band housing. Approximately 59.7% of the private dwellings were constructed prior to 1990, 19.3% were constructed between 1991 and 2000, and 20.1% were constructed in 2001 or more recently. Approximately 27.7% if the private dwellings were reported as in need of major repairs (Statistics Canada 2016m).

5.1.4 Community Safety and Wellbeing

Crime rate is generally used as an indicator for evaluating community safety. The crime rates observed in Stl'atl'imx Tribal Police jurisdiction (refer to **Section 5.1.5** below) are recorded by the Government of BC. In recent years, Stl'atl'imx jurisdictions have seen a decrease in crime rates. Total criminal code offences per 1,000 people (including property, violent, and other crimes) recorded for 2018 was 44% less than the number recorded for 2009 (BC 2019b).

5.1.5 Emergency, Health and Policing Services

St'át'imc Outreach Health Services delivers primary health services to Indigenous peoples on and off reserve in Northern St'át'imc territory, providing both mental health and wellness services (St'át'imc Outreach Health Services 2020).

The Stl'alt'imx Tribal Police Service provides policing services in ten St'át'imc communities. Xwísten, located about nine km north of Lillooet is policed by the RCMP. The Stl'atl'imx Tribal Police Headquarters are in Mount Currie, and a second detachment is located in Lillooet (Stl'atl'imx Tribal Police 2020).

5.2 Squamish Lillooet Regional District

The SLRD covers 16,211.6 km^2 and is divided into four Electoral Areas: A, B, C, and D. The Project is located in Electoral Area B, immediately adjacent to the community of Shalalth and seven km east of the community of Seton Portage, on the northwest shore of Seton Lake. In addition to the unincorporated communities of Shalalth and Seton Portage, Area B contains the District Municipality of Lillooet, which functions as the region's commercial hub. Electoral Areas A and C are to the west of Area B. The Village of Pemberton and the unincorporated community of D'Arcy are located in Area C; Pemberton functions as the commercial hub. Area D is located south of Area C and includes the Resort Municipality of Whistler as well as the District of Squamish (Squamish-Lillooet Regional District 2020a). The SLRD is located within the territories of the St'át'imc Nation and the Squamish Nation.

This section provides a brief overview of existing socio-economic conditions in Electoral Areas A and B. A detailed regional analysis of the entire SLRD is provided in **Appendix A**.

5.2.1 Demographics

The population of the SLRD was 42,665 in 2016 increasing 11.6% from 2011 to 2016 (Statistics Canada 2016m). Conversely, communities in the LSA, including Shalalth/ Seton Portage and Lillooet, saw a decrease in population size between the two census dates. The age distribution in these communities was also older than the SLRD and BC averages.

5.2.2 Economy

Median incomes in the SLRD are higher in the southern Electoral Areas (C and D) than the northern Electoral Areas (A and B) (Squamish Lillooet Regional District 2020a). According to an SLRD economic report, communities in Electoral Areas A and B (e.g., Lillooet, Seton Portage, and Shalalth) are increasingly challenged in attempting to grow their economies. Northern communities have been severely affected by the decline in logging and sawmill industries over the last few decades. This has contributed to economic hardship in the northern areas of the SLRD along with a trend of younger community members moving away to find work (Squamish Lillooet Regional District 2012). Recent SLRD economic development efforts have focused on the northern areas of the region (Squamish Lillooet Regional District 2020a).

5.2.3 Community Safety and Wellbeing

In terms of overall socio-economic wellbeing, the SLRD was ranked 8th out of 26 regions in BC's 2015 socio-economic indicators index. The socio-economic index summarizes key social and economic information for all areas of BC and indicates that SLRD compares well to other regions (Squamish-Lillooet Regional District 2015b).

The readiness of kindergarten-aged children for school is used widely as an indicator of community wellbeing. A child is considered vulnerable (i.e., lacking the social and emotional development needed to start school) if they score within the bottom 10% of the population. In the Sea to Sky school district, which includes Pemberton and D'Arcy, the number of children who were considered vulnerable was 31% in 2015

(School District No. 48 2020, Squamish-Lillooet Regional District 2015b). Pemberton, however, had fewer vulnerable children (approximately 25% in 2015) than the school district average. In the Gold Trail school district, which includes Lillooet, Shalalth, and Seton Portage, the number of vulnerable children is higher than in the Sea to Sky school district. Approximately 44% of children in Gold Trail school district were considered vulnerable in 2015; however, this number had dropped from 54% in 2006 (School District No. 74 2020, Squamish-Lillooet Regional District 2015b). As an indicator of wellbeing, there is disparity between the two school districts in SLRD although there have been recent improvements.

5.2.4 Emergency, Health and Policing Services

The SLRD manages two volunteer fire departments. In the north, fire services are dispatched by the Surrey Fire Communications Centre to Lillooet and Seton Valley, among other locations. Fire Services for the south are dispatched by Emergency Communications for British Columba Incorporated (ECOMM) to Pemberton, Whistler, and Squamish, among other locations (BC Hydro 2019).

Policing services are provided in SLRD by the RCMP and First Nations police. The RCMP and Stl'atl'imx Tribal Police have jurisdictions that cover all communities in the SLRD. There are RCMP detachments located in Pemberton and in Lillooet. The Lillooet RCMP services Seton Portage. The Stl'atl'imx Tribal Police services Indigenous lands in Mount Currie, Lillooet, and Shalalth. The Whistler RCMP detachment services D'Arcy (BC Hydro 2019, BC211 2020, Stl'atl'imx Tribal Police 2020).

5.2.5 Transportation and Traffic

The main highway through the SLRD is Highway 99. This route, known as the Sea to Sky highway, connects the major urban centre of Vancouver with Pemberton, Mount Currie, and Lillooet. The highway continues east to meet with Highway 97, through which the region is connected to the BC interior. Highway 12 also connects Lillooet to Hope, providing additional access to southern and interior BC communities. There are smaller highways that connect the communities of D'Arcy, Seton Portage, and Shalalth to either Pemberton or Lillooet. Additional highways and forest service roads run through the area and are used to access other rural settlements and recreation sites (Squamish Lillooet Regional District 2008b, BC Hydro 2019).

There are difficult driving conditions between some of the communities in the LSA, specifically between Lillooet and Shalalth. The road is a mix of gravel and paved surfaces, has windy sections, steep climbs and descents and tight passages. Potholes, washboard texture, and large rocks are common. It is also common to encounter logging trucks while driving. It is possible to travel by boat between Lillooet and Shalalth. The distance by boat is about 20 km and takes about 25 minutes, depending on the watercraft. It is about a 10 km drive from the dock at the end of Seton Lake into downtown Lillooet (BC Hydro 2019).

Canadian National (CN) Rail operates a rail line between Lillooet and D'Arcy, with a two-car passenger train called the Koaham Shuttle. The passenger train is contracted by Seton Lake First Nation and operates for local commuters, including school children (Lillooet 2020a).

6.0 CLOSURE

We sincerely appreciate the opportunity to have assisted you with this project and if there are any questions, please do not hesitate to contact the undersigned by phone at 604.669.0424.

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APPENDIX A

Squamish Lillooet Regional District Regional Context

The Squamish Lillooet Regional District (SLRD) covers 16,211.6 km^2 and is divided into four Electoral Areas: A, B, C, and D. The Project is located in Electoral Area B, immediately adjacent to the community of Shalalth and seven km east of the community of Seton Portage, on the northwest shore of Seton Lake. In addition to the unincorporated communities of Shalalth and Seton Portage, Area B contains the District Municipality of Lillooet, which functions as the region's commercial hub. Electoral Areas A and C are to the west of Area B. The Village of Pemberton and the unincorporated community of D'Arcy are located in Area C; Pemberton functions as the commercial hub. Area D is located south of Area C and includes the Resort Municipality of Whistler as well as the District of Squamish (Squamish-Lillooet Regional District 2020d). The SLRD is located within the territories of the St'át'imc Nation and the Squamish Nation.

The SLRD office is located in Pemberton and its staff are responsible for delivering a range of local, sub-regional and regional services to approximately 42,665 residents (Statistics Canada 2016d). The SLRD derives its authority from the *Local Government Act* and *Community Charter* of BC.

DEMOGRAPHICS

The population of the SLRD was 42,665 in 2016 increasing 11.6% from 2011 to 2016 (Statistics Canada 2016a). The SLRD has seen an increasing rate of population growth, exceeding that of the rest of BC, since 2001 (Statistics Canada 2006). A large percentage of the region's population resides in Whistler and Squamish (74%), both of which are located in the southern part of the district. **Table A.1** displays the population of the communities that make up the LSA and percentage change in population since the 2011 census. Information for the province of BC as well as the SLRD are also provided for context. The notably larger changes in the small populations of Shalalth/Seton Portage reflect the small populations of these communities, where even a small change in total numbers would result in a noticeable percent change. In addition, seasonal population change may cause fluctuations in numbers.

