Revised Study Plan
Boundary Hydroelectric Project (FERC No. 2144)

Study No. 11
Productivity Assessment

Seattle City Light

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Study No. 11 – Productivity Assessment

1.0 INTRODUCTION

The productivity of aquatic systems is characterized by primary and secondary productivity. Primary production forms the basis of the food chain and refers to the rate of biomass formation of organisms that photosynthesize. Primary producers in aquatic systems include phytoplankton (free-floating algae), periphyton (algae attached to substrata), and macrophytes (plants large enough to be visible to the naked eye). The littoral habitat of the reservoir refers to the channel area where the level of light penetration reaching the bottom is sufficient for photosynthesis. This area usually supports larger and more diverse populations of periphyton and macrophytes than deeper water habitats. In addition to using energy from the sun, primary producers also need organic nutrients, such as carbon, nitrogen and phosphorus, for growth.

Secondary productivity forms the second level of the food chain and refers to the rate primary producers are synthesized into animal tissue. Examples of secondary producers in aquatic systems include zooplankton and benthic macroinvertebrates (BMI), which in turn are eaten by organisms higher in the food chain such as fish. Both primary and secondary productivity are important in riverine systems because it partially controls the magnitude of fisheries that can be sustained. Therefore, it is important to understand the productivity of the Boundary Reservoir reach of the Pend Oreille River and how the productivity may or may not be affected by current operations and alternative operational scenarios.

2.0 STUDY PLAN ELEMENTS

2.1. Nexus Between Project Operations and Effects on Resources

Operations of the Boundary Project (Project) affect the water depth and velocity of the Pend Oreille River and the frequency of inundating and dewatering portions of the littoral zone of Boundary Reservoir. These factors can directly influence the growth of periphyton, macrophytes, zooplankton and BMI, all which are indices of aquatic productivity.

2.2. Agency Resource Management Goals

Agency Resource Management Goals are described under the Mainstem Aquatic Habitat Modeling Study (see Attachment 2, Study No. 7 of this RSP).

2.3. Study Goals and Objectives

The goal of the Productivity Assessment study is to determine the effects of current Project operations and alternative operational scenarios on primary and secondary productivity in Boundary Reservoir. The objective of this study is to quantify indices of primary and secondary productivity in reaches of the Pend Oreille River within the Boundary Project area under hydraulic conditions expected from alternative operational scenarios. The Productivity

Assessment will consist of evaluating nutrients, phytoplankton, periphyton, and macrophytes as indices of primary productivity, and zooplankton and BMI as indices of secondary productivity.

2.4. Need for Study

Summary of Existing Information

Available information for Boundary Reservoir and other areas of the Pend Oreille River suggest the productivity is low. A study of water quality in the Pend Oreille River by the U.S. Environmental Protection Agency (EPA) in 1993 classified the system as oligo-mesotrophic based on nutrient concentrations, algal growth, and water clarity (EPA 1993). Oligotrophic systems are nutrient poor and contain little aquatic plant or animal life. Typically, oligotrophic systems have chlorophyll *a* concentrations less than 3 mg/m^3, total phosphorus concentrations between 5-10 µg/L, total nitrogen concentrations less than 250 µg/L, and Secchi depths greater than 16.5 feet. Boundary Reservoir has nutrient and phytoplankton values within these ranges (Table 2.4-1). Analysis of data collected in Boundary Reservoir between 1984 and 2002 shows a mean total phosphorus concentration of 11.3 µg/L and a mean total Kjeldahl nitrogen concentration of 93.8 µg/L (Land and Water Consulting 2004). Chlorophyll *a* has been reported at concentrations of 1–3 mg/m^3 and Secchi depths in the range of 9.8–19.5 feet. Although Boundary Reservoir is in the oligotrophic range based on nutrients and phytoplankton, it is classified as oligo-mesotrophic based on the presence of aquatic macrophytes.

Table 2.4-1. Comparisons of lake trophic standards to measurements of Boundary Reservoir.

	Trophic Type [1]	**Chlorophyll *a* (mg/m^3)**	**Total Phosphorus (µg/L)**	**Total Nitrogen (µg/L)**	**Secchi Depth (ft)**
Trophic Standards	Ultraoligotrophic	0.01–0.5	<1–5	<1–250	
	Oligotrophic	0.3–3			17.7–92.8
	Oligomesotropic		5–10	250–600	
	Mesotrophic	2–15			4.9–26.5
	Mesoeutrophic		10–30	500–1,100	
	Eutrophic	10-500	30-100		2.6-23
	Hypereutrophic		100->500	500–>15,000	1.3–1.6
Boundary Reservoir	Pend Oreille River at Metaline[2]		11.3	93.8	4.6–14.7
	Boundary Reservoir 1996[3]	1.4–2.9	4–17	<100–138	13.5–21
	Boundary Reservoir 2000[4]	1.05	11		10.5–-12.8

Source

1 Adapted from Wetzel (1983)
2 Ecology (2005)
3 Herrera (1998)
4 McLellan (2001)

Aquatic macrophytes refer to aquatic plants such as milfoil that use energy from the sun (i.e., autotrophs) to grow. Aquatic macrophyte biomass has been found to be greatest in the littoral regions of the Pend Oreille River at depths of less than 10 feet (Falter et al. 1991). Little to no growth has been found at depths greater than 18 feet. Maximum macrophyte biomass in the mainstem occurs in the latter part of July and in August (Pelletier and Coots 1990).

