CRISP MODELLING 8910800

SHORT DESCRIPTION:
Provide analytical tools and databases required to evaluate the effectiveness of hydrosystem operations and other mitigation measures for improved fish survival as required to meet obligations of the ESA, NEPA, and NW Power Act.

SPONSOR/CONTRACTOR: UW
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SUB-CONTRACTORS:
none

GOALS

GENERAL:
Supports a healthy Columbia basin, Increases run sizes or populations, Adaptive management (research or M&E), Education

ANADROMOUS FISH:
Research, M&E

NPPC PROGRAM MEASURE:
3.2F.2

RELATION TO MEASURE:
The project provides tools for evaluation of the impacts of NPPC and the NMFS BIOP programs on salmon over several life stages.

BIOLOGICAL OPINION ID:
Program Support & NMFS BO RPA A1f; A13; A17

BACKGROUND

Subbasin:
Analysis focuses on river system from estuary to tributaries in the Snake and Columbia River systems

HISTORY:
The CRiSP project was initiated to develop a juvenile passage computer model and regionally networked decision support system to (1) estimate impacts due to changes in operation of the Federal Columbia River Power System, (2) evaluate fish migration alternatives, and 3) aid in design and evaluation of Columbia River fisheries research. In the first several years of this project we developed models of increasing complexity and flexibility (from CRiSP.0 to CRiSP.1.3, CRiSP1.4, and CRiSP1.5), added the capability to address life cycle processes (SLCMc) and harvest issues (CRiSP.2), and utilized these models in a variety of large-scale management processes, including the Systems Operation Review (SOR), the Army Corps' System Configuration Study (SCS), and numerous Biological Assessments and Section 7 Consultation rounds.
Recent accomplishments include:
1) The mainstem passage model CRiSP1.5 was validated with 1995 and 1996 PIT tag survival studies.
2) We developed a PC version of the CRiSP.2 harvest model which includes stochastic processes to represent climatic and natural variability in recruitment, and enhanced harvest management features, including accurate representation of the Columbia River harvest compact.
3) Operated a RealTime smolt tracking World Wide Web site. These included databases of current and historical river environmental and fish passage information and model predictions of the movement and survival of fish through the river system.
4) Analyses of the impact of ocean conditions on smolt survival in the estuary and ocean. This included developing new indicators of decadal scale climatic factors and analysis of the impact of estuary entrance timing on survival.
5) Provided analytical support for the PATH process (now under separate contract), System Operation Review, Snake River

Chinook Recovery Team, and the 1995 Biological Opinion.
6) Analyzed impacts of transportation operations on smolt survival and demonstrated that survival depends on estuary conditions and date of release in the estuary.

BIOLOGICAL RESULTS ACHIEVED:

CRiSP 1.5 has been used to evaluate and determine optimum smolt passage conditions. CRiSP 2 has been used to evaluate harvest allocation strategies.

PROJECT REPORTS AND PAPERS:

