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ASSESSMENT OF THE INSTREAM FLOW NEEDS FOR FISH AND FISH HABITAT IN THE SASKATCHEWAN RIVER DOWNSTREAM OF THE E.B. CAMPBELL HYDROELECTRIC STATION

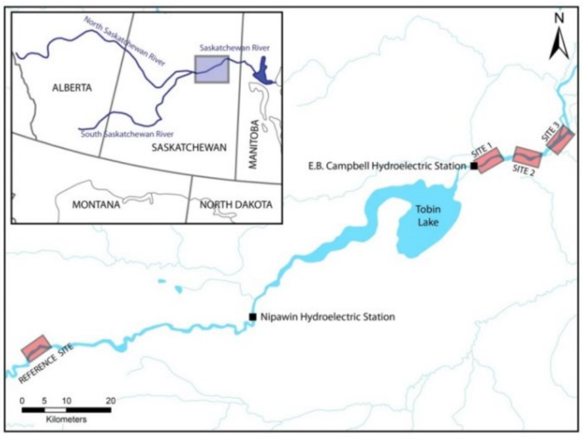

Figure 1. Map of study site locations in the Saskatchewan River, Saskatchewan (from Enders et al. 2017)

Figure 2. Small bodied fish stranded at ~6:50 h, July 21, 2005 in a Site 2 side channel (photo credit: D. Watkinson)

Context: *The E.B. Campbell Hydroelectric Station, owned and operated by SaskPower, is a hydropeaking facility on the Saskatchewan River (Figure 1). Fisheries and Oceans Canada (DFO) Fisheries Protection Program (FPP) is seeking science advice on Instream Flow Needs (IFN) to help inform a new* Fisheries Act *authorization, including measures to avoid, mitigate, and as necessary, offset serious harm to fish and fish habitat as a result of the ongoing operations of the existing facility.*

The present Fisheries Act *authorization includes a minimum flow release of 75* $m^3 \cdot s^{-1}$ *and was followed by a research study (conducted April 2005 to March 2007) to evaluate impacts on fish habitat. The results from this study, as well as additional reports, data, and publications were summarized in an unpublished 2008 DFO report. In March 2012, DFO provided national guidance on IFN (i.e., +/- 10% of instantaneous flow; 30% of mean annual discharge), however, cautioned that when data are available, a more detailed technical examination is required on the effectiveness of the recommended thresholds, in particular for cases of hydropeaking (DFO 2013). FPP has requested DFO Science to update the unpublished 2008 DFO report with a description of E.B. Campbell Hydroelectric Station's flow regulation impacts on fish and fish habitat and to provide IFN recommendations.*

The scientific advice herein focuses on the assessment of the IFN for fish and fish habitat in the Saskatchewan River downstream of the E.B. Campbell Hydroelectric Station and on the identification of potential avoidance, mitigation, and monitoring measures. This Science Advisory Report is from the regional peer review of the Assessment of the Instream Flow Needs for fish and fish habitat in the Saskatchewan River downstream of the E.B. Campbell Hydroelectric Generating Station held on May 9-10, 2018. Additional publications from this process will be posted on the DFO Science Advisory Schedule as they become available.

SUMMARY

- The natural flow regime in the Saskatchewan River system is highly altered due to the cumulative effects of several reservoirs (e.g., Lake Diefenbaker, Abraham Lake, Brazeau Reservoir), agricultural water withdrawal in Alberta and Saskatchewan, and water diversions to the Milk and Qu'Appelle rivers. The water management upstream directly affects the availability of water for the E.B. Campbell Hydroelectric Station (EBC), and its reservoir, Tobin Lake; thus, complicating the isolation of the effects directly due to the EBC hydropeaking facility on fish downstream.
- Returning to the natural hydrograph without a barrier would be preferential for fish and fish habitat, however, understanding that EBC will remain operational, science advice focused on instantaneous minimum flows and ramping rates to reduce risks to fish and fish habitat and discussed as a series of mitigation options.
- Rather than the use of absolute values of instantaneous minimum flows, the use of percentages of inflow to EBC as criteria for downstream releases may be more valuable to maintain the temporal and seasonal patterns of the natural hydrograph.
- It is recommended that the minimum flow downstream of EBC at any time should not be lower than the natural 95% exceedance flow rate for the 1912-1963 flow record.
- Higher minimum flows in BSP2 and 3 (i.e., April 30–July 24) will help protect spawning periods for the majority of fish species in the Saskatchewan River. Increasing the minimum flows will lead to a reduction in the ramping limits and consequently a decrease in the hydropeaking potential. Reduced hydropeaking will likely increase successful egg incubation and larval drift during BSP2 and 3 and reduce the stranding risk during all BSPs.
- Lake Sturgeon (*Acipenser fulvescens*) is a species of significant cultural importance. It is currently designated as endangered under COSEWIC and is under consideration for listing under the *Species at Risk Act*. To protect recruitment of Lake Sturgeon, absolute values of the instantaneous minimum flow of >700 $m^3 \cdot s^{-1}$, mean daily discharges of >800 $m^3 \cdot s^{-1}$ (not a percentage), and a reduction of daily peaking in the two week spawning window (first two weeks of BSP3) are recommended. Given the long life span of Lake Sturgeon, successful recruitment is not necessary every year to maintain a sustainable population structure. Therefore, the above mentioned instantaneous flow releases do not have to occur every year but in years when flows of these magnitudes are possible and the timing should coincide with Lake Sturgeon spawning.
- Hydropeaking leads to much higher flow variations than would naturally occur in a given day. Under the current peaking and minimum flow rules fish stranding is occurring on a daily basis downstream of EBC. Rapid down ramping due to hydropeaking increases fish stranding risk close to the dam (Figure 2). Flows <500 $m^3 \cdot s^{-1}$ result in the largest Wetted Useable Area changes. Gradual down ramping procedures (beginning at 500 $m^3 \cdot s^{-1}$) over an extended period of time is recommended to mitigate fish stranding. Specific research and monitoring should be conducted to provide further guidance on strategies to reduce the stranding risk.
- Flows >1,000 $m^3 \cdot s^{-1}$ provide flooding and connectivity in the Saskatchewan River Delta and potentially increase fishery productivity. Consequently, these high flows should not be avoided by storing water in upstream reservoirs.
- Lake Diefenbaker, Codette Reservoir, and Tobin Lake function as sediment traps leading to sediment starvation downstream of EBC and ultimately in the Saskatchewan River Delta.

