SaskPower – Saskatchewan

Preliminary Siting of a Nuclear Power Plant

Stantec

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1. EXECUTIVE SUMMARY

SaskPower requested the assistance of Stantec Consulting Ltd. (Stantec) in examining potential candidate sites for a nuclear power plant within two regions – one around Lake Diefenbaker and the second near Lac La Loche. SaskPower requested that Stantec include the following in the evaluation:

- Identify three candidate sites in each of the two regions.
- Assess the candidate sites using environmental and cost factors and identify a preferred site for each region.
- Consider the site criteria established by Atomic Energy Canada Ltd. (AECL).

The assignment includes three phases:

I. Regional Analysis – The objective of this phase was to identify potential candidate sites for the two regions using readily available data.

II. Screening Criteria and Data Collection – The objective of this phase was to develop a simple comparison methodology for the screening of candidate sites.

III. Screening of Sites – Based on the screening criteria identified in Phase 2, the candidate sites for each region are compared and ranked to obtain a preferred candidate site for each region.

Based upon our review of the two regions, using constraint mapping, we identified three candidate areas for the Lake Diefenbaker region and two candidate areas for the Lac La Loche region. Sites in the Lake Diefenbaker region were chosen primarily due to several desirable attributes, including:

- Located on relatively level plains.
- Proximity to the deeper portion of the lake.
- Relatively low population densities in the local rural municipalities.
- Minimal conflict with other land uses, including parks, cottage subdivisions, protected areas, and the Reservoir Development Area boundaries.
- Avoids the more rugged and potentially unstable valley slopes more characteristic of the western portion of the lake.
- Relatively close proximity to existing highways.

Sites in the Lac La Loche region were chosen for similar reasons

Using standard criteria and weighting as part of an evaluation matrix, all five sites in both regions were evaluated. All the sites in the Lake Diefenbaker Region scored higher (better) than the Lac La Loche sites. The two Lac La Loche sites were evaluated to be equal. Site #1 in the Lake Diefenbaker Region scored highest.

Lake Diefenbaker Site # 1 scored the highest of all alternatives for the following criteria:

- Terrestrial Ecological Impact - Location of New and Future Transmission Lines
- Aquatic Ecological Impact - Location of Additional Transmission Lines
- Aquatic Ecological Impact
- Accommodations for Employees
- Regional Amenities For Employees
- Transmission Systems - Distance related Power Losses
- Transmission Systems - Capital Cost

Lake Diefenbaker Site #1 also scored as high as any of the other alternatives for the following criteria:

- Meteorological Conditions
- Geotechnical
- Terrestrial Ecological Impact - Plant location
- Sensitivity to flooding
- Aboriginal Interests
- Archaeology and Heritage
- Radioactivity
- Public Health
- Cooling Water - Proximity to lake
- Cooling Water - Temperature
- Cost of Transportation Construction and Operations

Ironically, the remote location of the Lac La Loche region, compared to Lake Diefenbaker provide both positives and challenges, but the advantages are outweighed by the disadvantages including but not limited to:

- Lack of accommodations for employees
- Lack of regional amenities for employees
- Distance related power losses from transmission systems
- Additional capital costs for extending transmission systems
- Additional capital and operating costs for expanding transportation infrastructure

Recommendations

1. If SaskPower wishes to advance this project, future studies should be undertaken to confirm the suitability of the Lake Diefenbaker Region, specifically to assess the security of water supply due to competing uses upstream and potential climate change, and the competing demands for water downstream.
2. If the above issues are resolved to the satisfaction of all relevant authorities, then further study is required to select the specific property in the Lake Diefenbaker Region for siting the plant.

2. INTRODUCTION AND STUDY REQUIREMENTS

2.1. INTRODUCTION

Saskatchewan Power Corporation (SaskPower) is a crown owned, vertically integrated utility having primary responsibility for generation, transmission and distribution of electricity within the Province of Saskatchewan. SaskPower's aggregate generating capacity is 3,655 megawatts (MW), which includes 3,206 MW capacity of SaskPower's own facilities – three coal-fired stations, seven hydro stations, four natural gas stations, and two wind generation facilities. In addition, they have long-term power purchase agreements with various cogeneration and wind power projects in the province. SaskPower also maintains 154,269 km of power lines (12,159 km transmission and 142,110 km distribution).

