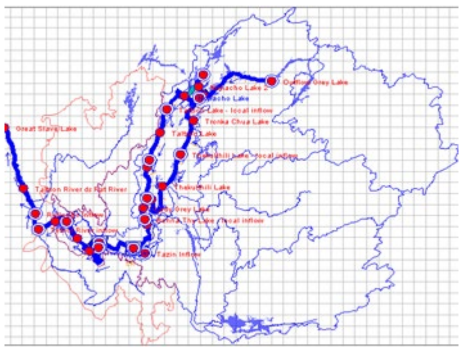
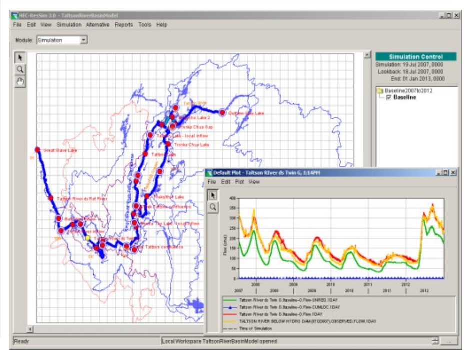
Aquatic Effects Monitoring Plan for the Taltson Hydro Generating Station

HEC-ResSim Hydrological Modelling Update V3



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EXECUTIVE SUMMARY

Mackenzie Valley Land and Water Board (MVLWB) Water Licence MV2011L4-00002 for the Taltson Hydro Generating Station (THGS) requires implementation of an Aquatic Effects Monitoring Plan (AEMP). The AEMP includes a requirement to update the Taltson River Basin (TRB) HEC-ResSim model, which was developed in 2006-2008 to simulate the effect of reservoir operations on the Taltson River Basin. Updates to the model were scheduled for 2013, 2014, 2019, and 2024. This report documents the model updates required for 2019 which include and supersede the model updates completed in 2013 and 2014. The purpose of the 2019 model update was to include five more years of recent data that can be used to assess appropriateness of permitted water levels and flows under the water licence if future operational changes are required.

The previous version of the TRB HEC-ResSim model (2014) was set up with data from July 2007 to December 2013. These data were obtained from four Water Survey Canada (WSC) hydrometric gauges: water level in Nonacho Lake, flow in the Taltson River above Porter Lake outflow, flow in the Tazin River near its confluence with the Taltson River, and flow in the Taltson River downstream of the Taltson Hydro Generating Station. Data for updating the TRB model were also obtained from Northwest Territories Power Corporation (NTPC); these data included water level in the Twin Gorges forebay, water level in the tailrace of the generating station, and power output from the generating station. The data from the WSC gauges and NTPC were used to estimate inputs to the TRB HEC-ResSim model, including inflows to Nonacho Lake and inflows to Taltson River from watersheds downstream of Nonacho Lake.

Compared to the previous version of the TRB HEC-ResSim model (2014), the updated 2019 model reproduced the water levels in Nonacho Lake to the same degree of accuracy. The updated model, however, showed reduced accuracy in predictions for water level in the Twin Gorges forebay. This is likely due to large amounts of noise in the observed forebay data. Nevertheless, good agreement was observed between the simulated and observed flows downstream of the Taltson Hydro Generating Station. Although data from gauges 07QA001 and 07QD004 were used in previous iterations of the model, data were not available at these gauges for the 2014 to 2018 period. Only finalized data provided by WSC were used in this model update and finalized data at all gauges were only available up to December 31, 2018.

The updated model provided reasonable agreement with flow observations downstream of the Taltson Hydro Generating Station. However, uncertainty in the outflow from the South Valley Spillway and the outflow from the Generating Station affects the confidence in outflow simulated from the forebay. This uncertainty could be reduced by surveying the spillway crest level relative to the datum used for measuring water level in the forebay and measuring flow through the Taltson Hydro Generating Station at different electric power outputs. These measurements could be used to develop an accurate rating equation for the spillway and to estimate operating efficiency as a function of station flow which would improve future estimates obtained from the TRB HEC-ResSim model for outflow from the Twin Gorges forebay, flow in Trudel Creek, and flow in Taltson River

downstream of the forebay. However, we note that surveying the spillway crest level is very unlikely to be feasible under current operations and associated water levels.

The analysis of water levels and flows from 2014-2018 indicated that excursions from the permitted values did not occur, and that values were well within the permitted range. Therefore, the model was not used to reassess the appropriateness of flows, which was previously completed for the 1987 to 2014 period during 2015.

The model now has 31 years of data that can be used to assess the impacts of changes in operations or inflows (e.g., with climate change) on water levels, power production, and downstream flow rates. This amount of data is considered sufficient to assess the inter-annual variability in effects of these changes, and as such the previously prescribed update to the model in 2024 is no longer recommended. Furthermore, the Water Licence (MV2011L4-0002) does not include any further analysis that require application or future updates to the TRB model.

Although not required, the TRB model could be applied to assess numerous questions associated with water flows and levels in the Taltson system. Examples include (1) assessing the potential impacts of climate change on ability to achieve permitted water flows and levels, (2) assessing the risk of flooding associated with extreme high flows years, (3) Assessing operational changes that could be implemented while maintaining permitted water flows and levels, and (4) assessing if any future excursions were preventable through operational adjustments.

TABLE OF CONTENTS

EXECUTIVE SUMMARY ..... **II**

LIST OF FIGURES ..... **V**

LIST OF TABLES ..... **VI**

LIST OF MAPS ..... **VI**

1. INTRODUCTION **1**

2. METHODS **4**

2.1. Study Site 4
2.2. Model Description 5
2.3. Flow and Water Level Data 8
2.4. Estimation of Inflows 14
2.4.1. Inflow to Nonacho Lake 14
2.4.2. Inflow from Watersheds between Nonacho Lake and Tsu Lake 17
2.4.3. Inflows from Tethul and Rutledge Rivers 19
2.5. Taltson Hydro Generating Station Outflow 20
2.6. Flow Routing for River Reaches, Lakes, and Reservoirs 21
2.7. Model Application 21

3. RESULTS **21**

3.1. Inflow Estimates 21
3.2. Model Validation 23
3.3. Assessment of Permitted Water Levels and Flows 27

4. UNCERTAINTY IN MODEL RESULTS **28**

5. CONCLUSION AND RECOMMENDATIONS **30**

REFERENCES **32**

LIST OF FIGURES

Figure 1. a) The Taltson River Basin. b) The HEC-ResSim model representation of the Taltson River Basin. This figure is reproduced from Rescan (2009). 7

Figure 2. Nonacho Lake raw data provided by NTPC. 11

Figure 3. a) Water level and b) flow for WSC gauges in the Taltson River basin. Thick black-coloured line segments indicate missing data that were estimated for the TRB HEC-ResSim model. 12

Figure 4. a) Daily water level in the Twin Gorges Forebay, b) daily water level in the tailrace of the Taltson Hydro Generating Station, and c) daily power output from the Taltson Hydro Generating Station. 13

Figure 5. Monthly-average evaporation rate at the Environment Canada climate stations at Yellowknife and Cluff Lake. 14

Figure 6. Comparison of increasing/decreasing flow trends between smoothed estimated inflow from Equation 2 and Gauge 07QD004. 16

Figure 7. Gate outflow a), and gate setting b) for the Nonacho Lake dam during 2014-2018. 16

Figure 8. Monthly-average evaporation applied to the lakes downstream of Nonacho Lake. 19

Figure 9. Comparison of hydrograph patterns for WSC gauges 07QD007 and the estimated inflows between gauge 07QD007 and Tsu Lake. 23

Figure 10. Estimated inflows: a) for Nonacho Lake; b) from Tethul and Rutledge Rivers; and c) from watersheds between Nonacho Lake and Tsu Lake. Panels a) and b) also show flows measured in Taltson River above Porter Lake outflow (at WSC gauge 07QD004) and in Tazin River near its confluence with Taltson River (at WSC gauge 07QC007), respectively. 25

Figure 11. a) Simulated and observed water levels in Nonacho Lake. b) Simulated and observed flow in Taltson River downstream of the Taltson Hydro Generating Station (at the WSC gauge 07QD007). c) Simulated and observed water levels in the Twin Gorges Forebay. 26

LIST OF TABLES

Table 1. WSC gauges from which data were obtained for the TRB HEC-ResSim model. "Model Version" denotes the version of the model that used data from each gauge; 2008 refers to the version described in Rescan (2009), 2014 refers to the previous model update (Imam *et al.,* 2015), and 2020 refers to this model update..10

Table 2. Location and period of the pan evaporation record for climate stations at Yellowknife and Cluff Lake. 10

Table 3. Distribution of total inflow estimated for the watersheds between Nonacho Lake and the WSC gauge below the Taltson Hydro Generating Station (gauge 07QD007). The inflow from Tazin River is excluded from this table and inflow accounted for separately. 18

LIST OF MAPS

Map 1. Taltson River Basin...3

Map 2. Overview of the Twin Gorges Forebay. 6

1. INTRODUCTION

The Taltson Hydro Generating Station is an 18 MW hydroelectric facility located within the Taltson River basin, 56 km northeast of Fort Smith in the Northwest Territories (Map 1). The facility was built in 1965 to supply electricity to the Pine Point Mine. In 1968, a dam was built at the outlet of Nonacho Lake to regulate flow to the Generating Station forebay and satisfy the demand for power production during peak season in winter. By the mid 1980's, the Pine Point Mine was exhausted and was closed in 1986. Following the mine closure, the Taltson Hydro Generating Station continued to supply power to the communities of Hay River, Hay River Reserve, Fort Smith, Fort Resolution, and Enterprise. In 1988, the ownership and operation of the Taltson Hydro Generating Station were transferred to the Northwest Territories Power Corporation (NTPC) which continues to operate the Generating Station to the present time (Dezé 2007).

Between 2006 and 2008, a reservoir-operation model was set up for the Taltson River basin. This model, the Taltson River Basin HEC-ResSim model (TRB model), was used to assess the effect of increasing the capacity of the Taltson Hydro Generating Station on the flow in the Taltson River. The development and application of the model was part of an environmental effects assessment for a proposal to expand the existing facility (Dezé 2007). At the time, the Dezé Energy Corporation proposed to increase the capacity of the existing facility by 56 MW. The proposed expansion project was not implemented.

In 2012, the water license for the existing 18 MW station was renewed for 15 years (Water Licence MV2011L4-0002). The new license is subject to an Aquatic Effects Monitoring Plan (AEMP) which, in part, requires updating the TRB model and eventually using the updated model to assist with an assessment of the permitted water levels and flows.

In summary, the AEMP requires the following two tasks for the TRB model:

1. **Taltson HEC-ResSim hydrologic modelling update:** Continual updates to the existing TRB HEC-ResSim Hydrologic model to incorporate data from recently installed hydrometric gauges.
2. **Nonacho Lake and Lower Taltson River flow analysis:** Use the updated TRB HEC-ResSim model to determine the appropriateness of permitted water levels and flows in the Nonacho Lake and Twin Gorges reservoirs.

The task of updating the TRB model is scheduled for 2013, 2014, 2019, and 2024. In 2015, water levels in the Twin Gorges and Nonacho Lake reservoirs were reviewed and compared to the permitted levels, as described in Water License MV2011L4-0002, which limits water levels to the historic high-water mark. The updated TRB HEC-ResSim model will be used to confirm that water levels and flows identified in Water License MV2011L4-0002 (conditions C.2, C.3, and C.4) are appropriate.

The main objective of this report is to document the updates that were completed in 2020 for the TRB model. These updates include:

- Integrating new finalized data from hydrometric gauges operated by Water Survey Canada (WSC) through 2018; and
- Applying the TRB model to simulate reservoir operations for a more recent time period (compared to the previous version of the model).

Following this, the next objective of this report is to use this model update to assess the existing permitted water levels and flow in Nonacho Lake and the Twin Gorges reservoir and determine appropriateness of these values.

The report is structured as follows. First, brief descriptions are provided on the study site and the 2014 version of the TRB model (Section 2.1 and 2.2). This overview is followed by a description of the methods used in updating the model in 2020 (Sections 2.3 to 2.7). The results section (Section 3) presents the inflows estimated for the model, compares model output to observations, and assesses model performance. Finally, the model uncertainties are discussed with conclusions and recommendations (Sections 4 and 5).

