Exhibit B-52

BC Hydro Fiscal 2020 to Fiscal 2021 Revenue Requirements Application

BC HYDRO UNDERTAKING NO. 29

HEARING DATE: February 24, 2020

REQUESTOR: BCUC, Mr. Miller

TRANSCRIPT REFERENCE: Volume 10, Page 1787, line 19 to Page 1789, line 12

TRANSCRIPT EXCERPT:

MR. MILLER: Q So we're almost done, panel, a couple more topics to address and I'll be finished.

The next topic I'd like to address is the independence of the energy study process on audit. I'm going to be going back to the witness aids that were done on the addendum.

So if you can start on page 60 of the addendum, and this is a response to Commission panel IR 2.7.4. In the first paragraph of the response there's the statement:

"There has been no external review of the market model since 2016 although the recent internal audit performed on October 8th, 2018 included external reviewers from SINTEF."

S-I-N-T-E-F, do you see that?

MS. MATTHEWS: A Yes.

MR. MILLER: Q And on page 62 of the addendum, and this is a response to Panel IR 2.4.1, you've confirmed that the authors of the BC Hydro's Corridor 3 Fiscal 2019 Energy Study's process audit not identified as SINTEF employees are members of BC Hydro's audit team.

So is that correct?

MS. MATTHEWS: A That's correct.

MR. MILLER: Q No, can you explain the scope of work for the external reviewers from SINTEF that were involved in the audit? What were they asked to look at, to opine upon?

MS. MATTHEWS: A Well, the external reviewers are experts in -- I think they use the word "hydro-dynamic bonding" but essentially optimization models for hydroelectric systems, hydroelectric thermal systems and how they are dispatched. So that's, I believe, why they were asked to participate in this audit, because they had that expertise on Hydro system modelling essentially.

MR. MILLER: Q did the individuals from SINTEF provide a report to BC Hydro? Or is it just incorporated into the audit? Is there a specific report coming from SINTEF?

MS. MATTHEWS: A You know, I didn't see those in-between stages. I believe the answer is yes, but I'll say yes, subject to check.

MR. MILLER: Q Okay, so again, we'll take that subject to check and also if there is a copy of the report, could you please file it?

QUESTION:

If SINTEF completed a separate report to inform the Internal Audit of BC Hydro's Energy Studies process, please provide that report.

RESPONSE:

Attachment 1 to this response provides the working paper report that SINTEF prepared for the BC Hydro Internal Audit team for the Energy Studies Internal Audit.

The attachment is not an external assessment report. Rather, it is part of the Internal Audit Report working files. SINTEF's findings are incorporated into the official issued Energy Studies Internal Audit Report.

BC Hydro's Internal Audit team and the subject matter experts from SINTEF collectively reviewed the SINTEF report and determined which recommendations addressed the key findings identified in the Audit. These recommendations were taken to the final Internal Audit Report. This process is consistent with all audits where subject matter experts are involved.

All of SINTEF's 15 recommendations were included and consolidated in the official issued Energy Studies Internal Audit Report with the exception of one:

> **SINTEF 3.2 (Governance – Recommendations) - "Investigate the possibility for establishing defined performance metrics"**

The performance metrics recommendation was not carried forward to the Internal Audit Report because discussions between SINTEF and BC Hydro's Internal Audit team concluded that recommendations #5 (Key Model - benchmarking) and #10 (Validation and Backtesting) in the BC Hydro Internal Audit Report, addressed the performance metrics recommendation in the SINTEF Report.

The Internal Audit Report and its 14 recommendations was discussed, reviewed and approved by SINTEF.

SINTEF

2018-01289- Restricted

Report

BC Hydro Energy Studies Audit

Author(s)
Arild Helseth
Birger Mo

SINTEF

SINTEF Energi AS
SINTEF Energy Research AS
Address
Postboks 4761 Torgarden
NO 7465 Trondheim
NORWAY
Switchboard +47 73592000

Enterprise /VAT No
NO 939 350 675 MVA

Report

BC Hydro Energy Studies Audit

KEYWORDS:
Hydro

VERSION
1.0

DATE
2018-10-29

AUTHOR(S)
Arild Helseth
Birger Mo

CLIENT(S)
BC Hydro Audit Services

CLIENT'S REF.
Client's reference

PROJECT NO.
502002064

NUMBER OF PAGES/APPENDICES:
24 + Appendices

PREPARED BY Arild Helseth	SIGNATURE Arild Helseth
CHECKED BY Marte Fodstad	SIGNATURE Marte Fodstad
APPROVED BY Knut Samdal	SIGNATURE

REPORT NO.	ISBN	CLASSIFICATION	CLASSIFICATION THIS PAGE
2018 01289		Restricted	Restricted

SINTEF

Document history

VERSION	DATE	VERSION DESCRIPTION
0.1	2018-10-19	First version sent to BC Hydro
1	2018-10-29	Final version sent to BC Hydro

SINTEF

Table of contents

SINTEF

About SINTEF Energy Research

SINTEF Energy Research is an institute for applied research dedicated to create innovative energy solutions. We offer cutting-edge knowledge in Norway and internationally based on research that provides for our clients added-value solutions and services. SINTEF Energy Research is part of the SINTEF Group, which is one of Europe's largest independent contract research organisations. SINTEF is an independent, not-for-profit organisation. None of its owners receive any form of dividend. Profits are invested in scientific equipment, skills and expertise.

SINTEF Energy Research has more than 40 years of experience in developing models suitable for planning and operation of hydrothermal power systems. In such models, our expertise is specifically linked to the modelling of complex hydropower systems. Our models include all relevant physical parameters related to the generation and transmission system and are based on leading industry practices for stochastic dynamic programming and stochastic optimization. The SINTEF Energy Research suite of models are widely used by market players in the Nordic market, and SINTEF Energy Research carries out its R&D in consultation with the users of the models. This promotes a development process that is well suited to the needs of the market.

Subject Matter Expert #1 – Birger Mo
Birger Mo is a senior research scientist at the 'production planning' team within SINTEF Energy Research. He has been a research scientist at SINTEF Energy Research since 1987, working with load forecasting, risk management, hydro scheduling and hydrothermal market modelling. He obtained his MSc in 1986 and PhD in 1991 from the Norwegian University of Science and Technology, Department of Engineering Cybernetics. He participated in SINTEFs previous reviews and consulting work related the MCM model (1998) and Columbia modelling and coordination (1999 and 2008).

Subject Matter Expert #2 – Arild Helseth
Arild Helseth is a research scientist for the 'production planning' team within SINTEF Energy Research. He has been a research scientist at SINTEF Energy Research since 2008, working with research, development and analyses related to hydrothermal market models and medium-term hydropower scheduling models. He obtained his PhD from the Norwegian University of Science and Technology, Department of Electric Power Engineering, in 2008.

SINTEF

1 Executive Summary

BC Hydro Audit Services Group contacted SINTEF Energi AS (SINTEF) in June 2018 to participate in the Energy Studies (ES) Audit as a member of the Internal Audit team. The purpose of the audit was to provide an independent evaluation of the ES function and to determine if the System Optimization (SO) Team is meeting its objective to provide timely and reliable Energy Study results to support operational, financial, and strategic planning at BC Hydro (BCH).

As specified by Audit Services in the Terms of Reference, the audit focused on three broad areas:

- Governance
- Energy Studies Process
- Outputs & Reporting

SINTEF reviewed ES documents and reports and conducted client interviews in Vancouver together with the BCH audit team of key BCH management and staff during the audit process to acquire an understanding of the current ES procedures and methodologies, the level of management oversight, staff expertise and resources, and the energy studies outputs provided to various other groups within BCH. In addition to the interviews, SINTEF relied upon available industry benchmarks and planning guidelines of the British Columbia Utilities Commission (BCUC). SINTEF reviewed numerous documents and files provided prior to and following the interviews to gain a better understanding of BCH's ES function and to identify its underlying strengths, risks, and areas of potential improvement.

1.1 Energy Studies

The SO Team is a part of the Operations Planning group within Generation System Operations at BCH.

The SO Team executes an Energy Study every month. The primary objective of the Energy Study is to forecast the optimal operation for the BCH system for a five-year time horizon. The optimal operation is found by maximizing the expected revenue from system operations while taking uncertainties in weather, market prices and demand into account. The BCH Energy Study process consists of a suite of proprietary models developed and maintained by the SO Team.

The Energy Studies primarily informs:

- Operational and trade decisions
- Consequence analysis
- Monthly financial forecast updates
- Cost of Energy

1.2 Key Findings

Governance

SINTEF finds that there are high level strategies and objectives in place to guide the SO Team. The key objective is to maximize risk neutral revenue from operations.

SINTEF

The high-level strategies also include using price signals[1] for operations and to develop and maintain in-house models. SINTEF believes the in-house development strategy is appropriate mainly because of the Columbia Treaty specialties.

There is no defined metrics in place to evaluate the results from the SO Team. However, this is expected because it is challenging to make good metrics for this type of stochastic[2] long-term planning problems with many uncertain variables.

There are clear responsibilities and accountabilities within the SO Team. There is an appropriate level of Board and Management oversight.