SaskPower operates primarily under the mandate and authority of The Power Corporation Act, which grants SaskPower the exclusive franchise and the exclusive obligation to supply, transmit and distribute electricity, as well as provide service to customers. In meeting this mandate, SaskPower explores many options for providing power to their customers. For example, they are actively involved in green power initiatives, are negotiating power purchase agreement with other producers, and have recently announced a potential site for the Clean Coal Project. Should the Clean Coal Project proceed, SaskPower will be owning and operating an advanced clean coal unit that will be the first of its kind in a utility scale application in the world.

Nuclear power is a source of energy currently being explored by SaskPower for potential future development. The potential development of a nuclear power plant within Saskatchewan is still very much at a conceptual stage. However, to further examine the nuclear option, SaskPower requested the assistance of Stantec Consulting Ltd. (Stantec) in examining potential candidate sites for a nuclear power plant (i.e., a preliminary siting evaluation). The requirements of the study are described in the following section.

2.2. STUDY REQUIREMENTS

SaskPower requested consulting services to conduct a preliminary screening and site selection for a nuclear power plant in Saskatchewan. Two regions were identified – one around Lake Diefenbaker and the second near Lac La Loche.

Potentially, the Lake Diefenbaker region could be the site of a CANDU 6 plant configured with two steam turbine generators instead of the standard 750MW single steam turbine unit. Plant output from this option would be split equally between Saskatchewan and Alberta.

The Lac La Loche region could be the site of a cogeneration plant producing electricity for Saskatchewan and steam for **potential** oil sands development in the region. There is currently no oil sands development in the region, and the study did not address proximity to end-point use of the steam in the Lac La Loche region or in North-east Alberta. For the purpose of this study the assumption is that the electrical output would be half of the nominal output of a CANDU 6.

SaskPower requested that Stantec generally include the following in the evaluation:

- Identify three candidate sites in each of the two regions.
- Assess the candidate sites using environmental and cost factors and identify a preferred site for each region.
- Consider the site criteria established by Atomic Energy Canada Ltd. (AECL). These criteria include topics such as cooling water requirements, exclusion zone, seismology, transmission systems, meteorological conditions, and geotechnical conditions.

The assignment includes three phases:

Phase I – Regional Analysis

The objective of this phase was to identify potential candidate sites for the two regions using readily available data. Various criteria were used to identify the areas having constraints and/or opportunities for nuclear plant development.

Phase II – Screening Criteria and Data Collection

The objective of this phase was to develop a simple comparison methodology for the screening of candidate sites. The screening criteria identified should consider environmental concerns, technical feasibility, and costs.

Phase III – Screening of Sites

Based on the screening criteria identified in Phase 2, the candidate sites for each region are compared and ranked to obtain a preferred candidate site for each region.

The following sections provide the results of this study. Section 3 describes Phase I; Section 4 describes Phase II, and Section 5 provides the results of the Phase III site screening.

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3. PHASE I – REGIONAL ANALYSIS

Phase I focused on two regions initially identified by SaskPower as having potential for the location of a nuclear power facility. The two regions, one near Lake Diefenbaker and the one near Lac La Loche, were sufficiently large in size that a power plant could potentially be located at some site within a rather large geographic area (Figure 1). The objective of this phase was to examine these two large areas and identify possible development constraints and/or opportunities. Three potential candidate sites for each region were to be identified through this process. The candidate sites would then be subject to a more detailed comparison within Phase II of this study.

The following sections provide an overview of the methods and assumptions used in this Phase, as well as a description of the two regions and the criteria used in identifying the candidate sites. The discussion will also explain why three candidate sites were chosen for the Lake Diefenbaker region and two were chosen for the Lac La Loche region.

3.1. METHODOLOGY AND ASSUMPTIONS

The Phase I Regional Analysis was completed using existing, readily available information. Information used included:

- Ecoregion maps and descriptions[1]
- National Topographic System 1:250,000 and 1:50,000 map sheets. (digital 1:250,000 map sheets were purchased and used a basemap for many of the maps produced in this report).
- Climate information obtained from Environment Canada
- Regional population data (towns, villages, Rural Municipalities) obtained from the 2001 Census of Canada website
- Surficial and bedrock geology digital files obtained from Geological Atlas of Saskatchewan (www.ir.gov.sk).
- The Atlas of Saskatchewan[2]
- General information on Lake Diefenbaker and the South Saskatchewan River Project, obtained from the Saskatchewan Watershed Authority website.
- Transmission line and generating facilities map provided by SaskPower.