Anderson, J., D. Dauble, and D. Neitzel. 1989. Proceedings of the Smolt survival workshop. Pacific Northwest Laboratory Publication.
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Zabel, R.W., Anderson, James J., 1991. Validating a Model of Juvenile Salmonid Migration with Radio-tagging Data
Anderson, J.J. 1991. Fish Bypass System Mathematical Models. WATERPOWER 91, Proceedings of the International Conference on Hydropower. July 24-26 1991, Denver, CO.
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Swartzman, Gordon L., Equilibrium Abundance of Salmon Stocks in a Life Cycle Model with Interacting Hatchery and Natural Substocks, Natural Resource Modeling, 5.(1), Winter 1991
Center for Quantitative Science, 1991, Columbia River Salmon Passage (CRiSP) Model: Documentation for CRiSP.1 Scenario Generating Form of Model, 8-91.
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Anderson, J.J., 1992. Documentation for CRiSP.1. (Draft Internal Report)
Hayes, J.A., J. Anderson, R. Hinrichsen. 1992 Preliminary Comparison Between CRiSP.1 and CRiSP.0. (Internal Report)
Ianelli, James. 1992. Approaches to Modeling the Harvest Component of Salmonids in the Columbia River Basin. (Internal report)
Thomas, Virginia and J.J. Anderson. 1992. Stochastic Life Cycle Model (SLCMc): Documentation for SLCMc. (Draft internal report)
Swartzman, Gordon L. 1992. Review of Binomial River Reach Passage Model (Internal report)
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Hayes, Joshua A., William Hewitt, George Kremlicka, 1992. Modem Manual for CRiSP.1 Users. (Documentation for users)
Lockart, Alice E. 1992. Users Manual for Vitality Model (Rough draft)
Thomas, Virginia, Michael McCann and J.J. Anderson. 1992. Stochastic Life Cycle Model (SLCMc): Documentation for SLCMc. (Draft internal report)
Himeda, Mark. 1992. Coded-Wire Tag Retrieval and Analysis System (CRAS) (Internal report)
Norris, James. 1992. Estimating Ocean Harvest Rates and Residence Proportions for Pacific Salmon Stocks. (Draft report)
Hayes, Josh. 1992. Real flow records versus CRiSP-modulated period average flows. (Internal report)
Thomas, Virginia, C. Wilson. 1992. Stochastic Life Cycle Model: SLCMc Version 5.1 Functional Description and Maintenance Document. (Draft internal report)
Hayes, Josh, 1993. Modeling Salmon Passage in the Columbia River System: Delayed Passage at Dam Powerhouses.
Zabel, Rich. 1993. Model of Juvenile Salmon Downstream Migration.
Anderson, J.J. 1993. Report to the Snake River Salmon Recovery Team on an Analysis of Spring and Fall Chinook Survivals using the CRiSP Mainstem Passage Model
McCann, Michael. 1993. Stochastic Life Cycle Model: A tool for Simulating the Population Dynamics of Anadromous Salmonids (Internal draft report)
Anderson, J.J. 1993. Second Report to the Snake River Salmon Recovery Team on an Analysis of Spring Chinook Survivals using the CRiSP Mainstem Passage Model
Anderson, J.J. 1993. Calibration, November, 1993.
Anderson, J.J. 1994. Two Scenarios for Columbia River Spring Chinook Survival

Hayes, Josh. 1994. Correspondence with U.S. Army Corps of Engineers, Walla Walla District, and 2) Results of TBR/Spread the Risk sensitivity model runs using CRiSP.1.4.3, SOR calibration.
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Anderson, J.J. 1994. Evaluation of NMFS Spill Recommendation
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Anderson, J.J. 1994. CRiSP 1.4.5 Analysis of the Proposed Summer Spill. Report filed to NMFS, Montlake Laboratory
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Anderson. J.J. 1994. Comparison of Mainstem Recovery Options Recover-1 and DFOP
Zabel, R. 1994. Spatial and Temporal Models of Migrating Duveile Salmon with Applications, Ph.D. thesis
Hinrichsen, R.A. 1994. Optimization Models for Understanding Migration Patterns of Juvenile Chinook Salmon, Ph.D. thesis
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Anderson, J.J. 1995. Evaluation of John Day drawdown and Columbia River flow Augmentation in the Revised 1994-1998 Biological Opinion
Norris, James G. 1995. A simple spreadsheet Model for Evaluating Recovery Strategies for Snake River Fall Chinook Salmon
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Anderson. J.J. 1995. Columbia River World Wide Web Group
Anderson, J.J. 1995. Climate Cycles, Habitat Boundaries and the Endangered Species Act: A New Perspective on Endangered Salmon
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Hinrichsen, R.A. and C.C. Ebbeseyer. 1996. Towards a Near-Shore Ocean Survival Index.
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Ebbesmeyer, Curt C. and Rich Hinrichsen and W. James Igraham, Jr., 1996. 20th Century Timing of the Spring and Fall Wind Transitions Along the West Coast of North America, to be published in the Proceedings of the Sustainable Fisheries Conference in Victoria. B.C., Canada April 26-30.
Ebbesmeyer, Curt C. 1996. CRiSP Project 1995 Progress Report.
Hayes, J.A., R. Zabel, P. Shaw and J.J. Anderson. 1996. Evaluation of the 1996 Predictions of the Run-Timing of Wild Migrant Yearling Chinook at Multiple Locations in the Snake and Columbia River Basins using CRiSP/RealTime.

ADAPTIVE MANAGEMENT IMPLICATIONS:

Informed and effective decision-making for hydrosystem operations, implementation of mitigation alternatives, and research needed to improve fish survival requires having available quantitative models that are biologically founded, calibrated and validated. This projects provides these models for juvenile and adult river passage and adult harvest.

