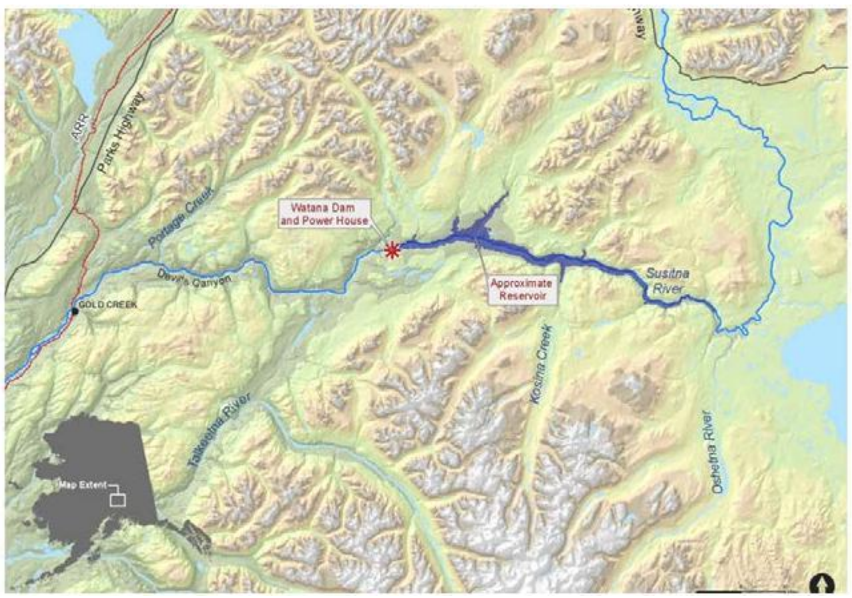
WQ-S2
Technical Memorandum
V1.0
Water Quality Baseline Monitoring: Nutrients and Chlorophyll *a*



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1 BACKGROUND

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project (Project). The application will use the Integrated Licensing Process (ILP). The Project is located on the Susitna River, at River Mile (RM) 184. The dam would be located within a steep-sided river valley approximately 15 miles upstream of Devil's Canyon. Currently the plan is to construct a 700-foot high dam to impound a 39-mile long reservoir with a gross storage capacity of 4,334,000 acre-feet. The installed capacity of the power plant would be approximately 600 MW.

Construction and operation of the Project as described in the Pre-application Document (PAD) will affect flow regimes and water temperature and water quality downstream of the proposed dam site. Prior to granting a license, the potential impacts of this project on the environment must be evaluated and presented to FERC. This can be done by collecting information from the area, and using modeling to project the impacts of the Dam on various physical parameters.

The collective goal of the water quality studies is to assess the effects of the proposed project operations on water quality in the Susitna River basin and to identify and develop protection, mitigation, and enhancement measures that can be implemented to minimize these effects.

A review of the objectives of the Baseline Water Quality Study are to:

- Build upon and use, as appropriate, the historical water quality data available for the study area.
- Continued collection of stream temperature and meteorological data.
- Characterize surface water physical, chemical, and bacterial water quality conditions in the Susitna River within and downstream of the proposed project area.
- Document baseline metals concentrations in sediment and fish tissue and compare to state criteria.
- Assess the potential for mercury methylation (i.e., bioavailable form) in the newly formed reservoir and assess the potential for changes to mercury levels in fishes in the proposed reservoir.
- Conduct a pilot thermal imaging assessment of a portion of the Susitna River.

Nutrient monitoring and chlorophyll *a* (chl) analysis are primary components of the currently proposed set of water quality parameters that will characterize conditions in the project area. Many of the proposed water quality parameters have a direct effect on survival of aquatic life, whereas, nutrient are the building blocks for primary production that affects food source and food base for all aquatic life in sloughs, tributaries, and the mainstem Susitna River. The nutrient cycle is an important component of the aquatic environment to understand and to manage so that impacts to aquatic communities is enhanced or diminished.

Available nutrient information in the Susitna drainage was reviewed in a Water Quality Gap Analysis (URS 2011). Nutrient analysis (e.g., ortho-Phosphate and Nitrate-Nitrogen) was conducted at limited tributary locations from the Susitna watershed in the 1980s. However, limits of detection as well as quantity of observations were inadequate. In addition, TP (Total Phosphorus), NH3-N (Ammonia Nitrogen), and direct TON (Total Organic Nitrogen) were not measured. Chlorophyll *a* was collected only at the lower portion of the mainstem Susitna River (RM 25.8) and reported low concentrations at this site prior to 2003.

