# PART I - ADMINISTRATIVE

## Section 1. General administrative information

**Title of project**

Impact Of Nutrients On Salmon Production In The Columbia River Basin

**BPA project number:** 20030
**Contract renewal date (mm/yyyy):** ☐ **Multiple actions?**

**Business name of agency, institution or organization requesting funding**
University of British Columbia

**Business acronym (if appropriate)** UBC

**Proposal contact person or principal investigator:**


| | |
|---|---|
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**NPPC Program Measure Number(s) which this project addresses**
Sections 7.6, 7.6A, 7.6B, 7.6C, 7.6D and Section 5

**FWS/NMFS Biological Opinion Number(s) which this project addresses**

**Other planning document references**

**Short description**
Examine the potential importance of nutrients on salmon production in the Columbia River basin by examining the impact of dams, reduced salmon returns and human activity on nutrient inputs to selected sections of the basin.

**Target species**
Anadromous salmon.

## Section 2. Sorting and evaluation

**Subbasin**
Systemwide

### *Evaluation Process Sort*

| CBFWA caucus | Special evaluation process | ISRP project type |
|---|---|---|
| Mark one or more | If your project fits either of these | Mark one or more categories |

| caucus | processes, mark one or both | |
|---|---|---|
| ☒ Anadromous fish<br>☒ Resident fish<br>☐ Wildlife | ☐ Multi-year (milestone-based evaluation)<br>☐ Watershed project evaluation | ☐ Watershed councils/model watersheds<br>☐ Information dissemination<br>☐ Operation & maintenance<br>☐ New construction<br>☒ Research & monitoring<br>☐ Implementation & management<br>☐ Wildlife habitat acquisitions |

## Section 3. Relationships to other Bonneville projects

***Umbrella / sub-proposal relationships.*** List umbrella project first.

| Project # | Project title/description |
|---|---|
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### *Other dependent or critically-related projects*

| Project # | Project title/description | Nature of relationship |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

## Section 4. Objectives, tasks and schedules

### *Past accomplishments*

| Year | Accomplishment | Met biological objectives? |
|---|---|---|
| | (new project) | |
| | | |
| | | |
| | | |

### *Objectives and tasks*

| Obj 1,2,3 | Objective | Task a,b,c | Task |
|---|---|---|---|
| 1 | Write an overview of what is currently known about nutrients in the Columbia River basin. | a | Review existing white and gray literature, solicit input from those working in local regions, focus on areas of concern to anadromous salmon. |
| 2 | Estimate impact of impoundments on nutrients. | a | Review existing white and gray literature. |
| | | b | Estimate nutrient response of selected impoundments. |
| | | c | Estimate impact of impoundments on nutrients in selected basin section(s). |
| 3 | Estimate impact of reduced salmon | a | Compile history of anadromous salmon |

| | | | |
|---|---|---|---|
| | returns on nutrients. | | returns (number, size, stock). |
| | | b | Determine nutrient content of each stock from literature. |
| | | c | Estimate nutrient returns by adult salmon to selected basin section(s). |
| 4 | Estimate impact of other human activity on nutrients. | a | Estimate nutrient input from sewage:<br>i. Compile history of population impacting selected section(s);<br>ii. Compile history of sewage/industrial treatment impacting section(s);<br>iii. Estimate nutrient history. |
| | | b | Estimate nutrient input from land -use impacts: forestry, agriculture:<br>i. From literature establish nutrient parameters for logging, agriculture;<br>ii. Compile history of land-use impacting selected section(s);<br>ii. Estimate nutrient history. |
| 5 | Determine resulting impact on total nutrients of 2-4 above. | a | Sum results from objectives 2-4 to estimate nutrient budget for selected section(s). |
| | | b | Compare historic to present nutrient levels. |
| | | c | Estimate potential future change in nutrients. |
| 6 | Write overview of impact of oligotrophication (nutrient reduction) on juvenile salmon. | | |
| 7 | Summarize outstanding research questions and enhancement options. | | |

### *Objective schedules and costs*

| Obj # | Start date mm/yyyy | End date mm/yyyy | Measureable biological objective(s) | Milestone | FY2000 Cost % |
|---|---|---|---|---|---|
| 1 | 10/1999 | 9/2000 | | | 10.00% |
| 2 | 10/1999 | 9/2000 | | | 30.00% |
| 3 | 10/1999 | 9/2000 | | | 10.00% |
| 4 | 10/1999 | 9/2000 | | | 20.00% |
| 5 | 10/1999 | 9/2000 | | | 10.00% |
| 6 | 10/1999 | 9/2000 | | | 10.00% |
| 7 | 10/1999 | 9/2000 | | | 10.00% |
| | | | | **Total** | 100.00% |

**Schedule constraints**

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**Completion date**
9/2000.