Information from these sources was compiled in an ArcGIS database and relevant information was output as a series of maps (Figures 1 to 10). Subsequently, the candidate sites were selected for each region and illustrated on Figures 11 and 12.

The regional evaluation depended upon a few assumptions. These were:

- The IAEA (International Atomic Energy Agency) Site Evaluation for Nuclear Installations (IAEA Safety Standards Series, No. NS-R-S) would serve as a framework for determining the screening criteria used in Phase I.
- Detailed bathymetry was not readily available and some general assumptions on lake depth were made. Based upon a review of existing information it is assumed that the

[1] Acton, D.F., G.A. Padbury & C.T. Stushnoff. 1998. The Ecoregions of Saskatchewan. Saskatchewan Environment and Resource Management and Canadian Plains Research Centre. Regina.
[2] Fung, Ka-lu (editor). 1999. Atlas of Saskatchewan. University of Saskatchewan. Saskatoon.

deeper portion of Lake Diefenbaker is toward the east and near the Gardiner Dam. Lac La Loche, if similar to nearby lakes (e.g., Peter Pond Lake), is a large, but relatively shallow lake.

- SaskPower will commission detailed, site-specific studies (e.g., Geotechnical, environmental, socio-economic, etc.) prior to finalizing the power plant location.

3.2. DEFINITION OF LAKE DIEFENBAKER REGION

The Lake Diefenbaker region within the agricultural landscape of southern Saskatchewan differs markedly from the forested environment of the Lac La Loche region. For the purposes of this study, regional boundaries were arbitrarily chosen to include the lakes, and are illustrated on Figure 1.

Lake Diefenbaker is a reservoir that was created by the construction of the Gardiner Dam on the South Saskatchewan River. This dam controls water flow on the South Saskatchewan River and is owned and operated by the Saskatchewan Watershed Authority. Another, smaller dam controls water flow through an interbasin transfer to the Qu'Appelle River system to the south. The large reservoir provides water for hydroelectric power generation, irrigation, and recreation. The reservoir is also important to downstream users such as the City of Saskatoon, which obtains their water supply from this lake. There are also three provincial parks, several regional parks, and cottage subdivisions along the shore or in close proximity to the lakeshore.

The lake straddles two ecoregions. The Moist Mixed Grassland ecoregion is located on the eastern edge of the study area and includes both arms of the reservoir. The remainder of the lake to the west lies in the Mixed Grassland ecoregion.

Moist Mixed Grassland[3]

This ecoregion marks the northern extension of open grassland in the province, and is closely correlated with semi-arid moisture conditions and dark brown soils. Most landscapes are comprised of glacial till, and have short, steep slopes and numerous undrained depressions or sloughs, although several large, level glacial lake plains also occur. Native vegetation is confined largely to non-arable pasturelands, where speargrasses and wheatgrasses, along with deciduous shrubs such as snowberry, rose, chokecherry, and wolf willow are among the more common species.

Small aspen groves are typically found around sloughs and are a characteristic feature of the landscape, particularly as compared to the drier Mixed Grassland ecoregion, which is largely treeless. The prairie potholes or sloughs, although less common than in the Aspen Parkland, provide a valuable habitat for waterfowl. Mule deer and white-tailed deer are conspicuous wildlife species. Other notable species include coyote, red fox, badger, Richardson's ground squirrel and jackrabbit.

The western meadowlark, eastern kingbird, yellow-headed blackbird, piping plover, sharp-tailed grouse and Franklin's gull are typical birds. Agriculture is by far the dominant land use, with cereals being the main crop. Feed grains, forage crops and oilseeds are also grown, but to a lesser extent than in the Aspen Parkland.