Table A.1 Population of Communities in the SLRD

Community	Population (2016 Canadian Census)	Percent Change (2011 to 2016)
Shalalth/ Seton Portage	46	-17.9
Lillooet	2,275	-2.0
Mount Currie	1,285	-1.6
Pemberton	2574	5.8
Whistler	8,713	21.4
Squamish	17,587	13.1
SLRD	42,665	11.6
Province of BC	4,648,055	5.6

Source: Statistics Canada 2016

The age distribution of the SLRD region represents a slightly younger population than the BC average. By community, the youngest population in 2016 was in Pemberton, while the age distributions of the other communities were older than the SLRD average. **Table A.2** displays the age distribution in the communities that make up the LSA, with the SLRD and BC averages provided for context.

Table A.2 Age Distribution of Communities in the Local Study Area (Percent of Total Population)

Community	Aged 0-14	Aged 15-64	Aged 65+
Shalalth/ Seton Portage	0.0	55.6	44.4
Lillooet	13.0	63.3	23.5
Mount Currie	21.8	70.0	8.2
Pemberton	22.7	72.0	5.2
D'Arcy	11.1	55.6	22.2
SLRD	17.3	72.1	10.6
BC	14.9	66.9	18.3

Source: Statistics Canada 2016

ECONOMY

The SLRD has a diverse economy, with key economic drivers being tourism, agriculture, forestry, mining, construction, and renewable energy. Tourism is a strong economic driver in the region; notably, the international resort destination of Whistler brings in approximately 3 million overnight and non-overnight guests to the region each year (Tourism Whistler 2020). Communities outside of Whistler see considerably less tourism, though Squamish has seen an increase in tourism since opening the Sea to Sky Gondola in the spring of 2014 (Sea to Sky Gondola 2014) and Pemberton has seen a recent increase in tourism related to local agriculture and food manufacturing.

Whistler has such high levels of tourism compared to the other communities that its numbers dictate tourism statistics for the whole region. Therefore, removing Whistler from consideration can help to better evaluate other communities' tourism industries. When Whistler is removed from calculations, tourism has remained relatively stable in the SLRD for the last decade. Room revenue from accommodation across the region (omitting Whistler) remained stable at approximately $11 million per year from 2006 to 2015. This indicates that the tourism industry in most of the SLRD has remained relatively stable and has not seen significant growth in terms of revenue per room (Squamish-Lillooet Regional District 2015a).

The SLRD has a long history of agriculture particularly in Lillooet and Pemberton where the warm climate has allowed for successful cattle ranching, farming, and fruit production (Squamish-Lillooet Regional District 2020f). Pemberton has developed a reputation as the seed potato capital of North America (Pemberton Farmer's Market Association 2020).

Mining has a long history in the SLRD dating back to the 1858 Fraser River Gold Rush when placer miners first travelled to the Bridge River area. The Bralorne gold mine operated in the area from 1932 to 1971, producing $340 million worth of gold in that period and a community developed around the mine site. The town, however, quickly became a ghost town when the Bralorne mine shut down in 1971 (Bralorne Pioneer Gold Mines 1984). New exploration began at the mine site in 1996. Recent mining activities at Bralorne have included milling and processing of ore (Avino Silver and Gold Mines Ltd 2016). In December 2019, Avino Silver and Gold Mines Ltd. sold the property to Talisker Resources Ltd. for $8.7 million (Avino Silver and Gold Mines 2019). This re-investment in the mine has created some regional jobs and also presents an opportunity for future economic gains.

Historically, forestry has been a major industrial contributor in the SLRD, bringing in 16% of total income in 1996. Forestry employment includes harvesting, silviculture, processing of solid wood and pulp and paper manufacturing (Squamish-Lillooet Regional District 2001). However, forestry has recently declined in the SLRD due to global market conditions and lumber export tariffs. Factors affecting the global market for lumber are the weak housing market in the United States, the relatively strong Canadian dollar, and emerging low-cost global competitors. The region has relatively high production costs and long transportation distances to reach suitable processing facilities. In addition, due to local policies in Electoral Areas A and B, the timber harvesting land base has decreased (Squamish-Lillooet Regional District 2008c).

Major industries that are predicted to continue as economic drivers in the SLRD are: construction, non-resource manufacturing, agriculture and food, and tourism. Construction is expected to be driven by population growth. Non-resource manufacturing is expected to be driven by entrepreneurship largely related to ocean and rail shipping opportunities in Squamish. Agriculture and food production are expected to grow based on increasing consumer interest in locally grown food and growth in food-related manufacturing such as wineries, distilleries, and breweries (Vann Struth Consulting 2013). One example of the growing strength in the agriculture and food industry is that farm receipts increased 18.2% from 2011 to 2016 and represented 13.7% of the SLRD's gross domestic product in 2011 (BC Ministry of Agriculture 2018). Tourism is expected to see strong interest and growth in a wide variety of tourist attractions related to outdoor adventure tourism and First Nations tourism opportunities (Vann Struth Consulting 2013).

Median incomes in the SLRD are higher in the southern Electoral Areas (C and D) than the northern Electoral Areas (A and B) (Squamish Lillooet Regional District 2020a). Median income in Pemberton is higher than that of smaller communities, such as Mount Currie, and those that are located farther from large economic centres, such as Lillooet. According to an SLRD economic report, communities in Electoral Areas A and B (e.g., Lillooet, Seton Portage, and Shalalth) are increasingly challenged in attempting to grow their economies. Northern communities have been severely affected by the decline in logging and sawmill industries over the last few decades. This has contributed to economic hardship in the northern areas of the SLRD along with a trend of younger community members moving away to find work (Squamish Lillooet Regional District 2012). Recent SLRD economic development efforts have focused on the northern areas of the region (Squamish Lillooet Regional District 2020a).

COMMUNITY SAFETY AND WELLBEING

Police presence and crime rates can be used to gain an understanding of community safety. In the SLRD, crime rates (calculated by total criminal code offences per 1,000 people) notably decreased by 48% from 2009 to 2018. Criminal code offences include property, violent, and other crimes, but exclude traffic related offences (British Columbia 2019a). Reduced crime rates can lead to greater feelings of safety in communities.

In terms of overall socio-economic wellbeing, the SLRD was ranked 8th out of 26 regions in BC's 2015 socio-economic indicators index. The socio-economic index summarizes key social and economic information for all areas of BC and indicates that SLRD compares well to other regions (Squamish-Lillooet Regional District 2015).

As indicators of community wellbeing can be difficult to determine, two are presented below that are used in the SLRD's Regional Growth Strategy (RGS) Monitoring Report (Squamish-Lillooet Regional District 2015): readiness of kindergarten-aged children for school and access to recreation, culture, and arts. This SLRD report was last published in 2015 but can be used to provide an overview of wellbeing in the region.

The readiness of kindergarten-aged children for school is used widely as an indicator of community wellbeing. Childhood development tends to reflect the social and economic environment in which a child is being raised and relates to overall community health. The Early Childhood Development indicator looks at multiple factors of kindergarten-aged children's physical and emotional health, and cognitive development. According to the indicator, a child is considered vulnerable (i.e., lacking the social and emotional development needed to start school) if they score within the bottom 10% of the population. In the Sea to Sky school district, which includes Pemberton and D'Arcy, the number of children who were considered vulnerable was 31% in 2015 (School District No. 48 2020, Squamish-Lillooet Regional District 2015). Pemberton, however, had fewer vulnerable children (approximately 25% in 2015) than the school district average. In the Gold Trail school district, which includes Lillooet, Shalalth, and Seton Portage, the number of vulnerable children is higher than in the Sea to Sky school district. Approximately 44% of children in Gold Trail school district were considered vulnerable in 2015; however, this number had dropped from 54% in 2006 (School District No. 74 2020, Squamish-Lillooet Regional District 2015). As an indicator of wellbeing, there is disparity between the two school districts in SLRD although there have been recent improvements.

Access to recreation, culture, and arts can indicate wellbeing of a community as a large number of opportunities for easy-access recreation suggest that more people can be and are involved in these activities (Squamish-Lillooet Regional District 2015). In 2016, there was a total of 28.4 ha (284,000 m^2) of recreational facilities in the SLRD, including playing fields, ice rinks, gymnasiums and pools (Squamish-Lillooet Regional District 2015). In addition, a variety of arts and culture and education opportunities are available in SLRD communities, as well as outdoor recreation in parks, trails, and backcountry areas.