NORTHWEST TERRITORIES POWER CORPORATION
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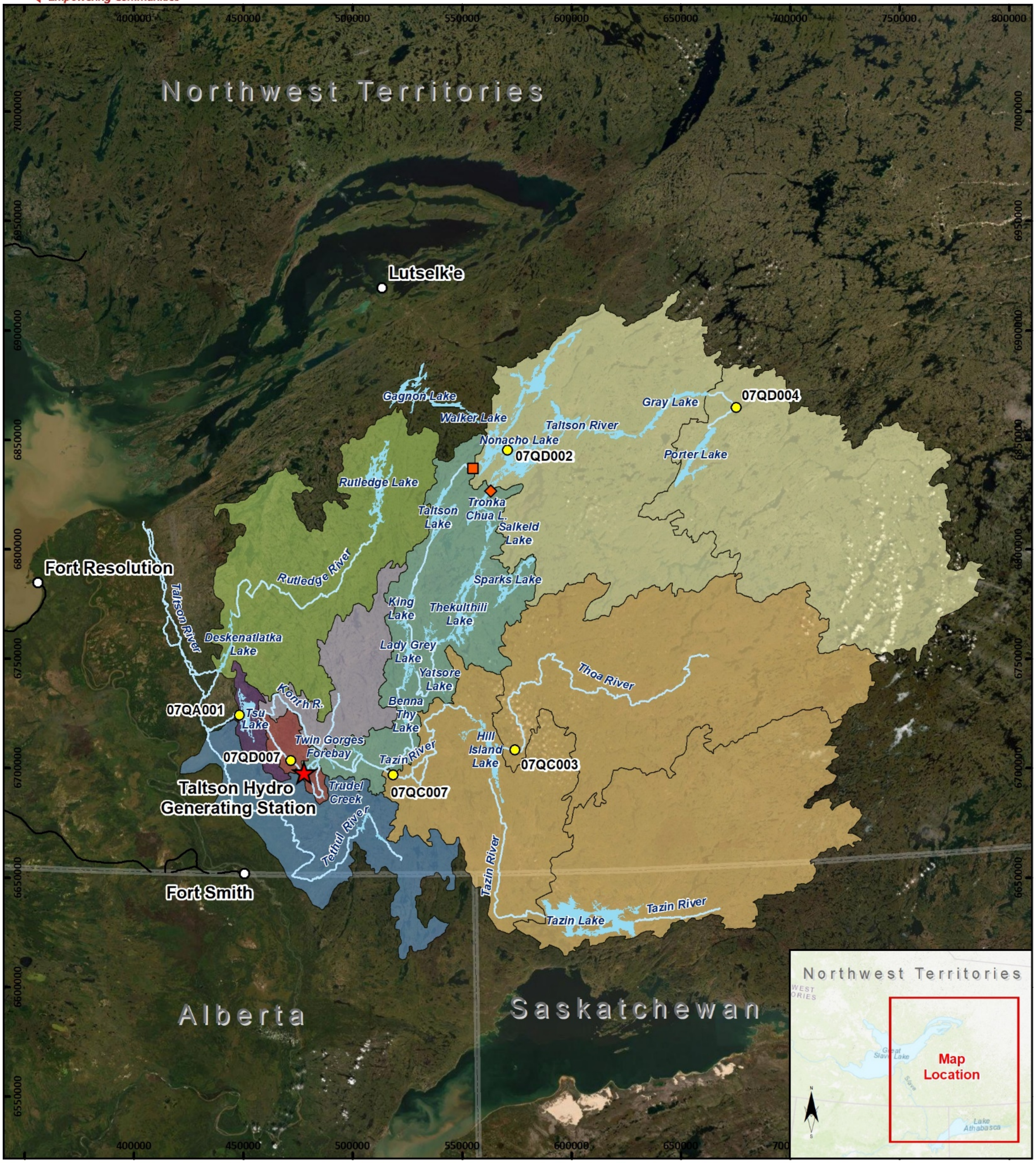
Taltson River Basin



Legend

Watersheds
- Konth River
- Nonacho Lake
- Rutledge River
- Taltson River
- Tazin River
- Tethul River
- Trudel Creek
- Tsu Lake

- WSC Gauge
- Community
- Project Location
- Nonacho Lake Dam
- Tronka Chua Gap

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 20 40 60 80 100 km

Scale: 1:2,500,000

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Coordinate System: NAD 1983 UTM Zone 12N

ECOFISH RESEARCH

Map 1

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2. METHODS

2.1. Study Site

A full description of the Taltson River basin can be found in Rescan 2001, 2006, and 2009 and in Dezé 2007. A brief description is given here to facilitate the presentation of the TRB model updates. The description given here is adapted from the above-mentioned references.

The Taltson River drains a watershed area of ~80,000 km^2 (National Hydro Network). The Taltson River starts in the east part of the watershed and flows northwest for ~210 km before entering Nonacho Lake which is the largest lake in the watershed (Map 1). The water level in Nonacho Lake is controlled by a rock-fill dam built in 1968. Water flows out of Nonacho Lake over the spillway of the dam and through three control gates installed at the dam. When the water level in Nonacho Lake rises above ~322.6 m above sea level (masl), additional outflow from Nonacho Lake occurs through a natural, ~40 m wide depression in the lake side known as the Tronka Chua gap (Map 1). Downstream of the Nonacho Lake Dam, the Taltson River flows through a series of lakes including Taltson Lake, King Lake, and Lady Grey Lake (Map 1). These three lakes have surface areas of 105 km^2, 29 km^2, and 74 km^2, respectively. For the Tronka Chua gap, its outflow re-enters the Taltson River after flowing southward for ~150 km through a series of lakes including Tronka Chua Lake and Thekulthili Lake which have surface areas of 62 km^2 and 187 km^2, respectively.

Downstream of Lady Grey Lake, the Taltson River flows for ~100 km before entering the forebay of the Taltson Hydro Generating Station. Along this reach, the Taltson River flows through relatively small lakes including Benna Thy Lake which has a surface area of 28 km^2. About ~35 km downstream of Benna Thy Lake, the Taltson River receives inflow from the Tazin River. The catchment area drained by the Tazin River is about 58% of the Taltson River watershed above the Taltson Hydro Generating Station; however, water from ~35% of the Tazin River catchment is diverted out of the watershed and does not flow into the Taltson River.

Water stored in the Twin Gorges forebay is released downstream through two outlets (Map 2). The first outlet releases up to 74 m^3/s through the Taltson Hydro Generating Station. Flow through the station is withdrawn from the Twin Gorges forebay through a gated intake, passes through the generating station penstock, powerhouse, and tailrace, and is released in Taltson River ~1.5 km upstream of Elsie Falls (Map 2). The second outlet for the Twin Gorges forebay is the South Valley Spillway which has no control gates and discharges water into Trudel Creek. The local catchment for Trudel Creek has a small area of 134 km^2 and the creek forms a ~30 km loop that re-joins the Taltson River downstream of Elsie Falls (Map 2).

Downstream of Elsie Falls, Taltson River continues for ~35 km to Tsu Lake and then 130 km to Great Slave Lake, the downstream boundary for the TRB model. Along this reach, three main tributaries enter Taltson River including Konth River, Tethul River, and Rutledge River which have catchment areas of ~2,180 km^2, 4,410 km^2, and 7,450 km^2, respectively (Map 1).

ECOFISH RESEARCH

2.2. Model Description

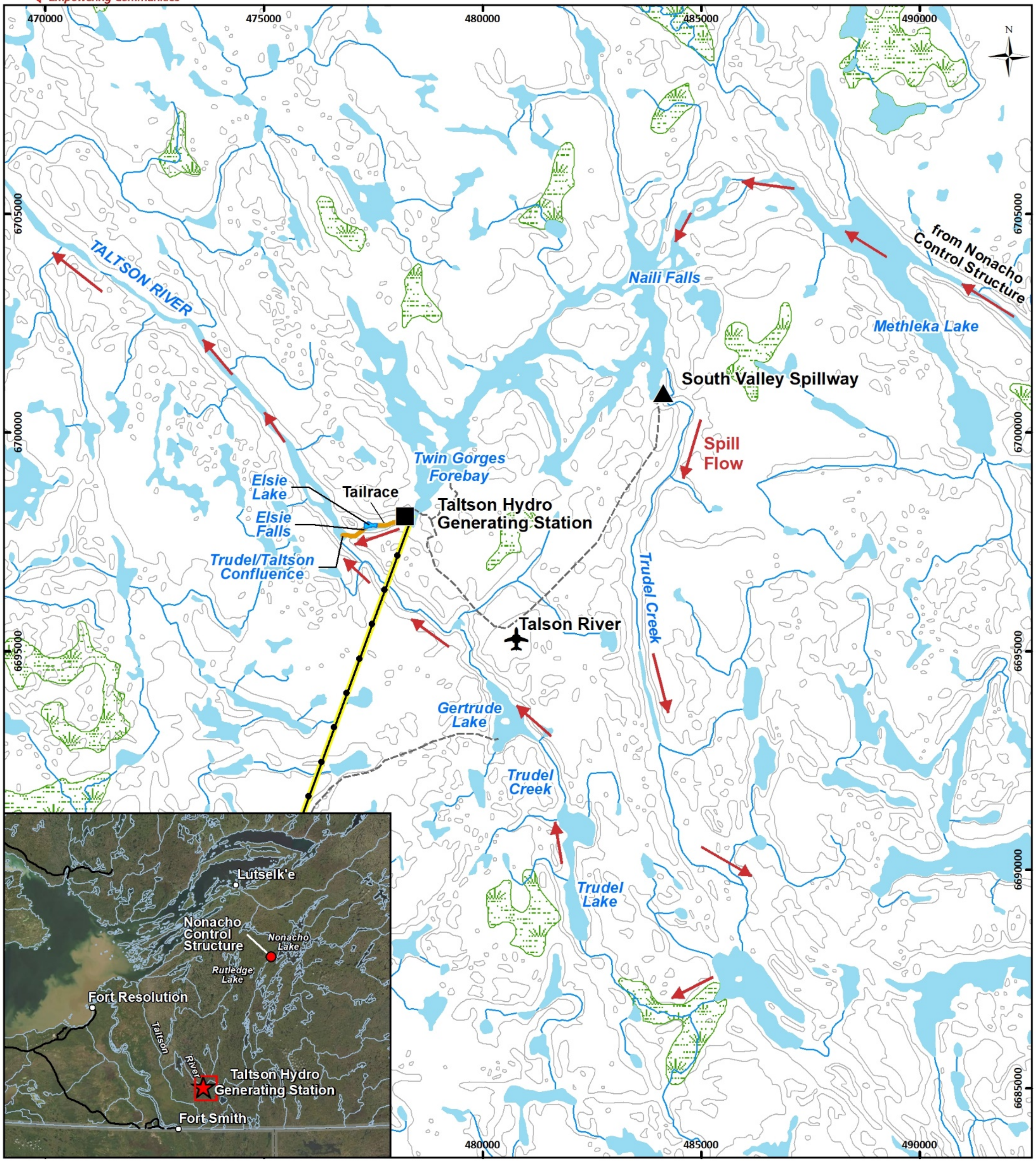
The TRB model was developed in 2006 and was updated in 2007 and 2008 (Rescan 2009), and by Ecofish in 2014. The TRB model was developed using the HEC-ResSim software package.

HEC-ResSim is developed by the United States Army Corps of Engineers and is widely used for simulating reservoir operations. Tributary inflows are estimated and entered into HEC-ResSim software which routes the flow through the river reaches, lakes, and reservoirs that are included in the model domain. For lakes and reservoirs, flow routing is done using elevation-storage relationships and elevation-outflow relationships. Outflow from hydroelectric power stations is simulated based on electric power demand and station capacity. For river reaches, flow routing is done with hydrologic routing methods that account for travel time and attenuation of flood waves.

As indicated above, the TRB model was developed in 2008. Figure 1 shows the configuration used for the 2008 version of the model, and the 2014 model update. The same configuration is used for the model update in 2020. The modelled domain covers Taltson River from Nonacho Lake to Great Slave Lake and is divided into five zones downstream of Nonacho Lake (Figure 1). Zone 1 extends from the dam of Nonacho Lake to the confluence of Taltson River with Tazin River. Zone 2 extends from the Tronka Chua gap to where the flow from the gap re-enters Taltson River at Lady Grey Lake. Zone 3 starts at the confluence of Taltson and Tazin Rivers, includes the Twin Gorges forebay, and ends at Tsu Lake. Zone 4 extends from Tsu Lake to Great Slave Lake. Zone 5 extends over Trudel Creek from the South Valley Spillway to the confluence with Taltson River flowing over Elsie Falls.