Mixed Grassland

This ecoregion represents the driest area of the province as evidenced by the absence of native trees and scarcity of wetlands and permanent water bodies. Its diverse landscapes

[3] The ecoregion descriptions for both the Lake Diefenbaker and Lac La Loche regions were obtained from the Saskatchewan Conservation Data Centre website (www.sk.biodiversity.ca)

include level, glacial lake plains; dune-covered, sandhill areas; the hilly, pothole country along the Missouri Coteau; and the rolling expanses of native grassland and intermittent "badlands" near the United States border. The native grasslands are characterized mainly by wheatgrasses and speargrasses and, to a lesser extent, by blue grama grass which gains prominence on extremely droughty soils or under high grazing pressure. Shrub communities composed of snowberry and wolf willow are found in areas of favourable soil moisture.

Aspen, which is characteristic in and around moist depressions in the Moist Mixed Grassland ecoregion, is generally absent here except in valley bottoms and sandhill areas. About half of the area is cultivated, with the remainder used for extensive grazing of livestock on native or introduced grasses. Cereals are the main crop on cultivated land, although feed grains, forages and oilseeds are also grown.

Pronghorn antelope, white-tailed and mule deer, coyote, jack rabbit, Richardson's ground squirrel, horned lizard, prairie rattlesnake and western painted turtle are typical of the region. The only Canadian population of black-tailed prairie dog is found here. Characteristic birds include ferruginous hawk, long-billed curlew, yellow-breasted chat, chestnut-collared longspur, burrowing owl and sage grouse.

Both ecoregions have little natural areas remaining due to the long history of agricultural use. The Matador Grasslands, located near the western end of Lake Diefenbaker, is an important natural area that has received provincial protection.

3.3. DEFINITION OF LAC LA LOCHE REGION

Lac La Loche is located within the Mid Boreal Upland ecoregion of the Boreal Plain Ecozone.

Mid Boreal Upland

This ecoregion includes the area in central and western Saskatchewan immediately south of the Shield, as well as several prominent upland areas known locally as the Thickwood, Pasquia and Porcupine Hills. Typically, the upland areas are characterized by an ascending sequence of steeply sloping, eroded escarpments, hilly glacial till plains and level plateau-like tops. The intervening areas are comparatively level, with large, sparsely treed peatlands being common.

Most of the ecoregion is characterized by loamy, gray soils, although near the Shield the soils are sandy and often poorly drained. The forests grow taller here than on the Shield and account for the bulk of the province's merchantable timber. Aspen occurs throughout the ecoregion and is dominant on the south-facing slopes of the major uplands. Where moisture conditions are favourable, white spruce is often mixed with aspen. Jack pine, in addition to its usual dominance in sandy areas, is found mixed with black spruce on the plateau-like tops of the uplands. Black spruce and tamarack dominate the low-lying peatland areas.

Wildlife populations are high and diverse with moose, woodland caribou, mule deer, white-tailed deer, elk, black bear, timber wolf and beaver being the most prominent. White-throated sparrow, American redstart, ovenbird, hermit thrush and bufflehead are typical birds. Fish populations include northern pike, walleye, whitefish, some perch and scattered populations of lake trout.

La Loche lies within the Garson Lake Plain of this ecoregion, which is a relatively level plain draining toward Peter Pond Lake. A mosaic of peatlands and intermittent upland areas characterizes the low-lying, rolling landscape. The peatlands are relatively shallow and often densely treed with black spruce and tamarack being dominant.

The Clearwater River Provincial Wilderness Park is located within the ecoregion and protects a portion of the Clearwater River valley.

3.4. REGIONAL COMPARISON

3.4.1. Evaluation Topics

The Phase I evaluation examined the two study regions using a variety of screening criteria that were based upon a review of the IAEA (International Atomic Energy Agency) Site Evaluation for Nuclear Installations (IAEA Safety Standards Series, No. NS-R-S), information, identified in the SaskPower Terms of Reference, and our study team's experience with nuclear facilities in Ontario. The Phase I evaluation topics or screening criteria are identified and briefly discussed in Table 3-1.