EMERGENCY, HEALTH AND POLICING SERVICES

The SLRD provides 911 services throughout the region. As the region is relatively remote, emergency services are supported by larger urban centres, from which calls are dispatched to local response teams (BC Hydro 2019).

The SLRD manages two volunteer fire departments. In the north, fire services are dispatched by the Surrey Fire Communications Centre to Lillooet and Seton Valley, among other locations. Fire Services for the south are dispatched by Emergency Communications for British Columba Incorporated (ECOMM) to Pemberton, Whistler, and Squamish, among other locations (BC Hydro 2019).

Policing services are provided in SLRD by the RCMP and First Nations police. The RCMP and Stl'atl'imx Tribal Police have jurisdictions that cover all communities in the SLRD. There are RCMP detachments located in Pemberton and in Lillooet. The Lillooet RCMP services Seton Portage. The Stl'atl'imx Tribal Police services Indigenous lands in Mount Currie, Lillooet, and Shalalth. The Whistler RCMP detachment services D'Arcy (BC Hydro 2019, BC211 2020, Stl'atl'imx Tribal Police 2020).

TRANSPORTATION AND TRAFFIC

The main highway through the SLRD is Highway 99. This route, known as the Sea to Sky highway, connects the major urban centre of Vancouver with Pemberton, Mount Currie, and Lillooet. The highway continues east to meet with Highway 97, through which the region is connected to the BC interior. Highway 12 also connects Lillooet to Hope, providing additional access to southern and interior BC communities. There are smaller highways that connect the communities of D'Arcy, Seton Portage, and Shalalth to either Pemberton or Lillooet. Additional highways and forest service roads run through the area and are used to access other rural settlements and recreation sites (Squamish Lillooet Regional District 2008a, BC Hydro 2019).

Transportation needs vary across the region. In the northern areas of the SLRD, safety, the need for highway service improvement, and the lack of public and/or private transportation options are the primary transportation issues. In the southern areas of the SLRD, safety, and capacity constraints are the primary issues. To address concerns in the northern areas, the SLRD's Regional Growth Strategy contains suggested improvements to Highway 99 between Pemberton and Lillooet and other northern routes including Highway 12, and the Highline Road that passes through Seton Portage and Shalalth. These improvements are suggested to improve accessibility, enhance safety and support economic development (Squamish Lillooet Regional District 2008b).

Highway safety in the SLRD is affected by the number of vehicles, vehicle incidents, and natural hazards, among other factors. The number of vehicles owned by residents of the region increased by 18.6% from 2008 to 2015. The SLRD attributes this increase partly to an increase in population, but also to an increase in per capita vehicle ownership. On major SLRD highways, the number of vehicle incidents and injuries stayed relatively constant between 2008 and 2015; however, the number of fatalities from vehicle incidents increased from two in 2008 to eight in 2015 (Squamish-Lillooet Regional District 2015).

There are difficult driving conditions between some of the communities in the LSA, specifically between Lillooet and Shalalth. The road is a mix of gravel and paved surfaces, has windy sections, steep climbs and descents and tight passages. Potholes, washboard texture, and large rocks are common. It is also common to encounter logging trucks while driving. It is possible to travel by boat between Lillooet and Shalalth. The distance by boat is about 20 km and takes about 25 minutes, depending on the watercraft. It is about a 10 km drive from the dock at the end of Seton Lake into downtown Lillooet (BC Hydro 2019).

Natural hazards exist on SLRD highways due to their proximity to steep mountains and their high elevation. Avalanches are common during winter months, and some mountain passes require avalanche control. If an avalanche does cross a highway, it is typically cleaned up and traffic is restored within 24 hours. Other natural threats come from falling rock. Highway areas are designated where risk of falling rock is high and rocks are cleaned off roads daily to limit risk of incidents (BC Hydro 2019).

Canadian National (CN) Rail operates a rail line between Lillooet and D'Arcy, with a two-car passenger train called the Koaham Shuttle. The passenger train is contracted by Seton Lake First Nation and operates for local commuters, including school children (Lillooet 2020b).

LAND USE AND RECREATION

Land use in the SLRD is largely characterized by outdoor recreation spaces such as parks and wilderness areas as well as small pockets of agricultural land, urban and rural settlements.

Land use designations in the SLRD are specified in the RGS, which was adopted in 2010 and provides a broad policy framework for the regional district and member municipalities to follow in promoting sustainable development of services. RGSs are required of regional districts under the *Local Government Act*.

The centres of Pemberton and Lillooet are zoned for urban land use, with rural community lands or rural residential lands surrounding the cores. The smaller communities of Seton Portage, Shalalth, and D'Arcy are designated as rural community land or rural residential land.

Agricultural lands are designated through province-wide zoning outlined in the *Agricultural Land Commission Act*, SC 2002, c. 36 that sets aside Agricultural Land Reserve (ALR) areas where non-agricultural uses are restricted. ALR land is outlined in the RGS to guide settlement patterns in the SLRD. ALR land is found near Squamish in the Squamish River valley, in and around Pemberton in the Lillooet River valley, and near Lillooet in the Fraser River valley (Provincial Agricultural Land Commission 2020).

Parks and protected areas are found throughout the SLRD. The main parks in the area are Garibaldi Provincial Park, located east of Highway 99 and spanning 194,676 ha between Squamish and Whistler areas, and Duffy Lake Provincial Park, located west of Highway 99, spanning 4,048 ha between Pemberton and Lillooet. The parks draw day-use and overnight recreationalists from the Vancouver lower mainland for activities such as hiking, camping, mountain biking, and backcountry skiing (BC Parks 2020a). There are multiple other parks and protected areas in the region; however, the two parks mentioned above draw the largest crowds because of the accessibility of day hikes, viewing areas and their proximity to larger urban centres. Generally, all parks in the region offer opportunities for camping, day hikes and over-night hikes, backcountry skiing along with backcountry skiing huts for staying overnight, and mountain biking.

Outdoor recreation activities in the SLRD attract residents and visitors to the region and drive much of the region's tourism. As highlighted above, tourism is a substantial economic driver in the region and is centered around the pursuit of outdoor activities. Recreation activities that bring the most visitors to the region are downhill skiing, golfing, and sight-seeing at Whistler Mountain Resort, sight-seeing and hiking at the Sea to Sky Gondola, and the many hiking and camping opportunities spread throughout the region. In addition, various day hike locations and backcountry ski and snowshoe locations, such as Garibaldi Provincial Park and Duffy Lake Provincial Park bring in large crowds from the Vancouver lower mainland for day hikes. Generally, the mountains and lakes in the area provide opportunities for hiking, hunting, fishing, backcountry skiing, motorized sports, ice and rock climbing, mountain biking, road cycling, paddling, and watercraft recreation. There are also several golf courses and disc-golf courses located in Lillooet, Pemberton, Whistler, and Squamish. The outdoor activities define the active culture of the communities in the region and have become recreation destinations known locally and internationally for accessibility to mountains, glaciers, and lakes.

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BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-14

Bridge River Contract Worker Conduct Requirements Policy

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Bridge River Contract Worker Conduct Requirements

Bridge River Management

Introduction

The BC Hydro Bridge River System is located within the traditional territory of the St'át'imc Nation. After 20 years of negotiation, in May 2011 BC Hydro and St'át'imc Nation entered into a series of Agreements, collectively referred to as the Settlement Agreements. These Agreements are intended to create certainty for all parties regarding BC Hydro operations and to assist in developing a collaborative and respectful working relationship between BC Hydro and St'át'imc. Our relationship with St'át'imc is integral to the ongoing operations of our facilities in the territory, and BC Hydro acknowledges it has a responsibility to do more – to be stewards of the relationship and to lead by example.

These Worker Conduct Requirement have been developed and revised in response to concerns raised specifically by the St'át'imc community of Tsal'alh, whose main community is directly impacted by the construction activities at Bridge River Generating Station, and by the presence of workers in the area. This Worker Conduct Requirements are in place alongside focused efforts to improve cultural awareness and sensitivity of the Bridge River workforce and throughout the territory. They supplement the *Contractor Standards for Ethical Conduct.*

Contractor and Worker Conduct Requirements

Definitions:

"**BC Hydro**" means BC Hydro and Power Authority or any of its subsidiaries that has entered into the Contract.

"**Bridge River Area**" means BC Hydro's Bridge River worksites and facilities, Seton Portage, Lillooet, and other areas indirectly related to Bridge River Operations.

"Bridge River Projects" consist of various projects throughout BC Hydro's Bridge River system which includes the LaJoie, Terzaghi Dam, Bridge 1 and 2 Generating Stations, and Seton facilities. The primary projects that are occurring are the replacement of all

ten generator and turbines at the four generating facilities and re-coating of the six penstocks at Bridge 1 and 2.

