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Mr. Tom Luster,
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Subj: The Port of Seattle's Potential Use of Drinking Water to Augment Summer Low Flows in Miller and Des Moines Creeks.

Dear Mr. Luster:

At the request of the Airport Communities Coalition, I have assessed the Port of Seattle's declared intent to use City of Seattle drinking water to augment summer flows in Miller or Des Moines Creeks when flows fall below 1.0 cfs (cubic feet per second). Of particular concern in my assessment, was the potential toxicity of chlorine and fluoride, which are introduced to the City of Seattle's drinking water supply by the Seattle Water Department. Possible effects associated with differences in conventional water quality parameters, e.g., temperature, dissolved oxygen, pH, and alkalinity, between drinking water and stream waters, were also assessed. In undertaking this assessment, I have relied on my education, specialized training, and professional skills acquired over a 40-year career as a Fisheries Biologist (see attached Curriculum Vitae).

Conclusion

In my opinion, for the following reasons, City of Seattle drinking water should not be used to augment summer low flows in area streams. Free chlorine in drinking water is highly toxic to fish and other aquatic life. The free chlorine reacts with humic substances in surface waters forming a variety of by-products that are persistent, bioaccumulated, and also toxic to fish and other aquatic life. Even with treatment, the levels of chlorinated by-products may still be high enough to be harmful. Fluoride found in drinking water also can have both lethal and sublethal effects for fish and other aquatic life, and may not be reduced to harmless levels employing current waste treatment technology. Differences in conventional properties, e.g., temperature, dissolved oxygen, pH, and alkalinity, between drinking water and stream water, may also produce impacts.

Use of well water from sites within either the Miller or Des Moines Creeks watersheds is potentially a less harmful alternative; although even the use of well water can prove to be problematic, if the conventional properties of well waters are very different from the conventional properties of the receiving waters.

The Port of Seattle will need to carefully model the transport, fate and potential effects of chlorine residuals and fluoride in area streams to provide reasonable assurance that use of City of Seattle drinking water will not harm fish and other aquatic life. The Washington Departments of Ecology and Fish and Wildlife also may not permit this alternative, knowing that chlorine residuals and fluoride are toxic to fish and other aquatic life at relatively low levels (<10 ug/L for chlorine residuals and < 1 mg/L for fluoride).

My opinions and the detailed evaluations on which they are based are found in the following sections:

Opinions

- **Chlorine and Chlorination By-Products Are Toxic to Fish and Other Aquatic Life at Relatively Low Concentrations.**

The City of Seattle chlorinates their water supply at concentrations of 1.5 to 2.5 mg/L, which leaves between 0.5 and 1.5 mg/L (total residual) at the tap (personal communication with Julie Hutchins, Senior Water Quality Engineer, City of Seattle Water Department, Seattle, Washington, August 18, 2000).

The State of Washington's acute water quality criterion (WAC173-201A-030) for chlorine (total residual) in freshwater is 19 ug/L, which is a 1-hour average concentration not to be exceeded more than once every three years on the average. The chronic water quality criterion for freshwater is 11 ug/L, which is a 4-day average concentration not to be exceeded more than once every three years on the average. The State's chronic criterion for chlorine, then, is more than 100 times lower than the chlorine residual in tap water.

The Aquatic Ecological Risk Assessment database (Parkhurst et al. 1996) lists the LC_{50} for daphnia (water flea) at 27.6 ug/L. The LC_{50} value is the concentration of a chemical that is lethal to 50 percent of the test (bioassay) organisms. The same database, indicates that rainbow trout and cutthroat trout have LC_{50}s of 61.92 and 85.46 ug/L, respectively. Cutthroat trout are found in both Miller and Des Moines Creeks. The above toxicity values (LC_{50s}) for daphnia, rainbow, and cutthroat trout are from the database used to set USEPA's Water Quality Standard for chlorine and chlorinated by-products (USEPA 1994), from which the State of Washington Water Quality Criterion for chlorine was developed.

Chlorination by-products, which include such compounds as trihalomethane (chloroform), bromoform and cloramine, may be more toxic than free chlorine. These compounds are formed when chlorine reacts with humic substances in surface waters, which are natural products of animal and vegetation decay. Many of these compounds are persistent, bioaccumulated, and toxic in their own right.

Chlorine by-products are regulated by the State of Washington from a public health perspective but not from an ecological perspective. Total trihalomethanes may not exceed 100 ug/L in drinking water in small water supplies, while larger water supplies like the City of Seattle, are being required to reduce the levels of trihalomethanes to <80 ug/L. The US Environmental Protection Agency, in their Water Quality Standards Regulation (USEPA 1994), indicates that trihalomethane (chloroform) is a carcinogen, where any concentration in water and seafood exceeding 5.7 ug/L, if consumed daily over a lifetime, will result in an increased cancer risk. Using the same convention to express risk, the USEPA (1994) indicates that a concentration of 0.27 ug/L of dichlorobromomethane, from water and seafood, will also increase the risk to cancer.

