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Yukon Next Generation Hydro and Transmission Viability Study:

Viability Study Report

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1 Purpose

The Yukon Development Corporation ("**YDC**") has commissioned Midgard Consulting Incorporated ("**Midgard**") and its team of sub-consultants to complete the *Yukon Next Generation Hydro and Transmission Viability Study*. The study, delivered through a series of technical papers, is intended to help inform the decisions necessary to fill the territory's growing energy gap and to support the Yukon's continued economic growth and development.

The purpose of this final paper, the *Viability Study Report*, is to integrate work from previous technical papers to assist in the selection of the Next Generation Hydro ("**NGH**") project(s) and/or transmission project(s) suitable for advancing to the next stage of study and investigation.

The *Viability Study Report*'s approach is to summarize previous technical papers, describe the different resource options available, compare each option within an assessment framework, and provide information required to assist in decision making. The *Viability Study Report* summarizes the different risks, benefits, and challenges of each NGH option in order to provide Yukon with the information needed to make a reasoned, defensible, and informed decision.

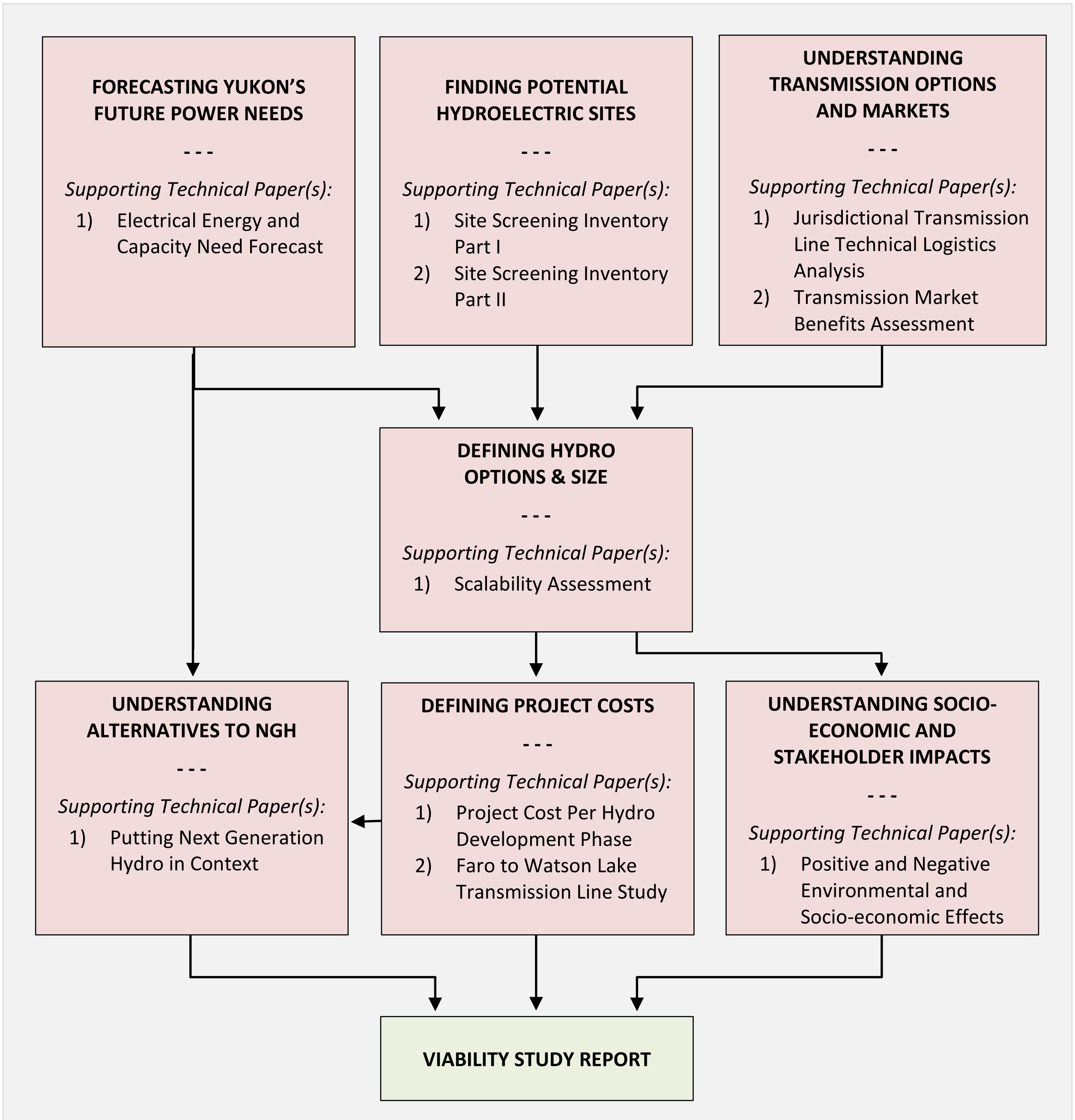
2 Background & Summary of Previous Technical Papers

The *Yukon Next Generation Hydro Transmission Viability Study* comprises a series of technical papers whose purpose is to inform this *Viability Study Report*. A brief description of each technical paper is as follows:

1) **Site Screening Inventory, Part I and II:** The Site Screening Inventory identified, evaluated, categorized, and ranked potential hydroelectric projects in the context of current economic, environmental, and societal expectations.
2) **Electrical Energy and Capacity Need Forecast:** The Electrical Energy and Capacity Need Forecast technical paper forecast plausible scenarios of future Yukon electrical energy and electrical capacity requirements 20 to 50 years into the future (from 2035 to 2065).
3) **Scalability Assessment:** The Scalability Assessment report studied ways to match the size and scale of potential hydroelectric projects to the Yukon's forecasted need for electrical energy and capacity in order to reduce potential negative impacts of larger projects. Six projects of interest were shortlisted.
4) **Jurisdictional Transmission Line Technical Logistics Analysis:** The Jurisdictional Transmission Line Technical Logistics Analysis paper investigated the cost of extending the Yukon's transmission system to Alaska and BC.
5) **Transmission Market Benefits Assessment:** The Transmission Market Benefits Assessment paper analyzed the net economic benefits that would accrue to the Yukon by developing a transmission interconnection that enables the Yukon to export and import electricity to and from a neighboring jurisdiction (BC or Alaska).
6) **Project Cost Per Hydro Development Phase:** The Project Cost Per Hydro Development Phase technical paper described the six shortlisted hydroelectric projects in terms of design features, scalability build out, cost, energy output, and Levelized Cost of Energy ("**LCOE**").
7) **Faro to Watson Lake Transmission Line Study:** The Faro to Watson Lake Transmission Line Study technical paper analyzed the transmission development options available to the Yukon along the Faro to Watson Lake transmission corridor.
8) **Positive and Negative Environmental and Socio-economic Effects:** The Positive and Negative Environmental and Socio-economic Effects technical paper provided a review of key potential environmental and socio-economic effects of the six shortlisted hydroelectric projects.
9) **Putting Next Generation Hydro in Context:** Next Generation Hydro and other generation technology portfolios are compared technically, economically, environmentally, and socially as they fulfill the forecasted Yukon energy and capacity gap from 2035 to 2065.

Figure 2-1 presents an overview of the *Yukon Next Generation Hydro and Transmission Viability Study* process and the role/purpose of each technical paper.

Figure 2-1: Yukon Next Generation Hydro and Transmission Viability Study Process Overview



2.1 The Existing Yukon Electrical Grid

Figure 2-2 shows Yukon's current electrical grid, including major generation sources, transmission infrastructure, and key industrial sites across the territory. In total, the Yukon interconnected grid currently has 132 megawatts ("**MW**") of installed capacity as follows:

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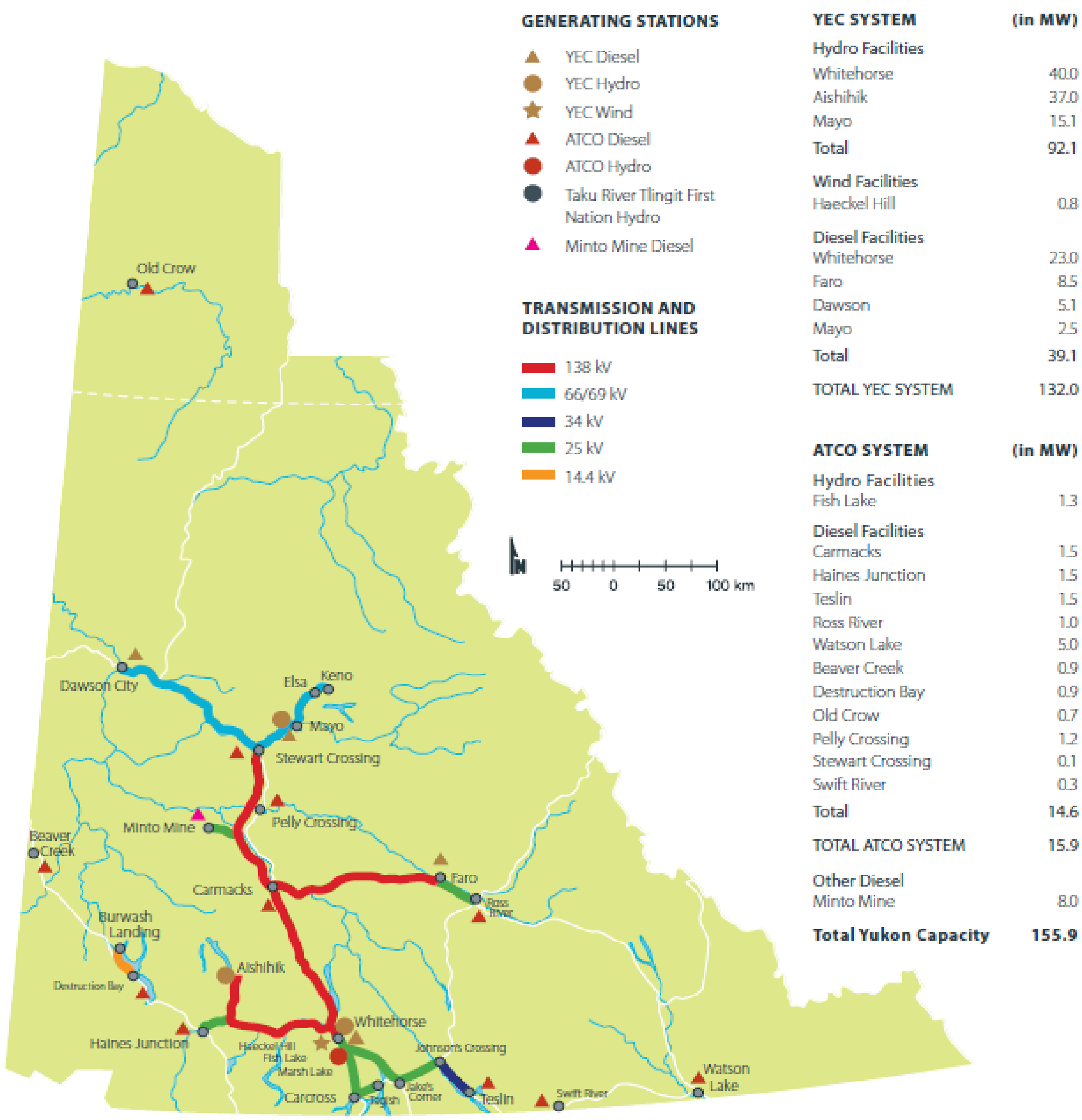
- 92 MW Hydroelectric: Whitehorse (40 MW), Aishihik (37 MW), and Mayo (15 MW)[1]
- 39 MW Thermal Generation: Diesel and Natural Gas generators
- 0.8 MW Wind: Two wind turbines on Haeckel Hill[2]

Figure 2-2: Map of Yukon and its Electrical Infrastructure[3]



[1] The 1.3 MW Fish Lake hydro scheme is not a Yukon Energy Corporation facility and is not included in this report.

[2] The existing turbines on Haeckel Hill will have reached the end of their service life by 2035 and are not included as resources in the 2035-2065 energy development scenarios.

[3] Map courtesy of Yukon Energy Corporation.