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## Section 5. Budget

**FY99 project budget (BPA obligated):**

### *FY2000 budget by line item*

| Item | Note | % of total | FY2000 |
|---|---|---|---|
| Personnel | | %50 | 92,500 |
| Fringe benefits | (20%) | %10 | 18,500 |
| Supplies, materials, non-expendable property | Computer 3,200<br>Backup device 400<br>Office Supplies 3,500<br>Communication 2,500 | %5 | 9,600 |
| Operations & maintenance | | %0 | 0 |
| Capital acquisitions or improvements (e.g. land, buildings, major equip.) | | %0 | 0 |
| NEPA costs | | %0 | 0 |
| Construction-related support | | %0 | 0 |
| PIT tags | # of tags: | %0 | 0 |
| Travel | | %6 | 12,000 |
| Indirect costs | 40% (or 0% if contribution agreement, see Section 8h). | %29 | 53,040 |
| Subcontractor | | %0 | 0 |
| Other | | %0 | 0 |
| **TOTAL BPA FY2000 BUDGET REQUEST** | | | $185,640 |

### *Cost sharing*

| Organization | Item or service provided | % total project cost (incl. BPA) | Amount ($) |
|---|---|---|---|
| | | %0 | |
| | | %0 | |
| | | %0 | |
| | | %0 | |
| **Total project cost (including BPA portion)** | | | $185,640 |

### *Outyear costs*

| | FY2001 | FY02 | FY03 | FY04 |
|---|---|---|---|---|
| **Total budget** | | | | |

## Section 6. References



| Watershed? | Reference |
|---|---|
| ☐ | Ashley, K., L.C. Thompson, D.C. Lasenby, L. McEachern, K.E. Smokorowski and D.Sebastian. 1997a. Restoration of an Interior Lake Ecosystem: the Kootenay Lake Fertilization Experiment. Water Qual. Res. J. Canada, 32 (2): 295-323. |
| ☐ | Ashley, K., L.C. Thompson, P. Warburton, Y.-R. Yang, F.R. Pick, P.B. Hamblin, D.C. Lasenby, K.E. Smokorowski, L. McEachern, D. Sebastian and G. Scholten. 1997b. Kootenay lake fertilization experiment , yr. 4 (1995). Fisheries Proj. Rep.RD58, MoELP, B.C. |
| ☐ | Bradford, M.E. and R.H. Peters. 1987. The relationship between chemically analyzed phosphorus fractions and bioavailable phosphorus. Limnol. Oceanogr., 32(5), 1124-1137. |
| ☐ | Dillon, P.J. and F. Rigler. 1974. A test of simple nutrient budget model predicting the |

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| | phosphorus concentration in lake water. J. Fish. Res. Bd. Canada 31: 1771-1778. |
| ☐ | Donaldson, J.R. 1966. The phosphorus budget of Iliamna Lake, Alaska as related to the cyclic abundance of Sockeye salmon. Ph.D thesis, Univ. of Washington, Seattle. |
| ☐ | Edmondson, WT and J.T. Lehman. 1981. The effect of changes in the nutrient income on the condition of Lake Washington. Limnol. Oceanogr. 26: 1-29. |
| ☐ | Larkin G.A. and P.A. Sleany. 1997. Implications of trends in marine-derived nutrient influx to South Coastal British Columbia salmonid production. Fisheries 22(11):16-24. |
| ☐ | Milbrink, G. and S. Holmgren. 1981. Addition of artificial fertilizers as means of reducing negative effects of "oligotrophication" in lakes after impoundment. Report 59, Swedish Board of Fisheries, Institute of Freshwater Research, Drottningholm. |
| ☐ | Ney, J. I. 1996. Oligotrophication and its discontents: effects of reduced nutrient loading on reservoir fisheries. American Fisheries Society Symposium 16: 285-295. |
| ☐ | Pieters, R., L.C. Thompson, L. Vidmanic, S. Pond, J. Stockner, P. Hamblin, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastian and G. Scholten. 1998. Arrow Reservoir limnology and trophic status report, Year 1. RD 67, Fisheries Branch, MoELP, B.C. |
| ☐ | Pieters, R., L.C. Thompson, L. Vidmanic, S. Pond, J. Stockner, M. Roushorne, K. Hall, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastian and G. Scholten. 1999. Arrow Reservoir limnology and trophic status report, Year 2. In preparation. |
| ☐ | Stockner, J.G. and K.S. Shortreed. 1975. Phytoplankton succession and primary productivity in Babine Lake, British Columbia. J. Fish Res. Board Can., 32, pp2413-2427. |
| ☐ | Stockner, J.G. and K.S. Shortreed. 1985. Whole-lake fertilization experiments in coastal British Columbia lakes: empirical relationships between nutrient inputs and phytoplankton biomass and production. Can. J. Fish. Aquat. Sci. 42, 649-658. |
| ☐ | Stockner, J.G. 1987. Lake fertilization: the enrichment cycle and lake sokeye salmon (O. nerka) production. In: H.D. Smith, L Margolis, and C.C. Wood (Eds.), Sockeye salmon population biology and future mgmt. Can. Spec. Publ. Fish. Aquat. Sci. 96, p198. |
| ☐ | Stockner, J.G. and E.A. MacIsaac, 1996. British Columbia lake enrichment program: two decades of habitat enhancement for sockeye salmon. Regulated Rivers: Research and Management, Vol. 12, 547-561. |
| ☐ | Stockner, JG, E. Rydin, and P. Heyenstrand 1999. Cultural Oligotrophication. Can. J. Fish. Aquat. Sci. (in review) |
| ☐ | Vollenweider, RA. 1976. Advances in defining critical loading levels of phosphorus in lake eutrophication. Mem. Ist. Ital. Idrobiol., 33: 53-83. |
| ☐ | Webster, JR and BC Patten. 1979. Effects of watershed perturbations on stream potassium and calcium dynamics. Ecol. Monogr. 49: 51-72. |
| ☐ | Wolf, P. 1960. Land drainage and its dangers as experienced in Sweden. The Swedish salmon and trout association, Spec. Publ., Malmo Sweden, 73p. |