Unfortunately, very few data documenting the potential harm of chlorine by-products to fish and other aquatic organisms are available. What data are available is limited to a few studies with chloramines. Chloramines were found to kill coho salmon in 20-hours (Holland et al. 1960) and rainbow trout in seven days (Merkens 1958) over essentially the same range of exposure concentrations, 100 to 1000 ug/L. Chronic studies based on reduction in egg production with an amphipod indicated that the TL_m (median tolerance limit) in 96-hr acute exposures was 220 ug/L (Arthur and Eaton 1971). A study with fathead minnow conducted by the same researchers resulted in total mortality of the test population in three days at a chloramine concentration of 154 ug/L. In 15-week chronic exposures, the lowest concentrations having no effects on reproduction were <3.4 ug/L for the amphipod and 16.6 ug/L for the fathead minnow. A sublethal test using avoidance behavior as an endpoint established that concentrations of chloramines as low as 5.7 ug/L were detected and avoided by killifish (Hidaka and Tatsukawa 1985), which suggests that similar effects could occur with salmon, affecting their ability to home on natal waters using olfactory cues.

If City of Seattle drinking water is introduced to either Miller or Des Moines Creeks during low summer flows (<1.0 cfs) without treatment (dechlorination), concentrations of free chlorine would exceed the State of Washington's Water Quality Standards, for both acute and chronic criteria (see first and second paragraphs above). These are very small streams offering little dilution during the summer months. For example, if 1 cfs of municipal water was added to a stream, itself flowing at 1 cfs, the dilution factor is only 2, or 50 percent. If the concentration of chlorine in the City of Seattle's drinking water is 1 mg/L, the concentration in the stream after initial mixing would still be 0.5 mg/L or 500 ug/L, which greatly exceeds both the Water Quality Standards and toxic thresholds as demonstrated in the scientific literature. While we don't know how much City of Seattle drinking water the Port of Seattle might add to a stream as flows fall below 1.0 cfs, it is not likely that target flows would be more than doubled or tripled. Even if tripled, the concentration of chlorine in the stream after mixing would still be approximately 333 ug/L and still would exceed the Water Quality Standards and toxic thresholds.

Clearly, dechlorination will be required and techniques are commercially available to remove residual chlorine down to <10 ug/L (Liu et al. 1997). However, these techniques are not typically employed in the context apparently proposed by the Port of Seattle and have significant drawbacks in terms of long-term reliability without extraordinary monitoring and maintenance. For example, use of activated carbon columns, with which I have personal experience (Strand 1975), will remove chlorine from tap water down to <10 ug/L (total residual), although the efficacy of removal is dependent on contact time, which is, in turn, dependent on the surface area of the activated carbon column, and the flow rate through the column. In use, the activated carbon column eventually loses its ability to remove (bind) chlorine and the efficacy of removal decreases, requiring back flushing and resettling the activated carbon column, or changing (recharging) the filter column with new activated carbon. Hourly monitoring is required to assure that the filter column achieves targeted dechlorination. Aeration is another method that can be used to remove chlorine but may not be as effective as carbon column filtration. Usually, aeration is employed in wastewater treatment plants where dilution is counted upon to reduce residual concentrations of free chlorine below harmful thresholds.

Unfortunately, activated carbon filtration will not remove all the free chlorine or chlorine residual from drinking water. Removal to <10 ug/L may be all that can be expected. This means that chlorination by-products will continue to form, indicating that fish and other aquatic life will continue to be exposed to potentially harmful levels of chlorine and chlorine by-products. As we established above (see the sixth paragraph in this section), chronic exposure to chlorination by-products at concentrations as low as 3.4 ug/L reduced reproduction in amphipods (Arthur and Eaton 1971), while concentrations of 5.7 ug/L were detected and avoided by killifish (Hidaka and Tatsukawa 1985).

- **Fluoride Is Toxic to Fish and Other Aquatic Life and Also Affects Salmon Migration**

The City of Seattle also fluoridates their drinking water maintaining a concentration of 1 mg/L fluoride at the tap (personal communication with Julie Hutchins, Senior Water Quality Engineer, City of Seattle Water Department, Seattle, Washington, August 18, 2000). The U.S. Environmental Protection Agency (USEPA 1973) and the Province of British Columbia (Foulkes and Anderson 1990) maintain a "permissible level" of 1.5 mg/L for fluoride discharges to freshwater. BC's "recommended guideline," however, is 0.2 mg/L but this is not the legal limit (Foulkes and Anderson, 1990).

A review of the scientific literature indicates that concentrations of fluoride below 1.5 mg/L can have both lethal and sublethal effects for fish and other aquatic life. There are studies with a wide spectrum of aquatic organisms. As reviewed in Foulkes and Anderson (1994), delayed hatching in rainbow trout occurred at 1.5 mg/L, brown mussels died at 1.4 mg/L, a red alga was killed after four hours exposure to 0.9 mg/L, and daphnia, the water flea, was killed at <0.1 mg/L.