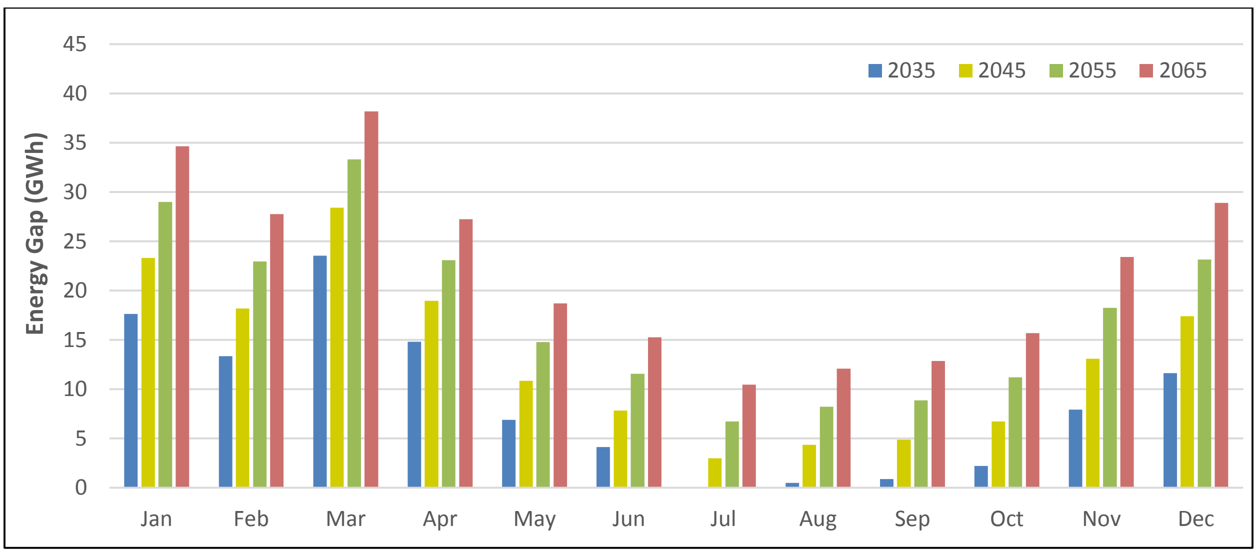
2.2 Forecasting Future Yukon Electricity Needs

The *Yukon Electrical Energy and Capacity Need Forecast (2035 to 2065)*, estimated the Yukon's future electrical energy and electrical capacity needs were estimated based upon expected demand drivers such as population, per capita electrical energy consumption, and industrial (e.g.: mining) activity. Consideration was also given to future scenarios that could alter electrical energy and electrical capacity demand such as the impacts of climate change, technological change, and changing electrical energy consumption patterns (e.g.: fuel switching from heating oil to electricity for heating homes). The Yukon need for electrical energy and capacity is growing and is expected to continue growing through to the end of 2065 and beyond. As a result, the Yukon must meet the monthly electrical energy gaps and capacity gaps for 2035 to 2065 as shown in Table 2-1 and Figure 2-3 below.

Table 2-1: Yukon Energy and Capacity Gaps Forecast (2035 → 2065)

Scenario	Capacity / Energy	2035	2045	2055	2065
Low Case Scenario	Capacity	11 MW	17 MW	24 MW	31 MW
	Energy	54 GWh	85 GWh	118 GWh	154 GWh
Baseline Case Scenario	Capacity	21 MW	31 MW	42 MW	53 MW
	Energy	103 GWh	157 GWh	211 GWh	265 GWh
High Case Scenario	Capacity	36 MW	62 MW	95 MW	136 MW
	Energy	180 GWh	311 GWh	476 GWh	682 GWh

Figure 2-3: Yukon Monthly 2065 Baseline Energy Gap



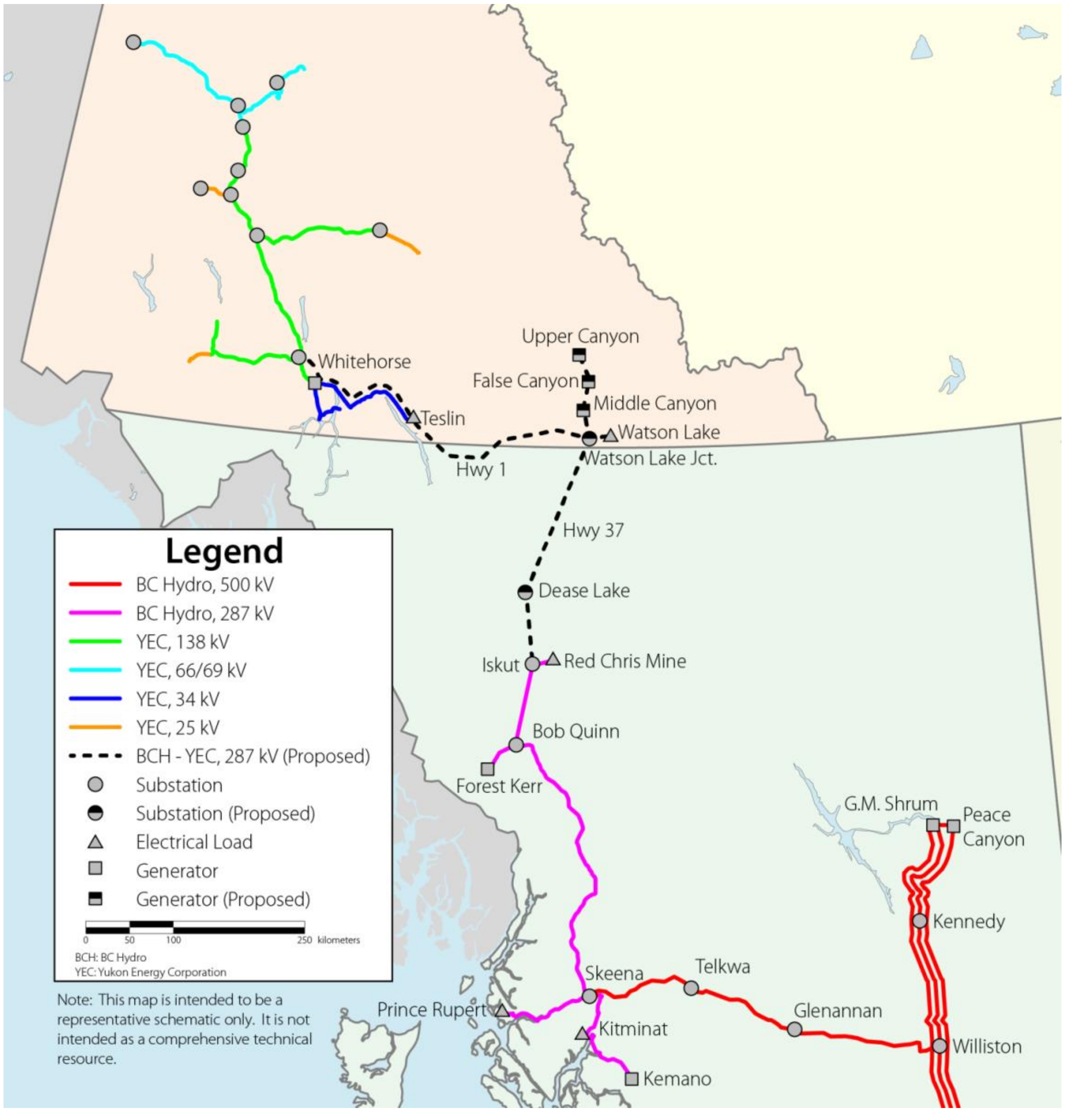
2.3 Understanding Transmission Line & Interconnection Options

One of the considerations for the *Yukon Next Generation Hydro and Transmission Viability Study* was to assess the viability of building transmission lines to interconnect the Yukon with external electricity markets.

Two interconnection options were analyzed in *the Jurisdictional Transmission Line Technical Logistics Analysis*:

1) Interconnection between Yukon and Iskut, British Columbia ("**BC**")
2) Interconnection between Yukon and Fairbanks, Alaska[4]

Figure 2-4: Proposed Whitehorse to Iskut Interconnection



[4] The proposed Whitehorse to Skagway interconnection was not considered because it was studied in the March 2015 Morrison Hershfield report, *Viability Analysis of Southeast Alaska and Yukon Economic Development Corridor*.

Figure 2-5: Proposed Aishihik to Delta Junction Interconnection

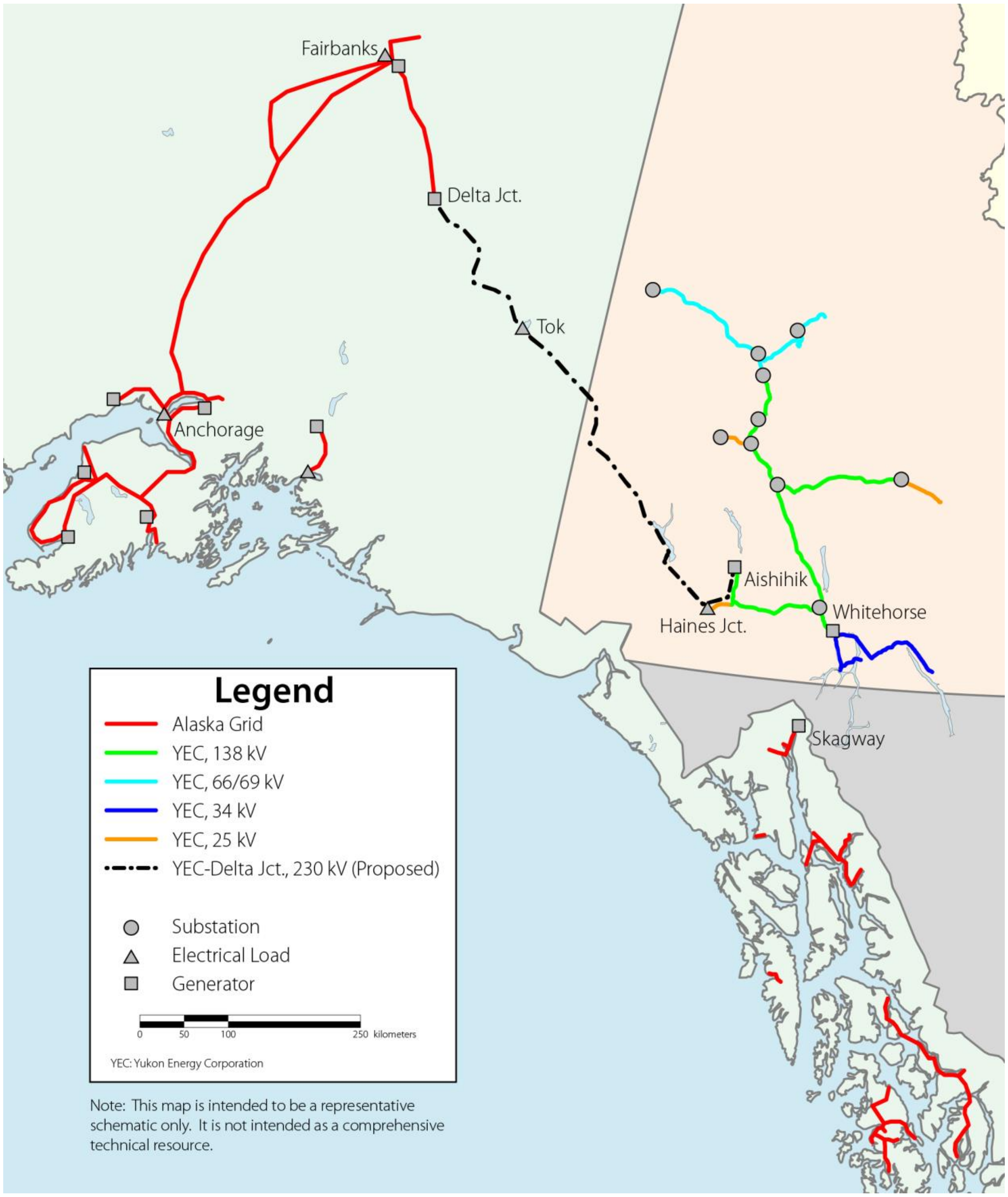


Table 2-2 compares the technical analysis and cost estimates prepared for the two Interconnection Options studied in this report (including variant #1A for the Yukon to BC Interconnection Option based upon specific Next Generation Hydro siting alternatives):

Table 2-2: Comparison of Interconnection Option Results

Interconnection Option	Description	Distance (km)	Capital Cost ($M)	Potential Net Yukon Export[5] Capacity (MW)
#1	287 kV from Whitehorse (Takhini) to Iskut, BC	763	$1,710	64 - 127[6]
#1A	Same as option 1 with Next Generation Hydro sites developed near Watson Lake	763	$1,710	94 - 139[7]
#2	230 kV from Aishihik to Delta Junction	662	$1,325	70 - 80[8]

These results confirm the findings of past studies[9], and demonstrate that the cost of implementing any Interconnection Option between the Yukon and its nearest neighbouring jurisdictions is high relative to the transfer capacity enabled by any of the interconnections.

The *Transmission Market Benefits Assessment* technical paper took the study further by assessing net economic benefits that accrue to Yukon by developing a transmission interconnection to a neighbouring jurisdiction. If the net benefits of electricity trade are greater than the net costs of required infrastructure necessary to facilitate trade, then developing an interconnection makes economic sense.