Input to the TRB model included the inflow to Nonacho Lake, inflows from watersheds between the outlet of Nonacho Lake and Tsu Lake, and inflows from Tethul River and Rutledge Rivers. Evaporation was estimated by applying average evaporation rates to each lake in the model. The evaporation rates used in 2020 are unchanged from 2014, as explained further in Section 2.4.2. In this model, estimated inflows for local watersheds represent the net of surface runoff, direct precipitation, and the difference between actual and average evaporation.

Project Overview



Legend

- Runway
- South Valley Spillway
- Taltson Powerhouse
- Tailrace
- Transmission Line
- Road
- Contour (20 m)
- Wetland

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 0.5 1 2 3 4 km

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Map 2

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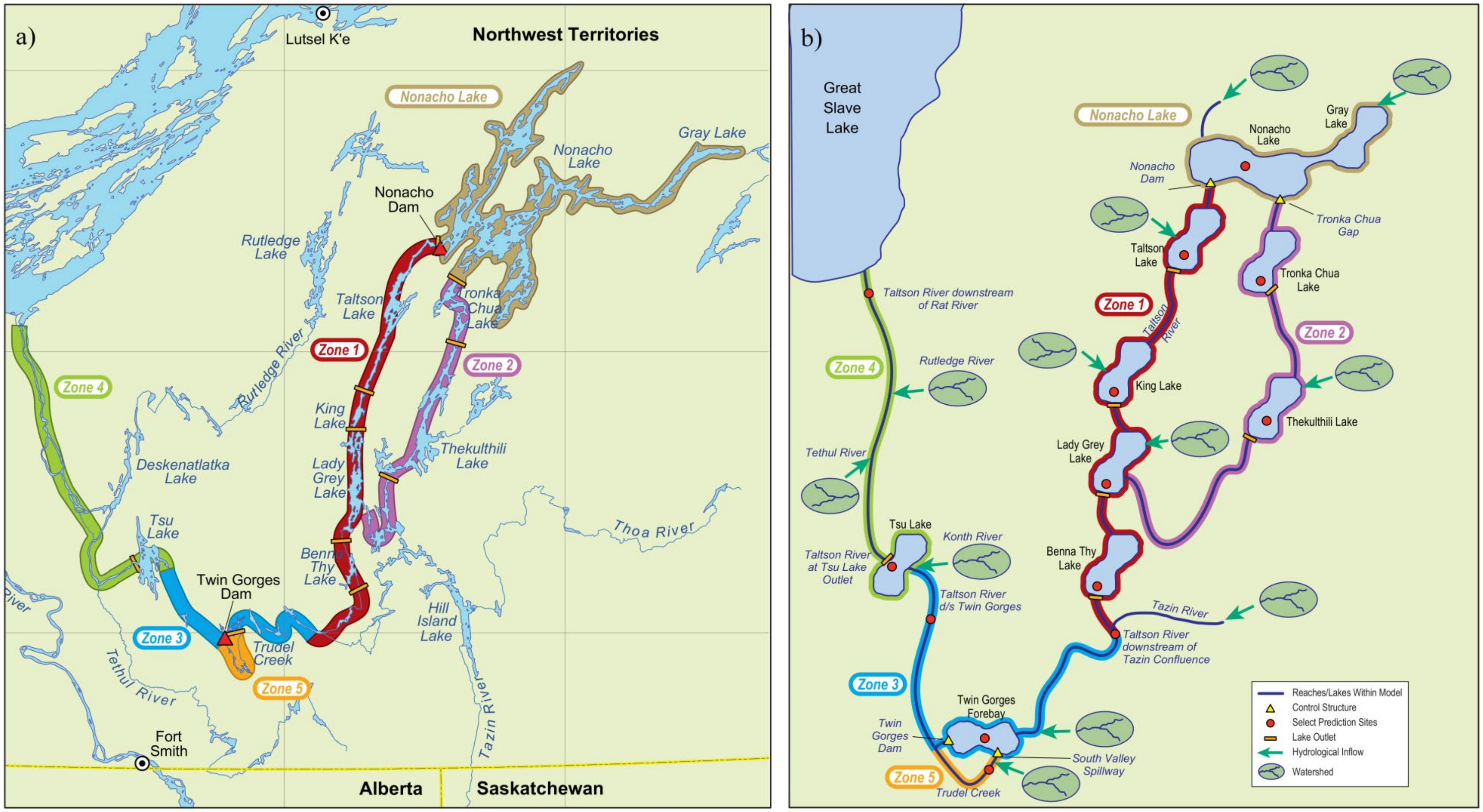
Figure 1. **a) The Taltson River Basin. b) The HEC-ResSim model representation of the Taltson River Basin. This figure is reproduced from Rescan (2009).**



2.3. Flow and Water Level Data

The TRB model was last updated by Ecofish in 2014. The simulations in the 2014 version covered a period of ~6.5 years from July 2007 to December 2013. These simulations were based on flow and water level data from four WSC gauges; 07QD002, 07QD004, 07QD007, and 07QC007 (Map 1 and Table 1). Data from stations 07QA001 and 07QC003 were used for the original 2008 version but monitoring at these stations was discontinued before 2007, the modelling period for the 2014 update. The simulations in the first version (2008) of the model covered the period from 1978 to 1990. The available data for the period from 1991 to 2006 were not sufficient for estimating inflows to the Taltson River.

The three stations considered for the updated model are 07QD002, 07QD007 and 07QC007 (Map 1 and Table 1). Although data from gauges 07QA001 and 07QD004 were used in previous iterations of the model, data were not available at these gauges for the 2014 to 2018 period. For the model inputs described in Table 1, only finalized data provided by WSC were used in this model update and finalized data at these gauges were only available up to December 31, 2018.

Gauge 07QD002 is located in Nonacho Lake (Map 1). As will be explained in Section 2.4.1, the daily water level record for this gauge was used in the TRB model to route flow through Nonacho Lake. The recorded water level was referenced to a local datum and was adjusted to mean sea level by adding 317.03 m (Rescan 2009). The water level record was 100% complete and did not feature any gaps (Figure 3a).

Gauge 07QD004 is located upstream of Nonacho Lake above the outflow of Porter Lake (Map 1). In the 2014 version of the model, daily flow data from this gauge were used to estimate inflows from the Tethul and Rutledge rivers and to assess the accuracy of inflow estimated for Nonacho Lake. Between January 2014 and December 2018, data at this gauge were only available for the year 2014 as WSC discontinued monitoring at this site. NTPC does not have any control over the removal of this station as it is solely managed by WSC. Due to this significant lack of data, this gauge could no longer be used to estimate Tethul and Rutledge inflows therefore, it was not used in this model update, and an alternate methodology for estimating these inflows was used (Section 2.4.3).

Gauge 07QD007 is located ~10 km downstream of the Taltson Hydro Generating Station (Map 1). As will be explained in Section 2.4.2, daily flow data from this gauge were used to estimate inflows to the Taltson River between Nonacho Lake and Tsu Lake (other than Tazin River). Gaps in the record were limited to 2.8% and were filled using linear interpolation (Figure 3b).

Gauge 07QC007 is located on Tazin River upstream of its confluence with Taltson River (Map 1). The daily flow at gauge 07QC007 is representative of the inflow from the Tazin River watershed to the Taltson River. Gaps in the record were limited to 1.2% and were filled using linear interpolation (Figure 3b).

In addition to the data from the WSC gauges, data for the Taltson Hydro Generating Station were available from NTPC and were used in the TRB model as explained in Section 2.5. The data from

NTPC included daily water level in the forebay, daily water level in the tailrace, and daily electric power output from the Taltson Hydro Generating Station (Figure 4). The water level data were referenced to a local datum used by NTPC and adjusted to mean sea level by adding 8.43 m (Rescan 2009) for use in the TRB model.

Data for Nonacho Lake were also provided by NTPC and included daily gate settings, gate outflow, leakage flow, spill flow, and Tronka Chua Gap flow (Figure 2). These operational data are based on provisional data at WSC gauge 07QD002 and thus may differ from the values calculated by the TRB model which used final WSC gauge data. As described in Section 2.4.1, the TRB model simulated these values based on existing stage-discharge relationships in the model and applied the gate settings as provided by NTPC. Data from the WSC gauges undergoes a quality assurance process before being finalized and published by WSC, NTPC does not have any control of the WCS quality assurance process and uses the data as provided. NTPC reviews generation data on a monthly basis when plant meter readings are calculated for comparison to hourly data as part of operational and water licence reporting.

Average evaporation losses from lakes on Taltson River downstream of Nonacho Lake were accounted for in this model update using the same methodology that was applied in 2014. Monthly-average lake evaporation was obtained from two climate stations operated by Environment Canada. The two stations were the Yellowknife climate station located ~285 km northwest of the Twin Gorges forebay, and the Cluff Lake climate station located in Saskatchewan ~245 km southeast of the Twin Gorges forebay (Table 2). Monthly-average lake evaporation for these two stations was estimated by Environment Canada based on pan evaporation, air temperature, water temperature, and wind run data collected between 1981 and 1998 (Table 2 and Figure 5). Further information about how this evaporation data was applied is provided in Section 2.4.2.

Table 1. WSC gauges from which data were obtained for the TRB HEC-ResSim model. "Model Version" denotes the version of the model that used data from each gauge; 2008 refers to the version described in Rescan (2009), 2014 refers to the previous model update (Imam *et al.,* 2015), and 2020 refers to this model update.

Station ID	Station Name	Geographic Coordinates		Period of Record	Watershed Area† (km²)	Model Version
		Latitude	Longitude			
07QA001	Taltson River at Outlet of Tsu Lake	60°38'59" N	111°56'49" W	1952 to 1954, 1962 to 1997	58,700 (49,300)	2008
07QD007	Taltson River Below Hydro Dam	60°28'01" N	111°30'45" W	1994 to 2018	55,500 (46,100)	2014, 2020
07QC007	Tazin River Near the Mouth	60°24'30" N	110°39'52" W	2007 to 2018	26,800 (17,400)	2014, 2020
07QD002	Nonacho Lake near Lutsel K'e	61°44'1" N	109°39'40" W	1962 to 2018	11,279	2008, 2014, 2020
07QD004	Taltson River above Porter Lake Outflow	61° 52' 34" N	107° 39' 56" W	1977 to 1991, 2007 to 2014	9,660	2008, 2014
07QC003	Thoa River near Inlet to Hill Island Lake	60° 30' 18" N	109° 38' 56" W	1968 to 1995	8,830	2008

† Flow from an area of ~9,400 km^2 is diverted out of the Taltson River Basin. The flow diversion is from the southern part of the Tazin River watershed. For the gauge in the Tazin River and the downstream gauges, numbers between parentheses represent the effective watershed area which exclude the area from where flow is diverted.

Table 2. Location and period of the pan evaporation record for climate stations at Yellowknife and Cluff Lake.

Station	Location			Record†			
	Latitude (N)	Longitude (W)	Elevation (masl)	Start Year	End Year	Number of Missing Years	Observations Count
Yellowknife	62°27'46"	114°26'25"	205.7	1981	1996	2	1,736
Cluff Lake	58°22'00"	109°31'00"	330.1	1981	1998	6	2,066

† Canadian Climate Normals 1981–2010, Environment Canada.

Figure 2. Nonacho Lake raw data provided by NTPC.