Energy Studies Process

In general SINTEF concludes that the models used in the ES process are reasonable and the methodologies applied are in line with leading industry practices. The ES models have undergone significant improvements through the COMET project, particularly improving on the optimization of the Columbia river.

The models are developed using standard development tools and programming languages. Version control keeps track of source code and input data is in line with industry practices.

SINTEF believes that several improvements in the ES process are possible and that some of them can bring significant added value to BCH:

- Improve the representation of US electricity prices to obtain more realistic water values.
- Automate the ES process to reduce the time it takes to complete the full study, and thus provide users with more updated information.
- Benchmark the models against historical operation and with other models to gain insight in model performance and point to possible and valuable improvements.
- Improve the model used to optimize the Peace River.

Outputs and reporting

The monthly ES reports are prepared on time and communicate well on a high-level.

Several client interviews indicate ES results do not provide sufficiently strong signals to the short-term operational planning, mainly because they are based on outdated information by the time the results are ready.

BCH uses a simpler and less optimal model to assist the ES models in providing signals to the short-term operational planning. Relying on the signals from simplified models will on average give less than optimal income from hydro production.

---

[1] Using price signals for operation mean using the calculated model water values as a decision signal for operation, i.e., produce more if the water value is below the market price and vice versa

[2] The problem is stochastic mainly because future inflows and external market prices in US and Alberta are unknown.

SINTEF

1.3 Recommendations

Governance

SINTEF recommends discussing possible performance metrics to evaluate the results from the SO Team. The succession matrix provides important oversight on competence and redundancy, but should be further improved to find a secondary owner for all models.

The Energy Studies approval policy is outdated and should be updated.

Energy Studies Process

SINTEF recommends automating the manual components of the Energy Study process to shorten the completion time and to free labour resources.

The Peace optimization model (MCM) needs to be updated or replaced. SINTEF recommends a replacement solution for this model.

The forecasted power prices for the different US markets are the most important factor for the BCH marginal prices and decisions on import/export and generation, however price inputs used in the ES models are only based on the Mid-C market. SINTEF recommends including California market prices (which also affect real operation), to improve on the models' ability in order to give optimal decision support and describe the real system.

SINTEF recommends benchmarking the Columbia River optimization models with results obtained by a second model.

Outputs and Reporting

Water values provided by the SO Team do not always serve the short-term operational needs. SINTEF recommends reviewing the use of ES results for short-term operational purposes.

The whole ES process takes too long time to complete. A shorter process would allow for more frequent results that are always based on the latest available information. SINTEF therefore recommends searching for bottlenecks and try to speed up the whole process. Parts of the process are most likely straightforward to automatize.

SINTEF recommends considering the use of a more robust medium-term operational model with a defined and strong coupling to the ES models.

SINTEF

2 Background

BCH operates hydropower from 2 large rivers, with two multi-year reservoirs (Williston on Peace River and Kinbasket on the Columbia River). The hydropower generation is coordinated with generation from independent power producers (IPPs), and from other energy sources to meet the demand within the region. Exchange with neighbouring power markets in Canada and the US are taken into account in the coordination. An illustration is provided in Figure 1.

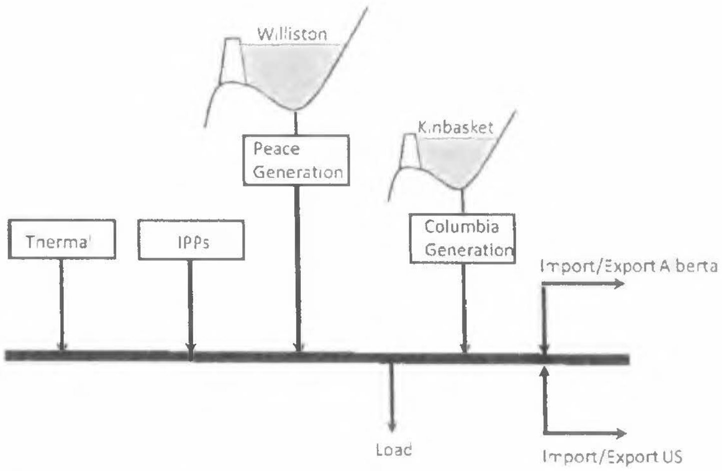

Figure 1 System illustration. Generation and exchange with external markets are balanced with the load.

The overall BCH objective for system coordination is to maximize risk neutral long-term net revenue from operations. To meet that objective, the water should be valuated to provide strategies for when to use and when to store water in the reservoirs. Without good strategies one will over time run into non-optimal systems states, where a) the reservoirs are full and cannot accommodate more inflow which will lead to spillage, or b) the reservoir levels are critically low, leading to activation of highly-priced peaking power plants or, in the worst case, to curtailment of demand.

Strategies can be found by applying some sort of mathematical model for hydro-thermal scheduling. We refer to these as *long-term hydrothermal scheduling models* in the following. Such models compute the marginal value of water for different points in the future, and these values serve as operational strategies. If the marginal value of water is above the market price at a given time stage, the best decision is to store water for generation at a later stage, and vice versa. BCH takes a risk-neutral approach to the hydrothermal scheduling, and thus the best strategy is to operate according to the expected marginal value of water (that we refer to as *water value*[3] in the following).

In order to compute accurate and robust water values the long-term scheduling models should reflect both

a) the dynamics and constraints that affect operation flexibility, and
b) the uncertainties that impact future reservoir operation (such as inflows and market prices).

[3] The term *basin price* has the same meaning.

SINTEF

2.1 Methodologies

Models and methodologies for long-term scheduling of hydropower-dominated systems have been widely used in the industry for the last 50 years. Countries such as Brazil, Canada, Norway, Sweden, New Zealand and Iceland all have rich traditions for using mathematical models for finding the long-term optimal use of water in their hydropower-dominated systems. There seems to be an international consensus on the applicability of stochastic dynamic programming or stochastic optimization for computing strategies in the form of water values. Applied methodologies come in different flavours, such as:

- Stochastic Dynamic Programming (SDP)
- Stochastic Dual Dynamic Programming (SDDP)
- Stochastic Sampling Dynamic Programming (SSDP)

These 3 methodologies are briefly explained below for completeness. As will be discussed later on, BCH models uses both SDP (MCM model for Peace River) and SSDP (MUREO model for Columbia River).

All three methods are based on decomposing a decision problem under uncertainty into stagewise subproblems, and recursively solving the Bellman equation for each stage in a backward iteration procedure. The main assumption for the Bellman equation is that optimal decisions for the future only depends on the current state of the system. The hydro optimization problem fits very well with this assumption where the most important state variables are the reservoir levels.

These three methodologies all have their strengths and weaknesses, and the best choice depends on the system at hand. The SDP method is the oldest and traditionally most applied. In this method the expected future profit as function of the state variables are calculated and stored for discrete values of the state variables. The need for discretizing state variables lead to the so called "curse of dimensionality" in SDP, meaning that the number of discrete states to be considered increases exponentially with the number of state variables.

The SSDP method was first introduced around 1990 and treats uncertainty differently than in the SDP method. In SSDP the future profit function is calculated for each specific scenario assuming that decisions are taken with respect to all possible future scenarios. SSDP is particularly well suited to deal with stochasticity represented by historical observations and scenario dependent constraints.

The SDDP was introduced in 1991 and is widely used for hydrothermal scheduling in many countries. The key benefit of the SDDP method compared to the SDP and SSDP methods is that the state variables do not need to be discretized, circumventing the "curse of dimensionality" and thus being applicable for systems with many state variables[4]. On the other hand, SDP and SSDP are more flexible in the representation of nonconvex functional relationships (such as head-dependent production functions and state-dependent environmental constraints).

2.2 Scheduling Model Hierarchy

The long-term hydrothermal scheduling models are normally part of a modelling hierarchy also comprising medium- and short-term scheduling models and the coupling between those, as illustrated in Figure 2. The long-term models typically emphasize on proper representation of uncertainties while keeping a rather coarse

[4] Reservoir levels and inflows are typically state variables.

level of technical detail. The medium-term models refine the level of technical detail covering a shorter time-horizon. Finally, the short-term models serve to further refine the level of technical detail for a short time-period subject to less uncertainty (often deterministic[5]), and their results are used for operational decision aid. Such model hierarchies are strongly incorporated in the system operation of the Brazilian system (a centrally planned system) and by the market players in the Nordic power market (a liberalized system)[6]. There are two main ways of coupling the models; volume and price coupling. A volume coupling involves letting the upstream model finding a target volume for the end of the downstream model horizon. A price coupling involves letting the upstream model find a value function for the stored water at the end of the downstream model horizon.

The ES models can be characterized as long-term models. The Ultralight model commented on in 5.3 can be seen as a medium-term model. SINTEF sees the overall approach as reasonable, but it seems to us that signals from the ES models to Ultralight are too weak and that the properties of the medium-term model can be improved.

Figure 2 Scheduling model hierarchy.

[5] Deterministic means that all uncertainty is assumed known for the whole planning period.
[6] Liberalized means competition between suppliers of electricity to reduce the price.

3 Governance

The review of the ES function with respect to governance focused on the defined strategies and objectives, roles and responsibilities, corporate structure and oversight.

