The two papers that you’re asked to read in this assignment focus on the interaction of river flow with lake water. When rivers flow into lakes, they create plumes of flowing water that are surrounded by otherwise stagnant water. If the density of the river water differs from that of the lake water, then the rivers can plunge to the bottom of the lakes or rise to the top. If this happens, we say that we have “underflow” or “overflow” currents of water passing through the lake. This is the basis of two-dimensional, or longitudinal, circulation (so named because the direction from the river to the dam is the longitudinal dimension of a lake). These principles are much easier to see in narrow lakes because the small lateral dimension means that longitudinal currents are less likely to be dispersed across the width of the lake. Many narrow lakes are reservoirs, and so, not surprisingly, the two papers on which this assignment focuses describe processes in reservoirs.

Let’s begin with the paper by Hebbert et al. It’s from 1979, and it’s written in a different style as a result. Thankfully, it’s direct in its language, and so it’s not too hard to figure out what they’re after. Please read it, but neglect the section called “entainment”, which is difficult and off topic for us. The reservoir is at -33.39768, 115.9907.

While reading this paper, bear two things in mind. First, the dates are given as Julian Day, which is just a count of days following a day defined as day 1. You need this for question 2, below. So, if the first day of the block was Day 1, then this assignment is being assigned on JD9. This is often a much cleaner way to express dates so that you don’t have ungainly axes like those Excel generates when it’s trying to work with dates. Because these authors are being exceptionally pure in their approach, they’ve defined JD1 as 1 January 1900, I think. That’s not important. What’s important is the number of days between each graph. Also notice that the decimal points are hard to see. The Julian Date is a 5-number integer, and then these authors are giving one decimal place so that you know that all measurements were made at roughly the same time of day.

Second, the derivation of the plunge point in the next-to-last section is complicated, but there are things we can extract from it without too much trouble. Focus on figure 7 and equations 19a and 19b and the variable definitions needed to understand these equations. You need these for question 3, below.

Please answer the following:
1. What was the purpose of this paper?

2. Please describe figure 3 in your own words.

3. On what do the depth of the water at the plunge point and the thickness of an underflow current depend? What is the assumption on which this calculation rests?

Let’s shift gears to the Matzinger et al. paper, which takes place much closer to home on a much larger reservoir. The Columbia River has several dams on it that are used for flood control and hydropower production, and the map in the first figure of this paper indicates that Arrow Lakes Reservoir is the third major reservoir (counting downstream from the headwaters) on this river. Its name is indicative of its origin: there were two glacial lakes that were made into a single reservoir when a dam (the Hugh G. Keenleyside Dam) impounded the outlet of the lower lake and increased the water depth such that the “narrrows”, which was the riverine passage between two lakes, was submerged. The result is a reservoir that is impressively large in both its depth and its volumetric flow rate.

This study was initiated because the kokanee fishery in this region slowly declined upon the completion of the dam (kokanee are landlocked sockeye salmon). The reason was a decrease in their food availability, and this resulted from decreased NPP. But nothing about the river, which brought the nutrients into the reservoir, changed, so there weren’t fewer nutrients in the reservoir. Why didn’t the algae grow? The answer lies in the altered longitudinal circulation.

The authors approach this with a modeling study. They use a 1-D model to simulate vertical profiles of several parameters. They focus on phosphorus, algae, and zooplankton. Once they simulate the reservoir as it is operated, they change inputs to the model so that they can evaluate the change in primary productivity given different hydrologic conditions. Reading about modeling can be a little difficult; just be patient with it. If you’re finding it difficult, you can skip all of the subsection titled “Model sensitivity (scenario 5)” and resume reading at the subsection titled “Model scenarios”. The rest of the results and discussion section is a little long, but it’s organized well. The authors do a fairly good job of summarizing their points when they conclude them. The “Relevance of Results” section is about how to fix the problems of low NPP; it’s not so important for understand Arrow Lakes itself.

With this in mind, please read the Matzinger et al. paper and answer the following:

4. The authors examine three hydraulic changes due to damming: the submerging of the narrows, the altering of the seasonal river hydrograph, and the releasing of water downstream from 20 m deep in the water column. Which of these is/are most important for NPP? Hint: the answer is in table 2 in concise form; the authors write about it extensively in their text.
5. Please describe figure 7 in your own words. What hydrologic modification(s) are represented there and what importance do they have for NPP in this system?

6. What is the effect of seasonal flow management on NPP?