The starvation of sediment causes armoring and down cutting of the riverbed and perching of tributaries and side channels (e.g., Old Channel). Consequently, both water quantity and water quality (including nutrients) must be considered for fish and fish habitat. Mitigations for sediment replenishment may be considered.

- Water storage along the Saskatchewan River system alters the water temperature from the natural temperature regime. Limited temperature data was available for the review; however, EBC has turbine intakes that release surface waters and not cold waters from the reservoir bottom, therefore, water temperatures up- and downstream of EBC are not very different.
- BSPs were developed during a workshop held in 2005 in Prince Albert, SK with a group of experts using the Delphi method. Although the BSPs are thought to be acceptable, the potential to modify them by linking their start dates to measured water temperatures could be further explored.
- Information on surface ice cover, ice dynamics, frazil or anchor ice formation was not reviewed but was considered a data gap. In addition to this, a considerable number of uncertainties due to the lack of monitoring and field studies conducted on the Saskatchewan River system were identified.
- A holistic water and sediment management scheme for the Saskatchewan River system is necessary to protect the ecological significance of the Saskatchewan River Delta.
- It was recommended to improve the documentation of Traditional Ecological Knowledge to obtain more valuable information on fish and fish habitat in the Saskatchewan River Delta.

INTRODUCTION

Fisheries and Oceans Canada (DFO) Fisheries Protection Program (FPP) manages impacts on fisheries productivity related to habitat degradation or loss and alterations to fish passage and flow. For projects that are expected to have impacts on fisheries productivity, FPP administers letters of advice or *Fisheries Act* authorizations that provide guidance on how to avoid or mitigate any impacts, and the requirements for restoration and offsetting where impacts are unavoidable and cannot be fully mitigated.

The E.B. Campbell (EBC) Hydroelectric Station, owned and operated by SaskPower, is a hydropeaking facility on the Saskatchewan River near Nipawin, SK (Figure 1). SaskPower has applied for a new *Fisheries Act* authorization, since their existing authorization expires June 2018. Consequently, FPP is seeking science advice on Instream Flow Needs (IFN) to help inform a new *Fisheries Act* authorization, including measures to avoid, mitigate, and as necessary, offset death of fish and alterations to fish habitat as a result of newly identified and ongoing impacts from of the existing facility.

EBC was commissioned in 1963 and operated as a hydropeaking station with no minimum flow requirements prior to September 7, 2004. Instantaneous flow on a given day through EBC may have been ~0 $m^3 \cdot s^{-1}$ and increased up to ~1,000 $m^3 \cdot s^{-1}$. Flows out of the Tobin Lake reservoir greater than ~1,000 $m^3 \cdot s^{-1}$ are released through the spillway channel, a ~5.6 km reach of the pre-1963 river channel that is now by-passed by EBC. In 2003, DFO Fish Habitat Management (FHM; now called FPP) and SaskPower completed negotiations to address an ongoing Harmful Alteration, Disruption or Destruction (HADD) of fish and fish habitat occurring in the Saskatchewan River downstream of EBC, which resulted in DFO issuing a formal authorization under Subsection 35(2) and Section 32 of the *Fisheries Act* that came into effect on August 30,

2005. A condition of the authorization was an instantaneous minimum flow release of 75 $m^3 \cdot s^{-1}$ in order to reduce the risk of fish stranding downstream.