Modeling of the effects of hydrosystem operations on fish provides testable hypotheses on the impacts of management actions. In situations where the effect of a management action is measurable a comparison of the monitored effect and the model predictions either confirms the understanding of the underlying mechanisms, or points to breakdowns between model and reality. This is required to develop optimum use of individual actions in a complex system. In situations where the effect of a

management action cannot be isolated from uncontrollable factors the models provide a scientifically-based approach to evaluating the potential benefit or detriment of the action.
In the past, river management has minimally used models in management because the conflict between alternative models was not resolved. The region has made significant progress in evaluating models and many of the issues have been or can be resolved through rigorous model validation. As a result it is becoming possible to use the passage models to evaluate and optimize river operations for smolt passage. In addition the efforts in this project are underway to resolve the issues of inriver passage versus barging fish through the river system, and resolving the impacts of gas bubble disease.

PURPOSE AND METHODS

SPECIFIC MEASUREABLE OBJECTIVES:

1) Continue the CRiSP.1 passage model through general I/O improvements, adding more flexible transport mortality modeling, characterizing wild fish migration patterns, modeling upstream adult migration, and updating model calibration as hydrosystem structure changes and new data become available, and developing a World Wide Web accessible model.
2) Complete development and calibrate an upstream passage model to evaluate the impact of hydrosystem operations on adult migration.
3) Develop PC versions of CRiSP juvenile and adult passage models for distribution in disks and through the World Wide Web.
4) Develop habitat model to evaluate the impact of land use activities on salmon survival.
5) Provide additional in-season analysis capabilities for the Technical Management Team (TMT) including prediction of the passage and survival of juveniles and adults through the hydrosystem as a function of hydrosystem operations. Model predictions will be evaluated and validated through statistical comparisons to the observed passage indices at the end of the migration season.
6) Evaluate the relationship between decadal scale fluctuations in ocean conditions and their impact on fish survival and incorporate the results into CRiSP models.
7) Conduct further studies on the "delayed mortality" in smolt barging.
9) Provide the BPA and other regional entities access to fisheries and riverine database. An essential purpose of the database is for in-house access required for operation and calibration of the CRiSP management decision support systems.
10) Provide real time and historic information and graphics via the World Wide Web.

CRITICAL UNCERTAINTIES:

The critical uncertainties of the project involve model predictions. To deal with uncertainty in predictions, a portion of the project activity is devoted to model validation in which model predictions are compared to data derived independently from the model calibration. A second way to deal with the critical uncertainty is through model sensitivity analyses in which the significance of unknown model parameters or mechanisms can be evaluated by identifying how the projected range of the parameters affects salmon survival predictions.

BIOLOGICAL NEED:

The CRiSP project provides advanced modeling capabilities to evaluate and improve the impacts of management options on Columbia River salmon stocks. Currently the models provide information to evaluate the impact of hydrosystem operations and harvest on the general fish life cycle and in particular, on the downstream migration phase. In the future, the modeling will include information on other critical life cycle components including their survival in spawning and rearing tributaries and survival through estuary passage.
The decline of salmon has been affected by anthropogenic and natural factors that have occurred at each life stage. The changing climatic regime has affected all life stage survivals. Human resource use has affected habitat quantity and quality, river passage, estuary survival and harvest. The interactions of natural and anthropogenic factors have caused a significant decline in salmon stocks but it is unclear what the contribution of each component is and how improvements can be made.
Specific life stage needs to be addressed by the project:
Presmolt: The project habitat modeling will provide information on the impact of land use on water quality and presmolt survival. This will enable managers to evaluate stream restoration efforts.
Smolt migration: The project will help in evaluating impacts of hydrosystem management in determining smolt migration and survival.
Estuary: Studies on the impact of smolt timing suggest that estuary survival could be improved by managing smolt arrival timing to the estuary.

Harvest: The studies on fish harvest and migration will improve harvest management allowing for stock specific harvest policies to include the spatial and temporal distribution of the stocks in the ocean fishery.
Adult upstream mortality: The studies on adults should provide information to improve upstream adult passage.
The models provide the region tools to evaluate and prioritize management actions, identify critical uncertainties, and assist in the design of the research needed to reduce the uncertainties.
The project is addressing how specific management actions affect fish survival. For example, we are studying how smolt estuary entrance timing affects fish survival. This information has direct relevance to understanding the causes of and reducing the "delayed mortality" associated with transportation. The information will be of critical importance to understanding the effects of reservoir drawdowns on fish travel time and the resulting impact of changing fish estuary arrival timing and survival.