The primary economic benefit to the Yukon from developing access to external transmission markets is the revenues earned from trading energy. A net benefit analysis was completed to assess the viability of interconnection with neighbouring jurisdictions. The condition for deeming an interconnection economic is defined as follows:

NET BENEFITS
Present Value of Revenue from Trading Energy with Neighbouring Jurisdictions

MUST BE GREATER THAN

NET COSTS
Present Value of Costs to Build / Operate Transmission and Generation

[5] Export Capacity was evaluated because it had the greatest potential impact upon Next Generation Hydro site and size selection. Import capacities will be similar to the stated export capacity, although the impact of incremental generation at Forrest Kerr or Delta Junction would be the reverse, i.e.: the import capacity of interconnections to BC or Alaska would expand with increased generation output at Forrest Kerr or Delta Junction, respectively.

[6] Net Exports are dependent upon output of Forrest Kerr Hydro because Forest Kerr output creates transmission constraints

[7] Net Exports are dependent upon output of Forrest Kerr Hydro because Forest Kerr output creates transmission constraints

[8] Net Exports are dependent upon output of Delta Junction generation

[9] For example, the Yukon - BC Interconnection Costing study issued by BBA in April 2011.

Net Benefits and Net Costs are described as follows:

- **Description of Net Benefits:** The price of electricity using the assumption that neither BC nor Alaska will enter into a Power Purchase Agreement ("**PPA**") with a power price higher than an equivalent local generator because otherwise the economic incentive is to build local generation. Therefore, representative PPA prices were developed for BC based on BC Hydro's Standing Offer Program pricing and for Alaska based on the avoided cost of power used by local independent power producers.
- **Description of Net Costs:** The net costs of infrastructure were based upon the construction and operating costs of an interconnecting transmission line as well as the incremental generation facilities needed to support electricity exports.

A present value economic analysis for the two interconnection options was completed to calculate the Net Benefits and Net Costs over a 40 year window (see Table 2-3 and Table 2-4). For the 763km Yukon to BC connection the present value of economic benefits was $214 million in contrast to the present value of costs estimated at $1.7 billion. The economic case for the 660 km connection to Alaska demonstrated a similar result. The present value of economic benefits was $202 million with the present value of costs estimated at $1.3 billion. As a result, both interconnection scenarios demonstrated negative economic benefits and were deemed uneconomic.

Table 2-3: Economic Evaluation of Exporting Electricity from Yukon

Interconnection Option	Net (Present Value) Benefits [$2015]	Net (Present Value) Costs [$2015]	Economic Evaluation (Net Benefits > Net Costs?)
Yukon → British Columbia	+$214M	-$1,689M	NOT ECONOMIC
Yukon → Alaska	+$202M	-$1,394M	NOT ECONOMIC

Table 2-4: Economic Evaluation of Importing Electricity to Yukon

Interconnection Option	Net (Present Value) Benefits [$2015]	Net (Present Value) Costs [$2015]	Economic Evaluation (Net Benefits > Net Costs?)
British Columbia → Yukon	$0M	-$1,556M	NOT ECONOMIC
Alaska → Yukon	$0M	-$1,247M	NOT ECONOMIC

To put the results of the market analysis into context:

1) Annual exports of over 4.5 times the total Yukon energy consumption in 2013 (approximately 2000 GWh) would be required to theoretically "break-even" financially; and
2) The sales price for the electricity would need to be equal or greater than the price that is currently offered under the BC Hydro Standing Offer Program (SOP).

However, there are major issues even if the Yukon could generate the required quantity of energy to "break even" at the preferred times of year:

1) Capacity Limits: The proposed 287kV transmission line to BC does not have sufficient capacity to enable the export of this volume of energy on an annual basis; and
2) Pricing: It is improbable that Yukon could secure a contract at the required price for this quantity of energy.

For example, BC Hydro's SOP pricing is approximately twice the current Mid-Columbia ("Mid-C") average price for electricity that PowerEx (BC Hydro's trading arm) has access to without any long term contractual obligation, and Yukon's energy production generally corresponds to times of the year when prices are low.

Similarly, an interconnection with British Columbia or Alaska for the purpose of importing electricity is also challenging for both economic and self-sufficiency reasons.

1. Economics: When transmission import costs are compared to costs for Yukon based generation, it is less expensive to remain self-sufficient and build Yukon based generation since the Forecast Levelized Cost of Energy ("**Forecast LCOE**") is $500/MWh for the YK – BC Transmission Interconnection, and $410/MWh for the YK – AK Transmission Interconnection. These costs compare unfavourably to the costs for almost all Next Generation Hydro projects (see Table 2-9), natural gas generation (Table 2-10), and other renewables portfolios (Table 2-10).
2. Self-Sufficiency: Relying on a long (662km or 763km) radial transmission line to satisfy Yukon's electricity growth undermines Yukon's self-sufficiency, and makes it dependent upon external parties for its electricity supply. Additionally, since the transmission line would supply a large fraction of Yukon's electricity needs, back-up generation such as diesel or natural gas generation would be constructed for when the long interconnection transmission line has a failure.

This situation could potentially change if an adjacent jurisdiction built a transmission line at its expense to/near the Yukon border (e.g. BC, Alaska or Canada), however there are no current plans for this type of infrastructure expansion at this time.

In summary, both exporting and importing electricity scenarios demonstrate significantly negative net economic benefits and are therefore uneconomic strategies under current conditions.

2.4 Identifying Potential NGH Sites

A screening inventory was conducted with the goal of identifying a group of potential hydroelectric sites that represent the best potential for development in the Yukon Territory. The *Site Screening Inventory (Part I & II)* technical papers began with over 200 identified potential hydroelectric projects and winnowed viable sites down to a selection of ten (10) recommended sites. The progression of site screening and refinement is detailed below in Table 2-5.

Table 2-5: Site Screening Inventory Stages and Resulting Site Refinement

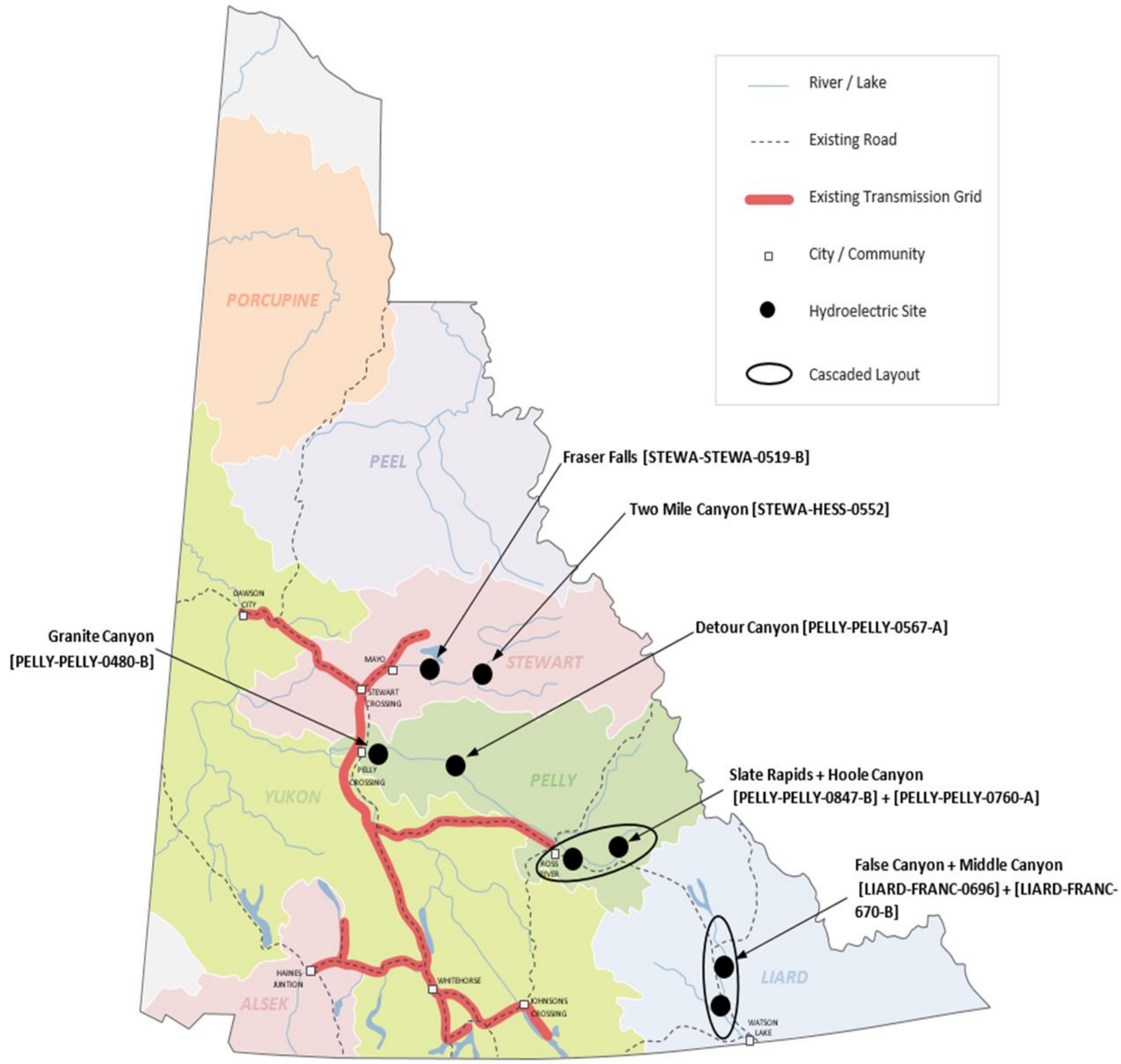
Part	Description	Refinement
1	Screen 0: Reconciliation of Known Project Sites	200+ → 108
	Screen 1: Fundamental Development Barrier Project Screen	108 → 47
	Screen 2: Fundamentally Uneconomic Project Screen	47 → 16
2	Ranking 3: Initial Project Ranking & Variation Consolidation	16 → 10

Projects were evaluated based upon their ability to meet the Yukon's capacity and energy requirements, environmental impacts, constructability issues, and project economics. The key themes that came out of the *Site Screening Inventory (Parts I & II)* technical papers for the shortlisted sites were that:

1) Historic hydroelectric project designs were sometimes larger than could be utilized in the Yukon,
2) All projects had environmental impacts that required further study,
3) All projects impacted stakeholder and First Nations lands, including both surface and sub-surface rights.

As a result of the themes found in the *Site Screening Inventory (Parts I & II)* technical papers, Midgard completed a *Scalability Assessment* technical paper that studied ways to resize potential hydroelectric projects to match the Yukon's forecast needs for electrical energy and capacity while reducing negative effects. At the end of the *Scalability Assessment* technical paper, six (6) projects were identified along with their associated build-out timelines. The locations of the six (6) priority sites identified by the Midgard Team are identified in Figure 2-6 and summarized in Table 2-6. Four of the projects are standalone sites and two projects are two site cascades on a common river system with an upstream water storage dam and a downstream Run-of-River ("**ROR**") facility.

Figure 2-6: Map of Potential Hydroelectric Projects



**Note: The color delineations represent the drainage basins of Yukon's major rivers*

Table 2-6: Scalability Shortlist

Hydroelectric Site Name	Existing Lake Area[10]	Incremental Reservoir Footprint	Total Reservoir Footprint	2065 Installed Capacity	2065 Annual Energy	Maximum Capacity	Maximum Annual Energy
Detour Canyon	0 km^2	130 km^2	130 km^2	60 MW	265 GWh	100 MW	587 GWh
Fraser Falls	0 km^2	311 km^2	311 km^2	57 MW	265 GWh	95 MW	563 GWh
Granite Canyon	0 km^2	173 km^2	173 km^2	57 MW	265 GWh	95 MW	588 GWh
Two Mile Canyon	0 km^2	101 km^2	101 km^2	54 MW	259 GWh	90 MW	489 GWh

[10] Existing lake areas do not include river beds.

Hydroelectric Site Name	Existing Lake Area[10]	Incremental Reservoir Footprint	Total Reservoir Footprint	2065 Installed Capacity	2065 Annual Energy	Maximum Capacity	Maximum Annual Energy
False Canyon + Middle Canyon (ROR)	109 km^2	154 km^2	263 km^2	78 MW	265 GWh	78 MW	451 GWh
Slate Rapids + Hoole Canyon ROR	37 km^2	154 km^2	191 km^2	107 MW	265 GWh	107 MW	487 GWh

The projects were also studied in terms of a staged build-out over time so that they could be better sized to match growing electricity demand in the years leading up to 2065 (i.e.: from 2035 up to 2065). Therefore, the *Scalability Assessment* technical paper evaluated projects on the basis of progressively increasing project energy and capacity over time. The shortlist projects scalability build out timeline is shown in Table 2-7.