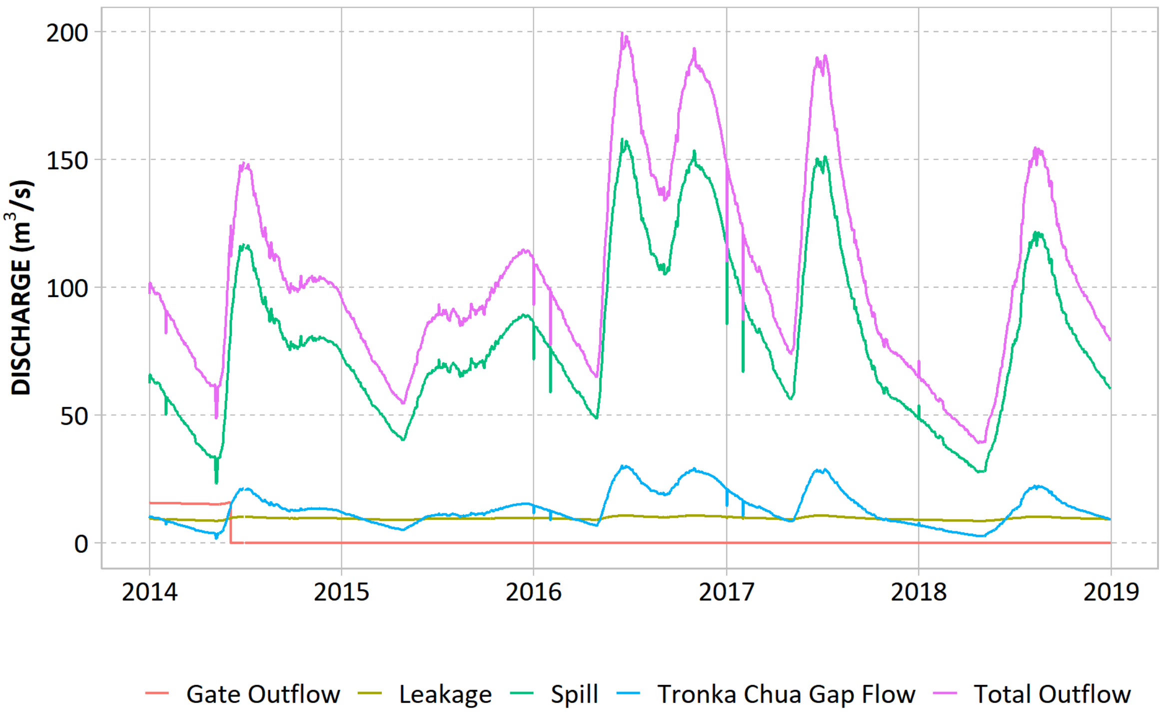


Figure 3. a) Water level and b) flow for WSC gauges in the Taltson River basin. Thick black-coloured line segments indicate missing data that were estimated for the TRB HEC-ResSim model.

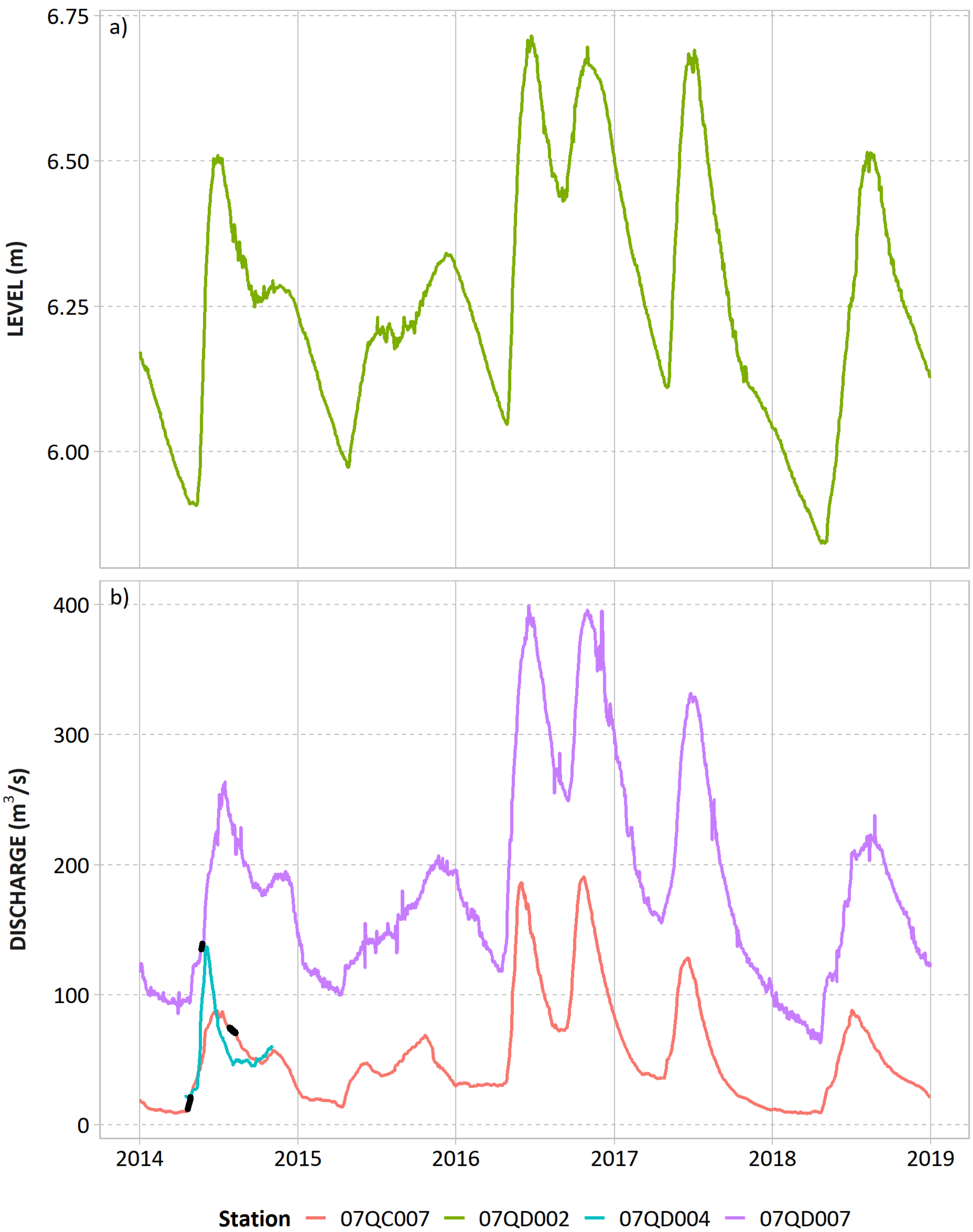


Figure 4. **a) Daily water level in the Twin Gorges Forebay, b) daily water level in the tailrace of the Taltson Hydro Generating Station, and c) daily power output from the Taltson Hydro Generating Station.**

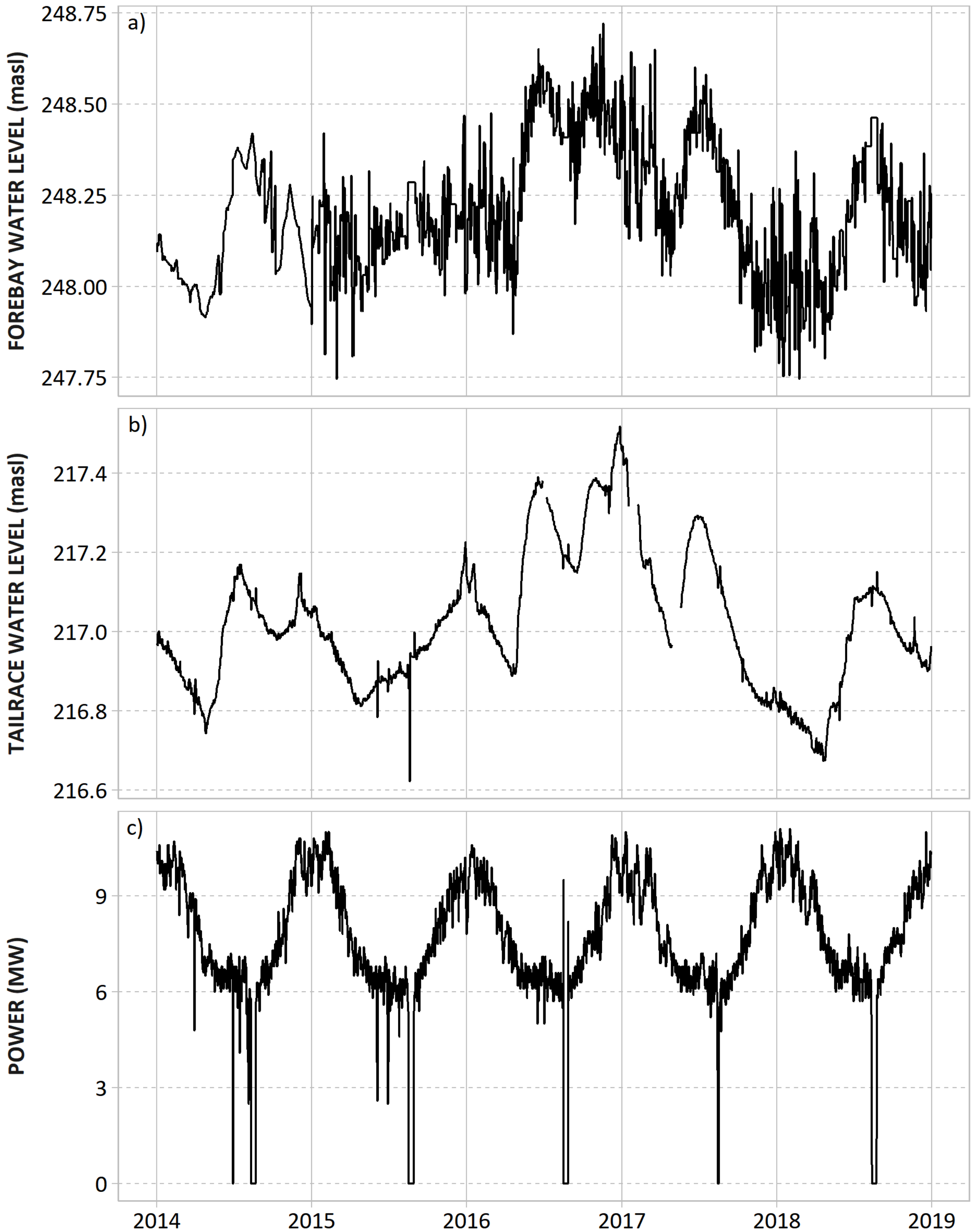
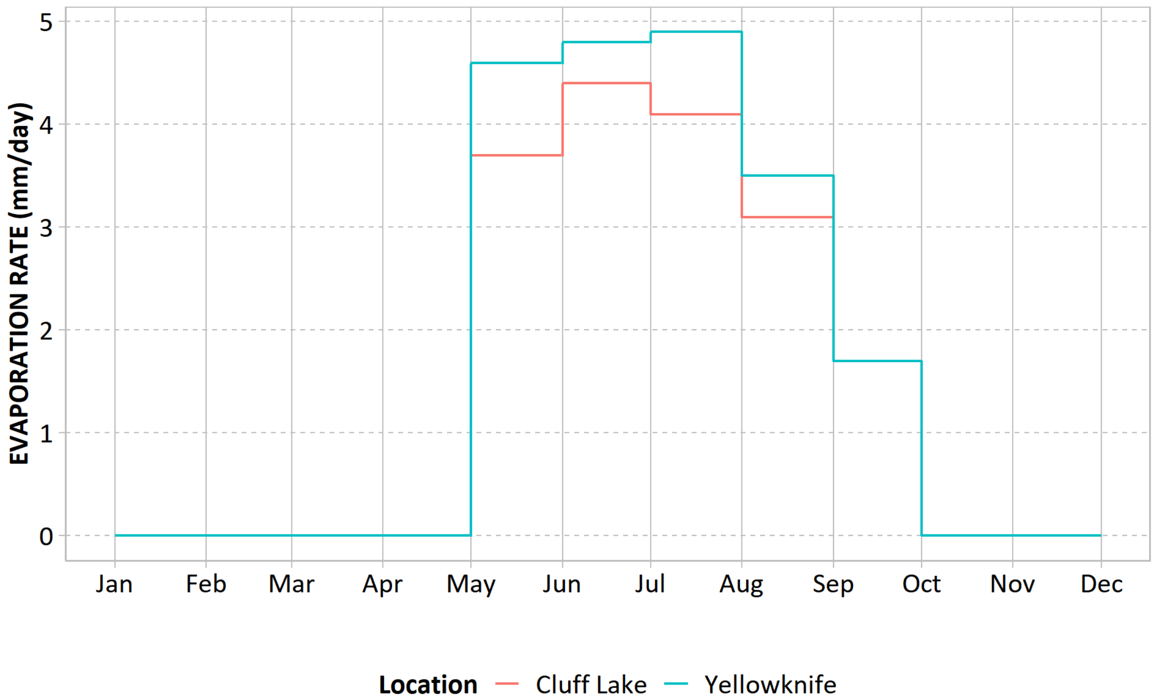


Figure 5. Monthly-average evaporation rate at the Environment Canada climate stations at Yellowknife and Cluff Lake.