In addition, a Research Partnership Agreement was developed among SaskPower, DFO FHM, DFO Science, Saskatchewan Environment, Saskatchewan Watershed Authority, and the University of Regina to study the impacts of the new hydropeaking operation of 75 $m^3 \cdot s^{-1}$ minimum releases on fish and fish habitat. This research spanned from April 2005 to March 2007 and resulted in an unpublished DFO report in 2008.

In March 2012, DFO Science provided national guidance on IFN (i.e., +/- 10% of instantaneous flow; 30% of mean annual discharge), but cautioned that when data are available, a more detailed technical examination is required on the effectiveness of the recommended thresholds (DFO 2013). Consequently, the purpose of this regional peer review meeting was to describe the impacts of flow regulations at the EBC on downstream fish and fish habitat and to provide IFN recommendations by compiling the data and information contained within the unpublished DFO report (2008), additional consultant reports from studies initiated by SaskPower, and recent primary literature publications. In particular, the assessment focused on:

1. describing the Biological Significant Periods (BSP) and Habitat Suitability Indices (HSI) for key fish species in the Saskatchewan River;
2. analyzing the changes in the natural hydrograph due to the flow management on the Saskatchewan River;
3. summarizing the impacts of the flow alterations on fish, fish habitat, and the Saskatchewan River ecosystem and channel morphology downstream of EBC; and,
4. providing recommendations for adjustments to the flow operation to mitigate impacts on fish and fish habitat and for mitigation and offset measures.

This Science Advisory Report summarizes the conclusions and advice from the peer-review meeting, held in Winnipeg, Manitoba on May 9-10, 2018. The research document combines field data collection, habitat modelling, literature results, the technical details, and the full list of references to support this advice (Watkinson et al. 2019). The meeting discussions are documented in the meeting proceedings (DFO 2019).

Flow Alterations in Saskatchewan River System

The 550 km long Saskatchewan River is a major river situated in Central Canada flowing eastward across the provinces of Saskatchewan and Manitoba into Lake Winnipeg (Figure 1). Through its tributaries (North Saskatchewan and South Saskatchewan), the 335,900 km^2 watershed of the Saskatchewan River encompasses much of the prairie regions of Central Canada, stretching westward to the Rocky Mountains in Alberta and northwestern Montana in the United States.

The natural flow regime in the Saskatchewan River system is highly altered due to the cumulative effects of several dams on the South Saskatchewan River (e.g., Gardiner Dam) and North Saskatchewan River (e.g., Bighorn and Brazeau dams), agricultural water withdrawal in Alberta and Saskatchewan, and water diversions to the Milk and Qu'Appelle rivers. Consequently, the water management upstream directly impacts the water availability for EBC and its reservoir (Tobin Lake), the most downstream facility on the system in the Province of Saskatchewan.

The EBC has eight turbine units in total with a combined generating capacity of 289 MW. The construction of the dam created an artificial reservoir, Tobin Lake, and altered flow and the water levels in the Saskatchewan River above and below the dam. The Generating Station is operated on a hydropeaking regime to balance fluctuating power requirements on a daily or hourly basis for the Province of Saskatchewan. Consequently, the Generating Station was operated on a hydropeaking regime that ranged from 0–1000 $m^3{\cdot}s^{-1}$ prior to 2004. When the discharge out of Tobin Lake exceeds 1000 $m^3{\cdot}s^{-1}$, the excess water is released over a spillway into a ~5.6 km section of a former river channel. On September 7, 2004, the operation was changed to include a minimum flow of 75 $m^3{\cdot}s^{-1}$ and the station discharge ranges now from 75–1000 $m^3{\cdot}s^{-1}$. The frequency of hydropeaking is daily with typical minimum discharges of 75 $m^3{\cdot}s^{-1}$, maximum discharges of 300–1000 $m^3{\cdot}s^{-1}$ and mean rates of flow alteration of 18.8–77.1 $m^3{\cdot}s^{-1}$ per hour resulting in water level changes up to 150 $cm{\cdot}h^{-1}$. The full real-time hydrographic record is available online from the Environment and Climate Change Canada website. As an example of the daily discharge variation downstream of the EBC, a week-long discharge time series is provided in Figure 3.

