Needs For and Alternatives To

APPENDIX 9.2

Description of SPLASH Model

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Description of SPLASH Model

Overview of SPLASH Model

The Simulation Program for Long-term Analysis of System Hydraulics (SPLASH) is a computer-based generation system simulation model developed by Manitoba Hydro to support the long-term resource planning process. SPLASH simulates system operational, revenue and cost impacts of changes to generating resources, interconnections, energy contracts or key input assumptions such as reservoir operating limits or export prices.

The SPLASH model determines the cost of system operation (production cost) on a monthly basis for a series of years into the future. The production cost is derived from the variable cost characteristics of the various generation sources and revenue is derived from surplus (opportunity) export sales. A simulation of system operation is undertaken for each of the 99 streamflow conditions between the years 1912 and 2010 in order to cover the range of possible flow conditions that may occur in the future. These factors combine to create a significant amount of complexity that must be accounted for in the simulation modeling tool.

Expected flow-related energy production costs and forecasted net flow-related revenues are required inputs to key Corporate processes such as resource planning and preparation of the Integrated Financial Forecast. Other capabilities of the SPLASH model include the evaluation of power sales contracts and the determination of the extent to which water levels and flows could be impacted by changes in Manitoba Hydro's integrated system or by revisions to operational limits or constraints.

The key simulation model outputs include: energy production (dependable and opportunity), future operating costs, operating revenues, and water levels and flows at key locations in the Manitoba Hydro system. The SPLASH model outputs facilitate economic and financial analyses and comparison of power resource development plans under consideration.

Model Capabilities

The SPLASH model has the capability of representing the physical characteristics of the hydraulic, thermal and transmission systems, the constraints imposed on the physical system by licenses and agreements, and the practical operating limits. The model also defines the extra-provincial opportunity export sales and import purchases, through a user-defined pricing structure, and the costs associated with energy generation (thermal fuel costs and water rental rates). This integrated system within the SPLASH model enables a detailed production costing estimate by incorporating the use of a linear programming optimization methodology where the primary objective is to maximize net flow related revenues.

Since Manitoba Hydro generates the majority of its power supply from hydraulic resources, the variations in hydrologic conditions play a significant role in system expansion evaluations (the need for new resources is driven by low flows and the average net flow related revenues are affected by the overall variability in flow). The model has the capability of representing this variation by utilizing a long term record of historical monthly inflows that have been modified to represent present day regulation. Each of the 99 flow years in the long term record is chronologically cycled through the simulation period such that the full range of streamflow conditions are evaluated in every load year in to the future (35 year planning horizon).

The simulation period is not modeled as a single continuous entity, but rather it is modeled in smaller time increments called ‘windows’. ‘Windows’ are generally of one year duration and are further broken down into monthly ‘time-steps’. The SPLASH model simulates the operation of the system for each of these time steps.

Each monthly ‘time-step’ is subdivided to represent periods used for energy consumption. The SPLASH model utilizes two periods to represent the Manitoba load shape (on-peak and off-peak strips representing the respective proportion of hours in each time step). The value of energy within each strip must be defined in order to optimize the system energy allocation throughout each load year.

Representation of the Manitoba Hydro System

The simulation of operation of the Manitoba Hydro system requires modeling of firm energy demand, firm energy supply, and opportunity market transactions, all of which include transmission losses and are subject to physical and licensing constraints. The objective is to maximize net flow related revenues over the range of streamflow conditions.

The following sections will briefly describe how each part of the components are defined and modeled within the SPLASH environment.

<u>Firm Energy Demand</u>

Domestic Load

The domestic load forecast for the 35-year planning horizon is input into SPLASH as monthly energy gigawatt-hour requirements for the system. Each monthly time step is separated into an on-peak and off-peak period during which energy requirements must be met. Additional load requirements such as construction power (required during the construction of new resources and/or system components) and load reductions such as Demand Side Management are also input to form the Net Manitoba load.