# PART II - NARRATIVE

## Section 7. Abstract


Recent studies of impoundments on the Upper Columbia River have demonstrated a tight correlation between salmon production and total phosphorus (TP). Reservoirs become effective sediment/nutrient sinks, and after a decade or so of aging show declining levels of pelagic and littoral zone production. When returning adult salmon are blocked or their passage severely restricted by dams another valuable source of biogenic TN and TP is lost, hastening and further exacerbating the oligotrophication process. Loss of these sources of nutrients to the reservoir and downstream riverine sectors will impact forage production and affect growth of rearing juveniles and survival of seaward migrant smolts. Small, stunted salmon smolts, with few exceptions, usually translate into low estuarine and marine survivals and poor adult returns.

We believe that nutrient balances that determine system productivity are important to juvenile salmon survivals. Evidence suggests that Columbia/Snake productivity have been altered by dams and by other

anthropogenic interventions. Using similar methods from our previous Upper Columbia basin nutrient work we propose to examine the TP dynamics and calculate a TP nutrient budget for a selected section(s) of either/or the Columbia main-stem and Snake River basin. Also included will be overview of the 'current status' of nutrients from a historical perspective. Such information should provide decision-makers with a better understanding of whether nutrient losses/gains from a half-century of perturbations are one of the bottlenecks to restoration of adult salmon returns to the Columbia.

## Section 8. Project description

**a. Technical and/or scientific background**

There is a well demonstrated, strong relationship between annual nutrient loads (total nitrogen TN, total phosphorus TP) and lacustrine biomass and productivity (Dillon & Rigler 1974, Vollenweider 1976, Edmondson and Lehman 1981). Though more variable, a similar relationship has recently been shown between mean annual TP concentration and fish standing stock or biomass (Ney 1996). The impoundment of river systems and/or outflows of lakes can have major impacts on nutrient dynamics.

The construction of a dam affects both the nutrients in the reservoir behind the dam and in the downstream riverine sector. For several years following the filling of a reservoir there is a 'boom' production period characterized by high nutrient concentrations in the water and high primary and secondary production of biomass in the reservoir (see Fig. 1). The nutrient pulse comes from leaching of flooded soils and vegetation decay. However, this boom period is soon followed by a 'bust' period as nutrients are exhausted, and this results in declining production levels, i.e. net oligotrophication. In a natural stream nutrients spiral down stream (Webster and Patten 1979), but after impoundment most incoming nutrients are utilized and then sedimented to the bottom of the reservoir, becoming in effect a nutrient sink. (Note that under certain conditions in moderately productive reservoirs, deep-water withdrawals can not only cool stream temperatures but also export hypolimnetic nutrients enhancing downstream production along the way.) Besides increasing nutrient retention, reservoir operations usually result in abnormal water level fluctuations (drawdown) and extensive areas of productive littoral habitat are often lost. In concert, these factors of nutrient retention and littoral loss tend to accelerate the rate of oligotrophication of impoundments (Milbrink and Holmgren 1986). Thus most reservoirs become effective total phosphorus (TP) sinks, and experience a gradual loss of production (oligotrophication) with a concomitant loss of fish production, usually occurring within 2-3 decades after completion. (Stockner et. al. 1999).

Studies in Alaska and British Columbia have shown that a large percentage, up to 50-60% in some cases, of the annual TP load to lakes and streams come from the decomposition of returning adult salmon carcasses, i.e. providing nitrogen (N) and phosphorus (P) of marine origin (Donaldson 1966, Stockner & Shortreed 1972, Stockner 1987). But throughout the past century commercial and recreational over-harvesting, coupled with continued habitat destruction (e.g. logging, dams, etc.), has significantly reduced this salmon carcass contribution to natal lakes and streams, i.e. shut off or reduced the 'anadromous nutrient pump' (Stockner and MacIsaac 1996). The major consequence has been the marked reduction of primary and secondary production in those ecosystems most reliant on imported (anadromous) nutrients, and we have witnessed over the last half century the progressive oligotrophication of salmon-bearing aquatic ecosystems in the Pacific Northwest and British Columbia (Stockner and MacIsaac 1996, Larkin and Sleany 1997).