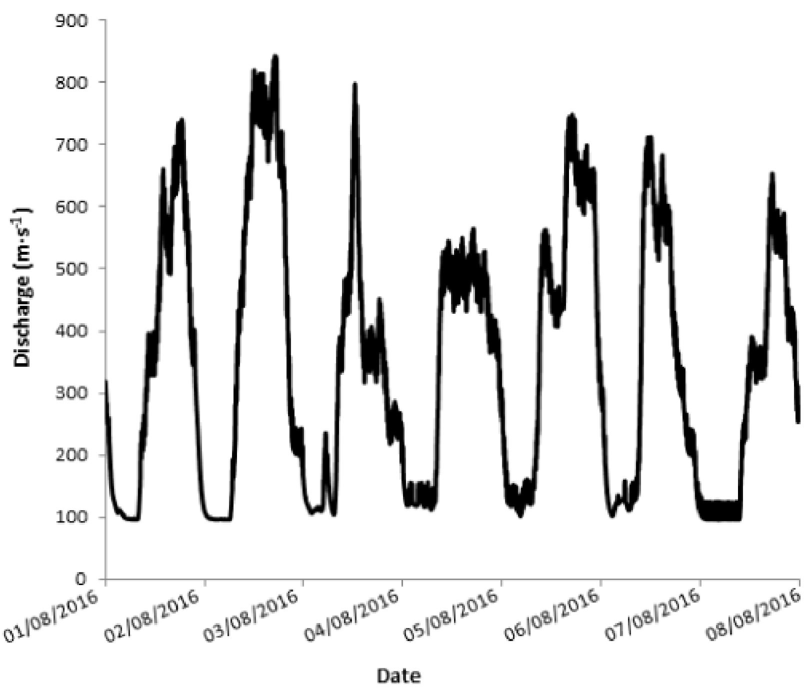

Figure 3. Example of the daily hydrograph downstream of the E.B. Campbell Generating Station for the first week of August 2016.

Changes in the hydrograph have significant impacts on the Saskatchewan River Delta, one of the largest active, alluvial inland deltas in North America. The delta is composed of wetlands, shallow lakes, and active and abandoned river channels. The diversity of wetlands in combination with the network of streams, lake ecosystems, and terrestrial vegetation made the Saskatchewan River Delta one of Canada's richest regions for abundance and diversity of wildlife, especially large mammals (e.g., moose, black bear), fur-bearing mammals (e.g., muskrat, beaver), and fish (Abu et al. 2018). The Saskatchewan River Delta is a designated Canadian Important Bird Area of global significance, in part because of its large concentrations of waterfowl, and is home for an estimated half million breeding-season waterfowl each year. The Saskatchewan River Delta also serves as a valuable spring and fall staging area for waterfowl and other water birds traveling to and from the northern boreal and arctic regions. Many of these species are vital to local indigenous peoples who depend on fishing, hunting, and trapping for means of livelihoods. The Saskatchewan River Delta begins ~100 km downstream of EBC. Its main water supply is the Saskatchewan River.

The Saskatchewan River Delta is formed by the deposition of river-borne sediment into a standing body of water. As the delta developed through time, the principal channels of the Saskatchewan River frequently changed courses (avulsed) as part of the normal process of delta evolution. In the 1870s, the river course avulsed likely due to an ice jam and the Old Channel was nearly abandoned, and now carries only about 5–10% of the annual flow (Smith and Perez-Arlucea 2008). The new Saskatchewan River channel has since consolidated from a series of formally active channels. Cumberland Lake is the largest lake in the Saskatchewan River Delta and the effects of the avulsion have been observed by local indigenous peoples that use the area. Cumberland Lake has subsequently become shallower from pre-avulsion depths of over 6 m, to average depths of less than 1.5 m at present (Smith et al. 1998).

ASSESSMENT

Fish Community Study

Hydropeaking can dramatically alter quantity and quality of habitat available to fish. Resulting effects can be direct (e.g., habitat abandonment, stranding, and mortality) or indirect (e.g., volitional movement, downstream displacement, depleted food production, and increased physiological stress). Shortly after the implementation of a minimum instantaneous flow in September 2004, a study was conducted in April 2005–2006 to analyze the fish abundance, community composition, population size structure, and growth rate in the Saskatchewan River system. For this study, fish species composition and fish age and size distributions were compared downstream of EBC with results from a Reference Site situated upstream of the reservoir (Figure 1).

A total of 5,194 fish representing 19 fish species were collected (Enders et al. 2017). Shorthead Redhorse (*Moxostoma macrolepidotum*) and White Sucker (*Catostomus commersonii*) comprised 72.6% of the total catch. The study revealed lower species diversity in the sites directly downstream of EBC in comparison to the Reference Site and a site located 20 km downstream of the dam (i.e., Site 3). Whereas all age classes were present at the Reference Site, very few juvenile fish were observed at any of the study sites below EBC. The size structure of the fish community downstream of EBC is therefore biased toward large bodied fish (Enders et al. 2017). This is likely a result of EBC impacting fish stranding, fish movement, fish recruitment, and/or juvenile fish habitat, thereby reducing the success of juvenile fish utilizing habitat downstream of EBC (Enders et al. 2017).

It is important to note that this study was conducted approximately nine months after a minimum flow of 75 $m^3 \cdot s^{-1}$ was established. Consequently, during this short time period, it was not possible for the fish population structure, specifically for small-bodied and juvenile fish, to adjust and move into the areas downstream of the hydro facility. The observed differences are likely a result from the former extreme hydropeaking on the Saskatchewan River. We might expect the differences in fish composition between sites to have changed as habitat availability is now less variable although still extreme compared to the natural hydrograph. It is possible that with the establishment of the minimum flow of 75 $m^3 \cdot s^{-1}$, fish habitat use is now quite different than what was observed in 2005 immediately after implementation of the minimum flow.

