University of Washington
Department of Civil and Environmental Engineering

SAMPLING DESIGN FOR AQUATIC ECOLOGICAL MONITORING PHASE II REPORT VOLUME II

Brian W. Mar
Dennis P. Lettenmaier
Richard R. Horner
Joanna S. Richey
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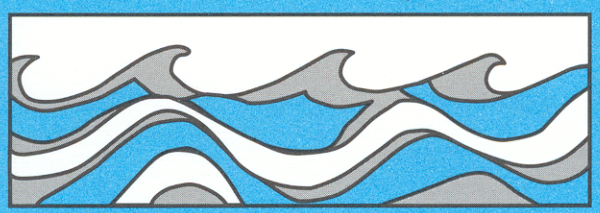

Water Resources Series
Technical Report No. 87
September 1983

Seattle, Washington
98195

Department of Civil Engineering
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SAMPLING DESIGN FOR AQUATIC ECOLOGICAL MONITORING

PHASE II REPORT - METHODS DEVELOPMENT

EPRI Project RP 1729-1

VOLUME II: APPENDICES

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FEBRUARY 1984

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PHASE II WORK STATEMENT

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DN #04

AMENDMENT NO. 2 TO AGREEMENT
between
UNIVERSITY OF WASHINGTON
and
ELECTRIC POWER RESEARCH INSTITUTE, INC.
RP1729-1

"Aquatic Sampling Design Project"

The parties hereby mutually agree to amend the contract as follows:

1. In subarticle 3.1 to the Agreement, the Contract Cost Limitation is increased by $7,428, from $483,313 to $490,741.

2. In subarticle 3.2 to the Agreement, the calendar year 1982 commitment is changed as follows:

> "EPRI support of the Work under this Agreement is conditional upon annual commitment of funds. EPRI has committed $178,494 for the Work in calendar year 1982. This revised 1982 commitment, when added to previous years' commitments of $48,420 represents the maximum amount ($275,334) that the Contractor is authorized to expend or have committed as of the last day of 1982."

This Amendment supersedes the commitment in Amendment No. 1 and increases the original 1982 CY commitment by $122,940, from $55,554 to $178,494.

3. In paragraph 1 of the Schedule to Agreement, Statement of Work, Contractor is authorized to perform Phase II as follows:

PHASE II - STATEMENT OF WORK

TASK 1

Development of a handbook of aquatic monitoring methods and interactive computer software to facilitate the implementation of these methods in monitoring network design.

Subtask 1A

The handbook will provide the user with:

(a) a conceptual framework for evaluating and prioritizing focuses of a monitoring program based on site-specific problems;

(b) the range of existing methods appropriate for addressing site-specific monitoring problems;

(c) guidelines for the development of hypotheses of impact and appropriate hypothesis tests;

(d) methods to evaluate sampling alternatives that are capable of providing the type of data necessary to test each hypothesis;

(e) guidelines for the selection of statistical methods that can be used to define the appropriate monitoring strategies and analyzing the resultant data;

(f) guidelines for the selection of cost-effective strategies for testing hypotheses.

Subtask 1B

The prototype interactive communication/analytical system will accept and display the monitoring network design concepts and sampling strategies contained in the handbook to permit choice of monitoring programs using a computer format.

TASK 2

Examination of alternative techniques to detect long-term population and ecosystem level effects as well as short-term, local impacts. Methods that show the greatest potential will be investigated in greater detail for specific application to electric power plant monitoring. Comparison of the three techniques (see below) would aid in evaluating the usefulness of:

Subtask 2A

The use of expert judgment (as quantified in the historical and contemporary record) to identify hypotheses of impact, diagnostic test variables, sampling methodologies, and simulation model structure.

Subtask 2B

The use of statistical/stochastic paradigms, including time series analysis, state estimation and spatial sampling techniques, for identifying long-term effects of power generation.

Subtask 2C

The use of simulation models to (a) elucidate long-term, population or ecosystem level impacts and (b) guide the selection of sampling sites, sampling intervals and test variables.

TASK 3

Development of Cost-effectiveness/optimization methods

Subtask 3A

Comprehensive cost data on sample collection and analysis will be gathered and classified to support the development effort.

Subtask 38

Several optimization techniques will be investigated for their ability to define cost-effective network designs and to evaluate trade-offs between spatial and temporal allocation of stations. Criteria for discontinuing monitoring of complete or partial sets of data will also be developed.

TASK 4

Selection of Case Studies for Phase III

Existing data sets will be evaluated for their suitability as test cases for application of selected methods identified in Task 2 and 3. A statement will be submitted to EPRI which identifies the chosen data sets and the methods by which test applications will be conducted during Phase III. All methods that demonstrate feasibility and cost-effectiveness after testing will be included in a revised edition of the handbook as part of the Phase III work plan.

Contractor is authorized to purchase Zenith 219 and Anderson Jacob Modems in an amount not to exceed $7,428.

4. In paragraph 3 of the Schedule to Agreement, the Period of Performance is extended by seventeen (17) months from seven (7) months to twenty-four (24) months, commencing November 1, 1981 and ending September 30, 1983.

5. In paragraph 4.1 of the Schedule to Agreement, Cost, the maximum cost to EPRI is changed to $490,741, based on standard billing rates and expenses as set forth below:

	Budget thru Amend. #1	Added by Amend. #2	Total Revised Budget
Equipment Rental	$ 12,900	$ -0-	$ 12,900
Direct Labor	277,301	-0-	277,301
Benefits	36,941	-0-	36,941
Special Equipment	17,572	7,428	25,000
Workshop	14,460	-0-	14,460
Travel	25,650	-0-	25,650
ODC	6,200	-0-	6,200
Overhead	126,895	-0-	126,895
Total Estimated Costs	$517,919	$7,428	$525,247

All other terms and conditions of the Agreement remain unchanged and in full force and effect.

UNIVERSITY OF WASHINGTON

By: _____
Name: WALLACE C. TREIBEL
Title: Government Fiscal Relations and Patent Officer
Date: JUN 1 1982

ELECTRIC POWER RESEARCH INSTITUTE, INC.

By: _____
Name:
Title:
Date:

APPENDIX B

DELPHI PROCESS

B.1 Criteria for Selection of Delphi Panelists

B.2 Pre-Delphi Survey

B.3 Questionnaire 1

B.4 Questionnaire 2

B.5 Questionnaire 3

B.6 Composition of Delphi Panel

Appendix B.1

CRITERIA FOR SELECTION OF DELPHI PANELISTS

After a list of 105 candidates was established, the next step of the Delphi selection process involved two levels of organization.

1. Past experience in at least two or more of ten speciality areas judged by the researchers to represent different subjects that would be considered during the development of the proposed research:

   a. Power plant design and operation (with reference to the aquatic environment).
   b. Ecological effects due to electrical power generation in aquatic systems.
   c. Ecological effects caused by other types of disturbance in aquatic systems.
   d. Quantitative evaluation of aquatic systems.
   e. Evaluation of toxic effects in aquatic systems.
   f. Evaluation of the response of aquatic communities through time following stress and disturbance events and under natural conditions.
   g. Environmental laws, especially those pertaining to power plant licensing and operation. Experience should reflect implementation and review from regulatory and industry perspectives.
   h. Water quality problems, especially those due to thermal loading, chlorine, and heavy metals.
   i. Hydrology/hydrodynamics.
   j. Design of monitoring programs (not limiting to power plant sites).

2. Past experience in at least one of six waterbody types.

   a. Coastal systems, including both protected and exposed sites.
   b. Large rivers, including both tidal and nontidal areas.
   c. Small rivers and streams.
   d. The Great Lakes.

e. Small lakes, reservoirs, and cooling ponds.
f. Estuaries, including both deep, enclosed systems and open, shallow detritus-based systems.

3. Representation of each of the major geographic areas of North America.

a. Northeastern U.S. or Eastern Canada.
b. Southeastern U.S.
c. Northcentral U.S or Central Canada.
d. Southcentral U S.
e. Northwestern U.S. or Western Canada.
f. Southwestern U.S.

4. A reasonable balance of at least four professional environments.

a. Private consulting firms (engineering and environmental).
b. Power utility industries.
c. Regulatory agencies (federal, state and/or municipal).
d. Academic/university research (may include national laboratories).

Persons representing other professional environments (e.g., non-regulatory agencies such as the U.S. Fish and Wildlife Service) were included if such persons appeared to have sufficiently attractive skills.

5. Length of professional involvement as determined by at least one of the following.

a. More than five years of experience in the field of ecology or environmental assessment and two or more years in direct assessment of the effects of electrical power generation.
b. More than 10 years of experience in ecology and environmental assessment work.
c. More than 10 years of experience in the power utility industry, with at least five of those years involving environmental assessment of electrical power generation.

6. A high level of professional productivity.

   a. More than 10 publications (both refereed and non-refereed) in the last 10 years in the general field of environmental assessment.
   b. Active membership in professional societies as evidenced by recent membership on governmental, utility or other scientific advisory panels, position(s) as an officer of professional society, and/or a position on the editorial board of a professional journal.
   c. Management of three or more large-scale projects in environmental assessment.

Appendix B-2

PRE-DELPHI SURVEY

This pre-Delphi survey is divided into three parts which question you about:

I. your opinion of the Delphi method and how it might best be implemented;
II. your opinion of various issues in monitoring program design;
III. your expertise and professional experience.

We would appreciate your answering Parts I and II of the survey; a current copy of your resume can be substituted for the answers to Part III. In this case, please return the resume, with the survey, in the enclosed envelope. Otherwise, we would appreciate your answers to Part III also.

The questions are posed in two different ways. The first type of question asks you to categorize your experience, or extent of agreement with a statement, on a scale of 1 through 5. The numeral 1 always designates complete agreement or extensive experience, while the numeral 5 designates complete disagreement or no experience. These questions are answered by circling the numeral that corresponds most closely to your opinion.

The second type of question asks you to give information about specific aspects of your professional experience (e.g. the geographical areas where you have worked). These questions are answered by writing the appropriate information in the space provided. A variety of topics are presented in order to encompass the multi-disciplinary nature of the respondents and to provide an adequate data base for the selection of specialized subpanels. As mentioned above, a resume can be substituted for answers to these questions.

Please return the questionaire by March 11, 1983, in the enclosed stamped envelope. We hope you will benefit from your participation in this Delphi panel. Thank you for your time.

Part I. The Delphi Process

	Yes absolutely				No not at all
1. I am familiar with the Delphi technique.	1	2	3	4	5
2. I would like more information.	1	2	3	4	5
3. I am familiar with the use of interactive computer systems.	1	2	3	4	5
4. I have access to an interactive terminal and a telephone hookup (modem).	1	2	3	4	5
5. At a later date, we may want to try implementing a Delphi round via interactive computer. Would you be willing to participate in this exercise?	1	2	3	4	5
6. We are considering specialized subpanels to address issues in a variety of areas. Which of the following do you have, i. expertise and, ii. interest in?					

	Extensive Expertise/ Interest				No Expertise/ Interest
Effects Issues:					
a. aquatic toxicology					
i. expertise	1	2	3	4	5
ii. interest	1	2	3	4	5
b. population dynamics (including long-term trends)					
i. expertise	1	2	3	4	5
ii.interest	1	2	3	4	5
c. thermal pollution					
i. expertise	1	2	3	4	5
ii. interest	1	2	3	4	5
d. habitat modification					
i.expertise	1	2	3	4	5
ii. interest	1	2	3	4	5

e. multiple power plant effects						
	i. expertise	1	2	3	4	5
	ii. interest	1	2	3	4	5
Issues in Program Development:						
f. development of criteria for target selection						
	i. expertise	1	2	3	4	5
	ii. interest	1	2	3	4	5
g. development of criteria for choosing among multiple hypotheses of impact						
	i. expertise	1	2	3	4	5
	ii. interest	1	2	3	4	5
h. identification of appropriate test variables for hypothesis evaluation						
	i. expertise	1	2	3	4	5
	ii. interest	1	2	3	4	5
Methodology:						
i. development of methods to evaluate target sensitivity						
	i. expertise	1	2	3	4	5
	ii. interest	1	2	3	4	5
j. others in any of the three areas (please specify)						

	Yes absolutely				No not at all
7. I am excited about being part of this Delphi panel; I expect we may develop some worthwhile ideas.	1	2	3	4	5
8. I anticipate that the Delphi will be a good means of arriving at a consensus about issues for which no objective solutions are known.	1	2	3	4	5
9. I would like to know who the other members of the Delphi panel are.	1	2	3	4	5

10. I am willing to make available a total of X hours over the next few months for implementing the Delphi process. <1 1-2 2-4 4-6 6-10 >10 hrs

---

Part II. Issues in Monitoring Program Design

11. Various criteria have been suggested as useful for the designation of biotic characteristics to be monitored. Rank each of the following in terms of their importance in your opinion.

	Most Important				Least Important
a. designation by law (e.g. rare/ endangered species; representative important species; etc.)	1	2	3	4	5
b. economic importance (e.g. commercial or recreational species)	1	2	3	4	5
c. ecological importance (i.e. to ecosystem structure or function)	1	2	3	4	5
d. high susceptibility to change	1	2	3	4	5
e. historical precedent (at this or similiar sites)	1	2	3	4	5

f. other (please insert the appropriate information)

	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5

12. In my opinion, existing monitoring programs are satisfactory/unsatisfactory in the following areas:

	Satis-factory				Unsatis-factory
a. statistical design (no Type I or II error)	1	2	3	4	5
b. establishment of goals and objectives	1	2	3	4	5
c. implementation of goals and objectives	1	2	3	4	5
d. execution of program design	1	2	3	4	5
e. faulty technology (e.g. lack of appropriate sampling gear)	1	2	3	4	5
f. establishment of significance of results (esp. relative to long-term change)	1	2	3	4	5
g. ability to distinquish change from other sources of variation (natural variation; other industrial outfalls; fishing industry; etc.)	1	2	3	4	5

h. other (please insert the appropriate information)	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5

13. I feel competent to evaluate ecological questions that involve these groups of organisms

	Competent				Not Competent
a. finfish	1	2	3	4	5
b. shellfish	1	2	3	4	5
c. benthic macroinvertebrates	1	2	3	4	5
d. zooplankton	1	2	3	4	5
e. phytoplankton	1	2	3	4	5
f. periphyton	1	2	3	4	5
g. macroalgae/macrophytes	1	2	3	4	5
h. microbes	1	2	3	4	5

14. I am competent in the use of quantitative methods for the evaluation of biological populations for the following groups:

	Competent				Not Competent
a. finfish	1	2	3	4	5
b. shellfish	1	2	3	4	5
c. benthic macroinvertebrates	1	2	3	4	5
d. zooplankton	1	2	3	4	5

e. phytoplankton	1	2	3	4	5
f. periphyton	1	2	3	4	5
g. macroalgae/macrophytes	1	2	3	4	5
h. microbes	1	2	3	4	5

15. I feel competent to evaluate the following types of information:

	Competent				Not Competent
a. age selective mortality	1	2	3	4	5
b. acute toxicity problems	1	2	3	4	5
c. effects of chronic toxicity	1	2	3	4	5
d. material cycling (energy or organic carbon)	1	2	3	4	5
e. mineral or nutrient cycling	1	2	3	4	5
f. water quality problems	1	2	3	4	5
g. biostatistics	1	2	3	4	5
h. population dynamics	1	2	3	4	5
i. physiological ecology	1	2	3	4	5
j. fisheries management techniques	1	2	3	4	5
k. hydrodynamics of waterbodies	1	2	3	4	5
l. hydrologic cycles	1	2	3	4	5

The following two questions refer to other aspects of the project. The first question asks you about the usefulness of the final product of the research relative to your needs. The second question asks you about the availability of cost information; such information is being used in the development of optimization routines.

16. When the final product of this project becomes available (i.e. an interactive computer model to guide monitoring program design), do you think you will find it:

	Very Useful				Not Useful
a. very/not useful to me or my organization	1	2	3	4	5
b. relative to a printed methods manual	1	2	3	4	5

17. Do you have access to reliable cost data for some of the methods used in aquatic monitoring programs, and could you make these data available to this project?

Yes				No
1	2	3	4	5

Part III. Areas of Expertise and Professional Experience

If you can send us a current copy of your resume, it is not necessary to answer the questions in Part III. Return the resume with completed Parts I and II in the enclosed, stamped envelope by March 11, 1983.

The first questionaire and the results of this survey will be mailed in approximately 2 to 3 weeks. Thank you very much for your time and committment. We could not accomplish this part of our research effort without the active involvement of experts in the field.

18. In what parts of North America have you done environmental assessment work? Please note if the study involved monitoring work specifically.

	Yes	No	Monitoring Work?
a. Northeastern U.S. or Eastern Canada	1	5	yes
b. Southeastern U.S.	1	5	yes
c. Northcentral U.S. or Central Canada	1	5	yes
d. Southcentral U.S.	1	5	yes
e. Northwestern U.S. or Western Canada	1	5	yes
f. Southwestern U.S.	1	5	yes

19. What kinds of waterbodies have you had experience with? Please note your level of experience and mark whether the work involved monitoring.

	Extensive Experience			No Experience		Monitoring Work?
a. coastal systems	1	2	3	4	5	yes
b. large rivers	1	2	3	4	5	yes
c. small rivers and streams	1	2	3	4	5	yes
d. Great Lakes	1	2	3	4	5	yes
e. small lakes, reservoirs, and cooling ponds	1	2	3	4	5	yes
f. estuaries	1	2	3	4	5	yes

20. How many years have you worked in the field of environmental assessment in each of the following environments?

	>20	11-19	5-10	1-4	0 years
a. electric utility industry	--	--	--	--	--
b. other industries (e.g. mining)	--	--	--	--	--
c. independent consulting firm	--	--	--	--	--
d. national laboratory	--	--	--	--	--
e. university	--	--	--	--	--
f. federal/state/municipal agency (e.g. E.P.A.)	--	--	--	--	--

21. Mark the level of experience you have with the following items:	Extensive experience				No experience
a. laws and regulations that pertain to power plant operation and potential aquatic effects.	1	2	3	4	5
b. implementation of these laws either as a regulator or as a utility manager.	1	2	3	4	5
c. evaluation of these laws as a direct advisor to a utility.	1	2	3	4	5
d. designing monitoring programs at power plants.	1	2	3	4	5
e. evaluating monitoring programs at power plants.	1	2	3	4	5
f. designing monitoring programs at sites other than power plant sites (e.g. mining, municipal discharges, etc.)	1	2	3	4	5
g. the design of cooling systems at thermal electric power plants.	1	2	3	4	5

h. the operation of cooling systems at thermal electric power plants.	1	2	3	4	5
i. waste streams at thermal electric power plants.	1	2	3	4	5
j. ecological effects in aquatic ecosystems due to electrical generation.	1	2	3	4	5
k. ecological effects in aquatic ecosystems due to other sources of disturbance (e.g. industrial wastes, acid deposition,etc.)	1	2	3	4	5

This is the end of the pre-Delphi survey. Please return it to us in the enclosed, stamped envelope by March 11, 1983. The first questionaire and the results of the survey will be mailed in approximately 2 to 3 weeks. Thank you for your time and committment. We could not accomplish this part of the research effort without the active involvement of experts in the field.

Appendix B-3

QUESTIONNAIRE 1

PLEASE RETURN BY APRIL 30, 1983 CODE NO._____

AQUATIC MONITORING DESIGN, DELPHI REVIEW

QUESTIONNAIRE 1

This questionnaire represents the first round of the Delphi Review being conducted by the University of Washington (UW) for its EPRI-sponsored research project on the design of aquatic monitoring programs at electrical generation facilities. The purpose of the Delphi Review is to solicit opinions from a diverse group of experts about a variety of pertinent issues for which no widely accepted viewpoint exists, and to integrate the results into a comprehensive consensus which incorporates the strengths and diversities expressed by the experts. The advantage of the Delphi review is that all participants contribute their opinions independently, thus avoiding the bandwagon effect that can occur in face-to-face meetings. The heterogeneity of the participants' viewpoints is preserved, and the validity of the results is enhanced. Further discussion of the Delphi technique is included in the attached sheets.

The first round questionnaire emphasizes the structure and philosophy of monitoring program designs, their implications relative to the UW research effort and the results of the pre-Delphi survey. The second round will emphasize specific subject areas being developed by the UW research effort and the results, and a reiteration of the first round.

The questionnaire is divided into 4 parts:

Part I: the first part summarizes information that was collected in the Pre-Delphi Survey about the characteristics of the Delphi panel. A further explanation of the Delphi method is included for those persons who requested such. Read these colored pages and keep them. Do not return Part I with Parts III and IV.

Part II: the second part summarizes those aspects of the developing model for aquatic monitoring design which we believe are essential before Parts III and IV are answered. The model is called EPAM, a model for Electric Power Aquatic Monitoring. Read these colored pages and keep them. Do not return Part II with Parts III and IV.

Part III: the third part asks questions about the philosophy and structure of the model. Questions are either posed in the same format used in the pre-Delphi survey, or in a format which asks you to insert information in the space provided or mark the choice which you think is most applicable to the problem at hand. For the first type of question, please circle the number (1-5) in the response column that reflects most closely your opinion about the importance of, or extent of agreement with, each of the questions or

statements. Remember the numeral 1 always designates complete agreement or extreme importance, while the numeral 5 designates complete disagreement or no importance. The second type of question is answered by inserting the appropriate information into the space provided,or circling the numerical choice which corresponds most closely to your opinion. If no choice is presented that you feel is appropriate, write in the value that you think is best. Participants are asked to answer all of the questions regardless of their level of expertise; when deemed appropriate, a final question in each section asks the panel member to rate his or her expertise in the in the particular area under consideration. Part III (white pages) should be returned with Part IV.

Part IV: the fourth part asks questions which follow up on issues we asked you about in the pre-Delphi survey. Each question is marked with the mean response of the Delphi panel and your original response. Please answer each question again. Part IV (white pages) should be returned with Part III.

Please return the questionnaire by APRIL 30, 1983 in the enclosed, stamped envelope.

You will receive the second round questionnaire and the results of this round approximately 3 to 4 weeks after that date.

Thank you for your time and commitment. We hope you will benefit from your participation in this Delphi panel.

PART I. CHARACTERISTICS OF THE DELPHI PANEL

The following pages summarize some of the information collected in the pre-Delphi survey relative to the characteristics of the Delphi Panel. The information is presented in the format of the original questions. The numbers given represent the percentage of the panel members who responded with the answer shown and/or the weighted mean score of all answers received. Seventy-four percent of the respondents asked that they be informed of the identity of the other panel members. This information will be made available following the final Delphi round. We have included a further explanation of the Delphi method since 77% of the respondents requested more information.

We hope you find this information useful and interesting. You are a member of a broadly experienced and widely recognized group of experts. The majority of panel members hold senior positions in their organizations and have extensive experience in managing a wide range of projects. A high level of professional activity is also apparent in the variety and number of publications, and number of memberships on advisory panels (national and international) that the Delphi participants reported.

These colored sheets are for your information. Do not return them with Parts III and IV of the questionnaire.

	Yes absolutely				No not at all
1. I am familiar with the Delphi technique.	1	2	3	4	5
	2%	12%	41%	22%	22%
2. I would like more information.	1	2	3	4	5
	49%	28%	11%	5%	7%
3. I am familiar with the use of interactive computer systems.	1	2	3	4	5
	26%	25%	18%	23%	9%
4. I have access to an interactive terminal and a telephone hookup (modem).	1	2	3	4	5
	49%	14%	9%	9%	19%

	Yes Absolutely				No not at all
5. At a later date, we may want to try implementing a Delphi round via interactive computer. Would you be willing to participate in this exercise?	1	2	3	4	5
	36%	30%	7%	13%	14%

	Competent				Not Competent
13. I feel competent to evaluate ecological questions that involve these groups of organisms					
a. finfish	1	2	3	4	5
	51%	14%	14%	12%	9%
b. shellfish	1	2	3	4	5
	12%	19%	25%	30%	14%
c. benthic macroinvertebrates	1	2	3	4	5
	18%	28%	30%	16%	9%
d. zooplankton	1	2	3	4	5
	9%	30%	35%	14%	12%
e. phytoplankton	1	2	3	4	5
	7%	16%	35%	23%	19%
f. periphyton	1	2	3	4	5
	4%	2%	28%	37%	30%
g. macroalgae/macrophytes	1	2	3	4	5
	5%	5%	25%	41%	23%
h. microbes	1	2	3	4	5
	2%	4%	9%	28%	58%

14. I am competent in the use of quantitative methods for the evaluation of biological populations for the following groups:

	Competent			Not Competent	
a. finfish	1	2	3	4	5
	44%	19%	19%	7%	11%
b. shellfish	1	2	3	4	5
	16%	19%	23%	21%	21%
c. benthic macroinvertebrates	1	2	3	4	5
	23%	26%	28%	11%	12%
d. zooplankton	1	2	3	4	5
	16%	25%	35%	11%	14%
e. phytoplankton	1	2	3	4	5
	11%	18%	28%	25%	19%
f. periphyton	1	2	3	4	5
	4%	5%	29%	32%	30%
g. macroalgae/macrophytes	1	2	3	4	U
	7%	7%	28%	30%	28%
h. microbes	1	2	3	4	5
	2%	7%	14%	19%	58%

15. I feel competent to evaluate the following types of information:

	Weighted Mean Score	Competent			Not Competent	
a. age selective mortality	2.54	1	2	3	4	5
		28%	26%	21%	12%	12%
b. acute toxicity problems	2.75	1	2	3	4	5
		14%	37%	21%	16%	12%
c. effects of chronic toxicity	2.89	1	2	3	4	5
		14%	26%	32%	12%	16%
d. material cycling (energy or organic carbon)	3.19	1	2	3	4	5
		9%	23%	25%	28%	16%
e. mineral or nutrient cycling	3.07	1	2	3	4	5
		14%	21%	21%	29%	14%
f. water quality problems	2.18	1	2	3	4	5
		32%	35%	23%	5%	5%
g. biostatistics	2.67	1	2	3	4	5
		28%	16%	25%	25%	7%
h. population dynamics	2.45	1	2	3	4	5
		28%	28%	26%	10%	9%
i. physiological ecology	3.30	1	2	3	4	5
		5%	20%	36%	18%	21%
j. fisheries management techniques	2.39	1	2	3	4	5
		35%	23%	21%	11%	11%
k. hydrodynamics of waterbodies	3.12	1	2	3	4	5
		12%	18%	30%	26%	14%

1. hydrologic cycles	3.27	1	2	3	4	5
		11%	14%	29%	30%	16%

18. In what parts of North America have you done environmental assessment work? Please note if the study involved monitoring work specifically.

	Yes	No	Monitoring Work?
a. Northeastern U.S. or Eastern Canada	1	5	yes
	56%	44%	40%
b. Southeastern U.S.	1	5	yes
	53%	47%	33%
c. Northcentral U.S. or Central Canada	1	5	yes
	51%	49%	32%
d. Southcentral U.S.	1	5	yes
	11%	89%	9%
e. Northwestern U.S. or Western Canada	1	5	yes
	33%	67%	23%
f. Southwestern U.S.	1	5	yes
	25%	75%	19%

19. What kinds of waterbodies have you had experience with? Please note your level of experience and mark whether the work involved monitoring.

	Extensive Experience			No Experience		Monitoring Work?
a. coastal systems	1	2	3	4	5	yes
	49%					40%
b. large rivers	1	2	3	4	5	yes
	61%					53%
c. small rivers and streams	1	2	3	4	5	yes
	35%					26%
d. Great Lakes	1	2	3	4	5	yes
	30%					21%
e. small lakes, reservoirs, and cooling ponds	1	2	3	4	5	yes
	44%					30%
f. estuaries	1	2	3	4	5	yes
	53%					39%

20. How many years have you worked in the field of environmental assessment in each of the following environments?

All panel members exceed the minimum criteria established for length and/or diversity of professional background. These criteria are:

1. more than 10 years experience in ecology and environmental assessment work; or
2. more than 5 years experience in ecology and environmental assessment work and more than 2 years in direct assessment of the effects of electrical power generation; or
3. more than 10 years experience in the power utility industry with at least 5 of those years representing direct involvement with environmental assessment.

A majority of the panel members hold very senior positions in their organizations and have had experience in managing large, often complex projects in environmental assessment. A random selection of positions held includes:

Head of the Fisheries and Wildlife Programs at a major east coast university;
Vice-president of an internationally known consulting firm;
Technical Director of a national consulting firm;
Past Senior Vice-President of a national consulting firm;
Supervising Biologist of a major west coast utility;
Full Professor in Environmental Engineering at a major midwestern university;
Project Leader at an internationally known consulting firm;
Staff Analyst for Corporate Planning at a major midwestern utility;
Professor of Oceanography and Chief Scientist in Marine Resources at a major east coast university;
Associate Director of a national consulting firm;
Group Leader at one of the national laboratories;
Manager for the environmental department of a major east coast utility;
Head of Water Resources and Environmental Engineering Division at a major east coast university;
Director, Environmental Programs at a large northeastern utility
Technical Director of Research at a national consulting firm.

More than three-quarters of the members have direct experience in the evaluation of ecological effects due to electrical generation and/or monitoring programs designed for electrical generation plants.

Panel members represent the following work environments currently, although the majority of members have worked in two or more different environments during their professional lives.

a. electric utility industry	18%
b. other industries (e.g. mining)	0%
c. independent consulting firm	23%
d. national laboratory	11%
e. university	37%
f. federal/state/municipal agency (e.g. E.P.A.)	12%

21. Mark the level of experience you have with the following items: experience	Extensive experience				No experience
a. laws and regulations that pertain to power plant operation and potential aquatic effects.	1	2	3	4	5
	33%	33%	15%	9%	11%
b. implementation of these laws either as a regulator or as a utility manager.	1	2	3	4	5
	26%	13%	7%	2%	52%
c. evaluation of these laws as a direct advisor to a utility.	1	2	3	4	5
	31%	22%	11%	7%	29%
d. designing monitoring programs at power plants.	1	2	3	4	5
	43%	30%	17%	9%	0%
e. evaluating monitoring programs at power plants.	1	2	3	4	5
	48%	26%	22%	4%	0%
f. designing monitoring programs at sites other than power plant sites (e.g. mining, municipal discharges, etc.)	1	2	3	4	5
	11%	24%	26%	22%	17%
g. the design of cooling systems at thermal electric power plants.	1	2	3	4	5
	20%	24%	7%	11%	39%
h. the operation of cooling systems at thermal electric power plants.	1	2	3	4	5
	15%	24%	13%	11%	37%

i. waste streams at thermal electric power plants.	1	2	3	4	5
	11%	33%	15%	9%	33%
j. ecological effects in aquatic ecosystems due to electrical generation.	1	2	3	4	5
	51%	33%	11%	4%	0%
k. ecological effects in aquatic ecosystems due to other sources of disturbance (e.g. industrial wastes, acid deposition,etc.)	1	2	3	4	5
	22%	28%	20%	22%	9%

This is the end of Part I of the first round questionnaire. Keep these pages. Do not return them with Parts III and IV.

A Brief Explanation of the Delphi Method

The Delphi method is one of several communication techniques developed during the last twenty-five years in the general field of technological forecasting. Its initial development and application by the Rand Corporation was for the purpose of estimating the potential effects of a large-scale atomic bomb attack on the United States. Recently, its usage has expanded beyond technological forecasting to include many other contexts in which judgmental information is needed: educational issues, environmental assessment, and so forth.

In most applications, the use of the Delphi method arises from a need to incorporate subjective information directly into evaluation models that deal with the complex problems facing society. The Delphi method has been found to be useful when the problem under consideration does not lend itself to precise analytical techniques, but can benefit from subjective judgments arrived at on a collective basis. Linstone and Turoff (1975) have characterized the Delphi as:

> ...a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem.

The conventional Delphi technique, which is being applied in this project, is essentially a combination and extension of a polling procedure and a conference procedure. In this technique a small monitor team designs a questionnaire that addresses the range of issues to be considered by the Delphi process. The questionnaire is sent to a larger group of expert respondents (the Delphi panel), each of whom submits answers to the monitor team. The monitor team reviews, and statistically summarizes the responses to this initial questionnaire. The monitor team develops a second questionnaire which includes both a reiteration of questions from the first round for which no clear consensus was evident and new questions which present new issues and options that were raised by the respondents during the first round. The expert respondents are given a chance to change their initial response based upon the knowledge gained from the group responses and the new options presented.

The process of response and reiteration is usually repeated for a third and, occasionally, a fourth round depending upon the extent of diversity in the panel membership and/or the complexity of the issues being considered. A final round presents all members of the Delphi panel with a copy of the conclusions derived from all views presented and also gives panel members a chance to evaluate the quality of their experience.

The intermediate rounds in the Delphi process allow a formal exploration of areas of disagreement and an evaluation of the underlying reasons for these disagreements. In many instances, the dissenting opinions may represent issues or options which require further consideration and/or new research.

The chance for exploration of these dissenting or minority views represents one of the strengths of the Delphi process. In a more traditional conference or small group meeting, minority views frequently receive less than adequate consideration due to the overriding influence of dominant personalities, lack of time or other logistical shortcomings.

A further advantage of the Delphi process is that the respondent group can include members of extremely diverse disciplines who would normally have little communication with each other. The Delphi method also has an advantage of being a relatively inexpensive means of accessing high levels of expertise and, perhaps, greater numbers than would be possible under normal budget constraints.

The greatest potential weakness in the Delphi method lies in the ability of the monitor team to correctly present the developing consensus and dissenting views to the respondent group. Assuming that this process is carried through effectively, the Delphi method represents a unique technique with excellent potential for the field of environmental assessment.

The two references given below will provide you with further information should you desire it.

Delbecq, Andre L., Andrew H. Van de Ven, and David H. Gustafson. 1975. Group Techniques for Program Planning, a guide to nominal group and delphi processes. Scott, Foreman and Co., Glenview, Ill. 174 pp.

Linstone, H.A. and M. Turoff (ed.). 1975. The Delphi Method: Techniques and Applications. Addison-Wesley Publishing Company, Inc., Reading, Massachusetts. 620 pp.

PART II: A BRIEF DESCRIPTION OF EPAM AND ITS SUBROUTINES

The University of Washington model, EPAM (a model for Electric Power Aquatic Monitoring) functions to guide a user (i.e. one who must design an aquatic monitoring program) in the development of a cost-effective and scientifically valid monitoring program to evaluate the existence, or lack thereof, of ecological change in an aquatic ecosystem due to electrical power generation at a thermal power plant.

EPAM has four basic functions:

1. the development of a prioritized list of monitoring program targets (i.e. ecosystem components, including such things as individual species, community indicators, chemical parameters, etc.) that have potential for being affected by plant operation or design;

2. the development of a list of potential impact hypotheses which will serve to guide the structure of the monitoring program; it is assumed that a monitoring program will typically include one or more hypotheses of impact;

3. the development of the actual sampling program for testing each of the hypotheses that is incorporated into the monitoring program;

4. an optimization routine that designates targets, hypotheses, and sampling stations and/or replicates based on measurement capability (due to best techniques, a low variance component, low cost, etc.), sensitivity to impact, or scientific value. The final version of this subroutine optimizes the tradeoff between dollars expended (cost) and increased accuracy in the monitoring program (error).

EPAM is structured into four hierarchical levels which correspond to:

1. the different stages in monitoring program design in which a user might find him - or herself (e.g. components to be measured are known but program hypotheses are not established; design has been developed but user is uncertain that it is optimal in terms of dollars expended); and 2. the four functions of the design process (e.g. designation of what should be measured, development of hypotheses, development of the sampling design and optimization of the whole program, as described above. An understanding of this hierarchical structure and the basic functions of the model is needed before proceeding to the questions in Part III of the questionnaire.

EPAM is an interactive computer program which will be written in FORTRAN 77 and will be initially operational on a VAX/VMS system. Each level of the model (Figure 1) is structured into subroutines which ask the user to insert, or develop and insert, information about each of the functions described above. At each lower level (LEVEL 3 being the lowest level), it is assumed that less information about the monitoring program and the ecosystem under consideration is available to the user. EPAM guides the user to develop the necessary data

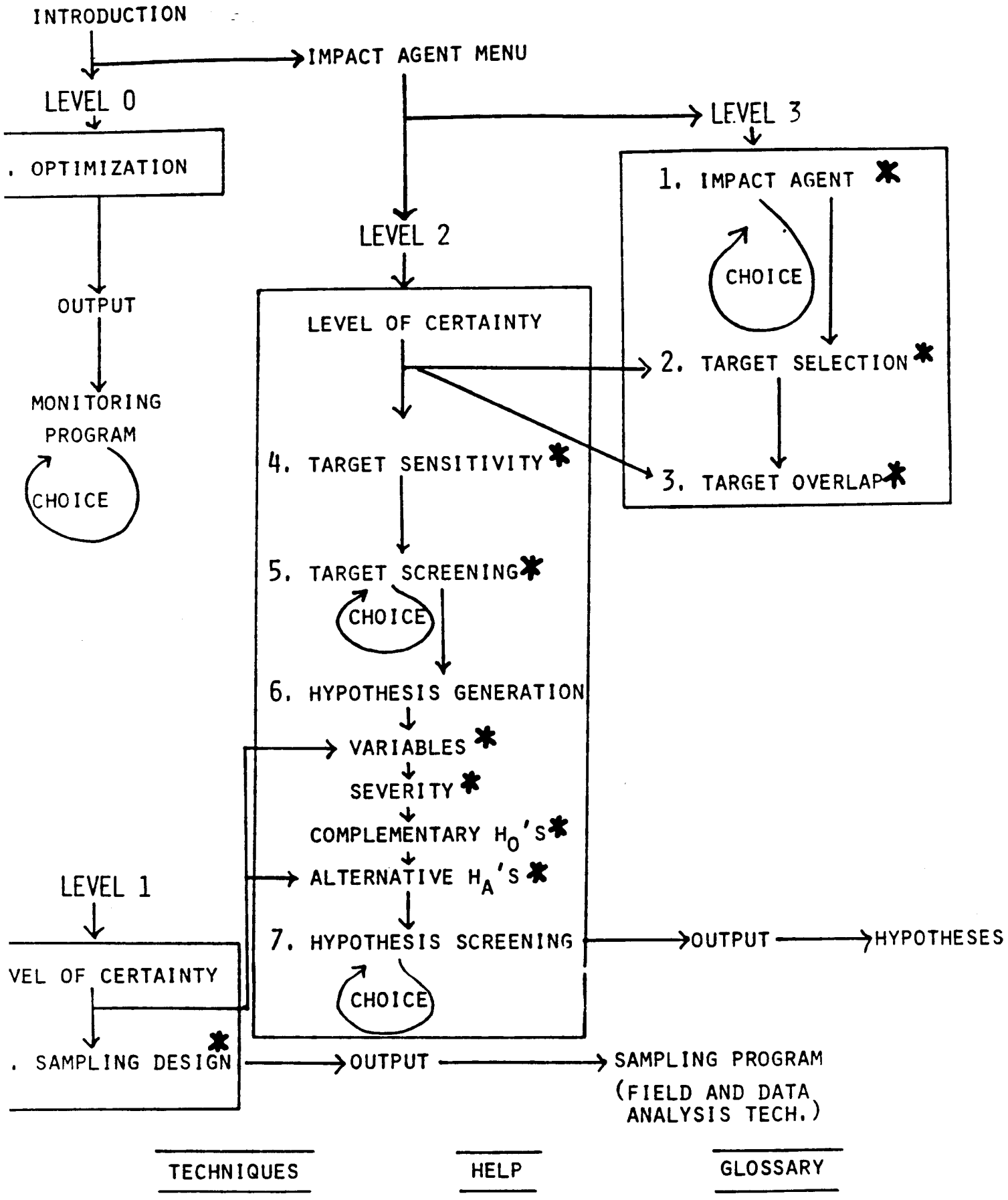


Figure B.3-1 EPAM STRUCTURE

base for each level entered. As all the information necessary at a lower level is inserted into EPAM, the user is moved to the next higher level. Eventually all users enter LEVEL 0 with a fully developed monitoring program in need of optimization.