2.4. Estimation of Inflows

2.4.1. Inflow to Nonacho Lake

The TRB model requires the inflow to Nonacho Lake. The lake inflow was estimated using reverse routing of outflow from the lake, with the same methodology used in Imam *et al.* (2015). For reverse routing, lake outflow and storage were determined from water level measured in Nonacho Lake at gauge 07QD002 (Map 1 and Figure 3a). Outflow and storage were based on the existing relationships in the TRB model for water level versus outflow and water level versus storage. Operations of the three gates at the control structure of Nonacho Lake were accounted for in determining the outflow from the lake (Figure 7).

To obtain the inflow to Nonacho Lake, reverse routing of the outflow was calculated using the modified Puls method (also known as the level pool method):

$$\frac{dS}{dt} = I - O \tag{1}$$

where S is the storage in Nonacho Lake, I is the inflow to the lake, O is the outflow from the lake, and t is time. In Equation 1, storage and outflow are functions of the water level and outflow is also a function of the setting of the control gates (Figure 7). Evaporation from Nonacho Lake was included in the inflow term I; this term represents the actual inflow to Nonacho Lake less the evaporation mass flux.

Equation 1 was solved numerically outside of HEC-ResSim using a time step $\Delta t = 1$ day, the same time step used in the TRB HEC-ResSim model. For the numerical solution, the derivative of storage with time in Equation 1 was approximated by a 6th order finite difference discretization to get:

$$I(t) = O(t) + \frac{1}{60 \times \Delta t} \times \Big\{45 \times [S(t+\Delta t) - S(t-\Delta t)] \\ -9 \times [S(t+2\Delta t) - S(t-2\Delta t)] \\ +[S(t+3\Delta t) - S(t-3\Delta t)]\Big\} \tag{2}$$

The solution of Equation 2 produced high frequency oscillations, which is expected for reverse flow routing schemes when the water level record that is used to determine outflow and storage contains noise due to surface waves, surface seiches, or measurement errors (Zoppou 1999, D'Oria *et al.* 2012). To remove the high frequency oscillations, the estimated inflow determined from Equation 2 was smoothed by applying a centered moving-average filter with a window of 1 month (precisely 31 days). To assess the reliability of the inflow estimated for Nonacho Lake, the inflow was compared to the flow record from gauge 07QD004, which is located on the Taltson River upstream of Nonacho Lake above the Porter Lake outflow, for the brief period of available data (April-November 2014) (Map 1). The patterns of increasing and decreasing flow present in the estimated inflow showed good agreement with the patterns observed at gauge 07QD004, suggesting the inflow was providing a reasonable estimate (r = 0.88, Figure 6).

Figure 6. Comparison of increasing/decreasing flow trends between smoothed estimated inflow from Equation 2 and Gauge 07QD004.

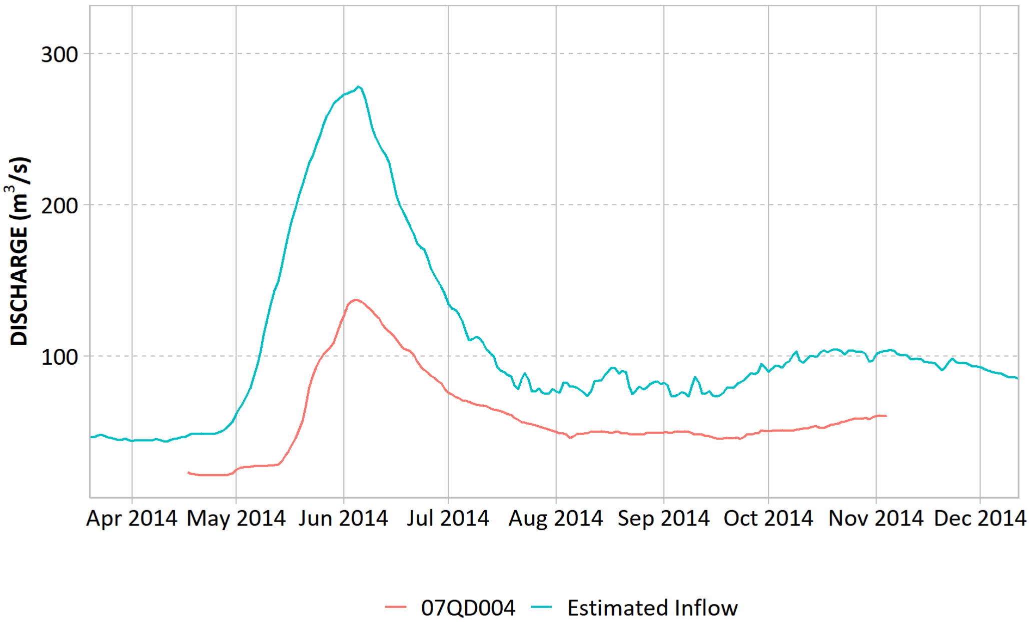
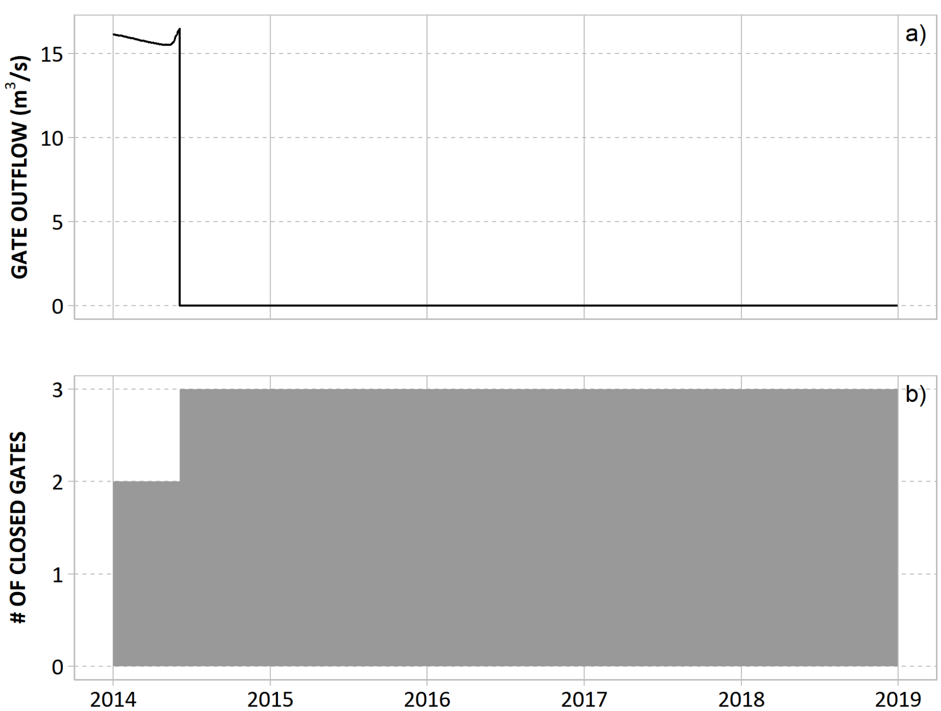


Figure 7. Gate outflow a), and gate setting b) for the Nonacho Lake dam during 2014-2018.



2.4.2. Inflow from Watersheds between Nonacho Lake and Tsu Lake

The Taltson River reach between Nonacho Lake and Tsu Lake receives flow from watersheds with a total area of ~58,700 km^2. These watersheds include the ~27,000 km^2 Tazin River watershed, smaller watersheds draining ~6,000 km^2 between Nonacho Lake and gauge 07QD007, and watersheds draining ~3,000 km^2 between gauge 07QD007 and the outlet of Tsu Lake (including the Konth River watershed). Inflows from these watersheds were estimated as follows. For the Tazin River watershed, inflow to Taltson River was obtained from the flow record at gauge 07QC007 which is located near the mouth of Tazin River (Section 2.7, Figure 3b). For the remaining watershed area of ~6,000 km^2 between Nonacho Lake and gauge 07QD007, inflow from this area was estimated by comparing the flow simulated with HEC-ResSim (with inflow in this section set to 0) downstream of Twin Gorges to the flow observed at gauge 07QD007. The methodology described here is unchanged from Imam *et al.*, 2015.

The differences between the observed and simulated flows were smoothed by applying a moving average filter with a window of 31 days and the smoothed flow record was taken to represent the inflow from the ~6,000 km^2 watershed. This inflow was divided and entered to the model at nine locations between Nonacho Lake and gauge 07QD007. The inflow was distributed over these nine locations in proportion to the watershed areas that drain to these locations (Table 3) (Rescan 2009).

It should be noted that the flow observed at gauge 07DQ007 was compared to simulated flow at a location ~8 km downstream of the gauge. This location downstream of the gauge corresponded to a computational node in the HEC-ResSim model. Adding a computational node at the gauge was avoided because the TRB model uses the Muskingum method to route the Taltson River flow from Elsie Falls to the existing computation node. The Muskingum method uses two parameters; the weighting factor X which determines the amount of attenuation and the storage time constant K which represents the travel time of flood waves if there is no attenuation $(X = 0.5)$. Because the TRB model uses a daily-time step ($\Delta t =$ 24 hr) and a Muskingum weighting factor of $X = 0.5$, the Muskingum method in the TRB model should be applied to route flow in channels with a storage time constant $K \sim \Delta t$ to obtain accurate results (McCuen 1998). The channel between Elsie Falls and gauge 07QD007 is short with $K =$ 5.4 hr $\ll \Delta t$ and the model cannot be reliably applied to route flow through this short channel. Overall, the effect of comparing the flow observed at gauge 07DQ007 to flow simulated slightly downstream of the gauge is likely negligible.

The inflow for the watershed area of ~3,000 km^2 between gauge 07QD007 and the outlet of Tsu Lake (including the Konth River watershed) was obtained by scaling the flow estimated above for the ~6,000 km^2 area using a factor of 0.53. The method used here to estimate the inflows from watersheds between Nonacho Lake and Tsu Lake is consistent with the method used in the 2014 version of the model.

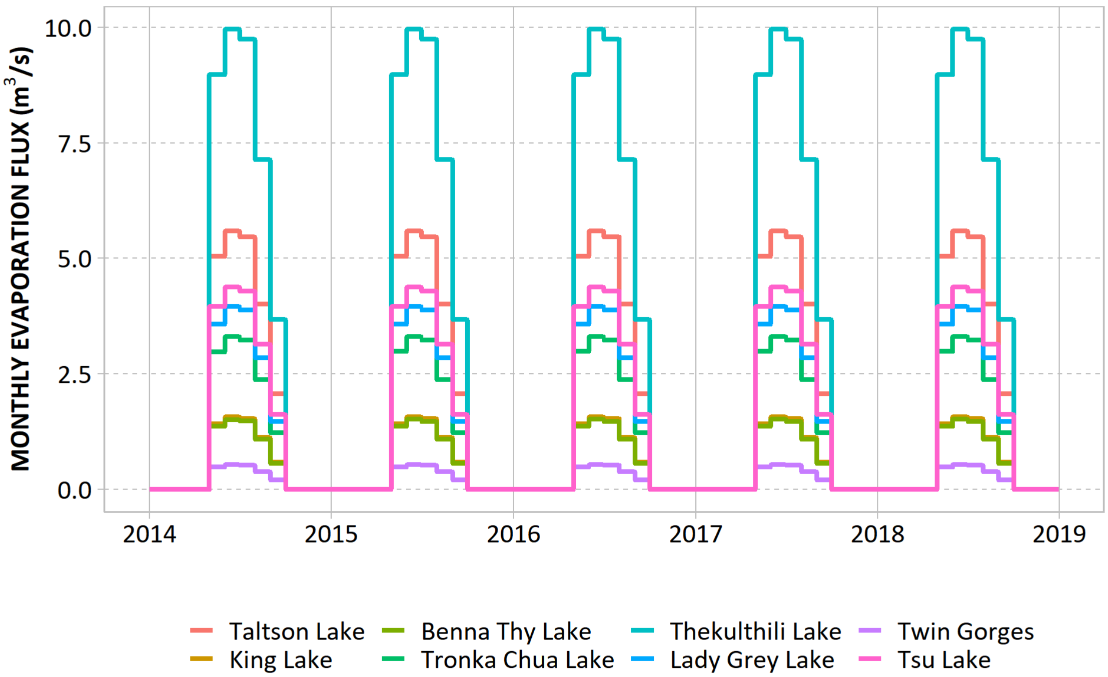
As in the 2014 version of the model, evaporation losses downstream of Nonacho Lake were partly accounted for using monthly-average evaporation rates for the Environment Canada climate stations at Yellowknife and Cluff Lake. The mean of the monthly-average evaporation rates for these two stations was computed and assumed to represent the average evaporation rate for the lakes downstream of Nonacho Lake including Taltson Lake, King Lake, Lady Grey Lake, Benna Thy Lake, Tronka Chua Lake, Thekulthili Lake, the Twin Gorges forebay, and Tsu Lake. To compute the evaporation flux from each of these lakes, the average evaporation rate for each month was multiplied by the corresponding lake area (Figure 8).