Habitat Modelling

In order to model fish habitat, Biological Significant Periods (BSP) were defined and Habitat Suitability Indices (HSI) developed for fishes in the Saskatchewan River. BSPs are periods of time when a given life stage is present or active in a particular habitat and for which habitat modelling of that life stage is relevant. The habitat suitability index (HSI) is a commonly used index to describe fish habitat quality (Bovee 1986). HSIs can be obtained through professional judgment or from life history studies in the literature (Category I), habitat use data based on frequency of occurrence of actual habitat conditions used by different species and life stages in a stream (Category II), or habitat preference data that combines the category II frequency analysis with additional information on the habitat availability in the sampling reaches (Category III).

BSPs were developed during a workshop held in Prince Albert, SK in November 2005 using the Delphi method (Table 1). Based on the fact that floods could historically, arrive after June 24th which would coincide with the juvenile rearing period for many species spawning earlier in the year, a decision was made during the regional peer review to extend BSP3 to July 24th, which is Day 205 and the time when flows would historically have begun declining (Watkinson et al. 2019).

Table 1. Biological Significant Periods for fishes in the Saskatchewan River based on the results of the November 2005 Prince Albert, SK workshop and Watkinson et al. (2018). The recommended minimum instantaneous flows to reduce risk to fish and fish habitat for each period are also presented.*

Biological Significant Period	Period	Life Stage Function	Instantaneous Minimum Flow Recommendation ($m^3 \cdot s^{-1}$)
1	15 Oct to 29 Apr	Fall and winter spawners; Overwintering	66
2	30 Apr to 27 May	Early spring spawners	232
3	28 May to 10 Jun	Lake Sturgeon spawning	700
	11 Jun to 24 Jul*	Spring spawners	459
4	25 Jul to 14 Oct	Growing season	239

At the Prince Albert Workshop, Category I Habitat Suitability Indices (HSI) were created for Saskatchewan River fish species using the same Delphi method approach. In addition, Category III HSIs were developed from results of the fish community study conducted in 2005-2006 (see appendices in Watkinson et al. 2019).

Using the developed BSP and HSI, the River2D model was used to generate Wetted and Weighted Useable Area simulations for each of the study sites downstream of EBC, assuming a minimum water depth of 20 cm was required to be considered useable fish habitat. The Wetted and Weighted Useable Areas are dependent on discharges and changes for the different sites downstream of EBC, likely due to differences in their channel morphology and slope. For this study area, the River2D suggested minimum flows to maintain Wetted Useable Area in Site 1 would be 300 $m^3 \cdot s^{-1}$, 350 $m^3 \cdot s^{-1}$ in Site 2, and 500 $m^3 \cdot s^{-1}$ in Site 3. The Weighted Useable Area calculations determined that BSP2 and 3 were the most sensitive time periods to flow changes, as the eggs and larva of most fish species are not mobile.

Fish Stranding

Ramping rate is the rate at which discharge is increased or decreased. Currently down ramping rates, represented by changes in water surface elevation, at EBC may be as high as 150 $cm \cdot h^{-1}$. To avoid fish stranding, slowing this rate during hydropeaking may allow fish to move to safe areas. Similar measures to mitigate the effects of hydropeaking have been recommended based on stranding experiments and biotope model simulations (Halleraker et al. 2003, Borsanyi 2005). For example, fish stranding caused by ramping rates >15 $cm \cdot h^{-1}$ have likely degraded fish communities in alpine Austrian hydropeaking rivers (Schmutz et al. 2015). The applicability of this threshold needs to be tested in the context of the Saskatchewan River. Furthermore, the importance of ramping rate may be highly dependent on other abiotic factors such as seasonal and diel patterns in light intensity and temperature and these should be considered when implementing mitigation strategies.

Returning to the natural hydrograph without a barrier would be preferential for fish and fish habitat. However, understanding that EBC will remain operational, we used exceedance curves to determine flow recommendations. Exceedance curves describe the percentage of occurrence of a given discharge. We used the 95% exceedance values corresponding to flows that occur 95% of the time to determine minimum flow recommendations to protect fish and fish habitat. The 95% exceedance values for daily average flows pre-dam construction correspond to 66, 232, 459, and 239 $m^3 \cdot s^{-1}$ for BSP1, 2, 3, and 4, respectively (Figure 4).

Sources of Uncertainty

Given the multiple water flow alterations, the multi-agency water management, and multiple jurisdictional (provincial and federal) responsibilities in the Saskatchewan River system, the resource management and planning decisions affecting the Saskatchewan River and the Saskatchewan River Delta will need to be effectively coordinated and more collaborative planning approaches will be needed in the future, particularly in the face of increasing environmental stresses (e.g., climate change, cumulative effects).