3.1 Conclusions

- High level strategies and objectives are in place to guide ES group.
- Clear responsibilities and accountabilities within ES group.
- Appropriate level of Board and Management oversight.
- No defined performance metrics in place for the ES group due to multiple variable outcomes and technical difficulties in implementing such metrics.
- Not all models have identified secondary owner.
- Outdated Energy Studies approval policy.

3.2 Recommendations

- Investigate the possibility for establishing defined performance metrics.
- Continue working on succession matrix to find a secondary owner for COSTA and CODA models.
- Update outdated Energy Studies approval policy.

3.3 Summary of Findings

3.3.1 Strategies and Objectives

BCH has decided to develop and maintain in-house models for the purpose of long-term hydrothermal scheduling. These models are built to reflect the defined key objective for system operation, namely to maximize risk neutral long-term net revenue.

An annual GSO Business Plan identifies objectives, metrics, and major activities for all the groups within GSO. At the activity level, GSO has monthly Action Plan Tracker to track monthly progress on specific action items, including ES.

There are no defined performance metrics in place for the ES group. This is as expected because such metrics are very difficult to design and implement due to the many uncertain variables that are included in the planning problem. However, SINTEF recommends investigating the possibility for establishing defined performance metrics. Relevant input and output data from the ES studies has been stored since 2009, opening the possibility for detailed benchmarking[7] of the process.

---

[7] Benchmarking could in this context mean to compare model results with observation for a historic period.

3.3.2 Roles and Responsibilities

There are clearly defined responsibilities and accountabilities within ES. The team roles and responsibilities are clear and well understood within the team. Two team members rotate each month to run the Energy Studies, while the other two members are tasked with model development, ad-hoc enquires and other team priorities.

There is a clear management structure in place. The management and reporting structure is clearly laid out in the GSO organization chart.

The SO Team is adequately resourced, comprising engineers with a background in various disciplines such as system design, hydro-technical, and water resources. There is adequate succession planning in place, as formally documented in the GSO Succession Matrix. Each ES model (some 85 models/routines are defined in total) has identified a primary and a secondary owner. There are exceptions for the models COSTA and CODA, which only has a primary owner.

3.3.3 Oversight

The level of board and management oversight is appropriate.

There is quarterly reporting to the Operations & Planning Committee of the Board on Energy Studies results.

Each month, there is a formal session to report and discuss the monthly Energy Studies Results with key user groups within BCH and Powerex. The monthly Energy Studies are reported to Executive VP Operations and Director of GSO.

Weekly meetings are held with GSO Management to discuss the ES results and related variances.

There is an ES approval policy defining approval levels for domestic buy/sell prices when there is a threshold change from the last approved price. This policy, however needs to be reviewed and updated as it was last edited in March 2011, and some of the policy details are outdated (titles, positions, etc).

SINTEF

4 Energy Studies Process

Review of the ES methodologies provided insight into the existing model suite, the applied modelling techniques, input and output data, and assumptions. SINTEF reviews emphasized on four key models:

- Market model
- Columbia River optimization (MUREO)
- Peace River optimization (MCM)
- System simulator (SOPHOS)

4.1 Conclusions

- The BCH system needs tailor-made scheduling solutions, which BCH prefer to develop in-house. In general SINTEF concludes that the models used in the ES process are reasonable and the methodologies applied are in line with leading industry practices. (Section 4.3.1)
- The inputs and assumptions used in the models are generally reasonable. (Section 4.3.3)
- The information flow between Powerex and ES does not facilitate optimal scheduling of the BCH system. (Section 4.3.3)
- There is no regular benchmarking of the ES results. (Section 4.3.4)
- The ES models has undergone significant improvements through the COMET project, particularly improving on the optimization of the Columbia river. (Section 4.3.7.2)
- The overall ES process takes too long time. Information is often outdated when provided to end-users. (Section 4.3.6)
- Version control keeping track of source code and input data is in line with industry practices. (Section 4.3.2 and 4.3.3)
- Models are developed using standard development tools and programming languages. (Section 4.3.2)
- Models are documented, comprising user and development documentation. A developer documentation of the MCM model is incomplete. (Section 4.3.2)
- The MCM model is based on legacy code and is described as less flexible. (Section 4.3.7.3)

4.2 Recommendations

- Automate the manual components of the ES process to shorten the completion time and to free labour resources. (Section 4.3.6)
- Finalize a replacement solution for the MCM Model. (Section 4.3.7.3)
- Include a state variable for snow in the optimization methodology used for the Peace River. (Section 4.3.7.3)
- Consider adding California pricing to obtain better water values. (Section 4.3.3)
- Consider periodically benchmarking models against historical system operation. (Section 4.3.4)
- Benchmark the Columbia River optimization models with results obtained by a second model. (Section 4.3.7.2)
- Improve the developer documentation for all models. (Section 4.3.2)
- Improve the high-level documentation for the MUREO and COSTA models. (Section 4.3.7.2)
- Consider basing parts of the SOPHOS simulator on optimization. (Section 4.3.7.4)

4.3 Summary of Findings

4.3.1 Overview

SINTEF concludes that significant recent improvements have been made to the ES models through the COMET project. The following key models were upgraded or developed through the COMET project:

- New Columbia River Treaty simulator (COSTA)
- New Columbia Operations Optimizer (MUREO)
- Upgrade to the Market Model (MARKET MODEL)
- New Daily System Simulator (SOPHOS)

COSTA is a simulation[8] model for the Columbia system designed to prove the following information:
- Future scenario-dependent constraints for the Columbia system
- Transition probabilities between scenarios for all future time periods

Results from COSTA are used in MUREO.

[8] A simulation model finds feasible operation of the real system by use of simulation techniques. Simulation models may use heuristic or optimization techniques to solve parts of the overall problem.

MUREO is the new optimization[9] model for the Columbia system. The main results from MUREO is an optimal strategy for operation of the major reservoirs in the Columbia system. The strategy is given by water values or production decisions for all future time periods as function of storage levels.

The purpose of the MARKET MODEL is to make scenarios for future prices in the external markets that BC sells to and to make a discrete Markov type statistical model that is consistent with the provided price scenarios. The Markov chain model is used in the optimization models (MUREO and MCM) and the price scenarios are used in the simulation model (SOPHOS).

SOPHOS is the simulation model that provides most of the results that are output from the SO Team in the monthly report.

The BCH modelling approach is briefly described below, and the key models' roles are indicated in Figure 3.

The models serve to optimize the long-term use of generation resources to serve load and trade with external power markets, while respecting all relevant system constraints. The optimization is done taking relevant uncertainties (such as inflow, market prices and demand) into account. This process is illustrated in Figure 3, where the names of the models reviewed are in purple. The system's generation capability comprises hydropower from the Peace and Columbia Rivers, independent power producers (IPP) and some thermal generation.

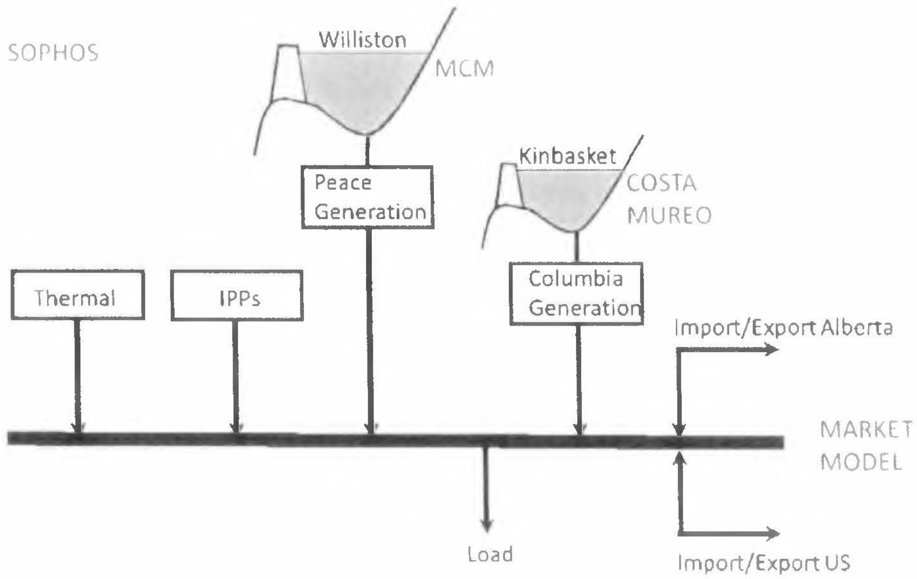

Figure 3 System illustration. Generation and exchange with external markets are balanced with the load. The BCH model names are given in purple.

[9] An optimization model is a mathematical model where the optimal decisions are found using optimization techniques, according to a defined objective and subject to a set of constraints.

A key challenge when planning the BCH system operation is to valuate the water in the large reservoirs to properly reflect the alternative costs. As mentioned in Section 2, the valuation translates to finding the water values. This is a complex task due to the long-term dynamics of the two large reservoirs, complicated constraints and the uncertainties in inflows, market prices and demand.

The two major river systems Columbia and Peace are optimized separately and coordinated based on updated residual demand profiles in an iterative manner. BC Hydro currently uses SDP for Peace and SSDP for Columbia. The existing coordination principle is reasonable.