Table 2-7: Scalability Build-Out Timelines

Site Name	Year 2035	Year 2045	Year 2050	Year 2060
Detour Canyon	Construct Dam with 2 Turbines	-	3rd Turbine Installed	-
Fraser Falls	Construct Dam with 2 Turbines	-	3rd Turbine Installed	-
Granite Canyon	Construct Dam with 2 Turbines	-	3rd Turbine Installed	-
Two Mile Canyon	Construct Dam with 2 Turbines	3rd Turbine Installed	-	-
False Canyon + Middle Canyon ROR	Construct Dam with 2 Turbines	-	3rd Turbine Installed	Construct Downstream ROR Facility
Slate Rapids + Hoole Canyon ROR	Construct Dam with 2 Turbines	-	Construct Downstream ROR Facility	-

Next, the six shortlisted hydroelectric projects were evaluated in terms of design features, scalability build out, cost, energy output, and Forecast Utilization Levelized Cost of Energy ("**LCOE**") in *The Project Cost Per Hydro Development Phase* technical paper. Forecast Utilization LCOE is a metric used to compare energy projects in a fair and consistent manner where the present value of project costs (over 65 years) are divided by the present value of energy generated and consumed (over 65 years). Ultimately, the Forecast Utilization Levelized Cost of Energy allows the cost of energy to be compared between different projects, regardless of technology or size.

Since the *Scalability Assessment* technical paper assumed that a transmission line corridor "pre-existed" from Faro to Watson Lake and that the two cascade projects, False Canyon + Middle Canyon ROR and Slate Rapids + Hoole Canyon ROR, would interconnect to this Faro to Watson Lake transmission line, Midgard and its team of sub-consultants completed the *Faro to Watson Lake Transmission Line Study* looking at the transmission development options available to the Yukon along the Faro to Watson Lake Transmission Corridor. The findings of this study were used as input to cost the project cost paper that estimates the project options with and without the pre-existing Faro-Watson Lake transmission corridor. Table 2-8 below summarizes the key information for each hydroelectric site, including size, cost, and economics (using the metric Full and Forecast Levelized Cost of Energy).

Table 2-8: Summary of Potential Hydroelectric Projects

Site Name		Installed Capacity (2035 → 2065 → Post 2065)	Max Annual Energy	Capital Cost [$2015]	LCOE (Full[11][12]) [$2015]	LCOE (Forecast[13][14], 2035 to 2065) [$2015]
Detour Canyon		40 → 60 → 100 MW	587 GWh	$1,413M	$110/MWh	$301/MWh
Fraser Falls		38 → 57 → 95 MW	563 GWh	$1,233M	$100/MWh	$263/MWh
Granite Canyon		38 → 57 → 95 MW	588 GWh	$847M	$68/MWh	$181/MWh
Two Mile Canyon		36 → 54 → 90 MW	489 GWh	$919M	$90/MWh	$199/MWh
False Canyon + Middle Canyon ROR	Assumes Faro-Watson Tx Does Not Exist	37 → 78 → 78 MW	451 GWh	$1,959M	$196/MWh	$379/MWh
	Assumes Faro-Watson Tx Already Exists	37 → 78 → 78 MW	451 GWh	$1,493M	$152/MWh	$286/MWh
Slate Rapids + Hoole Canyon ROR	Assumes Faro-Watson Tx Does Not Exist	42→ 107→ 107 MW	487 GWh	$2,962M	$269/MWh	$540/MWh
	Assumes Faro-Watson Tx Already Exists	42→ 107→ 107 MW	487 GWh	$2,764M	$251/MWh	$500/MWh

To further study the potential hydroelectric project options, *the Positive and Negative Environmental and Socio-economic Effects* technical paper was completed with the objective of providing a review of the key

[11] *Full Utilization LCOE*, or Full Utilization Levelized Cost of Energy, is calculated assuming that a project is built at its full size and capacity, that the project generates at maximum potential 100% of the time, and that all of the generated energy is consumed.

[12] Costs include both capital costs and operating & maintenance (O&M) costs. O&M costs include Direct Operations (Operators, Training, Consumables, Regular & Annual Maintenance, Major Maintenance, Communications and Travel/Meals), Indirect Operations (Environmental Monitoring & Compensation, Land Costs, Community Funding, and First Nations Training, Capacity Building, & Compensation), and Overhead & Administration (Insurance, administration, legal, program management, accounting, taxes etc.).

[13] *Forecast Utilization LCOE*, or Forecast Utilization Levelized Cost of Energy, is calculated on the basis that a project is built-out as per the timelines described in this report and that only enough energy to meet gaps is generated / consumed.

[14] See Costs for Full Utilization LCOE above.

environmental and socio-economic effects of the six (6) priority sites. The findings from this technical paper are used throughout the remainder of this *Viability Study Report*.

2.5 Considering Other Generation Technology Alternatives

In addition to locating the priority hydroelectric projects in the Yukon, Midgard also evaluated potential alternative generation technology solutions available and the tradeoffs in a Yukon context (see *Putting Next Generation Hydro in Context: Other Solutions to Meet Yukon's Long Term Energy Future)*.

As an electrical island without a connection to its neighbours, the Yukon must at all times match electricity self-supply and electricity demand in order to keep the electricity grid from blacking out. Moreover, electrical energy needs must be met over the longer term (e.g.: energy on a monthly basis) and the shorter term (e.g.: capacity to meet daily and winter peak demands). To fulfill these requirements, a series of generation types was evaluated on a standalone basis for their ability to meet the forecast 2065 energy and capacity gaps identified in the Baseline Scenario of the *Yukon Electrical Energy and Capacity Need Forecast.*

Of the evaluated generation types, only Natural Gas Generation and Next Generation Hydro can practically meet the Yukon's forecast electricity needs on a standalone basis, whereas the other generation types must be combined together to meet the Yukon's forecasted needs. As a result, four energy supply scenarios (see Table 2-9) were considered: Natural Gas, Next Generation Hydro, Renewables Portfolio (with No Pumped Storage), and Renewables Portfolio (with Pumped Storage).

Table 2-9: Yukon Alternative Energy Development Scenarios

#	Scenario	Description	Resources Included
1	Natural Gas	Build out natural gas generation	Natural Gas
2	Next Generation Hydro	Build a single Next Generation Hydro project	Next Generation Hydro (one of the six projects discussed in this *Viability Study Report*)
3	Renewables Portfolio (No Pumped Storage)	Build a combination of renewable generation resources (excluding pumped storage hydro) to meet energy needs. If required, add natural gas generation for capacity needs	Wind (with utility scale battery), solar, run-of-river hydro, small hydro with storage and natural gas (capacity only)
4	Renewables Portfolio with Pumped Storage	Build a combination of renewable generation resources including pumped storage hydro to satisfy energy needs. If required, add natural gas generation for capacity needs	Wind (with utility scale battery), solar, run-of-river hydro, small hydro with storage, pumped storage, and natural gas (capacity only)

After evaluating the scenarios, it was concluded that all of the generation scenarios had the potential to meet the forecast average energy and capacity needs of the Yukon in a socially acceptable manner. However, all of the generation scenarios also had certain advantages and disadvantages that made the decision about which generation types to pursue a selection among technical, economic, social and environmental tradeoffs (Table 2-10).

Table 2-10: Generation Scenario Summary Matrix

	Technical		**Economic**	**Socio-Economic**	**Environmental**	
Scenario	**Meets Yukon Energy Needs?**	**Meets Yukon Capacity Needs?**	**Forecast Utilization LCOE ($/MWh)**	**Social Impact**	**2065 Land-Use Footprint (hectares)[15]**	**2065 GHG Emissions (tonnes CO_2e)**
Scenario 1 – Natural Gas	Yes	Yes	250	Potentially Acceptable	22	190,000
Scenario 2 – Next-Generation Hydro	Yes	Yes	240	Potentially Acceptable	18,000	0
Scenario 3 – Renewables	Yes	Yes (with Natural Gas capacity)	350	Potentially Acceptable	29,000	≈0
Scenario 4 – Renewables with Pumped Storage	Yes	Yes (with Natural Gas capacity)	270	Potentially Acceptable	20,000	≈0

After evaluating the scenarios, Next Generation Hydro is arguably the preferred scenario for further consideration. Next Generation Hydro scenario has similar economic cost when compared to other scenarios, addresses Yukon's need for electrical winter energy and capacity from 2035 to 2065, and does not require Natural Gas generation in order to meet Yukon's capacity needs.

Moreover, the current level of uncertainty – and consequently risk - regarding the Technical, Economic, Socio-Economic and Environmental parameters is lower for the Next-Generation Hydro than it is for scenarios 3 and 4; more is known about the potential Next-Generation Hydro sites than is the case for the hypothetical alternatives. Additionally, cumulative impacts are potentially lower for a single larger site

[15] When comparing the scenario footprints it must be recognized that the impact of the different footprints are different for the different project types. For example, the majority of the Next Generation Hydro footprint is general land use and creating a new lake / water storage reservoir where a river previously existed, whereas the renewable portfolios (Scenarios 3 & 4) are a combination of new lakes / water storage reservoirs, modifying existing lakes, and general land use. Therefore, land use impacts cannot be directly compared without evaluating the types of impacts as well as the footprint.

solution as compared to multi-site solution. Similarly, economies of scale are gained by focusing Yukon's financial, regulatory, technical and permitting resources on a single site solution rather than a multi-site solution.

3 Assessment Framework

This *Viability Study Report* is intended to aid in the selection of the next hydroelectric and transmission project (or projects). As summarized in Section 2.3, Midgard does not see a plausible scenario where building a transmission line interconnection to neighbouring jurisdictions makes economic sense; therefore, a transmission interconnection was eliminated from further consideration. However, the six (6) priority NGH projects are appropriate for advancing to the next stage of development and potentially viable projects need to be selected.

In order to provide the Yukon with the necessary information needed to make a reasoned, defensible and fact based decision regarding which NGH projects to advance, Midgard has gathered findings from the previously submitted technical papers and feedback from various sources (e.g.: stakeholders, First Nations, YDC) into four (4) silos of interest to be used for project evaluation:

1) Technical Considerations
2) Economics Considerations
3) Environmental Considerations
4) Socio-economic Considerations

The key information of each silo of interest is listed below in Figure 3-1.

Figure 3-1: Assessment Framework & Silos of Interest

To facilitate the decision about which NGH projects to continue investigating the key findings for each project were identified within four (4) silos of interest, the key issues were ranked relative to other priority sites, and an overview provided of the steps needed to move the project forward. The four (4) silos are explained further below:

1) **Technical Considerations**: The key technical considerations of the projects include a high-level overview of the technical details pertaining to the dams, reservoirs, flooded areas, transmission line corridors, and road corridors. At this early stage in project development, the technical risks do not preclude the ability to construct a project, but simply indicate there may be increased risk factors that will need to be considered during the design, planning, cost estimation and construction of the facility. Other considerations also include the project's ability to meet long term capacity and energy needs of the Yukon.
2) **Economic Considerations**: The key economic considerations include the estimated capital costs, operations and maintenance costs, and the Forecast Utilization Levelized Cost of Energy ("**Forecast Utilization LCOE**") for each project. The Forecast Utilization LCOE is calculated by dividing the total lifetime cost of the project by the *electrical energy it provides to Yukon loads*. LCOE is typically expressed in $/MWh (dollars per megawatt-hour).

$$Forecast\ Utilization\ LCOE = \frac{Total\ Present\ Value\ of\ Costs}{Total\ Present\ Value\ of\ \mathbf{Forecast\ Utilization\ Energy}}$$

3) **Environmental Considerations**[16]: The environmental considerations are focused on potential impacts to fish and wildlife, including species at risk and impacts from the project's flooding area. Key effects assessed for fish and fish habitat include:
    a. Effects on migration (i.e. barriers to fish movement), both localized for non-anadromous species and regional for anadromous species;
    b. Effects on migration/spawning timing and triggers;
    c. Effects on spawning habitat and incubation of eggs;
    d. Effects on rearing habitat; and
    e. Effects on habitat that support adult life stages (feeding, holding, etc.).

    Key effects for wildlife and wildlife habitat include protected or conservation areas, species at risk and Environment Yukon's Wildlife Key Areas ("WKA") which represent a large aggregation of individuals (i.e., staging, nesting, moulting areas for water birds, etc.).

4) **Socio-economic Considerations**[17]: The socio-economic considerations include project benefits (jobs and Gross Domestic Product ("**GDP**") growth), impacts on land use and infrastructure relocations, as

[16] For additional information, please reference the *Yukon Next Generation Hydro and Transmission Viability Study – Positive and Negative Environmental and Socio-economic Effects* Technical Paper.