"**Contract**" means a contract with BC Hydro in which these Standards are included directly or by reference as a term or condition.

"**Contractor**" means the contractor, consultant, supplier or business associate who has a Contract. "Owner" means any person who, individually or together with relatives, directly or indirectly owns 20% or more of the voting rights of the Contractor.

"**Worker**" means an individual employee, subcontractor, consultant, subcontractor employee, or contractor of the Contractor who is engaged to perform work on the Bridge River Projects and who enters the Bridge River Area in the course of that work.

Ethics

Each Contractor is required by their contract with BC Hydro to comply with BC Hydro's *Contractor Standards for Ethical Conduct* (attached) at all times during the term of the Contract. Contractors are responsible for ensuring Workers are aware of and comply with the *Contractor Standards for Ethical Conduct* in the course of their work.

Included in the *Contractor Standards for Ethical Conduct* is the requirement that Workers treat people they encounter in the course of their work with dignity and respect and in a manner free of discrimination and harassment.

Worker Off-Site and Non-Working Hour Conduct Requirements

BC Hydro respects Worker privacy and activities outside of work. However, Worker actions off-site and outside of working hours have the potential to negatively affect the Bridge River Project, the Bridge River work environment, and BC Hydro's reputation and relationships in the Bridge River Area, specifically with the St'at'imc communities. As a result, Workers are expected to comply with the requirements below when off the worksite or outside of working hours while in the Bridge River Area as a result of their work on the Bridge River Projects.

Worker Travel Requirements

When Workers travel between the worksite and their accommodations, they are expected to conduct themselves in a respectful manner (whether the Worker is a driver or operator or a passenger) and comply with all applicable laws.

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Regardless of the mode of transportation, passengers will not influence the driver or operator to conduct unlawful or reckless maneuvers. Passengers will respect the driver or operator's decisions and not cause any type of distractions to the driver/operator that may result in unsafe travelling conditions. Consuming alcohol is prohibited during any type of travel, and smoking is prohibited in all transportation that is provided by the Contractor or BC Hydro.

When driving by automobile, the driver and passengers will obey all motor vehicle laws and regulations, including but not limited to:

- Do not exceed the maximum posted speed limit
- Comply with all school zone restrictions
- Do not tailgate other vehicles
- Wear seatbelts
- Comply with any maximum passenger capacities
- Driving while impaired by the effects or after effects of drugs or alcohol

When travelling by boat, the operator and passengers will:

- Wear lifejackets at all times as soon as they board the vessel
- Not hang off the edge of the vessel while in operation
- Arrive at the pick-up locations on-time
- Ensure the vessel has enough fuel for the trip before departing
- Conduct a pre-departure checklist and do not depart unless pre-departure requirements on the checklist are satisfied

Worker Accommodation Requirements

During non-working hours in the Bridge River Area, Workers must behave in a respectful and courteous manner when interacting with local communities, members of the public, local businesses, BC Hydro employees and other Workers. Workers must behave in a respectful manner toward hotel/accommodation staff, owners, and other residents.

Workers in Bridge River Area staying at hotels or accommodations during non-working hours are expected to comply with any requirements set by the hotel/accommodation, including:

- **Illicit Drugs-** The use, possession, distribution, or offering or sale of illicit drugs or illicit drug paraphernalia will not be tolerated.

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- **Disrespectful Behaviour –** Disrespectful behaviour includes the failure to treat others with dignity and respect. It also includes bullying, personal harassment, sexual harassment, discriminatory or racist conduct or comments directed at a specific person or group, which a reasonable person would consider to be intimidating, humiliating, unwelcome or offensive. This disrespectful behavior will not be tolerated.

- **Theft -** Theft of any kind will not be tolerated and will be reported to police.

- **Vandalism -** willful damage/vandalism to property or objects or to the property of any other person including damage/vandalism to the hotel or accommodation will not be tolerated. This includes consistently leaving the hotel or accommodation in a consistently dirty or untidy state resulting in complaints from the staff or owner of the hotel or accommodation.

- **Violence –** Violence of any kind will not be tolerated. This includes fist fights, battery or other forms of assault, threats of violence, encouraging or supporting others to engage in violent acts.

- **Unruly parties/social gatherings** – parties or social gatherings that result in complaints or disrespectful behaviour will not be tolerated.

- **Unlawful Behaviour** – unlawful behaviour, specifically criminal activity and trespassing, will not be tolerated in the Bridge River Area.

- **Failure to Respect Personal Privacy** - failure to respect the personal privacy of other residents, Workers, staff, accommodation owners will not be tolerated.

Worker Recreation Requirements

During non-working hours in the Bridge River Area, Workers taking part in recreational activities must comply with any applicable laws and take all reasonable safety precautions appropriate for the recreational activity.

In Bridge River and Lillooet, Workers will:

- **Obey Road & Property Restrictions -** Comply with road use and property restrictions when operating off-road vehicles

- **Obtain Applicable Licences** - Obtain any required fishing licences and follow local restrictions when fishing

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- **Avoid Consuming Alcohol in Public Places** – Workers may consume alcohol at designated areas such as pubs and private residences, but not public places.
- **Be Respectful –** Workers must behave respectfully in interactions with local communities, members of the public and local businesses. This means treating others with dignity and respect. It also includes a prohibition on bullying, personal harassment, sexual harassment, and discriminatory or racist conduct or comments directed at a specific person or group, which a reasonable person would consider to be intimidating, humiliating, unwelcome or offensive.

Compliance

Workers will report to their employer/Contractor for all issues, concerns, requests or permissions. The Contractor Representative may contact the BC Hydro Representative to resolve any matters. Workers and Contractors will not speak directly to BC Hydro Operations or coordinate with other contractors without the BC Hydro Representative present.

BC Hydro has the right under its Contracts to remove Workers who have engaged in misconduct. Failure to comply with these *Bridge River Contract Worker Conduct Requirements* will be considered misconduct and may result in Worker removal from the Bridge River Projects.

BC Hydro Bridge River Projects

Bridge River 1 Units 1 to 4 Generator Replacement Project

Appendix B-15

BR1 Stakeholder Engagement Materials

Bridge (Shalalth) – Seton (Lillooet) Capital Investment Update

April 2021

Carpenter Reservoir


Agenda
Bridge River System Overview
Capital Plan Update
Safety
Covid-19 Response
Workforce
Accommodation
Recreation Sites
Community Investment
Water Use Plan Order Review
Communications
Carpenter Reservoir
BC Hydro
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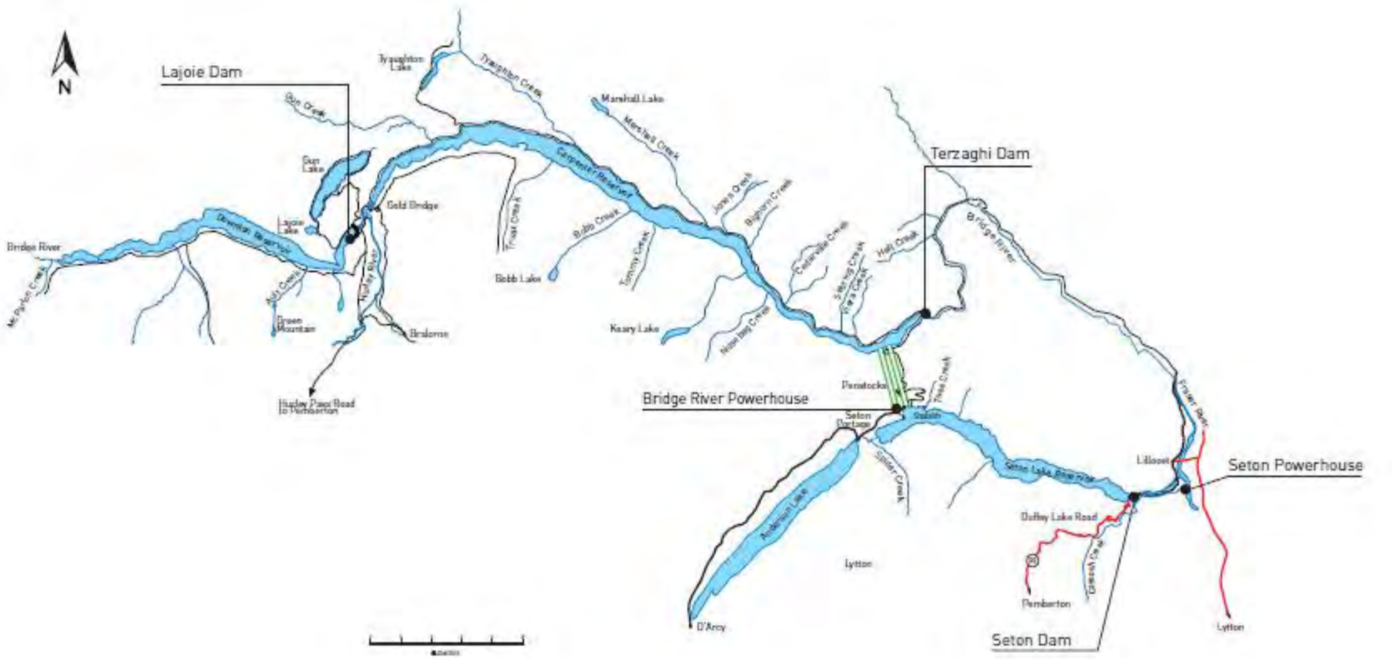
Overview

