Effects of hydropower operation on turbidity in a glacially-fed reservoir

D.M. Robb[1]*, R. Pieters[1,2], and G.A. Lawrence[1]

[1] *Civil Engineering, University of British Columbia, Vancouver, Canada*
[2] *Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, Canada*

**Corresponding author, e-mail drobb@eoas.ubc.ca*

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Hydroelectric reservoir; stratification; turbidity; glacial fines; aquatic productivity.

EXTENDED ABSTRACT

Introduction

While hydropower offers many benefits, there is an increasing desire to consider ecological values in water use planning. Of particular interest is the effect of changes in reservoir operation on aquatic productivity. Here we focus on one part of this complex problem, by looking at observations and model results of glacial inflow moving through a reservoir, and the effect of this inflow on turbidity and light extinction within the reservoir.

We examine Carpenter Reservoir, located in southwest British Columbia, Canada. The reservoir is long (50 km) and narrow (~1 km), with a surface area of 46 km^2 and a maximum depth of 50 m. The reservoir is a drowned river valley (Fig 1) formed from the Bridge River by the construction of Terzaghi Dam in 1960. Inflows into the reservoir are high in glacial fines, which are slow to settle, and which give the water a cloudy (turbid) appearance. There is concern that glacial meltwater is limiting light penetration within the reservoir, reducing algal growth, and in turn decreasing fisheries productivity.

Materials and methods

Field observations were collected over the biologically active season (May to October) in 2015 and 2016. Data included monthly surveys of the reservoir and tributaries, meteorological measurements, and a temperature mooring. To evaluate various reservoir operation scenarios, we used the two-dimensional laterally-averaged model, CE-QUAL-W2.

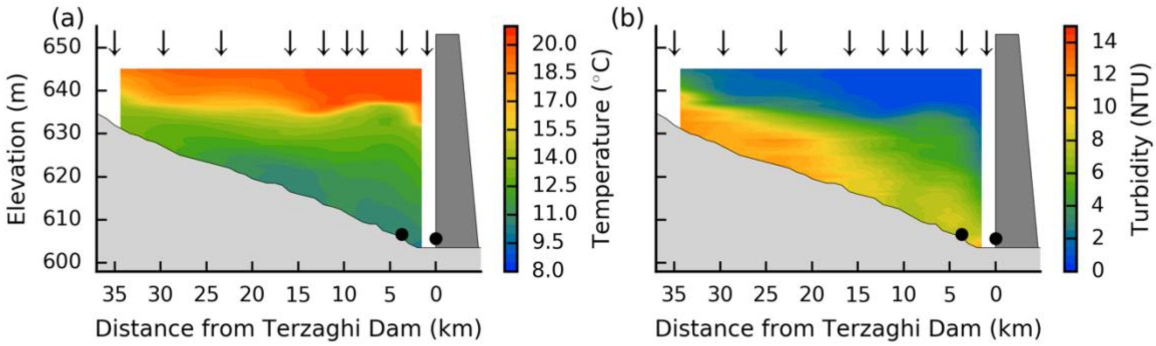

Figure 1. (a) Temperature and (b) turbidity profiles collected at Carpenter Reservoir on 16 July 2015. The downward arrows mark the location of each CTD cast and the black dots mark the location of the withdrawals.