HYPOTHESIS TO BE TESTED:

The CRiSP models will be used to develop testable biological and mechanistic hypotheses on the effects of hydrosystem operations and other mitigation of actions on salmon survival. Current hypothesis to be evaluated are
- entry date of smolts in the estuary affects their survival
- transportation efficiency can be improved by coordinating the transportation program with estuary conditions
- adult migration survival and timing is affected by spill
- climate conditions affect fish survival

The work in the model development will utilize the hypotheses being developed in the PATH process. Specific (PATH process Level 3) hypotheses will be developed for passage and travel time of fish through the hydrosystem and dam passage measures, including fish guidance and spill efficiencies and forebay delay. Aggregate hypotheses (PATH process Level 2) will be developed to address the factors contributing to the decline of the Columbia and Snake River stocks.

ALTERNATIVE APPROACHES:

The project approach is to define the relevant biological processes in term of mechanistic models that express, when possible, the underlying ecological principals in mathematical terms. When the ecological principals are not resolved, the models use empirical relationships based on observations from the Columbia river system or equivalent systems. The alternative approach is modeling by analogy which does not seek to understand the mechanisms controlling fish survival. In the analogy approach system, the goal is to make one stressed environment similar to an analogous system. The current example is the "normative river" approach that seeks to improve fish habitat by making one reservoir similar to the Hanford Reach. Although this is intended to return the river to a "natural state" in principal it is impossible to return the Columbia River to where it was in the 1900s, and so we are always dealing with technological fixes even to make it "natural." Efforts must be guided by understanding the underlying mechanisms from an ecological perspective.

JUSTIFICATION FOR PLANNING:

The CRiSP models can be used for both planning and assessment. Models used for planning are valuable to determine if many of the on-the-ground efforts are likely to be beneficial or detrimental to fish. This is particularly important for efforts that will have complex effects on fish ecology. For example, although reservoir drawdowns are expected to decrease fish travel time to the estuary, it is not clear if such a decrease will be beneficial or detrimental to fish. The evaluation of the trade-offs must be approached through quantitative methods or the end result of such actions may be ineffective or deleterious. It is not sufficient to describe the ecology of fish using qualitative analogies to "normative environments". The calibrated and validated models being developed in this project provide managers a cost-effective and efficient way to assess on-the-ground efforts prior to the investment.
The passage models and the analysis of the models will be available to managers from the federal, state and tribal agencies. No coordination will be funded under the project.

METHODS:

The approach in the CRiSP project is to describe the movement and survival of fish through their life cycle in terms of mathematically expressed ecological mechanisms. The models provide ecologically mechanistic connections between management actions and fish survival. In addition, the models incorporate major environmental variations on a range of time scales from within a season to decadal.A number of statistical methods are used to calibrate and validate the models. The principle methods include linear regressions and maximum likelihood techniques. The models address ocean and stream type chinook and steelhead in the Snake and Columbia drainage basins.

PLANNED ACTIVITIES

SCHEDULE:

Planning Phase **Start** 1996 **End** 2001 **Subcontractor**

Task Continued development of the model into freshwater stages of the salmon life cycle including: adult upstream migration, straying and survival in migration; egg to fry emergence timing and survival, fry to smolt survival, and timing of smolt migration.

Implementation Phase **Start** in progress **End** 2001 **Subcontractor**

Task Continued calibration and validation of the mainstem passage model in areas of fish migration, effects of spill on gas generations and Real time tracking and modeling of fish migration will continue in 1997. The purpose is to predict in real time the impact of the hydrosystem operation on the rate of migration and survival of juvenile fish through the hydrosystem. In 1997 we will also have the ability to predict the impacts of spill and flows on river properties including total dissolved gas, temperature and river velocity.

Implementation Phase **Start** in progress **End** 2001 **Subcontractor**

Task Continued development of the CRiSP.2 harvest model. The model will incorporate information gained from studies on fish ocean distributions and decadal scale fluctuations to better resolve historical trends and to improve stock predictions by inclusion of climatic predictions. The model calibration algorithm will be completed and made available to researchers in 1997.

Implementation Phase **Start** 1997 **End** 1999 **Subcontractor**

Task Continued studies in nearshore oceanographic effects to understand the impacts and mechanisms by which seasonal and decadal scale climatic fluctuations affect salmon productivity. In 1997 we will begin developing an ecologically-based description of why smolt survival varies with timing of entrance into the estuary. We will participate in the planning of research to evaluate potential mechanisms and will assist in developing fish transportation systems to improve overall fish survival.