Deviation of actual evaporation from this average flux was implicitly accounted for when estimating inflows by comparing observed and simulated flow at the WSC gauge 07QD007 (Rescan 2009). These estimated inflows represent runoff after removal of the average evaporation mass flux; inflows would be underestimated if actual evaporation exceeds average evaporation and would be overestimated if actual evaporation is lower than average evaporation.

Table 3. Distribution of total inflow estimated for the watersheds between Nonacho Lake and the WSC gauge below the Taltson Hydro Generating Station (gauge 07QD007). The inflow from Tazin River is excluded from this table and inflow accounted for separately.

Location for Inflow	Inflow (%)
Taltson Lake	9.9
King Lake	9.9
Lady Grey Lake	9.9
Benna Thy Lake	5
Tronka Chua Lake	5
Thekulthili Lake	29.8
Taltson River below Tazin Riv	10
Twin Gorges	19.9
Trudel Creek	0.6

Figure 8. Monthly-average evaporation applied to the lakes downstream of Nonacho Lake.



2.4.3. Inflows from Tethul and Rutledge Rivers

Previous versions of the TRB model used WSC gauges 07QC003 or 07QD004 to estimate inflows from the Tethul and Rutledge Rivers. Due to the lack of data available at these gauges for the 2014-2018 period covering this model update, Tethul and Rutledge inflows were estimated using a different approach. Conceptually, the approach used here is similar to previous approaches where flow is scaled by the ratio of corresponding watershed areas. The key difference is that in this model update, the estimated Nonacho inflows were used as the flows to be scaled.

For scaling the estimated Nonacho inflows (described in Section 2.4.1), a multiplier of 0.39 was used to estimate Tethul River inflow and a multiplier of 0.66 was used to estimate Rutledge River inflow. These multipliers are equal to the ratio of the watershed area for the Tethul and Rutledge Rivers (4,410 km^3 and 7,450 km^3, respectively) and the watershed area for Nonacho Lake (11,279 km^3, Table 1). This new methodology was compared to the previous approach used in 2014 by applying it to the previous 2007-2013 period. It should be noted that the updated method used in this model update resulted in increased inflows from the Tethul and Rutledge Rivers. The accuracy of the previous method is expected to be higher given the similarity in drainage area and lake cover, but this cannot be confirmed given the absence of validation data for Tethul and Rutledge Rivers. Using the Tazin River 07QC007 gauge for drainage area proration was also attempted, however, a cursory validation of this method using historical Nonacho Lake above Porter Lake flow data (07QD004) suggested an unrealistic flow ratio inconsistent with the corresponding drainage areas.

The inflow from Konth River to Taltson River could be estimated using the same method for Tethul and Rutledge Rivers. The Konth River watershed is 19% of the watershed area above Nonacho Lake. The inflow from Konth River, however, was estimated using the method described in Section 2.4.2 for consistency with the 2008 and 2014 versions of the TRB model which assumed that the Konth River watershed generated the same flow per unit area as other watersheds between Nonacho Lake and Tsu Lake.

2.5. Taltson Hydro Generating Station Outflow

The TRB model accounts for outflow from the Taltson Hydro Generating Station. The model determines outflow from the station based on the demand for electric power, operating efficiency, and the hydraulic head given by the difference in water level between the Twin Gorges forebay and tailrace. The demand for electric power was obtained from the station power output measured by NTPC, as will be explained in Section 2.7. NTPC follows industry-standard practice to calculate flow through the turbine based on the manufacturer's rating of the turbine and the geometry of the plant structures. Records of the input values and calculated flows are maintained by NTPC and reported under the requirements of the water licence.

Water level in the Twin Gorges forebay was simulated by the model based on the water budget of the forebay (Equation 1). Water level in the tailrace was set to a constant value of 217.02 m which represents the average of the water levels measured between January 2014 and December 2018 (Figure 4b). The tailrace water level of 217.02 m is slightly higher than the value of 216.9 m used for the tailrace water level in the 2014 version of the TRB model (Imam *et al.*, 2015). With a constant tailrace water level of 217.02 m, the hydraulic head ranged between 30.7 m and 31.7 m with an average value of 31.2 m. Compared to the variable tailrace water level, the error in estimating the hydraulic head with the constant water level of 217.02 m ranged between -0.5 m and +0.4 m. The corresponding error in estimating the outflow from the generating station ranged between -0.78% and +0.22% of the outflow computed with the measured tailrace water level. These errors are negligible, and the assumption of constant tailrace water level has little effect on the simulated outflow from the generating station.

The efficiency of the Taltson Hydro Generating Station was set to a constant value of 72% (as in the 2014 version of the model), which is lower than the efficiency of 80% used in the 2008 version of the model (Rescan 2009). The efficiency of 80% corresponds to the full capacity of the station which is rated at 18 MW. The station, however, operates at a lower capacity, between ~6 MW in the summer and ~10 MW in the winter (Figure 4c), and station efficiency is lower than 80% for these low power outputs. For simulating outflow from the generating station, the efficiency of 72% was used in the updated model instead of the former 80% value (which underestimated the station outflow). The efficiency of 72% corresponded to a power output of 9 MW, which is within the range 6 MW to 10 MW output from the generating station (Hettiarachchige, pers. comm. 2014).

2.6. Flow Routing for River Reaches, Lakes, and Reservoirs

For this update of the TRB model, flow routing was done using the same methods and parameters used in the 2008 and 2014 versions of the model. The modified Puls method was used for routing the flow through Taltson Lake, King Lake, Lady Grey Lake, Tronka Chua gap, Thekulthili Lake, Benna Thy Lake, and Tsu Lake (Rescan 2009). The Muskingum method was used for routing the flow in the river reaches between the Twin Gorges forebay and the confluence of Taltson River with Tazin River, in Trudel Creek, and in Taltson River downstream of Elsie Falls (Zones 3, 4, and 5; Rescan 2009). The Muskingum method was not used in river reaches in Zones 1 and 2 as "the linear reservoir routing through the lakes provides sufficient flow attenuation required to produce a reasonable fit to observed data" (Rescan 2009).

2.7. Model Application

The updated model was applied to simulate conditions observed for the period January 2014 to December 2018. The objective of this simulation was to compare model results to observations and assess the performance of the model. For this simulation, the power load on the station was set to the electric power output measured by NTPC (Figure 4c) and gate closure at the Nonacho Lake Dam was accounted for (Figure 7). The simulation was done with the inflows estimated for the period from January 2014 to December 2018. The Nash-Sutcliffe model efficiency coefficient was used to assess if the TRB model is a good predictor of the water level in the Twin Gorges forebay. The Nash-Sutcliffe model efficiency coefficient (NSE) was calculated using:

$$\mathrm{NSE} = 1 - \frac{\sum_{i=1}^{N}(S_i - B_i)^2}{\sum_{i=1}^{N}(B_i - \bar{B})^2} \qquad (3)$$

where S_i is the simulated water level, B_i is the observed water level, $\bar{B} = \frac{1}{N}\sum_{i=1}^{N} B_i$ is the mean of observed water levels, and $N = 2{,}360$ is the total number of observations.

3. RESULTS

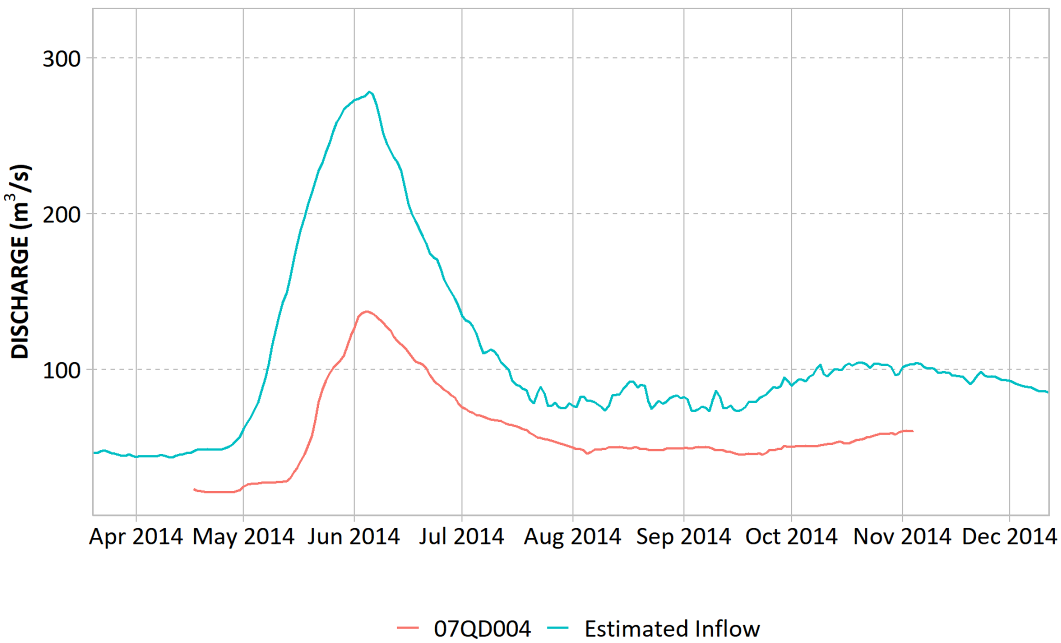
3.1. Inflow Estimates

This section presents the estimated inflows to Nonacho Lake, inflows from Tethul and Rutledge Rivers, and inflows from other watersheds downstream of Nonacho Lake. For Nonacho Lake, Figure 10a shows the inflow estimated using reverse flow routing and application of a moving-average filter. For Tethul and Rutledge Rivers, Figure 10b shows the estimated inflows from these rivers to Taltson River. These estimated inflows could not be validated with observations because there are no flow gauges on Tethul River, Rutledge River, or Taltson River between Tethul River and Great Slave Lake. The inflow estimates were obtained from estimated inflow for a watershed with a comparable area (above gauge 07QD002) and are expected to be representative of the actual flows for Tethul and Rutledge Rivers. The effect of these flow estimates on model results is limited to the lowest 100 km of the modelled domain (i.e., zone 4 of the model).

The inflow from the Tazin River watershed to Taltson River was obtained directly from the observations at the WSC gauge 07QC007 (Figure 3b, Section 2.4.2). For the remaining watershed area of ~6,000 km^2 between Nonacho Lake and gauge 07QD007, the estimated inflow to Taltson River is shown in Figure 10c. There is some similarity between the inflow from the area of ~6,000 km^2 and the Tazin River inflow; the two-time series had a linear correlation coefficient of 0.86 and a Spearman's rank correlation coefficient of 0.91. The area of ~6,000 km^2 gave a total runoff volume of approximately 89% of the flows observed at gauge 07QC007 in Tazin River between 2014-2018. This is much larger than the corresponding watershed area; the area of ~6,000 km^2 corresponds to ~34% of the Tazin River watershed. This is also an increase from the inflow estimated in the previous version of the model. After review of the timeseries at gauges 07QC007 and 07QD007, we note that flow regimes at both gauges are different in the 2014-2018 period compared to the 2007-2013 period. The changes in flow regime over time could therefore potentially affect the relationship between inflow in the ~6,000 km^2 watershed area and Tazin River inflow. We also note that changes in diversion from the Tazin River Basin are unlikely to explain this difference as these changes would be accounted for in the calculation of the inflow in the ~6,000 km^2 watershed area.

