MEMORANDUM

TO: Lake Whatcom Policy Group

FROM: Lake Whatcom Data Team

DATE: February 1, 2018

RE: Proposal to Use Aeration to Treat Elevated Phosphorus Levels

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Lake Whatcom Management Team staff has received a proposal from Mr. Enoch J. (E.J.) Ledet and Richard Bauman, both of Sudden Valley, recommending that the Lake Whatcom Management Program use aeration to address elevated phosphorus levels in Lake Whatcom in response to the recent adoption of the Total Maximum Daily Load (TMDL) for the Lake Whatcom Watershed. This proposal was referred to the Data Management Team for review. The proponents worked with a company called Clean-Flo to develop their proposal which is attached at the end of this memo. The proponents have also provided additional technical information. In addition to this material, staff met with Mr. Ledet on February 1st to discuss his proposal. This memorandum summarizes the Data Team's preliminary review of the proponents' proposal.

Proposal: The overall proposal is to install Clean Flo diffusers at depth in Basins 1 and 2 to treat both internal and external phosphorus (P) and nitrogen (N) nutrients entering the lake water and P and N nutrients in lake bottom sediments. Installing Clean Flo will supplement external soil filter construction and TMDL P estimated 50-year implementation timing by immediately capturing, fixing, and assimilating P and N nutrients in identified and unidentified storm water runoff pathways which enter the lake. A second step in the Clean Flo water treatment system is bioaugmentation of lake water with proprietary, beneficial bacteria and enzymes that help assimilate/consume P and N nutrients through known biochemical/biological pathways to promote a healthy ecosystem/food chain.

An alternative proposed solution would be to provide hypolimnion aeration by pumping cold, dense, oxygenated hypolimnion water from Basin 3 into Basins 1 and 2.

The proponents assert that the current TMDL P solution will only address Low Dissolved Oxygen demand causes created by algae respiration (algae oxygen consumption at night) and algae death/decomposition (aerobic bacterial oxygen consumption in water column and in sediment). Dead algae comprise a portion of total organic matter decomposed in the lake. The proponents have identified other demand and supply causes of low dissolved oxygen in the lake which they assert that TMDL P solution does not address. At this time, the proponents are proposing to initiate a pilot study in either Basin 1 or 2 for one year at a cost of approximately $1 million. Clean Flo International provided a free estimate of installation, materials, maintenance, and testing costs. Maintenance/testing costs estimates are $150-200 thousand per year.

An overriding concern of the data team is that the proposal is a departure from the current approach of trying to bring the lake into a natural equilibrium, in favor of a more interventionist, managed approach. In the view of the Data Team, all alternative beneficial tools for protecting the reservoir should be considered; however, a substantial deviation in approach should trigger a more thoughtful analysis of benefits and costs.

One major technical question that remains unanswered is whether there could be irreversible (or difficult to reverse) impacts on the lake ecosystem if the proposal fails or if the system is ever shut-off. Clean Flo provides consistent oxygen concentrations in both water column and sediment, reduces algae (chlorophyll, P and N nutrients, purges CO2,N2 from water), reduces drinking water treatment costs associated with natural organic matter removal (TSS, turbidity, algae, humic acids, etc.), eliminates anaerobic biochemical/chemical reactions by products release to water column (H2S, NH3, methyl mercury, Fe, Mn, Pb, etc.). If Clean Flo is shut off, the lake would return to its natural state prior to installation of Clean Flo.

A summary of specific issues is presented below.

Lake Process:

- The proposal and case studies provided indicate that aeration is suitable for reducing phosphorus loading in shallow, eutrophic lakes with low alkalinity where the primary source of phosphorus is internal loading. Lake Whatcom does not have these characteristics. Clean Flo has been used in over 2000 bodies of water (Lakes, Reservoirs, Ponds, Rivers, Streams, Fish Farms, Wastewater Treatment Plants) In US (MN, FLA, CA, MN). Clean Flo has 48 yrs. experience treating and improving water quality all over the world.