Fish community data was collected shortly after the establishment of the minimum flow requirement of 75 $m^3 \cdot s^{-1}$ in September 2004. Consequently, during this short time period, it was not possible for the fish population structure, specifically for small-bodied and juvenile fish, to adjust. The observed differences are likely a result from the former extreme hydropeaking on the Saskatchewan River. Consequently, current and longer term evaluation of the fish communities downstream of EBC would be valuable.

The topic of sediment starvation was a recurring issue identified during the assessment. The efficacy of potential mitigations measures to increase downstream sediment fluxes could be further explored for the Saskatchewan River.

There are uncertainties associated with the use of BSP as inter-annual variation exists. For example, spawning triggers in Lake Sturgeon can be interrupted or delayed by stochastic events, consequently the spawning period is based on approximate dates.

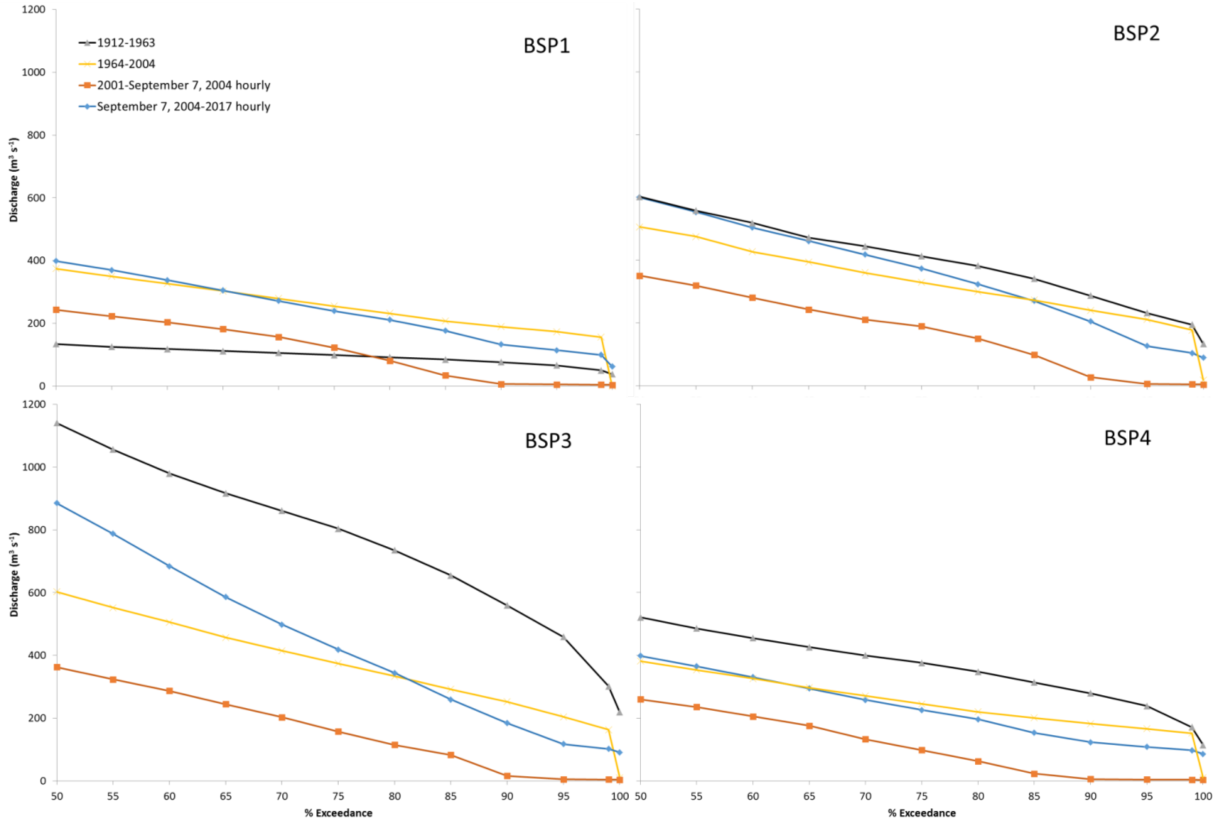

Figure 4. Exceedance (50-100%), mean daily discharge from 1912-1963 (South and North Saskatchewan rivers combined) and from 1964-2003 downstream of EBC. Hourly discharge for 2001-September 6, 2004 and September 7, 2004-2017 downstream of EBC for all four BSP.

In the River2D habitat modelling, the HSIs only consider three habitat variables (water velocity, substrate, water depth); other variables may also influence fish population and spawning success (e.g., water temperature, water quality).

Limited research and monitoring downstream of the EBC has revealed some limitations for this assessment, including the use of information from salmonids as a proxy and data from smaller streams and rivers that may not be relevant to the larger Saskatchewan River. To minimize this gap, the addition of the following data sources would be useful:

- a longitudinal water temperature profile along the Saskatchewan River;
- information on ice formation (surface, anchor, and frazil ice data);
- water level elevation downstream of EBC to better understand attenuation effects; and
- site-specific information on total dissolved gas supersaturation (TDGS) and the subsequent risk of gas bubble trauma.