The lowest level, 3, assumes that the user has no or minimal prior knowledge of the impacts which have potential to occur at the site, nor the targets likely to be affected. LEVEL 3 identifies impacts and potential targets by evaluating the interaction between plant characteristics and ecosystem components. The next higher level, 2, assumes the availability of this information and uses it to develop formal hypotheses of impact. LEVEL 2 also helps the user select from all hypotheses those that would be most effective in the developing monitoring program. In LEVEL 1, the sampling design and appropriate analytical techniques for testing the hypotheses are developed. The final level, 0, increases the cost-effectiveness of the monitoring program through the use of an optimization subroutine.

The model hierarchy (LEVELS 0, 1, 2, and 3) is designed to allow a user to benefit from EPAM's guidance regardless of how much prior information is available to describe the system. The flow chart (Figure 1) shows the main subroutines and their hierarchy. Several other auxiliary subroutines are also shown. A description of each follows:

INTRODUCTION - introduces user to EPAM, its goals, components and operational mode.

IMPACT AGENT (1) - allows user to identify the mechanisms which have potential to cause problems at the site in question. These so-called impact agents occur as a result of plant operation and design. They include such phenomena as the entrainment of organisms through the cooling system, toxicity due to the use of defouling agents, degradation of the benthic habitat due to outfall structures and flows, and so forth. At the moment, EPAM includes four impact agent categories: A. Chemical/Physical Alterations-Abiotic Effects; B. Impingement/Entrainment-Biotic Effects; C. Water Quality Degradation_Biotic Effects; D. Habitat Disruption-Biotic Effects. Other impact categories will be added if sufficient rationale arises during model testing or following the Delphi review.

TARGET SELECTION (2) - allows user to identify a preliminary list of targets to be considered for inclusion in the monitoring program. A target is defined as any component of the ecosystem that can be measured in order to determine the existence, or lack thereof, of change. A target can be any quantifiable entity (e.g. nitrate, copper, salinity, phytoplankton, juvenile striped bass etc.) that has a potential to be affected by plant operation or design. The preliminary list of targets is evaluated and, if possible, reduced in size on the basis of three criteria:

- public interest (i.e. a legislative or historical mandate for monitoring);
- economic value (both sport and commercial);
- environmental or ecological value.

TARGET OVERLAP (3) - allows user to identify those targets which demonsrate significant overlap with the impact agent in both time and space domains within their overall geographic range (relative to the impacted area) and on a local scale (within the local habitat available to the target in the impacted area). A user is required to designate the relative accuracy of these estimates, and the expected cost of collecting data having greater accuracy.

TARGET SENSITIVITY (4) - allows user to identify the relative sensitivity of each target to the hypothesized impact agent(s), given that the target has importance (public, economic, ecological) and is found in the area of potential impact. Again, the user must designate the relative accuracy of each estimate, and the cost of increasing the accuracy of the estimate by further data collection.

TARGET SCREENING (5) - presents a pair-wise comparison choice program (CHOICE on the flow diagram) which allows the user to select among targets on the basis of their relative vulnerability to the impact agent (including the extent of physical overlap and sensitivity), and their importance in the public, economic and ecological spheres. CHOICE ranks all targets for each impact agent (using a normalized scale, 0-1) on the basis of how each compares relative to all others for the criteria considered. CHOICE uses the eigenvalue-method for choosing among a variety of options on the basis of different criteria as developed by Thomas L. Saaty (1977) in "A Scaling Method for Priorities in Hierarchical Structures" in the Journal of Mathematical Psychology 15:234-281.

HYPOTHESIS GENERATION (6) - allows user to generate an initial list of quantitative and testable hypotheses of impact for the monitoring program by considering:

1. the potential impact;
2. the spatial scale of the potential impact;
3. the temporal scale of the potential impact;
4. the severity of the potential impact (initially describ ed as a function of spatial and temporal dimensions);
5. the type, cost and accuracy of the variable(s) necessary to measure the potential impact;
6. complementary hypotheses (a complementary hypothesis is defined as a hypothesized change that occurs as an indirect result of another hypothesis, e.g. impingement mortality may cause a decline in population size of a planktivorous finfish species; this decline may, in turn, result in an increase in the size of the zooplankton population due to reduced predation);
7. the potential for falsification of the hypothesis as a result of alternative explanations for the potential impact (e.g. a commercial fishery may be responsible for the decline in population size of a finfish species instead of mortality due to impingement).

HYPOTHESIS SCREENING (7) - presents a second version of the CHOICE program which allows the user to eliminate those hypotheses which rank poorly when compared against all others on the list on the basis of the criteria established in HYPOTHESIS GENERATION (2, 3, 4, 5, and 7 above), the first CHOICE score, established in TARGET SCREENING, and the confidence the user has in the data on which that score was based (i.e. data to describe target overlap, target sensitivity, etc.)

SAMPLING DESIGN (8) - uses the information collected in previous subroutines to develop a preliminary sampling design (station locations, sampling frequencies, and numbers of replicates) for each of the hypotheses that remained part of the monitoring program following HYPOTHESIS SCREENING. In particular, SAMPLING DESIGN calls for information about the spatial and temporal distribution of each target and the expected variance associated with a given technique for measuring the target. SAMPLING DESIGN also guides the user in designating appropriate methods for statistical analysis of the data base and considers conditions under which simulation models and/or specialized experimental studies might be implemented to improve the monitoring design.

OPTIMIZATION (9) - this final subroutine reevaluates the sampling design on the basis of its expected costs and the effectiveness (ability to detect change if it exists) of the monitoring program. This latter measure is a function of the error (accuracy and precision) inherent in the data base. Sampling stations, sampling frequencies and/or sampling replicates are eliminated, or added, in order to optimize the tradeoff between cost and effectiveness for each hypothesis kept in the final monitoring program. The optimization routine is based on the Lagrangian multiplier method and optimizes either for minimum cost (with fixed effectiveness) or maximum effectiveness (with fixed cost). OPTIMIZATION presents the user with a final version of the CHOICE program so that individual sections of the monitoring program can be eliminated if their optimal cost or effectiveness is determined (by the user) to be too high or too low.

TECHNIQUES - this subroutine presents a user with suggested methods for collecting the information base needed in the different subroutines. TECHNIQUES guides the user to consider both the cost expended and the accuracy gained when choosing among the different methods.

LEVEL OF CERTAINTY - this subroutine functions as a "policing" mechanism that helps to prevent a user from entering a given level or subroutine before the necessary background information has been assembled.

GLOSSARY - this subroutine defines all technical terms presented in EPAM.

HELP - this subroutine presents the user with instructions about the operational mode of EPAM's different sections. It also reminds the user of the function of each subroutine, its data needs and its final output.

This is the end of Part II of the first round questionnaire. Keep these pages for future reference. Do not return them with Parts III and IV of this questionnaire.

CODE NO. _____

PART III. ISSUES IN THE DEVELOPMENT OF EPAM

In order to answer the questions posed in this section of the questionnaire one of two strategies is appropriate:

1. Circle the numeral (1-5) that most closely reflects your opinion about, or extent of agreement with, the following questions or statements:

   1 = extreme importance; complete agreement; very pertinent to issue at hand
   2 = importance; agreement
   3 = some importance; partial agreement
   4 = minimal importance; limited agreement
   5 = no importance; no agreement (i.e. complete disagreement); no pertinence to issue at hand

2. Insert the appropriate information in the space provided.

As you answer the questions on the following pages, consider both the pragmatic realities of regulatory mandates and the scientific validities that guide monitoring program structure. It is meaningless to devise an idealized structure of a "best of all possible worlds" if its implementation is impossible.

Please answer all questions and return this part of the questionnaire with Part IV (i.e. all the white pages) in the enclosed envelope by APRIL 30, 1983.

Thank you for your time and commitment.

A. STRUCTURE OF MONITORING PROGRAMS

1. The structure of a monitoring program is most effective (i.e. most able to achieve a goal of demonstrating ecological change if it exists) if it is founded upon scientifically valid and quantifiable hypotheses. Do you agree with this statement?

Complete Agreement				No Agreement
1	2	3	4	5

2. Does some other foundation for a monitoring program make better sense to you ? (please write in)

Other foundation(s)

3. Chemical methods have become substantially uniform and well-established through the widespread usage of manuals such as Standard Methods. Do you think a similar standardization of methods (i.e. a diagnostic program) to guide development of environmental monitoring programs is possible?

Yes Absolutely				No not at all
1	2	3	4	5

4. Do you think the type of standardization discussed above is important?

1	2	3	4	5

5. Do you think that a set of standard methods for collection of field samples in aquatic environments can be developed for environmental assessment studies?

1	2	3	4	5

6. Do you think that the efficacy of environmental assessment studies will be increased by developing a set of standard methods for field collection of samples in aquatic environments?

1	2	3	4	5

	Yes Absolutley				No Not at all
7. Can sampling error estimates be established and made uniform (i.e. standardized) for different sampling techniques and field environments?	1	2	3	4	5
8. Do you think that the standardization of sampling error will increase the efficacy of environmental assessment studies?	1	2	3	4	5
9. Is the collection of data that are not defined as parameters in a formal hypothesis important?	1	2	3	4	5

10. Do any other criteria (i.e. other than identification in a formal hypothesis) justify data collection? (please write in)

Other criteria

	Yes Absolutely				No not at all
11. Before concluding that a given ecological change has occurred as a result of the hypothesized environmental perturbation, is it important for a researcher to evaluate alternative explanations (Ha's) for the observed change? [Note that this process has been termed falsification.]	1	2	3	4	5

12. What other approaches exist for making a hypothesis believable? (please write in)

Other approaches

	Yes Absolutely				No not at all
13. Is it important to test all reasonable alternative hypotheses (explanations) before a hypothesis is accepted?	1	2	3	4	5

	Yes Absolutely			No not at all	
14. Is the consideration of cost and error information a reasonable criterion for making the decision about which alternative hypotheses to evaluate?	1	2	3	4	5

15. Which of the following criteria need to be considered when evaluating the importance (i.e. prioritizing) of a group of suggested hypotheses (Ho's)?	Extreme Importance			No Importance	
i. a lack of ambiguity in the measurement technique	1	2	3	4	5
ii. low variance component in measured variable	1	2	3	4	5
iii. total cost of testing hypothesis	1	2	3	4	5
iv. suitability of controls	1	2	3	4	5
iv. other (please write in and rank)	1	2	3	4	5

16. The following criteria are important to consider in the optimization of a monitoring program design: (equal weighting for 1 or more criteria is acceptable)					
i. prioritization of all suggested hypotheses (Ho's) on the basis of established criteria (see question 15)	1	2	3	4	5
ii. design of an efficient sampling network (involving a tradeoff between stations, replicated and sampling frequencies)	1	2	3	4	5
iii. the error associated with each of the different program components	1	2	3	4	5
iv. the cost ($) of the different program components	1	2	3	4	5
v. other (please write in and rank)	1	2	3	4	5

17. Is a strong Ho (i.e. one that can be tested quantitatively to produce unambiguous results) — Circle 1 or more options

    a. one for which alternative hypotheses, Ha's, (explanations) are testable? — a

    [Note that an alternative hypothesis, Ha, is another factor in the ecosystem that could produce the hypothesized change: i.e. a commercial fishery can reduce fish population size as well as mortality due to entrainment.]

    b. one that has the fewest number of alternative hypothesis? — b

    c. one that has the fewest number of untestable alternative hypotheses? — c

    d. other (relative to alternative hypotheses) (please write in) — d (write in)

18. Has an inability to accurately quantify various ecological phenomena (e.g. finfish, population size, ecosystem production, etc.) limited environmental impact assessment efforts?

Yes Absolutely			No not at all
1	2	3	4	5

19. Do you think that many of the available techniques which are capable of accurate quantification are too costly to use in a majority of monitoring programs?

1	2	3	4	5

20. Do you think improved measurement techniques would be useful in certain areas (i.e. for specific taxonomic groups, ecosystem levels, etc.) Please write in.

Improved Techniques

B. STRUCTURE OF THE UW MODEL, EPAM

It may be useful to refer to the background information presented in Part II of the questionnaire when answering the questions in this section. The background information introduces EPAM's structure and goals as currently envisioned.

Section 1. Hypothesis Development

21. A scientific hypothesis must be specified at a variety of levels before it can be tested meaningfully. EPAM identifies several attributes to be specified. They are:

    1. Qualitative descriptors:
       - what impact agents exist (i.e. the mechanisms likely to effect change)?
       - what targets (i.e. ecosystem components) are likely to be changed?
    2. Identification of Potential for change:
       - what is the physical overlap of each target with the affecting agent?
       - what is the sensitivity or vulnerability of each target?
    3. Potential for quantification (measurability)
       - what variable or parameter (e.g. biomass, abundance, diversity, etc.) can be measured to evaluate the change?
    4. Analysis of Potential severity (reversibility/irreversibility)
       - what are the spatial and temporal dimensions of the effect (if any is observed)?

Do you agree that each of these attributes is important to specify in developing an hypothesis?	Complete Agreement 1	2	3	4	No Agreement 5

22. Are there any attributes that can be eliminated from the list above without weakening the hypothesis test? Please specify.

23. Are there other attributes (i.e. components of the ecosystem that need to be specified) that should be included in a hypothesis designed to test for ecological change due to power plant operation or design? Please specify.

Section 2. Defining the Type and Potential Severity of an Effect

	Complete Agreement				No Agreement
24. Ecological or environmental value of an ecosystem component is a variable function of society's view of the purpose and beneficial use of the ecosystem (i.e. the ecological value is BASED on the SOCIALLY PERCEIVED VALUE of the ecosystem component.)	1	2	3	4	5
25. Ecological or environmental value of an ecosystem component is an absolute (non-varying) attribute of that component's function within the ecosystem structure. (i.e. the ecological value is BASED on the FUNCTIONAL or ECOLOGICAL VALUE of the component.)	1	2	3	4	5
26. If a power plant operates continuously for several years, long-term effects are:					
i. expected	1	2	3	4	5
ii. need to be evaluated	1	2	3	4	5

27. Long-term, severe effects resulting from power plant operation or design have highest potential to occur under the following conditions: [Note: long-term is defined as continuing to exist for a period equal to, or greater than, plant life; severe is defined as irreversible or very slow to reverse.]

	Complete Agreement				No Agreement
a. several power plants are located on the same body of water.	1	2	3	4	5
b. other industrial and/or municipal discharges occur on the same body of water	1	2	3	4	5
c. extensive overlap in time and space between the agent having potential to cause an effect and the target likely to be affected	1	2	3	4	5
d. extreme vulnerability of the target to the agent having potential to cause an effect (usually coupled with poor recovery capacity)	1	2	3	4	5

	Complete Agreement			No Agreement	
e. extreme intensity of the agent having potential to cause an effect and a high concentration of the target(s) likely to be affected	1	2	3	4	5
f. other (please write in and rank)	1	2	3	4	5

28. The resiliency of a target (i.e. its ability to recover from an adverse effect, whether manifested at an individual, population, community or ecosystem level) has potential to be great if one or more of the following compensatory mechanisms is manifested in the population:

	Extreme Importance			No Importance	
a. high reproductive rate	1	2	3	4	5
b. high level of plasticity (ability to adapt)	1	2	3	4	5
c. organisms are very mobile and able to move away from impact; avoidance behavior	1	2	3	4	5
d. very short generation time	1	2	3	4	5
e. life history characteristics allow compensation (e.g. long-lived organisms with an ability to compensate for mortality in one life stage by increased growth during another life stage)	1	2	3	4	5
f. other (please write in)					

29. Which of the compensatory mechanisms listed above do you think have greatest importance? Please rank each on the 1 to 5 scale.	Extreme Importance				No Importance
a. high reproductive rate	1	2	3	4	5
b. high level of plasticity	1	2	3	4	5
c. organisms are very mobile and able to move away from impact; avoidance behavior	1	2	3	4	5
d. Very short generation time	1	2	3	4	5
e. life history characteristics allow compensation	1	2	3	4	5
f. other	1	2	3	4	5

30. How much confidence do you have in the answers you gave for the questions in this section (B)?	Extensive Confidence				No Confidence
	1	2	3	4	5

C. GENERAL QUESTIONS

31. Are you familiar with any other programs, manuals or other publications that have a similar goal* to EPAM?
[Note: other examples might include:
1. States, J. B., P.T.Haug, T.G.Shoemaker, L.W.Reed, and E.B. Reed. 1978. A Systems Approach to Ecological Baseline Studies. U.S.Fish and Wildlife Service, Washington, D.C., FWS/OBS-78/21, 406 pp.;
2. Fritz,E.S., P.J.Rago, and I.P.Murarka. 1980. Strategy for Assessing Impacts of Power Plants on Fish and Shellfish Populations. Power Plant Project, Office of Biological Services, Fish and Wildlife Service. FWS/OBS-80/34.]
*Note that the goal of EPAM is to provide guidance in the design of scientifically valid and cost-effective monitoring programs to evaluate ecological change due to electrical generation.

Yes				No
1	2	3	4	5

32. What ones specifically? (please write in)

This is the end of Part III of Questionnaire 1. Please go on to Part IV.

CODE NO. _____

PART IV. FOLLOW-UP QUESTIONS FROM PRE-DELPHI SURVEY

The two questions below were asked in the pre-Delphi survey. Each is marked with your original score and the mean weighted score of all Delphi participants. Please answer each question again by circling the numeral you think most appropriate in light of your knowledge, your initial score and the mean score of the Delphi panel.

Various panel members suggested other criteria (#11) and other problems (#12) that they felt warranted consideration. These choices are listed for consideration by the whole panel. Please rank each of the new options in terms of their importance in your opinion. Remember that you are ranking all options (new and old) relative to each other.

11. Various criteria have been suggested as useful for the designation of biotic characteristics to be monitored. Rank each of the following in terms of their importance in your opinion.

	Wt.Mean Score	Your Score	Most Important				Least Important
a. designation by law (e.g. rare/ endangered species; representative important species; etc.)	2.7		1	2	3	4	5
b. economic importance (e.g. commercial or recreational species)	2.02		1	2	3	4	5
c. ecological importance (i.e. to ecosystem structure or function)	1.51		1	2	3	4	5
d. high susceptibility to change	2.53		1	2	3	4	5
e. historical precedent (at this or similiar sites)	3.6		1	2	3	4	5
f. other							
i. correlation with other important components			1	2	3	4	5

ii. ease and accuracy of quantification	1	2	3	4	5
iii. dominant role in community metabolism	1	2	3	4	5
iv. dominant/abundant genera in community	1	2	3	4	5
v. ubiquity in similar habitats	1	2	3	4	5
vi. susceptibility to indirect change	1	2	3	4	5
vii. high probability of exposure/long duration of exposure	1	2	3	4	5
viii. long generation time	1	2	3	4	5
ix. indicators of disturbance ("indicator species")	1	2	3	4	5
x. history of regulatory use of data	1	2	3	4	5
xi. taxonomy is known	1	2	3	4	5
xii. biology/natural history is known	1	2	3	4	5

12. In my opinion, existing monitoring programs are satisfactory/unsatisfactory in the following areas:

	Wt.Mean Score	Your Score	Satis-factory		Unsatis-factory	
a. statistical design (no Type I or II error)	3.53		1	2	3	4	5
b. establishment of goals and objectives	3.56		1	2	3	4	5

c. implementation of goals and objectives	3.47	1	2	3	4	5
d. execution of program design	2.77	1	2	3	4	5
e. faulty technology (e.g. lack of appropriate sampling gear)	2.85	1	2	3	4	5
f. establishment of significance of results (esp. relative to long-term change)	4.37	1	2	3	4	5
g. ability to distinquish change from other sources of variation (natural variation; other industrial outfalls; fishing industry; etc.)	4.47	1	2	3	4	5
h. other						
i. consideration of similar studies		1	2	3	4	5
ii. statistical methodology		1	2	3	4	5
iii. definition of impact probability		1	2	3	4	5
iv. understanding of community processes		1	2	3	4	5
v. unrealistically short measurement periods		1	2	3	4	5
vi. cost-effectiveness		1	2	3	4	5
vii. ability of consultant(s)		1	2	3	4	5
viii. consistent with government guidelines rather than the ecology of the system		1	2	3	4	5
ix. utility to management		1	2	3	4	5
x. definition of controls		1	2	3	4	5

This is the end of Part IV of Questionnaire 1. Please return it with Part III in the enclosed, stamped envelope by APRIL 30, 1983. The second questionnaire and the results of this questionnaire with be mailed in approximately 2 to 3 weeks.

Thank you for your time and commitment. We could not accomplish this part of the research effort without the active involvement of experts in the field.

QUESTIONNAIRE 2

PLEASE RETURN BY MAY 31, 1983 CODE NO._____

AQUATIC MONITORING DESIGN, DELPHI REVIEW

QUESTIONNAIRE 2

This questionnaire represents the second round of the Delphi Review being conducted by the University of Washington for its EPRI-sponsored research project on the design of aquatic monitoring programs at electrical generation facilities. The purpose of this Delphi Review is to develop a consensus among a group of experts about a variety of pertinent issues for which no widely accepted viewpoint exists.

The questionnaire consists of two parts:

I. a reiteration of questions we asked in Round 1;

II. questions about specific subroutines in EPAM.

Please answer ALL the questions Part I except # 27. Answer # 27 only if you agree with the specific instructions. All the question in Part I are taken from the first questionnaire. We are reasking some of the questions (i.e. those which lacked a clear consensus) and adding questions about issues and/or categories that were raised by Delphi panelists during the first round. Please answer each question by circling the numeral you think most appropriate in light of your knowledge, your initial score and the mean score of the Delphi panel (where indicated).

The questions in Part II ask you about the general structure of the subroutines, and specific aspects of several of the subroutines for which we would like your opinion. Please answer each question by circling the numeral you think is most appropriate, or by writing the appropriate information in the space provided. If a series of given options does not include a choice that you agree with, write in the value(s) that you think provides the best answer to the question.

Please answer only those questions in Part II which you feel you have expertise in. If your score on a 1 to 5 scale (1 = great expertise; 5 = no expertise) for the general area defined at the beginning of each section is greater than 2, do not answer the questions in that section. Go on to the next section.

Remember that the numerals 1 through 5 refer to:

1 = extreme importance; complete agreement; very pertinent to issue at hand
2 = importance; agreement
3 = some importance; partial agreement
4 = minimal importance; very limited agreement
5 = no importance; no agreement (i.e. complete disagreement); no pertinence to issue at hand

As you answer the questions in both parts, consider the pragmatic realities of regulatory mandates and the scientific validities that guide monitoring program structure. It is meaningless to devise an idealized structure of a "best of all possible worlds" if its implementation is impossible.

Please complete the questions and return this questionnaire in the enclosed, stamped envelope by MAY 31, 1983. You will receive the next (and final) questionnaire in this Delphi round approximately 2 weeks from that date. The final questionnaire in this round will emphasize the nature of long-term cumulative impacts.

The second Delphi review will be conducted during Autumn, 1983 (October through December). You will be contacted at the appropriate juncture.

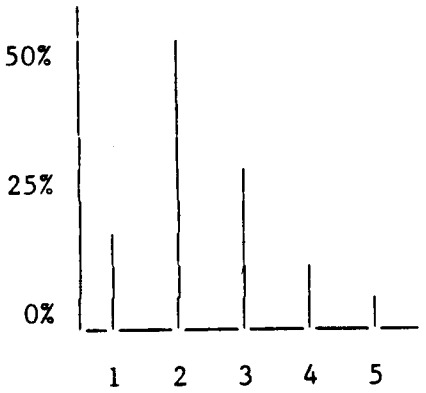
Thank you for your time and commitment.

PART I. REITERATION OF QUESTIONNAIRE 1

Questions for which a clear consensus existed have not been repeated (except in a few instances when we wanted to repeat interesting or substantial comments). The consensus opinions will be presented in the final report for this phase of the research (due date September, 1983) which all panel members will receive.

A. STRUCTURE OF MONITORING PROGRAMS

9. Most people on the panel thought that data other than that defined by a formal hypothesis should be collected:



Do you agree with this opinion (i.e. that data other that that defined by a formal Ho should be evaluated in a monitoring program)?

Your Score	Wt.Mean Score	Yes Absolutely				No Not at all
	2.3	1	2	3	4	5

10. The following criteria were suggested by panel members for justification of data collection. Please rank each relative to the above criterion (definition in a formal Ho) and relative to each other.

	Extreme Importance				No Importance
a. information that will be important for testing alternative hypotheses.	1	2	3	4	5
b. information to use for mechanistic/cause-effect explanations	1	2	3	4	5
c. information mandated by regulatory requirements/public relations/etc.	1	2	3	4	5

d. information needed in the predesign phase (i.e. pilot program information)	1	2	3	4	5
e. information for quality control purposes	1	2	3	4	5
f. information that continues a historical data base	1	2	3	4	5
g. information which is cost efficient	1	2	3	4	5

11. Solid consensus existed on the importance of evaluating alternative hypotheses in a hypothesis testing format (wt. mean score = 1.3). However, one dissenting opinion prompts us to ask a new question.

Which of the following goals do you think is(are) important for a monitoring program? (circle as many as you like)

	Extreme Importance				No Importance
a. collection of descriptive data to document "existing" conditions (i.e. the WHAT)	1	2	3	4	5
b. collection of cause-effect data to explain "existing" conditions (i.e. the WHY)	1	2	3	4	5
c. collection of data to comply with permit requirements/state water quality standards/etc.	1	2	3	4	5
d. collection of data to enhance regional and/or historical data bases	1	2	3	4	5
e. other (please specify)					

Monitoring Program Goals

12. What other approaches exist for making a hypothesis believable?	Extreme Importance				No Importance
a. laboratory testing	1	2	3	4	5
b. simulation model development	1	2	3	4	5
c. replication at other sites	1	2	3	4	5
d. tight correlation of observed biological change with chem/phys changes and/or known tolerance limits	1	2	3	4	5
e. demonstration that observed changes at one trophic level have indirect effects at another trophic level	1	2	3	4	5

13. The panel feels that, while it is important to test all reasonable Ha's before a hypothesis is accepted (wt. mean score = 2.0), this goal is often impossible or very impractical. Thus Ha's should be carefully evaluated before testing.

14. The panel feels that COST and ERROR information provide reasonable criteria for the decision as to which Ha's should be evaluated (wt. mean score = 2.2)

B. STRUCTURE OF THE UW MODEL, EPAM

It may be useful to refer to the background information presented in Part II of Questionnaire 1 when answering the questions in this section. The background information introduces EPAM's structure and goals as currently envisioned.

Good consensus existed regarding the elements that are necessary for the process of hypothesis development. No questions about hypothesis development will be re-asked (Section 1).

Section 2. Defining the Type and Potential Severity of an Effect

Questions 24 and 25 have been reworded to eliminate some of the confusion that existed:

24. Ecological or environmental value of an ecosystem component depends upon (circle 1 choice only, a, b, c, OR d):

a. the general public's opinion of its value and/or function (e.g. social or political, component has an important public use function in water quality control; economic, component has an important commercial usage)	a
b. the scientific opinion of its value and/or function (e.g. component is a critical element of the ecosystem)	b
c. both a and b	c
d. other, i.e. if you do not base value on economics, politics, or science, what do you base it on? (please specify)	d (write in)

26. If a power plant operates continuously for several years, long-term effects are: [Note: long-term is defined as continuing to exist for a period equal to, or greater than, plant life]

	Complete Agreement				No Agreement
a. likely to appear immediately after the plant starts operating	1	2	3	4	5
b. likely to appear some time after the plant starts operating	1	2	3	4	5
c. a and b are equally likely	1	2	3	4	5
d. it will be difficult to observe long-term effects (regardless of time of appearance) if no baseline data are available	1	2	3	4	5

Question 27 has been reworded to ask for more information about the general environmental conditions, or ecosystem thresholds, beyond which a potential for long-term effects is aggravated. If you believe it is impossible to evaluate this potential in the general case (i.e. evaluations MUST be site specific) do not re-answer question 27. Go on to question 28.

27. Long-term, irreversible effects to the aquatic environment will be aggravated when: [Note: long-term is defined as continuing to exist for a period equal to, or greater than, plant life]

a. more than 1 power plant is located within an X mile radius on an enclosed waterbody (lake, reservoir, estuary, etc.) Note that circling an X value implies agreement with the statement. If you do not agree, circle not likely....

10 25 50 100 200 mile

other distance (specify)

not likely to increase potent. for long-term effects

b. more than 1 power plant is located within an X mile radius on an open waterbody (river, coast, etc.)

10 25 50 100 200 mile

other distance (specify)

not likely to increase potent. for long-term effects

c. other industrial/municipal discharges are located within an X mile radius of the power plant on an enclosed waterbody (lake, reservoir, estuary, etc.) Note that circling an X value implies agreement with the statement. If you do not agree, circle not likely....

10 25 50 100 200 mile

other distance (specify)

not likely to increase potent. for long-term effects

d. other industrial/municipal discharges are located within an X mile radius of the power plant on an enclosed waterbody (lake, reservoir, estuary, etc.)

10 25 50 100 200 mile

other distance (specify)

not likely to increase potent. for long-term effects

The following four options were suggested by Delphi panelists. Do you agree that these are important diagnostic indicators of an increased potential for long-term effects?

	Extreme Importance				No Importance
e. similar conditions produced similar long-term effects on similar waterbodies	1	2	3	4	5
f. reproduction or growth of affected organisms are indicators of an increased potential for long-term effects	1	2	3	4	5
g. changing the basic habitat structure of the ecosystem will change the carrying capacity of the ecosystem	1	2	3	4	5

h. long-term physical or chemical changes of less than X % can be tolerated by an ecosystem without resulting in long-term ecological changes. Note that a percentage change in physical or chemical parameters could refer to area, volume, mass, concentration or intensity of the parameter. (circle the X value you think is most appropriate AND score the importance of this condition as a diagnostic criterion for predicting the potential for long-term effects)

1 5 10 25 50 75

other (write in)

not a useful criterion

Extreme Importance				No Importance
1	2	3	4	5

28. Target Resiliency (ability to recover and/or respond positively to adversity)

In Round 1 there was some agreement (wt. mean score of 2.2) that the following categories had the potential to increase target resiliency (i.e. decrease the potential for adverse effects). However, it was clear from the wide range of answers received that conviction was weak and a true consensus -at least for the general case- was unlikely to develop. Thus in reasking this question we want your opinion for specific taxonomic groups.

Please score only those groups for which you have specific expertise. For all groups that you do score, write in the numeral (1 to 5) which corresponds most closely to your estimate of your own competence level:

1 - very competent
2 - competent
3 - some competence (limited)
4 - minimal competence
5 - no competence

If you do not think specificity in taxonomic groups is important DO NOT ANSWER these questions. Go on to Part II.

	Competence Level (1-5)	Extreme Importance				No Importance
a. high reproductive rate						
i. finfish		1	2	3	4	5
ii. shellfish		1	2	3	4	5
iii. phytoplankton		1	2	3	4	5
iv. zooplankton		1	2	3	4	5
v. benthic invertebrates		1	2	3	4	5
vi. macrophytes/macroalgae		1	2	3	4	5
b. target is a generalist (large capacity to adapt to changing conditions)						
i. finfish		1	2	3	4	5
ii. shellfish		1	2	3	4	5
iii. phytoplankton		1	2	3	4	5
iv. zooplankton		1	2	3	4	5
v. benthic invertebrates		1	2	3	4	5
vi. macrophytes/macroalgae		1	2	3	4	5
c. target is very mobile and able to move away from impact; avoidance behavior						
i. finfish		1	2	3	4	5
ii. shellfish		1	2	3	4	5
iii. phytoplankton		1	2	3	4	5
iv. zooplankton		1	2	3	4	5
v. benthic invertebrates		1	2	3	4	5
vi. macrophytes/macroalgae		1	2	3	4	5

d. very short generation time

i. finfish	1	2	3	4	5
ii. shellfish	1	2	3	4	5
iii. phytoplankton	1	2	3	4	5
iv. zooplankton	1	2	3	4	5
v. benthic invertebrates	1	2	3	4	5
vi. macrophytes/macroalgae	1	2	3	4	5

Panel members also suggested several other conditions which they felt are likely to decrease the potential for adverse effects due to power plant operation. For each category in which you have either direct education or professional experience, please score each of the new conditions as to its relative importance (potential) for countering adverse impacts; score across all taxonomic groups on the 1 to 5 scale. If you do not have direct experience in a given category do not answer that part. Go on to the next part of the question.

f. refuge areas are available near affected areas	1	2	3	4	5
g. affected population is ubiquitous in distribution	1	2	3	4	5
h. affected population has broadly based environmental requirements for reproduction	1	2	3	4	5
i. affected population can be replaced artificially (hatchery/planting/etc.)	1	2	3	4	5
j. affected population has exhibited resiliency in historical studies	1	2	3	4	5

This is the end of Part I. Please go on to the new questions in Part II.

PART II. DEVELOPMENT OF SUBROUTINES FOR EPAM

Questions in Part II are answered using the same strategies used in Part I. Either circle the numeral (1-5) which corresponds most closely to your opinion about the following question or statement OR insert the appropriate information in the space provided. Remember the numeral 1 refers to complete agreement or extreme importance while the numeral 5 refers to complete disagreement or no importance. Refer to the first page of the questionnaire for more complete instructions.

In Section A (General Development Questions) please answer all questions. In Sections B through G, answer only those questions for which you feel you have either direct professional experience or extensive training: i.e., you would give yourself a score of 1 or 2 on a scale of 1 to 5 (1 = extreme competence and 5 = no competence) in the subject matter pertinent to the question.

A. GENERAL DEVELOPMENT QUESTIONS

1. The majority of ecological change associated with power plant operation or design results from the following "impact agents":

i. agent causes impingement of organisms at intake structure (e.g. high velocity field).

ii. agent causes entrainment of organisms through cooling water system.

iii. thermal loading of adjacent environs (or during entrainment).

iv. chemical changes in agjacent environs (or during entrainment).

v. physical disruption of existing habitats.

What other types of agents, which occur as a result of plant operation or design, do you think are important causes of ecological damage at thermal electric power plants? (please write in)

Other impact agents

2. The question of WHAT to measure in a monitoring program is a major concern in the initial design process. These so-called TARGETS can be any ecosystem component that is likely to be changed as a result of power plant operation or design. Do you agree that a target might be any of the following?

	Complete Agreement				No Agreement
a. a distinct species (all life stages)	1	2	3	4	5
b. a distinct species (one life stage only)	1	2	3	4	5
c. a taxonomically defined group (e.g. phytoplankton)	1	2	3	4	5
d. a trophic level (e.g. primary producers)	1	2	3	4	5
e. a community indicator (e.g. species diversity)	1	2	3	4	5
f. an ecosystem indicator (e.g. respiration rate, energy flux, production rate)	1	2	3	4	5
g. concentration or mass of a given chemical element (e.g. copper)	1	2	3	4	5
h. measure of a physical phenomenon (e.g. temperature, discharge)	1	2	3	4	5

i. other (please write in) Other target categories

3. The criteria for judging quantifiable test variables (parameters) are listed below. A test variable is defined as that characteristic of the target that is actually measured in the monitoring program (e.g. biomass, abundance, respiration rate, etc.). Do you agree with these criteria?

	Complete Agreement				No Agreement
a. utility as judged on the basis of historical precedent.	1	2	3	4	5
b. technical requirements of measurement	1	2	3	4	5
c. cost of measurement	1	2	3	4	5
d. error (including accuracy and precision) of measurement	1	2	3	4	5

4. What other types of criteria do you think are useful? (please write in) Criteria for variables

5. The criteria for judging the importance of the spatial extent of the hypothesized effect relative to the distribution of the biological target to be measured are listed below. Do you agree with these criteria?

	Complete Agreement				No Agreement
a. if less than the local range of the target, it is not critical for the monitoring program	1	2	3	4	5
b. if equal to the local range of the target, it may be critical for the monitoring program if all other criteria point towards such a conclusion (e.g. highly vulnerable, extreme economic importance)	1	2	3	4	5
c. if greater than the local range of the target, it should be monitored regardless	1	2	3	4	5

6. What other criteria should be considered in evaluating the spatial extent of an impact? (please write in)

Criteria for spatial extent

7. The criteria for judging the importance of the temporal extent of a hypothesized impact relative to the distribution of the biological target to be measured are listed below. Do you agree with these criteria?

	Complete Agreement				No Agreement
a. if less than a generation time of the target, it is not critical for inclusion in the monitoring program.	1	2	3	4	5
b. if equal to a generation time, it should be monitored if all other criteria point to this conclusion.	1	2	3	4	5
c. if greater than a generation time, it should be monitored regardless of other factors.	1	2	3	4	5

8. What other criteria should be used to evaluate the importance of temporal extent of an impact for inclusion in a monitoring program? (please write in)

Criteria for temporal extent

9. A hypothesis that identifies an ecological component that is likely to be affected by plant operation or design, should be evaluated regardless of other problems (e.g. alternative explanations, no variable that can be measured accurately due to technique, cost or some other problem, high natural variability, etc.)

	Complete Agreement				No Agreement
	1	2	3	4	5

10. EPAM asks a user to consider alternative explanations (i.e. in addition to the hypothesized condition) that could result in an observed change. For example, a commercial fishery can result in depletion of a fish stock as well as mortality due to impingement. Such alternative explanations render a hypothesis difficult to test. The criteria used for eliminating a hypothesis due to other explanations that could cause the same effect (falsification) are listed below. Do you agree with these criteria?

