PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Path Technical Support - James J. Anderson

BPA project number: 9800600
Contract renewal date (mm/yyyy): 1/1999 ☐ **Multiple actions?**

Business name of agency, institution or organization requesting funding
James J. Anderson Consulting

Business acronym (if appropriate) Anderson-Consultant

Proposal contact person or principal investigator:

Name	James J. Anderson
Mailing Address	3700 East Union
City, ST Zip	Seattle WA 98122
Phone	206-543-4772
Fax	206-616-7452
Email address	jim@fish.washington.edu

NPPC Program Measure Number(s) which this project addresses
3.2A, 3.2F, 4.2A, 4.3, 7.1E

FWS/NMFS Biological Opinion Number(s) which this project addresses
NMFS Hydrosystem BO RPA 13; RPA A17

Other planning document references
NMSF Rcovery Plan Tasks 0.3.b and 2.11.b

Short description
Develop hypotheses underlying key salmon recovery management decisions, develop decision analyses to evaluate alternative management strategies, and assist in designing research monitoring and adaptive management experiments.

Target species
Chinook and steelhead

Section 2. Sorting and evaluation

Subbasin

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories
☒ Anadromous fish ☐ Resident fish ☐ Wildlife	☐ Multi-year (milestone-based evaluation) ☐ Watershed project evaluation	☐ Watershed councils/model watersheds ☒ Information dissemination ☐ Operation & maintenance ☐ New construction ☒ Research & monitoring ☐ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

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

Project #	Project title/description
20537	Bonneville Power Administration Non-Discretionary Projects Umbrella

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
9700200	PATH - UW technical support - Columbia Basin Research	Complimentary analysis will provide new alternatives to 9700200
8910800	Monitoring and Evaluation modeling support - Columbia Basin Research	Complimentary applying analyses and adding results to models
9600800	ESSA PATH	Complimentary results will provide new alternatives to 9600800

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1998	Developed alternative hypothesis on passage and extra mortality. Reviewed PATH documents	Yes. Identified areas of uncertainty and participated in development of quantitative models.

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Evaluate critical functional forms of models in PATH	a	Evaluate passage survival models from ecological and mechanistic basis
		b	Evaluate alternative forms of spawner recruit density dependence
2	Review and analysis of quantatitive documents	a	Provide technical review and input to FY1999 and FY2000 PATH reports
		b	Participate in work group developing experimental management alternatives
		c	Participate in developing additional tools

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	10/2000	10/2000			60.00%
2	10/2000	10/2000			40.00%
				Total	100.00%

Schedule constraints
None

Completion date

Section 5. Budget

FY99 project budget (BPA obligated):

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel	Salary, Fringe benefits and overhead 489 hrs @ $100/hr	%98	48,900
Fringe benefits		%0	
Supplies, materials, non-expendable property		%0	
Operations & maintenance		%0	
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%0	
NEPA costs		%0	
Construction-related support		%0	
PIT tags	# of tags:	%0	
Travel	4 trips to Portland @ $275 each	%2	1,100
Indirect costs		%0	
Subcontractor		%0	
Other		%0	
		TOTAL BPA FY2000 BUDGET REQUEST	$50,000

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
		%0	
		%0	
		%0	
		%0	
		Total project cost (including BPA portion)	$50,000

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$50,000	$50,000	$50,000	$50,000