[17] For additional information, please reference the *Yukon Next Generation Hydro and Transmission Viability Study – Positive and Negative Environmental and Socio-economic Effects Technical Paper.*

well as potential effects on traditional Aboriginal activities, and community well-being.[18] More specifically, consideration was given to the following attributes:

a. **First Nation Settlement Lands and Other Land Tenures and Dispositions –** considers the overlap of the reservoirs with various types of First Nation settlement lands, interim protected lands and other non-resource related forms of land tenure.
b. **Land Use Plans** – considers the presence or absence of regional land use plans applicable to each priority site.
c. **Renewable Resource Lands** – considers the overlap of the reservoir with parcels of land that are protected or otherwise managed for their renewable resources and/or environmental values.
d. **Non-Renewable Resources** – considers the overlap of the reservoirs with parcels of land that have subsurface rights for minerals and oil and gas.
e. **Historic and Archeological Resources** – considers the presence or absence of known historic or archaeological sites within the reservoir areas and the likelihood for the project sites to be located within areas of high archaeological potential.
f. **Employment and Business Activity** – provides the estimated number of direct and indirect jobs created and the GDP generated by each project in the Yukon for the construction and operations phases.
g. **Traditional Aboriginal Activities** – qualifies the direct loss of areas available for traditional activities due to flooding of reservoir areas, and qualitatively examines the potential changes in access to land that might be afforded by the development of each priority site. This attribute also considers the presence of known or documented Aboriginal fishing sites/camp locations within and downstream of the reservoir footprint.

The following section provides a breakdown of the key findings of each project in terms of its technical, economic, environmental and socio-economic silos of interest.

[18] For the purposes of this report, the potential social Impact has been simplified to assume that projects are potentially socially acceptable assuming that stakeholder concerns and issues are addressed. As a result, social acceptance is not a criterion that is assessed further.

4 Project Descriptions

4.1 Detour Canyon

Detour Canyon is a potential hydroelectric project on the Pelly River, located approximately 85 km downstream (northwest) of Faro. Key findings per the four (4) silos of interest are identified in Table 4-1 below.

Table 4-1: Detour Canyon - Key Findings

TECHNICAL	▪ Dam: 72 m high Concrete Faced Rockfill Dam with gated concrete spillway ▪ Water Conveyance: Concrete water intake tower structure conveys water through diversion tunnel and steel penstock to powerhouse ▪ Maximum installed capacity: 100 MW (3 x 20 MW Kaplan turbines for 60 MW installed capacity with optional 40 MW two-unit expansion) ▪ Maximum annual energy: 587 GWh ▪ New Transmission Line: 83 km of 138 kV ▪ New Access Road: 82 km ▪ Flooded Area: 13,000 ha ▪ Reservoir Level Fluctuation: 7m on an average year
ECONOMIC	▪ Capital Cost: $1,413 Million ▪ O&M: $9.5 Million per year ▪ Forecast Utilization LCOE: $301/MWh
ENVIRONMENTAL	▪ Basin: Pelly River mainstem and its tributaries ▪ Fish: chinook salmon, chum salmon and arctic grayling ▪ Area of Ecological and Cultural Special Consideration: Overlap with lower Anvil Creek, Mica and Needle Rock Creek ▪ Wildlife: Absence of protected or conservation areas and overlap with Wildlife Key Areas (“WKA”) ▪ Species At Risk: Absence of documented species at risk within the reservoir footprint.
SOCIO-ECONOMIC	▪ Nearest Communities: Town of Faro & the Village of Ross River ▪ First Nations: Kaska Dena Council (Liard First Nation/Ross River Dena) & Selkirk First Nation ▪ Cultural and Archaeological: Presence of documented Aboriginal fishing site and traditional fish camps. No known overlap with documented Heritage and Cultural Resource Sites, but the project is located in area of high archaeological potential ▪ Reservoir Impacts: Overlaps Traditional Aboriginal Activity use areas, Renewable Resource Areas, Non-Renewable Resource Areas and other Land Tenures and Dispositions ▪ Economic Benefits: 5,500 construction jobs and 37 operations jobs ▪ Yukon GDP: Construction to add $634 Million; operations to add $7.3 Million/year ▪ Infrastructure: No displacement of existing infrastructure

4.2 Fraser Falls

Fraser Falls is a potential hydroelectric project on the Stewart River, approximately 40 km upstream of Mayo. Key findings per the four (4) silos of interest are identified in Table 4-2.

Table 4-2: Fraser Falls - Key Findings

TECHNICAL	▪ Dam: 56 m high Roller Compacted Concrete dam with stepped concrete spillway structure located on the face of the dam ▪ Water Conveyance: Concrete water intake conveys water through five penstocks to the powerhouse ▪ Maximum installed capacity: 95 MW (3 x 19 MW Kaplan turbines for 57 MW of installed capacity with optional 38 MW two-unit expansion) ▪ Maximum annual energy: 563 GWh ▪ New Transmission Line: 48 km of 138 kV ▪ New Access Roads: 46 km ▪ Flooded Area: 31,200 ha ▪ Reservoir Level Fluctuation: 3m on an average year
ECONOMIC	▪ Capital Cost: $1,233 Million ▪ O&M: $8.7 Million per year ▪ Forecast Utilization LCOE: $263/MWh
ENVIRONMENTAL	▪ Basin: Mainstem Stewart River & the lower reach of the Hess River ▪ Fish: chinook salmon, chum salmon and arctic grayling ▪ Protected or Conservation Areas: Horseshoe Slough Habitat Protection Area (HPA) ▪ Wildlife: Overlap of WKAs for duck, Canada goose, woodland caribou, peregrine falcon, bald eagle ▪ Species at Risk: 2 documented species at risk (peregrine falcon and woodland caribou)
SOCIO-ECONOMIC	▪ Nearest Communities: Village of Mayo (within 100km) & the community of Stewart Crossing ▪ First Nations: First Nation of Na-Cho Nyäk Dun ▪ Cultural & Archaeology: Presence of Aboriginal fishing camp and known sites of heritage and cultural resources. The project located in area of high archaeological potential. ▪ Reservoir Impacts: Overlaps Traditional Aboriginal Activity use areas, Renewable Resource Areas, Non-Renewable Resource Areas and other Land Tenures and Dispositions ▪ Economic Benefits: 4,800 construction jobs & 34 operations jobs ▪ Yukon GDP: Construction to add $553 Million; operations to add $6.7 Million/year ▪ Infrastructure: No displacement of existing infrastructure

4.3 Granite Canyon

Granite Canyon is a potential hydroelectric project on the Pelly River, approximately 20 km east of Pelly Crossing. Key findings per the four (4) silos of interest are identified in Table 4-3.

Table 4-3: Granite Canyon - Key Findings

TECHNICAL	▪ Dam: 60 m high Roller Compacted Concrete dam with stepped concrete spillway structure located on the face of the dam ▪ Water Conveyance: Concrete water intake conveys water through five penstocks to the powerhouse ▪ Maximum Installed Capacity: 95 MW (3 x 19 MW Kaplan turbines for 57 MW of installed capacity with optional 38 MW two-unit expansion) ▪ Maximum Annual Energy: 588 GWh ▪ New Transmission Line: 15 km of 138 kV ▪ New Access Roads:15 km ▪ Flooded Area: 17,600 ha ▪ Reservoir Level Fluctuations: 3m on an average year
ECONOMIC	▪ Capital Cost: $847 Million ▪ O&M: $7.2 Million per year ▪ Forecast Utilization LCOE: $181/MWh
ENVIRONMENTAL	▪ Basin: Pelly River & south MacMillan rivers ▪ Fish: chinook salmon, chum salmon and arctic grayling ▪ Areas of Special Cultural Consideration: Mica and Needle Rock Creek ▪ Wildlife: Overlap of WKAs for waterfowl and woodland caribou (possibly Tatchun herd) ▪ Species at Risk: Presence of two (2) documented species at risk (woodland caribou and trumpeter swan)
SOCIO-ECONOMIC	▪ Nearest Communities: Pelly Crossing, Stewart Crossing and the Village of Carmacks ▪ First Nations: Selkirk First Nation ▪ Cultural & Archaeology: Documented aboriginal fishing site, traditional fish camps and known sites of heritage and cultural resources. The project is located in area of high archaeological potential. ▪ Reservoir Impacts: Overlaps Traditional Aboriginal Activity use areas, Renewable Resource Areas, Non-Renewable Resource Areas and other Land Tenures and Dispositions ▪ Economic Benefits: 3,300 construction jobs & 28 operations jobs ▪ Yukon GDP: Construction to add $380 Million; operations to add $5.6 Million/year ▪ Infrastructure: No displacement of existing infrastructure

4.4 Two Mile Canyon

Two Mile Canyon is a potential hydroelectric project on the Hess River, located in the Stewart River Basin, approximately 100 km east of Mayo. Key findings per the four (4) silos of interest are identified in Table 4-4.

Table 4-4: Two Mile Canyon - Key Findings

TECHNICAL	▪ Dam: 68 m high Roller Compacted Concrete dam with stepped concrete spillway structure located on the face of the dam ▪ Water Conveyance: Concrete water intake conveys water through a single penstock to the powerhouse. ▪ Maximum Installed Capacity: 90 MW (3 x 18 MW Kaplan turbines for 54 MW of installed capacity with optional 36 MW two-unit expansion) ▪ Maximum Annual Energy: 489 GWh ▪ New Transmission Line: 113 km of new 138 kV ▪ New Access Roads: 111 km ▪ Flooded Area: 10,300 ha ▪ Reservoir Level Fluctuation: 9 m on an average year
ECONOMIC	▪ Capital Cost: $919 Million ▪ O&M: $8.5 Million per year ▪ Forecast Utilization LCOE: $199/MWh
ENVIRONMENTAL	▪ Basin: Hess River & Pleasant Creek ▪ Fish: chinook salmon, chum salmon and arctic grayling ▪ Wildlife: No overlap with WKAs ▪ Species at Risk: Absence of documented species at risk
SOCIO-ECONOMIC	▪ Nearest Community: Village of Mayo ▪ First Nations: First Nation of Na-Cho Nyäk Dun and part of the Na-Cho Nyäk Dun chinook fishery ▪ Cultural & Archaeology: The project located in area of high archaeological potential. ▪ Reservoir Impacts: Overlaps Traditional Aboriginal Activity use areas, Renewable Resource Areas, Non-Renewable Resource Areas and other Land Tenures and Dispositions ▪ Economic Benefits: 3,600 construction jobs & 33 operations jobs ▪ Yukon GDP: construction GDP to add $412 Million; operations GDP to add $6.6 Million per year ▪ Infrastructure: No displacement of existing infrastructure

4.5 False Canyon + Middle Canyon ROR

False Canyon + Middle Canyon Run of River ("**ROR**") is a potential cascade of two sites with False Canyon located upstream on the Frances River, approximately 75 km north of Watson Lake, providing both generation and active water storage. Middle Canyon ROR (built after False Canyon) is located downstream, approximately 40 km northwest of Watson Lake, and operates as a ROR facility with no active water storage. Key findings per the four (4) silos of interest are identified in Table 4-5.