	Complete Agreement				No Agreement
a. more than three alternative explanations for the same effect render a primary hypothesis difficult to test.	1	2	3	4	5
b. one (or more) alternative explanations which have a very high likelihood of occurring render a primary hypothesis difficult to test.	1	2	3	4	5
c. the degree of confidence in the data base on which the primary hypothesis is based is very low (e.g. physical overlap data were based on little more than a guess).	1	2	3	4	5

11. What other criteria would be useful in evaluating the importance of other explanations (i.e. falsification routines)? (please write in)

Criteria for other explanations

12. Given that a particular hypothesis is incorporated into a monitoring program and several different targets (biotic or abiotic components) have equal probability of being affected, how many targets should be measured (assuming equivalent ease of measurement)?

Choose the appropriate number (or percentage of total)

number	1	2	3	4-6	>6	all	other
percent	5	10	25	50	75	100	other

13. How frequently are the following elements useful for monitoring programs?

	Always				Never
i. simulation models	1	2	3	4	5
ii. experimental/laboratory studies	1	2	3	4	5
iii. pilot programs	1	2	3	4	5
iv. historical data about the site	1	2	3	4	5
v. regional data about the ecosystem type	1	2	3	4	5
vi. extensive (prior) ecological understanding of the system	1	2	3	4	5

B. CHOICE OF MONITORING PROGRAM TARGETS
(an evaluation of economic, social, and ecological issues)

	Extensive Expertise				No Expertise
14. My level of expertise in this area is: (you may want to skim the questions in Section B briefly before answering this question)	1	2	3	4	5

IF YOUR LEVEL OF EXPERTISE IS 3, 4, OR 5,
DO NOT ANSWER THIS SECTION. GO ON TO THE NEXT SECTION.

In the following three questions, how would you rank the listed options in terms of importance for use as a target in a monitoring program at a power plant? Use the 1-5 scale for each item but consider the importance of each item relative to the others in that question when assigning a rank. Ranks can be repeated if more than one item has equivalent value in your opinion.

15. Public Interest	Extreme Importance				No Importance
a. target has been designated by law as a monitoring entity (e.g. in an NPDES permit)	1	2	3	4	5
b. target has been designated as a representative important species	1	2	3	4	5
c. target is a rare or endangered species	1	2	3	4	5
d. target has been monitored traditionally at this site and a historical data base exists	1	2	3	4	5
e. target has other unique societal value	1	2	3	4	5
f. other (please write in and rank)					

16. Economic Value

	Extreme Importance				No Importanc
a. target has primary commercial value	1	2	3	4	5
b. target has primary sport fishing value	1	2	3	4	5
c. target has secondary commercial value	1	2	3	4	5
d. target has secondary sport fishing value	1	2	3	4	5
e. target has indirect economic value (i.e. provides a major food source to a commercial or sport fishery)	1	2	3	4	5
f. other (please write in and rank)					

17. Ecological Value
(in this question you are asked to designate the "X" value you think should be inserted in the first part of the question AND then mark the importance of each option -using your designated value- in the second part of the question.

Insert the appropriate percentage

(e.g. 10%, 25%, 50%, etc.)

a. target provides more than X % of the total biomass at a given trophic level

b. target provides a primary food supply (more than X %) to an organism having a clearly defined economic or social value

c. target provides a secondary food supply (more than X %) to an organism having a clearly defined economic or social value

d. target is a primary producer or primary producing group (e.g. phytoplankton) which provides more than X % of the food base for primary consumption

e. target is a major habitat former

No X value to be inserted for option e.

Extreme Importance	No Importance

In the list below, X is the value you selected above.

a. target supplies > X % of total biomass	1	2	3	4	5
b. target supplies > X % of primary food supply	1	2	3	4	5
c. target supplies > X % of secondary food supply	1	2	3	4	5
d. target supplies > X % of primary production	1	2	3	4	5
e. target is a major habitat former	1	2	3	4	5
f. other (please write in and rank)	1	2	3	4	5

18a. Absolute vulnerability is defined as thepercentage of the total number of organisms present that are affected by an impact agent. Such measures are often not available. Thus a measure of relative vulnerability could be used. Relative vulnerability is defined as an increased tendency on the part of the target being considered to be affected by changed chemical or physical conditions. It is a result of physiological tolerance or behavioral tendencies of the target organism and not simply a function of coincidence in time or space.

The data bases being used in EPAM for judging the relative vulnerability of a target to changed chemical or physical conditions are listed below. Do you think that these data bases (if available) will provide useful information for judging vulnerability?

	Complete Agreement			No Agreement	
a. historical records specific to given target (impingement)	1	2	3	4	5
b. historical records specific to given target (entrainment)	1	2	3	4	5
c. Delta T in the receiving waterbody is equal to or greater than 10 degrees C.	1	2	3	4	5
d. published temperature tolerance data for specific organisms (thermal)	1	2	3	4	5
e. published chemical tolerance data for specific chemicals and/or organisms (e.g. EPA 1976; EPA 1980)	1	2	3	4	5
f. published values for lethal dosages (e.g. LC-50 values)	1	2	3	4	5
g. laboratory or field studies done on site using designated targets and expected conditions	1	2	3	4	5

18b. Do you think the data bases listed above are generally available?

Yes, usually available			No, rarely available	
1	2	3	4	5

18c. If no, which ones (e.g. a, b, c, etc.) are least available? (please specify)

19. What other types of data bases do you think are useful for judging the relative vulnerability of a target? (please write in)

Data bases for judging vulnerability

20. Do you think that the definition of overlap and relative vulnerability (as discussed above) will help to prioritize the hypotheses, test organisms, and other components of a developing monitoring program in a more efficient manner than has been possible without this information?

21. Has the lack of such information limited impact assessment studies in the past?

	Yes Absolutely			No, not at all	
	1	2	3	4	5
20.	1	2	3	4	5
21.	1	2	3	4	5

C. ASSESSING THE SPATIAL DISTRIBUTION OF STOCKS

	Extensive Expertise			No Expertise	
	1	2	3	4	5
22. My level of expertise is this area is: (you may want to skim the questions in Section C briefly before answering this question)	1	2	3	4	5

IF YOUR LEVEL OF EXPERTISE IS 3, 4, OR 5,
DO NOT ANSWER THIS SECTION. GO ON TO THE NEXT SECTION.

	Yes Absolutely				No not at all
23. Can the physical overlap in time and space between an organism and an impact agent (e.g. volume of water experiencing increased thermal loading) be measured cost-effectively?	1	2	3	4	5
24. Should it be measured?	1	2	3	4	5
25. EPAM currently estimates physical overlap in time and space between a target and an impact agent in two respects. Do you agree that these two measures are appropriate?					
a. the ratio of the volume (or area) of the ecosystem affected by the impact agent to the volume (or area) of the ecosystem which constitutes the geographic range of the target likely to be affected (overlap of geographic range with affected parts of waterbody)	1	2	3	4	5
b. the total percentage of time that a target spends in the affected volume (or area) of the ecosystem as a result of diel or seasonal movements.	1	2	3	4	5

26. What strategy do you think would be appropriate in situations where the ratio of geographic overlap is very low but the percentage of time that a local population spends in the affected volume (or area) is large? (Please write in; e.g. target should be monitored; should not be monitored)

27a. Should such a measure be expressed as a probability to account more precisely for temporal differences during an annual cycle?	1	2	3	4	5

27b. Can such measures be expressed as probabilities? 1 2 3 4 5

28. What other types of criteria could be used for judging physical overlap (please write in)? (i.e. in addition to relative geographic overlap and some measure of its variability)

Criteria for Physical Overlap

D. PROBLEMS DUE TO IMPINGEMENT OR ENTRAINMENT

	Extensive Expertise				No Expertise
29. My level of expertise in this area is: (you may want to skim the questions in Section D briefly before answering this question)	1	2	3	4	5

IF YOUR LEVEL OF EXPERTISE IS 3, 4, OR 5,
DO NOT ANSWER THIS SECTION. GO ONTO THE NEXT SECTION.

30a. The following conditions, if present in the vicinity of the intake structure, are very important in terms of increasing the severity of impingement or entrainment:

	Complete Agreement				No Agreement
a. shoaling fish	1	2	3	4	5
b. abundant small fish	1	2	3	4	5
c. ichthyoplankton/zooplankton/phytoplankton	1	2	3	4	5
d. any organisms that are very active in terms of daily movement	1	2	3	4	5

30b. Circle the appropriate number relative to the question above (increasing severity of impingement or entrainment)

e. the volume of cooling water (as a percentage of the volume of the waterbody) is less than

0.5% 1% 5% 10% 10%

other (please specify)

f. more than one plant with an open cooling system is located within a radius of X miles

25 50 100 200

anywhere on waterbody

other (please specify)

g. the intake velocity is greater than X ft/sec

0.1 0.25 0.5 1 2

other (please specify)

only true for the following taxonomic groups: (specify both group(s) and velocity)

31. Is reproductive rate important to consider when evaluating the potential for significant population declines following entrainment?

Yes Absolutely — No not at all

1 2 3 4 5

32. Can values for reproductive rates (likely to decrease the potential severity of population declines) be specified?

Yes Absolutely — No not at all

1 2 3 4 5

33. If yes, insert values that you think meet this criterion for any of the specified taxonomic groups:

Reproductive rates (please specify units)

a. phytoplankton
b. zooplankton
c. benthic invertebrates
d. shellfish
e. finfish

34. What other types of conditions (in addition to everything listed in questions 28 - 33) do you think are important in increasing the likelihood and severity of problems due to impingement or entrainment at thermal power plants? (please write in)

Conditions which increase potential for impingement or entrainment

35. Do you know of any accepted models capable of deriving a probability density function (PDF) of the intake field as a function of approach velocity, intake structure geometry, etc.?

Yes No

1 2 3 4 5

36. If yes, can you give references? (please write in)

PDF Models of Intake Field

37. The following conditions, if present, are likely to be important in increasing the probability of long-term problems due to impingement or entrainment. A long-term problem is defined as one that continues for longer than a single generation of the affected target (usually greater than five years):

a. The ratio of cooling water volume/waterbody volume is greater than X.

.001 .005 .01 .05 .10 other

	Complete Agreement				No Agreement
b. Juvenile stages of any fin- or shellfish are found in the intake area in significant numbers (see below)	1	2	3	4	5

I consider SIGNIFICANT numbers to be X	Percent of Population (circle)					
% of the target population:	5	10	25	50	75	other

c. More than one power plant or other industrial facility exists on the water body in question	1	2	3	4	5
d. other (please write in and rank)					

E. PROBLEMS DUE TO CHEMICAL OR PHYSICAL ALTERATIONS

	Extensive Expertise				No Expertise
38. My level of expertise in this area is: (you may want to skim the questions in Section E briefly before answering this question)	1	2	3	4	5

IF YOUR LEVEL OF EXPERTISE IS 3, 4, OR 5,
DO NOT ANSWER THIS SECTION. GO ONTO THE NEXT SECTION.

39a. The following conditions, if present in the discharge plume area, or downstream from the waste disposal site, are likely to increase the severity of biotic effects observed as a result of changes in water quality:	Complete Agreement				No Agreement
a. sessile flora or fauna	1	2	3	4	5
b. organisms having reduced free mobility (e.g. juvenile fish)	1	2	3	4	5

c. organisms attracted to the outfall plume area as a result of feeding preference, habitat preference, thermal preference, etc. 1 2 3 4 5

39b. Circle the appropriate number relative to the question above (increase in biotic effects due to changes in water quality associated with power plant operation)

d. the volume of the discharged water is greater than X percentage of the volume of the waterbody 0.5 1 5 10 25

other (please specify)

40. What other types of conditions do you think are likely to increase the severity of biotic effects due to changes in water quality? (please write in)

Other Conditions

41. The following chemical and/or physical occurrences are:
i. very important in terms of inducing ecological change, and
ii. very likely to occur as a result of power plant operation or design.

		Extreme Importance/ Likely to occur				No import/ Not likely
a. changes in current patterns	i. import.	1	2	3	4	5
	ii. occur.	1	2	3	4	5
b. changes in salinity (seawater only)	i. import.	1	2	3	4	5
	ii. occur.	1	2	3	4	5
c. change in benthic substrates	i. import.	1	2	3	4	5
	ii. occur.	1	2	3	4	5
d. change in suspended solids	i. import.	1	2	3	4	5
	ii. occur.	1	2	3	4	5

e. changes in concentrations of macronutrients (N,P,C)	i. import.	1	2	3	4	5
	ii. occur.	1	2	3	4	5
f. changes in concentrations of trace elements (metals, organic compounds)	i. import.	1	2	3	4	5
	ii. occur.	1	2	3	4	5
g. other (please write in)	i. import.	1	2	3	4	5
	ii. occur.	1	2	3	4	5

42. Do you know of any accepted models capable of deriving a probability density function (PDF) of the discharge plume as a function of outfall velocity, discharge, etc.?

Yes				No
1	2	3	4	5

43. If yes, can you give references? (please write in)

44. Information to describe the spatial distribution of either intake plume or outfall plume is limited. Only uniform distributions can be inferred as a first-cut estimate of the volume of the plume envelope. This information, while crude, is useful in evaluating targets likely to be impacted.

Complete Agreement				No Agreement
1	2	3	4	5

45. A delta T greater than or equal to X degrees C. in the receiving waterbody, is indicative of a high probability of biotic problems due to thermal loading.

2 5 10 20 30

other (please specify)

do not agree that delta T values can be diagnostic of potential for thermal problems

F. STATISTICAL CHARACTERISTICS OF MONITORING DATA

(Statistical design and analysis of monitoring data)

	Extensive Expertise				No Expertise
46. My level of expertise in this area is: (you may want to skim the questions in Section F briefly before answering this question)	1	2	3	4	5

IF YOUR LEVEL OF EXPERTISE IS 3, 4, OR 5,
DO NOT ANSWER THIS SECTION. GO ONTO THE NEXT SECTION.

47. What statistical tests have you used most successfully for the assessment of long-term ecological change. Use the 1 to 5 scale but rank the tests relative to each other. Do not circle any number if you have not employed a given test.

	Most Successful				No Success
a. ANOVA or similar tests	1	2	3	4	5
b. cluster analysis	1	2	3	4	5
c. factorial analysis	1	2	3	4	5
d. time series analysis	1	2	3	4	5
e. nonparametric tests	1	2	3	4	5

f. other (please write in and rank)	1	2	3	4	5

48. Have you considered the effects of (a) temporal and (b) spatial correlation in the statistical tests you have used?

	Yes				No
a. temporal correlation	1	2	3	4	5
b. spatial correlation	1	2	3	4	5

49. How have you handled zeros in data sets analyzed for ecological change? Circle the number that corresponds to the success you have had with the given option. If you have not used a given option do not circle any number.

	Most Successful				No Success
a. ignore zeros	1	2	3	4	5
b. aggregate data to a sufficient level at which point zeros can be ignored:					
i. aggregation by time	1	2	3	4	5
ii. aggregation by space	1	2	3	4	5
iii. aggregation by species	1	2	3	4	5
iv. aggregation by other elements (please write in)	1	2	3	4	5
c. utilize tests that explicitly account for zeros (e.g. discrete distributions)	1	2	3	4	5
d. this has not been a problem in the data sets I am familiar with	true				false

50. How do you determine the space-time tradeoff for station allocation for the assessment of long-term change (where long-term is defined as above)?

	Most Successful				No Success
a. personal judgment	1	2	3	4	5
b. optimization model for allocation	1	2	3	4	5
c. other (please write in and rank)	1	2	3	4	5

51. Are you aware of data sets with sufficient time frequency of sampling (e.g. 1 date/month) and spatial density (e.g. 25 - 50 stations total) to allow retrospective assessment of the space-time tradeoff?

Yes				No
1	2	3	4	5

52. If yes, what data sets and who can be contacted for permission to utilize. Please give name, address and telephone number if possible.

G. SAMPLING COSTS FOR MONITORING PROGRAMS

	Extensive Expertise				No Expertise
53. My level of expertise in this area is: (you may want to skim the questions in Section G briefly before answering this question)	1	2	3	4	5

IF YOUR LEVEL OF EXPERTISE IS 3, 4, OR 5,
OR
IF YOU ANSWERED THESE QUESTIONS PREVIOUSLY AS PART OF THE COST SURVEY,

DO NOT ANSWER THIS SECTION. GO TO THE LAST PAGE OF THE QUESTIONNAIRE.

54. If monitoring cost could be separated into fixed costs that are independent of the number of stations or the number of replicates, they would be: (circle the appropriate percentage)

a. X % of the total cost of sampling fishes	10	25	50	75
b. X % of the total cost of sampling benthic invertebrates	10	25	50	75
c. X % of the total cost of sampling water quality	10	25	50	75
d. X % of the total cost of sampling plankton	10	25	50	75

55. The cost to collect a sample at a different station is approximately X times the cost to collect a sample at the same station and to analyze that sample: (circle the appropriate X value)

> 5 3 1 .5 .25 .10 < .10

56. The cost to sample fish is greater or less than the cost to sample the benthos by a factor of: (circle greater or less than and the appropriate factor)

greater than	5	3	1	.5	.25	.10
less than	5	3	1	.5	.25	.10

This is the end of Questionnaire 2. Please return it in the enclosed, stamped envelope by MAY 31,1983. You will receive the third (and final) questionnaire in this Delphi round in approximately 2 weeks from that date.

Thank you for your time and commitment. We could not accomplish this part of the research effort without the active involvement of experts in the field.

APPENDIX B-5

QUESTIONNAIRE 3

PLEASE RETURN BY JULY 31, 1983 CODE NO. _____

AQUATIC MONITORING DESIGN, DELPHI REVIEW

QUESTIONNAIRE 3

This questionnaire represents the third round of the Delphi Review being conducted by the University of Washington for its EPRI-sponsored research project on the design of aquatic monitoring programs at electrical generation facilities. The purpose of this Delphi Review is to develop consensus among a group of experts about a variety of pertinent issues for which no widely accepted viewpoint exists.

The questionnaire consists entirely of a reiteration of questions we asked in Questionnaire 2. We are reasking only those questions which lacked a clear consensus. Thus the number of each question refers to the original number found in Questionnaire 2. Please answer ALL questions which you answered in Questionnaire 2. These questions will be noted on your copy of the questionnaire. In addition, a few other questions will be marked (in RED) for you to answer. For all of these questions (old and new), circle the numeral you think most appropriate in light of your knowledge, your initial score and the mean score of the Delphi panel (where indicated), or by writing the appropriate information in the space provided.

Remember that the numerals 1 through 5 refer to:

1 = extreme importance; complete agreement; very pertinent to issue at hand
2 = importance; agreement
3 = some importance; partial agreement
4 = minimal importance; very limited agreement
5 = no importance; no agreement (i.e. complete disagreement); no pertinence to issue at hand

As you answer the questions consider the pragmatic realities of regulatory mandates and the scientific validities that guide monitoring program structure. It is meaningless to devise an idealized structure of a "best of all possible worlds" if its implementation is impossible.

Please complete the questions and return this questionnaire in the enclosed, stamped envelope by JULY 31, 1983.

This is the final questionnaire in this Delphi round. You will receive a copy of the results of this Delphi review in early October, 1983. At the same time we will send a follow-up survey which will give you a chance to comment upon the value (or lack of value) of your experience and a chance to give us suggestions for future Delphi reviews.

The second Delphi review will be conducted from October, 1983 through February, 1984. You will be contacted at the appropriate juncture for participation.

We would like to thank you for your time and commitment. The results of the Delphi review are making a substantial contribution to the research we have been conducting to develop a methodology for guiding the design of aquatic monitoring programs.

PART I. REITERATION OF QUESTIONS FROM QUESTIONNAIRE 1

Questions for which a clear consensus existed have not been repeated. The consensus opinions will be presented in the final report which you will receive in early October.

PLEASE ANSWER THE QUESTIONS IN THIS SECTION: YES ____ NO ____

A. STRUCTURE OF MONITORING PROGRAMS

12. In addition to evaluating alternative hypotheses, what other approaches exist for making a hypothesis believable?	Your Score	Wt.Mean Score	Extreme Importance				No Importance
a. laboratory testing		2.2	1	2	3	4	5
b. simulation model development		2.8	1	2	3	4	5
c. replication at other sites		2.3	1	2	3	4	5
d. tight correlation of observed biological change with chem/phys changes and/or known tolerance limits		2.0	1	2	3	4	5
e. demonstration that observed changes at one trophic level have indirect effects at another trophic level		2.6	1	2	3	4	5

PLEASE ANSWER THE QUESTIONS IN THIS SECTION YES ____ NO ____

B. STRUCTURE OF THE UW MODEL, EPAM

It may be useful to refer to the background information presented in Part II of Questionnaire 1 when answering the questions in this section. The background information introduces EPAM's structure and goals as currently envisioned. [No questions from Section 1 will be reasked.]

Section 2. Defining the Type and Potential Severity of an Effect

24. The majority of Delphi respondents (72%) felt that the ecological value of an ecosystem component depends upon BOTH choices a. and b.; no alternative criteria for value were given.

a. the general public's opinion of its value and/or function (e.g. social or political, component is an important public use function in water quality control; economic, component has an important commercial usage)	a	7%
b. the scientific opinion of its value and/or function (e.g. component is a critical element of the ecosystem)	b	21%
c. both a and b	c	72%

Do you agree with the majority opinion (c)?

Yes Absolutely				No not at all
1	2	3	4	5

26. If a power plant operates continuously for several years, long-term effects are: [Note: long-term is defined as continuing to exist for a period equal to, or greater than, plant life]

	Your Score	Wt.Mean Score	Complete Agreement				No Agreement
a. likely to appear immediately after the plant starts operating		3.5	1	2	3	4	5
b. likely to appear some time after the plant starts operating		2.2	1	2	3	4	5
c. a and b are equally likely		3.7	1	2	3	4	5
d. it will be difficult to observe long-term effects (regardless of time of appearance) if no baseline data are available		1.7	1	2	3	4	5

27. Long-term, irreversible effects to the aquatic environment will be aggravated when: [Note: long-term is defined as continuing to exist for a period equal to, or greater than, plant life]

- 63% of Delphi respondents felt that the potential for long-term effects was very site specific and could not be predicted on an a priori basis from information about the power plant locale.

Do you agree with this opinion?	Yes Absolutely				No not at all
	1	2	3	4	5

- 37% of Delphi respondents felt that the potential for long-term effects was not a site specific phenomenon and that at least some predictions could be made on an a priori basis.

Do you agree with this opinion?	1	2	3	4	5

- approximately 10% of these persons felt that the presence of multiple power or other industrial water users on the same water body was not likely to increase the potential for long-term effects.

Do you agree with this opinion?	1	2	3	4	5

Delphi panelists suggested that the following phenomena could be important diagnostic indicators of an increased potential for long-term effects. Do you agree that these are important to consider?

	Your Score	Wt.Mean Score	Extreme Importance				No Importance
e. similar conditions produced similar long-term effects on similar waterbodies		1.7	1	2	3	4	5
f. reproduction or growth of affected organisms are indicators of an increased potential for long-term effects		2.1	1	2	3	4	5
g. changing the basic habitat structure of the ecosystem will change the carrying capacity of the ecosystem		2.2	1	2	3	4	5

h. long-term physical or chemical changes of less than X % can be tolerated by an ecosystem without resulting in long-term ecological changes. Note that a percentage change in physical or chemical parameters could refer to area, volume, mass, concentration or intensity of the parameter.
Answer either i. or ii.:

	Agree				Disagree
i. Changes of less than 10% (the Delphi consensus) can be tolerated....	1	2	3	4	5
ii. This is not a useful criterion in the consideration of the potential for long-term change.	1	2	3	4	5

28. Target Resiliency (ability to recover and/or respond positively to adversity)

The following conditions have been suggested as being likely to decrease the potential for adverse effects due to power plant operation. For each category in which you have either direct education or professional experience, please score each of the conditions as to its relative importance (potential) for countering adverse impacts. If you do not have direct experience in a given category do not answer that part. Go on to the next part of the question.

	Your Score	Wt.Mean Score	Extreme Importance				No Importance
a. refuge areas are available near affected areas		2.2	1	2	3	4	5
b. affected population is ubiquitous in distribution		2.0	1	2	3	4	5
c. affected population has broadly based environmental requirements for reproduction		2.1	1	2	3	4	5
d. affected population can be replaced artificially (hatchery/planting/etc.)		3.2	1	2	3	4	5
e. affected population has exhibited resiliency in historical studies		2.3	1	2	3	4	5

This is the end of Part I of the original questionnaire (from which these questions are being reasked). Please go on to the questions in Part II.

PART II. DEVELOPMENT OF SUBROUTINES FOR EPAM

Questions in Part II are answered using the same strategies used in Part I. Either circle the numeral (1-5) which corresponds most closely to your opinion about the following question or statement OR insert the appropriate information in the space provided. Remember the numeral 1 refers to complete agreement or extreme importance while the numeral 5 refers to complete disagreement or no importance. Refer to the first page of the questionnaire for more complete instructions.

Part II is divided into sections A through G. Answer only the questions in the sections that you answered in Questionnaire 2. These sections are marked on your copy of the questionnaire. Your original score and the weighted mean score of all respondents are also marked. Some questions for which a consensus was apparent have been eliminated. You will receive the results of these questions plus the ones we are reasking in the final report scheduled to be mailed to you in early October.

Thank you again for your enthusiastic participation.

PLEASE ANSWER THE QUESTIONS IN THIS SECTION YES ____ NO ____

A. GENERAL DEVELOPMENT QUESTIONS

1. The majority of ecological change associated with power plant operation or design results from the following "impact agents":

i. agent causes impingement of organisms at intake structure (e.g. high velocity field).

ii. agent causes entrainment of organisms through cooling water system.

iii. thermal loading of adjacent environs (or during entrainment).

iv. chemical changes in adjacent environs (or during entrainment).

v. physical disruption of existing habitats.

Delphi panelists suggested additional agents that occur as a result of plant operation or design which might be important causes of ecological change at thermal electric power plants. Do you agree that these agents are important and should be considered in the design of a comprehensive monitoring program?

	Yes Absolutely				No not at all
a. construction activity	1	2	3	4	5

b. maintenance activity (e.g. dredging)	1	2	3	4	5
c. airbourne pollutants	1	2	3	4	5
d. rapid change in thermal regime following plant shutdown (e.g. cold shock)	1	2	3	4	5
e. runoff from site and/or site-generated wastes	1	2	3	4	5
f. fuel spills from barge traffic	1	2	3	4	5
g. organic enrichment of adjacent waters due to impingement/entrainment mortality	1	2	3	4	5
h. redistribution of water mass and/or organisms (including permanent diversion of water)	1	2	3	4	5
i. gas supersaturation	1	2	3	4	5
j. leakage of toxic wastes and/or radio-nuclides	1	2	3	4	5

2. The question of WHAT to measure in a monitoring program is a major concern in the initial design process. These so-called TARGETS can be any ecosystem component that is likely to be changed as a result of power plant operation or design.

We suggested various possibilities in Q2. The Delphi respondents suggested several others. We reask: Do you agree that a target might be any of the following?

	Your Score	Wt.Mean Score	Complete Agreement			No Agreement	
a. a distinct species (all life stages)		1.5	1	2	3	4	5
b. a distinct species (one life stage)		1.9	1	2	3	4	5
c. a taxonomically defined group (e.g. phytoplankton)		2.1	1	2	3	4	5
d. a trophic level (e.g. primary producers)		2.6	1	2	3	4	5
e. a community indicator (e.g. species diversity)		2.9	1	2	3	4	5
f. an ecosystem indicator (e.g. respiration rate, energy flux, production rate)		2.8	1	2	3	4	5

g. concentration or mass of a given chemical element (e.g. copper)	2.2	1	2	3	4	5
h. measure of a physical phenomenon (e.g. temperature, discharge)	2.0	1	2	3	4	5
i. new suggestions:						
i. population indicator (e.g. fecundity, change in population dynamics)		1	2	3	4	5
ii. commercial or sport harvest		1	2	3	4	5
iii. records of other social use of area (e.g. swimming, boating, etc.)		1	2	3	4	5
iv. level of stress indicators including biochemical stress indicators		1	2	3	4	5
v. measures of community change		1	2	3	4	5
vi. change in temporary vs. permanent flora and fauna		1	2	3	4	5
vii. plant fluctuations		1	2	3	4	5

3. The criteria for judging quantifiable test variables (parameters) are listed below. A test variable is defined as that characteristic of the target that is actually measured in the monitoring program (e.g. biomass, abundance, respiration rate, etc.). Do you agree with these criteria?

	Your Score	Wt.Mean Score	Complete Agreement				No Agreement
a. utility as judged on the basis of historical precedent.		2.4	1	2	3	4	5
b. technical requirements of measurement		2.2	1	2	3	4	5
c. cost of measurement		2.2	1	2	3	4	5
d. error (including accuracy and precision of measurement)		1.8	1	2	3	4	5

4. What other types of criteria do you think are useful?

These criteria were suggested by Delphi respondents. Do you agree with them?

a. theoretical significance of variable as part of an ecological model		1	2	3	4	5
b. ability to interpret variable		1	2	3	4	5

c. comparable error measurements at other laboratories (high quality control)	1	2	3	4	5
d. importance of variable in local system	1	2	3	4	5
e. potential that variable measures something with a high potential for social change	1	2	3	4	5
f. probability that variable will change	1	2	3	4	5
g. utility of variable for obtaining information that meets study objectives	1	2	3	4	5
h. availability of comparative data	1	2	3	4	5

6. The following criteria were suggested for judging the importance of the spatial extent of the hypothesized effect relative to the distribution of the target. Do you agree with these criteria?

	Complete Agreement				No Agreement
a. extent to which critical habitat coincides with affected area	1	2	3	4	5
b. extent to which organisms in affected area are found in other waterbodies or other parts of the same waterbody	1	2	3	4	5
c. percentage of population exposed to affected area	1	2	3	4	5
d. extent to which affected area overlaps with migratory routes	1	2	3	4	5
e. probability that target will be exposed to affected area	1	2	3	4	5
f. the comparative quality of the affected area relative to the unaffected area(s) as far as provision of preferred habitat space	1	2	3	4	5

8. The following criteria were suggested for judging the importance of the temporal extent of the hypothesized effect relative to the distribution of the target. Do you

	Complete Agreement				No Agreement
A. agree that the temporal extent of an effect is important to evaluate?	1	2	3	4	5
B. agree that these criteria should be considered when evaluating the temporal extent of an effect?					
a. effect overlaps in time with critical life cycle period (e.g. migration, spawning, etc.)	1	2	3	4	5
b. targets have minimal avoidance capacity due to temporal extent of effect	1	2	3	4	5
c. recurrence frequency of effecting agent at threshold levels is high	1	2	3	4	5

d. effect occurs continuously; avoidance is difficult; probability of encounter is high	1	2	3	4	5
e. effect is likely to coincide with naturally occuring stress events (e.g. periods of high discharge, upwelling, etc.)	1	2	3	4	5

9. A hypothesis that identifies an ecological component that is likely to be affected by plant operation or design, should be evaluated regardless of other problems (e.g. alternative explanations, no variable that can be measured accurately due to technique, cost or some other problem, high natural variability, etc.)

Your Score	Wt.Mean Score	Complete Agreement				No Agreement
	3.1	1	2	3	4	5

11. The following criteria or techniques were suggested as being useful for evaluating the importance of considering other explanations for an observed effect (falsification routines). Do you agree that these criteria are useful?

	Complete Agreement				No Agreement
a. correlation analysis	1	2	3	4	5
b. availability of believable mechanistic explanations for change	1	2	3	4	5
c. simulation model results	1	2	3	4	5
d. alternative explanation has a high probability of being true	1	2	3	4	5
e. space/time overlap of alternative explanation with target is high	1	2	3	4	5

12. Given that a particular hypothesis is incorporated into a monitoring program and several different targets (biotic or abiotic components) have equal probability of being affected, what percentage of targets should be measured (assuming equivalent ease of measurement)?

Your Score	Wt.Mean Score	Choose the appropriate percentage of total					
	36%	5	10	25	50	75	100

13. How frequently are the following elements useful for monitoring programs?

	Your Score	Wt.Mean Score	Always				Never
i. simulation models		2.9	1	2	3	4	5
ii. experimental/laboratory studies		2.5	1	2	3	4	5
iii. pilot programs		1.8	1	2	3	4	5
iv. historical data about the site		1.9	1	2	3	4	5
v. regional data about the ecosystem type		2.2	1	2	3	4	5
vi. extensive (prior) ecological understanding of the system		1.6	1	2	3	4	5

PLEASE ANSWER THE QUESTIONS IN THIS SECTION YES ____ NO ____

B. CHOICE OF MONITORING PROGRAM TARGETS
(an evaluation of economic, social, and ecological issues)

17. Ecological Value

In this question panelists inserted percentage values. A consensus value was attained. Do you agree with this value? If not insert the value you think is more appropriate.

	Delphi Value	Agree (X)	Do not Agree (insert value)
a. target provides more than X % of the total biomass at a given trophic level	20%		
b. target provides a primary food supply (more than X %) to an organism having a clearly defined economic or social value	30%		
c. target provides a secondary food supply (more than X %) to an organism having a clearly defined economic or social value	20%		
d. target is a primary producer or primary producing group (e.g. phytoplankton) which provides more than X % of the food base for primary consumption	20%		

19. The following data bases were suggested as being useful for judging the relative vulnerability of a target (in addition to the use of historical records, published tolerance data, and laboratory or field studies). Do you agree that these are useful?

	Complete Agreement				No Agreement
a. comparison of plant-induced mortality with sport/commercial harvest numbers	1	2	3	4	5
b. information from impact assessments in similar environments	1	2	3	4	5
c. information about the size, distribution, and life history of the target in question	1	2	3	4	5
d. information from other monitoring programs (e.g. waste disposal sites) on the same waterbody	1	2	3	4	5
e. survey data for targets of interest	1	2	3	4	5
f. other (insert)					

PLEASE ANSWER THE QUESTIONS IN THIS SECTION YES ____ NO ____

C. ASSESSING THE SPATIAL DISTRIBUTION OF STOCKS

25. EPAM currently estimates physical overlap in time and space between a target and an impact agent in two respects. Do you agree that these two measures are appropriate?

	Your Score	Wt.Mean Score	Yes Absolutely				No not at all
a. the ratio of the volume (or area) of the ecosystem affected by the impact agent to the volume (or area) of the ecosystem which constitutes the geographic range of the target likely to be affected (overlap of geographic range with affected parts of waterbody)		1.9	1	2	3	4	5
b. the total percentage of time that a target spends in the affected volume (or area) of the ecosystem as a result of diel or seasonal movements.		2.0	1	2	3	4	5

28. The following criteria were suggested for judging physical overlap (in addition to the relative geographic overlap of the target range and the impact agent and some measure of its variability). Do you agree that these criteria are useful?

	Complete Agreement				No Agreement
a. overlap with spawning areas	1	2	3	4	5
b. overlap into refuge areas	1	2	3	4	5
c. overlap into areas used during sensitive life stages (e.g nursery grounds)	1	2	3	4	5
d. overlap occurs during important life stages	1	2	3	4	5
e. overlap is such that probability of encounter for vulnerable life stages is high	1	2	3	4	5

PLEASE ANSWER THE QUESTIONS IN THIS SECTION YES ____ NO ____

D. PROBLEMS DUE TO IMPINGEMENT OR ENTRAINMENT

30a. The following conditions, if present in the vicinity of the intake structure, are very important in terms of increasing the severity of impingement or entrainment:

	Your Score	Wt.Mean Score	Complete Agreement				No Agreement
a. shoaling fish		1.9	1	2	3	4	5
b. abundant small fish		1.5	1	2	3	4	5
c. ichthyoplankton/zooplankton/phytoplankton		1.9	1	2	3	4	5
d. any organisms that are very active in terms of daily movement		2.6	1	2	3	4	5
e. the volume of cooling water as a percentage of the volume of the waterbody is greater than		10%	.5%	1%	5%	10%	25%

	Your Score	Wt.Mean Score	New Score				
f. more than one plant with an open cooling system is located within a radius of X miles		25	10	25	50	100	200
			anywhere on waterbody				
			cannot generalize				
g. the intake velocity is greater than X ft/sec		1	.1	.25	.5	1	2
			species dependent				
			not a useful criterion				

31. Is reproductive rate important to consider when evaluating the potential for significant population declines following entrainment?	Your Score	Wt.Mean Score	Yes Absolutely			No not at all	
		1.9	1	2	3	4	5
32. Can values for reproductive rates (likely to decrease the potential severity of population declines) be specified?		2.9	1	2	3	4	5

34. The following conditions (in addition to those listed in question 30) were suggested as being important in increasing the likelihood and severity of problems due to impingement or entrainment at thermal power plants. Do you agree that these are important?

	Complete Agreement			No Agreement	
a. targets have preference for being in intake conditions (e.g. thermal optimal)	1	2	3	4	5
b. screen mesh size eliminates or does not eliminate targets in intake area	1	2	3	4	5
c. intake location (e.g. coincident with important habitat space)	1	2	3	4	5
d. intake design (e.g. no potential for egress, return devices, etc)	1	2	3	4	5

e. plant operation coincides with natural catastrophic and/or other anthropogenically induced stresses	1	2	3	4	5
f. intake is difficult to see (shaded area)	1	2	3	4	5
g. local isolation of target near intake	1	2	3	4	5

37. Do you agree that the following conditions, if present, are likely to be important in increasing the probability of long-term problems due to impingement or entrainment? A long- term problem is defined as one that continues for longer than a single generation of the affected target (usually greater than five years):

	Your Score	Wt.Mean Score	New Score				
a. The ratio of cooling water volume/ waterbody volume is greater than X.		.06	.001	.005	.01	.05	.10

	Your Score	Wt.Mean Score	Complete Agreement			No Agreement	
b. Juvenile stages of any fin- or shellfish are found in the intake area in significant numbers (see below)		1.8	1	2	3	4	5
I consider SIGNIFICANT numbers to be X% of the target population:		30%	New Score 5	10	25	50	75%
c. More than one power plant or other industrial facility exists on the water body in question		2.4	1	2	3	4	5

PLEASE ANSWER THE QUESTIONS IN THIS SECTION YES ____ NO ____

E. PROBLEMS DUE TO CHEMICAL OR PHYSICAL ALTERATIONS

39a. The following conditions, if present in the discharge plume area, or downstream from the waste disposal site, are likely to increase the severity of biotic effects observed as a result of changes in water quality:

	Your Score	Wt.Mean Score	Complete Agreement			No Agreement	
a. sessile flora or fauna		1.8	1	2	3	4	5
b. organisms having reduced free mobility (e.g. juvenile fish)		1.8	1	2	3	4	5

c. organisms attracted to the outfall plume area as a result of habitat preference, thermal preference, etc.	2.1	1	2	3	4	5
d. the volume of the discharged water is greater than X percentage of the volume of the waterbody	12%	.5	1	5	10	25%

40. The following conditions were suggested as likely to increase the severity of biotic effects due to changes in water quality. Do you agree that these are important?