A baseline fisheries assessment in Boundary Reservoir conducted in 2000 also found productivity to be low. Mean chlorophyll *a* concentrations were 1.05 mg/m^3, periphyton chlorophyll *a* concentrations were 5.7 mg/m^3 and zooplankton abundance was an average of 5 organisms/L (McLellan 2001). These values are low when compared to other lakes and reservoirs (Table 2.4-2). This study found 18 species of phytoplankton with a mean density of 1,140 org/ml. All species were from four classes of phytoplankton: Clorophyta, Chrysophyta, Cryptophyta, and Eubacteria. The phytoplankton species found in Boundary Reservoir are dominated by cryptophytes, greens, and diatoms. This selection of species is indicative of populations early in succession prior to high grazing pressure, suggesting that grazing by zooplankton in Boundary Reservoir is low (McLellan 2001). Sixteen species of periphyton were also identified with a mean density of 2.59×10^6 organisms/m^2. This study also found 20 species of zooplankton with a mean density of 5 organisms/L. Densities of copepods were the highest during the summer, whereas rotifers were more abundant in the fall. The low density of cladocerans may have indicated heavy predation pressure, but McLellan (2001) also noted a general low abundance of fish in open-water habitats.

Table 2.4-2. Comparison of primary and secondary productivity in Boundary Reservoir and other lakes and reservoirs.

Location	Chlorophyll a Concentration (µg/L)	Zooplankton Abundance (organisms/L)
Boundary Reservoir	1.05 [(1)]	5 [(1)]
Box Canyon Reservoir	1.02 [(2)]	Main channel – mean 12; range 3-40 Littoral – mean 34; range 3-149 [(3)]
Sprague Lake	36.3 [(1)]	40 [(1)]
Rock Lake	19.6 [(1)]	2 [(1)]
Deer Lake	2.0 [(1)]	109 [(1)]
West Medical Lake		204 [(1)]
Lake Michigan	1-3 [(4)]	91 [(4)]
Lake Erie	1-7 [(5)]	322 [(4)]

Source
1 McLellan (2001)
2 Falter et al. (1991)
3 Ashe et al. (1991)
4 Makarewicz et al. (1994)
5 World Lakes Database (2006)

McLellan (2001) suggested that the short retention time of the Boundary Reservoir system may cause low densities of zooplankton because cladoceran generation times (>7.5 days) are longer than the retention time of Boundary Reservoir. The time required for water to pass through a reservoir is termed the hydraulic retention or residence time. Reservoir retention times are a function of inflow and reservoir capacity. The volume of Boundary Reservoir is relatively small, with 95,000 acre-feet of storage at the full-pool forebay elevation of 1,990 feet NGVD 29 (1,994 feet NAVD 88) and 43,000 acre-feet of storage available within the 40-foot maximum drawdown allowed under the current license. At full pool, the residence time of Boundary Reservoir is approximately 43.4 hours under the average annual inflow of 26,480 cfs (SCL 2006). At the 40-foot maximum allowable drawdown, the residence time of Boundary Reservoir is approximately 24.2 hours under the average annual inflow. The hydraulic retention time increases as inflow decreases, and during August low flow conditions, hydraulic residence times may exceed two weeks. In addition, there may be embayments with lower velocity water where hydraulic residence time increases. However, hydraulic retention times are influenced by reservoir capacity and inflow and during the majority of the year hydraulic residence time is measured in hours or days rather than weeks.

The total volume of water stored within Boundary Reservoir fluctuates on a 24-hour cycle due to the load-following operational strategy, as described in the Proposed Study Plan (PSP) section 1.3.5 (SCL 2006). Under current operations, the reservoir pool level is usually maintained within a 10-foot daily drawdown cycle during the summer (forebay elevation 1,980–1,990 feet NGVD 29 [1,984–1,994 feet NAVD 88]). During the fall, winter and spring, the water surface elevation within the reservoir forebay is typically maintained between elevations 1,990 feet and 1,970 feet NGVD 29 (1,994–1,974 feet NAVD 88). Under the current load-following operational strategy, there is little net daily change in reservoir storage; in other words, on a daily basis, outflow equals inflow.

Productivity information is also available for Box Canyon Reservoir located immediately upstream of Boundary Reservoir. Data for Box Canyon Reservoir suggests productivity is slightly higher than in Boundary Reservoir, but still relatively low. Phosphorus concentrations have been reported in the range of 10–40 µg/L (Skillingstad and Scholz 1993) and nitrogen concentrations in the range of 5–157 µg/L (Land and Water Consulting 2004). Falter et al (1991) reported peak chlorophyll *a* levels at 3.5 and 4.1 mg/m^3. One study found phytoplankton densities to be positively correlated to macrophyte biomass (Falter and Riggers 1993), suggesting that aquatic plants may be acting as a nutrient pump from the sediment to the water column through their growth and senescence (FERC 2000). Zooplankton data were collected at 11 sites in Box Canyon Reservoir in both the littoral and deep water areas in 1989 and 1990 (Ashe et al. 1991). Zooplankton abundance was higher in the littoral areas (mean of 34.5 organisms/L) than in the mid-channel areas (mean of 12.3 organisms/L). A different study on the effects of the Ponderay pulp and paper mill built on the Pend Oreille River in Box Canyon Reservoir also studied zooplankton communities (Skillingstad et al. 1993). This study found 22 species of zooplankton from 15 genera. Mean densities ranged from 8.5 to 22 org./L with monthly mean concentrations highest in June and August and lowest in October and April. These values are medium to low when compared to densities from other lakes (Table 2.4-2).