One could optimize the two rivers in one model, and thus avoid the added complexity of maintaining and coordinating two models. However, a single unified model would challenge the "curse of dimensionality" in the dynamic programming algorithms that BCH hydro currently uses (SDP for Peace and SSDP for Columbia). SDDP could be used for this purpose, but there is no straightforward solution for including the state- and scenario-dependent constraints of the Columbia Treaty in the SDDP algorithm. Consequently, the current decoupling of the optimization of the Peace and Columbia Rivers seems reasonable.

4.3.2 Models Development

Models are developed using standard programming languages such as Java, Fortran, AMPL and SAS. The source codes are under version control. All ES models are inventoried identifying purpose, primary and secondary owner. According to the SO Team, the models are generally responsive to accommodate changes in the BCH system. The MCM model is based on legacy code and is described as less flexible, cf. the discussion in 4.3.7.3.

The models have been reviewed externally by various consultants over the last 20 years as a part of continuous improvement initiatives:

- 1998: SINTEF – Reviewed Marginal Cost Model (Peace)
- 1999: SINTEF – Columbia-Peace coordination
- 2005: Deloitte & Touche – Market Model
- 2008: SINTEF – Columbia LPCM Model
- 2009: NERA – Developed estimates of Long-Term Marginal Costs
- 2013: Stochastic Optimization Limited – Investigated the use of SDDP for Columbia system
- 2016: COMET – Internal project with inputs from external consultants to upgrade/develop Models

User guides and technical documentation are up to date for 3 of the 4 models reviewed. A developer documentation for the MCM Model is incomplete. The newly developed developer documentation for MUREO, COSTA and SOPHOS are not self-explanatory based on SINTEF's review. Such technical documents are valuable for communicating with BCH colleagues and external experts/reviewers, and thus SINTEF recommends putting more effort in improving their quality.

4.3.3 Inputs and Assumptions

SINTEF concludes that the inputs and assumptions used in the various models are generally reasonable.

Model inputs primarily comprise of load forecast, temperature, water inflows, market prices, outages, and electricity purchase agreements. The input data has been stored in a version control system since 2009. These data can be valuable at some point in the future, e.g. to be used for benchmarking purposes.

Changes in assumptions are discussed amongst the SO Team, logged (using version control) and communicated externally.

The information flow between Powerex and the ES process is not optimal. Price inputs used in the optimization models MUREO and MCM are obtained from the Market Model, which in turn takes the forward prices for electricity for Mid-C as input (prepared by Powerex). On the other hand, Powerex trading activities are often significantly impacted by the electricity prices in California. Thus, SINTEF believes that BCH should consider incorporating the California market price signals in the Market Model to obtain better water values. In the end, the forecasted power prices for the different US markets are the most important factor of the of BC Hydro marginal prices and decisions on import/export and generation.

Client interviews also revealed that the timing of the load forecast and level of details provided could be changed for the purpose of improving the ES Process.

4.3.4 Validation

SINTEF concludes that a comprehensive review process is in place to validate the reliability of the results.

The review process comprises:

- A monthly comparison of the ES reports to:
    - Previous ES results
    - The Ultralight model (a simplified model with a shorter-term focus)
- A weekly vetting and review process with the SO Team, management, GSO Operations Planning, and Powerex
- A monthly formal meeting to discuss ES results with BCH and Powerex

There is no regular benchmarking[10] of the ES results. Typical benchmarking for these types of models involves simulating a historical period using the observed inputs (i.e. temperature, inflows, loads and external market prices) and the forecasts that was available at each point in time, and comparing model outputs with observed values. In a liberalized market one would compare model-simulated prices with the observed prices, but one could also compare reservoir operation and production with observed values. For the BCH system there are no observed prices to compare with, but reservoir operation or production could be compared. This type of benchmarking is comprehensive and challenging because the strategy is updated every month with new forecast information, and particularly so since each model run involves many manual operations. If the ES process could be further automatized, this type of benchmarking will be easier to perform. SINTEF recommends that BCH investigates the possibilities for periodic benchmarking of model

[10] The term backtesting can also be used in this context.

SINTEF

results. The results to be benchmarked and the frequency of the benchmarking should be discussed with management.

The benchmark would show how well the models describe the real system and the operation of it. The benchmark would not reveal whether the solution is optimal. This can only be verified by comparing with alternative models, model testing and qualitative evaluations of methods and algorithms.

4.3.5 Change Management

Model changes are logged and tracked using a version control system. One person can use, review, and edit the model given the small team size. However, all major changes are discussed among the team.

Significant changes or model enhancements should follow ITDSP.

4.3.6 Energy Studies Process

A full ES cycle takes approximately 3 weeks to complete. There are many manual components of the cycle and synchronizing points where one has to wait for input data that slow down the process. It is reasonable to believe that more automation of the ES cycle would provide more updated prices and free labour resources.

Because of the long processing time the information is often outdated when provided to end-users. SINTEF believes the ES suite of models provide the best decision support for operation and trade, given that the input is up to date. Providing ES results more frequently can therefore bring significant value to the company in the long run, even though this is difficult to prove in the short run.

4.3.7 Methodologies Used

4.3.7.1 Market Model

SINTEF concludes that the Market Model serves well the purpose it is made for.

The purpose of the Market Model is to make a forecast for future electricity spot prices for the electricity market in the US that BCH can sell to or buy from. Main inputs to the Market Model include forward market prices for gas at Henry Hub and forward prices for electricity at Mid-C. The Mid-C electricity price serves as reference for the output from the Market Model, i.e. the average of spot price scenarios that are output from the Market Model should be equal to the forward market at Mid-C. The gas price is one of the main drivers for changes in the electricity price.

SINTEF

Because gas is such an important driver the Market Model outputs a stochastic[11] model consisting of 5 discretized gas states[12] for each time step and corresponding transition probabilities. To each combination of gas state and weather scenario there is a corresponding Mid-C electricity price. The stochastic model is used in the MCM and MUREO models.

Forward markets are deterministic and have a much coarser granularity than the actual realized spot market price. The Market Model adds uncertainty and improves on the granularity, e.g. prices are not the same during high load and light load hours. Both uncertainty and granularity are added based on observations in the market. The uncertainty is represented by scenarios for the future that is tied to the same weather years that are used in the rest of the model portfolio. The scenarios are used in SOPHOS simulation model.

The Market Model is an econometric (regression)[13] model that is estimated based on historical observations of electricity prices at Mid-C and the main drivers for variation in these prices. Main drivers include, gas prices at different locations, wind power production, Columbia discharge and Mid-C heat rates.

The Market model was review by Deloitte in 2005 and has been completely reimplemented as part of the COMET project. The basic methodology behind the model has been more or less unhanged for many years but model regression parameters are updated regularly to reflect new observations.

The properties, i.e. the models' ability to forecast the future price uncertainty correctly, of the market model are to some extent tested against observed price variation. The Market Model should not forecast neither less nor more uncertainty than what is observed in the market.

SINTEF believes that the Market model serves well the purpose it is made for. The challenge is to update the model as the underlying electricity market in the US may change. Model properties are given by chosen structure and past observations and these may not be relevant for the future. However, the forecasted average future market price which is the most important input to the rest of the model are based on the forward price.

SINTEFs has no specific recommendations for the Market Model as long as the BCH practice is to use only Mid-C as reference for the US market. After all, the models should respect this practice.

4.3.7.2 Columbia River

SINTEF concludes that the general methodology used to schedule the Columbia River system is according to best practice. However, the complexity of the river system calls for further verification of the details in the methodology as well as the implemented models.

The Columbia River system is particularly complex to model due to the scenario- and state-dependent constraints imposed by the Columbia River Treaty. Prior to the COMET project, the Columbia River was optimized using a deterministic linear programming (LP) model[14]. Through the COMET project a new

---

[11] A stochastic model is a model for describing the uncertainties in input parameters.
[12] The practical consequence of this is that the calculated water values from MUREO and MCM will be dependent on these gas states. A higher gas state represents a higher gas price which again gives higher US and Alberta electricity prices. A high gas price will lead to higher water values than a low gas state.
[13] Econometric models are a statistical model used in econometrics. In its simplest form it could be a linear regression between e.g. observed gas price and electricity prices based on observed prices.
[14] A deterministic LP model is an LP model where all parameters are known, as opposed to a stochastic LP model where uncertainty in a set of parameters is described.

stochastic model known as MUREO was developed and is currently being used for optimizing the Columbia River. MUREO is based on SSDP, where the Kinbasket reservoir level, the non-treaty storage level, the Henry Hub gas price and the weather year are treated as state variables. The SSDP methodology was advised by an internationally renowned expert in the field of hydropower scheduling. Given the modest number of state variables, we find that SSDP is an appropriate methodology to optimize this river. The choice of the SSDP method in the MUREO model is primarily motivated by the high number of different stochastic processes, that are easily embedded in one weather state. SINTEF believes the use of SSDP enhances BCHs capability to estimate the expected value of flexibility in the Columbia River compared to the deterministic LP model used previously.

MUREO takes input in terms of transition probabilities and forecasted treaty constraints from the COSTA model.