Table 3-1. Phase I Evaluation Topics

Evaluation Topic	Discussion
Ecological Character	Characteristics of the natural environment that may be affected by potential radiological impacts in operational states and accident conditions should be investigated. They should also be observed and monitored through the lifetime of the installation.
Earthquakes and surface faulting	Earthquakes and surface faulting events are potential hazards that could disrupt the operation of the proposed facility and must be considered.
Surficial geology	Surficial geology will influence site stability, site drainage, and the related issues of site flooding, slumping, etc.
Climate and Meteorological Events (Refer to Table 3.2)	Climate and meteorological conditions are important to consider, particularly extreme events such as tornadoes, fog, blowing snow, thunderstorms, etc. Extreme weather conditions have the potential to affect plant operations. Poor weather conditions may also affect traffic to and from the site.
Population	Population density near the power plant is important, particularly in the event of a severe accident. The general principle is to site the facility in a sparsely populated area that is far from large population centres. Some international guidelines suggest that no other land uses occur within 1 km of the plant site. A protective zone that extends perhaps 5 km also surrounds the plant site, and within this zone are land use restrictions. An emergency planning zone extends for up to 20 km from the plant site. Detailed rescue plans would be made available for this zone. For Phase I, a 5 km planning buffer around the villages, towns, and resort villages near the lakes was used. Additionally, rural municipal population densities were mapped. Some communities have no buffer. These are old communities whose populations are no longer identified individually, but are incorporated within the local rural municipality.

Evaluation Topic	Discussion
Proximity to Lake and deep water	The power generation process will require water, which also requires cooling. Depending upon the process, the cooling may be done by using cooling towers, or by cycling the water back into the lake. Each method has its own set of environmental issues. Cooling towers, for example, could deplete the lake of water, as well as produce excessive ice fog during winter months, which could then produce safety hazards on nearby transportation routes. Recycling water back into the lake has the potential to alter the aquatic habitat and water temperature distributions within the lake.
Transportation	Transportation is required to move extremely heavy materials (e.g., boilers, construction materials, etc.) to the site. Also, waste materials (spent fuel) will need to be transported off-site once operation begins. Individual loads coming and going may exceed 80 tonnes and a high quality transportation infrastructure is required. Also, nearby highways may be prone to icing and fogging from cooling towers.
Land Use Issues	Relationships with other land uses must be considered in siting the power plant.
Regional Amenities	Nuclear power plant operators will be highly trained, have high wages, and likely will expect high quality regional amenities.

Climate and meteorological events are considered important location criteria. Table 3-2 provides a comparison of these characteristics for the two regions.

Table 3-2. Climate and Meteorological Information

Criteria	Lake Diefenbaker Area	La Loche Area
Climate region	Subhumid continental to the east and Steppe or semiarid to the west	Subarctic
General Climate characteristics	The subhumid continental climate has a mean annual daily temperature of 2.4 °C, a mean July temperature of 18.4 °C, and a mean January temperature of –16.7 °C. Mean annual precipitation is approximately 380 mm, with 240 mm of rainfall occurring from May to September. Summers are short and warm, with a frost-free period of 110 days. The semiarid climate characteristic of the more western portion of the region has a mean annual temperature of 4.0 °C, a mean July temperature of 18.9 °C, and a mean January temperature of –12.6 °C. Mean annul precipitation is approximately 350 mm, with 219 mm of rainfall from May to September. Summers are short and warm, with a frost-free period of 112 days.	Mean annual daily temperature is 0.3°C. Mean July temperatures are 16.3 °C and mean January temperature is –18.9 °C. Mean annual precipitation is 450 mm, with 290 mm of rainfall occurring from May to September. Summers are short and cool with a frost-free period of 91 days.
Permafrost	None	Lies within the sporadic, discontinuous zone

Criteria	Lake Diefenbaker Area		La Loche Area	
Snowfall (cm/yr)	80-100		120-140	
Winds (average speed (kph) and prevailing direction)	Dec-Feb	14-20, W	Dec-Feb	10-12, NW
	Mar-May	16-20, S	Mar-May	12-14, ESE
	Jun-Aug	14-18, W & NW	Jun-Aug	10-12, W
	Sep-Nov	16-18, NW	Sep-Nov	12-14, NW
Weather Hazards (mean annual # of days)	Fog	25-30	Fog	20-25
	Blowing snow	20-30	Blowing snow	10
	Freezing rain	6-10	Freezing rain	6-8
	Thunderstorms	20-25	Thunderstorms	15-20
	Hail	2-3	Hail	2-3
	Tornadoes	1-3	Tornadoes	0-1

3.4.2. The Lake Diefenbaker Region

Table 3-3 provides a discussion of the Lake Diefenbaker Region using the topics identified above.