Implementation Phase **Start** in progress **End** 2001 **Subcontractor**

Task Continued calibration and validation of the mainstem passage model in areas of fish migration, effects of spill on gas generations and the impacts on salmon, improved modeling of fish forebay and dam passage behavior.

O&M Phase **Start** 1997 **End** 2001 **Subcontractor**

Task Development and maintenance of Internet tools. We will develop Java-based Web tools for data access and the ability to run models over the World Wide Web. The goal is to improve access to the information and models used for fisheries management. Initial Web tools will be made available to the fisheries managers in 1998 including a Java interface to CRiSP.1 and CRiSP.2.

PROJECT COMPLETION DATE:

2001

CONSTRAINTS OR FACTORS THAT MAY CAUSE SCHEDULE OR BUDGET CHANGES:

Schedule changes can occur if
-model theory development is more involved than anticipated
-data for calibration is not made available from primary sites on schedule
-work tasks are reordered by the contractor or regional events that reorder the emphasis of the project tasks

OUTCOMES, MONITORING AND EVALUATION

SUMMARY OF EXPECTED OUTCOMES

Expected performance of target population or quality change in land area affected:

Informed and effective decision making for hydrosystem operations, implementation of mitigation alternatives, and research needed for improved fish survival.

Present utilization and convservation potential of target population or area:
NA

Assumed historic status of utilization and conservation potential:
NA

Long term expected utilization and conservation potential for target population or habitat:
NA

Contribution toward long-term goal:
Informed and effective decision making for hydro operations, implementation of mitigation alternatives, and research needed for improved fish survival.

Indirect biological or environmental changes:
The models, when utilized for fish management, can have an indirect impact on the biology of all salmon life history stages. Many biological or environmental changes related to hydrosystem operation could be implemented within the season.

Physical products:
NA

Environmental attributes affected by the project:
The models can affect the environmental attributes indirectly when utilized for fish management.

Changes assumed or expected for affected environmental attributes:
NA

Measure of attribute changes:
NA

Assessment of effects on project outcomes of critical uncertainty:
To assess the model impact on the critical uncertainties we make post-season analyses of the model predictions. Using the models, the effect of a management actions can be evaluated and compared to the projected effect of alternative scenarios. For example, it is possible to evaluate the impact of a spill program on smolt survival and compare this to the predicted survival of an alternative spill program.

Information products:
The project produces calibrated and validated models for life history stages of salmon (smolt passage, adult passage, habitat survival and harvest) and the impact of environmental and anthropogenic impacts on survival. The project maintains a database of information accessible on the world wide web including historical data, current conditions and projections of future conditions under potential future environmental conditions and management scenarios.

Coordination outcomes:
Accomplishments for the past year include: 1) Completion of updates, calibrations, and user/theory manuals for the CRiSP1 passage model and the CRiSP2 harvest model; 2) Participation in the development and application of an in-season database real-time access to river and fish passage conditions through the World Wide Web; 3) Provided initial analyses of the impact of ocean conditions on smolt survival in the estuary and ocean and made progress in analyzing and understanding the impact of decadal scale climatic fluctuations on Columbia River salmon; and 4) Provided analytical support for PATH analyses in 1996, the 1996 Biological Opinion and NMFS survival analyses.

MONITORING APPROACH
The approach in the CRiSP project is to describe the movement and survival of fish through their life cycle in terms of mathemati

cally expressed ecological mechanisms. The models provide ecologically mechanistic connections between management actions and fish survival. In addition, the models incorporate major environmental variations on a range of time scales from within a season to decadal.A number of statistical methods are used to calibrate and validate the models. The principal methods include linear regressions and maximum likelihood techniques. The models address ocean and stream type chinook and steelhead in the Snake and Columbia drainage basins.

Provisions to monitor population status or habitat quality:

The project does not directly monitor stock or habitat status. It does provide evaluation of the monitoring data and presents the information on the World Wide Web.

Data analysis and evaluation:

The project analyzes data from a variety of sources to infer the impact of those projects and management actions on fish survival. Analysis of how the community used the modeling information and the results of using or not using the information will be initiated in future budget periods.

Information feed back to management decisions:

We have and will continue to provide information to managers on the models' evaluations of their actions. These analyses have been put on the project web page.