The new models (COSTA and MUREO) were run in parallel with the old models over a test period for verification before taken into operational use. Moreover, the MUREO optimizer is to some extent verified against the SOPHOS simulator. SINTEF has not been engaged to quantitatively assess the MUREO and COSTA models. However, the reported data from the performed testing and verification processes serve to build confidence in the implementation.

In summary we find that methodologies used in the program system (COSTA+MUREO) are appropriate and in-line with best practices. However, given the complexities of the Columbia River system and the Columbia Treaty, we believe more effort should be put into verifying the program system. Verification could e.g. be done by benchmarking the program system with results obtained by a second model. A possibility is to establish a model based on SDDP for that purpose. The BCH-UBC group leads a "water value project" for that purpose.

The methodologies and program system used for the Columbia River are challenging for the ES members to communicate to colleagues and peers. To facilitate better communication with other groups, we recommend improving the high-level documentation of the models. This could for example be done by describing each model's key properties, its underlying assumptions, and what is actually being modelled. The description should be supported by illustrations at an appropriate level of detail. Having such material readily available would further ease and encourage discussions on basic principles both within the organization as well as with outside experts.

4.3.7.3 Peace River

SINTEF concludes that the methodology used to schedule the Peace River system is according to best practice. We recommend upgrading the MCM code with code from the MUREO model and to consider further improving the model by including a snow state after the MUREO upgrade has been implemented.

The Peace River system comprises one large reservoir (Williston) and is optimized with the MCM model. The MCM model is based on SDP, where the Williston reservoir level and the Henry Hub gas price are treated as state variables. The model uses historical inflow sequences (from 1973) to represent uncertainty in inflow, assuming that each inflow scenario is equally likely to happen in the future. Given the low number of state variables, we find that SDP is an appropriate methodology to optimize this river.

The MCM model was implemented some 30 years ago and has been massively tested through years of operational use. However, the current SO Team members report limited familiarity with the code. Since MCM and MUREO both are variants of SDP, large parts of the MCM code can be replaced by code from the newly developed MUREO model. For these reasons, SINTEF recommends considering replacement of the MCM model with code from MUREO.

To our understanding, no autocorrelation in the inflow (or snow) is represented in the MCM model. Thus, the MCM model will not correctly model the probabilities for prolonged wet or dry sequences, and the extreme weather will be underestimated when computing the water values for Williston. Consequently, when operating (simulating) according to water values obtained from the MCM operation of Williston may be closer to the reservoir boundaries than one would like to operate in reality. If the SSDP methodology of the MUREO model is applied to the Peace system, the inflow autocorrelation would be included indirectly. Including a snow state variable in the SSDP/SDP methodology could improve further on the strategy.

4.3.7.4 System Simulation

A new model named SOPHOS was implemented as a part of the COMET project to serve as a system simulator, providing most of the results needed for the ES reporting. In short, SOPHOS prepares input data to the Columbia and Peace optimizers and simulates system operation based on the water values and recommended releases from the optimizers.

The use of a simulator with a finer level of detail and time resolution than what can be used in the water value computations will usually give simulation results that better reflects the real system. Experiences so far also indicate that the results are more in line with physical operation than before.

SOPHOS is a rule-based simulator. SINTEF believes that parts of the SOPHOS simulator could be based on optimization, e.g. by use of a LP formulation. This would not necessarily make the current solution faster or better, but the formulation would be more general, easier to understand and adaptable to a different system description. The term "preference order" would then be superfluous, the loading of plants as well as the marginal prices would come as a direct result of the optimization.

SINTEF

5 Outputs

5.1 Conclusions

- The monthly Energy Studies Reports are prepared on time and communicates well on a high-level.
- ES results do not provide a sufficiently strong signals to the short-term operational planning, mainly because they are based on outdated information by the time the results are ready. (Section 5.3)

5.2 Recommendations

- Start a process to automate running the models. (Section 5.3)
- Review the use of ES results for short-term operational purposes.
- Consider having a more robust medium-term operational model with a more formal coupling with ES models. (Section 5.3)

5.3 Summary of Findings

The primary users of the monthly ES reports include: GSO Operations Planning, Powerex, Finance, and Executive Management. The information shared seems appropriate and communicates well on a high-level. More detailed information than what is covered in the monthly ES reports are available for those parties needing it.

Water values for the short-term horizon are computed as a part of the ES reporting. These water values should provide signals to the short-term operational planning. However, most interviews confirmed that the water values provided by the SO Team do not always serve the short-term operational needs. There are two *possible* reasons for this:

1) The information from the Energy Studies do not represent the current state of the system and are based on outdated information. This is mainly because of the low frequency (once a month) of the Energy Studies.
2) There may be weaknesses or errors in the ES models leading to systematic errors in the water values. Some interviews suggested that water values in some cases seems to be systematically wrong. E.g. water values are too high in Peace when storage levels are high in late winter. The Peace problem could be due to lack of snow state modelling and use of uncorrelated inflows. Our recommendation to use MUREO code for Peace could partly solve the problem. SINTEF has not observed any other modelling weaknesses than the above mentioned that we know should give any systematic errors.

As discussed in Section 4.3.6, the whole ES process takes approximately 3 weeks to complete. SINTEF recommend searching for bottlenecks and try to speed up the whole process. Parts of the process are most likely straightforward to automatize. It could prove important to be able to run the Energy Studies more frequently to provide more updated information. Based on our experience with similar models applied by

SINTEF

players in the Nordic market, a fully automated process that uses the latest available information of all inputs should take less than a day to run, and possibly a day for quality checking. This is for runs that are used to calculate updated water values. The regular monthly report that include more results and discussions could take longer time.

A second model, known as the Ultralight model, is used by the GSO Operations Planning to compute water values. The results from Ultralight are compared against those from the ES models. The interviews revealed that the water values from the Ultralight model often deviate from those obtained by the ES models. In such cases, the final decision aid to the short-term planning is selected through discussions and expert assessment.

It was not within the task of SINTEF to review the details of the Ultralight model. Based on high-level description of the model, we classify it as a heuristic-based medium-term model with an inflow independent volume coupling to the ES models, cf. Section 2.2.

SINTEF believes there might be a need for a "medium-term" model with a shorter planning horizon like the Ultralight. Such a model can include more physical details and can be run more often than the ES models. Using different models with different planning horizons in a planning hierarchy is common also in other hydro dominated systems like Scandinavia and Brazil, cf. Section 2.2. However, for the BCH implementation it seems that the Ultralight model is an alternative parallel model that is easier to run, rather than a model for refining the long-terms signals (i.e. water values) from the ES models.

SINTEF recommends an evaluation of the Ultralight model, both in terms of its role in the scheduling hierarchy and in terms of methodology and implementation. The Ultralight model is not as sophisticated as the ES models for the following reasons:

- The model uses heuristic instead of formal optimization. Heuristic-based methods are in general more difficult to understand and an optimal solution is not guaranteed.
- The end-of-horizon target is storage levels that are independent of inflows and prices in the planning period. A better model coupling approach would be to use water values as end-of-horizon valuation of storages, cf. Section 2.2. The second-best alternative is to use a target based on storage levels that are specific for each scenario.
- The implementation is based on Excel which is a less flexible development environment and does not facilitate a computationally efficient solution process.
- The implementation and working principle are fully known only by one person that is about to retire.

SINTEF

Technology for a better society

www.sintef.no

Exhibit B-52

BC Hydro Fiscal 2020 to Fiscal 2021
Revenue Requirements Application

BC HYDRO UNDERTAKING NO. 53

HEARING DATE: March 02, 2020

REQUESTOR: Commissioner D. Morton

TRANSCRIPT REFERENCE: Volume 13, Page 2514, lines 2 to 14

TRANSCRIPT EXCERPT:

THE CHAIRPERSON: Does your internal audit group ever look at your distribution vegetation maintenance program?

MS. DASCHUK: A There was an audit of the vegetation management program by internal audit. Subject to check, I believe it was in 2015

THE CHAIRPERSON: Was that filed with the Commission as far as you know>

MS. DASCHUK: A I don't know the answer?

THE CHAIRPERSON: Would it be possible to do so, please?

MS. DASCHUK: A Yes.

THE CHAIRPERSON: Thank you.

MR. MILLER: Would you like it filed, Commissioner Morton?

THE CHAIRPERSON: Yes, I would. I guess I didn't ask the final question.

MS. DASCHUK: A So to be clear, we'll be filing the internal audit on the vegetation management program.

THE CHAIRPERSON: Please. Thank you.

QUESTION:

Please file with the BCUC the BC Hydro 2015 Internal Audit of our Vegetation Management program.

RESPONSE:

Attachment 1 to this undertaking provides the Management Audit Report on BC Hydro's Vegetation Management Program.

Attachment 2 to this undertaking provides the Summary Audit Report on BC Hydro's Vegetation Management Program.

Attachment 3 to this undertaking provides the Follow-Up Report on BC Hydro's Vegetation Management Program Audit.