Need for Additional Information

Available information indicates that under existing conditions primary and secondary productivity in Boundary Reservoir is low. The operation of Boundary Reservoir has the potential to affect aquatic productivity by changing the frequency of inundation and dewatering of littoral habitats, which potentially support higher densities of periphyton and macrophytes than deeper water habitats. Water depth and velocity in both littoral and deep water habitats may change under potential alternative operational scenarios, thereby affecting primary and secondary productivity. Primary and secondary productivity form the basis of the food chain and affect the abundance, growth, and distribution of fish within Boundary Reservoir. As such, it is important to understand both aquatic productivity under existing conditions and how aquatic productivity may or may not be affected under alternative operational conditions.

2.5. Detailed Description of Study

Study Area

The study area for this study includes Boundary Reservoir and an approximately 4-mile reach of the Pend Oreille River downstream of Boundary Dam. (Refer to section 1.3 of the PSP [SCL 2006] for a description of the Boundary Project location, facilities, and reservoir.) The Aquatic Habitat Model, which will be used to evaluate the effects of alternative operational scenarios on aquatic habitats and biota in the Pend Oreille River, will be developed for the Pend Oreille River between the confluence with Red Bird Creek (RM 13.1) upstream to Box Canyon Dam (RM 34.5). For purposes of the Aquatic Habitat Model development and Productivity Assessment, four reaches have been identified to describe this area. The first reach (Upper Reservoir Reach) is from Box Canyon Dam downstream to Metaline Falls. This reach is wide and shallow with a gentle slope. The second reach (Canyon Reach) is from Metaline Falls downstream to the mouth of the canyon. This reach is characterized by a deep, narrow gorge with steep walls. The third reach (Forebay Reach) is from the mouth of the canyon downstream to Boundary Dam. This reach is relatively wide and deep. The last reach (Tailrace Reach) is from Boundary Dam downstream to the confluence with Red Bird Creek. This reach is regulated both by flow releases from Boundary Dam and the operations at Seven Mile Reservoir. Seattle City Light (SCL) will continue discussions regarding the downstream extent of studies with relicensing participants and if deemed appropriate, SCL may limit downstream investigations to the U.S.-Canada border.

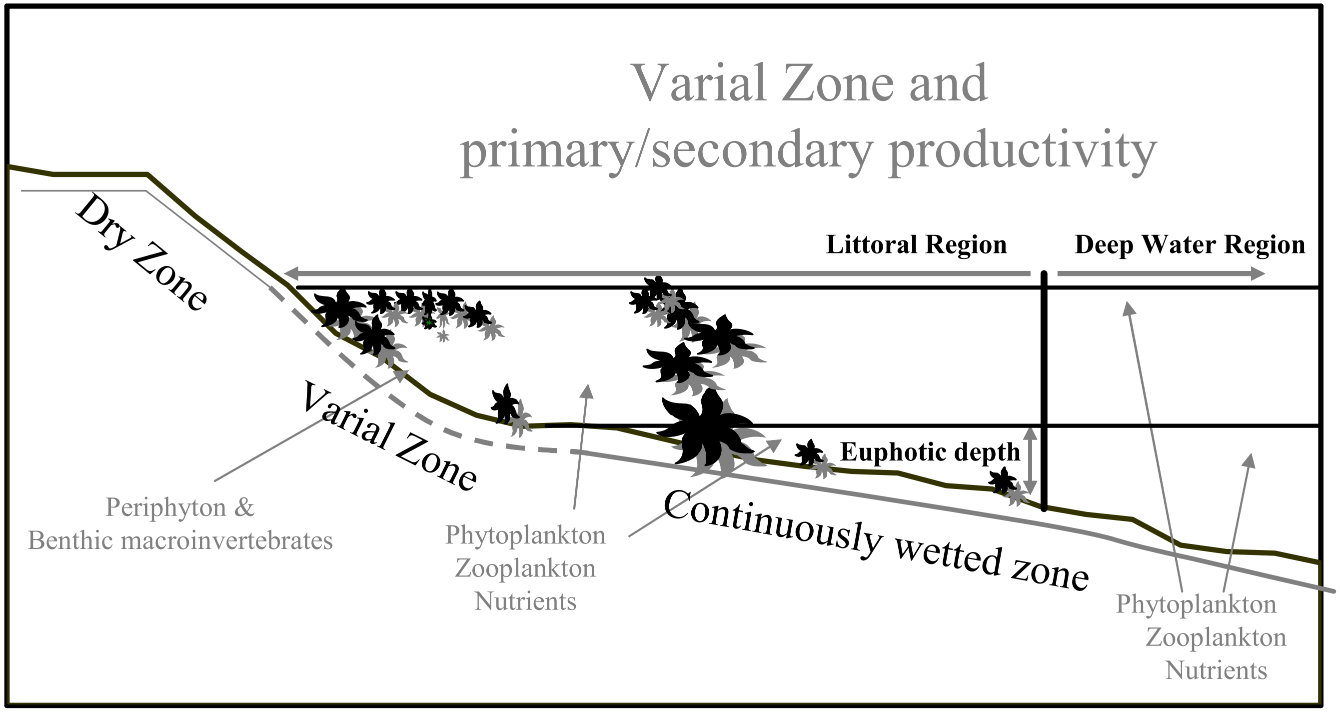
Proposed Methodology

The effects of Project operations on aquatic productivity will be described using six indices of productivity (nutrients, phytoplankton, periphyton, macrophytes, zooplankton, and BMI) (Figure 2.5-1). No attempt will be made to integrate the six indices into a measurement of total reservoir productivity, and the number of organisms potentially produced under each operational scenario will not be quantified. Instead, each of the indices will be assessed as a potential percent change from existing operations, and each constituent will be evaluated and reported as a separate index of productivity. Two separate approaches are proposed for the assessment. The first approach will be used for the attached fauna (macrophytes, BMI, and periphyton). The second approach will be used for nutrients and planktonic fauna.