Bridge River System



Capital Plan Update

Bridge River

- **Generating Station 1**
  - Units 1 - 4 – planning currently underway, targeted completion in 2030.
  - Units 1- 4 Penstock Recoating – planning currently underway, targeted completion in 2030.
- **Generating Station 2:**
  - Units 7&8 – generating unit assembly work complete, installation work has started, targeted completion in late 2021 to early 2022.
  - Penstock Internal Recoating – work is starting this summer with the targeted completion for both penstocks in 2022

A newly assembled rotor is transferred from Bridge River 1 to Bridge River 2 for installation as part of the BR2 7&8 upgrade project.

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Capital Plan Update

La Joie Dam

- La Joie Dam construction is targeted to begin in 2028 with targeted completion in 2032
- Early planning stages
- Early field studies completed summer 2020
- Construction will require very low water levels in Downton Reservoir to enable the work
- Target to identify a recommended leading alternative spring 2021.

Above: Field studies underway in summer 2020.

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Capital Plan Update

Seton

- Planning for the Seton Hydraulic By-Pass and Generator Replacement is currently underway, targeted completion in 2026 and 2027.

Dam Safety

- Construction has started for the Surge Spill Hazard Mitigation project (Mission Mountain). Targeted completion in 2021.

Capital Plan Update

Transmission

- Transformer replacement work at Bridge River 1 and Bridge River Terminal, currently underway, targeted completion in 2021 and 2023, respectively

- Preliminary planning underway for transmission line construction in the region, targeted completion fall 2025

Above: In late March, crews worked to install steel components as part of the Transformer 3 replacement project at Bridge River 1. The project is expected to be completed this summer.

Safety

- A BC Hydro Management Plan includes all aspects of safety and emergency response such as:
  - Travel
  - Working alone procedures
  - Code of Conduct
  - Evacuation
  - Policies and procedures
  - COVID-19
- No lost time incidents reported last year.

8

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COVID-19 Response

Pandemic Response Plan: outlines our response to various stages of an outbreak and our plans for critical and supporting functions.

- Workers work with established pods to minimize contacts
- More frequent cleaning
- Mandatory training for all workers on COVID-19 protocols
- Ongoing monitoring of symptoms
- Mandatory masks in common areas
- Enforcing social distancing
- Vaccine deployment

Workforce

- Approximately 50 workers will be needed in 2021 to complete project work.
    - Most of the construction is expected to be concentrated between April and July.
- Approximately 50 workers will be needed in 2022 to complete project work.
    - Most of the construction is expected to be concentrated between April and September.

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Accommodation

- Local accommodation is the priority, wherever possible.
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  - For projects at Seton, we will look to accommodate workers in Lillooet.
  - In Lillooet, local hotels or local private houses will be used.

Accommodation

Forecast

- **2021 (~50 workers)**
  - ~50 workers at Bridge River mostly accommodated in Tsal'álh/Seton Portage.
- **2022 (~50 workers)**
  - ~50 workers on various projects throughout the region accommodated close to the work sites, mostly at Bridge River and accommodated in Tsal'álh/Seton Portage.
- **2023 (~30 workers)**
  - ~30 workers at Bridge River mostly accommodated in Tsal'álh/Seton Portage.

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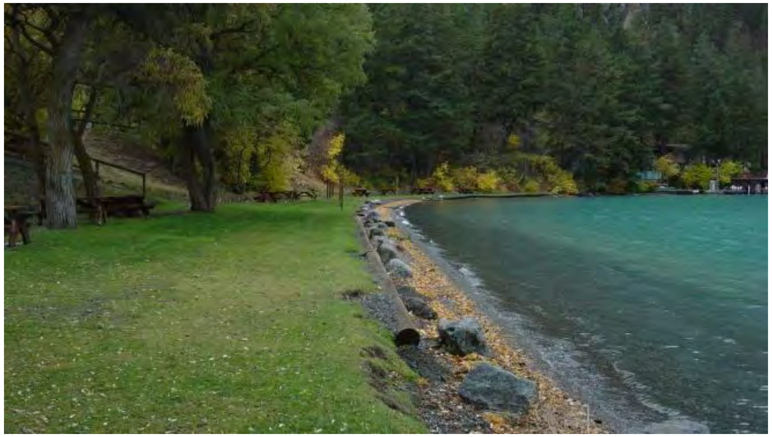
Status of Recreation Sites during COVID

We've implemented a number of safety measures at our recreation sites across the province in response to covid-19.



Visit www.bchydro.com/recreation for the latest information on access and closures at our Bridge River area sites:

- Muddy Clay picnic area
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Community Investment

- Post-Secondary Scholarships
  - $500 scholarships offered to students pursuing post-secondary studies in STEM or trades training
  - Open to all students graduating from Lillooet Secondary School.
  - Applications accepted April 5 to May 17, 2021
- Community grants
  - $5,000

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Cheakamus Water Use Plan Order Review

The next step in the Water Use Planning process.

- **January-March 2021:** identify priority issues.
- **April 2021 to early 2022:** structured review of priority issues and BC Hydro operations.
- **Spring 2022:** Submit the WUPOR report to the Comptroller of Water Rights.

www.bchydro.com/cheakamuswatershed

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Bridge River Hydroelectric System
Projects update—Fall 2020

We're working to renew the Bridge River electricity system which is about 300 kilometres north of Vancouver in the Traditional Territory of the St'át'imc Nation.

The system consists of the La Joie Dam and Powerhouse (Downton Reservoir), Bridge 1 and 2 Powerhouses (Terzaghi Dam and Carpenter Reservoir) and Seton Dam and Powerhouse (Seton Lake).

We're making significant investment in these 55 to 70 year-old facilities, whose proximity to the Lower Mainland helps us operate the electrical system more efficiently. This includes a number of projects in the region.

Update: Bridge River 2 Generating Station Upgrade – Units 7 and 8

We've begun upgrades on units 7 and 8 at the Bridge River 2 (BR2) generating station. Our main contractor, Voith, is on site and focussed on the pre-assembly work for both units, with unit 7 completed in July and unit 8 expected to be completed in September. Most major components have now arrived on site and the project is on track to meet its 2021 targeted completion date.

As we prepare to enter the next phase of the project, we'll ramp up site activity, which will result in an increased number of workers from major contractors and BC Hydro Construction Services. Employees and contractors will continue to follow all Provincial and Federal requirements around social distancing and self-isolation.

BR2 is a four-unit, 278-megawatt powerhouse built in the late 1950s. The station produces enough electricity to power 126,500 homes.

A crew member touches up paint on a rotor at BR2.

Crews have been busy with the pre-assembly work for units 7 and 8 at BR2.

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Communications

We communicate our activities in the Bridge-Seton region in a variety of ways.