During winter, the estimated inflows from the watershed area of ~6,000 km^2 and from the ~3,000 km^2 between gauge 07QD007 and Tsu Lake were generally at their lowest (Figure 10c). However, in contrast to the previous model update, the estimate inflows were usually greater than zero, whereas in the previous iteration, zero inflow was observed nearly every winter, as the simulated inflow at gauge 07QD007 was greater than the observed flow at the gauge, even before inclusion of inflow from the watershed area of ~6,000 km^2. It is unclear what the cause of this change in pattern is, but examination of the flow records at gauges 07QD007 and 07QC007 show a similar pattern of increasing flows in winter over time (Figure 9). Nevertheless, inflows from the watershed area of ~6,000 km^2 was set to zero when negative differences occurred between the observed and simulated flows at gauge 07QD007. Errors of up to 25% in estimating the inflow from the ~6,000 km^2 watershed would have a minor effect on the model results. If the inflow from the ~6,000 km^2 watershed was excluded from the TRB model, the mean absolute error between the observed and simulated flows at gauge 07QD007 downstream of Elsie Falls would be ~44 m^3/s, about 24% of the annual average flow at this gauge. An error of 25% in estimating the inflow from the watershed area of ~6,000 km^2 would correspond to only ~6% of the annual average flow at gauge 07QD007.

Figure 9. Comparison of hydrograph patterns for WSC gauges 07QD007 and the estimated inflows between gauge 07QD007 and Tsu Lake.



3.2. Model Validation

This section examines the agreement between observations and results obtained from the HEC-ResSim model for water level in Nonacho Lake, water level in the Twin Gorges forebay, and flow in Taltson River downstream of the forebay (Figure 11). For Nonacho Lake, the linear correlation coefficient between the simulated and observed lake water levels is 0.998 and the root mean square is 0.01 m (Figure 11a). The near-perfect agreement between the simulated and observed water levels is expected because the observed water level was used to estimate the inflows with reverse routing (Section 2.4.1). This agreement between the two time series shows that the reverse routing scheme gave accurate results that are consistent with the routing scheme in HEC-ResSim. The above agreement for the updated model is nearly identical to the 2014 version of the TRB model; the maximum difference in simulated and observed water levels was 0.08 m for the 2014 version and is 0.07 m for the updated model.

Over the simulation period of January 2014 to December 2018, the updated TRB model also reasonably reproduced the observed flow at gauge 07QD007 in Taltson River downstream of the Twin Gorges forebay (Figure 11b). The temporal patterns of the simulated and observed time series are similar with a high linear correlation coefficient of 0.98. The differences between the two-time series are relatively small; the root mean square error is 14.1 m^3/s, about 8% of the mean flow at gauge 07QD007 for the simulated period. Similar to the water level in Nonacho Lake, close agreement between simulated and observed flows at the gauge is expected because the observed flow at the gauge was used to estimate inflows from watersheds between Nonacho Lake and the gauge (excluding inflow from Tazin River) (Section 3.1). The Nash-Sutcliffe efficiency for flows at this location is quite high, at 0.97, indicating that the model accurately reproduces observed flows.

For the Twin Gorges forebay, the updated TRB model predictions had much lower variance on a daily to weekly scale compared to observed forebay water level over the simulation period January 2014 to December 2018 (Figure 11c). The temporal patterns of the simulated and observed time series are similar with a linear correlation coefficient of 0.84 and a Spearman's rank correlation coefficient of 0.82. The reduction in agreement compared to the 2014 version of the model appears to be driven by the noise in the observed forebay data (Figure 4a). Thus, the Nash-Sutcliffe efficiency coefficient (NSE) based on the forebay water level is only 0.56, where $\text{NSE} = 1$ indicates that the model exactly reproduces observations. For the 2014 version of the TRB model, Imam *et al.* (2015) reported a much higher NSE of 0.9, but review of the observed forebay data used in that version of the model shows that the noise affecting observed forebay level in 2014-2018 was not present.

Figure 10. Estimated inflows: a) for Nonacho Lake; b) from Tethul and Rutledge Rivers; and c) from watersheds between Nonacho Lake and Tsu Lake. Panels a) and b) also show flows measured in Taltson River above Porter Lake outflow (at WSC gauge 07QD004) and in Tazin River near its confluence with Taltson River (at WSC gauge 07QC007), respectively.

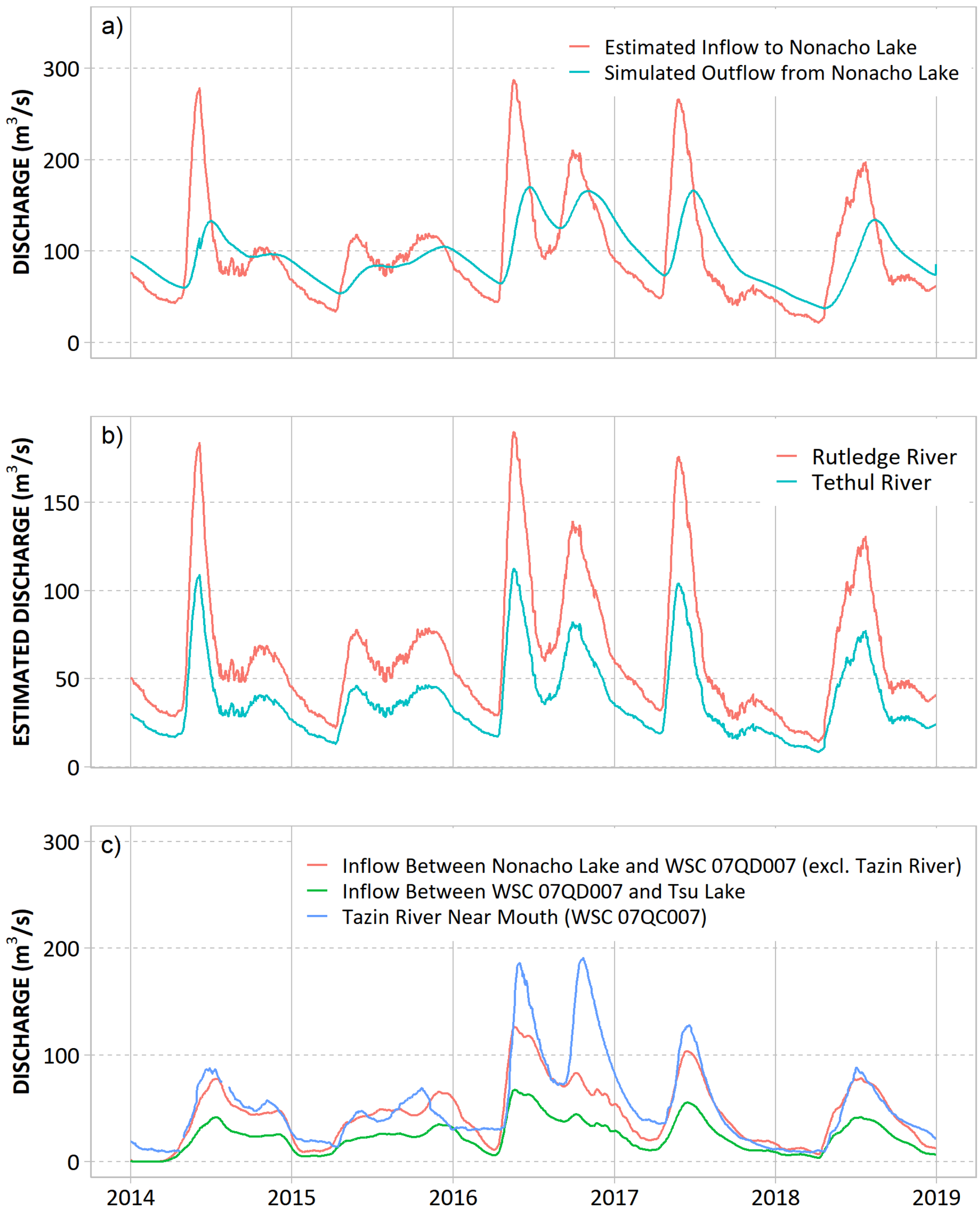
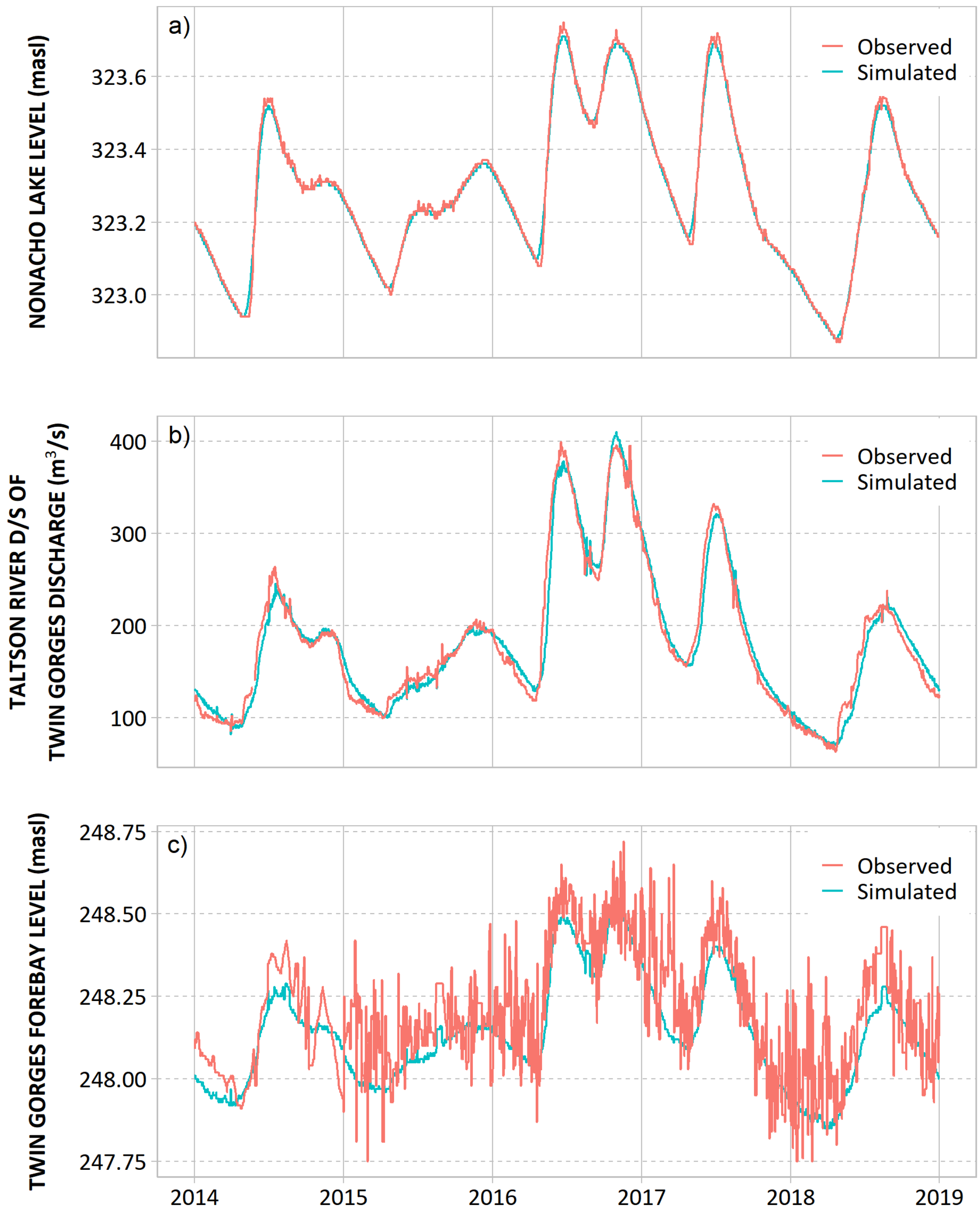


Figure 11. **a) Simulated and observed water levels in Nonacho Lake. b) Simulated and observed flow in Taltson River downstream of the Taltson Hydro Generating Station (at the WSC gauge 07QD007). c) Simulated and observed water levels in the Twin Gorges Forebay.**



3.3. Assessment of Permitted Water Levels and Flows

The scope of the Taltson Hydro HEC-ResSim Hydrological Modelling Update is a hydrologic analysis of facility and basin flows which included verification that water levels and flow requirements outlined Water License MV2011L4-0002 (conditions C.2, C.3, and C.4) were met. Analysis on the appropriateness of the permitted flows and water levels for maintaining ecosystem function is presented in the Taltson Hydro - 2019 Riparian Habitat and Fish Use Assessment Report which was also completed under the Taltson Aquatic Effects Monitoring Program under Water License MV2011L4-0002.