The methodology for macrophytes, BMI, and periphyton will be to calculate potential habitat indices for existing operations and alternative operational scenarios using the Aquatic Habitat Model (described in Attachment 2, Study No. 7 of this RSP) and the Scenario Tool (described in Attachment 1, section 3.2 of this RSP) (Figure 2.5-2). Data describing the physical and hydraulic characteristics of the Pend Oreille River will be collected along transects and potential habitat conditions modeled under the Aquatic Habitat Modeling study. Information on the response of macrophytes, BMI, and periphyton to changes in hydraulic conditions will be developed as part of the Habitat Suitability Index (HSI[1]) study (see Study No. 7). Habitat suitability information (i.e., HSI curves) represent a functional relationship between the independent variables depth, velocity, substrate, and frequency of inundation/dewatering and the response of organisms to a gradient of the independent variable (suitability), which is expressed over a scale of 0.0 (poor) to 1.0 (best). Output from the Scenario Tool and the Hydraulic Routing Model (see Study No. 7) will predict hourly flow and water surface elevations at transects within the Project area. The Aquatic Habitat Model will be used to predict depth and velocities within cells, or transect subdivisions. The HSI curves will be used in the aquatic habitat model to quantify the area of Pend Oreille River channel containing potentially suitable habitat. This process will be repeated to determine an index of potential productivity for each of the macrophyte, BMI, and periphyton indices under existing operations and for alternative operational scenarios to be evaluated by the Technical Scenarios Team.

Productivity for nutrients, phytoplankton, and zooplankton will be estimated using measurements of upper and lower bounding conditions, and interpolation between those bounds to estimate productivity under alternative operational scenarios (Figure 2.5-2). Measurements of nutrients, phytoplankton, and zooplankton will be collected in Boundary Reservoir under operational and environmental conditions experienced in 2007 and 2008. The measurements of Boundary Project conditions will represent one bounding condition and will be compared to measurements of conditions in the Box Canyon tailrace or the Box Canyon Reservoir as the other bounding condition. Box Canyon Reservoir is located immediately upstream of the Boundary Project and is exposed to a smaller range of pool level fluctuation. Measurement of productivity indices in areas exposed to either Boundary or Box Canyon operations will represent a contrast in operational conditions, and the effects of alternative Boundary Project operational scenarios will be interpolated between the two bounding scenarios.

[1] The abbreviation HSI is used in this document to refer to either Habitat Suitability Index (HSI) models or Habitat Suitability Curves (HSC), depending on the context. HSI models provide a quantitative relationship between numerous environmental variables and habitat suitability. An HIS model describes how well each habitat variable individually and collectively meets the habitat requirements of the target species and lifestage, under the structure of Habitat Evaluation Procedures (USFWS 1980). Alternatively, HSC are designed for use in the Instream Flow Incremental Methodology to quantify changes in habitat under various flow regimes (Bovee et al. 1998). HSC describes the instream suitability of habitat variables related only to stream hydraulics and channel structure. Both HSC and HSI models are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat). Both models and habitat index curves are hypotheses of species-habitat relationships and are intended to provide indicators of habitat change, not to directly quantify or predict the abundance of target organisms. For the Boundary Project aquatic habitat studies, HSC (i.e., depth, velocity and substrate/cover) and HSI (i.e., light availability, duration of inundation and dewatering) models will be integrated to analyze the effects of alternate operational scenarios.



Deep and Littoral Regions

Nutrients: elements required for plant growth, generally nitrogen, and phosphorus

Phytoplankton: algae that grow in the open waters

Zooplankton : grow in the open water and feed on phytoplankton

Littoral Region

Macrophytes: aquatic plants that are either emergent, submergent, or floating

Periphyton: algae that grow on substrates, primarily in water penetrated by light

Benthic macroinvertebrates: grow on substrates, highest density of most species in water penetrated by light

Figure 2.5-1. Indices of primary and secondary productivity.