Large reductions in TP loads and abrupt declines in fish production have been seen in lakes (reservoirs) of the Upper Columbia River basin in Canada, and recent studies suggest dam construction and other anthropogenic intervention (e.g. pollution from the Cominco fertilizer plant) as causal factors (Ashley et al 1997, Pieters et al. 1998). For example, annual loads of TP leaving Arrow Reservoir are reduced by over half compared to historic levels and exemplify the effects of upstream dam construction (Revelstoke and Mica Dams) on the oligotrophication of downstream lotic systems. It is clear that each impoundment on the Columbia River basin, whether storage or run-of-the-river dam, has the potential to reduce nutrient loads and cause oligotrophication. In addition oligotrophication of salmonid nursery systems is increased by elimination of returning adults. The impact of dams and reduced marine returns on nutrients can be masked, for a time, by cultural sources of phosphorus, e.g. sewage effluent (Ney, 1996; cf. Kootenay Lake, Ashley 1997a). However, as a result of pollution abatement and increased treatment standards, these sources of nutrients are also being dramatically reduced (see Fig. 1).

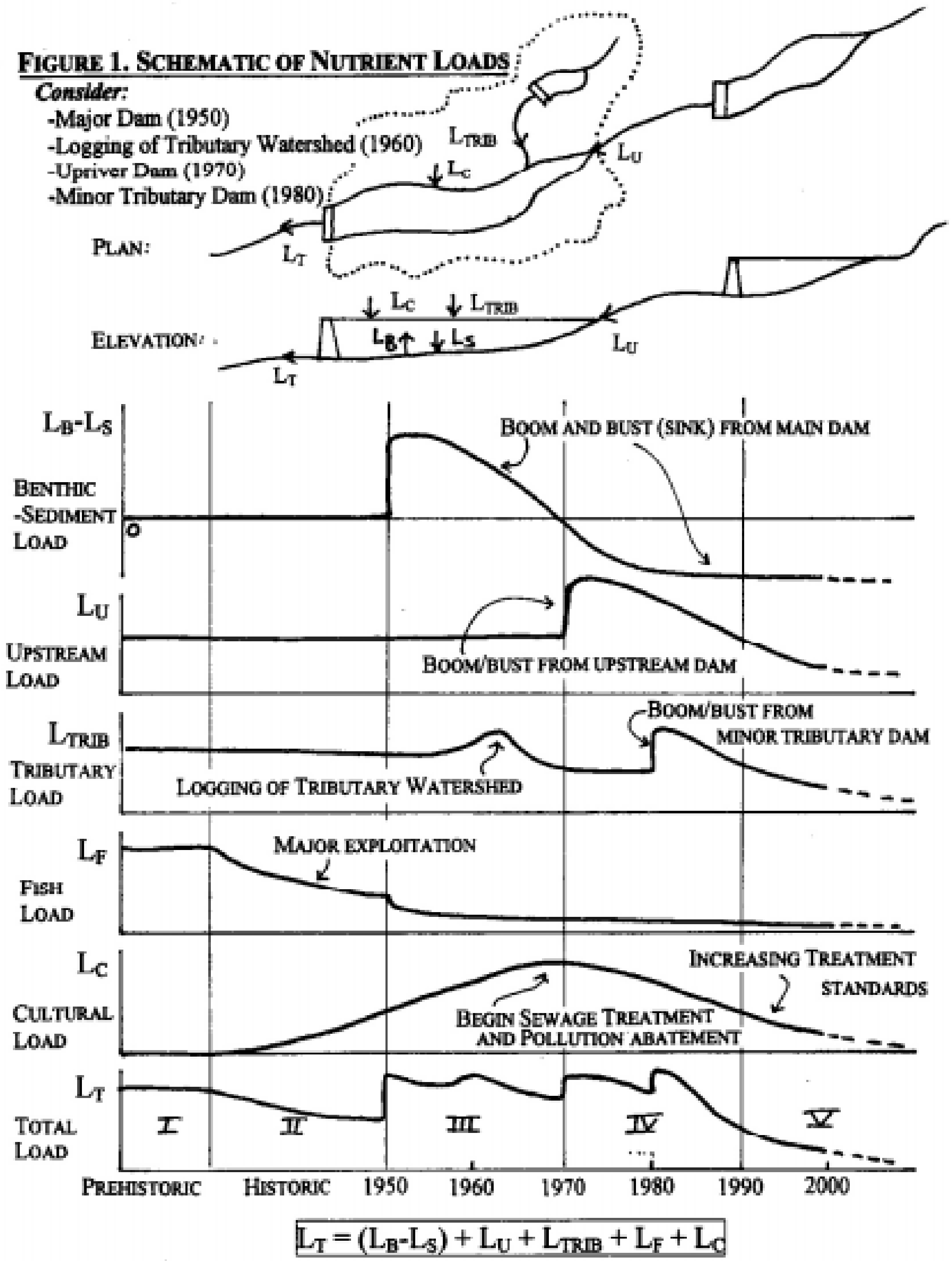
FIGURE 1. SCHEMATIC OF NUTRIENT LOADS
Consider:
-Major Dam (1950)
-Logging of Tributary Watershed (1960)
-Upriver Dam (1970)
-Minor Tributary Dam (1980)
PLAN:
ELEVATION:
LTRIB
LC
LU
LT
LB
LS
LB-LS
BENTHIC -SEDIMENT LOAD
BOOM AND BUST (SINK) FROM MAIN DAM
LU
UPSTREAM LOAD
BOOM/BUST FROM UPSTREAM DAM
LTRIB
TRIBUTARY LOAD
BOOM/BUST FROM MINOR TRIBUTARY DAM
LOGGING OF TRIBUTARY WATERSHED
LF
FISH LOAD
MAJOR EXPLOITATION
LC
CULTURAL LOAD
INCREASING TREATMENT STANDARDS
BEGIN SEWAGE TREATMENT AND POLLUTION ABATEMENT
LT
TOTAL LOAD
I
II
III
IV
V
PREHISTORIC
HISTORIC
1950
1960
1970
1980
1990
2000
LT = (LB-LS) + LU + LTRIB + LF + LC