CONCLUSIONS AND ADVICE

The Saskatchewan River is a complex system of free-running river stretches, reservoirs, water withdrawals/diversions, and hydroelectric generating stations. The river stretch downstream of EBC and the Saskatchewan River Delta are the combined product of flow management occurring throughout the system. Due to the hydropeaking operation of EBC, Wetted Useable

Areas downstream of the generating station are undergoing partial dewatering and fish stranding on a daily basis.

Minimum Flow Requirements

Although the natural hydrograph without a barrier would be preferential for fish and fish habitat, the following compromises between hydroelectric power production and environmental benefits for the ecosystems would be advisable to reduce risk to fish and fish habitat.

In any given BSP, the minimum flow should not be lower than the natural 95% exceedance flow rate for the 1912-1963 flow record. As examples, the 95% exceedance values for daily average flows pre-dam construction correspond to 66, 232, 459, and 239 $m^3 \cdot s^{-1}$ for BSP1, 2, 3, and 4, respectively.

An alternative method to using absolute values of instantaneous minimum flows could be the establishment of proportional downstream release of inflow to EBC. This may more closely mimic temporal and seasonal patterns of the natural hydrograph (Table 2) deemed beneficial to fish and fish habitat. In particular, the higher minimum flows in BSP2 and 3 will be protective of the spawning periods for the majority of fish species in the Saskatchewan River. Increasing the minimum flows will also lead to a reduction in the ramping limits and consequently a decrease in the hydropeaking potential. This should increase successful egg incubation and larval drift during BSP2 and 3 and a reduction in the stranding risks during all BSP.

Table 2. Example for the use of a proportion of inflow to EBC to maintain the temporal and seasonal patterns of the natural hydrograph in a given Biological Significant Periods (BSP) for fishes downstream of EBC and resulting average instantaneous minimum flows to reduce risk to fish and fish habitat and a cut-off flow.

Biological Significant Period	Average Daily Inflow to EBC ($m^3 \cdot s^{-1}$)	Proportion (%)	Average Instantaneous Minimum Outflow ($m^3 \cdot s^{-1}$)	Cut-off Flow ($m^3 \cdot s^{-1}$)
1	400	20	80	75
2	600	60	360	75
3	800	60	480	75
4	500	50	250	75

To enhance recruitment and recovery of Lake Sturgeon, absolute values of the minimum instantaneous flow of >700 $m^3 \cdot s^{-1}$ and mean daily discharges >800 $m^3 \cdot s^{-1}$ and not percentages as suggested in Table 2 should be used during the first two weeks of BSP3 from May 28–June 10. Lake Sturgeon is a species of significant cultural importance. COSEWIC has listed Lake Sturgeon in the Saskatchewan River as endangered and is awaiting listing decision under the federal *Species at Risk Act*. The higher minimum flow of 700 $m^3 \cdot s^{-1}$ would lead to reduced ramping potential. A cohort strength analysis has demonstrated that high flows and low hydropeaking may result in higher recruitment (Watkinson et al. 2019). However, due to the long life span of Lake Sturgeon, successful recruitment may not be necessary every year to maintain a sustainable population structure. Consequently, the above mentioned instantaneous flow releases may not need to be provided every year. However, in years when high instantaneous flow of 700 $m^3 \cdot s^{-1}$ are released, the timing of the releases should correspond to the Lake Sturgeon spawning period in that given year.

Hydropeaking

Fluctuations in river flows result from diverse natural and/or anthropogenic causes. Hydropeaking is a common anthropogenic flow alteration. Hydropeaking occurs from the rapid increase or decrease of water releases from reservoirs at hydroelectric power stations to meet variable demand for electrical power, thereby altering the flow regime of the river downstream of the hydroelectric power station. Hydropeaking causes short-term, artificial fluctuations in flow on an hourly, daily, and/or weekly basis. The frequent and regular occurrences of these high and low flow events are fundamentally different from natural flood and drought events and may affect fish fauna.

Under the current hydropeaking regime at EBC with ramping rates of 150 $cm \cdot h^{-1}$, fish stranding is occurring on a daily basis downstream of the generating station. Habitat model simulations have shown that the largest Wetted Useable Area changes occur at flows <500 $m^3 \cdot s^{-1}$. Threshold values of <15 $cm \cdot h^{-1}$ to reduce the risk of stranding have been suggested in the literature, the applicability of this threshold value in the Saskatchewan River will need to be tested. Consequently, specific research/monitoring is needed to provide guidance on strategies to reduce stranding risk as a result of hydropeaking.

Mitigation Options

Concern over maintaining and improving the connectivity of water and sediments downstream of EBC was discussed and some options were identified as potential mitigation measures, although it was acknowledged that many of the details for design was outside the scope of expertise of participants, and not all the necessary information was presented in order to review and provide advice.