AEA has requested that a thorough review of the importance of nutrient and chlorophyll *a* (chl) characterization be determined through a water quality baseline monitoring program. Nutrients and chl concentrations may be impacted by project operations and will have effects on primary and secondary production that can be predicted based on experimental results from other examples. Collection of nutrient and chl data in the Water Quality Baseline Monitoring Study (WQ-S2) will be used to confirm initial hypotheses and for use in developing a Water Quality Model for both the reservoir and riverine portion of the basin.

This technical review will address two issues:

1) Why chl and nutrients data should or should not be collected as part of the baseline water quality study and included in the modeling analysis; and
2) What nutrient-related parameters will or will not be modeled, including data that will need to be collected in order to be able to model nutrients, and a rationale for these decisions.

2 ENVIRONMENTAL CONSIDERATIONS

In order to understand and predict potential changes to any aquatic environment, a basic understanding of the fundamental drivers needs to be developed. Nutrients, light, water, and temperature are the fundamental drivers for all aquatic life.

2.1 Sources and Effect on Production

Large impoundments usually increase nutrient concentrations in tail waters that often lead to increased production and biomass of periphyton at substantial distances downstream. That can occur even in oligotrophic (low productivity) waters, because reservoirs create dissolved oxygen (DO) deficits due to thermal stratification. For example, Chester Morse Reservoir in the WA Cascades, which had a very low total phosphorus (TP) inflow concentration of 4 µg/L, also had and an areal hypolimnetic oxygen deficit (AHOD) of 175 mg/m² per day (Welch and Perkins, 1979). Hypolimnetic DO concentrations may or may not reach anoxic conditions in impoundments with oligotrophic input waters, but if anoxia occurs then soluble phosphorus (SRP) concentrations in tail waters can be high due to iron redox conditions in the anoxic hypolimnion. For example, large mats and long streamers of *Cladophora* occurred downstream from Tiber Reservoir on the Marias River in north central Montana in the 1960s following dam construction (Welch, E.B., personal observation). That may have been due to the typical peak in TP concentrations that occurs in newly constructed reservoirs and that lasts about a decade (Ney, 1996; Stockner et al., 2000). The large biomasses of *Cladophora* have since disappeared (personal comm. Montana Fisheries Manager).

Even if hypolimnetic DO does not reach anoxia in reservoirs, nitrogen (N) and phosphorus (P) accumulate in the hypolimnion as plankton and incoming organic matter settle and decompose, which is the cause for high AHODs. Also, inflows to reservoirs plunge and enter the metalimnion, depriving the epilimnion of nutrients. This tends to short-circuit much of the inflow nutrients to the outflow (Welch et al., 2011). Thus, tail waters can have elevated nutrient concentrations. Periphyton production is known to increase in oligotrophic rivers with modest increases in SRP concentrations from 1 to 9 µg/L (Stockner and Shortreed, 1978; Vancouver Island, BC) and 1 to 20 µg/L (Perrin et al., 1987; Thompson River, BC). Filamentous green algae reached 500 mg chl/m² in a week in channels with SRP increased from 2 to 10-15 µg/L (Horner et al., 1983, 1990; Walton et al., 1995; Anderson et al., 1999). Therefore, tailwaters from even oligotrophic reservoirs are apt to have increased periphytic algal production.

2.2 Introduction and Transport in the Aquatic Environment

Impoundments on turbid rivers also settle and retain the incoming sediment load. As a result, the tail waters are clear, which also produces conditions for higher rates of periphyton production from the increased nutrient input from the reservoir hypolimnion. That was the case for Tiber Reservoir on the naturally turbid Marias River, Montana (Gene Welch, 2012 personnel communication).

Large impoundments are also known to reduce productivity of oligotrophic river systems long-term by sequestering nutrients entering from upstream. This oligotrophication process has reduced fisheries production in reservoir/river systems in Sweden and British Columbia (Stockner and Milbrink, 1999; Stockner et al., 2000; Metzinger, et al., 2007; and Anders and Ashley, 2007). The importance of nutrients to fisheries production in these systems has been demonstrated by their restoration through artificial fertilization (Stockner and Milbrink, 1999; Milbrink and Holmgren, 1981; and Milbrink et al., 2008). The Kokanee fishery of Kootenay Lake and Hugh Keenleyside dam on Arrow Lakes in BC are examples. Production of migratory and resident fish in oligotrophic river systems of Alaska is known to be highly dependent on the nutrient release from the decaying carcasses of returning adult salmon. Thus, an impoundment imposed on river systems may affect both migratory and resident fisheries.