Based on our understanding of impoundments and nutrient dynamics we suggest that the current very low status of Columbia River salmon stocks may be related not only to causes such as passage problems and habitat loss but also to on-going oligotrophication processes in all sub-basins in both lentic and lotic habitat areas. Because natural forage production and juvenile salmon growth during their freshwater residence may be declining one would expect lower marine survivals of seaward migrant smolts and adults. For these reasons we believe it is paramount that managers gain a better understanding of the current nutrient status of the Columbia River basin, and determine whether nutrient changes over the past several decades have played a role in salmon stock declines.

**b. Rationale and significance to Regional Programs**

This proposal addresses a major question confronting decision makers: Are nutient dynamics and lower system production playing a pivotal role in the decline of adult salmon returns to the Columbia River system? Considerable effort is being expended in conservation of salmon species, yet, despite this effort, the impact of nutrients has, we believe, been either underestimated or ignored. We suggest that nutrient dynamics need to be considered in the management scenarios now being examined for stock restoration, e.g. in the on-going PATH process. If nutrient reduction from effects of impoundment (dams) and low adult escapement has resulted in underweight, small migrant smolts then reduced freshwater and marine survival rates will result in low returns or escapements. Nutrient replacement or enrichment may provide a viable alternative to methods currently being considered. We believe that a better understanding of nutrient dynamics and an assessment of the current trophic status of the sub-basins of the Columbia River system could play an important role in the assessment of current management options.

**c. Relationships to other projects**

(See also previous section.)

This research complements ongoing project "Spring Chinook Salmon Early Life History" (9202504), which is examining migration patterns, abundance, and survival of spring chinook salmon juveniles from Grande Ronde and Imnaha River basins. While passage through dams, over-harvest and habitat degradation remain important problems for these stocks, an understanding of the nutrient history of these basins is also crucial as juveniles reside in these basins through several life stages and are dependent on food (forage) production for growth and survival. This life history project will also provide important information about where juveniles reside and for how long, and this understanding is crucial to adjudicating nutrient enhancement options.

This project would complement ongoing projects such as the "Lake Pend d'Oreille Fishery Recovery Project". The focus of the Pend d'Oreille project is loss of shore and river spawning habitat for kokanee due to lake drawdown. However, our experience with Upper Columbia River basin lakes indicates that nutrient reductions (oligotrophication) also play a crucial role in resident fisheries as a result of the both lake regulation and the creation of nutrient sinks by upstream dams.

If project proposal 9136 for FY1999, "Influence of marine-derived nutrient influx on Columbia River basin salmonid production", is re-submitted and funded in FY2000, then we would endeavor to work in close collaboration with this proposal in the overlap in our objectives 3 and in components of our objectives 6-7.

**d. Project history** (for ongoing projects)

New project.

**e. Proposal objectives**

**Objective 1**. Write an overview of what is currently known about the nutrient status of the Columbia basin. Review white and gray literature, seek input from those working in the various regions of the Columbia basin and focus on regions of concern for anadromous salmon. A written report will be completed by 9/2000.