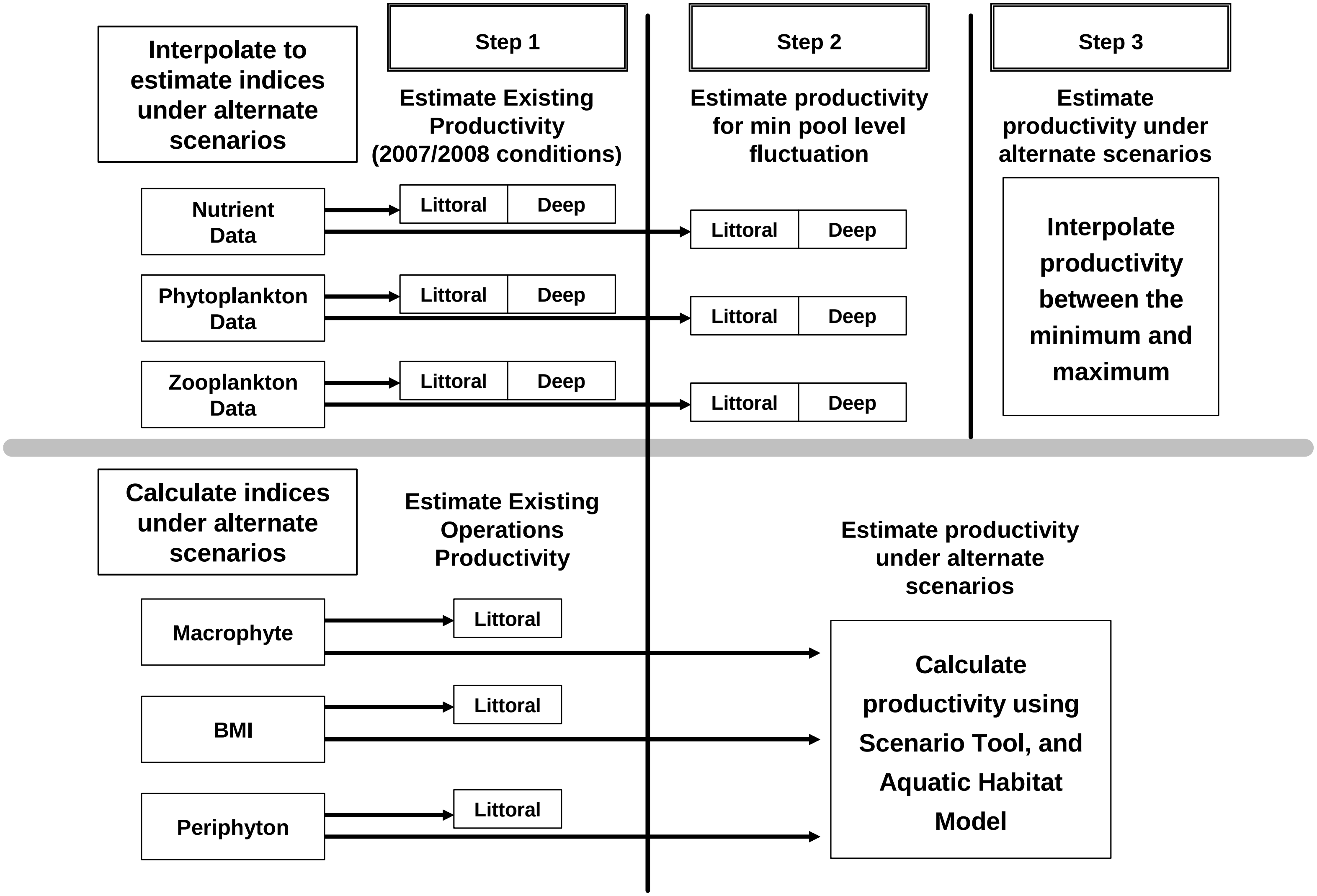


Figure 2.5-2. Productivity Assessment flowchart.

The effects of Boundary Project operations on nutrients, phytoplankton, and zooplankton may vary between littoral habitats and deep water habitats. The littoral area is assumed to extend to the euphotic depth below the maximum reservoir drawdown for the time period under consideration. The euphotic depth represents the depth where light intensity falls to 1 percent of the surface light. The euphotic depth will be estimated as three times the depth of Secchi disk readings (McLellan 2001). In order to evaluate both littoral and deep water habitats, Boundary Reservoir will be subdivided into deep water and littoral habitats based on the seasonal Secchi disk readings and channel cross-section data available from the Mainstem Aquatic Habitat Model (Study No. 7). One result from the Mainstem Aquatic Habitat Model will be estimates of the amount of deep water and littoral habitat area under alternative operational scenarios. Measurements of nutrients, phytoplankton and zooplankton data will be collected in both littoral and deep water areas in Boundary Reservoir to represent one bounding condition. Measurements of nutrients, phytoplankton and zooplankton will also be collected in littoral and deep water habitats in the Box Canyon tailrace or reservoir. Interpolation between the bounding conditions (Boundary 2007/2008 operations compared to Box Canyon operations) may identify differences in the effects of Project operations between littoral and deep water habitats.

Macrophytes colonize littoral areas and supply food and shelter, which enhances invertebrate production. The effects of Project operations on littoral habitat productivity may also be affected by the presence or absence of submerged or emergent aquatic macrophytes. Measurements of nutrients, phytoplankton and zooplankton will be collected in littoral areas both within and outside of macrophyte beds as part of the Water Quality Constituent and Productivity Monitoring study (see Attachment 2, Study No. 5 of this RSP). If the presence of macrophytes is found to have a significant effect on nutrient, phytoplankton and zooplankton productivity, the assessment of the effects of Project operations on littoral habitats may be conducted separately for areas with and without macrophyte beds.

Specific steps for calculating macrophyte, benthic macroinvertebrate and periphyton indices, and interpolating productivity indices for nutrients, phytoplankton and zooplankton are outlined below.

Task 1) Data Collection and Compilation

Collect and compile data from other Boundary Project relicensing studies to be used in the productivity analyses. Indices of productivity to be analyzed are nutrients, phytoplankton, zooplankton, macrophytes, periphyton, and BMI for both the deep water and littoral habitats, if applicable (Table 2.5-1). Data will be compiled from the following studies: Water Quality Constituent and Productivity Monitoring (Study No. 5), Relationship of pH and DO to Macrophytes (Study No. 6), and Aquatic Habitat Model (Periphyton and Macroinvertebrates subsection) (Study No. 7).