Section 6. References

Watershed?	Reference
☐	Railsback, S. et al. 1998. California Individual-Based Fish Simulation System: Stream Trout Model Formulation. Prepared for the Humboldt State University Department of Mathematics Instream Flow Modeling Project.
☐	Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. of the Fish Res. Bd. Canada.
☐	Marmorek et al. 1996. Plan for Analyzing and Testing Hypotheses (PATH): Final Report on Retrospective Analyses for Fiscal Year 1996. Compiled and edited by ESSA Technologies Ltd, Vancouver B.C.
☐	Marmorek et al. 1998. PATH Weight of Evidence Report. Compiled and edited by ESSA Technologies Ltd, Vancouver B.C.
☐	Anderson, J.J. A vitality based model relating stressors and environmental properties to organism survival. Accepted by Ecological Monographs, 1998.
☐	Sharp, G. 1995. It's about time: new beginnings and old good ideas in fisheries science. Fish Oceanogr. 4:4,324-341.
☐	Anderson, J.J. , J. Hayes, P. Shaw and R. Zabel. 1996. Columbia River Salmon Passage Model CRiSP1.5: Theory, Calibration and Validation. School of Fisheries, University of Washington. 220 pages.
☐	Marmorek et al. 1998. PATH Final Report for Fiscal Year 1998. Compiled and edited by ESSA Technologies Ltd, Vancouver B.C.
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PART II - NARRATIVE

Section 7. Abstract

The overall goal is to assist the region in developing the ability to identify and assess key alternative hypotheses relating to salmon stock recovery and rebuilding in the Columbia River ecosystem. This project will assist in developing and adapting models and analyses for the scientific ecosystem-based evaluation of the impacts of specific fish and wildlife program actions.

Specific objectives of this project are to evaluate functional forms critical to PATH conclusions including the hydrosystem survival rate and mechanisms of the density dependence in the spawner recruit curve used in the PATH analyses. A second objective is to participate in general regional PATH activities developing work plans for experimental management plus developing additional analytical tools and methods to supplement analyses of stocks.

The results will include reports describing hypotheses and their evaluations. If appropriate, the analyses on alternative mathematical forms will be published in reviewed journals.

Section 8. Project description

a. Technical and/or scientific background

Salmon populations in the Columbia River Basin have been in decline since the early days of western settlement, with dramatic declines occurring in the last three decades. The annual production of the Snake River spring/summer chinook during the late 1800's was probably in excess of 1.5 million fish or 39% to 40% of all Columbia River spring/summer chinook (NMFS Biological Opinion, 1995). Today the population of Snake River spring/summer chinook is approximately 0.5% of its historic abundance, with approximately 1,800 spring/summer chinook returning to the Snake River. The story is similar for the Snake River fall chinook. The returns of Snake River fall chinook fell from approximately 72,000 to 29,000. Today, after completion of the Snake River dams, approximately 300 to 500 Snake River fall chinook return to their spawning grounds. Such declines have led to both races of Snake River chinook being listed under the Endangered Species Act, though both have continued to decline since listing (NMFS, Proposed Recovery Plan for Snake River Salmon, 1995).

Past efforts to halt the decline have been ineffective and so a common adaptive management framework (analytical monitoring, evaluation and management assessment approach) for guiding research and monitoring activities and providing management advice for salmon population conservation and restoration has been instituted. The major portion of this analysis has been through PATH (Plan for Analyzing and Testing Hypotheses) which was created in the NMFS 1995-1998 Biological Opinion. Through the umbrella Project 9600600, PATH has made progress in building working relationships among scientists from agencies with different perspectives (i.e. BPA, NMFS, USACE, USFWS, State and Tribal agencies, NWPPC). PATH has helped to define many areas of common agreement and is specifying the information or management experiments needed to resolve other areas of disagreement.

Through the analyses of spring chinook, PATH has reached the conclusion that the stocks have not recovered because a substantial source of mortality somewhere in the fish life cycle is suppressing the natural capacity of the stocks to rebound. A number of hypotheses for this unidentified "extra mortality" have been postulated in PATH. These include: 1) the direct hydrosystem itself (as expressed by the FLUSH passage model) and an unspecified delayed mortally associated with hydrosystem passage, 2) as a delayed mortally associated with fish transportation fish, 3) as an unspecified source of mortality in the tributaries for which there is no obvious mitigation actions, and 4) by a climatic shift coincident with the construction of the Snake River dams that had greater impact on the Snake River stocks than the lower Columbia stocks used as a reference (Marmorek et al. 1998a).