BC hydro

MANAGEMENT AUDIT REPORT

TRANSMISSION, DISTRIBUTION AND CUSTOMER SERVICE
VEGETATION MANAGEMENT PROGRAM
Q4 F2015

MAY 6, 2015

Prepared By:

R. Ferraro
A. D'Andrea
P. Howard
A. Lagnado

Distributed To: C. Smith
T. Wells
L. Haffner
M. Daschuk
C. Matheson
G. Reimer
C. Yaremko

Vegetation Management Program Audit F2015

CONTENTS

Legend:

Minor issues and impacts identified

Significant issues and impacts identified

Vegetation Management Program Audit F2015

1a. Executive Summary

- For each audit, Audit Services provides two separate Audit Reports. The first report is a Summary Audit Report prepared for Senior Management and the Audit & Finance Committee (AFC) of the Board. This Management Audit Report provides additional information and related audit recommendations for management purposes and will not be presented to the AFC.
- Management should also refer to the Summary Audit Report for high level conclusions and findings.

1b. Background

- Trees and vegetation in contact with power lines are a major cause of electrical outages, impact system reliability and pose a safety hazard. Tree-related outages account for approximately 1.6 million customer hours lost annually.
- The BC Utilities Commission approved the North American Electrical Reliability Corporation standards to ensure electric system reliability by preventing outages from vegetation located on or adjacent to the transmission rights-of-way.
- Within Transmission, Distribution & Customer Service, two groups are responsible to deliver the Vegetation Management Program.
  - Asset Investment Management maintains standards, and manages the plans and budget.
  - Vegetation Management manages the clearance of vegetation and tree maintenance along 18,000 km of transmission and 48,000 km of distribution line corridors utilizing external contractors to perform the work.
- Vegetation Management is an ongoing program and is dependent on regional vegetation growth rates and seasonal conditions. Personnel work closely with agencies such as the Ministry of Environment and First Nations on planned maintenance work.
- In F2015, the Program budget was $47.5M (Distribution $28.4M and Transmission $19.1M) with cost recoveries of $5.2M from TELUS for the joint use pole sharing Distribution Program agreement.
- Two systems that support Vegetation Management are the PowerGrid application for Transmission and the SAM VegSMART application for Distribution work.
- The Vegetation Program was last audited in F2010 and only Distribution was in scope as the Transmission function was the responsibility of BC Transmission Corporation. Management has been working on addressing opportunities to improve processes.

Vegetation Management Program Audit F2015

1c. Audit Objective and Scope

Objective

- Provide assurance that Transmission and Distribution has adequate processes and controls to effectively plan and implement the Vegetation Management Program.

Scope

- Review the business processes, procedures and controls for Vegetation Management in Transmission, Distribution and Customer Service.
  - Governance and Planning - oversight, strategic and annual planning, standards, policies and procedures, roles and responsibilities
  - Procurement and Contracts - procurement strategy, contract awarding, contractual expectations and work specifications
  - Work Execution - contractor management, progress monitoring, quality control, application support and contractor payments
  - Monitoring and Reporting - performance monitoring, reporting and continuous improvement
- The audit reviewed both Transmission and Distribution processes supporting documentation through interviews and detailed testing from planning to payments.

Standards

- This audit was conducted in conformance with the International Standards for the Professional Practice of Internal Auditing.

Vegetation Management Program Audit F2015

1d. Findings, Recommendations and Management Action Plans

Summary

- Oversight and Program plans are in place. Both Transmission and Distribution have their own standards, procedures, systems and documents. Management has been working on harmonizing common work processes, which are not yet been fully completed. Practices are generally followed however there are several opportunities to improve efficiency and consistency in work processes which is acknowledged by management.
- Work is completed according to plan but supporting documentation varies. Reporting and monitoring processes are in place.

Governance and Planning

Overall Conclusion

Governance and planning for the Vegetation Management Program are in place. Transmission continues to follow some processes developed under BC Transmission Corporation, while Distribution follows BC Hydro established processes. Although there are some distinct differences between Transmission and Distribution work, opportunities exist to harmonize common processes.

Key Conclusions and Findings

- Oversight of the Vegetation Management Program (Program) is in place. Joint responsibility is vested with two groups. Asset Investment Management develops and monitors the Program's standards, plans and budgets. Vegetation Management provides plan input, develops the maintenance procedures, oversees and inspects contractors' work.
- Annual and long term (10-year) plans are in place for both Transmission and Distribution Programs. Environmental, regulatory and stakeholder requirements are included in the planning process. The plans factor in regional cyclical growth rates, physical inspections and poor reliability circuits.
- Roles and responsibilities are defined and understood. However the Responsible, Accountable, Consulted and Informed (RACI) matrix is not current and has not been updated since 2011 to reflect organization changes.
- A harmonized work process to support both the Transmission and Distribution Vegetation Management has not yet been implemented. Each group has separate standards, procedures, systems and documents.
  - Transmission continues to follow some processes developed by BC Transmission Corporation (e.g. Herbicide Standard). Distribution follows processes established prior to the merger. Certain standards were harmonized to ensure compliance with NERC.
  - Supporting documents are filed in several different locations (J drive, laptops, Hydro share) and are not easily found.

Vegetation Management Program Audit F2015

- Transmission and Distribution standards have not yet been updated into a common standard. Progress is slow on the harmonizing of standards due to resource constraints. As a result, staff may receive copies of standards that are not current or not consistent.
- Procedures are not consistent between Transmission and Distribution and may be out dated. Transmission has documented detailed Work Operating procedures and Standard Operating Procedures for contractors and staff, and testing found some procedures were not current.
  - Distribution procedures are only documented in a high level work flow diagram with the risk that there may be inconsistencies and gaps in procedures between regions.
- Quality Management Reports and Quality Assurance Reviews are not consistently performed. Quality Management Reports verify that Vegetation Management Coordinators and Contractors are complying with internal operating procedures, standards, legislative and regulatory requirements.
  - The Quality Management Review group was disbanded and reassigned to Distribution and Transmission Vegetation Managers. As a result, some of the function's reporting independence is lost and formal reports are not consistently being completed due to competing priorities.
  - In addition Asset Investment Management Quality Assurance Reviews to ensure compliance with Vegetation Management standards are not being consistently performed partially due to a lack of resources.

	Recommendations	Management Action Plans
	Governance and Planning	
1	❑ Update the RACI to reflect Program organization changes.	❑ Vegetation Management will update the RACI to reflect organization changes by June 30, 2015.
2	❑ Develop and implement a plan to ensure there are common processes for both Transmission and Distribution Vegetation Management including document filing standards.	❑ Vegetation Management will align common processes for both Transmission and Distribution including documentation with standard VG-01.40 by August 31, 2015.
3	❑ Complete the updating of the standards and determine how work procedures should be updated.	❑ Asset Investment Management (AIM) will update vegetation standards priorities and needs in the Asset Policy Strategy and Standards register. AIM will also work with Vegetation Management to update the work procedures. Transmission standards and procedures will be reviewed before October 31, 2015 and for Distribution by October 31, 2016.
4	❑ Ensure that both quality assurance reviews and management reports are being completed following an established schedule.	❑ Vegetation Management and AIM will develop a schedule and ensure the quality reviews are completed by June 30, 2015.

Vegetation Management Program Audit F2015

Procurement and Contracts

Overall Conclusion

Work is awarded fairly with clear contractual specifications, however a common procurement delivery model is not in place and insurance requirements are not proactively monitored.

Key Conclusions and Findings

Procurement Strategy

- There are different procurement strategies for the contracting of Transmission and Distribution work. To address inefficiencies, management is developing a common long-term procurement solution as part of the Supply Chain Category Management project.
  - Distribution procurement practices utilize prequalified contractors who bid on work at a specific location or job. Short term contracts are issued for these jobs.
  - Transmission contractors bid on work for a region and are assigned long term contracts. Current contracts are for a five year term.
  - Management stated timing on the common long-term procurement solution has not yet been finalized.

Contracting of Work

- Contracts are awarded on a competitive bid basis. Work is awarded fairly to qualified contractors based on contracts and supporting documentation reviewed. Contractors must meet specific requirements such as having a certified utility arborist on their crews. Performance scoring on previous BC Hydro work is taken into consideration when awarding work.
  - Signed contracts are in place and provide clear scope of work, terms, conditions and for the most part obligations of the parties. Two Transmission work specifications were not signed by contractors. Management asserted that one was signed electronically but there is no BC Hydro guidance on acceptable use of electronic signatures.
- Contractor work performance monitoring takes place although different processes exist. There may be opportunities for process efficiency improvements. Contractor performance results are used to determine if their contract will be renewed.
  - Distribution contractor performance monitoring provides contractors assessment on each job using a standard form.
  - Transmission contractor performance is based on annual performance review meetings.
- Contractor WorkSafe BC and liability insurance are not proactively monitored to ensure valid insurance is in place. No insurance records were found for 6 of 15 sampled contractors.
  - Management advised that the Purchasing group occasionally informed them of WorkSafe BC insurance expiry with no lead time, causing Contractors to immediately stop work.
  - Due to resource constraints, the Purchasing group changed the monitoring procedure to only check Distribution lump sum contracts insurance and to perform a quarterly review of WorkSafe BC expiry dates.

Vegetation Management Program Audit F2015

- The Purchasing group is placing more reliance on contractual terms and relationships to reduce insurance monitoring. Vegetation Management was not informed or given the opportunity to provide input on this change.