Table 2.5-1. Summary of productivity data, study collecting the data, and study conducting the analysis.

Constituent	Primary/Secondary Productivity	Habitat (Deep Water or Littoral)	Constituent Description	Data Source	Analyses
Nutrients	Primary	Both	Concentration of phosphorus and nitrogen	WQ: *Constituent and Productivity Monitoring*	F&A: *Productivity Analyses*
Phytoplankton	Primary	Both	Concentration of chlorophyll *a*	WQ: *Constituent and Productivity Monitoring*	F&A: *Productivity Analyses*
Zooplankton	Secondary	Both	Number per liter, species present	WQ: *Constituent and Productivity Monitoring* F&A: *Productivity Analyses*	F&A: *Productivity Analyses*
Macrophytes	Primary (with Secondary influences secondary)	Littoral	Mapping, abundance, % native/non-native species	WQ: *Relationship of pH and DO to Macrophytes* F&A: *HSI-Macrophyte Assessment*	F&A: *Aquatic Habitat Model*
Periphyton	Primary	Littoral	Number per square meter, biomass	F&A: *Aquatic Habitat Model (Benthos subsection)*	F&A: *Aquatic Habitat Model*
BMI	Secondary	Littoral	Biomass, number per square meter, species present	F&A: *Aquatic Habitat Model (Benthos subsection)* F&A: *Productivity Analyses*	F&A: *Aquatic Habitat Model*

Notes:

F&A – Fish and Aquatics Study
WQ – Water Quality Study

a) Nutrient, Secchi depth, phytoplankton, and zooplankton data will be provided by the Water Quality Constituent and Productivity Monitoring Study (methods are described in Study No. 5). These data will be available at eight stations (Table 2.5-2) by season in deep water and littoral habitats (Table 2.5-3). Nutrient data will be in concentration form, Secchi depth data will be in feet, phytoplankton abundance will be in chlorophyll *a* concentration, and zooplankton data will be in organisms per unit volume. Additional indices of zooplankton abundance, such as species composition and size, will be developed as described in the Water Quality Constituent and Productivity Monitoring Study (see Study No. 5). These indices are available to supplement and interpret changes in zooplankton abundance measured as organisms per unit volume. Nutrient data will only be available in the deep water habitats, while phytoplankton and zooplankton data will be available in the deep water habitat and littoral habitats without macrophytes. As described in the Water Quality Constituent and Productivity Monitoring Study (described in Study No. 5), zooplankton will be collected every 2-hours over a 24-hour cycle to provide an indication of diurnal changes in the zooplankton community. Total phosphorus and total Kjeldahl nitrogen will be representative of nutrient requirements for productivity.

b) An assessment of macrophytes will be conducted under the Aquatic Habitat Modeling study, macrophyte HSI development subsection. This information will be used in the aquatic habitat model to estimate the potential colonization area for macrophytes under alternative operational scenarios. This information will then be combined with the information under the present study to estimate aquatic productivity for littoral habitats by reach.

c) Periphyton and BMI data will be provided by the Aquatic Habitat Model (Periphyton and Macroinvertebrate subsection). This study will provide HSI information, which will be used in the Aquatic Habitat Model to quantify the effects of Boundary Project operations on BMI and periphyton. This information will then be combined with the information under the present study to estimate aquatic productivity for littoral habitats by reach. It is assumed the BMI data will be summarized in number per unit area and periphyton data will be summarized in biomass or chlorophyll *a* per unit area.

d) Information on the morphology of the Pend Oreille River within the Boundary Reservoir will be available from the hydraulic routing component of the Mainstem Aquatic Habitat Modeling Study (see Study No. 7). This information will be used to assess whether the primary study reaches (i.e., Upper Reservoir, Canyon, Forebay and Tailrace) should be sub-divided into separate zones for productivity field sampling. While Boundary Reservoir appears to be well-mixed, some reservoirs have embayments or arms that are hydraulically isolated from the main channel. For instance, the base of Pewee Falls is in a large embayment where the localized morphology may affect the hydraulic retention time, and thus, zooplankton productivity. If the Pewee Falls embayment is hydraulically isolated, separate zooplankton measurements may be appropriate for the main Forebay Reach and the Pewee Falls arm of the Forebay Reach.

Table 2.5-2. Summary of productivity data available from the Water Quality Constituent and Productivity Monitoring study.

Sample station	Location description	Productivity Data Collected
Box Canyon Tailrace	In Boundary Reservoir just downstream of Box Canyon Dam	Chlorophyll *a*, nutrients, zooplankton[1], Secchi depth
Wolf Creek	Pend Oreille River adjacent to Wolf Creek inlet (upstream of Metaline Falls)	Chlorophyll *a*, nutrients, zooplankton, Secchi depth
Metaline Old	Old channel of the Pend Oreille River across from the city of Metaline (upstream of Metaline Falls)	Chlorophyll *a*, nutrients, Secchi depth
Pend Oreille Mine	Downstream of Pend Oreille Mine (downstream of Metaline Falls)	Chlorophyll *a*, nutrients, Secchi depth
Slate Creek	Downstream of Slate Creek across from campsite on left bank (downstream of Metaline Falls)	Chlorophyll *a*, nutrients, Secchi depth, zooplankton,
Everett Creek Island	Upstream of Everett Creek Island (downstream of Metaline Falls)	Chlorophyll *a*, nutrients, Secchi depth
Boundary Reservoir Forebay	Boundary Forebay	Chlorophyll *a*, nutrients, zooplankton, Secchi depth
Boundary Tailrace	Downstream of Boundary Dam	Chlorophyll *a*, nutrients, zooplankton[1], Secchi depth

1. Two zooplankton tows will be taken mid-channel at tailrace sites.

Table 2.5-3. Summary of productivity methods used in the Water Quality Constituent and Productivity Monitoring study.