	Complete Agreement			No Agreement	
a. targets are immobile	1	2	3	4	5
b. flushing rate of water is discharge area is very low	1	2	3	4	5
c. discharge water mixes poorly (localized concentration)	1	2	3	4	5
d. existing water quality is poor	1	2	3	4	5
e. vertical mixing with bottom contact occurs	1	2	3	4	5
f. bioaccumulation in sediments occurs	1	2	3	4	5
g. biota inhabiting discharge area are already close to tolerance levels	1	2	3	4	5
h. discharge concentrates in preferred depth strata	1	2	3	4	5

44. Information to describe the spatial distribution of either intake plume or outfall plume is limited. Only uniform distributions can be inferred as a first-cut estimate of the volume of the plume envelope. This information, while crude, is useful in evaluating targets likely to be impacted.

Your Score	Wt.Mean Score	Complete Agreement			No Agreement	
	2.3	1	2	3	4	5

45. Fifty percent of Delphi respondents thought that a delta T equal to or greater than 10 degrees C. was indicative of a high probability of biotic problems due to thermal loading. The other 50 percent thought delta T was not a useful diagnostic criterion.

Mark the choice below that corresponds most closely to your opinion on this matter.

	Yes				No
a. Delta T = or > 10 degrees C. is useful	1	2	3	4	5
b. Maximum temperature measures are more useful	1	2	3	4	5
c. Time and space duration of the maximum temperature is more useful	1	2	3	4	5

d. Predictions are dependent on the ambient temperature of the waterbody and the tolerance of the targets being considered 1 2 3 4 5

F. STATISTICAL CHARACTERISTICS OF MONITORING DATA

No questions are being reasked from Section F. The results of this section will be reviewed in the final report which you will receive in October.

PLEASE ANSWER THE NEXT QUESTION REGARDLESS OF WHETHER YOU ANSWERED SECTION G IN QUESTIONNAIRE 2.

G. SAMPLING COSTS FOR MONITORING PROGRAMS

53. The Delphi results show that only about 25% of you consider yourselves experts in analyzing or discussing costs. We would like to know why this is the case.

	Yes				No
a. my job explicitly disallows cost consideration	1	2	3	4	5
b. someone else usually evaluates cost who is this person (title, name)	1	2	3	4	5
c. our budget is not limited	1	2	3	4	5
d. I never thought about it	1	2	3	4	5
e. other (please write in)					

AND FOR THOSE WHO ANSWERED SECTION G IN QUESTIONNAIRE 2...

57. One new question:
What is the cost of replicates for the following types of samples relative to the total cost of an independent sample?
(replicate costs include laboratory processing)

a. X% of the cost for a fish sample	10	25	50	75 %
b. X% of the cost for a benthic invertebrate sample	10	25	50	75 %
c. X% of the cost for a water quality sample	10	25	50	75 %
d. X% of the cost for a plankton sample	10	25	50	75 %

This is the end of Questionnaire 3. Please return it in the enclosed, stamped envelope by JULY 31,1983. You will receive a copy of the results of this Delphi review in early October. We will also send you a follow-up survey at that time.

A second Delphi review will be conducted from October, 1983 through February, 1984 as we proceed with the testing of the methodologies developed during this phase of the research. You will be contacted at that time for further involvement.

Thank you for your time and commitment. We could not accomplish this part of the research effort without the active involvement of experts in the field. We feel that the products of this research and the Delphi input to those products will make a substantial contribution to the design of aquatic monitoring programs to evaluate the effects of thermal electric power plants on aquatic ecosystems.

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Appendix B.6

COMPOSITION OF THE DELPHI PANEL

Table B.6.1. Professional Affiliation of Panel Members

Professional Affiliation	Percent of Members
University	34
National Laboratory	5
Independent Consulting Firms	26
Electric Utility Industry	25
Other Industries (e.g., mining)	0
Federal/State/Municipal Agency	11

Table B.6.2. Geographic Areas in which Panel Members Have Experience

Geographic Areas	Percent with Experience
Northeastern U.S. or Eastern Canada	60
Southeastern U.S.	54
Northcentral U.S. or Central Canada	52
Southcentral U.S.	8
Northwestern U.S. or Western Canada	29
Southwestern U.S.	20

Table B.6.3. Waterbody Types in Which Panel Members Have Experience

Waterbody	Percent with Experience
Coastal Systems	3
Large Rivers	63
Small Rivers and Streams	37
Great Lakes	32
Small lakes, Reservoirs, Cooling Ponds	48
Estuaries	54

Table B.6.4. Professional Expertise (Functional Areas)

Functional Area	Percent having expertise
Toxicity (Chronic Toxicity)	51 (43)
Material (and/or Nutrient) Cycling	32 (38)
Water Quality Problems	71
Population Dynamics	60
Fisheries Management	58
Biostatistics	46
Hydrodynamics (Hydrology)	31 (25)
Pertinent Laws and Regulations	71
Monitoring Program Design	73
Evaluation of Monitoring Programs	75
Design of Cooling Systems	43
Ecological Effects Due to Electrical Generation	82

Table B.6.5 Professional Expertise (Taxonomic Divisions)

Taxonomic Division	Percent having expertise
Finfish	66
Shellfish	35
Benthic Macroinvertebrates	46
Zooplankton	42
Phytoplankton	26
Periphyton	11
Macroalgae/Macrophytes	14
Microbes	5

APPENDIX C

DEVELOPMENT AND EXAMPLE OF EPAM

C.1 A Conceptual Framework To Guide Aquatic Monitoring Program Design For Thermal Electric Power Plants

C.2 EPAM Files

C.3 Example Use Of EPAM

Appendix C.1

A Conceptual Framework to Guide Aquatic Monitoring Program Design for Thermal Electric Power Plants

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ABSTRACT

Thermal electric generating stations have a high potential to alter the biotic and abiotic conditions in adjacent water bodies. Federal regulations require electrical utilities to monitor for such changes as insurance against deterioration of aquatic ecosystems. The cost of many monitoring efforts could be reduced by more precise applications of the scientific method (hypothesis testing), improved statistical design, and a focus on measures of cost-effectiveness. A multidisciplinary team of scientists and engineers from the University of Washington has developed such a conceptual framework to guide the design of power plant aquatic monitoring programs. This framework is organized into four hierarchical levels to accommodate the quality of information the potential users might possess. Algorithms within the hierarchy help the monitoring program designer identify and prioritize impact agents, ecosystem components that might demonstrate a response, hypotheses of impact, and an appropriate sampling design for hypothesis testing. The entire framework has been programmed for interactive computer application.

KEY WORDS: aquatic ecosystems, cooling water, electric power generation, entrainment, hypothesis testing, impact assessment, impingement, model, monitoring, water quality.

INTRODUCTION

The operation of thermal electric generating stations requires the withdrawal and subsequent discharge of large volumes of cooling water from natural or manmade water bodies. Fuel and waste handling create additional interactions with aquatic systems. All of these functions have a potential to alter the biotic and abiotic conditions in the affected water bodies. Effects may include impingement and entrainment of pelagic organisms by cooling water intakes, changes in water quality, and modification of habitats for aquatic biota. Water quality may be affected by release of heated effluent, biofouling control agents, and various other constituents from point and area sources of contamination within the plant, potentially exceeding thermal or toxicant tolerances of receptor organisms. Power plant operations can affect habitats through alteration of currents, disturbance of the sediments, and increasing turbidity and siltation.

During the past 20 years considerable attention has been given to monitoring in attempts to discover whether aquatic ecological change was being caused by the operation of electric power plants. These efforts were given impetus by the National Environmental Policy Act of 1969, various provisions of the 1977 amendments to the Clean Water Act and its predecessor legislation, state energy facility siting commissions, and other state actions. However, results often have been unsatisfactory because of a lack of clear objectives and consequent unfocused monitoring programs. Many of these programs have been very broad in coverage but of insufficient depth to discern change in key components of the ecosystem. Despite their frequent high cost, they have been generally ineffective in determining any connection between ecological change and power plant operations (Sharma, 1978; Rago et al., 1983).

In an effort to alleviate some of these problems, the Electric Power Research Institute commissioned a research project to develop methods to improve the monitoring program design process and the resulting data and its interpretation. The research is being conducted by the Environmental Engineering and Science Program of the Department of Civil Engineering at the University of Washington, with participation by the university's Fisheries Research Institute and Center for Quantitative Sciences. It is a three-year effort involving environmental engineers, ecologists, systems analysts, fisheries biologists, and statisticians at the University of Washington

working in conjunction with personnel in the electric utility industry and their consultants, regulators, and a nationwide expert panel.

The general objectives of the research effort are:

1. To develop a comprehensive conceptual framework for guiding aquatic monitoring program design

2. To give specific consideration to certain statistical aspects which have limited the success of monitoring programs

3. To develop methods for evaluating monitoring cost-effectiveness

This paper will emphasize initial results of applying the first objective. Specifically, the paper describes a model for Electric Power Aquatic Monitoring (EPAM) which has been developed to guide a user in the design of a scientifically valid monitoring program. EPAM also incorporates statistical design and optimization concepts arising from research undertaken to fulfill the second and third objectives.

BASIS OF THE MODEL FOR ELECTRIC POWER AQUATIC MONITORING

PRIOR WORK

The EPAM approach has its roots in the classical scientific method of inductive inference. As set forth theoretically by Platt (1964), this method attempts to strengthen the inferences drawn by applying the inductive procedure systematically to devise hypotheses and experiments to test them.

Several previous investigators have endeavored to simplify the process of determining what to measure in a monitoring program by providing a set of guidelines. These guidelines use data to identify components of an ecosystem likely to be impacted by a proposed development. Other investigators have specified that particular organisms or biotic components be included in the study regardless of the site-specific conditions. Such mandates have usually been based upon ecological perceptions or the socioeconomic value of the

identified components. In general, the criteria for determining what to measure in a monitoring program have been as follows:

1. All biotic components of the ecosystem because of their high degree of interdependence and interaction (Meyer and Bremer, 1975).
2. Species determined to have critical importance based on one or more of the following:
   a. commercial or recreational value.
   b. rare or endangered classification.
   c. relevance to the well-being of a species in a or b above.
   d. importance to the structure or function of the ecosystem (Munn, 1975; U.S. Nuclear Regulatory Commission, 1976; U.S. Environmental Protection Agency, 1977a, b).

3. Species designated by legislative mandate (Tetra Tech, 1981).

4. Species likely to be impacted, based on the interaction in time and space with the characteristics of the plant (Munn, 1975; Fritz et al., 1980; Rago et al., 1983).

5. A combination of the above with consideration given to the existence and feasibility of reliable measurement techniques (States et al., 1978).

6. A combination of the above plus some consideration for the expected magnitude of the effect and the time scale of recovery. For example, a long term effect on a commercial fishery would cause much greater concern (and hence, should be quantified more exactly) than a short-term effect, even if the same fishery were affected (States et al., 1978).

This last criterion formed the basis for a portion of the EPAM framework. That is, the designation of the subjects of a monitoring scheme (outside of legal mandate) would be based primarily upon three issues: (1) the expected impacts of plant operation, (2) the extent to which the temporal and spatial distribution of these impacts overlap with the measured distribution of the

susceptible organisms, and (3) the sensitivity of the target to the impact. The necessity to measure a given component will vary with the importance of the role that organism or biotic component (i.e. target) plays in the ecosystem, and in the socioeconomic sphere of the area. Large overlap of the distribution of an economically unimportant and highly redundant organism (in terms of function) with the field of influence of the intake structure of a large power plant might not justify the expense and complications of a major monitoring program. However, the partial overlap of a commercial species of critical importance with the same intake structure might justify an extensive program (e.g., an overlap extending only for two months a year during the period of migration of young fry). Thus, the nature of a given program becomes a function of the role that the interacting components play both in the ecosystem and in the political, socioeconomic, and legal spheres.

Other researchers also have considered the definition of hypotheses of effects on monitoring program subjects, as well as the design of experiments to test hypotheses. States et al. (1978) noted that the responses of ecosystem components to impact agents may or may not be linked in the context of formal hypotheses of impact. Holling (1978) and Fritz et al. (1980) generally adhered to the hypothesis-based design concept, and advocated developing it through the assembly of a multidisciplinary panel of specialists having familarity with the site to be monitored. Proctor et al. (1980) also favored basing monitoring efforts on a hypothesis foundation. Rago et al. (1983) declared their belief that the logical process of monitoring program design can be standardized, although specific elements of a given program should be selected by investigators at the site. They recommended proceeding by developing a conceptual model of the aquatic system in question, leading to identification of hypotheses for testing.

Jeffers (1978) and Green (1979) treated experimental design and data analysis and management in detail in a response to the difficulties of testing formal hypotheses with field data, and of providing statistical inference to impact. Green (1979), particularly, emphasized the selection of response variables that can be measured to evaluate the potential impacts and provided extensive guidance in this area. Comiskey and Brandt (1982) also were concerned with the need to identify appropriate data analysis techniques, including, in some cases, data management systems.

A major shortcoming of the existing guides to monitoring design was their

dependence on in-house expertise. The resulting assumption was that these experts would be available and would be able to make a wide variety of value judgments about diverse subjects, such as the nature of functional linkages between two different trophic groups and the appropriateness of a particular variable or statistical or optimization technique. In practice, in-house expertise rarely covers the complete range of these needed skills. Even when extensive catalogs of elements to consider and open-ended sample impact matrices are presented (States et al., 1978), development of a viable set of hypotheses and appropriate test variables becomes an artful process at best. When little guidance information is presented, as, for example, in the selection of representative important species (RIS) advocated by the U.S. Environmental Protection Agency (1977 a, b), the process can be very cumbersome.

A further shortcoming existed in the complexity of the presentation format of many of the existing approaches. With the exception of the lists prepared by Jeffers (1978) and Comiskey and Brandt's (1982) efforts, the guides cited have used textual and diagrammatic formats that are cumbersome or confusing to use. There is frequently no obvious point of initiation, nor any means of transition between parts of the framework. Other shortcomings included: a lack of criteria to make decisions, a focus on short-term impacts, a lack of concern for cost-effectiveness, and a lack of consideration of alternative but attractive methods. An additional major drawback is that the utility of previous guides has not been demonstrated through application in actual case studies. As a result, most of these guides have not been implemented by aquatic monitoring program designers.

THE USE OF THE DELPHI TECHNIQUE IN EPAM DEVELOPMENT

Two additional problems that arose during development of the conceptual framework necessitated incorporation of an innovative methodology, the Delphi technique (Linstone and Turoff, 1975). These two problems were:

1. The need to consider a wide range of specialties (e.g. statistics, hydrodynamics, fisheries biology, toxicology, etc.) in the framework.

2. The need to address scientific issues for which no consensus opinion or clear-cut objective criteria exist.

The Delphi technique has been used successfully to solve similar problems in the field of technological forecasting and in the evaluation of educational issues, socio-cultural questions, and environmental management options (Bakus et al., 1982). The technique utilizes a panel of experts to consider and develop a consensus opinion about issues of uncertainty.

The Delphi methodology was used in the current project to access the opinions of diverse experts for validation of the general framework and for assistance in the development of certain areas of the framework for which no widely accepted criteria existed. In particular, the Delphi panel assisted in identifying conditions having a high potential to cause long-term ecological change, and in verifying that the various criteria considered in the framework had scientific and socioeconomic validity (see below). Details of the panel composition and specific results are presented elsewhere (Mar et al., 1983).

DESCRIPTION OF THE MODEL FOR ELECTRIC POWER AQUATIC MONITORING

GENERAL EPAM FRAMEWORK

The conceptual framework devised by the University of Washington team guides a user (i.e. one who must design a monitoring program to evaluate the existence, or lack, of ecological change at a thermal electric power plant) through a logical sequence of program design steps, regardless of the extent of previous data available for the specific site and regardless of the extent to which a monitoring program, or subsections thereof, may already exist for the site. Consequently, the framework, which takes the form of an interactive (computer) model is organized in a hierarchy. Each of the four levels of the hierarchy assumes an increasing amount of knowledge on the part of the user and emphasizes specific program outputs. A given user may enter only the lowest level if a preliminary monitoring program already exists for his or her site, or, alternatively, may need to enter all four levels in sequence if minimal previous work exists.

The EPAM framework is currently being evaluated through the use of case studies. While some details of model structure may change, the conceptual basis of the general model and its specific outputs have received support from the Delphi panel (Mar et al., 1983) and previous studies (States et al., 1978; Green, 1979; Rago et al., 1983).

The four levels of the EPAM hierarchy are illustrated in Figure 1. The outputs from each level are designated in this figure and correspond to the four basic functions of the model:

LEVEL 3. The development of a list of impact agents (i.e. those elements of power plant design or operation that have a high likelihood of inducing ecological change) and associated monitoring program targets (i.e. ecosystem components, including such elements as individual species, community indicators, and chemical parameters) that have potential to be changed.

LEVEL 2. The development of a list of hypotheses of impact which will serve to guide the structure of the monitoring program; it is assumed that a monitoring program typically will include one or more hypotheses of impact.

LEVEL 1. The development of the actual sampling program for testing each of the hypotheses that is incorporated into the monitoring program. The sampling program includes the designation of formal primary and alternative hypotheses, sampling stations, frequencies, replicates and statistical tests.

LEVEL 0. An optimization routine which balances the trade-off between cost and increased accuracy in the monitoring program.

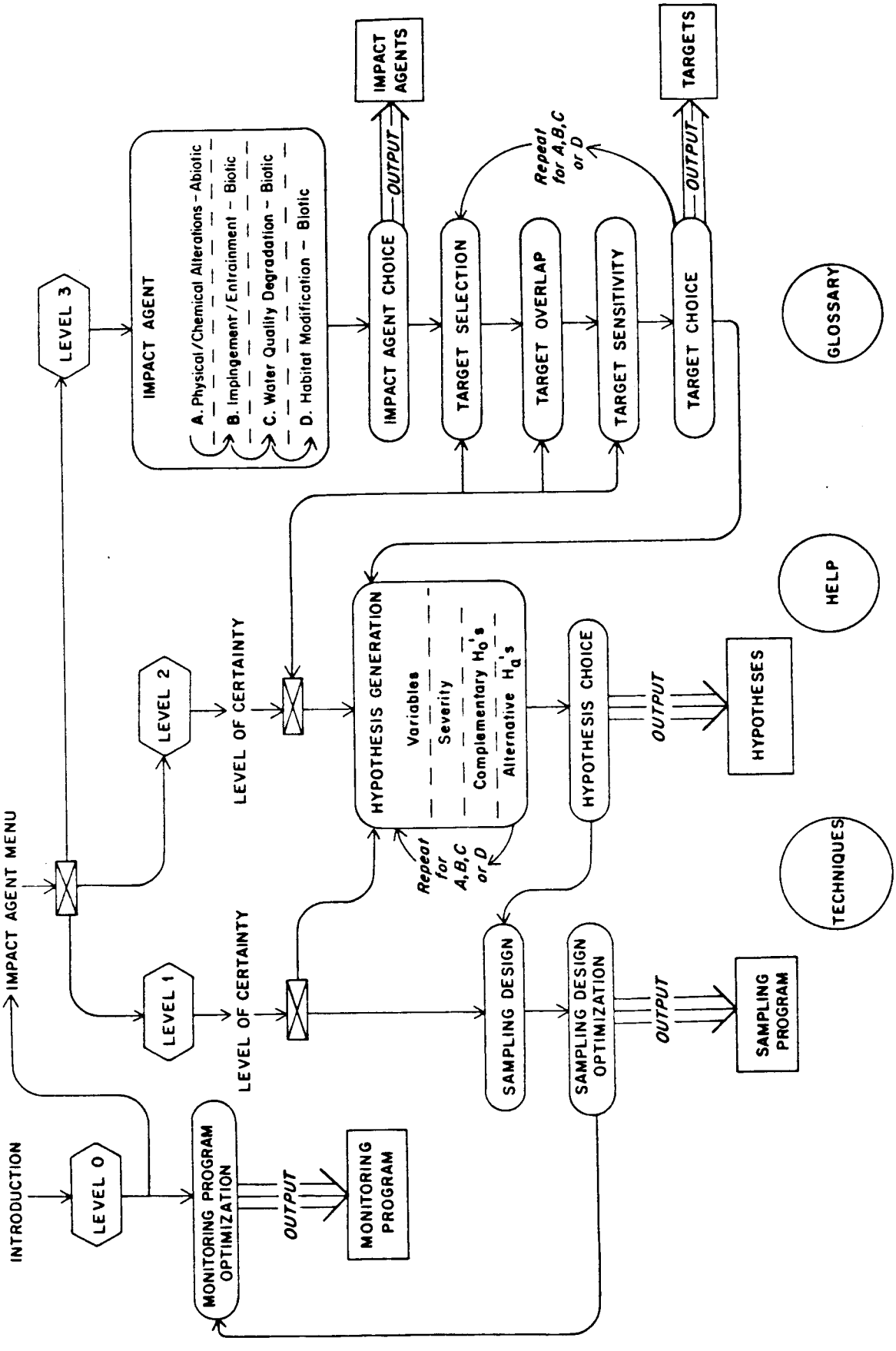

Figure 1.1 Coverage of EPAM Components in Delphi Questionnaires

Each level of EPAM is structured into subroutines which ask a user to insert, or develop and then insert, information pertinent to the aspect of monitoring program design under consideration. A user's path through EPAM depends upon the answers given to questions posed at decision points, an organization a systems analyst would recognize as a decision tree and a biologist would consider analogous to a dichotomous key. EPAM is an interactive computer model programmed in FORTRAN 77 and initially operational on a Digital Equipment Corporation VAX/VMS system.

In the case where little or no previous monitoring program design has occurred, the user would be directed to LEVEL 3, which serves the purposes of identifying and prioritizing agents that could impact the aquatic ecosystem and their associated monitoring program targets. After defining these aspects of the program, the user proceeds to LEVEL 2, which helps the user formulate general hypotheses of impact for the selected targets and choose the variables to measure target response. After prioritization of the general hypotheses, the user proceeds to LEVEL 1 which assists in the design of sampling schemes for testing each formal hypothesis that is retained. LEVEL 1 is a package, resulting from the statistical research, for selecting sampling program attributes according to maximum statistical power for a given cost or minimum cost for given power. In LEVEL 0, the user exercises a final optimization routine, in which the various sampling efforts are allocated to produce an overall monitoring program design according to cost-effectiveness criteria. Beyond the four levels of EPAM, several auxiliary subroutines exist outside the level format and may be called at the user's option (see Figure 1).

At each level the user develops an initial list for the designated outputs and assigns a relative confidence score to each element on the list. The confidence score corresponds to the degree of certainty that the user has in the data on which his choice of that element is based. In addition, the user assigns a cost to each element on the list. This cost represents the amount of money necessary to improve the data base for a given element so that the confidence score is increased (by one or more units).

Suppose, for example, a given species of fish is included on the target list, although no data exist, in order to verify its distribution at the site. Its confidence score is low. Its cost score represents the amount of money necessary to perform a pilot study to determine its distribution. If that particular species becomes an important element in the monitoring program, the

user can choose whether or not to invest in a pilot study. If, however, the designated species is determined to be unimportant as a result of subsequent decisions, no money will be spent on the pilot study. Thus, the advantages of assigning cost and confidence scores are to prevent the unnecessary expenditure of monies on pilot programs and to ensure that the retention of any element in the final monitoring program is based upon data in which the user has confidence. The user proceeds through all chosen levels "on paper". Decisions to spend money on a pilot program, or other preliminary sampling, are made only when the element at issue has been shown to have value for the whole monitoring program.

A key feature of EPAM is the CHOICE subroutine, which is invoked in LEVELS 2 and 3 to prioritize the initial lists of impact agents, targets, and hypotheses, as well as in the LEVEL 0 optimization. The purpose of CHOICE is to evaluate alternatives according to designated criteria and assigned weights which represent objective information or, when necessary, subjective judgments. CHOICE was based on a mathematical solution to an eigenvalue problem developed by Saaty (1977) for ranking a set of alternatives depending upon their relative abilities to meet specified goals. Exercising CHOICE requires the user to make a series of quantitative comparisons between pairs of alternatives for each criterion, as well as pairwise comparisons representing the relative weights of the criteria. Output includes the alternative ranks and a measure reflecting the user's consistency in making the pairwise comparisons. The approach, unlike many others in the multiobjective literature, emphasizes the incorporation of human judgment in the decision-making process and the quantification of inconsistencies or uncertainties when they exist. Mar et al. (1983) have presented further detail on the basis for CHOICE and its application.

The remainder of this paper will explore LEVELS 2 and 3 in detail. LEVELS 0 and 1 are beyond the scope of this presentation.

LEVEL 3: IMPACT AGENT AND TARGET IDENTIFICATION

LEVEL 3 is designed for users who lack sufficient knowledge of conditions at the site in question to determine impact agents and potential targets without assistance. Its six subroutines are:

1. IMPACT AGENT - This initial LEVEL 3 component is a series of prompts instructing the user to consider four major categories of impacts associated with electric power plants.

2. IMPACT AGENT CHOICE - This mechanism is employed to prioritize the specific impact agents in the four categories.

3. TARGET SELECTION - This subroutine initiates the process of identifying targets that may respond to the impact agent(s) in operation. It provides a format for tabulating attributes of the targets (the Target Table) and begins the process of ordering them with respect to ecological and socioeconomic value.

4. TARGET OVERLAP - A structure is presented to aid the user in characterizing the spatial and temporal distributions of the targets and establishing their overlap with the impact agent distributions. The results of the overlap analysis are inserted in the Target Table.

5. TARGET SENSITIVITY - This subroutine guides the user in rating the vulnerability of the targets to the respective impact agents. The Target Table is completed when the user inserts the findings of these analyses.

6. TARGET CHOICE - This procedure is employed to prioritize targets for each impact agent with respect to criteria drawn directly from the Target Table.

The objective of LEVEL 3 is to offer a general structure for analyzing the primary elements underlying program design, not to create a generic basis for monitoring programs irrespective of site differences. Considerable opportunity exists for the user to incorporate local factors and exercise judgment. Thus, it is not intended to reduce the role of the utility or consultant experts who have traditionally designed aquatic monitoring programs but to provide them with a logical framework for documenting the key aspects of the relationship between impact agents and targets at a particular site. Beyond this concern, LEVEL 3 offers a demonstrated means of prioritizing

alternatives through the CHOICE subroutine and documenting the detail of available data through the cost and confidence scores.

Upon entering LEVEL 3, the user first exercises IMPACT AGENT and IMPACT AGENT CHOICE to characterize, prioritize, and select the agents to be investigated. The need to define the agents of impact is fundamental in some sense to all of the previous attempts at systematizing monitoring program design and was confronted most directly by States et al. (1978), Fritz et al. (1980) and Rago et al. (1983). Delphi results strongly concurred with the basic importance of a specific impact agent definition (Mar et al., 1983).

IMPACT AGENT places the potential impacts in one of four groups:

Physical/Chemical Alterations (Abiotic Effects).
Impingement/Entrainment (Biotic Effects).
Water Quality Degradation (Biotic Effects).
Habitat Modification (Biotic Effects).

The first category represents the ability of an impact mechanism to affect the physical or chemical attributes of the aquatic environment while the latter three include agents which have potential to create a biological response. Some agents (e.g., discharge of a heavy metal) have the potential to affect both water chemistry (in terms of the metal concentration) and the biota (e.g., increased mortality due to metal toxicity or bioaccumulation). EPAM directs the user to list the impact agents in each category in specific terms and, through an extended menu, provides guidance to assist the user in doing so. Once a full list of specific agents is available, the user proceeds to IMPACT AGENT CHOICE to prioritize them with respect to three criteria, spatial extent, frequency or duration, and expected intensity, and to select those impact agents to carry through the remaining analysis. As described above, cost and confidence scores are recorded for the data used in these analyses. These scores are considered in the hypothesis selection subroutine (LEVEL 2), when EPAM provides an indication of where application of additional resources would effect most improvement in the monitoring program design.

TARGET SELECTION assists the user in creating an initial list of targets for each of the chosen impact agents. The user constructs this list by considering those ecosystem components that may be affected by the agent and which have a distinct ecological or economic value, or otherwise are of public

interest. These general bases for target selection agree with those proposed by Munn (1975', the U.S. Nuclear Regulatory Commission (1976), and the U.S. Environmental Protection Agency (1977a, b). The Delphi review devoted considerable attention to this question, and the formulation of this subroutine came from its consensus (Mar et al., 1983).

TARGET SELECTION also provides an arrangement for tabulating these targets and their attributes, a form referred to as the Target Table. After directing the listing of targets, the subroutine guides the user in rating the value of each target relative to various criteria. Three example criteria include: (1) Public interest due to legal or regulatory designation (e.g., rare or endangered species) or, simply, to local recognition or a tradition of monitoring; (2) economic value in either commercial or recreational markets; and (3) ecological value, including dominant food producers or food sources, consumers, and habitat-formers. A value index for later consideration in TARGET CHOICE results from the total of the assigned scores for all criteria.

The method applied in TARGET OVERLAP seeks to overlay the impact agent and target distributions to reveal the potential degree of interaction or overlap, and thereby guide final target selection and hypothesis development. The issue and the proposed approach were reviewed by the Delphi panel (Mar et al., 1983). TARGET OVERLAP involves two separate but related considerations:

Relative Geographic Overlap - the ratio of the volume of the impact field to the total habitat volume of the target.

Relative Density Fluctuation - the proportion of time a given target spends in the impact agent envelope.

The first consideration has most importance in the case of targets with very restricted ranges. The second, which defines the variability of overlap, permits the incorporation of target moblity in the analysis, i.e., diel or seasonal movements into and away from the impact agent field. Both of these overlap elements are ranked and considered as CHOICE criteria in the Target Table.

The TARGET SENSITIVITY subroutine provides a framework for quantifying a target's susceptibility to change. It has its roots in the approach presented by States et al. (1978). Delphi panel deliberations helped to formulate the

TARGET SENSITIVITY subroutine (Mar et al., 1983). The subroutine relies on the scientific literature and relevant past monitoring records, where available, to quantify vulnerability. The type of data employed depends on the specific impact agent (e.g., tolerance data in the case of toxicants, impingement records at an existing similar power plant). All targets are ranked with respect to sensitivity and the ranks are entered in the Target Table.

All elements (scores and ranks) in the Target Table are used as criteria in the TARGET CHOICE prioritization. The output from exercising TARGET CHOICE is a set of prioritized lists of targets for each specific impact agent. The user completing the analysis at this level is routed to LEVEL 2 to develop hypotheses for testing target response. Cost and confidence scores for the data used in the various LEVEL 3 subroutines are recorded for consideration in the development and final selection of hypotheses in LEVEL 2.

LEVEL 2: HYPOTHESIS DEVELOPMENT

LEVEL 2 of EPAM provides the framework to determine specifically what to test in an aquatic monitoring program design in order to demonstrate whether environmental changes resulting from the construction and operation of an electric power generating facility are acceptable. The framework proposed by States et al. (1978), reviewed earlier, was used as a point of departure to develop LEVEL 2.

The purpose of LEVEL 2 is to formulate clearly stated objectives or general hypotheses and to translate these objectives into precise questions and, subsequently, measurements which can answer these questions. The structure of LEVEL 2 parallels that of LEVEL 3: the user develops an initial list of general hypotheses and uses the CHOICE subroutine to prioritize these hypotheses on the basis of established criteria. A user entering this level must demonstrate that the impact agents and targets of interest are known; otherwise, the user is routed to LEVEL 3 to develop these data.

LEVEL 2 guides the user of EPAM through a three-step process:

1. LEVEL OF CERTAINTY MENUS - A series of questions is arranged in several menus to check whether the user has enough information to

complete this level of analysis.

2. HYPOTHESIS GENERATION - A series of questions and prompts are provided to assist the user in developing statements expressing hypotheses of impact and certain aspects of the program under which they will be tested.

3. HYPOTHESIS CHOICE - The CHOICE subroutine is used, in this case to rank the list of hypotheses.

Prior work and the Delphi results support the fundamental direction of LEVEL 2, the development of explicitly stated hypotheses of impact which will be submitted to objective evaluation. As discussed previously, Platt (1964) provided a general theoretical basis for the approach; furthermore States et al. (1978), Fritz et al. (1980), Proctor et al. (1980), Comiskey and Brandt (1982) and Rago et al. (1983) all recognized the central role of hypothesis testing in investigating ecological change. Members of the Delphi panel expressed substantial dissatisfaction with the establishment of goals and objectives for past monitoring efforts and agreed that monitoring programs should be founded on quantifiable and scientifically valid hypotheses (Mar et al., 1983). States et al. (1978) advocated a selection process to arrive at those hypotheses which actually should be evaluated, a point which the Delphi results supported (Mar et al., 1983).

HYPOTHESIS GENERATION assists the user in developing an initial list of quantitative, testable hypotheses of impact for the monitoring program based on information developed in LEVEL 3 on impact agents and targets. Each hypothesis is defined by the following elements:

1. The potential impact agent.

2. The target potentially affected by the impact agent.

3. The spatial distribution of the potential effect.

4. The temporal distribution of the potential effect.

5. The type, cost, and accuracy of the variable(s) necessary to measure the potential effect.

6. The complementary hypothesis, if any (a complementary hypothesis is defined to be a hypothesized change that occurs as an indirect result of another hypothesis, e.g., impingement mortality may cause a decline in population size of a planktivorous finfish species; this decline may, in turn, result in an increase in the size of the zooplankton population due to reduced predation).

7. The potential for falsification of the hypothesis as a result of alternative explanations for the potential effect; e.g., a commercial fishery may be responsible for the decline in population size of a finfish species, instead of mortality caused by impingement.

These proposed attributes of a hypothesis were presented to the Delphi panel for review. A general consensus developed on the advisability of incorporating these elements, although inclusion of the spatial and temporal distributions received less support than the others (Mar et al., 1983).

A major subsection of HYPOTHESIS GENERATION is VARIABLES, which provides a means of organizing the selection of a variable to employ in hypothesis testing. This subsection lists choices appropriate to aquatic monitoring of targets in the various ecological groups (finfish, shellfisn, phytoplankton, etc.) subject to direct and indirect effects at the individual, population, or community levels. Actual selection of a variable from the list is left to the user and presupposes knowledge of the capabilities of the gear to be employed in measurement. Gear capability also is an important determinant of the statistical procedure to be used eventually in analyzing data. Because this subject is outside the scope of the present research and is poorly documented in the literature, advice on the final selection of sampling gear is limited to broad considerations of cost and statistical accuracy.

Another major subsection of HYPOTHESIS GENERATION identifies alternative hypotheses. Platt (1964) cited the failure to specify and test alternative hypotheses as the major impediment to progress in resource management fields. This concern is based most fundamentally on Holling's (1978) concept of the falsification routine. The definition of alternative hypothesis is the one

proposed by Rago et al. (1983), i.e. the connotation is a testable hypothesis referring to a different mechanism, rather than the antithesis of the null hypothesis. The Delphi panel concurred that investigation of alternative explanations for observed change is crucial to understanding the dynamics of the ecosystem (Mar et al., 1983). The subroutine provides an extensive list, adapted from Munn (1975), of natural conditions and human activities extraneous to the power plant which could obscure the power plant effect and lead to either a Type 1 or Type 2 error. EPAM directs the user to formulate statements of alternative hypotheses in terms similar to the primary hypotheses of impact.

The now generally accepted position that not all ecosystem components should be represented in monitoring programs necessitates prioritizing hypotheses for selection of the most important ones. HYPOTHESIS CHOICE is the mechanism for performing this ranking. Several appropriate ranking criteria were suggested by States et al. (1978), including the relative magnitude of the effect, potential for recovery from the effect, and the reliability of available measuring techniques. The Delphi panel rated cost, error, and the availability of good measuring techniques as important criteria and concluded that the latter was the most important of the three. The panel also agreed that alternative hypotheses are a reasonable basis on which to judge primary hypotheses (Mar et al., 1983). More specifically, a primary hypothesis having few alternative explanations, or few with a high probability of occurring, would be easier to test than one having a number of potentially confounding explanations.

These criteria are used in the HYPOTHESIS CHOICE subroutine, along with a criterion that considers the potential for long-term or cumulative change or both. Long-term effects are regarded as those that continue to exist for a period equal to, or greater than, power plant life. Cumulative effects are those resulting from a concentration of the particular impact agents in question on the water body. Conditions likely to produce such effects are being reviewed by the Delphi panel and will be reported upon at a later time. The output of LEVEL 2 is a prioritized set of hypotheses composed of the elements listed under the conceptual statement for HYPOTHESIS GENERATION above. Upon completing this level, the user is directed to LEVEL 1 to consider the design of sampling programs and finally to LEVEL 0 for optimization of the resulting monitoring program.

CONCLUSIONS

The complexity of aquatic monitoring program design for electric power plant impact assessment makes development of a comprehensive framework a challenging task. Previous efforts have made notable progress in this direction, but have not been fully successful. In this research, an algorithmic framework, termed the model for Electric Power Aquatic Monitoring (EPAM), has been developed to provide a comprehensive set of guidelines to assist aquatic monitoring program design. EPAM moves beyond previous formats in several important respects:

1. Through the Delphi process, expert judgment is incorporated with greater efficiency than was true of its predecessors.

2. EPAM represents a hierarchical framework aimed at monitoring program designers having different levels of knowledge about the system under consideration. This approach is well-suited to interactive computer manipulation; therefore the EPAM framework and many of the special purpose algorithms have been programmed for this application.

3. EPAM presents specific algorithms to aid the monitoring program designer in identifying and prioritizing impact agents, targets, and hypotheses of impact, in designing sampling schemes, and in optimizing the cost-effectiveness of the final monitoring program.

The research effort is now being directed at evaluating EPAM through the use of several case histories drawn from the aquatic monitoring experience. After evaluation employing these actual data, EPAM will be refined as necessary for comprehensiveness and utility. This case study review is considered to be of crucial importance in developing a conceptual framework that will be useful to the electric utility industry and the aquatic monitoring community.

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Appendix C.2

EPAM FILES

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WELCOME TO THE UNIVERSITY OF WASHINGTON ELECTRIC POWER RESEARCH INSTITUTE MODEL OF AQUATIC MONITORING PROGRAM DESIGN. THIS MODEL, EPAM (ELECTRIC POWER AQUATIC MONITORING), WILL HELP YOU TO DESIGN A COST -EFFECTIVE AND SCIENTIFICALLY VALID MONITORING PROGRAM TO EVALUATE THE EXISTENCE, OR LACK THEREOF, OF ECOLOGICAL CHANGE IN AN AQUATIC EXOSYSTEM DUE TO ELECTRICAL POWER GENERATION AT THERMAL POWER PLANTS.