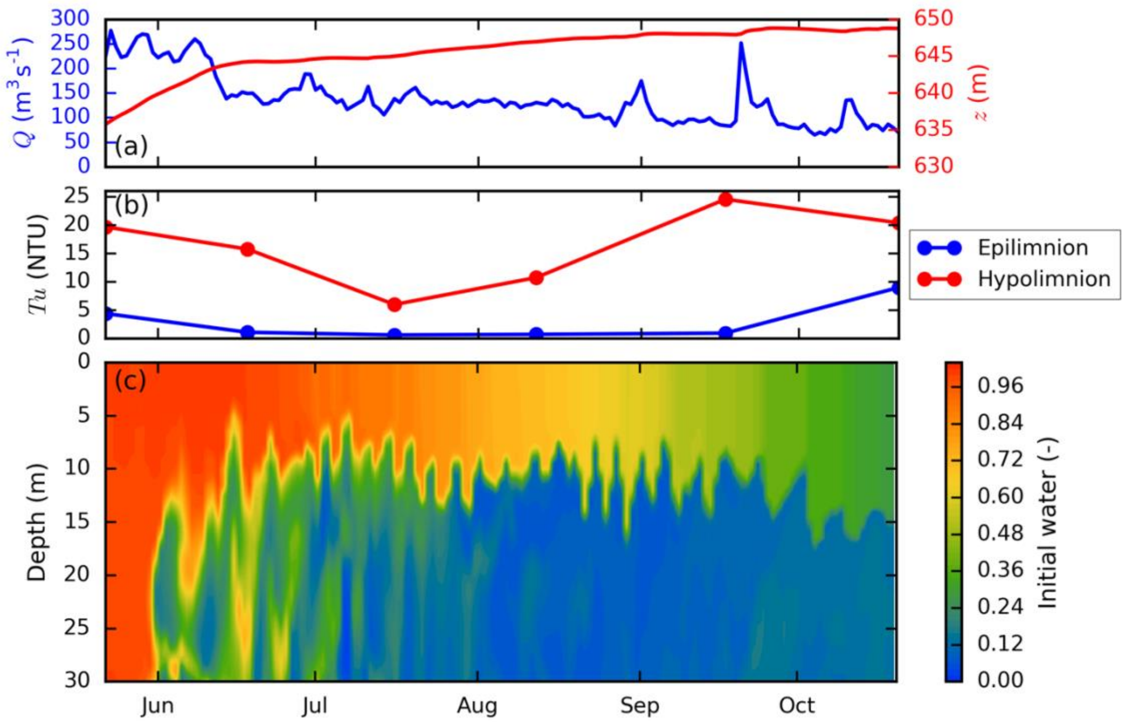

Figure 2. (a) Total inflow (blue) and water level (red) in Carpenter Reservoir; (b) measured turbidity in the epilimnion (blue) and hypolimnion (red); (c) fraction of water in the reservoir at the start of the model run, 22 May to 20 October, 2015.

The model was run from May to October, starting at the first sampling trip and ending at the last. Initial conditions for temperature, conductivity, and turbidity were given by profiles from the first trip. Boundary conditions included inflow, outflow, tributary temperature, tributary water quality and meteorological data. Model temperature agreed well with the measurements (RMSE ~0.9°C). To match observed turbidity required a settling rate of 0.2 m day^{-1}. We added passive tracers to the model to examine the mixing and transport of water originating from different sources, including a tracer to track the fraction of water in the reservoir at the start of the model run.

Results and discussion

The CTD profiles collected on 16 July 2015 are an example of the temperature and turbidity observed during the summer months (Fig 1). Given the high inputs of glacial fines, we expected the epilimnion to be turbid, so we were surprised to observe such a clear (~1 NTU) epilimnion over most of the summer (Fig 2b). The model tracer helps explain this as follows. At the beginning of the model run (May 22), the entire water column was occupied by the initial water in the reservoir (Fig 2c). After 10 days, much of the initial water below 20 m was replaced by water from the inflows, and by July, essentially all the initial water in the hypolimnion had been flushed. In contrast, the initial water in the epilimnion remained for most of the stratified season. It was not until fall that appreciable quantities of turbid water from depth were mixed into the epilimnion (Fig 2b,c). In other words, the epilimnion—with a long residence time—clears as the initial turbidity settles, while the large volume of turbid inflow short circuits through the hypolimnion below.

Future work involves identifying reservoir operations associated with extremes in turbidity. Preliminary results indicate that maintaining a lower water level during the spring leads to higher turbidity in the epilimnion, thereby limiting light availability.