The PATH Scientific Review Panel (SRP) that has weighted the hypothesis has concluded the hydrosystem is the most likely causes of the extra mortality and consequentially for the decline of the stocks. As a result, the SRP has proposed as an adaptive management experiment that includes the breaching of the Snake River dams and reduction in hatcheries that may have some unspecified impact on this productivity (Marmorek et al 1998b).

Even though the PATH process has reached what appears to be resolution on the fundamental source of the problem an "extra mortality" and an experimental approach to mitigate it through breaching dams and drawing down reservoirs, there are still considerable scientific uncertainties as to the potential causes of the stocks decline and the approaches for their recovery. In particular, the two areas of critical importance need further consideration. First is the actual direct mortality that is attributable to the hydrosystem. The PATH conclusions to date require a strong relationship between hydrosystem survival and travel time which results in an average hydrosystem survival of 17% (Marmoerk et al 1998c). New analysis of the survival to Bonneville dam tailrace indicate survivals are on the order of 50% and with no observable within season relationship between fish travel time and survival. The mismatch between observation and the PATH conclusions present a major unresolved uncertainty the PATH work.

In addition to the mismatch between observation and theory in passage mortality, the conclusions within PATH rest strongly on an assumed relationship between the productivity of the Snake River stocks and the stock density at the low levels observed in the Snake River system. In the PATH work ,the natural inherent productivity of the stock has been assumed to follow a Ricker curve, which requires that the logarithm of the number of recruits per spawn in linear with the number of spawners. This assumption, which is at the foundation of all PATH analyses, means that the natural productivity of the stocks must strongly increase as the stock declines. In PATH a cursory analysis was conducted to determine if there was density depensation, in which the productivity decreases in proportion to spawners levels. This approach itself may be inadequate to identify a more likely and important response in which the productivity per individual fish is simply unrelated to the number of spawners at the current levels in the Snake River system. If the Snake stocks have a density neutral spawner recruit response while the lower river stocks have a Ricker type response, the conclusions arrived in PATH relating to extra mortality and the effect of the proposed recovery actions may be profoundly different.

The issue of density dependence in the spawner recruit relationship is not isolated to the issues of the Columbia/Snake River stocks. The issue has been unresolved since the first relationship was proposed by Ricker in 1950s even though there have been a series of discussions and papers suggesting the mechanisms of density dependence or the lack of dependence (Ricker 1975, Slobdkin et al 1967, Sharp 1995). The simple two-parameter Ricker type equation has persisted for two basic reasons: 1) it can easily be fit to data and 2) for stocks that are near their carrying capacity, it has a general qualitative agreement with data even though the statistical fits are generally not significant. The theory has provided a useful approximation for management commercially harvestable stocks and it has been a mainstay of the analysis for several members of the PATH group and its scientific review panel. With the listing of the Snake River salmon stocks, the Ricker curve is being applied outside its historical basis to stocks that are at historically low levels. In this situation, the applicability of the Ricker type density dependence and the depensation forms evaluated in PATH are questionable and there is a need to further consider factors controlling stock productivity at low levels and the implications of the functional forms of the mechanisms on the conclusions of PATH.

The importance of these two assumptions, a strong hydrosystem survival response to smolt travel time, and the Ricker curve productivity relationship are at the foundation of the PATH analysis and the conclusions and direction of experimental management. If either or both of these hypotheses are inadequate, the hypothesis of a large productivity at low stock levels and a large extra mortality may be incorrect. If this were the case, our approaches to stock recovery could be significantly revised. These two examples illustrate the need for careful evaluation of the functional forms of the life stage and life cycle models used to evaluate stocks.