Parameter	Number of Analyses	Method
Secchi Depth	1 per station	Average of two readings in deep water habitats
Chlorophyll *a*	2 per station 3 per zooplankton station	One at surface and one at approximately 15 feet in the deep water habitat One in the littoral habitat without macrophytes
Nutrients (Kjeldahl nitrogen, total phosphorus, orthophosphorus)	1 per station	Surface sample
Zooplankton	4 tows per station	2 tows in the littoral habitat (without macrophytes) and 2 tows in the deep habitat

Task 2) Field Sampling

Conduct field sampling to collect additional remaining productivity data to be used in the productivity analyses. Collect field samples of nutrients, phytoplankton, and zooplankton in the Box Canyon Forebay in both the littoral and deep water regions for all seasons. Data will be collected in the deep water region and in both the macrophyte and non-macrophyte areas of the littoral region (see Study No. 5).

Task 3) Estimate Productivity for Macrophytes, BMI, and Periphyton: Calculation Methodology

Calculate indices of aquatic productivity (weighted usable area) for macrophytes, BMI, and periphyton under existing operations and each alternative operational scenario using HSI curves and the aquatic habitat model. Each productivity constituent will be calculated and reported separately by reach. Using the HSI curves and information on the depth and velocity, the aquatic habitat model will identify a habitat preference for each cell of the model. Each of these cells will be combined to estimate a potential weighted useable area for macrophytes, BMI, and periphyton.

Task 4) Estimate Productivity for Nutrients, Phytoplankton, and Zooplankton: Interpolation Methodology

a) Calculate indices of aquatic productivity for the 2007/2008 operations. Use data collected in Boundary Reservoir in Tasks 1 and 2 along with estimates of the littoral and deep water areas from the aquatic habitat model and areas with and without macrophyte growth from the habitat mapping task to estimate indices of 2007/2008 productivity for nutrients, phytoplankton, and zooplankton.

b) Calculate aquatic productivity in Boundary Reservoir under the minimum expected range of pool level fluctuations. Nutrients, phytoplankton, and zooplankton will be calculated and reported on separately by littoral and deep water areas within each reach.

   Estimate productivity in the deep water regions of Boundary Reservoir. Use the deep water region productivity data collected for the Box Canyon Tailrace and Forebay sites in Tasks 1 and 2 to determine an appropriate productivity index value. This value is representative of productivity in the remainder of the reservoir under the scenario describing the minimum expected range of pool level fluctuations. Scale the minimum fluctuation scenario estimate by the total amount of deep region area (available from the Aquatic Habitat Model study) within each reach.

   Estimate productivity in the littoral regions of Boundary Reservoir by reach. Use the productivity data collected for the Box Canyon Tailrace and Forebay sites in Tasks 1 and 2 to determine an appropriate productivity index value. This value is representative of productivity in the remainder of the reservoir under the minimum fluctuation scenario. Scale the minimum fluctuation scenario estimate by the littoral region area (available from the Aquatic Habitat Model study) to estimate productivity for each reach. Data will be collected in Task 2 in both the macrophyte and non-macrophyte regions of the reservoir and if significant differences are observed, productivity will be estimated in each of these areas separately.

c) Using the productivity bounds for the 2007/2008 operation and minimum pool level fluctuation scenarios calculated in Tasks 5 and 6 to estimate the relative amount of productivity under other operational scenarios. Relative productivity for other scenarios can be estimated by scaling the productivity information by the area of deep and littoral regions calculated for alternative operational scenarios in the Aquatic Habitat Model study.

The above interpolation methodology for nutrients, phytoplankton, and zooplankton relies on productivity information that may vary either longitudinally in the reservoir, in the deep water versus littoral regions of the reservoir, or in areas with and without macrophytes. For the interpolation methodology to be effective, it is assumed that the longitudinal variation in productivity is significantly less than the variation in productivity between the deep water and littoral regions. Box Canyon forebay and/or tailrace data will be used to estimate productivity at different locations in the reservoir under the minimum reservoir fluctuation scenario. However, it may not be appropriate to use the Box Canyon forebay or tailrace data if the longitudinal variation is substantial because it may not be representative of different locations in Boundary Reservoir. As a result, if data collection efforts find the longitudinal variation in productivity is significant, the outlined methodology will be inconclusive. Under these circumstances, the productivity analysis will instead have to rely on the measured data and general productivity characterizations to assess productivity under alternative operational scenarios.

Task 5) Compilation of Results

Compile a table using the calculations completed in Tasks 1 through 4 of the percent change in productivity comparing alternative operational scenarios to 2007/2008 conditions (nutrients, phytoplankton and zooplankton), or an existing operations scenario (macrophytes, BMI and periphyton). Each of the indices will be assessed as a potential percent change and each constituent will be evaluated and reported as a separate index of productivity. No attempt will be made to integrate the six indices into a single measurement of reservoir productivity, and the number of organisms potentially produced under each operational scenario will not be quantified. Summary data will also be provided by reach and by littoral or deep water habitat in supporting documentation.