EPAM OPERATES BY DEFINING HYPOTHESES OF IMPACT THAT CAN BE TESTED TO DETERMINE THE EXISTENCE AND EXTENT OF ECOLOGICAL CHANGE AT A GIVEN SITE. THESE HYPOTHESES OF IMPACT ARE DEFINED WITHIN FOUR EFFECTS CATEGORIES THAT CORRESPOND TO THE DOMINANT PROBLEM AREAS THAT HAVE BEEN FOUND TO EXIST AT THERMAL POWER PLANTS. WITHIN EPAM THESE AREAS ARE KNOWN AS IMPACT AGENTS:

A. Physical or Chemical Alterations (Abiotic Effects)
B. Impingement/Entrainment (Biotic Effects)
C. Water Quality Degradation (Biotic Effects\
D. Habitat Modification (Biotic Effects\

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EPAM OPERATES AT FOUR HIERARCHICAL LEVELS WITHIN THE DIFFERENT EFFECTS CATEGORIES. A USER CHOOSES AN INITIAL LEVEL ON THE BASIS OF THE CURRENT STATUS OF KNOWLEDGE AT THE PARTICULAR SITE. HE/SHE IS THEN ROUTED THROUGH EACH HIGHER LEVEL UNTIL A COMPLETE MONITORING PROGRAM HAS BEEN DEVELOPED. THE FOUR LEVELS, THEIR ASSUMPTIONS AND GOALS ARE:

EPAM-0: ASSUMES THE EXISTENCE OF A FUNCTIONING MONITORING PROGRAM; EPAM-0 INCREASES THE COST-EFFECTIVENESS OF THE EXISTNG PROGRAM.

EPAM-1: ASSUMES PRIOR KNOWLEDGE OF AN IMPACT AGENT AND THE TARGETS TO BE TESTED (I.E., THE HYPOTHESES OF IMPACT), BUT NO KNOWLEDGE OF APPROPRIATE TESTING PROCEDURES. EPAM-1 IDENTIFIES A SAMPLING DESIGN AND ANALYTICAL TECHNIQUES FOR TESTING THE HYPOTHESES.

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EPAM-2: ASSUMES PRIOR KNOWLEDGE OF THE IMPACT AGENT AND A GENERAL IDEA OF AN APPROPRIAE TARGET, BUT NO HYPOTHESES OF IMPACT.
EPAM-2 IDENTIFIES APPROPRIATE HYPOTHESES OF IMPACT AND HELPS THE USER SELECT THOSE WHICH WOULD BE MOST EFFECTIVE IN A MONITORING PROGRAM.

EPAM-3: ASSUMES NO OR MINIMAL PRIOR KNOWLEDGE OF THE IMPACT AGENTS, APPROPRIATE TARGETS OR LIKELY EFFECTS AT THE SITE. EPAM-3 IDENTIFIES THE INTERACTION (IF ANY) BETWEEN PLANT CHARCTERISTICS AND ECOLOGICAL COMPONENTS IN ORDER THAT HYPOTHESES CAN BE DEVELOPED.

EPAM HAS SEVERAL FEATURES WHICH MAKE IT EASY TO USE AND VERY ADAPTABLE TO DIFFERENT TYPES OF PLANTS, ENVIRONMENTS, AND BUDGETS.

THE BASIC STRUCTURE OF EPAM CONSISTS OF A SERIES OF YES/NO QUESTIONS. AN AFFIRMATIVE ANSWER WILL ROUTE THE USER TO THE NEXT PROBLEM AREA. A NEGATIVE ANSWER WILL ROUTE THE USER TO A SUB-ROUTINE WHICH GUIDES THE USER IN GENERATING THE ANSWER BEING SOUGHT. THE BASIC SUBROUTINE PACKAGE FOR PROVIDING THIS GUIDANCE IS TERMED TECHNIQUES. THE FIRST STEP IN TECHNIQUES PRESENTS A MATRIX DISPLAY OF THE DIFFERENT OPTIONS AVAILABLE FOR COLLECTING THE NECESSARY INFORMATION. EACH OPTION IS IDENTIFIED BY A COST COMPONENT AND AN ERROR COMPONENT. THUS A USER CAN CHOOSE TO DEVELOP HIS ANSWER IN AS GREAT OR AS LITTLE DETAIL AS IS DESIRED. THE COSTS INCURRED IN THE SUBROUTINES ARE ADDED INTO THE TOTAL PROGRAM COST AND CONSIDERED AS PART OF THE TOTAL PROGRAM OPTIMIZATION (EPAM-0). THE ERRORS ARE EVALUATED ON A RELATIVE SCALE, AND RECONSIDERED DURING THE HYPOTHESIS GENERATION SUBROUTINE IN TERMS OF THEIR BEARING ON THE PROGRAM AS A WHOLE.

WITH THE EXCEPTION OF EPAM-3, WHERE SOME PRELIMINARY DATA COLLECTION IS MANDATED FOR INITIAL IDENTIFICATION OF THE MONITORING PROGRAM "ON PAPER". THUS THE STRENGTHS AND WEAKNESSES AND THE COSTS CAN BE ASSESSED BEFORE A GREAT DEAL OF EFFORT OR MONEY IS EXPENDED.

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Some simple guidelines for using EPAM follow. They can be accessed at any time by typing HELP and pressing RETURN.

1. Type MAP to access a flow diagram of EPAM structure.

2. Type EXIT to get out of EPAM at any point in the program.

3. Type GLOSSARY to obtain a glossary of terms used in EPAM.

You are now ready to start the program.

GOOD LUCK.

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<                                                                            >>
<    Welcome to EPAM, a model for Electric Power Aquatic Monitoring.         >>
<                                                                            >>
<      You are in LEVEL 0.                                                   >>
<                                                                            >>
<      You must first decide if this level is the correct one for you.       >>
<      If so you will be given the opportunity to optimize your              >>
<      monitoring program design. If not you will be given instructions      >>
<      to place you in the proper level. Throughout EPAM, type the           >>
<      appropriate letter(s) from the given choices, and press RETURN        >>
<      to indicate your answer to a given question.                          >>
<                                                                            >>
<    0.1  Do you want to develop or optimize a monitoring program?           >>
<                                                                            >>
<          Y-yes  (develop a program (go to 0.2)                             >>
<          N-no   (optimize an existing program, i.e. cost-effectively       >>
<                 allocate the sampling effort; go to OPTIMIZATION)          >>
<                                                                            >>
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<                                                                            >>
<                                                                            >>
<    0.2 Do you have a good idea of the potential agents that may            >>
<        create impacts that exist at this site or do you need help          >>
<        in initial definition of the problems?                              >>
<                                                                            >>
<          N-no   (impact agents are known; go to IMPACT AGENT MENU,         >>
<                 SHORT FORM)                                                >>
<          Y-yes  (help is needed in initial definition; go to IMPACT        >>
<                 AGENT MENU, LONG FORM)                                     >>
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IMPACT AGENT MENU, LONG FORM

This menu will allow you to identify the types of causative mechanisms (impact agents) that might be operational at your site. These impact agents are typically chemical or physical changes that will occur as a result of interaction between some aspect(s) of plant design and/or operation and the aquatic ecosystem at that site. The first type of impact agent represents changes that occur in the chemical or physical components of the ecosystem. The targets measured to determine the existence of such changes are abiotic chemical or physical entities (e.g. the concentration of selenium, the velocity fields around the plant, etc.). The second, third, and fourth types all refer to impact agents that cause changes in some component of the biota around a plant. The targets for these impact agents are either organisms or some biotic aspect of the system, e.g. rate of primary production.

Choose the possibilities that correspond most closely to conditions at your plant. You may list subcategories within the four basic groupings if appropriate. Label these subcategories IAA1, IAA2, IAB1, IAB2, etc.

Which of the following impact agents concern you?

1 - IAA: PHYSICAL/CHEMICAL ALTERATIONS (ABIOTIC EFFECTS)

Likely to occur if plant operation is conducive to the disruption of the ordinary physical and/or chemical environment including:

- change in current patterns
- change in salinity gradients
- change in composition of benthic substrates
- change in the amount and/or character of suspended particles
- change in the concentration of macronutrients (N,P,C)
- change in the concentration of trace elements (metals, hydrocarbons, etc.)
- change in the temperature, pH, alkalinity, etc.
- increased concentrations of various biofouling control substances (e.g. chlorine)

2 - IAB: IMPINGEMENT/ENTRAINMENT (BIOTIC EFFECTS)

Likely to occur if any of the following occur in or around the vicinity of the intake during all or parts of the year:

- shoaling fish
- abundant, small fish
- ichthyoplankton or large zooplankton
- small zooplankton or phytoplankton
- organisms that are very active in terms of daily movement
- pelagic nekton
- volume of cooling water relative to the volume of waterbody is large (Delphi issue)
- several power plants are located on the same waterbody within 500 km (' or >, Delphi issue)
- the total volume of water going through the plant alone, or through all the power plants located within the 500 km area, is more than X% of the volume of the water body 'or in the case of open water bodies the effective water body) (Delphi issue)

3 - IAC: WATER QUALITY DEGRADATION 'BIOTIC EFFECTS)

Likely to occur if any of the following are found in or around the discharge plume area or the areas in which the discharge of polluted waters (either by chemicals or heat) from the cooling system or from waste disposal occurs:

- sessile and/or attached organisms
- organisms having reduced free mobility (ichthyoplankton'
- attached plants (e.g kelp, filamentous algae)
- motile organisms attracted to plume area due to thermal, feeding, or habitat preference, or increased protection
- volume of polluted water discharge is large relative to the volume of the water body

4 - IAD: HABITAT IMPACTS

Likely to occur if any of the following are found in or around areas that have been changed physically by the discharge plume or some other aspect of the plant, or its operation:

- sessile and/or attached organisms
- attached plants
- motile organisms frequently associated with benthic substrates
- organisms that depend upon current patterns for dispersion

5 - MORE INFORMATION IS NEEDED TO CHOOSE

I do not know enough about the conditions at this site to classify potential effects into the above categories. I need to have more information before I make this selection. (You will be routed directly to LEVEL3.

Enter the number or numbers (in sequence without commas) corresponding to the agents of concern in your case. You will be routed sequentially through the program for each choice.

0.3 Do you have hypothesis(es) of impact that describe potential ecological changes at your site? A hypothesis must define the target likely to be affected, the expected spatial and temporal dimension of the effect, the agent likely to be responsible for the effect and the variable that should be measured to evaluate the effect.

yes (go to LEVEL 1)
no (go on)

0.4 Do you know the spatial and temporal dimensions of the action of the impact agent(s) operating at this site?

yes (go to LEVEL 2)
no (go to LEVEL 3)

LEVEL 1

FROM HEREON ALL INFORMATION IN BRACKETS {} WILL BE AVAILABLE ON CALL. IF A USER KNOWS WHAT IS NEEDED AT A GIVEN POINT, THE EXPLANATIONS ARE OMITTED. IF A USER NEEDS HELP, THE INFORMATION IN BRACKETS IS MADE AVAILABLE BY TYPING YES TO THE HELP QUESTION. A NO ANSWER TO THE HELP QUESTION MEANS THAT THE USER IS ROUTED AROUND THE EXPLANATORY INFORMATION.

You are in LEVEL 1. HELP Y/N?

{YOU HAVE IDENTIFIED:

1. one or more primary hypotheses (Ho's) of impact;
2. the impact agent operating for each Ho;
3. the target likely to be affected for each Ho;
4. the test variable to be measured in each hypothesis test;
5. the potential spatial and temporal dimensions of the problem.

LEVEL 1 will help to identify:

1. the field sampling program;
2. the errors and costs of the sampling options;
3. data analysis techniques.}

Start wi4h the first hypothesis identified for the first impact agent you considered. EPAM will route you through each subsequent hypothesis. You will then be sent to LEVEL 0 to optimize the monitoring program design.

1.1 Have you identified and evaluated the assumptions (bias) and alternative hypotheses (Ha's) that are associated with this primary hypothesis?

HELP Y/N?

{An alternative hypothesis should identify a causative agent, separate from the impact agent identified in the primary hypothesis, capable of inducing the same effect on the target (e.g. commercial fishery activity in the power plant vicinity can reduce the population of a target fish species to an extent comparable with a reduction due to impingement at a power plant intake). The Ha must also identify the target and the variable to be measured. The spatial and temporal dimensions are assumed to compare with those being considered by the Ho.}

1.1 Have you identified and evaluated the assumptions (bias) and alternative hypotheses (Ha's) that are associated with this primary hypothesis?

Y - yes (go to LEVEL OF CERTAINTY MENU, Alternative Hypotheses)
N - no (go to ALTERNATIVE HYPOTHESES in the HYPOTHESIS GENERATION subroutine)

1.2 If you have identified more than three (3) reasonable Ha's, or if the number of assumptions necessary for this Ho seems excessive, you may want to reconsider the importance of this Ho.

Y - yes, I'd like to reconsider (go to the HYPOTHESIS SCREENING subroutine)
N - no, I feel confident that this Ho is important (go on)

1.3 Do you know what variables to measure to test this Ho (or Ha)?

HELP Y/N?

{A variable must be defined in terms of its units (e.g. grams/cubic meter), its assumptions and goals (i.e. what it actually measures), and, ideally, the technique that will be necessary for measurement. Later, in the SAMPLING DESIGN subroutine, it will be necessary to identify the error and cost associated with this measurement. }

1.3 Do you know what variables to measure to test this Ho or Ha)?

Y - yes (go on)
N - no (go to VARIABLES in the HYPOTHESIS GENERATION subroutine)

1.4 Do you have a sampling design that specifies the field measurements and statistical tests needed to test this Ho?

Y - yes (go on)
N - no (go to SAMPLING DESIGN subroutine)

1.5 Do you have alternative hypothesis(es) (Ha's) that you wish to evaluate in order to strengthen the test of the primary hypothesis?

Y - yes (go back to 1.3)
N - no (go on)

1.6 Do you have another Ho that you want to include in the monitoring program?

Y - yes (go back to 1.1)
N - no (go to 0.3 for next impact agent or HYPOTHESIS CHOICE subroutine if all agents considered)

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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                  >>
<<                                                                  >>
<<      You are in SAMPLING DESIGN SUBROUTINE                       >>
<<                                                                  >>
<<                          -[SAMDES]-                              >>
<<                                                                  >>
<<                                                                  >>
<<      HELP Y/N?                                                   >>
<<                                                                  >>
<<                                                                  >>
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<<                                                                  >>
<<           {The subroutine SAMDES is located in Level 1.  It      >>
<<      assumes that the user knows what variable(s) to measure     >>
<<      in order to test a specific Ho.                             >>
<<                                                                  >>
<<           The purpose of SAMDES is to guide the user in the      >>
<<      selection of station location, sampling frequency           >>
<<      and of number of replicates to be taken.                    >>
<<      The optimal sampling network design is determined based     >>
<<      upon a fixed cost contraint or a minimum effectiveness      >>
<<      constraint.}                                                >>
<<                                                                  >>
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                  >>
<<      SD1.  Do you have a potentially affected (treatment) area   >>
<<            and control area(s) selected?                         >>
<<                                                                  >>
<<            Y - yes (go to SD2)                                   >>
<<            N - no                                                >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                  >>
<<         You have indicated that no selection has been made       >>
<<         of treatment and control areas.  Initial determination   >>
<<         of these areas must be made before proceeding.           >>
<<                                                                  >>
<<         Hydraulic models of the plume of influence should        >>
<<         be developed or reliance upon location monitoring        >>
<<         experts in the selection of sites is necesary.           >>
<<                                                                  >>
<<         When such information has been gathered, return to       >>
<<         EPAM.                                                    >>
<<                                                                  >>
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                 >>
<<     SD2.  Do you have a set of potential sampling stations      >>
<<           that include the treatment and control areas          >>
<<           from which to choose stations for the monitoring      >>
<<           program?                                              >>
<<                                                                 >>
<<           Y - yes (Go to SD3)                                   >>
<<           N - no                                                >>
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                 >>
<<        To continue, you must choose potential station           >>
<<        sites.  These will be selected from the areas            >>
<<        described in SD1.  Factors such as ease of sampling      >>
<<        location of targets, and monetary constraints            >>
<<        should be considered.                                    >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                 >>
<<     SD3.  Do you have an estimate of the variance inherent in   >>
<<           the data base?                                        >>
<<                                                                 >>
<<           Y - yes (Go to SD4)                                   >>
<<           N - no                                                >>
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                 >>
<<        Estimates of Variance are necessary to continue.         >>
<<        Estimates can be derived from published literature       >>
<<           of areas similar to that under investigation          >>
<<           or from reconnaissance studies.                       >>
<<                                                                 >>
<<                                                                 >>
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                 >>
<<     SD4.  Do you have estimates of spatial and/or temporal      >>
<<           correlations for the station pair differences if      >>
<<           you believe they are non-zero?                        >>
<<                                                                 >>
<<           Y - yes                                               >>
<<           N - no                                                >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
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Estimates of spatial/temporal correlation are necessary to continue.

If you consider them insignificant, or equal to zero, a yes should be entered to question SD4.

Estimates can be derived from published literature of areas similar to that under investigation or from reconnaissance studies.

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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                          >>>>
<<                              EPAM                                        >>>>
<<                                                                          >>>>
<<                             LEVEL 2                                      >>>>
<<                                                                          >>>>
<<     You are in LEVEL 2. HELP Y/N?                                        >>>>
<<                                                                          >>>>
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<<                                                                          >>>>
<<  {You have identified:                                                   >>>>
<<                                                                          >>>>
<<                                                                          >>>>
<<          1. the impact agent (e.g. entrainment) operating at this        >>>>
<<             plant, its spatial dimensions (alongshore, offshore and      >>>>
<<             vertically  with respect to depth), and its temporal         >>>>
<<             dimensions (daily, seasonally, annually and greater          >>>>
<<             than annually, if pertinent);                                >>>>
<<                                                                          >>>>
<<          2. the targets (organismal groups, species, chemical            >>>>
<<             constituents, etc.) likely to be affected;                   >>>>
<<                                                                          >>>>
<<                                                                          >>>>
<<          3. the geographic distribution and relative overlap of the      >>>>
<<             target with the impact agent.                                >>>>
<<                                                                          >>>>
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LEVEL 2 will help to identify:

1. the sensitivity of each target to the potential impact;
2. test variables for testing each primary or alternative hypothesis of input (e.g. biomass, species diversity, nitrate concentration, etc.);
3. The primary hypotheses of impact (Ho's);
4. The alternative hypotheses (Ha's) that may provide other explanations for an Ho, or may make quantitative testing of an Ho infeasible;
5. a subroutine to help the user select those hypotheses that will provide the most meaningful results from among all Ho's identified (HYPOTHESIS CHOICE).

2.1 Do you have an ecological target (e.g. an organism or some other biological, chemical or physical indicator) to study that is likely to be affected by plant operation or design?

Y - yes (go to LEVEL OF CERTAINTY MENU, Target Selection)
N - no (go to TARGET SELECTION)

2.2a Do you know the spatial and temporal dimensions of the target distribution in the vicinity of the impact agent and in its complete geographic range?

Y - yes (go to LEVEL OF CERTAINTY MENU, Target Overlap)
N - no (go to TARGET OVERLAP)

2.2b Do you know the sensitivity of the target to the impact agent?

Y - yes (go to LEVEL OF CERTAINTY MENU, Target Sensitivity)
N - no (go to TARGET SENSITIVITY)

2.3 You must decide whether to enter the HYPOTHESIS GENERATION subroutine. Do you want HELP Y/N?

{You have identified:

1. the monitoring program targets for each impact agent you wish to include in the monitoring program;
2. the sensitivity of each to its hypothesized impact agent;
3. the extent of physical overlap of each target with the hypothesized impact agent;
4. the spatial and temporal dimensions of the impact agent.

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<<                                                                       >>>>
<<   HYPOTHESIS GENERATION will use this information to help identify    >>>>
<<   (for each target of interest):                                      >>>>
<<                                                                       >>>>
<<             1. primary hypotheses of impact (Ho's);                   >>>>
<<             2. test variables appropriate for quantitative evaluation >>>>
<<                of an Ho or Ha;                                        >>>>
<<             3. alternative hypotheses (Ha's) and assumptions that are >>>>
<<                associated with each Ho;                               >>>>
<<             4. the relative importance of each Ho for one impact      >>>>
<<                agent relative to the Ho's developed for the other     >>>>
<<                impact agents. }                                       >>>>
<<                                                                       >>>>
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                       >>>>
<<    Do you wish to enter the HYPOTHESIS GENERATION subroutine?         >>>>
<<                                                                       >>>>
<<                 Y - yes (go to HYPOTH)                                >>>>
<<                 N - no (go to 2.4)                                    >>>>
<<                                                                       >>>>
<<                                                                       >>>>
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                       >>>>
<<   2.4  You have chosen to develop the Ho without any quidelines.      >>>>
<<        Please consider the severity of, and spatial and temporal      >>>>
<<        scales over which the effect will operate when you develop     >>>>
<<        the Ho. You must also identify test variables for              >>>>
<<        quantitative evaluation of the Ho. Later, you will be          >>>>
<<        required to insert into the program cost and error data for    >>>>
<<        testing the chosen Ho. You will also be required to            >>>>
<<        demonstrate that you have considered alternative explanations  >>>>
<<        (Ha's) for the hypothesized effect. Now develop the Ho and     >>>>
<<        its associated Ha's. When you are ready to continue, choose    >>>>
<<        from the following options:                                    >>>>
<<                                                                       >>>>
<<          2.3 - return to question 2.3 to consider another             >>>>
<<                target for this or another impact agent                >>>>
<<       CHOICE - go to the choice subroutine (HYPOTHESIS CHOICE)        >>>>
<<                to evaluate all Ho's relative to each other            >>>>
<<                (you have developed all Ho's and Ha's for IAA,         >>>>
<<                IAB, IAC and IAD)                                      >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
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```

You are in HYPOTHESIS GENERATION SUBROUTINE

{HYPOTH}

HELP Y/N?

{The subroutine HYPOTH is located in Level 2. It assumes that the impact agent has been identified and that a decision has been made as to what targets are important to measure relative to the expected mode(s) of impact.

The purpose of HYPOTH is to guide the selection of hypotheses of impact that will be appropriate to measure in the developing monitoring program. HYPOTH considers each suggested hypothesis on the basis of five conditions. These are:

1. the type of expected response, and the class of variables appropriate to the measurement of that type of response, including the cost and error associated with each variable;
2. the spatial dimension of the expected response;
3. the temporal scale of the expected response;
4. the severity of the expected response;
5. the alternative hypotheses (Ha's) that could falsify the primary hypothesis (Ho).

HYPOTH presents a user with criteria for evaluating each of these conditions. The user is required to make a decision relative to elimination or retention of a given hypothesis. This process is repeated for each impact agent and subcategory in sequence.

After all Ho's have been selected by the user, the final subroutine HYPOTHESIS SCREENING is introduced. This is a choice evaluation based on a technique developed by Saaty (1977). The subroutine allows a user to compare all of the hypotheses being considered relative to one another on the basis of their scientific validity, the cost required for testing and the expected accuracy of the test results.}

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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                        >>
<<    H1. From the following listing, please make the choices that        >>
<<    correspond most closely to what you think will happen at            >>
<<    this site, under the hypothesized conditions, to this               >>
<<    target. For each choice you make, type the appropriate              >>
<<    letter and press RETURN.                                            >>
<<                                                                        >>
<<    Type of Response: DIRECT - target is directly affected by           >>
<<    impact agent.                                                       >>
<<                                                                        >>
<<    DI - individual response (bioaccumulation, disease                  >>
<<         propagation, behavioral change, etc.)                          >>
<<    DP - population response (numbers, age structure, growth,           >>
<<         fecundity, reproductive strategy, sex ratio, length-           >>
<<         weight ratio, etc.)                                            >>
<<    DC - community response (species composition, diversity,            >>
<<         total biomass, total abundance, relative abundance,            >>
<<         percent similarity, etc.)                                      >>
<<    DE - ecosystem response (change in trophic dynamics,                >>
<<         nutrient cycling, energy flow, etc.)                           >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                        >>
<<    Type of Response: INDIRECT - target is affected indirectly,         >>
<<    i.e. as a result of a direct effect on another ecosystem            >>
<<    component.                                                          >>
<<                                                                        >>
<<    II - individual response                                            >>
<<    IP - population response                                            >>
<<    IC - community response                                             >>
<<                                                                        >>
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                        >>
<<    User is routed to the variables identification subsection of        >>
<<    HYPOTH for the response type that is identified.)                   >>
<<                                                                        >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
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VARIABLES IDENTIFICATION

This section of HYPOTH presents a compilation of variables that have been used in aquatic monitoring programs. All variables are classified first according to the type of response as identified above, and, second, according to the impact target as identified previously (e.g. finfish, phytoplankton, etc.). Within these categories, each variable is considered in terms of its general or specific applicability, the availability of techniques for measurement, the general dollar cost associated with measurement, and the expected accuracy (variance) of the measurement.

The choice of appropriate variable is a decision made by the user. The information is presented to prompt consideration of characteristics that have been found to be important. Read the information given below and respond to the instructions.

V1 In what ecological group does your target occur? Choose from the following menu.

- F - finfish
- S - shellfish
- IC - ichthyoplankton
- IN - benthic macroinvertebrates
- Z - zooplankton
- PH - phytoplankton
- PE - periphyton
- MA - macrophytes/macroalgae
- MI - microbes (bacteria, fungi, etc.)
- D - detritus

Type the appropriate letter and press RETURN. Only one target will be considered at a time. If more than one target ranked highly in TARGET SCREENING, consider each one in turn.

NOTE: VARIABLES IDENTIFICATION will use the format shown below. Detail will be entered as it is developed by the project team members and reviewed through the Delphi process.

Individual Response

Finfish

Variable List: Bioaccumulation
Disease Propagation
Behavioral Change
Endangered Species

Shellfish

Variable List: Bioaccumulation
Disease Propagation

Phytoplankton/Periphyton/Macrophytes/Macroalgae

Variable List: Bioaccumulation

Population Response

Finfish

Variable List: Abundance (#/unit effort)
Abundance (#/volume water; #/surface area)
Biomass (weight/unit effort)
Biomass (weight/volume water)
Population Statistics (length versus weight)
Population Statistics (sex ratio/fecundity)

Shellfish

Variable List: Abundance (#/unit area)
Biomass (weight/unit area)

Macroinvertebrates

Variable List: Abundance (#/unit area)
Abundance (#/sample)
Biomass (weight/unit area)
Biomass (carbon or nitrogen/unit area)
Biomass (weight/sample unit)
Population Statistics (length or age structure p.)

Zooplankton

Variable List: Abundance (#/sample; discrete sample)
Abundance (#/volume water;continuous sample)
Biomass (weight/sample; discrete sample)
Biomass (weight/volume water; continuous sample)
Biomass (carbon, nitrogen, or calorie content/sample)
Biomass (carbon, nitrogen, or calorie content/volume water)

Phytoplankton

Variable List: Abundance (#, cells or individuals/sample)
Abundance (#, cells or individuals/volume water)
Biomass (weight/volume)
Biomass (weight estimated from cell volume and #/volume)
Biomass (chlorophyll a/volume)
Biomass (carbon or nitrogen/volume)
Biomass (ATP/volume)

Community and Ecosystem options plus any additional population or individual options will be inserted.

(user is routed to this question:)

V2 From the compilation presented to you, what variable do you choose? Enter variable name and units:

Variable :_____

Units: _____

(information is stored and user is routed to consideration of the spatial dimensions of the anticipated effect)

H2 Based upon your knowledge of the interaction in space between the impact agent and the target and your knowledge of the spatial distribution of the target itself, what spatial dimension do you think the expected impact will have? Choose from the following menu:

M - effect is manifested on a spatial scale of meters (e.g. effect and/or repercussions of the effect are observed only in the immediate area of the impact agent.) Scale is less than the local range of the target.

K - effect is manifested on a spatial scale of kilometers (e.g. effect and/or repercussions of the effect are observed in the vicinity of the impact agent and in other areas of the water body and/or in the water body as a whole.) Scale is equal to the local range of the target.

T - effect is manifested on a spatial scale of hundreds to thousands of kilometers (e.g. effect and/or repercussions of effect are observed in widely separated areas, perhaps beyond the receiving water body itself.) Scale is equal to the geographic range of the target; greater than the local range.

Type the appropriate letter and press RETURN.

(information is stored and user is routed to next question)

H3 Based on your knowledge of the target and the impact agent, over what time scale do you anticipate the effect will continue to be observed?

Consider the conditions below (all of which decrease the severity of an observed effect):

1. positive response capacity of target has high probability of occurring due to:
   a. high reproductive rate;
   b. large capacity for adaptation to altered conditions;
   c. other (Delphi-ed)
2. compensatory response of non-affected life stages of target counteract consequences of effect.
3. organisms are highly mobile and able to move away from impact agent, thereby decreasing probability of continuous effects.
4. generation time is very short.
5. other (Delphi-ed)

Choose from the following options:

L - less than a generation time (usually less than a year)

E - equal to a generation time (usually within 1 to 5 years)

G - greater than one generation time (usually more than 5 years)

(DELPHI ISSUE)

Type the appropriate letter and press RETURN.

(information is stored and user is routed to next question)

H4 Using the following matrix, pinpoint the relative severity of the hypothesized effect under consideration:

(DELPHI ISSUE)

SPACE	METERS	< GENERATION	= GENERATION	> GENERATION
		not severe	not severe	may be severe
	KILOMETERS	not severe	may be severe	severe
	100 - 1000'S KILOMETERS	not applicable	may be severe	severe

NOTE: matrix is prototype. Detail will be presented to Delphi panel.

Based on the location of the target under consideration in the matrix above, choose from the following options:

NOT SEVERE: reject this hypothesis and

- H1 - return to H1 and consider the next target
- H9 - go to H9 to consider the CHOICE subroutine in HYPOTHESIS SCREENING. (this was the last target and the last impact agent)

MAY BE SEVERE: reconsider this target in terms of relative overlap

- TS - return to TARGET SCREENING and reconsider the relative overlap of target;

(More choices on next page)

SEVERE: target should be evaluated; continue to H5 to formulate Ho.

Type the appropriate letters and press RETURN.

H5 You now have enough information to formulate this primary hypothesis(Ho).

Using the following prototype, enter your Ho in words. If the Ho does not fit into the given format, enter it in the space given below.

Ho: the _____ (variable) of _____ (target) will change on a spatial scale of _____ km and a temporal scale of _____ (hours,days or years) due to the action of _____ (impact agent).

Ho: _____

_____

_____

_____

_____

_____

When Ho is inserted, type H6 and press RETURN.

(the Ho is stored sequentially by number, following the previous Ho.)

Describe the hypothesized distribution of the effect as a guide to sampling program design, using data from TARGET OVERLAP, or equivalent, as a basis:

Spatial distribution -

Temporal distribution -

H6 Are there any complementary hypotheses that you wish to consider? i.e. did you note any potential for indirect effects on other targets associated with the above hypothesized impact?

Y - yes, develop into hypotheses
N - no, go on to H7

Insert complementary hypotheses in space below:

H7 Consider any alternative explanations and assumptions that might invalidate acceptance of this Ho. These will be used to formulate possible alternative hypotheses to be tested as a means of strengthening a decision based on acceptance or rejection of this Ho, or as a partial basis for discarding this Ho as part of the monitoring program.

Conditions (in the vicinity of the power plant or in the range of the target being considered) likely to result in alternative explanations for acceptance or rejection of the Ho:

1. significant upwelling events;
2. major changes in tidal flux during an annual cycle;
3. major changes in river runoff which affect discharge, turbidity, salinity, chemical environment, due to the natural annual cycle or annual fluctuations in reservoir storage and release patterns;
4. significant changes in meteorological conditions;
5. large annual variation in natural population;
6. resource extraction activity:
   - commercial fisheries
   - oil/gas
   - other mining activity
   - forestry
   - drilling

7. resource renewal activity:
   - reforestation
   - waste recycling
   - dredging for navigation
   - hatchery activity
   - nursery grounds
   - flood control (water storage) reservoir - age; size
8. industrial activity
   - pulp and paper mills
   - petrochemical plants
   - food processing plants
   - iron and steel mills
   - manufacturing plants
   - smelters

9. other energy facilities
   - oil
   - gas
   - coal
   - nuclear
   - hydroelectricity
10. waste disposal facilities
   - municipal discharge
   - ocean dumping
   - landfills
   - environmental contaminants and toxic substances
   - storage
   - biological emissions

11. recreational activity
    - sport fishing
    - parks
    - resorts
    - boating
    - swimming
    - aesthetic amenities (scenic)
12. land use and transportation
    - urban
    - agricultural
    - airport
    - transportation
    - transmission lines
    - offshore structures
    - history of recovery (e.g. system is recovering from a period of degradation and observed changes in biota may be due to the altered nutrient regime and not the power plant operation or design).

Formulate the alternative hypotheses (Ha's) following the prototype given above for the Ho's. An Ha will be appropriate if any of the above activities occur near the plant, or in the range of the target being considered, at a significant level.

Significance can be judged by comparing: (categories to be reviewed by Delphi process)

1. the ratio of flow into or out of the water body due to the alternative activity relative to the flow due to the impact agent being considered.
2. the ratio of resource extracted relative to the total resourc present, or to the resource likely to be affected (see TARGET SENSITIVITY).
3. other

If any of these ratios is greater than X, the Ho should be discarded. Change due to the hypothesized impact agent will be indistinquishable from change due to other factors.

(DELPHI ISSUE)

If you decide to retain an Ho in spite of one or more existing Ha's, these Ha's will be evaluated as part of the full monitoring program. Type the Ha's below and give them the same number as the associated Ho (e.g.) Ho-1, Ha-1a, Ha-1b).

Ha's, if any, should be inserted in prototype or in lines provided.

The _____ of _____ will
(variable) (target)
change spatial scale of _____ and
a temporal scale of _____ due to
the action of _____
_____. (alternative agent)

_____

_____

_____

_____

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<<                                                                        >>
<<     H8     Choose from the following options:                          >>
<<                                                                        >>
<<            H7 - return to H7 (there are more Ha's to consider for      >>
<<                 this Ho).                                              >>
<<            H9 - go to H9 (all Ha's have been considered for this Ho).  >>
<<                                                                        >>
<<                                                                        >>
<<     Type the appropriate letters and press RETURN.                     >>
<<                                                                        >>
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<<                                                                        >>
<<     H9    Choose from the following options:                           >>
<<           H1 - return to H1 (there are more targets to consider        >>
<<                for this impact agent or other impact agents).          >>
<<           CHOICE _ go to the HYPOTHESIS CHOICE subroutine              >>
<<           (there are no more impact hypotheses to be developed).       >>
<<                                                                        >>
<<     Type the appropriate letters and press RETURN.                     >>
<<                                                                        >>
<<                                                                        >>
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<<                                                                       >>>>
<<                                                                       >>>>
<<                            LEVEL 3                                    >>>>
<<                                                                       >>>>
<<    You are in LEVEL 3. HELP Y/N?                                      >>>>
<<                                                                       >>>>
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<<    {You have identified:                                              >>>>
<<                                                                       >>>>
<<    1. the impact agent(s) likely to operate at your site (or have     >>>>
<<       indicated you wish to receive assistance in identifying impact  >>>>
<<       agents                                                          >>>>
<<                                                                       >>>>
<<    LEVEL 3 will help to identify:                                     >>>>
<<                                                                       >>>>
<<    1. the spatial and temporal dimensions of each impact agent;       >>>>
<<    2. the monitoring program targets that should be considered        >>>>
<<       during program development;                                     >>>>
<<    3. the geographic distribution of each target;                     >>>>
<<    4. the extent of physical overlap between each target and          >>>>
<<       the impact agent(s) of concern. }                               >>>>
<<                                                                       >>>>
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<<                                                                       >>>>
<<     3.1  Have you selected the impact agent(s) likely                 >>>>
<<          to operate at your site?                                     >>>>
<<                                                                       >>>>
<<          Y - yes  (go to 3.4)                                         >>>>
<<          N - no   (go to 3.2)                                         >>>>
<<                                                                       >>>>
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3.2 Reconsider the IMPACT AGENT MENU, LONG FORM. List all agents that may conceivably act at your site. You may list subcategories within the four basic groupings if appropriate (e.g. specific chemicals in group IAA; impingement separate from entrainment in group IAB; thermal discharge and various chemicals in group IAC; modification of currents and sedimentation in group IAD). Label these subcategories IAA1, IAA2, IAB1, IAB2, etc. Press RETURN to return the menu to the the screen and make your selections.

3.3 You will next proceed to IMPACT AGENT CHOICE to prioritize the agents on your list and make final selections for consideration in the remainder of the analysis. Do you wish to eliminate any selections on the tentative list before exercising CHOICE (those clearly of less importance or probability of occurance than others)? Decide upon criteria to employ in evaluating agents in CHOICE. When you are ready, press RETURN and you will be routed to IMPACT AGENT CHOICE.

```
3.4   Select a specific impact agent among those you selected above:
      Type the letters corresponding to the group in which it lies.

           IAA - physical/chemical alteration (abiotic affects)
           IAB - impingement/entrainment (biotic effects)
           IAC - water quality degradation (biotic effects)
           IAD - habitat modification (biotic effects)


     Type the appropriate letters and press RETURN.
```

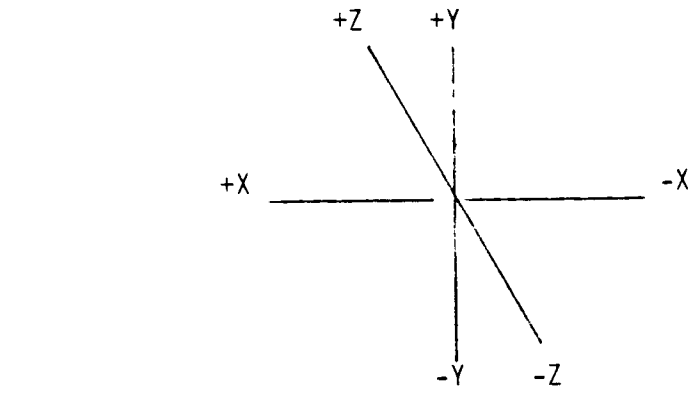
```
IAA. Impact Agent A - Physical/Chemical Alterations (Abiotic Effects)

You are in Impact Agent A. You will need to collect some
information in order to continue with the program. If you know what
information is needed answer N to the first question. If you do not
know, answer Y.

IAA.1  EPAM needs information to define the portion of the water
body that is likely to be alterred either physically or chemically
as a result of power plant operation or design, and the ratio of
this portion of the water body to the whole water body on which
the plant is sited [using the ratio of water volumes for changes
associated with the water column and the ratio of benthic areas for
changes associated with the benthos]. Remember water column changes
are most likely to be associated with the outfall or waste disposal
areas, and benthic changes are most likely to be associated with
intake, outfall or waste disposal areas.     HELP Y/N?
```

{You will need to insert information into EPAM to define:

1. the spatial extent (in meters) of a water parcel, located along the shoreline (in the x-dimension), adjacent to the outfall structure, or in the vicinity of the waste disposal site(s) that can be identified as altered in some chemical (e.g. copper concentration) or physical (e.g. temperature) parameter; or the spatial extent (m) of a surface area located along the shoreline (in the x-dimension), adjacent to the intake, the outfall, or the waste disposal site that can be identified as altered (either physically or chemically).