Table 3-3. Lake Diefenbaker Region – A General Evaluation

Evaluation Topic	Lake Diefenbaker Region
Ecological Character	The region lies within a highly modified agricultural landscape. However, there remain several areas having significant ecological qualities. Some of these locations include the sandhills of Douglas Provincial Park, and the protected grasslands near Matador.
Earthquakes and Surface Faulting	Lake Diefenbaker lies within the Phanerozoic Basin and the underlying bedrock is the Bearpaw formation from the Upper Cretaceous. With the exception of a small "Southern Saskatchewan Source Zone", which is located along the Saskatchewan/Montana/North Dakota border, Saskatchewan lies in the lowest earthquake risk category, where seismic ground acceleration, if any, should be less than 4 percent of gravity (i.e., Zone 0) (Fung et al 1999). The Southern Saskatchewan Source Zone is located more than 200 km southeast of Lake Diefenbaker and falls within Zone 1, where seismic ground acceleration should be less than 8 percent of gravity.
Surficial Geology	Lake Diefenbaker is surrounded by a glaciolacustrine plain, hummocky moraine, and flat to undulating ground moraine. The river valley varies from relatively gentle slopes (eastern side) to steep, unstable slopes (e.g., toward the western end). The uplands beyond the valley are often relatively flat, stable, not subject to flooding or reservoir level fluctuations, and may provide good opportunities for site development. The more western portion of Lake Diefenbaker has steep, unstable slopes that may prevent building development in close proximity to the lake. A Reservoir Development Area has been placed along the shoreline and building development is restricted within this variable width zone. In some areas the zone extends for several kilometers.

Evaluation Topic	Lake Diefenbaker Region
Climate and Meteorological Events	Refer to Table 3-2, which provides a climate summary. Global climate change may become an issue in the future. For example, Lake Diefenbaker depends upon spring runoff from the mountains. Should that decrease in the future, the lake may have difficulty reaching full supply level.
Population	The Lake Diefenbaker area has many communities with small populations. Rural municipal population densities are low (often only 1 person per 0.3 km) and no major urban centres are nearby.
Proximity to Lake and deep water	The east end of Lake Diefenbaker is relatively deep and near the Gardiner Dam and Coteau Creek Hydroelectric Station, depths are near 58 m at Full Supply Level (FSL). Close proximity to the reservoir is possible in some locations, although the shoreline, particularly to the west, can be steep and unstable. A Reservoir Development Area of variable width is in place around the lake and does have some restrictions on building development. The lake is a multipurpose reservoir used for hydroelectric power generation, four major irrigation projects, and provides domestic water for approximately 40% of Saskatchewan (includes water drawn from the South Saskatchewan River downstream of the reservoir). The Saskatchewan Watershed Authority owns and operates the South Saskatchewan River Project and is directly responsible for its operation and maintenance. Flow in the river downstream of the dam is not allowed to drop below 42.5 m3/s. The lake's operating range from lowest flow to FSL is 11 m. Detailed studies would be required to determine if a nuclear facility could operate within the constraints of the South Saskatchewan River Project.
Transportation	Lake Diefenbaker has several highways in the vicinity, although only Highways 4, 42 and 19 come near or to the lake.
Land Use Issues	Lake Diefenbaker is surrounded by agricultural lands (crops, grazing) and has numerous recreation sites (provincial parks, regional parks, cottage subdivisions) along its shore. Lake Diefenbaker has land use restrictions within the "Reservoir Development Area", a variable width zone that borders much of the shoreline. Some portions of the shoreline are steep, unstable, and subject to slumping. This is particularly noticeable along the western end of the lake. The RDA poses some constraint to development in these areas. The agricultural land use will likely have no influence on the potential plant development and operation. The recreational areas, however, may be a potential constraint as these locations have campsites and the locations could be difficult to evacuate should that be required during an emergency event.
Regional Amenities	The Lake Diefenbaker area is within a reasonable driving distance of the cities of Saskatoon, Regina, Moose Jaw, and Swift Current. Saskatoon and Regina, in particular, provide a full range of goods and services and have populations greater than 200,000.