**Objective 2**. Nutrient fluxes following construction of dams on the Columbia system affects both the reservoir habitat behind dams and the unregulated river downstream. The impact of dam construction and escapement losses on total phosphorus (see methods) will be estimated for selected section(s)(see methods) of the Columbia River basin. This information will provide a better understanding of the impact of these large perturbations on nutrients and productivity. Focus will be on (1) estimating nutrient levels in the pre-historic period, for comparison with the present, and (2) on the present period to estimate what further nutrient reductions might be anticipated.
Hypothesis: Impoundments have resulted in an increase and then a decline below original base TP levels in selected section(s) of the Columbia River system.

**Objective 3**. Salmon spawners can contribute up to 60% of the phosphorus to their natal lakes and streams (Donaldson 1966, Stockner 1987). Thus it is important to estimate the impact of large reductions in this nutrient source to the Columbia throughout the 20$^{th}$ century. While reduction of marine-derived nutrient input will be calculated for sub-sections, and not for individual streams (see methods), it is a first step to indicating which regions of the Columbia have undergone the largest impact of spawning escapement reduction (oligotrophication).
Hypothesis: Reduction in salmon spawner returns has resulted in a decline in total phosphorus load in all sub-sections of the Columbia River.

**Objective 4**. The impact of sewage discharges, logging and agricultural activities are generally unexamined for the Columbia basin from a nutrient mass-balance perspective. Thus estimation of the impact of these anthropogenic effects on nutrient supplies to the Columbia are important if we are to better understand current nutrient levels and productivities and to predict the impacts of further nutrient reductions on juvenile salmon production in the Columbia.
Hypothesis: General increase in anthropogenic total phosphorus loadings through the 1970's has been followed in the 1980's by a general decline in nutrient inputs to the present.

**Objective 5**. Integrating major nutrient impacts is important to assessing the present trophic state of various sub-basins of the Columbia. While this overview will not address each tributary in detail, it will provide an integrated first step to assessing the state of nutrients in the Columbia system, and in identifying where further efforts need to expended. It will also identify the role nutrient losses/gains and attendant forage base production has played in the dramatic declines of most salmon stocks in the Columbia system. The methods and results of objectives 2-5 will be detailed in a written report to be completed by 9/2000.
Hypothesis: Compensating impacts have resulted in generally high levels of total phosphorus until the last 20-30 years over which total phosphorus has undergone a dramatic decline, e.g. oligotrophication.

**Objective 6**. Review of literature and summary of how reduced nutrients impact juvenile salmon is an important link to critically assessing the role of nutrients in juvenile salmon growth and survival. Of special importance is the pathway of these nutrients through benthic and pelagic food webs in both riverine and lacustrine sections of the Columbia. This literature review will be part of the overview report to be completed by 9/2000.

**Objective 7**. An overview or summary of the outstanding research questions pertaining to nutrients will provide a framework for prioritizing the requirements for restoration work (e.g. reservoir/tributary or mainstem fertilization).

**f. Methods**

**Objective 2-5**. *Selected section(s).* After consultation, one or two sections of the Columbia River basin (productive, unproductive) will be selected in which to estimate a TP budget and examine nutrient dynamics in further detail.

**Objective 2-5**. *Time periods.* The history of the selected sub-basin of the Columbia or Snake rivers will be divided into approximately 5 major periods as shown in Fig. 1.

**Objective 2-5**. *Nutrients*: The focus of this work will be on total phosphorus (TP). Total phosphorus is relatively inexpensive to measure and is a proxy for what is of actual interest, namely, the biologically available phosphorus (BAP). While anthropogenic and salmon sources of TP are of high bioavailability, only part of the naturally occurring TP is bioavailable. In order to correct for this, TP from different sources will be scaled by a bioavailability fraction that will be determined from literature values (e.g. see Bradford and Peters, 1987).

**Objective 2**. Task A. Existing white and gray literature will be reviewed to summarize what is known about the impact of impoundments on nutrients, including recent studies on the Upper Columbia River system, e.g. Kootenay and Arrow Lakes (Ashley, 1997a,b; Pieters, 1998).
Task B. The impact on nutrients of impoundments on and above the selected section(s) will be estimated based on the morphometric and flow characteristics of the impoundments. Existing nutrient data for the given impoundments will be examined as necessary to validate these estimates.
Task C. The nutrient response from B will be applied to and above the selected section(s) to estimate the nutrient history in the selected section(s).

**Objective 3**. Task A,B,C. Estimates of historic escapement will be obtained from existing retrospective histories of salmon returns. Nutrient contents for various stocks will be obtained from the literature and these will be used to estimate the marine-derived nutrient loading to and above the selected section(s).

**Objective 4**. Task A. The history of population growth and land-use on and above the selected section(s) will provide estimates of the nutrient inputs from wastewater and the history of sewage treatment with a focus on recent improvements to remove phosphorus. This will be integrated to provide an estimate of the history of TP input from wastewater to the selected section(s).
Task B. Estimates of land clearance (logging) and agricultural activities on TP inputs will be made based on area of land logged and in agricultural production and will be determined by the application of loss coefficients from the literature.