2. the spatial extent (m) of a water parcel located perpendicular to the shoreline (in the y-dimension), adjacent to the outfall structure, or in the vicinity of the waste disposal site(s) which can be identified as being altered in some chemical or physical parameter; or the spatial extent (m) of a surface area located perpendicular to the shoreline (in the y-dimension), adjacent to the intake, the outfall, or the waste disposal site that can be identified as being altered in some chemical or physical parametetr;

3. the spatial extent (m) of a water parcel, located vertically in the water column (in the z-dimension), adjacent to the outfall structure, or in the vicinity of the waste disposal site(s) which can be identified as being altered in some chemical or physical parameter;

4. the proportion of time in an annual cycle that this spatially defined envelope or area exists in these or in other dimensions as a function of changes in plant operation, meteorological and/or environmental conditions (a set of n conditions that produce substantially different configurations of the envelope or area);

5. the total volume of water (or total effective volume of water) in the water body on which the plant is sited or the total area that can be defined as providing comparable habitat space as the area having high potential to be altered;

6. the costs of obtaining this information (in actual dollars expended)

7. the degree of confidence you have in the estimate(s), on a scale of 1 to 5, where:

5 = complete confidence
1 = no confidence

Cost data and confidence estimates will be used in subsequent subroutines (OPTIMIZATION and HYPOTHESIS CHOICE respectively) to permit reconsideration of the monitoring program design with respect to the underlying accuracy and total funds expended in the design effort. }

IAA.2 Do you know the spatial dimensions of the envelope of water or the area having high potential for disturbance for n conditions that occur over an annual cycle?

Y - yes (go on)
N - no (go to TECHNIQUES)

IAA.3 Insert the necessary information in the table below: This information will be used to define the extent of physical overlap between a monitoring program target and the impact agent. Information may be available to you (through previous measurements or modeling exercises) to define the envelope or area more exactly. If you have such information (e.g. the spatial distribution of the alterred parcel of water in 3 dimensions), use it to estimate the location and volume or area of the envelope. Otherwise, the spatial distribution will be assumed to be relatively uniform (see IAA.4 below). (If you wish to recall this table later, enter IAATABLE.

IAA.4 Given the information available, make a rough estimate of the "volume" of the altered envelope in the water column ; or draw 3-dimensional spaces on maps that can be used to estimate overlap (in TARGET OVERLAP). In the case of benthic disturbance, make a rough estimate of the "area" of the space with potential to be disturbed; or draw 2-dimensional spaces on maps that can be used to estimate overlap.

Viaa = X x Y x Z

or

Aiaa = X x Y

These values will be rough estimates of the actual volume or area, (i.e. assumes a uniform distribution from +X to -X, +Y to -Y, and +Z to -Z). The values will suffice for the current application. (DELPHI ISSUE)

ENTER V (or A) in units of cubic (or square) meters.

IAA.5 Determine the total volume of the waterbody (Vwb) on which the power plant is sited. Determine the total area (Awb) in the water body that provides comparable habitat space to the area having high potential for disturbance. Use whatever data are available (e.g. hypsographic curves, depth contour information, maps, etc.)

If the water body is an open system (e.g. coastal site; riverine site), use an estimate of effective volume or area. Effective volume is that water that is likely to be considered a part of the total habitat available in the overall vicinity of the plant (e.g. the water above a certain depth contour, the mean daily flow past the site in question and so forth). Effective area is that space that provides comparable habitat that is likely to be considered a part of the total habitat available in the plant vicinity.

ENTER Vwb (or Awb) in units of cubic (or square) meters.

IAA.6 If more than one power plant exists on the waterbody within an X km area, calculate IAA.4 for each of the individual plants and sum for an estimate of the total volume and/or area likely to be altered physically or chemically during an annual cycle in this water body (Vt or At).

ENTER Vt (or At) in units of cubic (or square) meters.

IAA.7 Determine the ratio Vt/Vwb (or At/Awb).

If the ratio is greater than X, the probability of long-term problems due to chemical or physical alterations in the water column or on the benthos is very high (DELPHI ISSUE) This information will be utilized in the TARGET SENSITIVITY subroutine.

ENTER Vt/Vwb (or At/Awb)

IAA.8 Enter cost and confidence ratings for Viaa and Vwb (or Aiaa and Awb)Ab), and Awb.

ENTER Viaa Cost.
ENTER Viaa Conf.
ENTER Vwb Cost.
ENTER Vwb Conf.
ENTER Aiaa Cost.
ENTER Aiaa Conf.
ENTER Awb Cost.
ENTER Awb Conf.

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<<                                                                           >>>
<<   IAA.9 Choose from the following menu:                                   >>>
<<                                                                           >>>
<<            IAA   return to consider additional subcategories within       >>>
<<                  this impact agent group.                                 >>>
<<            IAB - return to 3.4 to consider impact agent questions for     >>>
<<                  IAB, Impingement/Entrainment                             >>>
<<            IAC - return to consider impact agent questions for IAC,       >>>
<<                  Water Quality Degradation                                >>>
<<            IAD - return to consider impact agent questions for IAD,       >>>
<<                  Habitat Modification                                     >>>
<<            TS  - all impact agents have been evaluated.  Go to            >>>
<<                  TARGET SELECTION.                                        >>>
<<                                                                           >>>
<<    Type the appropriate letters and press RETURN.                         >>>
<<                                                                           >>>
<<                                                                           >>>
<<                                                                           >>>
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<<                                                                          >>>>
<<                                                                          >>>>
<<       IAB. Impact Agent B - Impingement/Entrainment                      >>>>
<<                                                                          >>>>
<<       You are in Impact Agent B. You will need to collect some           >>>>
<<       information in order to proceed with the program. If you know      >>>>
<<       what information is needed, answer N to the first question.        >>>>
<<       If you do not know, answer Y.                                      >>>>
<<                                                                          >>>>
<<       IAB.1 EPAM needs information to define the portion of the          >>>>
<<       waterbody that will be entrained during cooling system             >>>>
<<       operation (i.e. that will be used for cooling), the total          >>>>
<<       volume of water used in an annual cycle during plant               >>>>
<<       operation and the total volume of the water body from which        >>>>
<<       the water is drawn.          HELP Y/N?                             >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
```
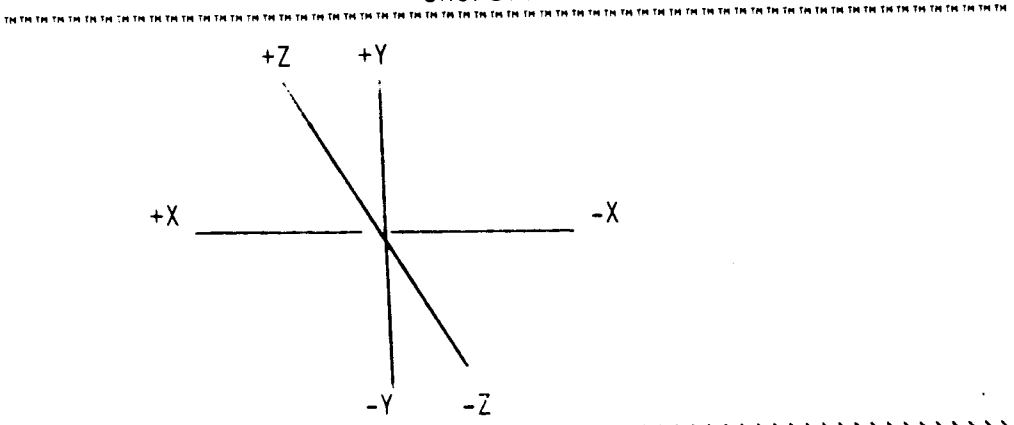

{You will need to insert information into EPAM to define:

1. the spatial extent (in meters) of a water parcel, located along the shoreline (in the x-dimension), adjacent to the intake structure, which is in the entrainment envelope;



2. the spatial extent (m) of a water parcel located perpendicular to the shoreline (in the y-dimension), adjacent to the intake structure, which is in the entrainment envelope;

3. the spatial extent (m) of a water parcel, located vertically in the water column (in the z-dimension), adjacent to the intake structure, which is in the entrainment envelope;

4. the proportion of time in an annual cycle that this spatially defined entrainment envelope exists in these or in other dimensions as a function of changes in plant operation, meteorological and/or environmental conditions (a set of n conditions that produce substantially different configurations of the entrainment envelope);

5. the total volume of water being used by the plant during an annual cycle (flow rate in volume/time X time of plant operation during 1 year);

6. the total volume of water (or total effective volume of water) in the water body from which the cooling water is being drawn;

7. the costs of obtaining this information (in actual dollars expended)

8. the degree of confidence you have in the estimate(s), on a scale of 1 to 5, where: 5 = complete confidence 1 = no confidence

Cost data and confidence estimates will be used in subsequent subroutines (OPTIMIZATION and HYPOTHESIS CHOICE respectively) to permit reconsideration of the monitoring program design with respect ot the underlying accuracy and total funds expended in the design effort. }

IAB.2 Do you know the spatial dimensions of the entrainment envelope for n conditions that occur over an annual cycle?

Y - yes (go on)
N - no (go to TECHNIQUES)

IAB.3 Insert the necessary information* in the table below:
This information will be used to define the extent of physical overlap between a monitoring program target and the impact agent.

* Information may be available to you (through previous measurements or modeling) to define the entrainment envelope more exactly. If you have such information (e.g. the spatial distribution of the entrainment parcel in 3 dimensions) use it to estimate the location and volume of the entrainment envelope. Otherwise, the spatial distribution will be assumed to be relatively uniform (see IAB.4 below).

After you have completed the table, press RETURN to continue.
If you wish to recall this table later enter IAB TABLE.

IAB.4 Given the information available, make a rough estimate of the "volume" of the entrainment envelope; or draw 3-dimensional spaces on maps that can be used to estimate overlap (in TARGET OVERLAP) in McHargian fashion.

VIAB = X x Y x Z

This "V" will be an rough estimate of the actual volume,(i.e. "V" assumes a uniform distribution from +X to -X,+Y to -Y, and +Z to -Z). "V" will suffice for the current application. (DELPHI ISSUE)

ENTER V in units of cubic meters.

IAB.5 Determine the total volume of cooling water (Vcw) used during an annual cycle:

Vcw = flow rate (vol/time) X time of plant operation

ENTER Vcw in units of cubic meters.

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<<                                                                        >>>>
<<      IAB.6 Determine the total volume of the waterbody (Vwb)from         >>>>
<<      which the cooling water is removed and into which spent cooling   >>>>
<<      water is discharged.  Use whatever data are available              >>>>
<<      (e.g.hypsographic curves, depth contour information, maps,etc.)   >>>>
<<      If the water body is an  open system (e.g. coastal site;           >>>>
<<      riverine site) use an estimate of effective volume.                >>>>
<<      Effective volume is that water that is likely to be entrained      >>>>
<<      during plant operation, e.g. the water above a certain depth       >>>>
<<      contour, the mean daily flow past the site in question,an daily   >>>>
<<      and so forth.                                                      >>>>
<<                                                                        >>>>
<<      ENTER Vwb in units of cubic meters.                                >>>>
<<                                                                        >>>>
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<<                                                                        >>>>
<<      IAB.7 If more than one power plant exists on the waterbody         >>>>
<<      within an X km area, calculate IAB.5 for each of the               >>>>
<<      individual plants and sum for an estimate of the total volume      >>>>
<<      entrained during an annual cycle in this water body (Vt).          >>>>
<<                                                                        >>>>
<<      ENTER Vt in units of cubic meters.                                 >>>>
<<                                                                        >>>>
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<<                                                                        >>>>
<<      IAB.8 Determine the ratio of Vt/Vwb.  If the ratio is greater      >>>>
<<      than X, the probability of long-term problems due to               >>>>
<<      impingement or entrainment is very high.  (DELPHI ISSUE)           >>>>
<<      This information will be utilized in the TARGET SENSITIVITY        >>>>
<<      subroutine.                                                        >>>>
<<                                                                        >>>>
<<      ENTER Vt/Vwb.                                                      >>>>
<<                                                                        >>>>
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<<                                                              >>>>
<<      IAB.9 Enter cost and confidence ratings for Vcw and Vwb >>>>
<<                                                              >>>>
<<            ENTER Vcw cost                                    >>>>
<<            ENTER Vcw confidence                              >>>>
<<            ENTER Vwb cost                                    >>>>
<<            ENTER Vwb confidence                              >>>>
<<                                                              >>>>
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<<                                                              >>>>
<<      IAB.10 Choose from the following menu:                  >>>>
<<                                                              >>>>
<<                                                              >>>>
<<      IAA - return to 3.4 to consider impact agent questions for >>>>
<<              IAA, Physical/Chemical Alterations              >>>>
<<      IAB - return to consider additional subcategories within >>>>
<<              this impact agent group                         >>>>
<<      IAC - return to consider impact agent questions for IAC, >>>>
<<              Water Quality Degradation                       >>>>
<<      IAD - return to consider impact agent questions for IAD, >>>>
<<              Habitat Modification                            >>>>
<<      TS  - all impact agents have been evaluated. Go to TARGET >>>>
<<            SELECTION.                                        >>>>
<<                                                              >>>>
<<                                                              >>>>
<<      Type the appropriate letters and press RETURN.          >>>>
<<                                                              >>>>
<<                                                              >>>>
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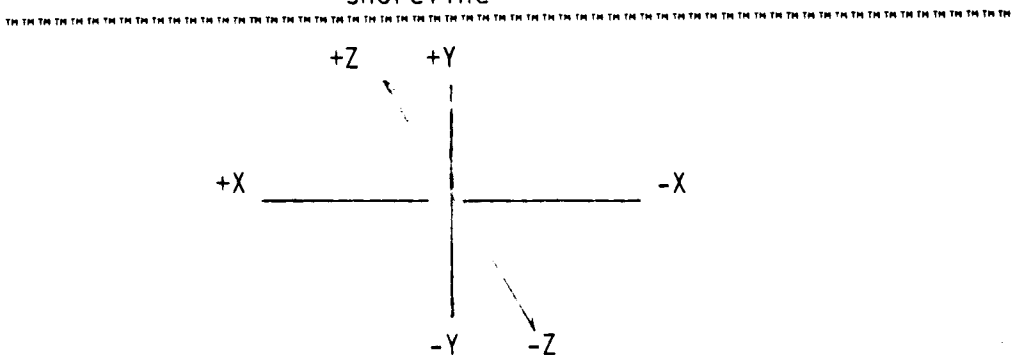
<<                                                              >>>
<<    IAC. Impact Agent C - Water Quality Degradation  (Biotic Effects)   >>>
<<                                                              >>>
<<    You are in Impact Agent C. You will need to collect some information >>>
<<    in order to proceed with the program. If you know what information >>>
<<    is needed, answer N to the first question. If you do not know, >>>
<<    answer Y.                                                 >>>
<<                                                              >>>
<<    IAC.1 EPAM needs information to define the portion of the waterbody >>>
<<    that is likely to receive discharge from the cooling system or from >>>
<<    waste disposal systems associated with the power plant and the total >>>
<<    volume of the water body into which the water is discharged. >>>
<<    HELP Y/N?                                                 >>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
```

{You will need to insert information into EPAM to define:

1. the spatial extent (in meters) of a water parcel, located along the shoreline (in the x-dimension), adjacent to the outfall structure or the waste disposal site which is in the discharge envelope;



2. the spatial extent (m) of a water parcel located perpendicular to the shoreline (in the y-dimension), adjacent to the outfall structure, or the waste disposal site which is in the discharge envelope;

3. the spatial extent (m) of a water parcel, located vertically in the water column (in the z-dimension), adjacent to the outfall structure, or the waste disposal site which is in the discharge envelope;

4. the proportion of time in an annual cycle that this spatially defined discharge envelope exists in these or in other dimensions as a function of changes in plant operation, meteorological and/or environmental conditions (a set of n conditions that produce substantially different configurations of the discharge envelope);

5. the total volume of water being discharged by the plant, in either cooling or waste disposal, during an annual cycle (flow rate in volume/time X time of plant operation during 1 year) or the volume likely to be leached from the waste disposal site if piping of liquid wastes does not occur;

6. the total volume of water (or total effective volume of water) of the water body into which the water is being discharged;

7. the costs of obtaining this information (in actual dollars expended)

8. the degree of confidence you have in the estimate(s), on a scale of 1 to 5, where:

5 = complete confidence
1 = no confidence

Cost data and confidence estimates will be used in subsequent subroutines (OPTIMIZATION and HYPOTHESIS CHOICE respectively) to permit reconsideration of the monitoring program design with respect to the underlying accuracy and total funds expended in the design effort.}

IAC.2 Do you know the spatial dimensions of the discharge envelope for n conditions that occur over an annual cycle?

Y - yes (go on)
N - no (go to TECHNIQUES)

IAC.3 Insert the necessary information in the table below: This information will be used to define the extent of physical overlap between a monitoring program target and the impact agent. Information may be available to you (through previous measurements or modeling efforts) to define the discharge envelope more exactly. If you have such information (e.g. the spatial distribution of the discharge parcel in 3 dimensions) use it to estimate the location and volume of the discharge envelope. Otherwise, the spatial distribution will be assumed to be relatively uniform (see IAC.4 below). If you wish to recall this table later, enter IACTABLE.

IAC.4 Given the information available, make a rough estimate of the "volume" of the discharge envelope; or draw 3-dimensional spaces on maps that can be used to estimate overlap (in TARGET OVERLAP).

Viac - X x Y x Z

This "V" will be a rough estimate of the actual volume,(i.e. "Vd" assumes a uniform distribution from +X to -X,+Y to -Y, and +Z to -Z). "V" will suffice for the current application.
(DELPHI ISSUE)

ENTER V in units of cubic meters.

IAC.5 Determine the total volume of water discharged (Vd) during an annual cycle;

Vd = Flow rate (vol/time) * time of plant operation.

ENTER Vd in units of cubic meters.

IAC.6 Determine the total volume of the waterbody (Vwb) into which the waste waters are discharged. Use whatever data are available (e.g.hypsographic curves, depth contour information, maps,etc.) If the water body is an open system (e.g. coastal site; riverine site), use an estimate of effective volume. Effective volume is that volume that is likely to provide habitat space in the whole water body that is comparable to the habitat space available in the vicinity of the power plant (e.g. the water above a certain depth contour, the mean daily flow past the site in question and so forth).

ENTER Vwb in units of cubic meters.

IAC.7 If more than one power plant or other plant likely to discharge wastes (e.g. an industrial point source) exists on the waterbody within an X km area, calculate IAC.5 for each of the individual plants and sum for an estimate of the total volume discharged during an annual cycle in this water body (Vt).

ENTER Vt in units of cubic meters.

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<<                                                                         >>>
<<    IAC.8 Determine the ratio of Vt/Vwb. If the ratio is greater than X, >>>
<<    the probability of long-term problems due to water quality           >>>
<<    degradation is very high. (DELPHI ISSUE) This information will be    >>>
<<    utilized in the TARGET SENSITIVITY subroutine.                       >>>
<<                                                                         >>>
<<          ENTER Vt/Vwb                                                   >>>
<<                                                                         >>>
<<                                                                         >>>
<<                                                                         >>>
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<<                                                                         >>>
<<   IAC.9 Enter cost and confidence ratings for Vd and Vwb.               >>>
<<                                                                         >>>
<<         ENTER Vd  COST.                                                 >>>
<<         ENTER Vd  CONF.                                                 >>>
<<         ENTER Vwb COST.                                                 >>>
<<         ENTER Vwb CONF.                                                 >>>
<<                                                                         >>>
<<                                                                         >>>
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<<                                                                         >>>
<<   IAC.10 Choose from the following menu:                                >>>
<<                                                                         >>>
<<          IAA - return to 3.4 to consider impact agent questions for     >>>
<<                IAA, Physical/Chemical Alterations                       >>>
<<          IAB - return to consider impact agent questions for            >>>
<<                IAB, Impingement/Entrainment                             >>>
<<          IAC - return to consider additional subcategories within       >>>
<<                this impact agent group.                                 >>>
<<          IAD - return to consider impact agent questions for IAD,       >>>
<<                Habitat Modification.                                    >>>
<<          TS  - all impact agents have been evaluated.  Go to            >>>
<<                TARGET SELECTION.                                        >>>
<<                                                                         >>>
<<    Type the appropriate letters and press RETURN.                       >>>
<<                                                                         >>>
<<                                                                         >>>
<<                                                                         >>>
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```

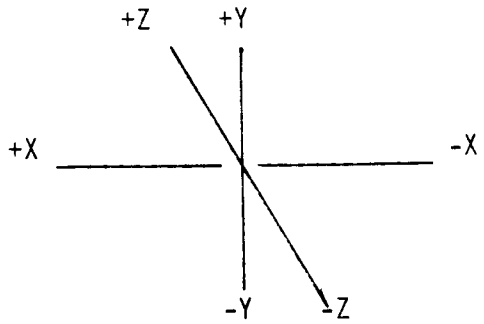
IAD. Impact Agent D - Habitat Modification (Biotic Effects)

You are in Impact Agent D. You will need to collect some information in order to proceed with the program. If you know what information is needed, answer N to the first question. If you do not know, answer Y.

IAD.1 EPAM needs information to define the portion of the water body that will be disturbed physically (e.g. benthic disruption, change in current patterns) by plant operation or design and an estimate of the ratio of this portion of the water body to the total water water body on which the plant is sited. HELP Y/N?

{You will need to insert information into EPAM to define:

1. the spatial extent (in meters) of the modified area, located along the shoreline (in the x-dimension), adjacent to the intake structure, the outfall structure, and/or the waste disposal site;



2. the spatial extent (m) of the modified area located perpendicular to the shoreline (in the y-dimension), adjacent to the intake structure, the outfall structure, or the waste disposal site;

3. the proportion of time in an annual cycle that this spatially defined area exists in these or in other dimensions as a function of changes in plant operation, meteorological and/or environmental conditions (a set of n conditions that produce substantially different spatial configurations);

---

4. the total area of the water body that is comparable in habitat type to the area being modified;

5. the costs of obtaining this information (in actual dollars expended)

6. the degree of confidence you have in the estimate(s), on a scale of 1 to 5, where:

5 = complete confidence
1 = no confidence

Cost data and confidence estimates will be used in subsequent subroutines (OPTIMIZATION and HYPOTHESIS CHOICE respectively) to permit reconsideration of the monitoring program design with respect to the underlying accuracy and total funds expended in the design effort. }

IAD.2 Do you know the spatial dimensions of the area with potential to be modified for n conditions that occur over an annual cycle?

Y - yes (go on)
N - no (go to TECHNIQUES)

IAD.3 Insert the necessary information in the table below: This information will be used to define the extent of physical overlap between a monitoring program target and the impact agent. Information may be available to you (through previous measurements or modeling efforts) to define the disturbed space more exactly. If you have such information (e.g. the spatial distribution of the disturbed space in 2 dimensions through time) use it to estimate the location and area of the disturbed space. If you wish to recall the table later, enter IADTABLE <RETURN>.

IAD.4 Given the information available, make a rough estimate of the "area" of the modified space; or draw 2-dimensional spaces on maps that can be used to estimate overlap (in TARGET OVERLAP).

$$A_{iad} = X \times Y$$

This "A" will be an rough estimate of the actual area,(i.e. "A" assumes a uniform distribution from +X to -X and +Y to -Y). "A" will suffice for the current application. (DELPHI ISSUE)

ENTER A in units of square meters.

IAD.5 Determine the total area of the water body (Awb) which consists of habitat space comparable to the area that is modified by power plant operation or design. Use whatever data are are available (e.g. maps, fish and wildlife records, etc.). If the water body is an open system (e.g. coastal site; riverine site), use an estimate of effective area. Effective area is that part of the water body that provides similar habitat space within the geographic range of the dominant organisms found in the vicinity of the power plant site.

ENTER Awb in units of square meters.

IAD.6 If more than one power plant or other industrial facility likely to cause habitat disruption exists on the waterbody within an X km area, calculate IAD.4 for each of the individual plants and sum for an estimate of the total area with potential to experience habitat disruption during an annual cycle in this water body.

ENTER At in units of square meters.

IAD.7 Determine the ratio of At/Awb. If the ratio is greater than X, the probability of long-term problems due to habitat disruption is very high. (DELPHI ISSUE) This information will be utilized in the TARGET SENSITIVITY subroutine.