b. Rationale and significance to Regional Programs

Both the Council Fish and Wildlife Program (FWP) and the NMFS 1998 Supplemental Biological Opinion (SBO) indicate a need to develop and assess regional strategies to rebuild fish and wildlife populations through the use of credible and understandable analytical tools. SBO Section III-5 indicates the needs to fund a regionally-coordinated analysis through a forum such as PATH and to coordinate with the ongoing PATH process to estimate the effects of the proposed actions in the context of a species level biological requirements. The FWP section 3.2F identified that computer models are essential to the framework to provide a means to align program measures to survival targets and fish rebuilding schedules. The tools developed will span legitimate scientific differences and approaches and the processes should not stifle these differences but should promote understanding of their implications and integrate them into a unified approach.

The proposed research is directly relevant to the regional issues because it will provide an additional evaluation of the significant assumptions in PATH, and which are not identified as issues within PATH for further analysis. The work will provide a better theoretical foundation for the development of experimental management (Marmorek 1998c).

c. Relationships to other projects

This project will provide additional evaluation of the essential hypotheses within PATH, which have received limited evaluation and prioritization within the PATH planning group. This work will provide a better clarification of the agreement and uncertainty in PATH by addressing the central issues within PATH that are critical to the overall conclusions of the process. This further evaluation is essential because the PATH project is a major forum for a coordinated and consistent approach to technical analyses supporting salmon rebuilding and recovery efforts over the life cycle; it provides a formal process to efficiently utilize and focus regional technical expertise on such analyses. Critical issues that are not fully resolved have the potential of seriously challenging the efficacy of PATH and the analytical tools being developed for recovery management. The proposed work in this project will help insure the issues that are not unresolved in PATH. For explanation of how the facilitators of PATH see their contributions to the regional efforts, see Project 9600600. The proposed work also is an integral part of the BPA non-discretionary projects and will address issues that BPA identify as required to carryout its mandate.

d. Project history (for ongoing projects)

Dr. Anderson's technical support to PATH is an extension of his contributions to PATH through other projects in which models and hypotheses have been formulated and evaluated. This project expands his critique role and development of new theoretical constructs needed to develop an ecosystem approach. Previous critiques were developed under Project 9700200.

Past Critiques have included:
- A comparison of spawner recruit models (Anderson, Paulsen and Hinrichsen 1997)
- Critique on the transport and extra mortality hypotheses of the alpha and delta models (Anderson 1998).

In FY98, contributions included the PATH reports.

Submission 11. Aggregate hypotheses for spring chinook
Submission 12. Initial predation rate with drawdown
Submission 14. Weight of evidence for passage, transport, extra mortality and aggregate hypotheses

Review of PATH reports

PATH Weight of Evidence Report
Preliminary Decision Analysis Report on Spring/Summer Chinook
PATH Final Report for fiscal Year 1998

Papers developed in part with the project funding:

Anderson, J. J. A vitality based model relating stressors and environmental properties to organism survival. (Accepted by Ecological Monographs).

Anderson, Zabel, Hayes and Salinger. The relationship of travel time and distance on smolt passage survival (submitted to North American Journal of Fisheries Management).

e. Proposal objectives

Objective 1. Evaluate critical mathematical forms used in PATH.

The PATH analysis at its fundamental basis uses simple mathematical equations describing the salmon life cycle and survival between life stages. The results of PATH in regards of the probability of stock recovery depend on the forms of these equations. Several critical will be re-evaluated and alternatives with greater mechanistic basis will be developed and applied to determine sensitivity of the equations to the PATH conclusions. Analysis will be conducted on the rate equation for hydrosystem passage and the form of density dependence in the spawner-recruit curve.

Task a. The in-river survival rate assumption. Two passage survival equations have been developed in PATH: one in which the rate of mortality increases over time and another in which it is constant. Other equation forms relating to the significance of distance traveled and travel time have also been developed (Anderson et al. submitted) as well as a survival equation that depends on the cumulative stress of an organism (Anderson, in press). These different equations will be evaluated and compared to the recent and historical survival estimates through the river system. A report will be prepared on the results, recommendations for new passage survival equations, and a paper on passage equations will be prepared for a reviewed journal.