**Objective 5**. Tasks A-C. Sum the results from objectives 2-4 to obtain a rough estimate of the history of nutrient inputs for the selected section(s) of the Columbia.

*Factors that may limit the success of the project:* The method we are proposing provides only an 'overview' of the potential impact of nutrients in the Columbia River system. The results are limited by the various estimates, e.g. dam retention, estimates of wastewater inputs, logging, etc. This approach, while not perfect, does provide a first estimate of nutrient inputs which allows for assessment of significance to salmon production.

### g. Facilities and equipment

A home office will be used (J.S.) with existing Pentium II 350 MHz computer, color ink-jet and laser printers, internet connection on dedicated phone line, photocopier and fax machine on dedicated fax line. Office space, computers, software and office equipment are available at the University of British Columbia (R.P., G.L.).

### h. Budget

<u>Personnel</u> includes salary for one research assistant.

Supplies includes one computer, software, printer and backup device for the research assistant; backup device for an existing computer; office and computer supplies, including funds for duplication and distribution of the final report; and long distance telephone charges.
Travel is required to collect overview and site specific data.
Indirect costs contains provision for a maximum of 40% overhead by the University of British Columbia. However, depending on the fund arrangements (e.g. funding as a grant or contribution agreement) this overhead may not apply.

## Section 9. Key personnel

## John Stockner, Senior Research Scientist (0.25 FTE)

### Education

1968 NSF Postdoctoral Fellow (Plankton Ecology)
Freshwater Biological Assoc., Ambleside, Cumbria, England

1967 Ph.D. (Zoology, Limnology & Oceanography)
University of Washington, Seattle

1962 B.A. (Biology, Chemistry)
Augustana College, Rock Island, Illinois

### Current Employment

Principal, Eco-Logic Inc., Vancouver, B.C.
Adjunct Professor, Fisheries Center, University of British Columbia (1993-present)

### Professional Experience

1997-1998 Director and Professor of Limnology, Institute of Limnology, Uppsala University, Sweden

1984-1997 Senior Res. Scientist, Dept. Fisheries & Oceans, W. Van. Lab., W. Van., British Columbia, Canada (*Early departure package taken, Jan., 1997*)

1982-1984 Assoc. Dir., Fish. Res. Br., Dept. Fisheries & Oceans, Vancouver, British Columbia, Canada

1972-1982 Res. Scientist, Dept. Fisheries & Oceans, W. Van. Lab. W. Vancouver, British Columbia, Canada

1968-1972 Res. Scientist, Dept. Fisheries & Oceans, Freshwater Institute, Winnipeg, Manitoba, Canada

### Expertise

Research interests focus on nutrient dynamics, food web interactions and carbon flows in aquatic ecosystems. In particular the analysis of carbon production in pelagic communities and the assessment of 'carrying' capacity of lentic and lotic salmonid nursery habitats; reservoir nutrient fluxes and carbon production dynamics as they relate to fisheries stock production and management, and the application of lake and stream fertilization as a restorative technique for salmonid enhancement.

**Publications** (5 most relevant)

Stockner, J.G. 1998. Global warming, picocyanobacteria and fisheries decline: is there a connection? Atti del 12° Congresso dell'AIOL, Vol II - Genova AIOL 1998, Piccazzo (ed.): p. 29-37.

Stockner, J.G., and E.A. MacIsaac. 1996. The British Columbia Lake fertilization program: overview after two decades of salmon enhancement. Reg. Rivers. 12: 344-356.

**John Stockner, Senior Research Scientist** continued

**Publications** continued

Henderson, M, J.G. Stockner, and D.A. Levy. 1992. Probable consequences of climate change on freshwater aspects of the production of Adams River sockeye salmon (*Oncorhynchus nerka*), Geo. Journal 28.1: 51-59.

Stockner, J.G. and K.G. Porter. 1988. Microbial food webs in freshwater planktonic ecosystems, p. 71-84. In: S.R. Carpenter (ed.) Complex interactions in lake communities. Springer-Verlag, New York, N.Y., 283 p.

Stockner, J.G. 1987. Lake fertilization: The enrichment cycle and lake sockeye salmon (*Oncorhynchus nerka*) production, p. 198-215. In: H.D. Smith, L. Margolis and C.C. Wood (eds.). Sockeye salmon (Oncorhynchus nerka) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96, 486 p.