ENTER At/Awb.

```
IAD.8 Enter cost and confidence ratings for Aiad, and Awb.

      ENTER Aiad COST.
      ENTER Aiad CONF.
      ENTER Awb  COST.
      ENTER Awb  CONF.
```

```
IAD.10 Choose from the following menu:

       IAA - return to 3.4 to consider impact agent questions for
             IAA, Physical/Chemical Alterations
       IAB - return to consider impact agent questions for IAB,
             Impingement/Entrainment
       IAC - return to consider impact agent questions for IAC,
             Water Quality Degradation
       IAD - return to consider additional subcategories within this
             impact agent group.
       TS  - all impact agents have been evaluated.  Go to
             TARGET SELECTION.

       Type the appropriate letters and press RETURN.
```

```
3.5  EPAM needs information to define the sensitivity of this
     target.  Go to TARGET SENSITIVITY.

     ENTER <RETURN>
```

```
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                      >>>>
<<   3.6  EPAM will prioritize targets for the impact agent in          >>>>
<<        question according to the data collected in the LEVEL 3       >>>>
<<        subroutines.  Go to TARGET CHOICE.                            >>>>
<<                                                                      >>>>
<<        ENTER <RETURN>                                                >>>>
<<                                                                      >>>>
<<                                                                      >>>>
<<                                                                      >>>>
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<<                                                                      >>>>
<<   3.7  Choose from the following options:                            >>>>
<<                                                                      >>>>
<<        TS1 - go to TARGET SELECTION to evaluate targets              >>>>
<<              for another impact agent.                               >>>>
<<                                                                      >>>>
<<        2.3 - go to LEVEL 2.  All impact agents and their targets     >>>>
<<              have been evaluated and prioritized.                    >>>>
<<                                                                      >>>>
<<        Type the appropriate letters and press RETURN.                >>>>
<<                                                                      >>>>
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You are in TARGET SELECTION

TS1.2 Enter the letters and numerals for the impact agent subcategory you want to consider. Names up to 40 characters may also be entered to provide further identification.

You will evaluate each target for this subcategory (through TARGET CHOICE) before you begin on the next subcategory or the next impact agent.

When you finish all targets for this subcategory, you will be directed to the next one.

TS1.2 You will be asked to consider potential targets for the impact agent (and subcategory) under consideration.

HELP Y/N?

{For IAB, IAC, and IAD a target can be defined as loosely or as precisely as the user thinks is desirable for evaluating the particular case in question:

- a species (e.g. Alosa pseudoharengus, alewife)
- a life history stage of a species (e.g. juvenile striped bass)
- a taxonomically distinct group (e.g. finfish, phytoplankton)
- a trophic level (primary producer biomass)
- a community indicator (species diversity)
- other (DELPHI ISSUE)

The abiotic targets used in IAA will typically be:

- a chemical concentration or loading
- a physical measurement (e.g. discharge)
- other (DELPHI ISSUE) }

Do you have a list of potential targets for the impact agent (and subcategory) under consideration?

Y - yes (go on)
N - no (go to TECHNIQUES)

TS1.3 Using the table below, insert information into the appropriate columns (1 - 5) by responding to the questions.

HELP Y/N ?

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<<                                                                              >>>>
<<    { This Target Table will be carried through                               >>>>
<<      different subroutines in EPAM until the final list of                   >>>>
<<      potential targets is complete. At this point the information            >>>>
<<      in the Target Table will be used to evaluate each target in             >>>>
<<      terms of a testable hypothesis if such exists. All targets              >>>>
<<      entered into the Target Table should be given a unique and              >>>>
<<      sequential code number that continues across all                        >>>>
<<      subcategories and impact agents. Any target shown to have               >>>>
<<      high potential utility for being incorporated into the                  >>>>
<<      monitoring program (following TARGET SELECTION screening)               >>>>
<<      will be identified in subsequent subroutines by this code               >>>>
<<      number. All data collected about this target will be stored             >>>>
<<      in the Target Table under the code number. If the same target           >>>>
<<      is identif d for different subcategories or impact agents,              >>>>
<<      or if the user wants to review pertinent data, such data can            >>>>
<<      by recalled by calling the correct code in the Target Table. }          >>>>
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<<                                                                              >>>>
<<      TS1.4 Column 1: list all potential targets by sequential code           >>>>
<<      number and either by species name, ecological group, or                 >>>>
<<      whatever identification is deemed appropriate. Name must be             >>>>
<<      less than 12 characters. It may be useful to develop this               >>>>
<<      potential list for all impact agents you intend to consider             >>>>
<<      before going any farther in the program. In this way you can            >>>>
<<      identify targets that are likely to be affected by more than            >>>>
<<      one impact agent in the early stages of program development.            >>>>
<<      These targets will receive extra weight in TARGET SENSITIVITY.          >>>>
<<                                                                              >>>>
<<      ENTER THE NUMBER OF TARGETS                                             >>>>
<<                                                                              >>>>
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<<                                                                              >>>>
<<      TS1.5 Column 2: give all targets for which a strong public              >>>>
<<      interest* exists a score of 1. Give all other targets a score           >>>>
<<      of 0.  Any targets that have substantially greater interest             >>>>
<<      than the others may be assigned a score of 2 or higher.                 >>>>
<<                                                                              >>>>
<<      HELP Y/N?                                                               >>>>
<<                                                                              >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
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{Include all targets that are designated by legislative mandate, e.g. representative important species (RIS), rare or endangered species, designation in an NPDES permit, etc.) or targets that are simply of local interest or have been monitored traditionally. The public interest category does not necessarily include targets for which a direct or indirect economic value exists.

If a target has been specifically mandated as a requirement for monitoring either by an NPDES permit (National Pollution Discharge Elimination System) or by some other local, state of federal action, it should be designated separately by receiving a score of 5. If the user feels the legal mandate might be in error, that target should be taken through the EPAM selection procedure as if it had received a lower score as appropriate

In the final subroutine for target selection (TARGET SCREENING), the mandated target's score will be compared with all other potential targets. At this point, a user will have good data with which to judge the appropriateness of the legal mandate and, if necessary, argue against it.}

TS1.6 Column 3: give all targets which have a direct economic value in either commercial or sports/recreational markets a score of 1. Give all other targets a score of 0. Any targets that have substantially greater value than the others may be assigned a score of 2 or higher.

TS1.7 Column 4: give all targets which have particular environmental value a score of 1. Give all other targets a score value of 0. Any targets that have substantially greater environmental value than the others may be assigned a score of 2 or higher.

HELP Y/N?

{Targets with particular environmental value may include dominant primary producers, food sources for carnivores, or consumers, important habitat formers, etc.}

TS1.8 Column 5: sum the scores of each target: (Column 2 + Column 3 + Column 4);

TS1.9 Delete those targets which received a total score of 0 in TS1.8.

TS1.10 Record the code number of the last target to use as the starting number for the next subcategory or impact agent.

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<<                                                                         >>>>
<<     TS1.11 Take the remaining targets one-by-one through TARGET         >>>>
<<     OVERLAP. (type TARGET OVERLAP and press RETURN)                     >>>>
<<                                                                         >>>>
<<     You may not complete EPAM with this target; you can return to       >>>>
<<     TARGET SELECTION at any time and choose the target with the         >>>>
<<     next highest score if you wish, for any reason.                     >>>>
<<                                                                         >>>>
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<<                                                                >>
<<                                                                >>
<<              You are in TARGET OVERLAP.                        >>
<<                                                                >>
<<                Do you need HELP? Y/N                           >>
<<                                                                >>
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<<                                                                  >>
<<      {You will need to insert information into EPAM to define:   >>
<<       1. the overall geographic range of each target being       >>
<<       considered relative to the location of the impact agent,   >>
<<       and the habitats occupied by specimens in the vicinity of  >>
<<       the impact agent. Theoretically the geographic and habitat >>
<<       ranges should be defined in three dimensions (x, y, z) for >>
<<       the n conditions identified for the impact agent's         >>
<<       distribution and any other conditions that are pertinent   >>
<<       (e.g. differences due to life history strategy). Frequently >>
<<       range data are available only at a very coarse level (e.g  >>
<<       abundant in-shore, throughout Lake Michigan). These data   >>
<<       can be used if necessary.                                  >>
<<                                                                  >>
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<<                                                                  >>
<<       2. the proportion of the target's geographic and habitat   >>
<<       ranges which overlap with the impact agent envelope (or    >>
<<       "volume") during the defined "n" conditions. These         >>
<<       proportions are defined as relative geographic and habitat >>
<<       overlaps.                                                  >>
<<       3. the cost (in dollars) of obtaining this information.    >>
<<       4. the degree of confidence expected in the estimate       >>
<<       (rated on a scale of 1 to 5, where 5 = complete confidence >>
<<       and 1 = no confidence). }                                  >>
<<                                                                  >>
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```

TO.1 Do you know the overall geographic range in 3 dimensions, x, y, and z (alongshore, offshore and vertically with depth) of the target for the n conditions defined as representing significant differences in the range?

Y - yes (go on)
N - no (go to TECHNIQUES)

TO.2 Collect the necessary information for n=1...n conditions (as defined for impact agents) for the table below and save; do not insert on screen.

Information Class		Degree of Confidence (1 to 5)	Cost of Obtaining Data ($)
Geographic Range			
	distance from the intake (m)	time during which condition holds	
n=1,n			
-x			
+x			
-y			
+y			
-z			
+z			

TO.3 Calculate the relative overlap (RGO) of the target's geographic range with the impact agent envelope during all n conditions. If data are presented in qualitative terms, make the best estimate possible using maps of the area. Save information; do not insert on screen.

$$RGO = \frac{IAx}{GRx} \times \frac{IAy}{GRy} \times \frac{IAz}{GRz} \quad \text{for } n=1...n \quad \text{(DELPHI ISSUE)}$$

where RGO = relative geographic overlap
IAx,y,z = the extent of the impact agent's range in the x, y, or z dimension (in meters) from IAATABLE, IABTABLE, etc. (recall by entering this designation if needed)
GRx, y, or z = the extent of the target's geographic range in the x, y, or z dimension (in meters)

TO.4 Compute a composite RGO for the n conditions on a time-weighted basis. Save information; do not insert on screen.

RGOcomp = Sum§time RGOi applies/total time†RGOi

(DELPHI ISSUE)

TO.5 Do you have information on the temporal fluctuations in target density in the immediate vicinity of the impact agent in the x, y, and z dimensions for the n conditions defined as representing significant differences in the range?

Y - yes (go on)
N - no (go to TECHNIQUES)

T0.6 Compute the percentage of the time the target is in the impact agent field as a density fluctuation rating. Collect information and save in a table as shown below; do not insert on screen.

DFR	Degree of Confidence (1-5)	Cost($) of Data to increase confidence rating (1 unit)
n=1,n		

T0.7 Compute a composite DFR for the n conditions on a time - weighted basis. Save information; do not insert on screen

DFR comp = Sum { time DFRi applies / total time }DFRi

(DELPHI ISSUE)

T0.8 Choose from the following options:

T01 - go to T0.1 to evaluate additional targets for this impact agent

T09 - go to T0.9 to rank target/impact agent overlap

Type the appropriate letters and press RETURN.

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<<                                                                      >>
<<  TO.9 Rank the RGO and DFR values for all targets considered         >>
<<       for this impact agent, assigning 1 to the target having the    >>
<<       lowest value, 2 to that with the next lowest, and so on.       >>
<<       Assign the same rank to targets having equal values. Enter     >>
<<       in columns 6 (GO) and 8 (DF) in the Target Table developed     >>
<<       in TARGET SELECTION.  Enter TT to recall the table.            >>
<<                                                                      >>
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<<                                                                      >>
<<  TO.10 Enter confidence ratings for GO and DF in columns 7           >>
<<        and 9, respectively (5 = high confidence; 1 = low             >>
<<        confidence).                                                  >>
<<                                                                      >>
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<<                                                        >>
<<                                                        >>
<<      You are in TARGET SENSITIVITY.  HELP Y/N?         >>
<<                                                        >>
<<                 Help Y/N ?                             >>
<<                                                        >>
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<<                                                                  >>
<<                                                                  >>
<<   {You will need to insert information into EPAM to define:      >>
<<                                                                  >>
<<    1. the sensitivity of the target to the impact agent under    >>
<<       consideration; sensitivity measures are given below for    >>
<<       each of the biotic impact agent subcategories.  The user   >>
<<       should employ the measure having the highest confidence    >>
<<       for which data exist or can be collected at reasonable cost; >>
<<    2. the cost (in dollars) of obtaining this information;       >>
<<    3. the degree of confidence expected in the estimate, rated   >>
<<       on a scale of 1 to 5 where 5 = complete confidence and 1 = >>
<<       no confidence.                                             >>
<<                                                                  >>
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<<                           IAB1. Impingement                       >>
<<                                                                   >>
<<    Conditions: mean length>screen mesh size                       >>
<<    Sensitivity (listed in order of decreasing confidence):        >>
<<                                                                   >>
<<        a. historical records of impingement at the site being     >>
<<           considered (preferably combined with the equation in b.) >>
<<        b. calculation of                                          >>
<<            R = E/B where R = relative entrapment coefficient      >>
<<                                                                   >>
<<                         E = entrapment/unit time                  >>
<<           If R is greater than X, target is considered sensitive. >>
<<        c. data for impingement collected at plants in similar     >>
<<           waterbodies having similar design and operating         >>
<<           specifications                                          >>
<<        d. evaluate physiological function, swimming speed, strength >>
<<           and behavior of target relative to the location and flow >>
<<           field of the intake structure.                          >>
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IAB.2. Entrainment

Conditions: mean length< screen mesh size

Sensitivity (listed in order of decreasing confidence):

a. historical data on target sensitivity to entrainment collected at the site under expected operating conditions (preferably combined with the equation in b.)

b. calculation of
K = N/B where K = relative survival coefficient
N = dead/unit time (as measured at outfall)
B = total population in intake area
If K > X (to be evaluated via Delphi process) target is sensitive.

c. data for entrainment survival collected at plants in similar waterbodies having similar design and operating specifications

d. any positive overlap (i.e. > 0) of phytoplankton, zooplankton, or ichthyoplankton populations in the correct size that have low reproductive capacity (r< 0.1/day) should be taken as having sensitivity to entrainment with a low confidence rating (e.g. 1-2).

IAC.1. Thermal

Conditions: targets in outfall plume area; delta T > or = 10'C.

Sensitivity (listed in order of decreasing confidence):

Thermal sensitivity is a function of delta T, time of exposure, the target's physiological requirements and capacity for adaptation.

a. historical data at the site being considered.
b. regional data collected at similar sites in the area.
c. laboratory test data using target and expected conditions (recognizing that the cost will be high and field conditions will be simulated poorly).
d. published tolerance data: (to be inserted).

IAC.2. Chemical (defouling)

Conditions: target in outfall plume area; chemical biofouling treatments used during condenser operation, variable schedule; naturally occurring chelating agents (e.g. dissolved organic carbon) in low concentration.

Sensitivity (listed in order of decreasing confidence):

Chemical tolerance to defouling agents (e.g. ClO2, Cl2 gas Cytox, DBNPA, etc.) is a function of the agent, its concentration, time of exposure, the target's life stage, sensitivity and ability to avoid and/or adapt to the exposure.

a. historical data at the site being considered.
b. regional data collected at similar sites in the area.
c. laboratory test data using target and expected conditions

(recognizing that the cost will be high and the ability to detect anything beyond short-term, acute effects is negligible).

d. published tolerance data (e.g. Mattice and Zittel 1976; EPRI 1980)

IAB.3. {Chemical (waste disposal and condenser leaching)

Conditions: target in area adjacent to waste disposal site, waste disposal discharge or outfall plume; on-site waste disposal discharges directly to waterbody or potential for leaching is high due to highly permeable substrate; leaching of metals used in condenser tubes occurs.

Sensitivity (listed in order of decreasing confidence):
Chemical tolerance to the trace elements (e.g. heavy metals) found in condenser leachate or from waste disposal sites is dependent upon the element, its concentration, the time of exposure, the target's life stage, sensitivity and ability to adapt.

a. historical data at this site.
b. regional data from sites similar in water chemistry conditions.
c. laboratory data using target and expected conditions (recognizing that cost is high and only short-term information on acute effects will be available).
d. published tolerance data: EPA Water Quality Criteria (1976, 1980); Battelle (1973).

IAD.1 Habitat Modification due to changes in Current Patterns

Conditions: passive organisms found in area where intake or outfall create an altered hydrodynamic regime.

Sensitivity (listed in order of decreasing confidence):

a. historical data at this site.
b. regional data from sites similar in current patterns.
c. published literature on the effects of currents on the target or similar organisms.

IAD.2 Modification of Benthic Substrate

Conditions: attached benthic organisms (particularly molluscs or other filter feeders, kelp and macrophyte beds) found in the disturbed area.

Sensitivity (listed in order of decreasing confidence):

a. historical data at this site.
b. regional data from sites similar in benthic substrate.
c. published literature on the effects of substrate modification on the target or simiar organisms.

IAD.3 Modification of Water Clarity

Conditions: presence of filter feeders and primary producers, including phytoplankton, periphyton, macrophytes or macroalgae, in the area of change.

Sensitivity (listed in order of decreasing confidence):

a. historical data at this site.
b. regional data from sites with similar conditions.
c. published literature on the effects of water clarity alteration on the target or similar organisms.

TS.1 Do you know what proportion of the target (population) is sensitive to the hypothesized impact, or, do you know how to obtain this information?

Y - yes (go on)
N - no (go to TECHNIQUES)

TS.2 Insert information in the table below; do not insert on screen

Type of Information	Degree of Confidence (rank on a scale of 1 to 5; 5 = complete confidence; 1 = no confidence)	Cost to increase confidence rating (1 unit) ($)
Examples:		
Trapping ratio,E/B: field survey		
Survival during passage:field survey		
Estimate of the effect of selective mortality on adult pop. size: simulation model.		

TS.3 Given information available, what proportion of the target is sensitive to the hypothesized impact?

If possible, express the data on a numerical scale from 0 to 1 where

0 = no sensitivity

1 = all targets are sensitive to the hypothesized impact agent.

For example, if R is estimated for impingement sensitivity, give actual R values. If data are qualitative, score as shown below:

0 = no or very low sensitivity

0.25 = some sensitivity

0.5 = significant sensitivity

0.75 = high sensitivity

1.0 = extreme sensitivity (all targets are sensitive)

Collect information but do not enter on screen.

TS.4 Do any of the meteorological, environmental and/or biotic (life history) conditions associated with this target have an affect on its sensitivity rating?

Examples: increased turbidity during spring runoff periods will increase entrapment coefficient; seasonal changes in target distribution will change the sensitivity of mobile populations.

Y - yes; adjust the rating up or down to reflect the differences; go to TS.5

N - no, go to TS.5

TS.5 Choose from the following options:

TS1 - go to TS.1 to evaluate the sensitivity of additional targets for this impact agent

TS6 - go to TS.6 to rank target sensitivity; all targets for this impact agent have been evaluated.

Type the appropriate letters and press RETURN.

TS.6 Rank the target sensitivity ratings for all targets considered for this impact agent, assigning 1 to the target having the lowest sensitivity, 2 to the one with the next lowest and so on. Assign the same rank to targets having equal sensitivity. Enter in column 10 in the Target Table: type TT <RETURN> to recall the table.

TS.7 Enter confidence ratings for TS in column 11.

5 - high confidence;
1 - low confidence

Type TT <RETURN> to recall table and enter.

TS.8 Assign a rating for potential long-term problems in column 12 of the Target Table, as follows:

1 - no long-term (temporal) problems anticipated
2 - the presence of a concentration of comparable power plants or other industrial or municipal impact agents within a 200 km distance on the same water body;
OR
sensitive targets of the following types:
i. juvenile life stages of any finfish or shellfish target
ii. chemical sensitivity to trace elements in a dominant food organisms (manifested either through increased mortality or bioaccumulation)
iii. thermal or chemical sensitivity of a major habitat former (e.g. macroalgae, filamentous algae, macrophytes).

OR
ratio of Vcw/Vwb as estimated in IMPACT AGENT was greater than X.
OR
other problems to be developed.

3 - the occurrence of both multiple plants and sensitive targets in the above list

Type TT <RETURN> to recall the table and enter.

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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<                                                                               >>
<            You are in TARGET CHOICE                                           >>
<                                                                               >>
<                                                                               >>
<            HELP Y/N?                                                          >>
<                                                                               >>
<                                                                               >>
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<                                                                               >>
<     {You should have:                                                         >>
<              1. a final list of potential targets for the impact              >>
<                 agent under consideration;                                    >>
<              2. an estimate for each target of the proportion of              >>
<                 the total target distribution that overlaps with              >>
<                 the impact agent and overlap rankings for all                 >>
<                 targets;                                                      >>
<              3. an estimate for each target of its sensitivity to             >>
<                 the impact agent and sensitivity rankings for all             >>
<                 targets.                                                      >>
<     These data will be used to complete the Target Table developed            >>
<     in TARGET SELECTION. }                                                    >>
<                                                                               >>
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<                                                                               >>
<     TS2.1 Check that the following information is in the                      >>
<           appropriate columns in ALL the Target Tables. You should            >>
<           have one table for each impact agent subcategory you                >>
<           considered.  If information is missing, insert as needed.           >>
<                                                                               >>
<     Recall tables by typing IAA1, IAA2, etc. <RETURN> for checking.           >>
<                                                                               >>
<                                                                               >>
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```

TS2.2 Column 6: Geographic overlap rankings for each target that remains on the list.

TS2.3 Column 7: Confidence rating for the confidence held in the geographic overlap rankings in column 6.

TS2.4 Column 8: Density fluctuation ranking for each target that remains on the list.

TS2.5 Column 9: Confidence ratings for the confidence held in the density fluctuation rankings in column 8.

TS2.6 Column 10: Target sensitivity rankings for each target that remains on the list.

TS2.7 Column 11: Confidence rating for the confidence held in the target sensitivity rankings in column 10.

TS2.8 Column 12: Long-term probability scores from TARGET SENSITIVITY.

TS2.9 Conduct a final screening using TARGET SCREENING CHOICE for each impact agent subcategory.

Call the CHOICE subroutine by typing CHOICE <RETURN>

LEVEL OF CERTAINTY MENU

ALTERNATIVE HYPOTHESES

Answer the following questions about alternative hypotheses by entering the appropriate answer:

	Yes	No	Did not consider	Does not apply
1. If there are significant meterological, oceanographic or hydrologic events in the plant vicinity which could affect monitoring program targets (e.g. upwelling, tidal fluctuations, river runoff), have you formulated an alternative hypothesis(es) representing the condition(s)?	yes	no	dnc	dna
2. If there are significant resource extraction or renewal activities in the plant vicinity which could affect monitoring program targets, have you formulated an alternative hypothesis(es) representing the activity(ies)?	yes	no	dnc	dna
3. If there are significant energy facilities other than the power plant or other industrial activities in the plant vicinity which could affect monitoring program targets, have you formulated an alternative hypothesis(es) representing the activity(ies)?	yes	no	dnc	dna

4. If there are significant waste disposal activities in the plant vicinity which could affect monitoring program targets, have you formulated an alternative hypothesis(es) representing the activity(ies)?

yes no dnc dna

5. If there are significant uses of land in the plant vicinity which could affect monitoring program targets (e.g. urban, agricultural, transportation), have you formulated an alternative hypothesis(es) representing the activity(ies)?

yes no dnc dna

If you answered "no" or "did not consider" to any of the questions you will be routed to ALTERNATIVE HYPOTHESES in the HYPOTHESIS GENERATION soubroutine. Otherwise, you will go on to QUESTION 1.2.

Please continue by entering a carriage return.

LEVEL OF CERTAINTY MENU

TARGET SELECTION

Answer the following questions about your target by entering the appropriate answer:

	Yes	No	Did not consider
1. Does a strong public interest exist for monitoring this target (e.g. rare/endangered species)	yes	no	dnc
2. Does this target have any economic importance either as a commercial or as a sport (or both) commodity?	yes	no	dnc
3. Does this target play a dominant or unique ecological role in this system?	yes	no	dnc

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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                         >>
<<     4. Is the major portion of                                          >>
<<        the geographic distribution                                      >>
<<        of this target located outside                                   >>
<<        the vicinity of the impact agent?      yes     no     dnc        >>
<<                                                                         >>
<<                                                                         >>
<<                                                                         >>
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<<                                                                         >>
<<     If you answered "no" or "did not consider" to any of the            >>
<<     questions you will be routed to TARGET SELECTION. Otherwise, you    >>
<<     will go on to QUESTION 2.2 . Please continue by entering a          >>
<<     Carriage Return                                                     >>
<<                                                                         >>
<<                                                                         >>
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LEVEL OF CERTAINTY MENU

TARGET OVERLAP

Answer the following questions about the spatial and temporal distribution of your target by entering the appropriate response:

Yes No Did not consider

1. Can you describe the vertical distribution of the target with respect to the impact agent (e.g. the outfall plume)? yes no dnc

2. Can you describe the alongshore distribution of the target with respect to the impact agent? yes no dnc

3. Can you describe the distribution of the target offshore from the impact agent (orthogonal)? yes no dnc

4. Do you know the distribution of the target in the vicinity of the impact agent and can you express this distribution as a proportion of the target's geographic range? yes no dnc

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<                                                                         >>
<         If you answered "no" or "did not consider" to any of the       >>
<    questions you will be routed to TARGET OVERLAP. Otherwise            >>
<    you will go on to QUESTION 2.2.                                      >>
<                                                                         >>
<    Please continue by entering a carriage return.                       >>
<                                                                         >>
<                                                                         >>
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LEVEL OF CERTAINTY MENU

TARGET SENSITIVITY

Answer the following questions about the sensitivity of your target by entering the appropriate response:

	Yes	No	Did not consider
1. Can you state what proportion of the target (population) is sensitive to the hypothesized impact?	yes	no	dnc
2. Do you know how meteorological, environmental and/or biotic conditions affect the target's sensitivity?	yes	no	dnc
3. Can you describe the potential for long-term change to the target (population) as a result of interaction between the impact agent and especially vulnerable life stages or the occurance of multiple impact agents of the same type in the vicinity?	yes	no	dnc

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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                             >>
<<     If you answered "no" or "did not consider" to any of the                >>
<<     questions you will be routed to TARGET SENSITIVITY. Otherwise,          >>
<<     you will go on to QUESTION 2.3. Please continue by entering a           >>
<<     carriage return                                                         >>
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HELP

A BRIEF DESCRIPTION OF EPAM AND ITS SUBROUTINES

The University of Washington model, EPAM (a model for Electric Power Aquatic Monitoring) functions to guide a user (i.e., one who must design an aquatic monitoring program in the development of a cost-effective and scientifically valid monitoring program to evaluate the existence, or lack thereof, of ecological change in an aquatic ecosystem due to electrical power generation at a thermal power plant.

EPAM has four basic functions:

1. the development of a list of monitoring program targets (i.e., ecosystem components, including such things as individual species, community indicators, chemical parameters, etc.) that have a high likelihood of being affected by plant operation or design ·

2. the development of a list of hypotheses of impact which will serve to guide the structure of the monitoring program; it is assumed that a monitoring program will typically include one, or more hypotheses of impact;

3. the development of the actual sampling program for testing each of the hypotheses that is incorporated into the monitoring program;

4. a optimization routine that designates targets, hypotheses, and sampling stations and/or replicates based on measurement capability (due to best techniques, a low variance component, low cost, etc.), sensitivity to impact, or scientific value. The final version of this subroutine optimizes the tradeoff between dollars expended (cost) and increased accuracy in the monitoring program (error).

EPAM is structured into four hierarchical levels which correspond to 1. the different stages in monitoring program design in which a user might find him- or herself (e.g. components to be measured are known but program hypotheses are not established; design has been developed but user is uncer tain that it is optimal in terms of dollars expended)· and 2. the four functions of the design process (e.g. designation of what should be measured, development of hypotheses, development of the sampling design and optimization of the whole program, as described above.

EPAM is an interactive model which will be written in FORTRAN 77 and will be initially operational on a VAX/VMS system. Each level of the model (Figure 1) is structured into subroutines which ask the user to insert, or develop and insert, information about each of the functions described above. The first five subroutines (Level 3 and the first part of Level 2) develop and refine the list of targets; the second two subroutines (Level 2) formulate the expected impacts on each of these targets into testable hypotheses;

the next subroutine (Level 1) develops the sampling design; while the last subroutine (Level 0) exercises a final optimization. Interim optimization routines are invoked to prioritize choices in the final target-oriented subroutine and in the last hypothesis-oriented subroutine.

INTRODUCTION - introduces user to EPAM, its goals, components and operational mode.

IMPACT AGENT (1) - allows user to identify the mechanisms which are likely to cause problems at the site in question. These so-called impact agents occur as a result of plant operation and design. They include such things as the entrainment of organisms through the cooling system, toxicity due to the use of defouling agents, degradation of the benthic habitat due to jet diffusers on the outfall structure, and so forth. At the moment, EPAM includes four impact agent categories: A. Chemical/Physical Alterations-Abiotic Effects; B. Impingement/Entrainment-Biotic Effects; C. Water Quality Degradation Biotic Effects; D. Habitat Disruption-Biotic Effects. Other impact categories will be added if sufficient reason arises.

TARGET SELECTION (2) - allows user to identify a preliminary list of targets to be included in the monitoring program. A target is defined as any component of the ecosystem that can be measured in order to determine the existence, or lack thereof, of change. A target can be any quantifiable entity (e.g. nitrate, copper, salinity, phytoplankton, juvenile striped bass, etc.) that is deemed worthy of measurement in a monitoring program. The list of targets is evaluated and, if possible, reduced in size on the basis of three criteria: public interest (i.e. a legislative or historical mandate for monitoring), economic value (both sport and commercial), and environmental or ecological value.

TARGET OVERLAP (3) - allows user to identify those targets which demonstrate significant overlap with the impact agent in both time and space domains within their overall geographic range (relative to the impacted area) and on a local scale (within the local habitat available to the target in the impacted area). A user is required to designate the relative accuracy of these estimates, and the expected cost of collecting data having greater accuracy.

TARGET SENSITIVITY (4) - allows user to identify the relative sensitivity of each target to the hypothesized impact agent(s), given that the target has importance (public, economic, ecological) and is found in the area of potential impact. Again, the user must designate the relative accuracy of each estimate, and the cost of increasing the accuracy of the estimate by further data collection.

TARGET SCREENING (5) - presents a pair wise comparison choice program (CHOICE on the flow diagram) which allows the user to select among targets on the basis of their relative vulnerability to the impact agent (including the extent of physical overlap and sensitivity), and their importance in the public, economic and ecological spheres. CHOICE ranks all targets for each impact agent (using a mormalized scale, 0-1) on the basis of how each compares relative to all others for the criteria considered. CHOICE uses the eigenvalue-method for choosing among a variety of options on the basis of different criteria as developed by Thomas L. Saaty (1977) in "A Scaling

Method for Priorities in Hierarchical Structures" in the Journal of Mathematical Psychology 15:234-281.

HYPOTHESES GENERATION (6) - allows user to generate an initial list of quantitative and stable hypotheses of impact for the monitoring program by considering:

1. the expected impact;
2. the spatial scale of the expected impact;
3. the temporal scale of the expected impact;
4. the severity of the expected impact initially described as a function of spatial and temporal dimensions);
5. the type, cost and accuracy of the variable(s) necessary to measure the expected impact;
6. complementary hypotheses (a complementary hypothesis is defined as a hypothesized change that occurs as an indirect result of another hypothesis, e.g. impingement mortality may cause a decline in population size of a planktivorous finfish species; this decline may, in turn, result in an increase in the size of the zooplankton population due to reduced predation);
7. the potential for falsificaton of the hypothesis as a result of alternative explanations for the expected impact (e.g. a commercial fishery may be responsible for the decline in population size of a finfish species instead of mortality due to impingement).

HYPOTHESIS SCREENING (7) - presents a second version of the CHOICE program which allows the user to eliminate those hypotheses which rank poorly when compared against all others on the list on the basis of the criteria established in HYPOTHESIS GENERATION (2, 3, 4, 5, and 7 above), the first CHOICE score, established in TARGET SCREENING, and the confidence the user has in the data on which that score was based (i.e., data to describe target overlap, target sensitivity, etc.)

SAMPLING DESIGN (8) - uses the information collected in previous subroutines to develop a preliminary sampling design (station locations, sampling frequencies, and number of replicates) for each of the hypotheses that remained part of the monitoring program following HYPOTHESIS SCREENING. In particular, SAMPLING DESIGN calls for information about the spatial and temporal distribution of each target and the expected variance associated with the user in designating appropriate methods for statistical analysis of the data base and considers conditions under which simulation models and/or specialized experimental studies might be implemented to improve the monitoring design.

OPTIMIZATION (9) - This final subroutine re-evaluates the sampling design on the basis of its expected costs and the effectiveness (ability to detect change if it exists) of the monitoring program. This latter measure is a function of the error (accuracy and precision) inherent in the data base. Sampling stations, sampling episodes and/or sampling replicates are eliminated, or added, in order to optimize the tradeoff between cost and effectiveness for each hypothesis kept in the final monitoring program. The optimization routines based on the Lagrangian multipler method and optimizes either for minimum cost (with fixed effectiveness) or maximum effectiveness (with fixed cost). OPTIMIZATION then gives the user a final version of the

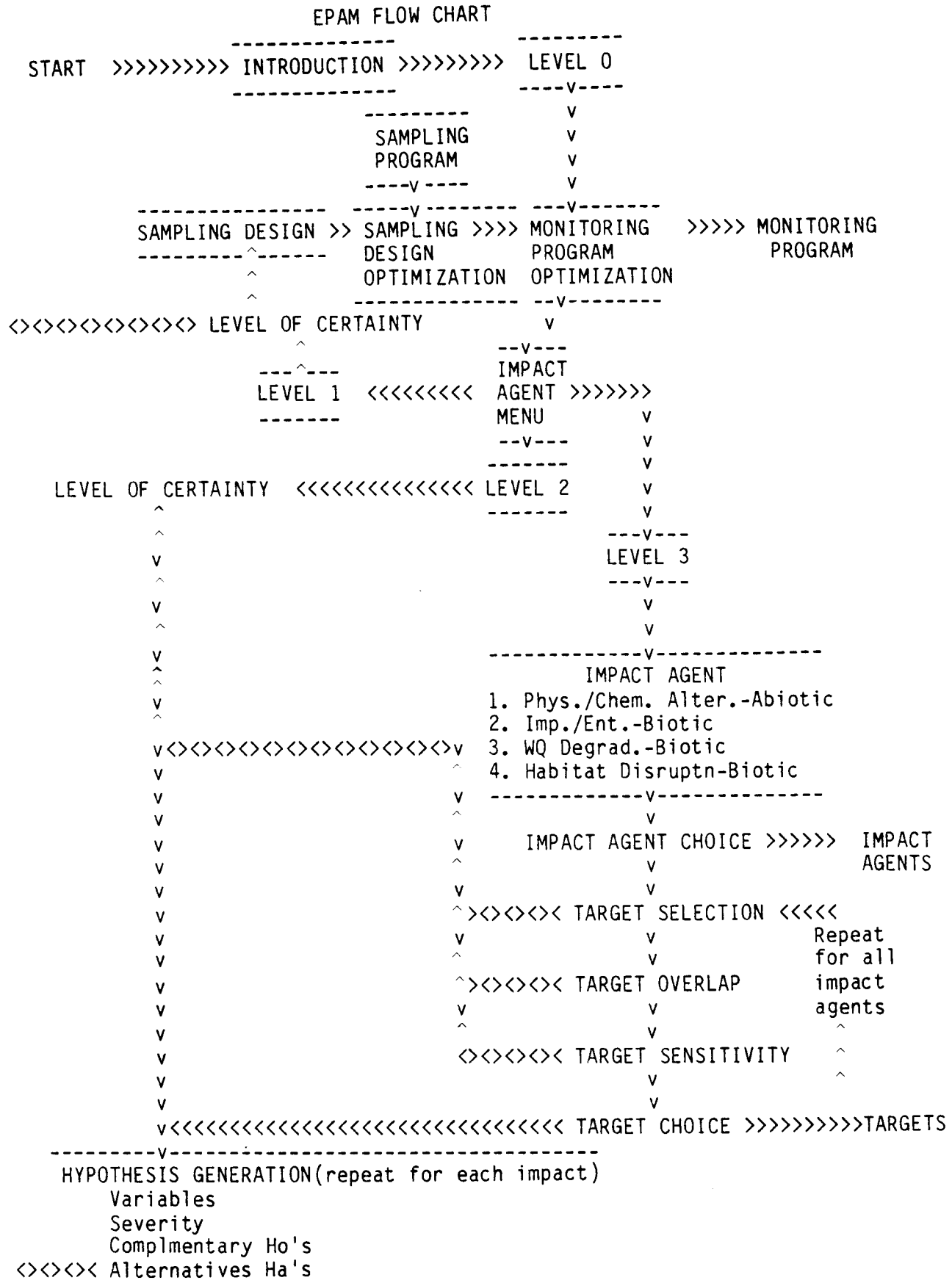
CHOICE program so that individual sections of the monitoring program can be eliminated if their optimal cost or effectiveness is determined (by the user) to be too high or too low.

TECHNIQUES - this subroutine presents a user with suggested methods for collecting the information base needed in the different subroutines. TECHNIQUES guides the user to consider both the cost expended and the accuracy gained when choosing among the different methods.

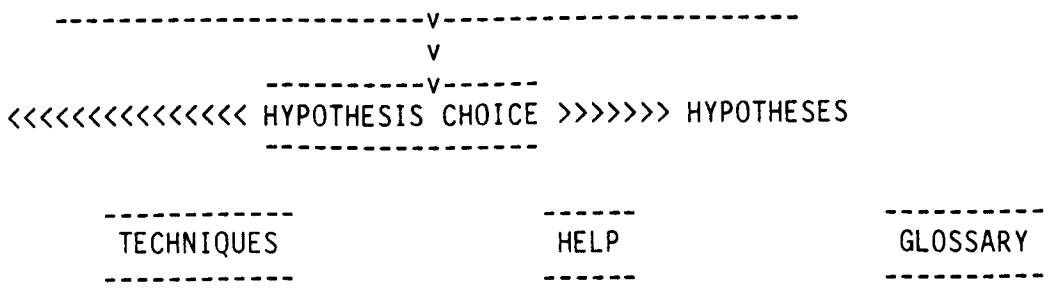
LEVEL OF CERTAINTY - this subroutine functions as a "policing" mechanism that helps to prevent a user from entering a given level or subroutine before the necessary background information has been assembled.

GLOSSARY - this subroutine defines all technical terms presented in EPAM.

HELP - this subroutine presents the user with instructions about the operational mode of EPAM's different sections. It also reminds the user of the function of each subroutine, its data needs and its final output.


EPAM FLOW CHART
START
INTRODUCTION
LEVEL 0
SAMPLING PROGRAM
SAMPLING DESIGN
SAMPLING DESIGN OPTIMIZATION
MONITORING PROGRAM OPTIMIZATION
MONITORING PROGRAM
LEVEL OF CERTAINTY
LEVEL 1
IMPACT AGENT MENU
LEVEL 2
LEVEL 3
IMPACT AGENT
1. Phys./Chem. Alter.-Abiotic
2. Imp./Ent.-Biotic
3. WQ Degrad.-Biotic
4. Habitat Disruptn-Biotic
IMPACT AGENT CHOICE
IMPACT AGENTS
TARGET SELECTION
Repeat for all impact agents
TARGET OVERLAP
TARGET SENSITIVITY
TARGET CHOICE
TARGETS
HYPOTHESIS GENERATION(repeat for each impact)
Variables
Severity
Complmentary Ho's
Alternatives Ha's

EPAM Flow Chart Cont.



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<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>
<<                                  >>
<<            GLOSSARY              >>
<<                                  >>
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Page through glossary by pressing <RETURN>
Return to program by entering <CTRL>Z

ASSESSMENT - The estimation or determination of the significance or importance of observed effects as measured in a monitoring program.

COMMUNITY LEVEL EFFECTS - Effects manifested in all of the populations that occupy a specific geographic area.

DIRECT EFFECTS - Effects that are clearly caused by the plant operation and can be measured as such by the collection of samples (e.g. numbers of ichthyoplankton impinged on a screen in a set period of time).

ECOSYSTEM LEVEL EFFECTS - Effects manifested in the community(ies) and the nonliving environment that function together as an ecological system in a specific geographic area.

EFFECTS - Physical, chemical, or biological changes in any phenomenon that manifest deviation from from the usual historical condition of that entity. Effects can be either positive or negative.

FAR-FIELD EFFECTS - Effects manifested in the area of the water body beyond the plant, its intake and discharge; in the water body as a whole; and even, in the case of migratory species, beyond the water body on which the plant(s) is(are) located.

INDIRECT EFFECTS - Effects that cannot necessarily be attributed to plant operation by an immediate set of measurements. Such secondary effects may result from direct effects. Measurement of such effects usually requires that cause/effect mechanisms be hypothesized and elucidated (e.g. change in prey density as a result of increased predator mortality).

INTERACTIVE SOFTWARE - A CRT screen-oriented computer program or family of programs that presents a dialog prompting user input and decisions to aid computer applications or computation.

LONG TERM EFFECTS - Effects manifested on a time scale that is long relative to important biological generation periods. Such effects are typically manifested over a period greater than one year and may operated on a time scale that is comparable to plant life (i.e. 20 to 50 years). Long term effects may or may not result from short-term effects. Long-term effects are chronic (in the sense of lasting a long time). No judgement is implied relative to significance. There is a continuous time gradient from short-term to long-term effects: the seperation made herein is simply heuristic.

MONITORING (PROGRAM) - The process of data collection, analysis, and interpretation to establish the state of an (aquatic) ecosystem in both time and space domains. Monitoring can include sytematic ("routine") surveillance or experimental/special studies or some combination of both.

MONITORING PROGRAM DESIGN - The determination of the number and types of samples to be taken in time and space to test a given set of hypotheses concerning the response of the aquatic environment to the presence of a power plant. The types of analyses to be used for data reduction and interpretation and specification of simulation models and cost-effectiveness models, if such models will be used are part of the program design.

NEAR-FIELD EFFECTS - Effects manifested in the immediate vicinity of the plant, its intake and discharge areas. In this project, near-field is not necessarily the zone of discharge dilution.

POPULATION LEVEL EFFECTS - Effects manifested in a group of organisms of one kind (i.e. the same species) that occupy a specific geographic area.

SAMPLING - The act of obtaining physical, chemical, or biological measurements or specimens in the field.

SAMPLING DEVICE - Equipment which can selectively capture biological organisms or chemical water samples from the aquatic environment.

SHORT-TERM EFFECTS - Effects manifested on a time scale that is short relative to important biological life spans and the period of plant operation (response is rapid). Such effects are typically manifested immediately or in a period of less than one year but may continue indefinitely (until a new set of conditions is present). No judgement is implied relative to significance.

TECHNIQUES

NOTE: ALL TECHNIQUES MENUS WILL BE DEVELOPED IN GREATER DETAIL IF A MUTUAL DECISION IS MADE TO INCORPORATE TECHNIQUES INTO PHASE III. THE BASIC FORMAT SHOWN BELOW WILL BE UTILIZED IN THAT EVENT.

TECHNIQUES is designed to help a user collect information about any topic for which data are needed in order to complete a given section of EPAM.

TECHNIQUES provides a user with a variety of different methods of data collection. The different options are described on the basis of:

1. the type of technique (e.g. field survey, literature review, etc.)
2. the relative error associated with the technique
3. the relative cost of implementing each technique (the user provides actual costs once a given technique is implemented).

During initial development of the monitoring program, a user should use the least expensive option available which provides the necessary data. This may be little more than an educated guess. This will allow the user to move through the model and be exposed to its complete structure and underlying logic before being required to expend any significant resources.

Later when the model requirements, goals and assumptions become clearer to the user, he or she may wish to return to a particular TECHNIQUES section and implement a higher level option. At that point, the decision to expend resources to obtain information about a particular topic in order to gain increased accuracy may make more sense.

```
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<                     TECHNIQUES MENU                                      >>
<                                                                          >>
<   TMSD -TECHNIQUES MENU, SPATIAL DIMENSIONS (of an impact agent)         >>
<                                                                          >>
<   TMTS -TECHNIQUES MENU, TARGET SELECTION 1 (list of potential targets   >>
<                                                                          >>
<   TMTO -TECHNIQUES MENU, TARGET OVERLAP (geographic range of organisms   >>
<          and baseline chemical/physical conditions)                      >>
<                                                                          >>
<   TMTSIE -TECHNIQUES MENU, TARGET SENSITIVITY to IMPINGEMENT and         >>
<            ENTRAINMENT                                                   >>
<                                                                          >>
<   TMTST -TECHNIQUES MENU, TARGET SENSITIVITY to THERMAL LOADING          >>
<                                                                          >>
<   TMTSC -TECHNIQUES MENU, TARGET SENSITIVITY to CHEMICAL CHANGES         >>
<                                                                          >>
<   TMTSH -TECHNIQUES MENU, TARGET SENSITIVITY to HABITAT ALTERATIONS      >>
<           Type the appropriate letters and press RETURN.                 >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<                                                                          >>
<              TECHNIQUES MENU, SPATIAL DIMENSIONS (TMSD)                  >>
<                                                                          >>
<        TMSD presents the user with options for evaluating the            >>
<    spatial distribution of an impact agent. The impact agents            >>
<    considered include categories A, B, C, and D. The cost of             >>
<    implementing the option chosen by the user will be added to the      >>
<    total cost of the monitoring program. Cost data are presented on     >>
<    a relative scale only since the actual dollars expended will be      >>
<    site and utility dependent. The error associated with the option     >>
<    will be reflected in the cumulative confidence of the user in        >>
<    the hypothesis(ses) generated. If, at the end of HYPOTHESIS           >>
<    GENERATION, a given hypothesis appears to be central to the          >>
<    monitoring program, it may benefit the user to return to TMSD        >>
<    and select a more detailed option in order to increase               >>
<    confidence in that particular program element.                       >>
<                                                                          >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
```

Technique	Error	Cost (relative scale)
1. existing in-house expertise	(increasing)	1
2. external expertise 'Delphi)		3
3. simulation model		4
4. field surveys		6
5. simulation model with field verification		10

TECHNIQUES MENU, TARGET SELECTION (TMTS)

TMTS presents the user with method options for developing initial lists of potential biotic and abiotic targets for monitoring programs.

Technique	Error	Cost (relative scale)
1. existing in-house expertise	(increasing)	1
2. external expert		2
3. literature review		3
4. panel of external experts (Delphi)		3
5. 1-dimensional pilot survey		6
6. n-dimensional pilot survey		10+

TECHNIQUES MENU, TARGET OVERLAP (TMTO)

TMTO presents the user with method options to evaluate the geographic range of a biotic target or the baseline (pre-plant operation) chemical or physical conditions.

Technique	Error	Cost (relative scale)
1. existing in-house expertise	(increasing)	1
2. records of federal and/or state fish and wildlife agencies; other data collection agencies (e.g. USGS)		2
3. commercial and sport catch data (fin- and shellfish species of economic interest only)		2-3
4. panel of external experts (Delphi)		3
5. 1-dimensional pilot survey		6
6. n-dimensional pilot survey		10+

TECHNIQUES MENU, TARGET SENSITIVITY TO IMPINGEMENT OR ENTRAINMENT (TMTSIE)

Technique	Error	Cost (relative scale)
1. literature survey	(increasing)	3
2. data from similar plant at similar sites		4-5
3. historical data from this site		4
4. field surveys coupled with historical data		8-10

TECHNIQUES MENU, TARGET SENSITIVITY TO THERMAL LOADING (TMTST)

Technique	Error	Cost (relative scale)
1. literature survey (thermal tolerance data)	/ (increasing)	3
2. historical data from sites with similar targets and thermal regimes		4-5
3. historical data from this site		4
4. experimental studies of thermal tolerance (acute)		6-10
5. experimental studies of thermal tolerance (chronic)		15+

TECHNIQUES MENU, TARGET SENSITIVITY TO CHEMICAL CHANGES (TMTSC)

Technique	Error	Cost (relative scale)
1. literature survey (EPA, state or other published criteria for chemical sensitivity of targets present)	/ (increasing)	3
2. historical data from similar sites		4-5
3. historical data from this site		4
4. experimental studies of chemical sensitivity (acute)		6-10
5. experimental studies of chemical sensitivity (chronic)		15+

TECHNIQUES MENU, TARGET SENSITIVITY TO HABITAT DEGRADATION (TMTSH)

Technique	Error	Cost Relative
1. literature survey	(increasing)	3
2. historical data at similar sites		4-5
3. historical data at this site		4
4. laboratory studies		10+
5. experimental field manipulations		15+

Appendix C.3

EXAMPLE USE OF EPAM

As an illustration of the application of EPAM to actual data, the San Onofre Nuclear Generating Station (SONGS) of Southern California Edison (SCE) was used as a case study. An interactive computer session was recorded in which potential impact agents and targets were identified and selected for study; then hypotheses were developed for an aquatic monitoring program at SONGS. The record of the session is included on the following pages. The printout has been annotated in the right margin at various points to indicate the logic behind choices made and references for the entries, and to provide notes to guide the reader. To save space only one example has been included for sections of the exercise which were repetitive. Such sections include TARGET SELECTION, TARGET OVERLAP, and TARGET SENSITIVITY (LEVEL 3) AND HYPOTHESIS GENERATION (LEVEL 2). The full process was presented for a single target in the LEVEL 3 subroutines and for one primary hypothesis and one associated alternative hypothesis in LEVEL 2. CHOICE also involves a considerable amount of repetitive input and printout and is called in the IMPACT AGENT CHOICE, TARGET CHOICE, and HYPOTHESIS CHOICE subroutines. In the IMPACT AGENT portion of LEVEL 3, a complete record is included only for the first occurrence. The example record does contain the final results of target identification (Target Tables) and prioritization (TARGET CHOICE) for each impact agent considered and a full listing of candidate primary hypotheses of impact and their associated alternative hypotheses, along with their overall ranking (HYPOTHESIS CHOICE).

CASE STUDY SITE DESCRIPTION

SONGS consists of three base-load, nuclear-fueled units with capacities of 436 MW for Unit 1 and 1087 MW each for Units 2 and 3 (Southern California Edison Company, 1983a). It is located in Northern San Diego County, California, in an open coastal setting. Unit 1 began commercial service in 1968 but has operated intermittently in recent years, although cooling water circulating pumps run rather continuously. Unit 2 began low power testing in

1982 and will be in full power service soon. Unit 3 currently is in low-power testing.

The three units have separate once-through cooling water intake and discharge systems. The following descriptions of these systems were provided by Southern California Edison Company (1983a).

For cooling Unit 1,

> seawater is drawn from a point 977.4 m (2977 ft) offshore at a water depth of approximately 8.2 m (27 ft). The offshore intake structure is a riser fitted with a velocity cap designed to reduce the entrapment of marine organisms. Water is drawn horizontally from the water column at a depth of 3 to 4 m. After passage through the intake conduit and the condensers, the cooling water travels through a discharge conduit which terminates in a vertical discharge structure located 750.4 m (2,462 ft) offshore in approximately 7.6 m (25 ft) of water. The discharge results in a surface-oriented thermal plume. Under normal operating, the temperature of the cooling water is raised approximately 22F across the condensers at flow rate of 1,211 m^3/min (320,000 gpm).

In the cases of Units 2 and 3,

> the once-through cooling system is expected to have a flow rate of 3,137 m^3/min (830,000 gpm) for each unit and a normal operational temperature increase across the condensers of 19.2°F... the intakes are located 970.2 m (3,183 ft) offshore in 9.8 m (32 ft) of water. Both units have diffuser type discharges consisting of 63 ports spread over a distance of 750 m (2,462 ft). The Unit 2 discharge diffuser extends from 1,795 m (5,888 ft) to 2,545 m (8,350 ft) offshore (measured from the screenwell ....) and ranges in depth from 11.9 m (39 ft.) to 14.9 m (49 ft). The Unit 3 discharge diffuser extends from 1,084 m (3,558 ft) to 1,835 m (6,020 ft) offshore and ranges in depth from 9.8 m (32 ft) to 11.6 m (38 ft).

The three units' screenwell systems are described in greater detail below.

> The Unit 1 screen well contains traveling screens and bar racks to remove debris and entrapped marine organisms from the cooling water before it reaches the pumps and steam condensers. The Units 2 and 3 screenwells contain fish guidance and return systems in addition to the traveling screens and bar racks. The fish handling systems consist of a series of vertical louvers that guide any entrapped fish to a large quiet-water area in the screenwell, fish elevators that remove the fish from the screenwells, and a 4 ft diameter water conduit that returns the fish to the ocean, depositing them 579 m (1,900 ft) offshore. The fish return conduit is common to both units.

Marine biofouling control at all units consists of chlorination for condenser tube defouling and heat treatment by thermal backwash for removing

mussels and barnacles in the intake conduits and screenwells. Chlorination occurs approximately three times per day on one-half of a condenser at a time for 10-15 minutes. The target total residual chlorine (TRC) concentration is 0.5 mg/l at the condenser discharge. The TRC standard at discharge to sea is also 0.5 mg/l and is met easily through chlorine demand and substantial dilution by other flows (Palmer, 1983). Thermal backwash operates by recirculating a portion of the discharge water back through the condensers to attain an elevated temperature within the circulating water system. Gates and cross connections between intake and discharge conduits and the screenwell provide the means for flow reversal and recirculation.

SCE has given the thermal backwash system considerable attention at SONGS and other plants, and several studies have been performed to docuemnt and optimize its performance (Lockheed Center for Marine Research, 1977, 1978; Stock and De La Parra, undated). The current operating mode is a 38°C heat application in each screenwell for approximately 1.75 hours every 6-10 weeks, depending on the degree of fouling (southern California Edison Company, 1982). Heat treatment actually does not represent an impact agent separate from entrapment, since entrapped organisms perish with or without heat treatment at Unit 1 and are removed bythe fish return mechanism prior to heat treatment at the other units. The few organisms not returned represent a minor exception to this statement, since a heat treatment would end their chances of surviving until a subsequent return cycle.