Table 4-5: False Canyon + Middle Canyon ROR - Key Findings

TECHNICAL	*False Canyon* ▪ Dam: 65 m high Concrete Faced Rockfill Dam with a concrete spillway ▪ Water Conveyance: concrete water intake tower conveys water through diversion tunnel to the powerhouse ▪ Installed Capacity: Three (3) Kaplan turbines for 56 MW of installed capacity *Middle Canyon ROR* ▪ Dam: 17 m high Roller Compacted Concrete dam with stepped concrete spillway ▪ Water Conveyance: water intake conveys water through three (3) penstocks to the powerhouse ▪ Installed Capacity: three (3) Kaplan turbines for 22 MW of installed capacity *Cascade* ▪ Maximum Installed Capacity: 78 MW ▪ Maximum Annual Energy: 451 GWh ▪ New Transmission Line: 370 km (14 km assuming pre-existing Faro to Watson Lake Transmission Line) ▪ New Access Road: 50 km (20 km assuming pre-existing Faro to Watson Lake Transmission Line) ▪ Flooded Area: 26,100 ha ▪ Reservoir Level Fluctuation: 5 m over an average year
ECONOMIC	▪ Capital cost: : $1,959 Million ($1,493 Million assuming pre-existing Faro-Watson Lake Transmission Line) ▪ O&M: $12.5 Million ($10.7 Million per year assuming pre-existing Faro-Watson Lake Transmission Line) ▪ Forecast Utilization LCOE: $379/MWh ($286/MWh assuming pre-existing Faro-Watson Lake Transmission Line)
ENVIRONMENTAL	▪ Affected Bodies of Water: Frances lakes, Frances River, False Canyon Creek extending to Stewart Lake ▪ Fish: Fresh water only fish including Arctic grayling and bull trout ▪ Wildlife: Overlap of WKAs for waterfowl, moose, bald eagle ▪ Species at Risk: 2 documented species at risk (barn swallow, trumpeter swan)
SOCIO-ECONOMIC	▪ Nearest Communities: Ross River (within 100 km) and the Town of Watson Lake ▪ First Nations: Kaska Dena Council (Liard First Nation/Ross River Dena) ▪ Cultural & Archaeology: Overlaps known Heritage and Cultural Resource sites and several burial sites. The project located in area of high archaeological potential. ▪ Reservoir Impacts: Overlaps Traditional Aboriginal Activity use areas, Renewable Resource Areas, Non-Renewable Resource Areas and other Land Tenures and Dispositions ▪ Economic benefits: 7,700 construction jobs & 41 operations jobs ▪ Yukon GDP: Construction GDP $879 Million; operations GDP $8.3 Million/year ▪ Infrastructure: Displacement of Robert Campbell Highway and Nahanni Range Road

4.6 Slate Rapids + Hoole Canyon ROR

Slate Rapids + Hoole Canyon ROR is a potential cascade of two sites with Slate Rapids located upstream on the Pelly River, approximately 75 km east of the community of Ross River, providing both water storage and generation. Hoole Canyon ROR (built after Slate Rapids) is located downstream in the Pelly River Basin, approximately 30 km upstream of the community of Ross River, and operates as a run-of-river facility with no active water storage. Key findings per the four (4) silos of interest are identified in Table 4-6.

Table 4-6: Slate Rapids + Hoole Canyon ROR – Key Findings

TECHNICAL	*Slate Rapids* ▪ Dam: 57 m high diversion dam and 36 m high power dam, both of Concrete Faced Rockfill Dam type with concrete spillways ▪ Water Conveyance: Concrete water intake at the power dam conveys water through a steel penstock to the powerhouse ▪ Powerhouse: Two (2) Kaplan turbines for 42 MW of capacity *Hoole Canyon ROR* ▪ Dam: 71 m high Concrete Faced Rockfill Dam with a concrete spillway ▪ Water Conveyance: Concrete water intake tower conveys water through diversion tunnel to the powerhouse ▪ Powerhouse: Two (2) Kaplan turbines for 65 MW of installed capacity *Cascade* ▪ Maximum Installed Capacity: 107 MW ▪ Maximum annual energy: 487 GWh ▪ New Transmission Line: 163 km (11 km assuming pre-existing Faro to Watson Lake Transmission Line) ▪ New Access Road: 32 km (12 km assuming pre-existing Faro to Watson Lake Transmission Line) ▪ Flooded Area: 19,100 ha ▪ Reservoir Level Fluctuation: 5 m over an average year
ECONOMIC	▪ Capital cost: $2,962 Million ($2,764 Million assuming pre-existing Faro-Watson Lake Transmission Line) ▪ O&M: $15.9 Million per year ($15.2 Million per year assuming pre-existing Faro-Watson Lake Transmission Line) ▪ Forecast Utilization LCOE: $540/MWh ($500/MWh assuming pre-existing Faro-Watson Lake Transmission Line)
ENVIRONMENTAL	▪ Affected Bodies of Water: Fortin Lake, Pelly Lakes, a number of smaller lakes and portions of the Pelly River mainstem ▪ Fish: chinook salmon, chum salmon and arctic grayling ▪ Areas of Special Cultural Consideration: Mica and Needle Rock Creek ▪ Wildlife: Overlap of WKAs for woodland caribou (Finlayson herd), moose and riparian raptors. ▪ Species at Risk: Documented presence of one (1) species at risk (bank swallows)

SOCIO-ECONOMIC	▪ Nearest Communities: Ross River (within 100 km) and the Town of Faro ▪ First Nations: Kaska Dena Council (Liard First Nation/Ross River Dena) ▪ Cultural & Archaeology: Documented aboriginal fishing sites and known Heritage and Cultural Resource sites. The project located in area of high archaeological potential. ▪ Reservoir Impacts: Overlaps Traditional Aboriginal Activity use areas, Renewable Resource Areas, Non-Renewable Resource Areas and other Land Tenures and Dispositions ▪ Economic Benefits: 11,600 construction jobs & 59 operations jobs ▪ Yukon GDP: Construction GDP $1,329 Million; operations GDP $11.7 Million/year ▪ Infrastructure: Displacement of Robert Campbell Highway

5 Project Assessment

Based on the key findings listed in Section 4 and on the assessment framework set out in Section 3, Table 5-1 below provides a summary of the key advantages and disadvantages of each priority site and the respective silo scores relative to other priority sites.

Table 5-1: Project Site Assessment Matrix - 4 Silos of Interest

Site	Technical	Economic	Environmental	Socio-economic	Synopsis
Detour Canyon	▪ Technically feasible ▪ Meets forecasted 2065 need ▪ Site Accessibility: ○ New Tx Line: 83 km ○ New Roads: 90 km	▪ Capital Cost: $1,413M (Most expensive standalone project) ▪ O&M: $9.5M/year ▪ Forecast LCOE: $301/MWh	*General* ▪ Flooded area: 13,000 ha (2nd smallest area) ▪ Impacted bodies of water: Pelly River and its tributaries ▪ Reservoir Water Level Fluctuations: 7m average ▪ Areas of Special Cultural Consideration: Anvil Creek, Mica and Needle Rock Creek *Fisheries:* ▪ Fish Habitat: loss of spawning and rearing habitats for Arctic grayling ▪ Fish Migration: Potential barrier for chinook and chum salmon *Wildlife:* ▪ Protected or Conservation Area: None ▪ Wildlife: No WKA ▪ Documented Species at Risk: None	▪ Economic Benefits: Significant ▪ Infrastructure Displacement: None *Reservoir footprint overlap with:* ▪ Kaska Dena Council (Liard First Nation/Ross River Dena) Interim Protected Lands: 2,300 ha ▪ Selkirk First Nation Settlement Land: 3 ha ▪ Heritage and Cultural Resource sites: No Documented ▪ Aboriginal Fishing Sites: Yes ▪ Traditional Aboriginal Activity Land Use: 13,000 ha (2nd lowest) ▪ Renewable Resource Areas 27,000 ha (2nd lowest) ▪ Non-renewable Resource Areas: 10,800 ha (2nd highest) ▪ Land Tenures and Dispositions: 6 ha (Lowest)	Detour Canyon is the most expensive standalone project and has moderate potential effects on fisheries and areas of special cultural consideration. Relative to the other priority sites, Detour Canyon appears to offer fewer potential impacts with respect to wildlife and wildlife habitat, and potential socio-economic effects. In addition, the location of the project is relatively remote and may therefore present less challenging environmental and socio-economic issues.
Fraser Falls	▪ Technically feasible ▪ Meets forecasted 2065 need ▪ Site Accessibility: ○ New Tx Line: 48 km ○ New Roads: 40 km	▪ Capital Cost: $1,233M (2nd most expensive standalone project) ▪ O&M: $8.7M/year ▪ Forecast LCOE: $263/MWh	*General* ▪ Flooded Area: 31,200ha (Largest area) ▪ Impacted Bodies of Water: Stewart River, Hess River and Pleasant Creek ▪ Reservoir Water Level Fluctuations: 3m average ▪ Areas of Special Cultural Consideration: Downstream aboriginal fishing camp. *Fisheries:* ▪ Fish Habitat: loss of spawning and rearing habitats for chinook salmon, chum salmon and Arctic grayling ▪ Fish Migration: Potential barrier for chinook and chum salmon *Wildlife*: ▪ Protected or Conservation Area: Federally protected Horseshoe Slough Wildlife Area ▪ WKA: Overlap of WKAs for duck, Canada goose, woodland caribou, peregrine falcon, bald eagle ▪ Documented Species at Risk: Peregrine falcon and woodland caribou	▪ Economic Benefits: Significant ▪ Infrastructure Displacement: None *Reservoir footprint overlap with:* ▪ Na-Cho Nyäk Dun Settlement Land: 3,300 ha ▪ Heritage and Cultural Resource Sites: Present ▪ Documented Aboriginal Fishing Sites: Present ▪ Traditional Aboriginal Activity use: 31,200 ha (Highest) ▪ Renewable Resource Area: 71,700 ha (Highest) ▪ Non-Renewable Resource Areas: 7,800 ha (3rd highest) ▪ Land Tenures and Dispositions: 900 ha (3rd lowest)	Fraser Falls is the 2nd most expensive of the standalone projects, has the largest flooded area, and inundates the Horseshoe Slough Habitat Protection Area. Like all NGH projects, Fraser Falls offers significant economic benefits to the Yukon which must be contrasted with the significant environmental and socio-economic impacts.

Site	Technical	Economic	Environmental	Socio-economic	Synopsis
Granite Canyon	▪ Technically feasible ▪ Meets forecasted 2065 need ▪ Site Accessibility: ○ New Tx Line: 15 km ○ New Roads: 15 km	▪ Capital Cost: $847M (Least cost project) ▪ O&M: $7.2M/year ▪ Forecast LCOE: $181/MWh	*General:* ▪ Flooded Area: 17,600 ha (3rd lowest) ▪ Impacted Bodies of Water: Pelly River and south MacMillan River ▪ Reservoir Water Level Fluctuations: 3m average ▪ Areas of Special Cultural Consideration: Mica and Needle Rock Creek *Fisheries:* ▪ Fish Habitat: Loss of spawning and rearing habitats for Artic grayling ▪ Fish Migration: Potential barrier for chinook and chum salmon Wildlife: ▪ Protected or Conservation Areas: None ▪ WKA: Overlap of WKAs for waterfowl and woodland caribou (possibly Tatchun herd) ▪ Species at Risk: Documented Woodland caribou and trumpeter swan	▪ Economic Benefits: Significant ▪ Infrastructure Displacement: None *Reservoir footprint overlap with:* ▪ Selkirk First Nation Settlement Land: 8,800 ha ▪ Heritage and Cultural Resource sites: Present ▪ Documented Aboriginal Fishing Sites: Present ▪ Traditional Aboriginal Activities: 17,600 ha (3rd lowest) ▪ Renewable Resources Area: 32,500 ha (3rd highest) ▪ Non-Renewable Resources Areas: 35 ha (Lowest) ▪ Land Tenures and Dispositions: 4,600 ha (3rd highest)	Granite Canyon is the lowest economic cost project due to having the lowest construction cost (and cost risks). However, despite its technical and economic advantages, Granite Canyon impacts fish and fish habitat, wildlife areas, and presents significant socio-economic impacts because the reservoir would flood culturally significant areas with documented cabins, graveyard(s) and at least six other archaeological sites.
Two Mile Canyon	▪ Technically feasible ▪ Satisfies 97% of the forecasted 2065 need ▪ Site Accessibility: ○ New Tx Line: 113 km ○ New Roads: 110 km	▪ Capital Cost: $919M (2nd most economic project) ▪ O&M: $8.5M/year ▪ Forecast LCOE: $199/MWh	*General:* ▪ Flooded Area: 10,300 ha (Smallest) ▪ Impacted Bodies of Water: Hess River and Pleasant Creek ▪ Reservoir Water Level Fluctuations: 9m average ▪ Areas of Special Cultural Consideration: None *Fisheries:* ▪ Fish Habitat: Loss of spawning and rearing habitats for chinook salmon, chum salmon and Arctic grayling ▪ Fish Migration: Potential barrier for chinook and chum salmon *Wildlife:* ▪ Protected or Conservation Areas: None ▪ WKA: None ▪ Documented Species at Risk: None	▪ Economic Benefits: Significant ▪ Infrastructure Displacement: None *Reservoir footprint overlap with:* ▪ Na-Cho Nyäk Dun Settlement Land: 2,000 ha ▪ Heritage and Cultural Resource sites: None ▪ Documented Aboriginal Fishing Sites: None ▪ Traditional Aboriginal Activities use: 10,300 ha (Lowest) ▪ Renewable Resource Areas: 20,600 ha (lowest) ▪ Non-Renewable Resource Areas: 380 ha (2nd lowest) ▪ Land Tenures & Dispositions: 10,300 ha (2nd highest)	Two Mile Canyon is 2nd most economic project even though it only provides 97% of the forecasted Baseline 2065 energy demand. The site appears to offer some advantages with respect to wildlife and wildlife habitat, and potential socio-economic effects relative to the other priority sites. Additionally, the location of the project is relatively remote and may therefore present less challenging environmental and socio-economic issues relative to other NGH projects.
False Canyon + Middle Canyon ROR	▪ Technically feasible ▪ Meets forecasted 2065 need ▪ Site Accessibility: ○ New Tx Line: 370 km (14 km with pre-existing Faro-Watson Lake Tx Line)	*Without Pre-existing Faro-Watson Lake Tx Line:* ▪ Capital Cost: $1,959M (2nd most expensive project) ▪ O&M: $12.5M/year ▪ Forecast LCOE: $379/MW	*General:* ▪ Flooded Area: 26,100 ha (2nd largest) ▪ Impacted Bodies of Water: Frances Lake, Frances River, False Canyon Creek extending to Steward Lake ▪ Reservoir Water Level Fluctuations: 5m average *Fisheries:* ▪ Fish Habitat: Loss of spawning and rearing habitats for arctic grayling and bull trout (species at risk). Does not affect salmon.	▪ Economic Benefits: Significant ▪ Infrastructure Displacement: Robert Campbell Highway and Nahanni Range Road *Reservoir footprint overlap with:* ▪ Kaska Dena Council (Liard First Nation/Ross River Dena) Interim Protected Land: 1,500 ha ▪ Heritage and Cultural Resource sites: Present ▪ Documented Aboriginal Fishing Sites: None	False Canyon + Middle Canyon ROR project has the 2nd highest capital cost and 2nd largest reservoir footprint of all the projects. On a Forecast Utilization LCOE basis, without a pre-existing transmission corridor between Faro and Watson Lake, the project is more expensive than the four (4) standalone projects, and with a pre-existing