Condition C.2 relates to water levels in Nonacho Lake and the Twin Gorges Reservoir, defining a required range for Nonacho Lake of 319.3-321.6 m (NTPC datum), and a minimum requirement of 238.9 m (NTPC datum) for the Twin Gorges Reservoir. For Nonacho Lake, this requirement corresponds to a range of 321.71-324.01 masl. During the period of 2014-2018, the modelled Nonacho Lake level stays well within this range (Figure 11a). For the Twin Gorges Reservoir, the minimum requirement corresponds to a level of 247.33 masl, which is also met at all times during 2014-2018 (Figure 11c).

Condition C.3 specifies that a minimum flow of 14 m^3/s be maintained as the outflow of the control structure of Nonacho Lake and the Twin Gorges forebay. This condition refers to a minimum flow at the outlet of the Nonacho Lake Reservoir. This flow is calculated based on water levels recorded by WSC gauge 07QD002 and the dimensions of the spillway. The results of the model indicate that the minimum flow through the Nonacho Lake spillway from 2014-2018 was 25 m^3/s which is in accordance with Condition C.3, and the minimum outflow from the Twin Gorges forebay from 2014-2018 was 69.5 m^3/s.

Condition C.4 specifies that a minimum flow of 28 m^3/s be maintained 100 m below the confluence of Trudel Creek and the Taltson River. The closest location to this that was evaluated in the TRB model is the Taltson River downstream of the Taltson Hydro Generating Station, and the minimum flow during 2014-2018 was 68.7 m^3/s (Figure 11b) which is in accordance with Condition C.4. .

All three of the water flow and level conditions of Water License MV2011L4-0002 were met at all times between 2014-2018, providing support for the appropriateness of the permitted water levels and flows. This conclusion builds on the findings of Imam and Cullen (2015), in which the TRB model was used to determine if operational changes could result in excursions from the permitted water levels and flows with past hydrological conditions. The Imam and Cullen (2015) analysis found that excursions were possible with certain gate settings at the Nonacho Lake Dam and flow rates through the Taltson Generating Station, but that these excursions would only occur during extreme hydrological conditions and operational settings (e.g., less than 5% of the time). Given that excursions did not occur during the 2014-2018 period, the TRB model was not re-applied to assess the change in excursion frequency associated with altered operational regime.

Further analysis on the appropriateness of the permitted flows and water levels for maintaining ecosystem function is presented in the Taltson Hydro 2019 Riparian Habitat and Fish Use Assessment Report (Thornton *et al.*, 2020) which was also completed under the Taltson Aquatic Effects Monitoring Program under Water License MV2011L4-0002.

4. UNCERTAINTY IN MODEL RESULTS

The updated TRB HEC-ResSim model was developed with a dataset from 2014-2018, different from the 1978-1990 dataset used for the 2008 version of the model, and the 2007-2013 period used for the 2014 version of the model. However, all model versions have almost the same assumptions for the parameters and methods used in flow routing and inflow estimation. These assumptions lead to some uncertainty in the model results.

A notable source of uncertainty is the outflow from the Twin Gorges forebay through the South Valley Spillway. Outflow from this spillway was estimated in the TRB model using a rating equation obtained from NTPC. Rescan (2009) identified that this rating curve underestimated the spillway flow for different water levels in the Twin Gorges forebay. Rescan (2009) argued that the error in estimating spillway overflow is equivalent to an error of ~0.2 m in the forebay water level. However, an error of ~0.2 m in the forebay water level may correspond to large differences in outflow, particularly at higher heads above the spillway crest. For example, the NTPC rating equation for the spillway gives a flow of 245.7 m^3/s for a forebay water level of 248.33 masl and a flow of 371.6 m^3/s for a forebay water level of 248.53 masl. The increase of 0.2 m from the forebay water level of 248.33 masl to 248.53 masl increases the spillway overflow by ~50%. This example shows how the rating equation for the South Valley Spillway can significantly affect the estimated outflow from the Twin Gorges forebay.

The value used for the operating efficiency of the Taltson Hydro Generating Station and how the efficiency varies with output power is another source of uncertainty. For the 2008 version of the model, a constant efficiency of 80% was used. For the 2014 and 2020 versions of the model, a lower constant efficiency of 72% was used, which corresponds to an output power of 9 MW (Hettiarachchige, pers. comm. 2014). This value was obtained from a chart produced by the turbine manufacturer and may overestimate the actual efficiency due to turbine wear. Overestimating or underestimating the operating efficiency may affect the simulated flow downstream of the Taltson Hydro Generating Station and affect conclusions about appropriateness of water levels and flow rates in zones 3 and 4 of the model (Elsie Falls to Great Slave Lake).

Additionally, estimates for lake evaporation (Section 2.4.2) are rough estimates based on older data at stations located quite far away from the study area. This may lead to uncertainty in the estimated inflows across the watersheds between Nonacho Lake and WSC gauge 07QD007 (Table 3).

Another source of uncertainty that is new to the 2020 model is the absence of inflow observations to Nonacho Lake that were previously provided by the decommissioned Taltson River above Porter Lake WSC gauge (07QD004). This gauge also provided a surrogate to estimate Rutledge and Tethul flows. The absence of this gauge is not expected to have a substantial impact on model accuracy for predicting the effect of operations on flows and water levels between Nonacho Lake and Taltson River at the gauge downstream of the Taltson Hydro Generating Station. However, the lack of quality surrogate data for predicting Rutledge and Tethul flows is expected to reduce the accuracy of these estimates and the associated estimates of flow in Taltson River downstream of these inputs.

Finally, flow measurements at WSC gauges are likely a source of uncertainty in modelling wintertime operations when lakes and reaches of Taltson River are ice-covered. WSC typically indicates a lower quality for flow data collected under ice cover compared to flow data collected for open water (Section 2.3). Errors in flow measurements at WSC gauges affect inflows input to the TRB model. The magnitude of this effect is difficult to quantify; WSC did not give bounds on errors for flow measurements under ice cover. The increased winter flows observed during the 2014-2018 period could be a result of changes in the WSC approach to calibrating rating curves during winter conditions, or an effect of climate change. Determining the cause would require further investigation.

The evaluation of how these uncertainties may affect the model can be assessed using a quantitative sensitivity analysis. However, due to the large number of assumptions and complexity of the model this is a highly onerous task. Due to the limited scope of this model update focusing on the appropriateness of the permitted flows and water levels, a qualitative sensitivity analysis was performed instead. This qualitative analysis focuses on comparing the model outputs relative to the permitted flows and water levels and provides context to how uncertainty would affect compliance of the Water Licence Conditions.

In the context of this model and the comparison of modelled flows to the permitted water levels (Section 3.3), it is highly unlikely that the uncertainties discussed above would have a material impact on meeting any of the Water Licence Conditions. Condition C.2 specifies a range of acceptable level for Nonacho Lake and the Twin Gorges forebay. For Nonacho Lake, the minimum modelled level is 1.17 m (36%) above the minimum threshold, and the maximum modelled level is 0.3 m (9%) below the maximum threshold. At the Twin Gorges forebay, the minimum modelled level is 0.52 m (21%) above the minimum threshold.

Condition C.3 specifies a minimum outflow of 14 m^3/s at Nonacho Lake and the Twin Gorges forebay. At the Nonacho Lake spillway, this threshold is 44% lower than the minimum modelled flow, and at Twin Gorges forebay the threshold is 80% lower than the modelled flow. For Condition C.4, the specified threshold is 59% lower than the minimum modelled flow in Taltson River downstream of the Taltson Hydro Generating Station. The very large exceedances of these thresholds are expected to be much larger than the uncertainty of rating curves, offsets, and evaporation rates that may impact the modelled values at the Water Licence locations, providing confidence in this assessment of permitted water levels and flows. Given this information a detailed sensitivity analysis is not required as regardless of variation within the input parameters discussed above the Water License MV2011L4-0002 Conditions C.2, C.3, and C.4) would be met by the flows/output of the model.

5. CONCLUSION AND RECOMMENDATIONS

The TRB model was updated with data from January 2014 to December 2018. Compared to the previous version of the model (2014), the updated model reproduced the water levels in Nonacho Lake with a similar degree of accuracy. The updated model, however, gave worse predictions for the water level in the Twin Gorges forebay; the Nash-Sutcliffe efficiency coefficient was ~0.56 for the updated model, lower than the Nash-Sutcliffe efficiency coefficient of ~0.90 for the 2014 version of the model. It is apparent that this reduction in performance is closely tied to the large amount of noise in the observed Twin Gorges forebay water level data. Determining if the water level noise was spurious or resultant of a real process would help to confirm uncertainty associated with model applications.

To reduce uncertainty in the model results, flow from the South Valley Spillway could be measured for different water levels in the Twin Gorges forebay. These measurements could be used to develop an accurate rating equation for the South Valley Spillway and this equation could be included in the TRB model to give more reliable predictions for outflow from the Twin Gorges forebay, flow in Trudel Creek, and flow in Taltson River downstream of the forebay. However, we note that obtaining these measurements would be very logistically challenging and there would currently be no operational benefit (Miller, pers. comm. 2020).

To develop and apply the rating equation for the South Valley Spillway, it is important to accurately determine the forebay water level relative to the spillway crest. As indicated in Section 4, small errors in estimating the water level above the spillway crest can lead to large errors in estimating flow over the spillway. For determining water level over the spillway, NTPC uses a spillway crest level of 239.3 m above local datum, which is equivalent to 247.73 masl. This value could be confirmed by surveying the elevation of the spillway crest relative to the datum used by NTPC for measuring water level in the Twin Gorges forebay. However, we note that surveying the spillway crest level is very unlikely to be feasible under current operations and associated water levels (Miller, pers. comm. 2020).

Besides developing a more accurate rating equation for the South Valley Spillway, flow through the Taltson Hydro Generating Station could be measured for different electric power outputs. These measurements could be used to estimate station efficiency as a function of flow and applied in the TRB model to improve the confidence in the model predictions for the flow through and downstream of the Generating Station. Turbine rating curves are developed by the manufacturer at the time of purchase. Using known values for the turbine operation and calculated spill from the South Valley Spillway have historically provided good correlation with downstream flow measurements throughout the operating life of the plant. Naturally occurring high water levels on the system in the last quarter of the 2020 calendar year provided an opportunity to assess the accuracy of the spillway calculations at higher water levels and flows. This enabled an adjustment to the spillway coefficient to improve the accuracy of calculated spill volumes throughout the operating range of the system. The assessment of spillways flows under high water levels and corresponding updates were outlined in the 2020 Annual Water Licence Report.

The 2020 TRB model update can be used to support the assessment of appropriateness of permitted water flows and levels should operational changes be required that differ from the scenarios explored in Imam and Cullen (2015). An analysis of excursions from permitted values was completed for 2014-2018 and all water flows and levels met their corresponding requirements. This analysis builds on the findings of Imam and Cullen (2015), in which various plant and control structure operational scenarios were assessed and the resulting water flows and levels were compared to the permitted limits for the 1987 to 2014 period. Their analysis showed that excursions from the permitted limits would only occur during extreme scenarios. Updating the TRB model with recent data was a requirement of the Water Licence; However, repeating the analysis completed by Imam and Cullen (2015) was not a requirement. The 2020 TRB model update provides an additional five years of flow data that can be used to assess changes in water flows and levels associated with different operational regime or inflows. The water flows and levels for the 2014-2018 period were well within the permitted values, and therefore assessment of such changes was not completed. The model now has 31 years of data that can be used to assess changes if required. This amount of data is considered sufficient to assess the inter-annual variability in effects of these changes, and as such the previously prescribed update to the model in 2024 is no longer recommended. Furthermore, the Water Licence (MV2011L4-0002) does not include any further analysis that require application or future updates to the TRB model.

Although not required, the TRB model could be applied to assess numerous questions associated with water flows and levels in the Taltson system. Examples include (1) assessing the potential impacts of climate change on ability to achieve permitted water flows and levels, (2) assessing the risk of flooding associated with extreme high flows years, (3) Assessing operational changes that could be implemented while maintaining permitted water flows and levels, and (4) assessing if any future excursions were preventable through operational adjustments.

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