High flow releases are important for sediment transport, channel formation, and connectivity in the Saskatchewan River Delta. For example, flows >1,000 $m^3 \cdot s^{-1}$ would provide flooding in the system and theoretically increase fishery productivity in the system. The Old Channel is connected to the Saskatchewan River at flows >500 $m^3 \cdot s^{-1}$. However, releasing high flows would not be sufficient. In order to enhance fish productivity the flow level would also need to be maintained for a specified duration to improve habitat conditions and not function as a disturbance to the ecosystem.

Re-sculpturing the riverbed in the spillway channel (the former Saskatchewan River bed before the construction of EBC) could help to connect isolated pools. Adding continuous flow in the spillway would also increase the wetted fish habitat area and reduce stranding risk. Habitat model simulations of the spillway is warranted and can a inform the feasibility of this mitigation option providing predictions of the flows needed to achieve wetted habitat area with an appropriate water depth to function as fish habitat.

Considering the importance of the Saskatchewan River Delta, several wetland management projects have been conducted by governments and non-profit organizations in the past. For example, Ducks Unlimited Canada manages several wetlands within the Saskatchewan River Delta in cooperation with the Manitoba and Saskatchewan governments.

Reservoirs above EBC trap sediments, which leads to sediment starvation downstream of EBC and ultimately in the Saskatchewan River Delta. Mitigation strategies for sediment replenishment could be further explored.

Adaptive Management, Research, and Monitoring

A holistic water and sediment management plan for the Saskatchewan River system is necessary to protect the ecological significance of the Saskatchewan River Delta and to maintain the sustainability of the river for future use. More specifically, an adaptive management plan is needed to ensure efficient and proper mitigation measures are established for fish and fish habitat downstream of EBC. The plan should include a monitoring design that supports the management questions regularly posed to science, and should consider the current data gaps and research needs. The science-based plan should also lay out the appropriate mechanisms for assessment and reassessment of the monitoring data to support adaptive management decisions that serve the environment as well as the social, cultural, and economic needs of the users.

Cumulative effects are changes to the environment that are caused by a human activity in combination with other past, present, and future anthropogenic activities. In regards to fish and fish habitat downstream of EBC, consideration of the effects from other anthropogenic activities including, but not limited to, water storage, diversion, withdrawal, and agricultural land use, will need to be considered. The assessment of cumulative effects requires considerations of effects over a larger, regional area that may cross jurisdictional boundaries and during a longer period of time into the past and future, and not just the effects of the single activity under review.

OTHER CONSIDERATIONS

Indigenous Traditional Ecological Knowledge

The Saskatchewan River Delta has a substantial history of pre-European occupation and it has long served as a travel corridor and gathering centre for aboriginal peoples. Cumberland House was a major crossroads of the fur-trading routes and is subsequently the oldest settlement in Saskatchewan. The delta is still an essential cultural and economic resource for local community members today. A participant from Cumberland House provided insight and valuable background information for the review of the working paper, including history of local use (presence/absence) and Traditional Ecological Knowledge (TEK) on fish and fish habitat in Saskatchewan River Delta.

Many of the species that exist within the delta are vital to local indigenous peoples who depend on fishing, hunting, and trapping for means of livelihoods. Over the years, many changes have been observed and have impacted the local community and users of the land since the commission of EBC and other developments on the Saskatchewan River system. Specific examples of changes to the environment were provided, including observed changes to the water depth of Cumberland Lake (shallower), which consequently increased summer water temperature and fish mortality, changes to fish spawning habitat and success and fishing effort in the lake (DFO 2019). Further documentation of the observed changes to the delta has been prepared in other published materials (Abu 2017, Abu and Reed 2018).

The incorporation of TEK into scientific assessments brings together two ways of knowing. In the absence of historic data, TEK has been shown to be invaluable to understand changes over time and to provide context to many of the review discussions. The inclusion of local knowledge can also be used to help guide research and monitoring and will be key to the success of any future monitoring and research efforts downstream of the EBC.

Climate Change

Climate change predictions for the Canadian prairie provinces has forecasted changes to precipitation and snow pack and an increase in water allocation needs for water withdrawal, which will likely lead to a reduction of water resource availability and quality. Increased climate variability indicates that stream flow of rivers will be smaller in magnitude, with flow rates becoming more unpredictable, especially in rivers with dams. This means that reservoir management will become more difficult because baseline data will not be available for the specific climate parameters. Cumulatively, the changes to Saskatchewan's wetlands and water resources may significantly impact native flora and fauna. The long-term impacts of changing climatic conditions on the flow regime, IFN, and fish and fish habitat will need to be better understood and investigated. This also highlights the need for management and monitoring plans in the watershed.

SOURCES OF INFORMATION

This Science Advisory Report is from the May 9–10, 2018 regional peer review on the Assessment of the Instream Flow Needs for fish and fish habitat in the Saskatchewan River below the E.B. Campbell Hydroelectric Station. Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

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