Site	Technical	Economic	Environmental	Socio-economic	Synopsis
	○ New Roads: 50 km (20 km with pre-existing Faro-Watson Lake Tx Line)	*With Pre-existing Faro-Watson Lake Tx Line:* ▪ Capital Cost: $1,493M (2nd most expensive project) ▪ O&M: $10.7M/year ▪ Forecast LCOE: $286/MWh	▪ Fish Migration: Barrier for Arctic grayling. Not a salmon bearing river system. *Wildlife:* ▪ Protected or Conservation Areas: None ▪ WKA: Overlap of WKAs for waterfowl, moose, bald eagle ▪ Documented Species at Risk: Barn swallow, trumpeter swan	▪ Traditional Aboriginal Activities area: 26,100 ha (2nd highest) ▪ Renewable Resource Areas: 31,420 ha (3rd lowest) ▪ Non-Renewable Resource Areas: 3,000 ha (3rd lowest) ▪ Land Tenures and Dispositions: 30,000 ha (Highest)	transmission line the project is more expensive than all the standalone projects except Detour Canyon. There are also key constraints with respect to effects on wildlife and wildlife habitat, and socio-economic constraints in the Fortin Lake area. Despite these drawbacks, False Canyon + Middle Canyon ROR is the only project that does not affect salmon, and is the only project that would connect Watson Lake to the Yukon electrical grid.
Slate Rapids + Hoole Canyon ROR	▪ Technically feasible ▪ Meets forecasted 2065 need ▪ Site Accessibility: ○ New Tx Line: 163km (11 km with pre-existing Faro-Watson Lake Tx Line) ○ New Roads: 32 km (12 km with pre-existing Faro-Watson Lake Tx Line)	*Without Pre-existing Faro-Watson Lake Tx Line:* ▪ Capital Cost: $2,962M (Most expensive project) ▪ O&M: $15.9M/year Forecast LCOE: $540/MWh *With Pre-existing Faro-Watson Lake Tx Line:* ▪ Capital Cost: $2,764M (Most expensive project) ▪ O&M: $15.2M/year ▪ Forecast LCOE: $500/MWh	*Fisheries:* ▪ Flooded Area: 19,100 ha (3rd highest) ▪ Impacted Bodies of Water: Fortin Lake, Pelly Lakes, Pelly River and a number of smaller lakes ▪ Reservoir Water Level Fluctuations: 5m average ▪ Areas of Special Cultural Consideration: Mica and Needle Rock Creek *Fisheries:* ▪ Fish Habitat: Effects on shoreline habitat ▪ Fish Migration: Potential barrier for chinook and chum salmon *Wildlife:* ▪ Protected or Conservation Areas: None ▪ WKA: Overlap of WKAs for woodland caribou (Finlayson herd), moose and riparian raptors. ▪ Documented Species at Risk: Bank swallows	▪ Economic Benefits: Significant ▪ Infrastructure Displacement: Robert Campbell Highway *Reservoir footprint overlap with:* ▪ Kaska Dena Council (Liard First Nation/Ross River Dena) Interim Protected Land: 4,900 ha ▪ Heritage and Cultural Resource sites: Present ▪ Documented Aboriginal fishing sites: Present ▪ Traditional Aboriginal Activities area: 19,100 ha (3rd highest) ▪ Renewable Resource Area: 38,200 ha (2nd highest) ▪ Non-Renewable Resource Areas: 19,100 ha (Highest) ▪ Land Tenures and Dispositions: 130 ha (2nd lowest)	Slate Rapids + Hoole Canyon ROR is the most expensive project, both with and without a pre-existing Faro-Watson Lake Transmission Line. In addition to high costs, no major advantages have been identified relative to the other NGH projects except for a low overlap with Land Tenure and Dispositions. The project has the 3rd largest flooded area, and results in impacts to key environmental and socio-economic areas for both aboriginal and non-aboriginal groups.

6 Next Generation Hydro Development Strategy

The following section provides an outline of a development strategy for a Next Generation Hydro project, including an high level outline of the project selection and reconnaissance phase (Phase 0) as well as a general overview of the hydro development phases to follow (Phase 1 → 6). The seven phases in total are as follows:

- Phase 0: Project Selection and Reconnaissance Study Phase (1 to 4/5 Years)
- Phase 1: Pre-Feasibility (1 Year)
- Phase 2: Feasibility (2 to 4 Years)
- Phase 3: Preliminary Engineering (1 Year)
- Phase 4: Permitting (3 to 5 Years)
- Phase 5: Detailed Engineering (1 Year)
- Phase 6: Pre-Construction (1 Year)
- Phase 5: Construction (3 to 4 Years)
- Phase 6: Commissioning & Operations (Ongoing)

Figure 6-1 and Figure 6-2 describe the hydroelectric development phases in the NGH context. As shown in Figure 6-2 most phases end with a gate review to determine if a project should continue forward to the next phase of development. It is also important to note that although there is only one preferred project expected in Phase 1 through Phase 4, a project is not selected for construction until the end of Phase 4. Therefore, should a project fail to pass a gate review, that project is halted and not advanced any further.

Figure 6-1: NGH Development Timeline

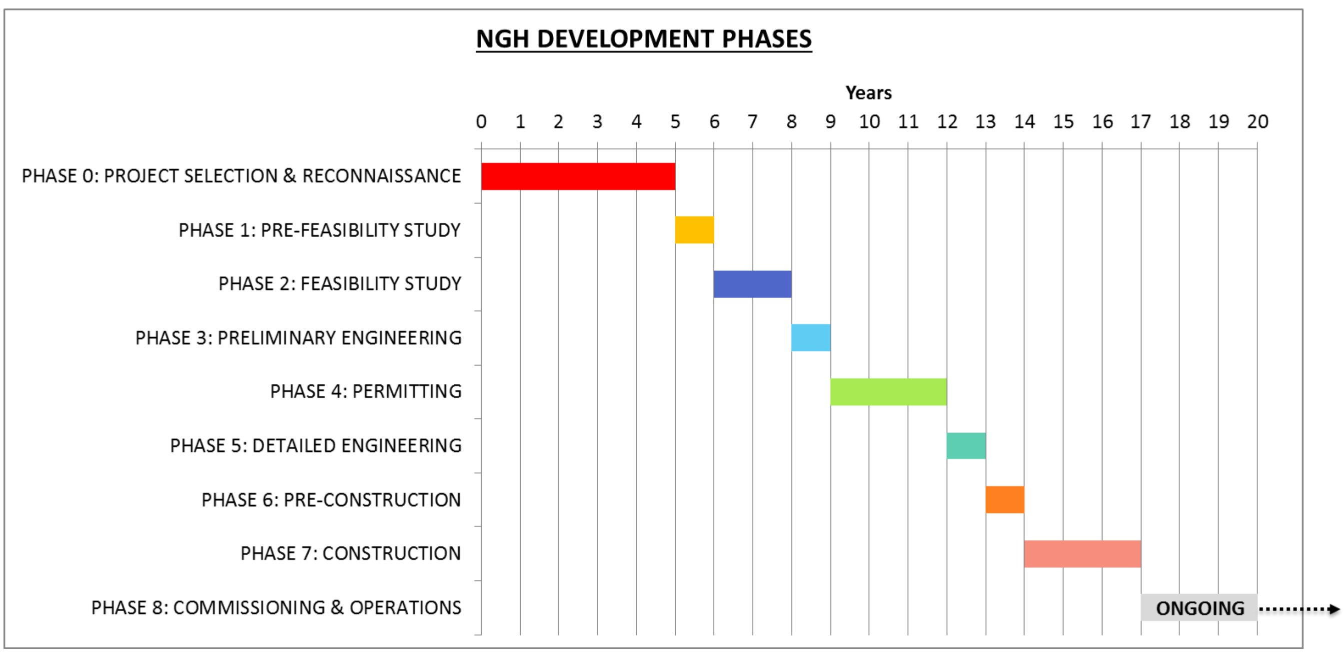
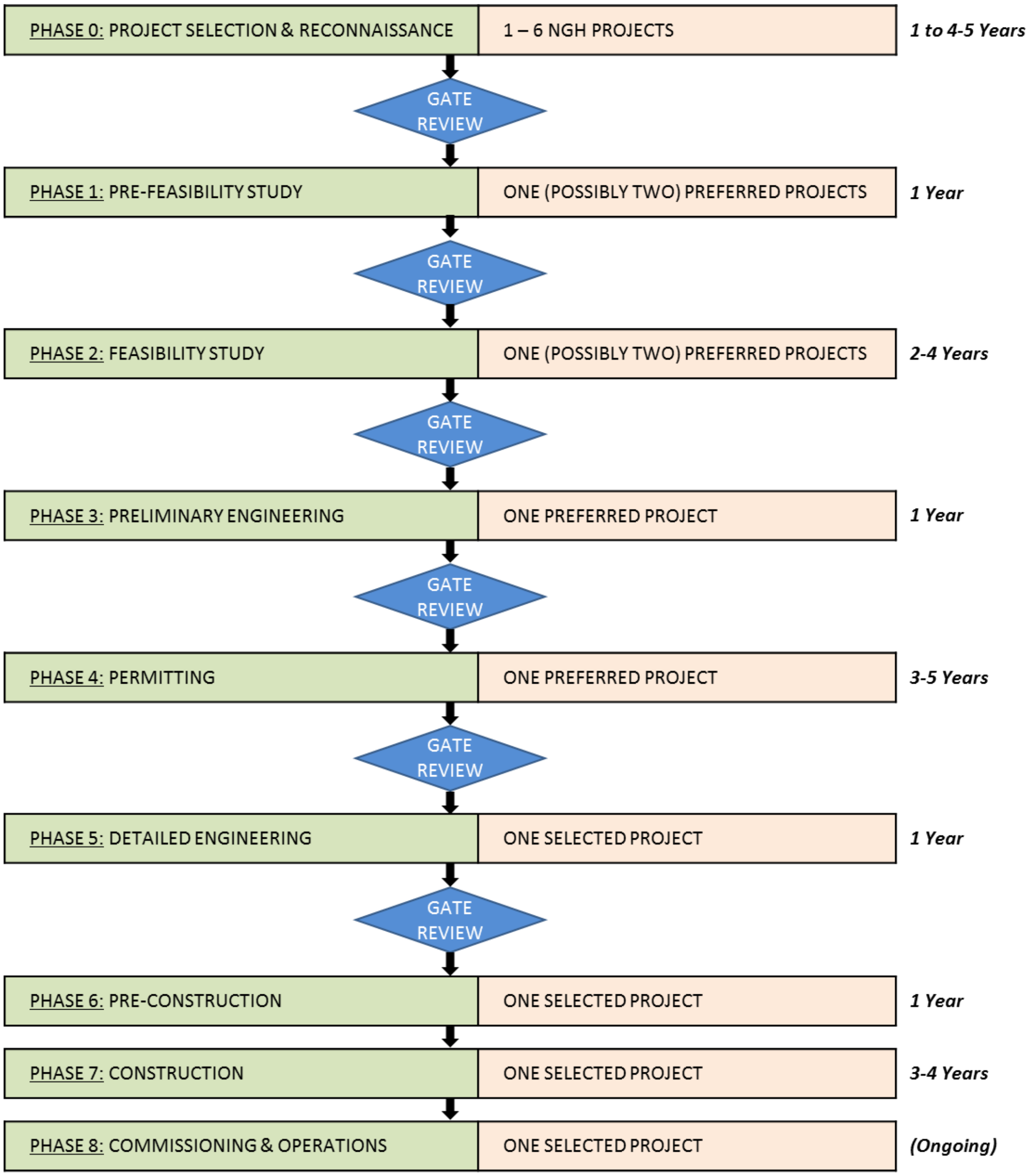


Figure 6-2: Next Generation Hydro Development Phases



6.1 Phase 0: Project Selection and Reconnaissance Study Phase (Year 1 → Year 4/5)

Phase 0 focuses on project selection and relationship building with First Nations and other stakeholders. In this phase the major impacts and benefits will inform investment decisions, but the differences between projects will drive the selection of one project over another. In a similar manner, it will be critical to build trust based relationships as a pathway to a "Social License to Operate" and scoping of subsequent investigation activities.