In studies conducted by Angelovic et al. (1961), the 240-h (chronic) LC_{50} for rainbow trout exposed to sodium fluoride was found to be 5.9-7.5 mg/L at 44mg/L hardness (see Foulkes and Anderson 1994) and 7.2°C. At 12.5°C, the LC_{50} was 2.6-6.0 mg/L; while at 18.3°C, it was 2.3-7.3 mg/L. Neuhold and Sigler (1960) reported the same levels of toxicity at 44 mg/L hardness and 12.8°C. Using the data from Angelovic et al. (1961) and Pimental and Bulkley (1983), the LC_{50} at lower hardness levels (12 mg/L) was estimated to be 0.2 mg/L (Foulkes and Anderson 1994).

Fluoride like chloramines may mask olfaction and adversely affect migration in salmonids. Damkaer and Dey (1989) in field tests at John Day Dam on the Columbia River found that fluoride at 0.5 mg/L, from a smelter 1.6 km above the dam, significantly increased migration times of Chinook and coho salmon in the reach below the dam to 155 hours, with a 55 percent loss in adult fish. At 0.17 mg/L fluoride, the migration time was reduced to 28 hours with only an 11 percent loss of adult fish. At 0.2 mg/L, the loss of adult salmon was reduced to 5 percent. The results of the field tests were essentially duplicated in the laboratory using a two-choice or "y" flume, where it was determined that 0.2 mg/L fluoride again was detected by test fish and avoided..

Treatment of City of Seattle drinking water will again most certainly be required to reduce residual fluoride to harmless levels before discharge to area streams. Principal fluoride removal methods are precipitation by lime, absorption on activated alumina, or removal by an ion exchange process, all of which are expensive, and may not remove fluoride below 1-2 mg/L level (Liu et al. 1997). This level of efficacy, as we have determined earlier in this assessment (see paragraphs 1-3 in this section), will not be protective of fish and other aquatic life.

- **Conventional Properties of City of Seattle Drinking Water May Also Harm Fish and Other Aquatic Life.**

Care will need to be exercised to see that the conventional properties of City of Seattle drinking water, e.g., temperature, dissolved oxygen, pH, alkalinity, are similar to the conventional properties of the stream into which the drinking water might be discharged. For example, differentials in temperature of more than 2-3° C could kill fish and other aquatic life in streams receiving a significant volume of either cooler or warmer drinking water (Nielsen et al. 1983). Temperature of the drinking water should be as similar to the temperature at the discharge site as possible so that thermal shock is avoided. Alkalinity and pH will be lower in drinking water when compared with the stream and may have to be adjusted upward to avoid osmotic shock.

- **Use of Well Water Is Also Not Free of Potential Impacts**

If available, use of well water from sites within either the Miller or Des Moines Creeks watersheds, could prove a less harmful alternative, assuming that the source of well water is free of chemical contamination, and its use does not draw-down area wetlands and streams. Again, care will need to be exercised to see that the conventional properties of the well water, e.g., temperature, dissolved oxygen, ph, alkalinity, are similar to the conventional properties of the stream into which the well water might be discharged. In particular, temperature in well water will likely be different, and dissolved oxygen may also be depleted, so that aeration may be required. Dissolved oxygen should always be maintained at or above a level of 5mg/L (Nielsen et al. 1983).

- **There Are Too Many Unanswered Questions.**

The Port of Seattle has not indicated which treatment technology(s) they will employ if they decide to use City of Seattle drinking water to enhance low summer flows in area streams. Clearly, in the absence of treatment, toxicity will result from chlorine, chlorinated by-products, as well as fluoride. I believe that the Washington State Departments of Ecology and Fish and Wildlife would concur in this assessment. Has the Port of Seattle even contacted these two State agencies in this regard?

Even with treatment, there still is need to assess the transport, fate, and potential bioeffects of chlorine, chlorinated by-products, and fluoride in area streams. Chlorine residuals and fluoride are toxic to fish and other aquatic organisms at fairly low levels. Unfortunately, the Port of Seattle has not indicated how they will guarantee that use of either City of Seattle drinking water or well water from either the Miller Creek or Des Moines Creek watersheds will not be harmful to fish and other aquatic life. Is the Port of Seattle contemplating formal risk assessment backed by simulation modeling in this regard?

Thank you for the opportunity to comment on this Report. I am available to discuss any of my comments in greater detail.

Yours very truly,

John A. Strand, Ph.D.
Principal Biologist

Cc: ACC

References

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Arthur, J.W., and J.G. Eaton. 1971. Chloramine Toxicity to the amphipod *Gammarus pseudolimnaeus*, and the fathead minnow, *Pimephales promelas*. *Journal of the Fisheries Research Board of Canada* 28(12): 1841-1845.