The above, briefly described problems of eutrophication and oligotrophication resulting from impounding river systems warrant establishing a thorough database for nutrients and periphytic algae before and after dam construction, as well as reservoir water column nutrient and chl concentrations afterward. Phosphorus as TP and SRP, and N as nitrate and total N should be determined, as well as chl and alga taxa in the river (periphyton) and water column during impoundment monitoring.

Without a baseline database for nutrient, chla, and algae, impacts to existing production within the Susitna River and the Project area will remain undefined. Reasoning for potential changes in the aquatic life community after the Project is completed will be unknown in terms of direct impacts to water quality. Knowing pre- and post-Project nutrient concentrations and production within the river and Project Area will allow AEA to determine and quantify impacts on aquatic life.

3 MODELING NUTRIENTS:RIVERINE/RESERVOIR ENVIRONMENTS

Phosphorus is probably the key nutrient that determines algal productivity in a presumably oligotrophic river system, like the Susitna. However, nitrate also can be an important determinant of algal growth rate at times. Therefore, both nutrients should be incorporated into models that simulate river periphyton production and biomass. Modeling of river periphyton has not been as successful as phytoplankton in lakes and reservoirs. Complex models for both phytoplankton and periphyton contain submodels and coefficients that have general relevancy, but which may not apply in specific water bodies.
For example, the CE-QUAL-W2 water quality model for reservoirs works well for temperature and DO, but often poorly simulates algal and nutrient concentrations. Also, consensus experimental evidence and understanding for algal dominance is lacking among limnologists, and this model includes that presumed capability. While complex models are reliable for some variables, they are not for others. Therefore, basic, reliable data are necessary, to assure, that model output is reasonable. Simple models may be preferable for some purposes, such as predicting summer average epilimnion algal concentrations (i.e., chlorophyll) from TP loading and equilibrium TP concentrations, or more appropriate the bathtub model for reservoirs with zones often marked by different nutrient and algal concentrations.

3.1 Problems Encountered Modeling Nutrients

Several issues associated with modeling nutrients are commonly encountered. These issues reinforce the need to monitor nutrients both to provide accurate nutrient data and to help calibrate nutrient and productivity modeling efforts. Among those issues are the following:

- It is difficult to model biological interactions with nutrients; including uptake and release; complex interactions between aquatic life, nutrients, and DO;
- It is difficult to model food web interactions without information on primary productivity and nutrient concentrations as well as secondary productivity information;
- Various forms of nutrients, including soluble, particulate, bio-available and non-bioavailable, make modeling difficult. Models will have to choose the form of each nutrient that best represents system characteristics;
- It is difficult to predict changes in anthropogenic sources; whether they increase or decrease with time; and
- Nutrient and chla are variable year-to-year depending on climate, weather, season, etc.

4 RECOMMENDATIONS

The following table summarizes the rationale for collecting and monitoring of nutrient parameters, companion water quality parameters, and chlorophyll for developing understanding in both reservoir and riverine ecosystems.

Water Quality Parameter	Rationale for Inclusion
Total Phosphorus	Metabolic dynamics of aquatic ecosystems and either driver or stress for entire food web
Soluble Reactive Phosphorus	Available phosphorus that can sustain, enhance or limit biological production
Total Nitrogen (Organic)	Tracer for nitrogen cycling within the system
Nitrate-Nitrogen	Available nitrogen form for sustaining or enhancing aquatic life
Ammonia-Nitrogen	Potentially available nitrogen source for aquatic life, but also a stressor, plus it is a tracer for DO interactions and organic decay
Algae (water column)	Tracer for primary production both in terms of location (backwater versus main stem) and how active is periphyton scouring versus planktonic production to secondary and tertiary production
Periphyton (substrate)	Both primary production and community structure integrated aquatic balance
Chlorophyll *a*	Direct tracer of primary production and where production is occurring
Phaeophyton	Relative measure of photosynthetic activity versus decline of primary producers
Discharge (flow)	Removal, stability, and Residence time of nutrients and biota

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