	Recommendations	Management Action Plans
	Procurement and Contracts	
5	❑ Vegetation Management should continue to participate through the Supply Chain initiative to work towards a common procurement process and contractor performance monitoring.	❑ Vegetation Management will participate with the Supply Chain initiative for a common procurement process by September 30, 2017. ❑ Vegetation Management will implement a common Contract performance monitoring process by April 1, 2017 with the commencement of the new Transmission contracts.
6	❑ Ensure contractor signatures or acknowledgement is received for work specifications and determine type of electronic signature is acceptable.	❑ Vegetation Management will work with Contract Management to ensure contractor signatures or acknowledgements are received for work specifications by April 24, 2015.
7	❑ Reassess the insurance monitoring requirements with the Purchasing and Treasury.	❑ Vegetation Management will work with Purchasing to determine the appropriate insurance monitoring requirements by September 30, 2015.

Vegetation Management Program Audit F2015

Work Execution

Overall Conclusion

Work is being completed according to plan. As of February 2015, $44.6M has been spent of the $47.5M approved budget (94%). Testing for the Vegetation Management Program identified key areas where procedures were not consistently followed and supporting documentation varied.

Key Conclusions and Findings

- Work is generally completed according to plan. The Vegetation Financial Update monthly report, confirms the Program is on track to complete planned work by fiscal year end.
  - As of February 2015, $44.6M has been spent of the $47.5M approved budget (94%). Estimated work completion is 93% with a forecast of 106% completion by year end. The additional 6% is primarily due to an approved increase of $2.6M in Operations Maintenance and Administration expenses provided in January 2015 above the budget.
- Samples tested confirmed that the plans and schedules are followed according to plan and were allocated a budget. Work processes require work plans and schedules be followed with pre-job meetings prior to work starting.
  - While the hazard and barrier section was completed in the pre-job package in most cases, there were three instances where this section had not been completed. This section is required to ensure contractors are fully aware of specific safety requirements and should always be completed.
- Documented scope changes and extra work are authorized and approved. PassPort ensures the required financial approval is provided prior to scope change payments. Processes are in place requiring the documentation of scope changes and extra work however the processes vary between Transmission and Distribution and are out of date.
  - Transmission scope change procedure requires changes to be recorded on the Inspection form. However management stated the procedure was out of date and changes should now be recorded on the pre-work Unit Summary form.
  - Distribution has not documented the scope change procedure but uses a standard Equitable Adjustment form as a proxy. Testing identified that equitable adjustments were not consistently entered in Passport. In addition we noted that a reduction in required work was not recorded.
- Work inspections are required for milestones, however processes vary and evidence is inconsistent to demonstrate inspections were completed.
  - Transmission uses a standard inspection form, however interim and final inspections were not consistently documented.
  - Distribution does not have a standard inspection form. Testing noted progress and final inspections were not consistently documented.
  - Inspection records reviewed were not signed or acknowledged by Contractors. Management stated that a new North American Electric Reliability Corporation compliance requirement effective August 1, 2015, will be better met if inspection deficiencies and corrections are acknowledged by Contractors.

Vegetation Management Program Audit F2015

- An inspection report is required prior to paying a Contractor's invoice.
  - While the majority of payments were made with final inspection reports completed, there were payments made without final inspection reports provided. Transmission and Distribution processes require an inspection report prior to payment to ensure work is performed to quality standards. A review of 15 samples noted:
    - Reliance is being placed on emails between Vegetation Coordinators and Administrators seeking to verify work progress in place of inspection reports.
    - A Transmission payment was made without a final inspection report which was completed one month after payment.
    - Three Distribution payments did not have evidence of inspection supporting work progress prior to payment.
    - Two payments were not supported by ether an inspection report or Coordinator email.
- The Vegetation Management Program has separate Information Technology systems for Transmission and Distribution supporting similar planning and work execution processes. There may be opportunities to integrate the systems.
  - Transmission utilizes PowerGrid and a contractor is developing an iPad input process. BC Hydro IT was recently made aware of this project and is now reviewing it and including the BC Hydro Freedom of Information Office to determine if a Privacy Impact Assessment is required.
    - PowerGrid includes information such as transmission structure locations, access routes, first nation's traditional territories, and Vegetation Management information.
  - Distribution utilizes SAM VegSMART and the system is updated twice a year with enhancements.
    - SAM VegSMART includes information such as distribution locations, rivers, and Vegetation Management information.
  - The outcome of a Lean initiative (process efficiency exercise) identified that the Vegetation Management systems lacked adequate technical support and training for staff and contractors.

	Recommendations	Management Action Plans
	Work Execution	
8	❑ Ensure completion of pre-job hazard and barrier section of the pre work documents to demonstrate that this activity has taken place.	❑ Vegetation Management will review the filing process and discuss with staff the need to complete hazard and barrier sections of pre work documents by May 29, 2015.
9	❑ Implement a formal common scope change process.	❑ AIM will implement a formal common scope change process by June 26, 2015.

Vegetation Management Program Audit F2015

	Recommendations	Management Action Plans
10	❑ Ensure work inspection reports are completed before payments are made.	❑ Vegetation Management will review current practices and discuss with staff the need to complete work inspection by May 31, 2015.
11	❑ Consider re-assessing IT systems requirement to more efficiently meet business needs and resource demands.	❑ Vegetation Management will work with IT to assess IT systems and determine if efficiency could be improved by January 31, 2017.

Vegetation Management Program Audit F2015

Reporting and Monitoring

Overall Conclusion

Internal and external reporting and monitoring processes are in place to support safety and reliability objectives. However, a process is not in place to track customer complaints and completion of planned jobs.

Key Conclusions and Findings

- Management and Executives receive regular internal reports on performance and system reliability to monitor and manage the business, however there is no reporting of jobs completed compared to plan.
  - The business group Leadership Team receive monthly information on the actual dollars and volumes compared to plan. In addition, a dash board metric tracks unit cost efficiency gain (cost increase/decrease compared to the years' baseline).
  - Management does not track or report the number of planned jobs completed from the original approved annual plan. There may not be a complete picture of what was accomplished for the dollars spent if the percentage of the jobs completed is not reported.
  - The Director Program & Contract Management receives a weekly update report of significant issues and the status of the Program from the Senior Vegetation Manager. When warranted issues are shared with the Leadership Team.
- Vegetation Management monitors performance and system reliability and manage the business. Key reports include:
  - The monthly Vegetation Financial Update (prepared by Finance) with actual dollars and volume compared to planned with variance analysis.
  - The Monthly Contractor Tracking Spreadsheet with detailed job information for each region within Transmission and Distribution. However, the spreadsheet requires significant manual input and control totals are not always reconciled for key information such as approved plan total.
  - Formal Quality Management Review reports ensure contractors receive adequate instructions, procedural guidance, and information on legislative and regulatory requirements. At the time of our review only 2 of 8 formal reports were completed.
- A formal process to track and ensure customer complaints are addressed is not in place. Customer requests are currently handled on an ad-hoc basis. As a result, customer complaints may not be adequately addressed and root cause analysis cannot be effectively performed.
- External reporting is compliant with requirements.
  - Annually, the Asset Investment Management group reports to the North American Electric Reliability Corporation (NERC) on the results of a self-assessment of Transmission's Vegetation Management Program compliance with NERC standards.

Vegetation Management Program Audit F2015

- Every three years, NERC performs an independent review for compliance to standards. The last NERC review was performed in October 2014 with no findings identified.

- An annual report on BC Hydro's use of pesticide is provided to the Ministry of Environment.
- Informal requests are received from B.C. Utilities Commission on the status of the plan and system maintenance activities. Annual plans or excerpts are frequently used as evidence to document maintenance schedules and expenditures in response to information requests from the Regulator.

	Recommendations	Management Action Plans
	Reporting and Monitoring	
12	❑ Consider reporting actual jobs completed against the original approved annual plan.	❑ Vegetation Management will assess and discuss with management the need to include job completion information by May 17, 2015.
13	❑ Assess the contractor tracking spreadsheet to determine the most efficient method to track this information and ensure accuracy of key fields.	❑ Vegetation Management to review the contractor tracking spreadsheet process and determine if there is a more efficient method by June 26, 2015.
14	❑ Implement a process to track and monitor customer complaints and how they were addressed.	❑ Vegetation Management to review and develop a process to better track and monitor customer complaints by May 29, 2015.

BC hydro

SUMMARY AUDIT REPORT

TRANSMISSION, DISTRIBUTION & CUSTOMER SERVICE VEGETATION MANAGEMENT PROGRAM Q4 F2015

APRIL 30, 2015

AU1511TDCS

Prepared By:

R. Ferraro
A. D'Andrea
P. Howard
A. Lagnado

Distributed To: C. Smith
L. Haffner
M. Daschuk
C. Matheson
G. Reimer
C. Yaremko
J. McDonald
Audit & Finance Committee

Vegetation Management Program Audit F2015

AUDIT TYPE	AUDIT RATING
RISK BASED AUDIT	Y

Legend:
Minor issues and impacts identified
Significant issues and impacts identified

Audit Objective

- Provide assurance that Transmission and Distribution has adequate processes and controls to effectively plan and implement the Vegetation Management Program.
- This audit was conducted in conformance with the International Standards for the Professional Practice of Internal Auditing.