**Roger Pieters, Senior Research Scientist (0.3 FTE)**

## Education

| | | |
|---|---|---|
| 1988 | Ph.D. Physics | U. California, Santa Barbara |
| 1982 | B.Sc. Chemistry and Physics (1st Class Honours) | U. Calgary |

## Employment

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|---|---|---|
| 1992-present | Research Associate | Department of Civil Engineering, and<br>Department of Earth and Ocean Sciences<br>University of British Columbia, Vancouver, B.C. |

## Previous Employment

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|---|---|
| 1990-1992 | Postdoctoral Fellow, Oceanography, University of British Columbia |
| 1988-1990 | Instructor (TESOL), Hefei, Anhui, People's Republic of China |

## Professional Experience

Study of nutrient dynamics, hydrology and physical limnology in Arrow and Kootenay Lakes as part of a multidisciplinary investigation into the decline of Kokanee stocks.
Study of physical limnology and hydraulics of exchange flows between heavily polluted Hamilton Harbour and western Lake Ontario; project manager.
Numerical modelling of the physical dynamics of flushing and deep water renewal in coastal fjords; analysis of numerical algorithms.

## Relevant Reports and Publications


Pieters, R., L.C. Thompson, L. Vidmanic, S. Pond, J. Stockner, M. Roushorne, K. Hall, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastian and G. Scholten. 1999. Arrow Reservoir limnology and trophic status report, Year 2 (1998/99). In preparation.

Pieters, R., L.C. Thompson, L. Vidmanic, S. Pond, J. Stockner, P. Hamblin, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastian and G. Scholten. 1998. Arrow Reservoir limnology and trophic status report, Year 1 (1997/98). RD 67, Fisheries Branch, Ministry of Environment, Lands and Parks, Province of British Columbia.

Pieters, R. 1998. Dams and kokanee in the Arrow Lakes. In: Mountains to Sea: Human Interaction with the Hydrologic Cycle. Ed. Younes Alila. Canadian Water Resources Association, Cambridge, Ontario.

Greco, S.L., G.A. Lawrence, R. Pieters. 1988. Exchange flow in the Burlington Ship Canal. In: Mountains to Sea: Human Interaction with the Hydrologic Cycle. Ed. Younes Alila. Canadian Water Resources Association, Cambridge, Ontario.

Pond, S., Z.P. Nowak, R. Pieters, C. Knock, C. Reason and P.H. LeBlond. 1998. A numerical model of Burrard Inlet and Indian Arm, British Columbia. In preparation.

### Gregory A. Lawrence, Senior Research Scientist (0.1 FTE)

### Education

| | | | |
|---|---|---|---|
| 1985 | Ph.D. | Hydraulic Engineering | U. California, Berkeley |
| 1981 | M.S. | Hydraulic Engineering | U. California, Berkeley |
| 1977 | B.E. (1st Class Honours) | Civil Engineering | U. Western Australia |

### Current Employment

1987-present Professor, Civil Engineering, University of British Columbia

### Previous Employment

| | | |
|---|---|---|
| 1985-87 | Aerospace Engineering,U. of Southern California | Post-Doctoral Fellow |
| 1981-85 | University of California, Berkeley | Research Assistant |
| 1979 | University of Western Australia | Research Assistant |
| 1976-79 | Public Works Department of Western Australia | Civil Engineer |
| 1973-76 | Public Works Department of Western Australia | Cadet Civil Engineer |

### Expertise

Research interests focus on the dynamics of density stratified flows and physical limnology. In particular the analysis of pollutant discharge problems; flow instabilities, turbulence, chaos and mixing in density stratified flows; selective withdrawal from a stratified reservoir; stratified flow over obstacles and through contractions; lake dynamics; lake fertilization and rehabilitation; and sediment suspension in tailings ponds.

### Relevant Reports and Publications

Lawrence, G. A., J. M. Burke, T. P. Murphy, and E. E. Prepas. 1997. The exchange of water and oxygen between the two basins of Amisk Lake. *Canadian Journal of Fisheries and Aquatic Sciences,* 54(9): 2121-2132.

Pieters, R., L.C. Thompson, L. Vidmanic, S. Pond, J. Stockner, P. Hamblin, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastian and G. Scholten. 1998. Arrow Reservoir limnology and trophic status report, Year 1 (1997/98). RD 67, Fisheries Branch, Ministry of Environment, Lands and Parks, Province of British Columbia.

Hamblin, P. F., C. L. Stevens, and G. A. Lawrence. Simulation of vertical transport in a mining pit lake. Accepted for publication, subject to revision, in the *Journal of Hydraulic Engineering,* April 1998, 34 pp.

Stevens, C. L., and G. A. Lawrence. 1997. Estimation of wind-forced internal seiche amplitudes in lakes and reservoirs, with data from British Columbia, Canada. *Aquatic Sciences,* 58(4): 1-19.

Rogers, C. K., G. A. Lawrence, and P. F. Hamblin. 1996. Thermal impact of artificial circulation on an ice-covered mid-latitude lake. *Canadian Journal of Civil Engineering*, 23(5):1081-1091.

## Section 10. Information/technology transfer

Copies of the report that will be completed detailing methods and results will be given to BPA and will be provided to others upon request.

## Congratulations!