  At several points the proponents suggest that phosphorus "stays locked in the sediment" when oxygen concentrations are high, thus decreasing this source of phosphorus. In fact, sediment-bound phosphorus at the bottom of Basins 1-2 is a small part of the total phosphorus budget for Lake Whatcom. Most of the phosphorus enters the lake attached to suspended sediments in storm runoff. Many algae, including many Lake Whatcom cyanobacteria, excrete alkaline phosphatase, an enzyme that solubilizes phosphorus attached to particulates, making it bioavailable to algae and bacteria. Jonnel Deacon's MS thesis demonstrated that 37-95% of the total phosphorus associated with suspended sediments in storm water flowing into Lake Whatcom was potentially bioavailable (Jonnel Deacon, 2015, "*Determining biologically available phosphorus in storm water entering Lake Whatcom, WA using the dual culture diffusion apparatus"*). Clean FLO captures and assimilates Phosphorous and Nitrogen Nutrients transported into a body of water and into bottom sediment in all nutrient forms. Clean Flo first uses oxygen to fix P and N nutrients and then uses bioaugmentation to assimilate P and N nutrients through known biochemical/biological pathways to improve water quality and promote a healthy ecosystem.

- Because the major source of bioavailable phosphorus in the lake enters the lake via storm runoff, reducing the internal phosphorus loading in Basins 1-2 may not solve the increasing algal densities. This is illustrated in Figure 2.20 (draft figure from 2016/2017 annual report), which shows that the chlorophyll levels are increasing throughout the lake, not just in Basins 1-2. The relationship between extended stratification and low hypolimnetic DO is incomplete because the proponents fail to state that there is a declining trend in Basin 1 DO that is not matched by an increasing trend in warmer hypolimnetic temperatures or longer periods of stratification. Length of stratification helps explain some of the year-to-year variation but does not account for the overall decline in DO. They also include a confusing and potentially misleading discussion of the atypical 2015 stratification pattern, which was not repeated in 2016 or 2017.

- Clean Flo oxygenates and de-stratifies the water column which, in turn, reduces the impact of water temperature and thermal stratification on dissolved gas/oxygen solubility and concentration. Clean Flo improves/provides a more sustainable Oxygen/dissolved oxygen concentration through the water column and sediment throughout the calendar year which improves water quality and encourages a healthier ecosystem. Since it captures and assimilates external as well as internal P and N nutrients, it will manage algae growth and promote a viable food chain for fish.

- One of the major benefits described by the proponents is a reduction of toxic cyanobacteria and replacement with beneficial algae such as diatoms. But there are no blooms of toxic cyanobacteria in Lake Whatcom. The algal community contains mostly diatoms and golden algae. The cyanobacteria community is dominated by Aphanocapsa, Aphanothece, and Snowella, which are not associated with toxic blooms. And, because the Lake Whatcom algal community is already dominated by diatoms, there is no reason to assume that increasing the diatom density would, necessarily, enhance zooplankton and fish production. Food web relationships in any lake are very complex, and in Lake Whatcom, there is no obvious connection between the aeration system and its predicted effects on algae, zooplankton, and fish.

- Whatcom Watch June 2016 article showed cyanobacteria graphics depicted as the dominant algae species in all 3 basins. Caption stated cyanobacteria numbers surpassed green algae. Clean Flo has a number of case studies which show the benefits of Clean Flo systems impact on lake ecosystem and re-establishment on a health food chain.
- The proposed method would result in artificially breaking stratification of the lake, which in most instances, will result in a water quality violation as per WAC 173-201A-200 (1) (c) (v). For lakes, human actions considered cumulatively may not increase the 7-DADMax temperature more than 0.3°C (0.54°F) above natural conditions.
- **Dr Jones comments**

In Michigan, our state MDEQ (regulatory agency) used to permit whole-lake systems for lakes with deep basins (>25 feet) but there were some concerns about effects of destratification on the lake zooplankton migration. As a result, they are evaluating lake permits on a case by case basis and now require zooplankton data be collected to aid in future decision-making. Lakes that are not permitted to have deep basin aeration, have aerators located in the 0-12 foot contour. This has led to muck reduction in those areas but little nutrient reduction in the water column without aeration in the deep basin. Deep basins are notorious for the release of phosphorus under anoxic conditions. These nutrients then enter the sediment pore water and water column throughout the lake and lead to increased primary production (algae, aquatic plants).