- Open houses
- Local ads
- Bi-annual newsletter
- Project one-pagers
- Delegations to local governments
- www.bchydro.com/bridgeriver

To sign up for the newsletter or to send us questions, you can email projects@bchydro.com

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Questions ?
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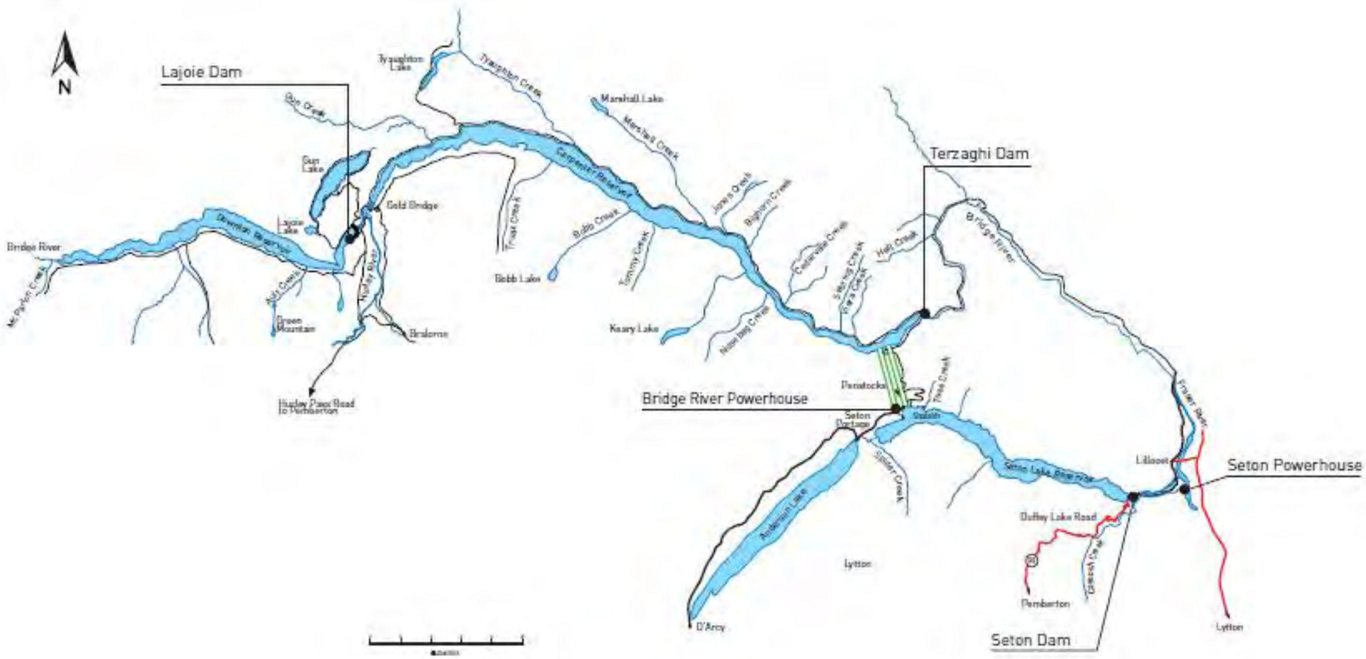

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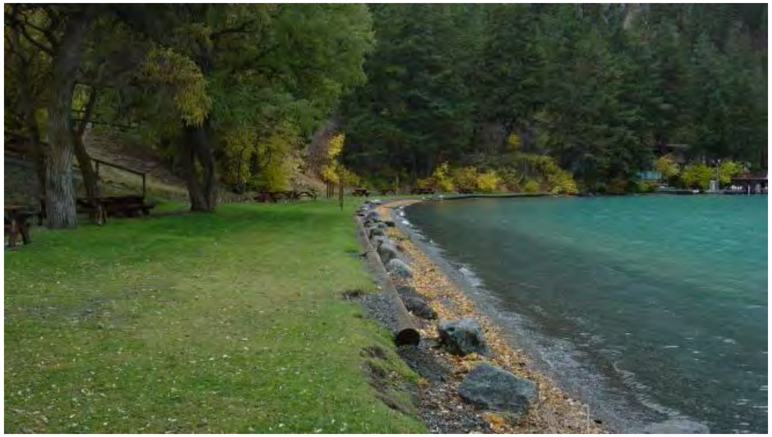

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Questions ?
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Bridge (Shalalth) – Seton (Lillooet)
Capital Investment Update
April 2021
Carpenter Reservoir
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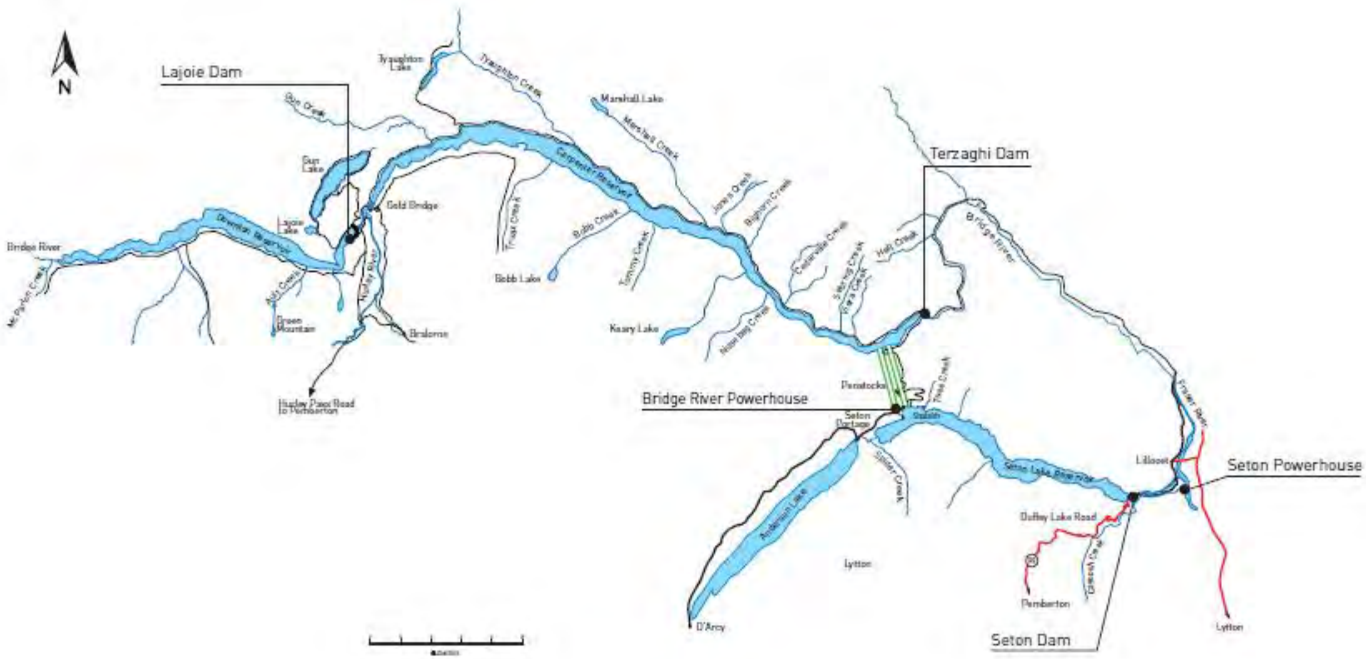
Overview

Bridge River System



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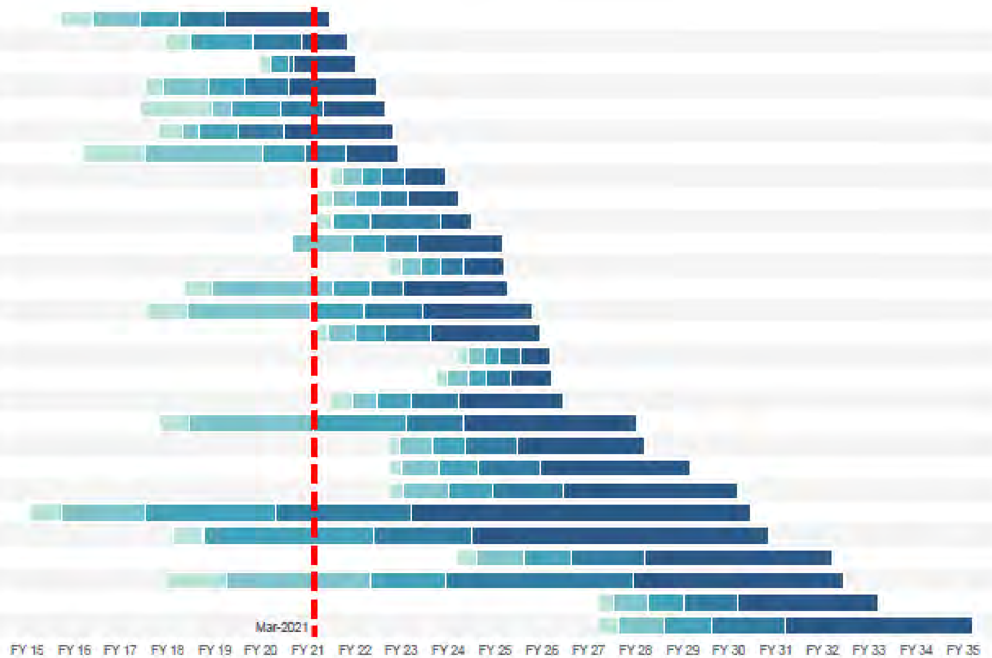
Capital Plan

Bridge River System

Report created on 17 March, 2021 (Work Day 13)