Task b. The effects of density dependence on stock recruitment dynamics will be explored and the significance to the Snake and Columbia River stocks further evaluated. Although the PATH analysis initially considered density depensation (PATH 1996), no significant deviation from a linear density dependence in the spawner recruit curve was found. In the two equations tested, the depensation factor was described by a three-parameter equation fit over the entire range of spawner data, including the high levels in the early years and the low levels in the recent years. It is unclear if this approach was capable of identifying actual neutral or non-linear density dependence, particularly if the dynamics changes in a fundamental manner between high and low densities of spawners.

In this project, mechanistic equations will be explored that articulate such factors as competition for redds at high densities, effects of stream fertilization, mate search limitations at very low densities, and a neutral relationship between density and productivity at intermediate densities. If the Snake River stock dynamics are density neutral, the conclusions on differences in stock productivity between the Snake River stocks and the lower Columbia River stocks may have to be re-evaluated.

Objective 2. Review and analysis of quantitative documents.

Anderson will participate in technical reviews and discussion of PATH and other regional forums and participate in the planning and development of additional tools as requested by BPA.

Task a. Provide technical reviews and input to the PATH process.

Task b. Participate in work groups developing experimental management plans.

Task c. Participate in developing additional tools to meet BPA's obligations.

f. Methods

Through the PATH process, an evolving adaptive management system involving analysis of data and modeling has been developed. The modeling has evolved as a stepped process: a) development of analytical forms for the models for different life stages including egg-fry, juvenile survival, smolt survival, ocean survival, upstream migration and spawning. b) calibration, where possible, of different life stage survivals, c) fitting the combined life-cycle model to spawner-recruitment data in a retrospective analysis, d) hypothesizing effect of actions on mortality elements in the life cycle of the fish. The main focus of the work of this project is on assessing the analytical forms of the models and to determine if alternative forms have better ecological foundation and if the results are significant to the conclusions of PATH.

To assess the impacts of cumulative stress on juvenile hydrosystem passage a survival model based time cumulative and time independent mortality processes will be incorporated into the passage model and calibrated with the survival data. The model is based on the concept of vitality which is a stochastic rate process that is proportional to the effects of stressors including, gas bubble disease, temperature and dam passage (Anderson, in press). This model provides a realistic biologically based method of characterizing the delayed impacts of stress in hydrosystem passage.

A central assumption of the PATH analysis is that the stock productivity response is log-linear with respect to spawner density. In this framework, the productivity increases with decreasing stock levels. Although the assumption is supportable under populations near their carrying capacity, under the current low stock levels in the Snake and Columbia River system there is no distinct relationship (See Chapter 3, Contrast of Stock-Recruitment Patterns of Snake and Columbia River Spring and Summer Chinook, in

PATH final Report on Retrospective Analyses for 1996). In many of the Snake River stocks, the log-linear relationship breaks down and the data exhibits a large amount of variability. This pattern suggests the possibility of a density neutral productivity at the low current levels of stocks in the system. The form of productivity with low stock levels may also be influenced by the lack of stream carcass fertilization and short and long period weather cycles that perturb the deterministic dynamics of the spawner-recruitment relationship. These features are missing from the Ricker spawner-recruit curve used in PATH.

To evaluate density dependence dynamics, an interactive approach will be taken in which the relationship is approached from the large scale information available in time series of spawner-recruit data and small scale including information on physical and hydrological environment of the redds and the physiology and behavior of the spawners. Two levels of data will be evaluated with two levels of models. At the large scale, a semi-empirical spawner-recruit curve will be developed that includes low level depensation, mid-range density neutral response and high-range linear density dependence. The small scale dynamics will use the California Individual-Based Fish Simulation System (Railsback et al. 1998). In this approach, details of fish physiology and behavior are simulated over a small scale of the physical and hydraulic environment of the redds. Through fitting the models to their respective data and comparing the model results to each other, connections between small scale dynamics and large scale responses can be evaluated and stable patterns and properties dynamics can be identified.