Phase 0 covers a 4 to 5 year period starting in 2016 with an overall objective of preserving the option of having a Next Generation Hydro project in operation sometime in the window of 2030 to 2035 (15 to 20 years from today). At the end of the 4 to 5 year project selection and reconnaissance period, one (or possibly two) project(s) can be selected as the preferred candidate for entry into Pre-feasibility study as part of a more traditional project development path. The preferred project is only a preferred project and will be advanced to further study through a series of gate reviews, but should the preferred project be stopped at a gate review the preferred project will be halted and another project may be advanced at that time.

Table 6-1 describes the activities in the project selection and reconnaissance study phase and Figure 6-3 depicts the time timeline of the activities under this phase. At the end of Phase 0, estimates will produce a Class 5 (+100%/-50% cost estimate).

Figure 6-3: NGH Development Phase 0 Activities

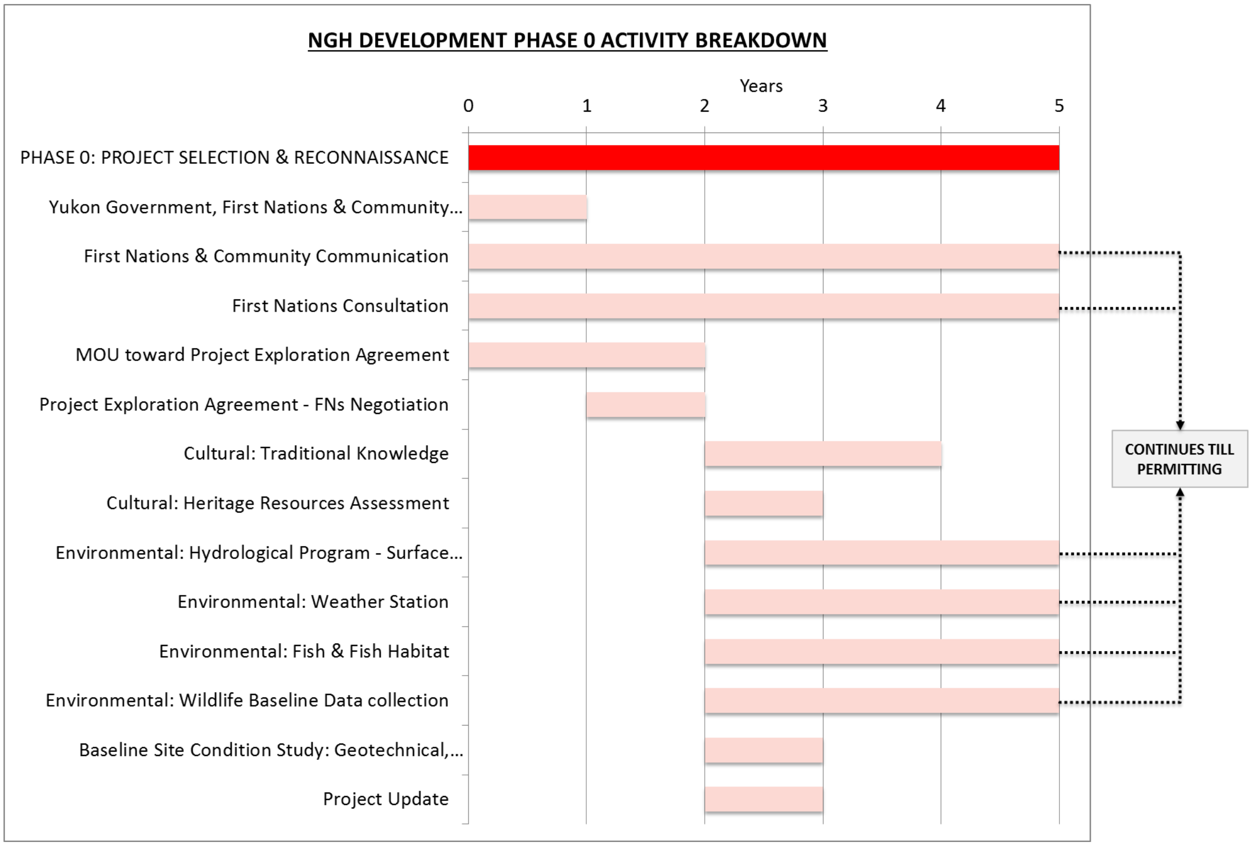


Table 6-1: Project Selection and Reconnaissance Study Phase - Activities, Outcomes, and Expected Timelines

Category	Activity	Description
Social License	Yukon Government, First Nations & Community Engagement Mandate	▪ Clear and concise mandate from Yukon Government to conduct series of community engagements to facilitate bi-directional information sharing
Social License	First Nations & Community Communication	▪ Multiple visits to First Nations Communities in Yukon. Present Next Generation Hydro findings to date. ▪ Update First Nations and Communities on project status.
Social License	First Nations Consultation	▪ First Nations consultation with Chief and Council and First Nation communities.

Category	Activity	Description
MOU toward Project Exploration Agreement	Yukon Government & Community Engagement	▪ Mandate to negotiate non-binding terms building towards a Project Exploration Agreement ▪ The Exploration Agreement, among other things, formalizes First Nation influence on decision-making regarding the Project in question, establishes cost sharing formula for First Nation resource expenditures (required to support Exploration Agreement obligations), and outlines process / requirements prior to Project advancing to next stage.
Project Exploration Agreement	First Nations Negotiations	▪ Yukon discussions with First Nations to obtain an initial Project Exploration Agreement to jointly carry out the next set of site investigations. ▪ NOTE: The Project Exploration Agreement is not an Impact Benefits Agreement.
Cultural Baseline Data Collection	Traditional Knowledge	▪ Traditional Knowledge studies with First Nations as outlined in above Project Exploration Agreement
Cultural Baseline Data Collection	Heritage Resources Assessment	▪ Archaeological Overview Assessment on affected project footprints.
Environmental Baseline Data Collection	Hydrological Program - Surface Water	▪ Establishment of hydrology gauging to build long term and continuous data set(s)
Environmental Baseline Programs	Weather Station	▪ Establishment of weather stations at priority sites for continuous monitoring to build long term weather data set(s)
Environmental Baseline Programs	Fish & Fish Habitat – Absence / Presence / Population / Migration	▪ Drainage basin level fisheries studies to determine presence / absence of fish species, populations and migration patterns.
Wildlife Baseline Data collection	Wildlife & Wildlife Habitat – Absence / Presence / Population / Migration	▪ Yukon's Wildlife Key Areas, presence/absence of documented species, traditional knowledge and land use; studies to determine presence / absence of species, populations and migration patterns.
Baseline Site Condition Study (Geotechnical, Geological, Layout / Construction)	Preliminary delineation of ground conditions associated with priority sites	▪ Site Visit(s) to evaluate o Geotechnical / Foundation Conditions o Surficial Geology o Permafrost o Construction Material Availability o Mapping o Project Layout & Construction

Category	Activity	Description
Project Update	Project Update Report to update project design, cost, economics and operations	▪ Project Update to re-assess o Project Layout & Design o Cost o Hydrology (Revenue) o Operations (Social / Environmental Constraints) o Project Economics ▪ Report is an input to FNs Exploration Agreement discussions

6.2 Phase 1: Pre-Feasibility (1 Year)

The purpose of the Pre-Feasibility phase is to establish enough understanding of the project to assess the viability of, and desirability for, more detailed levels of study. Work to be completed in this phase includes high-level assessments of available resources (project capacity and energy), capital cost estimates, financial modeling, environmental study updates, and socio-economic updates.

In preparations for a gate review, the updated project is summarized in the four areas of economics, technical, environmental and socio-economic. The project update is then presented in a gate review format to see if it is to become the preferred project for further study. At the end of Phase 1, estimates will produce a Class 5 (+100%/-50%) cost estimate.

6.3 Phase 2: Feasibility (2-4 years)

The purpose of the Feasibility phase is to study the project to a sufficient level of detail to allow for a go/no-go decision to continue investing and additional engineering to support the permitting phase of development. Work completed in this phase includes refined assessments of available resources (using site specific gauge data), capital cost estimates, and financial modeling. Additionally, in preparation for the Environmental Assessment process, preliminary permitting work may be started in the Feasibility phase to inform additional engineering and an enhanced project description for the purpose of entry into the Environmental Assessment process.

Once again a gate review is performed to determine if the project should advance to the next development phase. At the end of Phase 2, estimates will produce a Class 4 (+50%/-25%) cost estimate.

6.4 Phase 3: Preliminary Engineering (1 year)

The purpose of the Preliminary Engineering phase is perform additional engineering to clarify key technical risks and enable entry into permitting. As in Feasibility, the goal is to support a go/no-go decision to continue investing in the project and advance into the permitting phase of development. Work completed in this phase includes risk investigation & design refinement, resource updates (e.g. hydrology), capital cost estimates, and financial modeling. Additionally, in preparation for the Environmental Assessment process, preliminary permitting work may be started (or continued) in this phase to inform additional engineering and an enhanced project description for the purpose of entry into the Environmental Assessment process.

Once again a gate review is performed to determine if the project should advance to the next development phase. At the end of Phase 3, estimates may produce a Class 3 (+30%/-15%) cost estimate dependent upon the project risks (technical, environmental, social) identified and the solutions to those risks. If the risk profile warrants, the cost estimate may remain a Class 4 (+50%/-25%) estimate until sufficient permitting activities are completed to obtain a Class 3 estimate.

6.5 Phase 4: Permitting (3-5 years)

The purpose of the Permitting phase is to obtain all licenses, tenures, and other material permits required for construction and commissioning of the project. Work completed during this phase includes environmental and stakeholder studies to support the submission of an Environmental Assessment application. In addition, hydrology, energy estimates, and revenue estimates are updated with long-term synthetic flow data sets (after correlating the site specific gauge with Water Survey of Canada data). Several term sheets are developed (debt financing and construction contractor included) and an Impact Benefits Agreement with the affect First Nation(s) is executed.

After all material permits are obtained the final gate review is conducted to decide on whether or not the project should continue forward into design, construction and ultimately operations. At the end of Phase 4, estimates will produce a Class 3 (+30%/-15%) cost estimate.

6.6 Phase 5: Detailed Design (1 year)

Depending on the contracting method for construction that is selected, the Detail Design phase takes the Environmental Assessment permits and translates them into detailed project designs and pre-construction activities (e.g. identification of long lead items, issuing requests for construction proposals). At the end of this phase a gate review is held based on an updated project design, updated cost estimate and plans for entering the construction phases of the project.

It is important to note that the implementation method of the Detailed Design and Pre-Construction phases is highly dependent on the selected construction contracting method. At the end of Phase 5, estimates will produce a Class 2 (+20%/-10%) cost estimate.

6.7 Phase 6: Pre-Construction (1 year)

The purpose of Pre-Construction is to prepare the execution of project construction. Work completed in this phase includes negotiation and execution of construction contracts, submitting for and obtaining all required late-stage permits, ensuring all other required agreements are in place, and completing the detailed design of the project. The construction contractor is readied to initiate work and any long-lead time equipment is selected and ordered as required.

It is important to note that the implementation method of the Design & Pre-Construction phase is highly dependent on the selected construction contracting method. At the end of Phase 6, estimates will produce a Class 1 (+15%/-5%) cost estimate.

6.8 Phase 7: Construction (3-4 years)

The Construction phase covers the project's construction. Additional tasks also fall into this phase, including the training and employment commitments made under any Impact Benefits Agreements and the execution of the environmental management plan. Lending agreements and relationships continue to be managed throughout the construction process.

6.9 Phase 8: Commissioning & Operations (Ongoing)

The purpose of this phase is to commission the project and commence operation of the generating facility. Aside from the commissioning process, "as built" drawings are issued for the purpose of future maintenance. In addition, permanent structures are set up for debt financing and other financial processes (accounting, etc.). The Operational Environmental Management Plan is implemented and executed for the remainder of the plant operation.