Background

- Trees and vegetation in contact with power lines are a major cause of electrical outages, impact system reliability and pose a safety hazard. Tree-related outages account for approximately 1.6 million customer hours lost annually.
- The BC Utilities Commission approved the North American Electrical Reliability Corporation standards to ensure electric system reliability by preventing outages from vegetation located on or adjacent to the transmission rights-of-way.
- Within Transmission, Distribution & Customer Service, two groups are responsible to deliver the Vegetation Management Program.
  - Asset Investment Management maintains standards, and manages the plans and budget.
  - Vegetation Management manages the clearance of vegetation and tree maintenance along 18,000 km of transmission and 48,000 km of distribution line corridors utilizing external contractors to perform the work.
- Vegetation Management is an ongoing program and is dependent on regional vegetation growth rates and seasonal conditions. Personnel work closely with agencies such as the Ministry of Environment and First Nations on planned maintenance work.
- In F2015, the Program budget was $47.5M (Distribution $28.4M and Transmission $19.1M) with cost recoveries of $5.2M from TELUS for the joint use pole sharing Distribution Program agreement.
- Two systems that support Vegetation Management are the PowerGrid application for Transmission and the SAM VegSMART application for Distribution work.
- The Vegetation Program was last audited in F2010 and only Distribution was in scope as the Transmission function was the responsibility of BC Transmission Corporation. Management has been working on addressing opportunities to improve processes.

Key Findings

- Oversight and Program plans are in place. Both Transmission and Distribution have their own standards, procedures, systems and documents. Management has been working on harmonizing common work processes, which are not yet been fully completed. Practices are generally followed however there are several opportunities to improve efficiency and consistency in work processes which is acknowledged by management.
- Work is completed according to plan but supporting documentation varies. Reporting and monitoring processes are in place.

Vegetation Management Program Audit F2015

Governance and Planning

- Governance and planning for the Vegetation Management Program are in place with roles and responsibilities defined and understood.
  - Joint responsibility is vested with two groups. Asset Investment Management develops and monitors the Program's standards, plans and budgets. Vegetation Management provides plan input, develops the maintenance procedures, and oversees and inspects contractors' work.
  - Annual and long term (10-year) plans are in place for both Transmission and Distribution Programs.
- Transmission follows some processes developed under BC Transmission Corporation, while Distribution follows BC Hydro established processes. Although there are some distinct differences between Transmission and Distribution work, opportunities exist to harmonize common processes.

Procurement and Contracts

- Work is awarded fairly with clear contractual specifications, however a common procurement delivery model is not yet in place and insurance requirements are not proactively monitored.
  - Contracts are awarded on a competitive bid basis. Signed contracts are in place and provide clear scope of work, terms, conditions and obligations of the parties.
  - There are different procurement strategies for contracting out Transmission and Distribution work. To address inefficiencies, management is developing a common long-term procurement solution as part of the Supply Chain Category Management project.
  - Contractor WorkSafe BC and liability insurance certificates are not proactively monitored to ensure valid insurance is in place. There were no insurance records found for 6 of 15 sampled contractors.

Work Execution

- Work is being completed according to plan. As of February 2015, $44.6M has been spent of the $47.5M approved budget (94%).
  - Estimated work completion is 93% with a forecast of 106% by year end. The 6% increase is primarily due to an approved increase of $2.6M in Operations Maintenance and Administrative expenses provided in January 2015 above the budget.
- Lifecycle testing of 15 contracts for the Vegetation Management Program identified key areas where procedures were not consistently followed and supporting documentation varied.
  - While the hazard and barrier section was completed in the pre-job package in most cases, there were examples where this section had not been completed. This section is required to ensure contractors are fully aware of specific safety requirements and should always be completed.
  - Work inspections are required for milestones, however processes vary and evidence is inconsistent to demonstrate inspections are completed.
  - While the majority of payments were made with final inspection reports completed, there were payments made without final inspection reports provided. Transmission and Distribution processes require an inspection report prior to payment to ensure work is performed to quality standards.

Vegetation Management Program Audit F2015

Reporting and Monitoring

- Internal and external reporting and monitoring processes are in place to support safety and reliability objectives. Management and Executives receive regular reports on performance and system reliability at an appropriate level to monitor the Program. However, a process is not in place to track customer complaints.
  - Customer requests are currently handled on an ad-hoc basis. As a result, customer complaints may not be adequately addressed and root cause analysis cannot be effectively performed.

Management Comments and Action Plans

- Management agrees with the recommendations in the audit report and will address the majority of the recommendations by March 31, 2016. Recommendations involving the procurement strategy will be addressed by September 30, 2017.

BC Hydro
Power smart

INTERNAL AUDIT FOLLOW-UP REPORT

TRANSMISSION AND DISTRIBUTION & CUSTOMER SERVICE

VEGETATION MANAGEMENT PROGRAM AUDIT

(AUDIT REPORT DATE: APRIL 30, 2015)

PREPARED BY: A. D'Andrea
P. Howard
A. Lagnado

DATE: APRIL 29, 2016
FU1611TDCS

DISTRIBUTED TO: C. Smith
L. Haffner
M. Daschuk
A. Kumar
G. Reimer
C. Yaremko
J. McDonald

BC Hydro
Power smart

Vegetation Management Program Audit- Follow-up

	Recommendations	Management Action Plans
	Governance and Planning	
1	❑ Update the RACI to reflect Program organization changes.	❑ **Complete:** Vegetation Management has updated the RACI to reflect organization changes.
2	❑ Develop and implement a plan to ensure there are common processes for both Transmission and Distribution Vegetation Management including document filing standards.	❑ **In Progress:** Further examination has determined that there are differences in the processes between Transmission and Distribution which may limit the development of common processes. ❑ Asset Investment Management (AIM) and Vegetation Management are working on developing a plan to examine and align standards and processes where possible by January 2017.
3	❑ Complete the updating of the standards and determine how work procedures should be updated.	❑ **Complete:** AIM has updated and approved 12 vegetation maintenance standards in 2015. AIM is working with Vegetation Management on updating specific work procedures as required.
4	❑ Ensure that both quality assurance reviews and management reports are being completed following an established schedule.	❑ **In Progress:** Vegetation Management Quality Assurance Reviews were assigned and completed by staff in F2016 but not following an established schedule. A formal schedule will be implemented for F2017.
	Procurement and Contracts	
5	❑ Vegetation Management should continue to participate through the Supply Chain initiative to work towards a common procurement process and contractor performance monitoring.	❑ **Complete:** Vegetation Management continues to work with the Supply Chain towards a common procurement process and contractor performance monitoring. The initiative will be completed over the next two years.
6	❑ Ensure contractor signatures or acknowledgement is received for work specifications and determine type of electronic signature is acceptable.	❑ **In Progress:** Vegetation Management is in the process of documenting the procedures for the acceptance of work and signature requirements by June 2016.

Vegetation Management Program Audit- Follow-up

	Recommendations	Management Action Plans
7	❑ Reassess the insurance monitoring requirements with the Purchasing and Treasury.	❑ **Complete:** Vegetation Management and Purchasing have reassessed the insurance monitoring requirements and determined the current practice is acceptable.
	Work Execution	
8	❑ Ensure completion of pre-job hazard and barrier section of the pre work documents to demonstrate that this activity has taken place.	❑ **Complete:** Vegetation Management has updated the Transmission and Distribution pre-work check list and has discussed the need to complete the pre-job hazard and barrier documentation with staff.
9	❑ Implement a formal common scope change process.	❑ **Complete:** It was determined that a common scope change process cannot be implemented for Transmission and Distribution due to NERC requirements.
10	❑ Ensure work inspection reports are completed before payments are made.	❑ **In Progress:** Vegetation Management has discussed the need to complete work inspections before payments are made with Transmission staff. ❑ Procedures for Distribution staff will be developed and communicated by June 2017.
11	❑ Consider re-assessing IT systems requirement to more efficiently meet business needs and resource demands.	❑ **Complete:** Vegetation Management has decided to complete implementation of VegNET for Transmission and will explore using VegNET for Distribution. A decision is expected by December 2017.
	Reporting and Monitoring	
12	❑ Consider reporting actual jobs completed against the original approved annual plan.	❑ **Complete:** Asset Investment Management is now tracking actual jobs completed against the original annual plan.
13	❑ Assess the contractor tracking spreadsheet to determine the most efficient method to track this information and ensure accuracy of key fields.	❑ **In Progress:** Vegetation Management has incorporated contract tracking and progress in the VegNET system for Transmission. ❑ Tracking of information for Distribution will be determined once the decision on the system is finalized.

Vegetation Management Program Audit- Follow-up

	Recommendations	Management Action Plans
14	❑ Implement a process to track and monitor customer complaints and how they were addressed.	❑ **Complete:** Vegetation Management is tracking customer complaints using the PCM Complaint tracker as required. Most vegetation complaints are addressed within 48 hours of receiving the complaint. ❑ At this time, there are no further plans to develop an enterprise wide system.