Critical uncertainties affecting project's outcomes:

The critical uncertainty of the project is that managers ignore and often reject model use on political grounds. To resolve this uncertainty in how the models are used the managers should actively support model evaluation, removing from consideration models that cannot be substantiated. Research is required to identify better use of models in management.

EVALUATION

The region can assess the models performance through retrospective analysis comparing the models predictions against monitoring results. All models in the region should be thoroughly evaluated. This is currently not being done in the PATH process.

Incorporating new information regarding uncertainties:

New information becomes available every year as more monitoring studies are carried out. As a consequence, the calibration of the models may need to be updated to accommodate new observations. That is in the nature of models new opportunities for calibration arise. As these data are made available, we will work to incorporate the processes into the models. For example, survival studies carried out using PIT tags beginning in 1993 represented new data, and those data were used to validate our passage model.

Increasing public awareness of F&W activities:

The project provides many quantitative assessments of the region's efforts to protect and enhance fish populations. This information is made available across the World Wide Web and through preparation of public documents conveying the information contained in the models. Readership of our web pages has steadily increased since their debut, and this information is already used by NMFS, COE, BPA, and other agencies and interested parties.

RELATIONSHIPS

RELATED BPA PROJECT	RELATIONSHIP
4) NMFS smolt survival analysis supported by National Marine Fisheries Service (Smolt Mortality Data Analysis NA57FE0570).	This project is directed at developing mechanistic models for the environmental and biological conditions required for fish to initiate smolt migration.
3) Technical Management Team Web page maintained by Pacific Northwest Laboratory (PNL)	The information the PNL maintains for its TMT Web page is principally obtained from our Web page.

2) PATH - UW Technical Support. Contract BPA 97BI-98816.	Our staff contributes directly to the PATH process. Our specific tasks involve mainstem passage issues, effects of the ocean and estuary on survival, and harvest issues.
1) Dr. John Skalski's Endangered Species Act contract BPA #DE-B179-87BP35885.	Information from this project is used to calibrate and validate the CRiSP models.

RELATED NON-BPA PROJECT	**RELATIONSHIP**
NMFS Harvest modelNMFS	The NMFS project develops a multi-stock multi-species ocean harvest model that will include spatial and temporal harvest details; this is related to the development of modeling tools in the CRiSP monitoring and evaluation project.
DEGAS Army Corps of Engineers	The Army Corps DEGAS project is evaluating the impacts to fish of the total dissolved gas produced from spill. The project is developing ways to mitigate the impacts of spill. The CRiSP project is working closely with this Army Corps project. We are using their results to improve CRiSP algorithms and calibration.

OPPORTUNITIES FOR COOPERATION:

The full value of the decision support systems being developed on this project can be achieved by close cooperation with the Federal, State and Tribal fisheries agencies.

1. Results of models can be used by the technical management team (TMT) for evaluating hydrosystem operations.
2. Results of harvest models can be used to evaluate and optimize harvest policies in harvest co-management and ESA decisions.
3. The work provides alternative analysis for use by NMFS and the Power Planning Council.
4. The database maintained by the project is accessible to the community through the World Wide Web. The project serves a secondary database system that obtains information from primary database systems and combines the data into forms useful to managers and the public. These data can be used to evaluate specific issues, including dissolved gas production from spill programs and effectiveness of transportation programs.

COSTS AND FTE

1997 Planned: $200,000

FUTURE FUNDING NEEDS:

FY	$ NEED	% PLAN	% IMPLEMENT	% O AND M
1998	$400,000	10%	70%	20%
1999	$400,000	10%	70%	20%
2000	$400,000	10%	70%	20%
2001	$400,000	10%	70%	20%

PAST OBLIGATIONS (incl. 1997 if done):

FY	OBLIGATED
1989	$273,806
1990	$96,231
1991	$904,572
1992	$1,792,997
1994	$733,420
1995	$921,310
1996	$699,892
1997	$289,027
TOTAL:	$5,711,255

Note: Data are past obligations, or amounts committed by year, not amounts billed. Does not include data for related projects.

OTHER NON-FINANCIAL SUPPORTERS:

US Army Corps of Engineers, National Marine Fisheries Service

1997 OVERHEAD PERCENT: 35%

HOW DOES PERCENTAGE APPLY TO DIRECT COSTS:
percentage is to total direct cost minus equipment

CONTRACTOR FTE: 6 FTE

SUBCONTRACTOR FTE: NA