Project Definition	Project Definition Name	Active Phase	Project Forecast ISD
GY-0345	BR2 Units 7 & 8 Upgrade	Implementation	30-Jun-2021
GM-0248	BR1 - Mitigate Surge Spill Hazard	Implementation	18-Nov-2021
TM-0244	BR1 - T3 Transformer Replacement	Implementation	01-Feb-2022
GM-0009	BR2 - Ground Grid Safety Improvements	IDN-Conceptual	11-Jul-2022
GM-0037	LAJ - Upgrade Unit Protection and Contro	Definition	09-Sep-2022
GM-0011	BR2 - Strip and Recoat Penstock2 (U7&8)	Implementation	15-Nov-2022
TM-0310	Bridge River T4 Transformer Replacement	Definition	23-Dec-2022
GM-0292	TRZ - Install Remote Communications and	Planned	03-Jan-2024
GM-0210	SON - Strip and Recoat Penstock Interior	Planned	03-Apr-2024
GM-0399	BR1 Penstock Foundation Refurbishment	IDN-Needs	18-Jul-2024
GY-0150	BR1 Slope Drainage Improvements	IDN-Conceptual	17-Mar-2025
GM-0240	TRZ - Downstream Infill Berm	Planned	31-Mar-2025
GM-0343	TRZ - Provide Safe Access to Spillway Ch	IDN-Conceptual	29-Apr-2025
TM-0287	BRTP Bridge River Trans Project	IDN-Feasibility	31-Oct-2025
GM-0195	LAJ - Refurbish South Penstock	Planned	31-Dec-2025
GM-0101	LAJ - Replace Downton Narrows Debris Boo	Planned	27-Mar-2026
GM-0122	TRZ - Upgrade Dam Instrumentation	Planned	31-Mar-2026
GM-0323	LAJ - Replace Governor and PRV	Planned	30-Jun-2026
GM-0076	SON - Unit Replacement	IDN-Feasibility	27-Jan-2028
GM-0119	SON - Upgrade Headwork Gates	Planned	31-Mar-2028
GM-0120	TRZ - Improve Low Level Outlet Gate Reli	Planned	29-Mar-2029
GM-0008	BR1 - Refurbish Penstocks 1 to 4 Exterio	Planned	29-Mar-2030
GY-0239	BR1 Units 1 to 4 Generator Replacement	Definition	04-Jul-2030
GM-0182	BR1-Strip and Recoat Penstock 1-4	IDN-Feasibility	28-Nov-2030
GM-0144	LAJ - Upgrade Generator, Governor & Excl	Planned	30-Mar-2032
GM-0246	LAJ - Dam Improvements	IDN-Conceptual	30-Jun-2032
GM-0085	BRR - Improve BR1/2 Intake Seismic Withs	Planned	31-Mar-2033
GM-0123	TRZ - Upgrade Embankment Dam Seismic Sta	Planned	30-Mar-2035



- IDN-Needs
- IDN-Conceptual
- IDN-Feasibility
- Definition
- Implementation
- Null

Example of capital project activity timeline.
Subject to approvals.

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Capital Plan

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Capital Plan Update

Bridge River

- **Generating Station 1**
  - Units 1 - 4 – planning currently underway, targeted completion in 2030.
  - Units 1- 4 Penstock Recoating – planning currently underway, targeted completion in 2030.

- **Generating Station 2:**
  - Units 7&8 – generating unit assembly work complete, installation work has started, targeted completion in late 2021 to early 2022.
  - Penstock Internal Recoating – work is starting this summer with the targeted completion for both penstocks in 2022

A newly assembled rotor is transferred from Bridge River 1 to Bridge River 2 for installation as part of the BR2 7&8 upgrade project.

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Capital Plan Update

La Joie Dam

- La Joie Dam construction is targeted to begin in 2028 with targeted completion in 2032
- Early planning stages
- Early field studies completed summer 2020
- Construction will require very low water levels in Downton Reservoir to enable the work
- Target to identify a recommended leading alternative spring 2021.

Above: Measuring ground vibrations around the dam.

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Capital Plan Update

Seton

- Planning for the Seton Hydraulic By-Pass and Generator Replacement is currently underway, targeted completion in 2026 and 2027.

Dam Safety

- Construction has started for the Surge Spill Hazard Mitigation project (Mission Mountain). Targeted completion in 2021.

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Capital Plan

Transmission

- Transformer replacement work at Bridge River 1 and Bridge River Terminal, currently underway, targeted completion in 2021 and 2023, respectively
- Preliminary planning underway for transmission line construction in the region, targeted completion fall 2025

Above: In late March, crews worked to install steel components as part of the Transformer 3 replacement project at Bridge River 1. The project is expected to be completed this summer.

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Workforce

- Approximately 50 workers will be needed in 2021 to complete project work.
    - Most of the construction is expected to be concentrated between April and July.
- Approximately 50 workers will be needed in 2022 to complete project work.
    - Most of the construction is expected to be concentrated between April and September.

Accommodation

- Local accommodation is the priority, wherever possible.
    - For projects at Bridge 1, Bridge 2 and the Bridge River Terminal substation, spaces in Tsal'álh and Seton Portage will be prioritized.
    - For projects at Seton, we will look to accommodate workers in Lillooet.
    - In Lillooet, local hotels or local private houses will be used.

Accommodation

Forecast

- **2021 (~50 workers)**
  - ~50 workers at Bridge River mostly accommodated in Tsal'álh/Seton Portage.
- **2022 (~50 workers)**
  - ~50 workers on various projects throughout the region accommodated close to the work sites, mostly at Bridge River and accommodated in Tsal'álh/Seton Portage.
- **2023 (~30 workers)**
  - ~30 workers at Bridge River mostly accommodated in Tsal'álh/Seton Portage.

General Labour Needs and Training Information

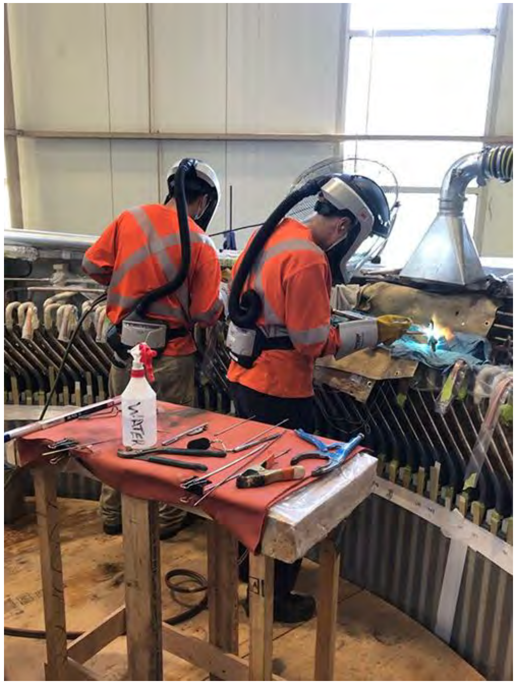
Generator Replacement Projects

Projects:

- Bridge 2 Units 7&8: target completion late 2021/ early 2022
- Seton Unit Upgrade: 2026/2027
- Bridge 1 Units 1-4 : 2030

Labour and Training

- Winder Electricians
- Millwrights
- Concrete Finishers
- Construction craft workers/general labourers



General Labour Needs and Training Information

Dam Upgrade Projects

Projects:

- Terzhagi: 2031-2035
- La Joie: 2028-2032

Labour and Training

- Class 1 Truck Drivers
- Heavy equipment operators
- Drillers and blasters, drillers helpers
- Ironworkers
- Carpenters
- Concrete Finishers
- Steamfitters/Pipefitters
- Construction Craft Workers (labourer)
- Mechanics/technicians
- Welders

Above: La Joie

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General Labour Needs and Training Information

Other Common Jobs

Labour and Training

- Construction Management
- Site Superintendents
- Qualified Environmental Professional
- Environmental Monitors
- Flagging
- First Aid
- Safety Manager/ Officer
- Quality Manager
- Administration

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General Labour Needs and Training Information