Another approach is that a lake manager / taxpayer for funding has to consider the trade-off of what is more detrimental to the health of the lake---a DE stratified deep basin with uniform temperatures but low nutrients and better clarity or a stratified deep basin with low oxygen, excessive nutrients, and low clarity due to excessive primary production. Low dissolved oxygen is also not conducive to a healthy fishery or ecological balance.

Sincerely,

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- All of the nutrients released from oxidizing the sediment will be in the water column until the system is shut off or discontinued, after which the lake is expected to be worse off as the organic-rich biota created by the aeration system drops into the sediments.

- Clean Flo utilizes oxidation and bioaugmentation to fix, treat, assimilate P and N nutrients. Oxidized metals (iron, manganese, lead, mercury, etc.) should precipitate and remain in sediment not in the water column.
- Water clarity will likely be affected.

- Clean Flo reduces turbidity and TSS and clarifies the water. Insert Clean Flo inversion statement

Cost:

- The proponents are proposing to initiate a pilot study in either Basin 1 or 2 for a year for a cost of approximately $1 million. It is unclear what the total cost of fully implementing the technology would be. Aside from the cost to a vendor, there are likely to be other costs to implement the technology such as equipment, land purchase/lease, compressor housing, setup, maintenance, and monitoring.

- Clean Flo costs estimates were included in article which included installation, materials, maintenance, testing.

Water Treatment:

- Breaking thermal stratification will release nutrients from sediments in the summer and create more algae, and with it more taste and odor issues, disinfection byproducts, and require higher coagulant and disinfectant dosing. More algae will lead to clogged screens and/or increase dissolved air floatation runtimes.

- Clean Flo oxidation and bioaugmentation reduces algae, reduces taste and odor precursors, disinfectant by products and drinking water treatment costs. Clean Flo also utilizes diffusers which create similar tiny bubbles seen in DAF units.
- The recommendation to switch from free chlorine disinfection to chlorine dioxide is not without issues. Chlorine dioxide produces the disinfection byproducts of chlorate and chlorite (though it does produce less trihalomethanes [THM]), requires more technical skill to produce, requires daily chlorite monitoring, requires the use of hazardous chemicals (the city just retired the use of gaseous chlorine in favor of generating chlorine from salt), and costs more than chlorine disinfection.

- LanXess, a subsidiary of ADOX international, has 50 years' experience in supplying automated CLO2 SKID Mounted systems which are intrinsically safe and prevent human exposure.

Recreation/Aesthetics:

- The proposal would generate more algal growth, which the proponents say would then be eaten by fish, thereby enhancing depleted fish populations. It is not clear that current fish populations are depleted, and if not, would they be able to respond to the increase in available food?

- Clean Flo reduces algae growth by fixing/assimilating P and N nutrients. Clean Flo promotes a healthy food chain (all zooplankton and aquatic insects which feed on algae and in turn are eaten by higher aquatic life forms,
- How is it known that fish will benefit from more algae and how can we know the algae produced will be the kind that is the preferred diet of lake inhabitants?

- Assumption that fish eat only algae. What about zooplankton, and lower aquatic life forms which may eat algae and in turn are consumed by higher life forms? Show Clean Flo slide example from Dave.
- What would be the impact of increased algae on wading, swimming, and boating?

- Algae are reduced from current Lake Conditions.
- What would be the impact on boating from in-water infrastructure?

- No boating issues because water quality will be improved with Clean Flo
- The proposal would result in the thermal destratification of the lake, which will lead to colder surface temperatures in the summer, which would impact recreation.

- Destratification will lower total water temperature and may require wet suits for swimmers/water skiers but should not affect boating/sailing/diving
- The proposal will require the acquisition of property and the installation of an array of compressors and associated infrastructure. This will lead to visual and noise impacts.

- Air Compressor housing is non-obstructive/obtrusive. Compressor housing can be sound insulated. Placement of compressors can be negotiated with city and home owners.

This memorandum summarizes the data team's initial review of the attached proposal.

The Data Team appreciates the input and concern for the quality of Lake Whatcom from Mr. Ledet and Mr. Bauman. We recognize that their proposal reveals important aspects of nutrient cycling that need to be better understood. We may be able to answer many of those questions as we update the lake cycling model over the next few years.

If you have questions, please feel free to contact Clare Fogelsong at (360) 778-7800.