In Objective 2 quantitatively reviews of products in PATH and other regional forums will be evaluated. Particular emphasis will be devoted to the mathematical and ecological basis of models used in the analyses.

g. Facilities and equipment

The project uses the existing facilities and does not require new facilities or equipment.

h. Budget

The budget for Anderson's service is 489 hrs at $100/hr. This includes benefits, supplies and overhead costs. Four trips to Portland from Seattle are included at $275 per trip.

Section 9. Key personnel

James J. Anderson

Columbia Basin Research, University of Washington
1325 – 4th Ave., Suite 1820
Seattle, WA 98101
Phone: 206-543-4772; Fax: 206-616-7452
Email: jim@fish.washington.edu

Associate Professor (WOT)

Fisheries Research Institute and Center for Quantitative Science in Forestry, Fisheries and Wildlife
College of Ocean and Fisheries Sciences

Teaching Activities:

Graduate course in modeling organism dynamics (QSCI 551)
Graduate course in Ecosystem models (QSCI 550)

Students Receiving Degrees: Three in M.S. Fisheries, Two in M.S. Quantitative Ecology & Resource Management, and Two in Ph.D. Quantitative Ecology & Resource Management.

Current Research Projects:

Bonneville Power Administration (Funding level: $6+ million): Developing computer models for management of Columbia River hydroelectric and fisheries agencies.

U.S. Army Corps of Engineers (Funding level: $1+ million): Developing analysis and computer models for the impact of gas bubble disease on migrating salmon.

National Marine Fisheries Service (Funding level: $500K+):

1) Studying mortality processes of juvenile salmon in tributaries
2) Developing a multi-species multi-regional salmon harvest model

Honors and Awards:

1) Research Faculty Fellowship, College of Ocean and Fishery Sciences 1985, 1989.
2) Special Recognition for participation in the U. S. Fish and Wildlife Service Fish Passageways and Division Structures course in 1990.
3) Nomination for Computerworld Smithsonian Awards in programming for the CRiSP computer model
4) College of Ocean and Fishery Sciences Distinguished Research Award, 1996.

Professional Activities: Consulting; Expert Testimony on Fish Migration and Dam Passage; Guest Speaker

Selected recent publications from over 45 publications and reports include:

Anderson, J.J. 1998 (in press). Decadal Climate and Declining Columbia River Salmon. Proceedings of the sustainable Fisheries Conference, Victoria B.C., Canada. Eric Knudsen, Editor. American Fisheries Society special publication no. 2x. Bethesda, MD.

Anderson, J.J. A vitality based model relating stressors and environmental properties to organism survival. Accepted by to Ecological Monographs in 1998.

Helu, S.L., J.J. Anderson, D.B. Sampson. 1998. An individual-based boat fishery model can generate fishery stability. Natural Resource Modeling. (In press)

Zabel, R.W., J.J. Anderson, and P.A. Shaw. 1998. A multiple reach model describing the migratory behavior of Snake River yearling chinook salmon (Oncorhynchus tshawystscha). Canadian Journal of Fisheries and Aquatic Sciences: 55:658-667.

Section 10. Information/technology transfer

Result from this work will be distributed through four forms:

1. Communications on PATH issues will be submitted to relevant participants in PATH via e-mail.

2. PATH documents will be placed on the PATH web page maintained at the Columbia Basin Web Server. This service is provided to all PATH participants and the page currently holds material from two years of PATH work. Documents can be read on line as HTML documents, or downloads as PDF, Word or Excel files.

3. Documents will be transmitted to ESSA for inclusion in PATH reports.

4. Selected documents will be submitted to reviewed journals.

Congratulations!