Export Energy Demand

The SPLASH model has the ability to simulate firm export transactions. Firm export energy is similar to domestic load since contractual obligations require that specific quantities of energy must be supplied during a specific time period. The quantity of contractual firm energy for on-peak and off-peak periods for each month is provided as input to the model. This export energy requirement is combined with net Manitoba load to obtain a total firm energy requirement for each on-peak and off-peak period. The simulation ensures that sufficient energy is available to meet the total firm energy requirement in each time period under all flow conditions including the lowest historic water supply conditions.

Firm Energy Supply

Hydro Generation

The SPLASH model defines the hydraulic network through a configuration of reservoirs, rivers and hydro-electric generation sources. The model is extremely flexible in being able to represent the hydraulic network that is being modeled. Hydro-electric generating stations are defined using power versus discharge relationships based on forebay and tailrace rating curves for both open water and winter ice conditions. The power-discharge relationship considers turbine and generator efficiency as well as design parameters of the units. Maintenance and fixed forced outages are considered by reducing the number of units operating in specific months throughout the planning horizon.

Initial conditions and system constraints are used to specify license and operation ranges for reservoirs and river reaches, starting elevations of controlled reservoirs, specific flow sequences, and operating rules such as storage and outflow capabilities of both controlled and uncontrolled reservoirs. Water rental costs are also defined and used during production costing simulations.

The full range of streamflow conditions is represented by the input of the 99 year-long flow record at key locations in the hydraulic network. The inflow record is representative of current regulation patterns and upstream water uses and is comprised of regulated inflows from three major watersheds entering Manitoba; the Winnipeg River, the Saskatchewan River and the Churchill River. The remaining inflows are defined as local inflows at various locations in the network, the largest being the local inflow available for outflow from Lake Winnipeg. The firm hydro supply is the energy generated by hydraulic resources during the lowest recorded coincident water supply conditions as defined by Manitoba Hydro’s Generation Planning Criteria.

Non-Hydro Generation

The SPLASH model defines Manitoba Hydro's thermal generation supply by specifying the maximum and minimum output from each thermal station. The minimum output reflects the requirement to test and maintain units on an annual basis, while the maximum output considers planned maintenance, forced outages, and license restrictions. Fuel cost information is also defined and used during production costing simulations. In addition, carbon adders are incorporated including the existing carbon tax on coal from the *Climate Change and Emissions Reductions Act* and a forecast of future carbon adders for Manitoba-based generation (federal/provincial).

SPLASH simulates wind generation as a baseloaded non-dispatchable energy supply. The amount of energy is based on monthly capacity factors and is allocated proportionally between on-peak and off-peak strips. The cost attributed to the supply of wind energy is applied post simulation.

Import Energy

The SPLASH model has the ability to simulate firm import transactions. This import energy can be required to supply firm energy during critical low flow periods when Manitoba Hydro's generation capability is at a minimum, and can be reduced under higher flows if favorable. In general, firm imports are simulated such that transactions occur during the lowest price periods (off-peak) first, and are subject to the generation planning criteria as well as transmission and market limitations. A full description of existing import contracts is described in Chapter 5 of this NFAT submission.

Opportunity Market Transactions

The objective of a SPLASH simulation is to maximize the net flow related revenue across each of the historical streamflows for each window within the simulation period. SPLASH optimizes operations by balancing surplus (opportunity) energy available from hydro generation with the import/export capability of the system. Some combination of these two factors can be used to increase net flow related revenues by either displacing higher priced generation or shaping energy to increase energy exports in higher priced periods. The ability to optimize the operations is subject to transmission and market limitations.

The opportunity energy markets are represented by unit revenue (export) or cost (import) price-volume relationships for each monthly on-peak and off-peak strip in a simulation. As the volume of opportunity export energy sales increases, the ability to optimize the timing of additional export sales becomes constrained by either system capability or interconnection limits, resulting in incremental export energy being sold in lower priced periods. Similarily, as the volume of import energy increases the ability to optimize the timing of additional import transactions becomes constrained, resulting in incremental import energy being purchased in higher priced periods.