2.6. Work Products

The results of the productivity study will be compiled and presented in interim and final study reports. The reports will include the following information:

- A description of data collection methods
- A summary of field data compiled from other relicensing studies used in the analysis
- A summary of field data collected under the present study for the analysis
- A description of productivity calculations
- A discussion of 2007/2008 productivity conditions within Boundary Reservoir

- A comparison of productivity under alternative operational scenarios

2.7. Consistency with Generally Accepted Scientific Practice

The methods described herein have been developed in consultation with relicensing participants. All data collection efforts will follow state or federal guidelines. In addition, any laboratory analysis will be conducted by an Ecology- or EPA-certified facility.

2.8. Consultation with Agencies, Tribes, and Other Stakeholders

Input regarding the Productivity Assessment study was provided by relicensing participants during Workgroup meetings. Workgroup meetings were held in Spokane, Washington, on June 27, 2006, and on August 14, 2006. During the June workgroup meeting, an outline for the Productivity Assessment study plan was presented and comments were provided by relicensing participants. The proposed Productivity Assessment study plan was developed from the outline based on agency and relicensing participant comments. Relicensing participants attending the June 27 workgroup meeting included Pend Oreille County PUD, WDFW, USFS, and CCRIFC. Comments provided by relicensing participants on the review outline for this study plan are summarized in the PSP Attachment 4-1 (SCL 2006) and can also be found in the workgroup meeting summaries (available on SCL's relicensing website, http://www.seattle.gov/light/news/issues/bndryRelic/).

In its PAD/Scoping comment letter (USFWS 2006), the USFWS endorsed the Productivity outline presented at the workgroup meetings. The USFS did not specifically reference the Productivity Assessment study outline in its PAD/Scoping comment letter (USFS 2006), but in a follow-up conference call on September 8, 2006, USFS staff indicated that there was general agreement on the outlines. In a letter to SCL dated August 28, 2006, WDFW requested additional detail on several of the study tasks, and requested additional zooplankton sample sites, sample frequency, and sample analysis (see WDFW's letter, included in the PSP Attachment 4-1; SCL 2006). In response, SCL revised the text of the study plan and included reference to the Water Quality Constituent and Productivity Monitoring study plan (see Study No. 5), which includes additional descriptions of sample sites, frequency and sample analysis. Reference was also made to the Mainstem Aquatic Habitat Modeling Study plan (Study Plan No. 7) which addresses sample size, sample sites and sampling frequency for periphyton and benthic macroinvertebrates. Many of the requested modifications are described in Study No. 5 and Study 7. These study plans were included in the PSP that was filed with FERC on October 16, 2006.

Since filing the PSP, SCL has continued to work with relicensing participants on its proposed study plans. In response to comments made during the November 15 study plan meeting and comment letters filed with FERC by the USFS (2007), WDFW (2007), and USFWS (2007), no substantive changes have been made to the plan for the Productivity Assessment. Comments regarding sample sizes, sample sites and sample frequency are addressed in the Water Quality Constituent and Productivity Monitoring Study plan (Study No. 5) and the Mainstem Aquatic Habitat Modeling Study plan (Study No. 7). (SCL's responses to comments are summarized in Attachment 3 and consultation documentation is included in Attachment 4 of this RSP.) SCL has made a few minor modifications to the Productivity Assessment Study to maintain consistency with information presented in Study Nos. 5 and 7. SCL intends to finalize study implementation details with the Technical Consultant in early 2007 (see Attachment 1, section 2.2 of this RSP). Any remaining questions regarding the sampling strategy will be addressed in coordination with relicensing participants at that time.

2.9. Schedule

The Productivity Assessment is scheduled to begin in early 2007 and extend through mid-2008 (Table 2.9-1). Any necessary field data collection will be conducted during the summer of 2007.

Table 2.9-1. Study schedule, Productivity Assessment.

Activity	**2007**				**2008**				**2009**
	1 Q	**2 Q**	**3 Q**	**4 Q**	**1 Q**	**2 Q**	**3 Q**	**4 Q**	**1 Q**
Study mobilization/startup	------								
Data Collection		------	------	------					
Field Sampling			▲▲						
Data Compilation					------				
Prepare interim study report (first-year results)				●					
Distribute interim study report					●				
Meet with relicensing participants to review first year efforts and results and discuss plans for any second year efforts					●				
Include interim study report in Initial Study Report (ISR) filed with FERC					●				
Hold ISR meeting and file meeting summary with FERC					●				
Productivity Calculations						------			
Prepare "draft" final study report								●	
Distribute "draft" final study report for relicensing participant review								●	
Meet with relicensing participants to review study efforts and results and "cross-over" study results									●
Include final study report in Updated Study Report (USR) filed with FERC									●
Hold USR meeting and file meeting summary with FERC									●

2.10. Progress Reports, Information Sharing, and Technical Review

Interim and final study reports for this study will be available to relicensing participants. Prior to release of the Initial and Updated Study Reports (which will include the results of this study), SCL will meet with relicensing participants to discuss the study results, as described in Attachment 1, section 2.3 of this RSP. In addition, relicensing participants will have opportunities to discuss and comment on study progress at quarterly workgroup meetings and ad hoc subcommittee meetings, as needed.

2.11. Anticipated Level of Effort and Cost

Based on a review of field effort, analysis, documentation, and report writing, the estimated cost to complete this study for the Boundary Project ranges from $140,000 to $180,000.

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