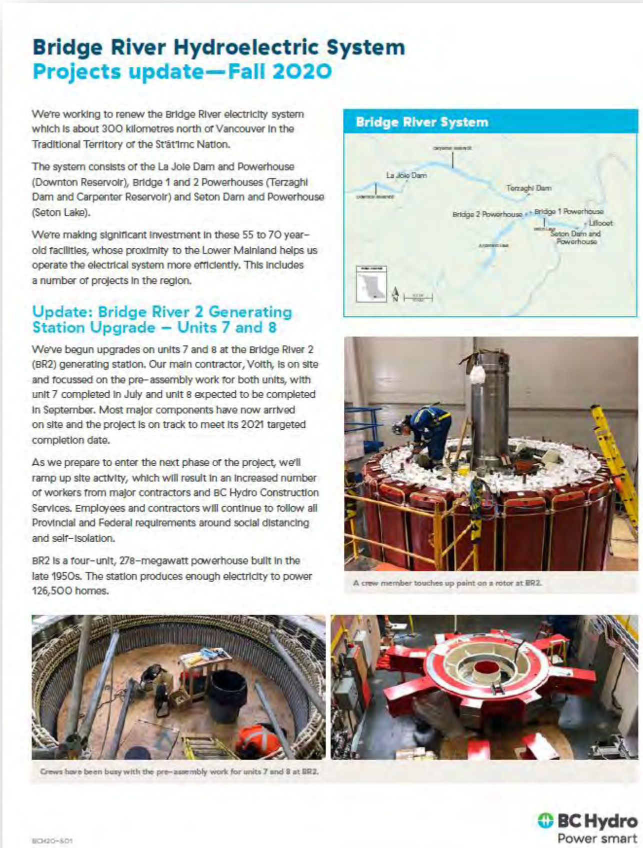
Links

BC Hydro

- General Information
  www.bchydro.com/careers
- Students and graduates:
  https://www.bchydro.com/toolbar/careers/students_grads.html

Industry Training Authority BC

www.itabc.ca



Bridge River Hydroelectric System
Projects update—Fall 2020

We're working to renew the Bridge River electricity system which is about 300 kilometres north of Vancouver in the Traditional Territory of the St'át'imc Nation.

The system consists of the La Joie Dam and Powerhouse (Downton Reservoir), Bridge 1 and 2 Powerhouses (Terzaghi Dam and Carpenter Reservoir) and Seton Dam and Powerhouse (Seton Lake).

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Bridge River Newsletter
Projects update—Spring 2021

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Bridge River System

Update on Bridge River regulatory filings

In fall 2020, the BC Utilities Commission directed BC Hydro to file a joint Certificate of Public Convenience and Necessity (CPCN) for the Bridge River 1 Units 1–4 Generator Replacement Project and the Bridge River Transmission Project (**bchydro.com/brtp**). We're preparing to submit this combined application in June 2021. More information on the CPCN process is available at **bcuc.com/get-involved**.

The project at Bridge River 1 will replace aging generating equipment in the station to improve reliability, restore capacity and increase operating flexibility. Targeted completion is 2030. The transmission project will ensure that the regional transmission system continues to move electricity from these generating facilities to our customers during peak periods. Targeted completion is 2025.

The powerhouses at Bridge River

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CS-765

Update on the Transformer Replacement Project

Crews install steel components in late March as part of the Transformer 3 Replacement Project at Bridge River 1. The project is expected to be completed this summer.

Bridge River 2 Generating Station – Units 7&8 commissioning

We've been upgrading units 7 & 8 at the Bridge River 2 (BR2) Generating Station. This spring, unit 8 will undergo commissioning and is expected to be in service in late May while work on Unit 7 continues. Targeted completion is late 2021/early 2022. BR2 is a four-unit, 278-megawatt powerhouse built in the late 1950s. The station produces enough electricity to power 126,500 homes.

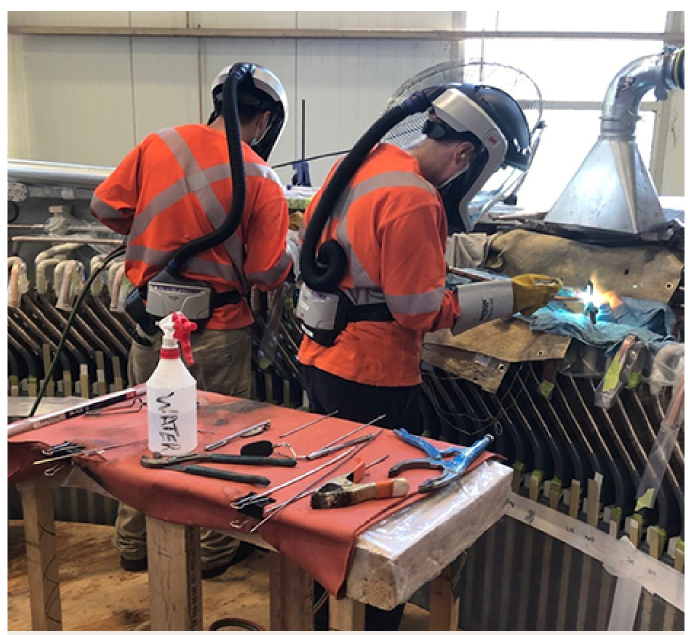
Workforce forecast

The workforce needed to complete capital project work in the region can vary depending on project status. This summer, about 80 workers will be working at our Bridge River facilities in Tsal'álh/Seton Portage. Most of the construction is expected between April and July. Workers will stay at existing facilities in Tsal'álh/Seton Portage. No additional accommodation is required this year by BC Hydro in the Bridge region.

Focus on skills: Winders

There are a variety of skilled workers needed to maintain our system and deliver our capital projects. Winders are equipment specialists who test, rewind, rebuild, and replace electric motors, generators, alternators, transformers, control equipment and mobile machines.

It's a rare trade where its uniqueness and often the age of equipment require special skillsets. BC Hydro has its own Winder apprentices and often partners with others in this niche environment for training opportunities. For more information about BC Hydro employment, visit **bchydro.com/careers**.



Winders brazing copper coil connections. Oxygen/acetylene torches were used with extreme caution.

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Post-secondary scholarships

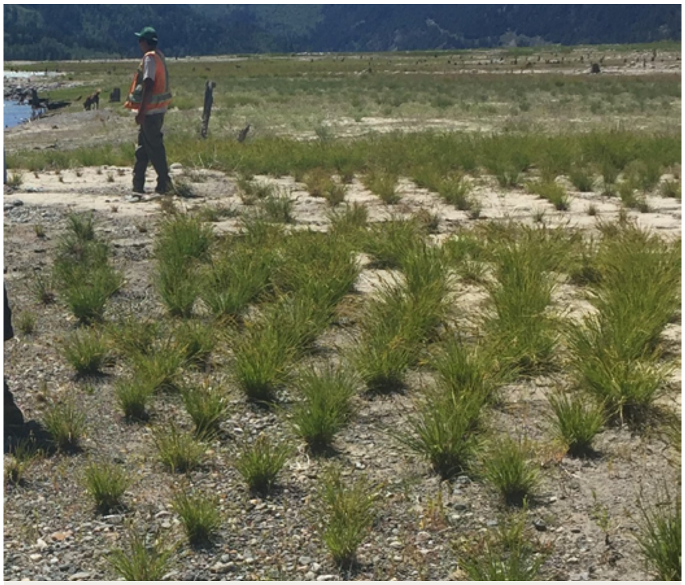
We offer two, $500 scholarships to students pursuing post-secondary studies in Science, Technology, Engineering, Math (STEM) or trades training. All students graduating from Lillooet Secondary School are welcome to apply. Applications will be accepted April 5 to May 17, 2021. For more information, students are encouraged to reach out to their local counselor. You can also contact communityinvestment@bchydro.com.

Something is growing in Carpenter Reservoir – Help us protect this area

We're working to increase riparian habitat and reduce dust in the draw down zone of Carpenter Lake Reservoir. This transitional area is an important connection between the reservoir and the upland forest. Cuttings from local native species of willow and cottonwood along with Kellogg's Sedge have been planted to help vegetation grow in the area. Small landforms have also been created to protect planted vegetation and encourage natural re-vegetation.

This multi-year project is part of BC Hydro's commitments identified in the Bridge River Water Use Plan and is being delivered with the help of St'át'imc businesses. You'll see similar sites around the reservoir. We're testing out a few methods to see what works the best and monitoring the results.

Please avoid the planted sites and leave the area as you found it.



Planted Kellogg's Sedge in Carpenter Lake Reservoir.

COVID-19 response

In March 2020, we introduced measures to reduce the risk of exposure to our workers and the public in the Bridge River area. We continue to focus on ensuring safe practices are in place. Current measures include:

- Workers work with established pods to minimize contacts
- More frequent cleaning
- Mandatory training for all workers on COVID-19 Protocols
- Ongoing monitoring of symptoms
- Mandatory masks in common areas
- Enforcing social distancing
- Vaccine Deployment

In March 2021, BC Hydro's Bridge River Camp was selected for AstraZeneca vaccine deployment. On Wednesday, March 24th approximately 50 workers received vaccines at Lillooet Hospital and Health Centre.

For questions about our Covid-19 response, please contact **projects@bchydro.com**

For more information on Bridge River projects, visit **bchydro.com/bridgeriver**.
If you have questions, please contact us at **projects@bchydro.com** or **604 623 4472** or toll free at **1 866 647 3334**.

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