```
$ RUN EPAM
  E
<<                                                                    >>
<<                    WELCOME TO EPAM                                 >>
<<                                                                    >>
<<       ANSWER ALL PROMPTS YES OR NO UNLESS                          >>
<<         INSTRUCTED OTHERWISE.  FOLLOW EACH                         >>
<<         ANSWER AND EACH "PAGE" WITH A <RETURN                      >>
<<                                                                    >>
<<         IF YOU NEED HELP TYPE HELP OR H.  IF                       >>
<<         YOU WANT TO SEE A FLOWCHART OF EPAM                        >>
<<         TYPE MAP                                                   >>
<<                                                                    >>
<<         DO YOU WANT TO SEE A FULL INTRODUCTION?                    >>
<<                                                                    >>
<<                                                                    >>
<<                                                                    >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
>> N
  E
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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<                                                                    >>
<<    Welcome to EPAM, a model for Electric Power Aquatic Monitoring  >>
<<                                                                    >>
<<      You are in LEVEL 0.                                           >>
<<                                                                    >>
<<      You must first decide if this level is the correct one for you.>>
<<      If so you will be given the opportunity to optimize your      >>
<<      monitoring program design.  If not you will be given instructions>>
<<      to place you in the proper level.  Throughout EPAM, type the  >>
<<      appropriate letter(s) from the given choices, and press RETURN>>
<<      to indicate your answer to a given question.                  >>
<<                                                                    >>
<<    0.1  Do you want to develop or optimize a monitoring program?   >>
<<                                                                    >>
<<          Y-yes  (develop a program (go to 0.2)                     >>
<<          N-no   (optimize an existing program, i.e. cost-effectively>>
<<                 allocate the sampling effort, go to OPTIMIZATION)  >>
<<                                                                    >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
% Y
  E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<                                                                    >>
<<                                                                    >>
<<                                                                    >>
<<    0.2 Do you have a good idea of the potential agents that may    >>
<<        create impacts that exist at this site or do you need help  >>
<<        in initial definition of the problems?                      >>
<<                                                                    >>
<<          N-no   (impact agents are known; go to IMPACT AGENT MENU, >>
<<                 SHORT FORM)                                        >>
<<          Y-yes  (help is needed in initial definition; go to IMPACT>>
<<                 AGENT MENU, LONG FORM)                             >>
<<                                                                    >>
%
```

>> signals responses required by EPAM.
E indicates carriage return.

IMPACT AGENT MENU SHORT FORM

Choose the possibilities that correspond most closely to conditions at your plant. You may list subcategories within the four basic groupings if appropriate. Label these subcategories IAA1, IAA2, IAB1, IAB2, etc.)

1 - IAA: PHYSICAL/CHEMICAL ALTERATIONS (ABIOTIC EFFECTS)
2 - IAB: IMPINGEMENT/ENTRAINMENT
3 - IAC: WATER QUALITY DEGRADATION
4 - IAD: HABITAT DISRUPTION

Enter the number or numbers (in sequence without commas) corresponding to the agent(s) of concern in your case. You will be routed sequentially through the program for each choice.

>> 1234

E

Q 3 Do you have hypothesis(es) of impact that describe potential ecological changes at your site? A hypothesis must define the target likely to be affected, the expected spatial and temporal dimension of the effect, the agent likely to be responsible for the effect and the variable that should be measured to evaluate the effect.

yes (go to LEVEL 1)
no (go on)

%

E

Q 4 Do you know the spatial and temporal dimensions of the action of the impact agent(s) operating at this site?

yes (go to LEVEL 2)
no (go to LEVEL 3)

%

>> N

E

```
                                LEVEL 3

     You are in LEVEL 3.  HELP Y/N?

%
>> N
  E
 <<<
 <<<      3.1  Have you selected the impact agent(s) likely
 <<<           to operate at your site?
 <<<
 <<<           Y - yes  (go to 3.4)
 <<<           N - no   (go to 3.2)
 <<<
 <<<
 <<<
 <<<
%
  E
>> N
 <<<
 <<<    3.2  Reconsider the IMPACT AGENT MENU, LONG FORM.  List all agents
 <<<         that may conceivably act at your site.  You may list
 <<<         subcategories within the four basic groupings if appropriate
 <<<         (e.g. specific chemicals in group IAA, impingement separate
 <<<         from entrainment in group IAB; thermal discharge and various
 <<<         chemicals in group IAC; modification of currents and
 <<<         sedimentation in group IAD).  Label these subcategories IAA1,
 <<<         IAA2, IAB1, IAB2, etc.  Press RETURN to return the menu to the
 <<<         the screen and make your selections.
 <<<
*
>>
  F
```

This menu will allow you to identify the types of causative mechanisms (impact agents) that might be operational at your site. These impact agents are typically chemical or physical changes that will occur as a result of interaction between some aspect(s) of plant design and/or operation and the aquatic ecosystem at that site. The first type of impact agent represents changes that occur in the chemical or physical components of the ecosystem. The targets measured to determine the existence of such changes are abiotic chemical or physical entities (e.g. the concentration of selenium, the velocity fields around the plant, etc.). The second, third, and fourth types all refer to impact agents that cause changes in some component of the biota around a plant. The targets for these impact agents are either organisms or some biotic aspect of the system, e.g. rate of primary production.

Choose the possibilities that correspond most closely to conditions at your plant. You may list subcategories within the four basic groupings if appropriate. Label these subcategories IAA1, IAA2, IAB1, IAB2, etc.

E

Which of the following impact agents concern you?

1 - IAA PHYSICAL/CHEMICAL ALTERATIONS (ABIOTIC EFFECTS)

Likely to occur if plant operation is conducive to the disruption of the ordinary physical and/or chemical environment including

- change in current patterns
- change in salinity gradients
- change in composition of benthic substrates
- change in the amount and/or character of suspended particles
- change in the concentration of macronutrients (N, P, C)
- change in the concentration of trace elements (metals, hydrocarbons, etc.)
- change in the temperature, pH, alkalinity, etc.
- increased concentrations of various biofouling control substances (e.g. chlorine)

E

2 - IAB IMPINGEMENT/ENTRAINMENT (BIOTIC EFFECTS)

Likely to occur if any of the following occur in or around the vicinity of the intake during all or parts of the year:

- shoaling fish
- abundant, small fish
- ichthyoplankton or large zooplankton
- small zooplankton or phytoplankton
- organisms that are very active in terms of daily movement
- pelagic nekton
- volume of cooling water relative to the volume of waterbody is large (Delphi issue)
- several power plants are located on the same waterbody within 500 km (< or >, Delphi issue)
- the total volume of water going through the plant alone, or through all the power plants located within the 500 km area, is more than X% of the volume of the water body (or in the case of open water bodies the effective water body) (Delphi issue)

Conditions of Potential Concern at SONGS

IAA:
(a) Increased suspended particles due to redistribution of turbid bottom waters by Units 2 and 3 diffusers (DeMartini, 1981).
(b) Increased nutrient concentrations (DeMartini, 1981), due to diffuser action.
(c) Increased trace metal concentrations due to condenser tube and sheet piling erosion and dissolution (Palmer, personal communication).
(d) Increased chlorine or chlorine - containing compound concentrations (DeMartini, 1981).
(e) Increased BOD and solids concentrations due to wastewater treatment plant effluent (Palmer, personal communication).

IAB: All organisms listed occur in SONGS - area waters. Impingement of nekton and entrainment of ichthyoplankton are recognized potential problems (Southern California Edison Co., 1983; 1983).

3 - IAC WATER QUALITY DEGRADATION (BIOTIC EFFECTS)

Likely to occur if any of the following are found in or around the discharge plume area or the area to which the discharge of polluted waters (either by chemicals or heat) from the cooling system or treatment/disposal occurs

- sessile and/or attached organisms
- organisms having reduced free mobility (ichthyoplankton)
- attached plants (e.g. kelp, filamentous algae)
- motile organisms attracted to plume area due to thermal, feeding, or habitat presence, or increased protection
- volume of polluted water discharge is large relative to the volume of the water body

IAC: (a) Heat treatment effect on fish inhabiting Units 2, 3 screenwells and not removed by fish return mechanism.
(b) Chlorine effect on marine biota (DeMartini, 1981).
(c) Thermal effect of discharge on marine biota.
(d) Effects of wastewater treatment effluent on marine biota (Palmer, personal communication).
(e) Effects of trace metals on marine biota (Palmer, personal communication).

4 - IAD: HABITAT IMPACTS

Likely to occur if any of the following are found in or around areas that have been changed physically by the discharge plume or some other aspect of the plant, or its operation.

- sessile and/or attached organisms
- attached plants
- motile organisms frequently associated with benthic substrates
- organisms that depend upon current patterns for dispersion

IAD: (a) Modification of predator/prey interactions by Units 2, 3 diffusers (DeMartini, 1981).
(b) Shear stress on fish created by Units 2, 3 diffusers (DeMartini, 1981)
(c) Effects of suspended particles on kelp, kelp bed fishes, and subtidal community (DeMartini, 1981).

```
>>
 E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                              >>
<<   5 - MORE INFORMATION IS NEEDED TO CHOOSE                                   >>
<<                                                                              >>
<<   I do not know enough about the conditions at this site to classify         >>
<<   potential effects into the above categories  I need to have more           >>
<<   information before I make this selection  (You will be routed              >>
<<   directly to LEVEL3.                                                        >>
<<                                                                              >>
<<   Enter the number or numbers (in sequence without commas)                   >>
<<   corresponding to the agents of concern in your case   You will be          >>
<<   routed sequentially through the program for each choice                    >>
<<                                                                              >>
<<                                                                              >>
<<                                                                              >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> 1234
  E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

<<<
<<<   3.3  You will next proceed to IMPACT AGENT CHOICE to prioritize the
<<<         agents on your list and make final selections for consideration

<<<         in the remainder of the analysis   Do you wish to eliminate
<<<         any selections on the tentative list before exercising CHOICE
<<<         (those clearly of less importance or probability of occurance
<<<         than others)   Decide upon criteria to employ in evaluating
<<<         agents in CHOICE   When you are ready, press RETURN and you
<<<         will be routed to IMPACT AGENT CHOICE
<<<                                                                          >>>>
<<<                                                                          >>>>
<<<                                                                          >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
*
>>
     E
```

<u>Potential Impact Agents</u>

IAA. Abiotic Conditions
- IAA1. Residual chlorine and/or chlorine-containing compound concentrations
- IAA2. Measure of suspended particles or light transmittance
- IAA3. Nutrient concentrations

IAB. Impingement/Entrainment

IAC. Water Quality Degradation
- IAC1. Anti-biofouling heat treatment
- IAC2. Chlorination
- IAC3. Thermal
- IAC4. Wastewater treatment
- IAC5. Condenser tube material (copper)
- IAC6. Sheet piling (iron, zinc)

IAD. Habitat Modification (units 2, 3 diffusers)
- IAD1. Disruption of predator/prey interactions
- IAD2. Shear stress
- IAD3. Turbidity

```
 THIS IS THE CHOICE PROGRAM


 ENTER TITLE OF MATRIX ANALYSIS OR MAIN OBJECTIVE
>> IMPACT AGENT CHOICE
 ENTER NUMBER OF CRITERIA
>> 3
 ENTER VARIABLE NAME FOR CRITERIA            1
>> FREQUENCY
 ENTER VARIABLE NAME FOR CRITERIA            2
>> MAGNITUDE
 ENTER VARIABLE NAME FOR CRITERIA            3
>> SEVERITY
 ENTER THE NUMBER OF ELEMENTS, AN ELEMENT IS A
 TARGET, HYPOTHESIS, ETC.
>> 8
 ENTER THE NAME OF ELEMENT                   1
 ENTER THE NAME OF ELEMENT                   2
>> IAA1/IAC2-CHLORINE
 ENTER THE NAME OF ELEMENT                   3
>> IAA2/IAD3-TURBIDITY
>> IAA3-NUTRIENTS
 ENTER THE NAME OF ELEMENT                   4
>> IAA4/IAC6-METALS
 ENTER THE NAME OF ELEMENT                   5
>> IAB-IMPACT
 ENTER THE NAME OF ELEMENT                   6
>> IAC1-HEAT TREATMENT
 ENTER THE NAME OF ELEMENT                   7
>> IAD1-PRED./PREY DISRUP
 ENTER THE NAME OF ELEMENT                   8
>> IAD2-SHEAR STRESS
0

     THE HIERARCHY SET-UP IS


     OBJECTIVE

     IMPACT AGENT CH
```

Pre-Choice Elimination

IAC 3 (Maximum temperature increase over ambient ever measured in discharge plume = 2.2°c (Southern California Edison Company, 1982).)

IAC 4

IAC 5 (Units 2 and 3 have titanium alloy tubes, and Unit 1 condensers are in the process of conversion to titanium (Palmer, personal communications).)

IMPACT AGENT CHOICE will illustrate the full CHOICE process and printout. Only set-up and output will be shown for subsequent CHOICE subroutines.

```
     CRITERIA

     FREQUENCY
     MAGNITUDE
     SEVERITY

     ELEMENTS

     IAA1-CHLORINE
     IAA2/IAD3-TURBI
     IAA3-NUTRIENTS
     IAA4/IAC6-METAL
     IAB-IMP/ENT
     IAC1-HEAT TREAT
     IAD1-PRED./PREY
     IAD2-SHEAR STRE
 YOU WILL BE PROMPTED TO ENTER RATIOS OF THE WEIGHTS
 OF THE ELEMENTS WITH RESPECT TO CRITERIA          1
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAA2/IAD3-TURBI
>> .33
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAA3-NUTRIENTS
>> .33
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAA4/IAC6-METAL
>> .33
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAB-IMP/ENT
>> .33
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAC1-HEAT TREAT
>> 8
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAD1-PRED /PREY
>> .33
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAD2-SHEAR STRE
>> .33
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAA3-NUTRIENTS
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAA4/IAC6-METAL
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAB-IMP/ENT
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAC1-HEAT TREAT
>> 9
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAD1-PRED /PREY
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAD2-SHEAR STRE
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAA4/IAC6-METAL
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAB-IMP/ENT
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAC1-HEAT TREAT
>> 9
 ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAD1-PRED /PREY
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAD2-SHEAR STRE
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAA4/IAC6-METAL COLUMN IAB-IMP/ENT
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAA4/IAC6-METAL COLUMN IAC1-HEAT TREAT
>> 9
 ENTER PAIRWISE ELEMENT FOR ROW IAA4/IAC6-METAL COLUMN IAD1-PRED /PREY
```

Pairwise comparisons for Frequency criterion.

```
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAA4-IAC6 MP [illegible] COLUMN IAD2-SHEAR STRE
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAB IMP/ENT      COLUMN IAC1-HEAT TREAT
>> 9
 ENTER PAIRWISE ELEMENT FOR ROW IAB IMP/ENT      COLUMN IAD1-PRED /PREY
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAB IMP/ENT      COLUMN IAD2-SHEAR STRE
>> 1
 ENTER PAIRWISE ELEMENT FOR ROW IAC1-HEAT TREAT COLUMN IAD1-PRED /PREY
>> 11
 ENTER PAIRWISE ELEMENT FOR ROW IAC1-HEAT TREAT COLUMN IAD2-SHEAR STRE
>> 11
 ENTER PAIRWISE ELEMENT FOR ROW IAD1 PRED /PREY COLUMN IAD2-SHEAR STRE
>> 1
1

 WITH RESPECT TO :

 THE PAIRWISE COMPARISON MATRIX IS:
1.0000    0.3300    0.3300    0.3300    0.3300    8.0000    0.3300
0.3300
3.0303    1.0000    1.0000    1.0000    1.0000    9.0000    1.0000
1.0000
3.0303    1.0000    1.0000    1.0000    1.0000    9.0000    1.0000
1.0000
3.0303    1.0000    1.0000    1.0000    1.0000    9.0000    1.0000
1.0000
3.0303    1.0000    1.0000    1.0000    1.0000    9.0000    1.0000
1.0000
0.1250    0.1111    0.1111    0.1111    0.1111    1.0000    0.1100
0.1100
3.0303    1.0000    1.0000    1.0000    1.0000    9.0909    1.0000
1.0000
3.0303    1.0000    1.0000    1.0000    1.0000    9.0909    1.0000
1.0000

 THE MAXIMUM EIGENVALUE =    8.10

 ITS CORRESPONDING EIGENVECTOR IS
     0.3921    0.9989    0.9989    0.9989    0.9989    0.1005    1.0000
1.0000
 ITS NORMALIZED EIGENVECTOR IS
     0.0604    0.1540    0.1540    0.1540    0.1540    0.0155    0.1541
0.1541

 THE CONSISTENT COMPARISON MATRIX IS
1.0000    0.3925    0.3925    0.3925    0.3925    3.9027    0.3921
0.3921
2.5477    1.0000    1.0000    1.0000    1.0000    9.9430    0.9989
0.9989
2.5477    1.0000    1.0000    1.0000    1.0000    9.9430    0.9989
0.9989
2.5477    1.0000    1.0000    1.0000    1.0000    9.9430    0.9989
0.9989
2.5477    1.0000    1.0000    1.0000    1.0000    9.9430    0.9989
0.9989
0.2562    0.1006    0.1006    0.1006    0.1006    1.0000    0.1005
0.1005
2.5506    1.0011    1.0011    1.0011    1.0011    9.9543    1.0000
1.0000
2.5506    1.0011    1.0011    1.0011    1.0011    9.9543    1.0000
```

```
    1.0000

     THE DIFFERENCE COMPARISON MATRIX IS
     0.0000    0.0625    0.0625    0.0625    0.0625    4.9231    0.0621
    -0.0621
     0.4826    0.0000    0.0000    0.0000    0.0000   -0.9430    0.0011
     0.0011
     0.4826    0.0000    0.0000    0.0000    0.0000   -0.9430    0.0011
     0.0011
     0.4826    0.0000    0.0000    0.0000    0.0000   -0.9430    0.0011
     0.0011
     0.4826    0.0000    0.0000    0.0000    0.0000   -0.9430    0.0011
     0.0011
    -0.1312    0.0105    0.0105    0.0105    0.0105    0.0000    0.0095
     0.0095
     0.4797   -0.0011   -0.0011   -0.0011   -0.0011   -0.8634    0.0000
     0.0000
     0.4797   -0.0011   -0.0011   -0.0011   -0.0011   -0.8634    0.0000
     0.0000
 YOU WILL BE PROMPTED TO ENTER RATIOS OF THE WEIGHTS
 OF THE ELEMENTS WITH RESPECT TO CRITERIA           2
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE    COLUMN IAA2/IAD3-TURBI
>> .14
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE    COLUMN IAA3-NUTRIENTS
>> .25
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE    COLUMN IAA4/IAC6-METAL
>> .33
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE    COLUMN IAB-IMP/ENT
>> .11
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE    COLUMN IAC1-HEAT TREAT
>> .33
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE    COLUMN IAD1-PRED./PREY
>> .5
 ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE    COLUMN IAD2-SHEAR STRE
>> .33
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAA3-NUTRIENTS
>> 4
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAA4/IAC6-METAL
>> 6
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAB-IMP/ENT
>> .25
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAC1-HEAT TREAT
>> 8
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAD1-PRED./PREY
>> 5
 ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAD2-SHEAR STRE
>> 5
 ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAA4/IAC6-METAL
>> 2
 ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAB-IMP/ENT
>> .17
 ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAC1-HEAT TREAT
>> 6
 ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAD1-PRED./PREY
>> 2
 ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAD2-SHEAR STRE
>> 2
 ENTER PAIRWISE ELEMENT FOR ROW IAA4/IAC6-METAL COLUMN IAB-IMP/ENT
>> .11
 ENTER PAIRWISE ELEMENT FOR ROW IAA4/IAC6-METAL COLUMN IAC1-HEAT TREAT
>> 2
 ENTER PAIRWISE ELEMENT FOR ROW IAA4/IAC6-METAL COLUMN IAD1-PRED./PREY
>> 5
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Pairwise comparisons for Magnitude criterion.

```
 ENTER PAIRWISE ELEMENT FOR ROW IAA4/IAC6-METAL COLUMN IAD2-SHEAR STRE
>>  5
 ENTER PAIRWISE ELEMENT FOR ROW IAB-IMP/ENT      COLUMN IAC1-HEAT TREAT
>> 9
 ENTER PAIRWISE ELEMENT FOR ROW IAB-IMP/ENT      COLUMN IAD1-PRED /PREY
>> 7
 ENTER PAIRWISE ELEMENT FOR ROW IAB-IMP/ENT      COLUMN IAD2-SHEAR STRE
>> 7
 ENTER PAIRWISE ELEMENT FOR ROW IAC1-HEAT TREAT COLUMN IAD1-PRED /PREY
>>  5
 ENTER PAIRWISE ELEMENT FOR ROW IAC1-HEAT TREAT COLUMN IAD2-SHEAR STRE
>>  5
 ENTER PAIRWISE ELEMENT FOR ROW IAD1-PRED /PREY COLUMN IAD2-SHEAR STRE
>> 1
1


     WITH RESPECT TO :

     THE PAIRWISE COMPARISON MATRIX IS:
    1.0000    0.1400    0.2500    0.3300    0.1100    0.3300    0.5000
    0.3300
    7.1429    1.0000    4.0000    6.0000    0.2500    8.0000    5.0000
    5.0000
    4.0000    0.2500    1.0000    2.0000    0.1700    6.0000    2.0000
    2.0000
    3.0303    0.1667    0.5000    1.0000    0.1100    2.0000    0.5000
    0.5000
    9.0909    4.0000    5.8824    9.0909    1.0000    9.0000    7.0000
    7.0000
    3.0303    0.1250    0.1667    0.5000    0.1111    1.0000    0.5000
    0.5000
    2.0000    0.2000    0.5000    2.0000    0.1429    2.0000    1.0000
    1.0000
    3.0303    0.2000    0.5000    2.0000    0.1429    2.0000    1.0000
    1.0000

     THE MAXIMUM EIGENVALUE =   8.50

     ITS CORRESPONDING EIGENVECTOR IS:
        0.0549    0.5470    0.2288    0.1022    1.0000    0.0757    0.1291
    0.1358
     ITS NORMALIZED EIGENVECTOR IS:
        0.0242    0.2406    0.1006    0.0449    0.4399    0.0333    0.0568
    0.0597

     THE CONSISTENT COMPARISON MATRIX IS:
    1.0000    0.1004    0.2401    0.5377    0.0549    0.7255    0.4254
    0.4045
    9.9588    1.0000    2.3912    5.3545    0.5470    7.2256    4.2363
    4.0285
    4.1648    0.4182    1.0000    2.2393    0.2288    3.0218    1.7716
    1.6847
    1.8599    0.1868    0.4466    1.0000    0.1022    1.3494    0.7912
    0.7524
   18.2064    1.8282    4.3715    9.7890    1.0000   13.2096    7.7446
    7.3648
    1.3783    0.1384    0.3309    0.7410    0.0757    1.0000    0.5863
    0.5575
    2.3509    0.2361    0.5645    1.2640    0.1291    1.7057    1.0000
    0.9510
    2.4721    0.2482    0.5934    1.3287    0.1358    1.7936    1.0516
    1.0000
```

```
THE DIFFERENCE COMPARISON MATRIX IS
 0.0000    0.0396    0.0099    0.2077    0.0551    0.3955    0.0746
-0.0745
-2.8159    0.0000    1.6088    0.6455   -0.2970    0.7744    0.7637
 0.9715
-0.1648   -0.1682    0.0000   -0.2393   -0.0588    2.9782    0.2284
 0.3153
 1.1704   -0.0201    0.0534    0.0000    0.0078    0.6506   -0.2912
-0.2524
-9.1155    2.1718    1.5109   -0.6980    0.0000   -4.2096   -0.7446
-0.3648
 1.6520   -0.0134   -0.1643   -0.2410   -0.0354    0.0000   -0.0863
-0.0575
-0.3509   -0.0361   -0.0645    0.7360    0.0137    0.2943    0.0000
 0.0490
 0.5582   -0.0482   -0.0936    0.6708    0.0071    0.2064   -0.0516
 0.0000
YOU WILL BE PROMPTED TO ENTER RATIOS OF THE WEIGHTS
OF THE ELEMENTS WITH RESPECT TO CRITERIA          3
ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAA2/IAD3-TURBI
>> .25
ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAA3-NUTRIENTS
ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAA4/IAC6-METAL
>> .5
>> .5
ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAB-IMP/ENT
ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAC1-HEAT TREAT
>> .11
>> .5
ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAD1-PRED./PREY
ENTER PAIRWISE ELEMENT FOR ROW IAA1-CHLORINE   COLUMN IAD2-SHEAR STRE
>> .25
>> .25
ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAA3-NUTRIENTS
>> 4
ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAA4/IAC6-METAL
>> 4
ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAB-IMP/ENT
>> .25
ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAC1-HEAT TREAT
>> 3
ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAD1-PRED./PREY
>> 3
ENTER PAIRWISE ELEMENT FOR ROW IAA2/IAD3-TURBI COLUMN IAD2-SHEAR STRE
>> 3
ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAA4/IAC6-METAL
>> 3
ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAB-IMP/ENT
>> .14
ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAC1-HEAT TREAT
>> 3
ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAD1-PRED./PREY
>> 2
ENTER PAIRWISE ELEMENT FOR ROW IAA3-NUTRIENTS  COLUMN IAD2-SHEAR STRE
>> 2
ENTER PAIRWISE ELEMENT FOR ROW IAA4/IAC6-METAL COLUMN IAB-IMP/ENT
>> .13
ENTER PAIRWISE ELEMENT FOR ROW IAA4/IAC6-METAL COLUMN IAC1-HEAT TREAT
>> .5
ENTER PAIRWISE ELEMENT FOR ROW IAA4/IAC6-METAL COLUMN IAD1-PRED./PREY
>> .25
ENTER PAIRWISE ELEMENT FOR ROW IAA4/IAC6-METAL COLUMN IAD2-SHEAR STRE
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Pairwise comparisons for Severity criterion.

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>> .25
 ENTER PAIRWISE ELEMENT FOR ROW IAB IMP/ENT      COLUMN IAC1-HEAT TREAT
>> 5
 ENTER PAIRWISE ELEMENT FOR ROW IAB IMP/ENT      COLUMN IAD1-PRED /PREY
>> 6
 ENTER PAIRWISE ELEMENT FOR ROW IAB IMP/ENT      COLUMN IAD2-SHEAR STRE
>> 6
 ENTER PAIRWISE ELEMENT FOR ROW IAC1-HEAT TREAT COLUMN IAD1-PRED /PREY
>> 2
 ENTER PAIRWISE ELEMENT FOR ROW IAC1-HEAT TREAT COLUMN IAD2-SHEAR STRE
>> 2
 ENTER PAIRWISE ELEMENT FOR ROW IAD1-PRED /PREY COLUMN IAD2-SHEAR STRE
>> 1
1

     WITH RESPECT TO :

     THE PAIRWISE COMPARISON MATRIX IS:
    1.0000    0.2500    0.5000    0.5000    0.1100    0.5000    0.2500
    0.2500
    4.0000    1.0000    4.0000    4.0000    0.2500    3.0000    3.0000
    3.0000
    2.0000    0.2500    1.0000    3.0000    0.1400    3.0000    2.0000
    2.0000
    2.0000    0.2500    0.3333    1.0000    0.1300    0.5000    0.2500
    0.2500
    9.0909    4.0000    7.1429    7.6923    1.0000    5.0000    6.0000
    6.0000
    2.0000    0.3333    0.3333    2.0000    0.2000    1.0000    2.0000
    2.0000
    4.0000    0.3333    0.5000    4.0000    0.1667    0.5000    1.0000
    1.0000
    4.0000    0.3333    0.5000    4.0000    0.1667    0.5000    1.0000
    1.0000

     THE MAXIMUM EIGENVALUE =    8.73

     ITS CORRESPONDING EIGENVECTOR IS:
         0.0722    0.4402    0.2420    0.0830    1.0000    0.1833    0.1703
    0.1703
     ITS NORMALIZED EIGENVECTOR IS:
         0.0306    0.1864    0.1025    0.0351    0.4235    0.0776    0.0721
    0.0721

     THE CONSISTENT COMPARISON MATRIX IS:
    1.0000    0.1641    0.2985    0.8706    0.0722    0.3941    0.4241
    0.4241
    6.0942    1.0000    1.8194    5.3056    0.4402    2.4015    2.5847
    2.5847
    3.3496    0.5496    1.0000    2.9161    0.2420    1.3199    1.4207
    1.4207
    1.1486    0.1885    0.3429    1.0000    0.0830    0.4526    0.4872
    0.4872
   13.8440    2.2716    4.1330   12.0524    1.0000    5.4554    5.8716
    5.8716
    2.5377    0.4164    0.7576    2.2093    0.1833    1.0000    1.0763
    1.0763
    2.3578    0.3869    0.7039    2.0526    0.1703    0.9291    1.0000
    1.0000
    2.3578    0.3869    0.7039    2.0526    0.1703    0.9291    1.0000
    1.0000
```

THE DIFFERENCE COMPARISON MATRIX IS

0.0000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.1741
0.1741						
-2.0942	0.0000	[illegible]	-1.3056	[illegible]	0.5285	0.4153
0.4153						
-1.3496	0.2996	0.0000	0.0837	-0.1020	1.6801	0.5793
0.5793						
0.8514	0.0615	0.0096	0.0000	0.0470	0.0474	-0.2372
-0.2372						
-4.7531	1.7284	3.0098	-4.3601	0.0000	-0.4554	0.1284
0.1284						
-0.5377	-0.0831	-0.4243	-0.2093	0.0167	0.0000	0.9237
0.9237						
1.6422	-0.0536	-0.2039	1.9474	-0.0036	-0.4291	0.0000
0.0000						
1.6422	-0.0536	-0.2039	1.9474	-0.0036	-0.4291	0.0000
0.0000						

ENTER PAIRWISE ELEMENT FOR ROW FREQUENCY COLUMN MAGNITUDE

ENTER PAIRWISE ELEMENT FOR ROW FREQUENCY COLUMN SEVERITY

>> 1

>> 33

ENTER PAIRWISE ELEMENT FOR ROW MAGNITUDE COLUMN SEVERITY

>> .33

1

Pairwise comparisons for Criteria.

WITH RESPECT TO :

THE PAIRWISE COMPARISON MATRIX IS:

1.0000	1.0000	0.3300
1.0000	1.0000	0.3300
3.0303	3.0303	1.0000

THE MAXIMUM EIGENVALUE = 3.00

ITS CORRESPONDING EIGENVECTOR IS:

0.3300 0.3300 1.0000

ITS NORMALIZED EIGENVECTOR IS

0.1988 0.1988 0.6024

THE CONSISTENT COMPARISON MATRIX IS:

1.0000	1.0000	0.3300
1.0000	1.0000	0.3300
3.0303	3.0303	1.0000

THE DIFFERENCE COMPARISON MATRIX IS

0.0000	0.0000	0.0000
0.0000	0.0000	0.0000
0.0000	0.0000	0.0000

1

THE EIGENVECTOR MATRIX FOR THE CRITERIA IS

0.06043	0.02416	0.03059
0.15396	0.24060	0.10643
0.15396	0.10062	0.10247
0.15396	0.04493	0.04514
0.15396	[illegible]	[illegible]
0.01548	[illegible]	[illegible]
0.15413	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

```
THE EIGENVECTOR FOR CRITERIA IS

  0 19880    0 19880    0 60241
0

  FROM THE MULTIPLICATION OF THESE MATRICES WE GET

  IAA1-CHLORINE                              0 03524397
  IAA2/IAD3-TURBI                            0 19074187*
  IAA3-NUTRIENTS                             0 11233529
  IAA4/IAC6-METAL                            0 06070603
  IAB-IMP/ENT                                0 37316692*
  IAC1-HEAT TREAT                            0 05646251
  IAD1-PRED /PREY                            0 08538054
  IAD2-SHEAR STRE                            0 08576280

  PRESS RETURN TO CONTINUE
>>
 E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<                                                                              >>>>
<<<<  3.4   Select a specific impact agent among those you selected above         >>>>
<<<<        Type the letters corresponding to the group in which it lies.         >>>>
<<<<                                                                              >>>>
<<<<             IAA - physical/chemical alteration (abiotic effects)             >>>>
<<<<             IAB - impingement/entrainment (biotic effects)                   >>>>
<<<<             IAC - water quality degradation (biotic effects)                 >>>>
<<<<             IAD - habitat modification (biotic effects)                      >>>>
<<<<                                                                              >>>>
<<<<                                                                              >>>>
<<<<        Type the appropriate letters and press RETURN.                        >>>>
<<<<                                                                              >>>>
<<<<                                                                              >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
 E
```

Output.

*Impact agents selected for further consideration.

```
>> IAA2/IAD3
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<                                                                                >>>
<<<   IAA  Impact Agent A - Physical/Chemical Alterations (Abiotic Effects)        >>>
<<<                                                                                >>>
<<<   You are in Impact Agent A  You will need to collect some                     >>>
<<<   information in order to continue with the program  If you know what          >>>
<<<   information is needed answer N to the first question  If you do not          >>>
<<<   know, answer Y.                                                              >>>
<<<                                                                                >>>
<<<   IAA 1  EPAM needs information to define the portion of the water             >>>
<<<   body that is likely to be alterred either physically or chemically           >>>
<<<   as a result of power plant operation or design, and the ratio of             >>>
<<<   this portion of the water body to the whole water body on which              >>>
<<<   the plant is sited (using the ratio of water volumes for changes             >>>
<<<   associated with the water column and the ratio of benthic areas for          >>>
<<<   changes associated with the benthos). (remember water column changes         >>>

<<<   are most likely to be associated with the outfall or waste disposal          >>>
<<<   areas, and benthic changes are most likely to be associated with             >>>
<<<   intake, outfall or waste disposal areas      (HELP Y/N)                      >>>
<<<                                                                                >>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> N
  E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<                                                                                >>>
<<<   IAA.2 Do you know the spatial dimensions of the envelope of water or         >>>
<<<   the area having high potential for disturbance for n conditions that         >>>
<<<   occur over an annual cycle?                                                  >>>
<<<                                                                                >>>
<<<                   Y - yes (go on)                                              >>>
<<<                   N - no (go to TECHNIQUES)                                    >>>
<<<                                                                                >>>
<<<                                                                                >>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> Y
  E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<                                                                                >>>
<<<   IAA.3 Insert the necessary information in the table below  This              >>>
<<<   information will be used to define the extent of physical overlap            >>>
<<<   between a monitoring program target and the impact agent.                    >>>
<<<   Information may be available to you (through previous measurements           >>>
<<<   or modeling exercises) to define the envelope or area more exactly.          >>>
<<<   If you have such information (e g  the spatial distribution of the           >>>
<<<   alterred parcel of water in 3 dimensions), use it to estimate the            >>>
<<<   location and volume or area of the envelope  Otherwise, the spatial          >>>
<<<   distribution will be assumed to be relatively uniform (see IAA.4             >>>
<<<   below). (If you wish to recall this table later, enter IAATABLE              >>>
<<<                                                                                >>>
<<<                                                                                >>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
*
>>
```

E

Fraction of year over which condition holds ? 1

Dimension	Distance from plant	Degree of Certainty (1-5)	Cost of Obtaining Information Having Greater Certainty (1 unit) ($)
-x	500	3	3
+x	5000	3	3
-y	2400	2	3
+y	2400	2	3
-z	15	4	1
+z	0	5	1

Distributions are estimates based on general references in Southern California Edison Company (SCE) and Marine Review Committe (MRC) reports and confirmed by discussion with SCE personnel and observation at SONGS. Specific data on discharge locations were taken from Southern California Edison Company (1982).

E

IAA 4 Given the information available, make a rough estimate of the "volume" of the altered envelope in the water column , or draw 3-dimensional spaces on maps that can be used to estimate overlap (in TARGET OVERLAP). In the case of benthic disturbance, make a rough estimate of the "area" of the space with potential to be disturbed, or draw 2-dimensional spaces on maps that can be used to estimate overlap

Viaa = X x Y x Z

or

Aiaa = X x Y

These values will be rough estimates of the actual volume or area, (i.e. assumes a uniform distribution from +X to -X, +Y to -Y, and +Z to -Z) The values will suffice for the current application. (DELPHI ISSUE)

ENTER V (or A) in units of cubic (or square) meters.

%

>> 400000000

E

IAA 5 Determine the total volume of the waterbody (Vwb)on which the power plant is sited. Determine the total area (Awb) in the water body that provides comparable habitat space to the area having high potential for disturbance. Use whatever data are available (e.g. hypsographic curves, depth contour information, maps, etc.)

If the water body is an open system (e.g. coastal site; riverine site), use an estimate of effective volume or area. Effective volume is that water that is likely to be considered a part of the total habitat available in the overall vicinity of the plant (e.g. the water above a certain depth contour, the mean daily flow past the site in question and so forth) Effective area is that space that provides comparable habitat that is likely to be considered a part of the total habitat available in the plant vicinity.

ENTER Vwb (or Awb) in units of cubic (or square) meters.

%

The effective water volume was considered to be the nearshore waters less than 30 meters deep in which many fish species of concern concentrate (Feder et al., 1974). These depths are confined to approximately 7 km from shore (Thomas et al., 1980b). The bond was considered to extend from Point Conception to the Mexican border, a distance of approximately 300 km, and to average 15 m depth. Water exchange with offshore waters or waters to the north or south was neglected in this analysis.

```
>> 20000000000
  E
<<<                                                                    >>>
<<<   IAA.6 If more than one power plant exists on the waterbody within  >>>
<<<   an X km area, calculate IAA.4 for each of the individual plants and >>>
<<<   sum for an estimate of the total volume and/or area likely to be    >>>
<<<   altered physically or chemically during an annual cycle in this     >>>
<<<   water body (Vt or At)                                               >>>
<<<                                                                      >>>
<<<         ENTER Vt (or At) in units of cubic (or square) meters        >>>
<<<                                                                      >>>
<<<                                                                      >>>
<<<                                                                      >>>

  E
>> 400000000
<<<                                                                    >>>
<<<   IAA.7 Determine the ratio Vt/Vwb (or At/Awb).                    >>>
<<<                                                                    >>>
<<<         If the ratio is greater than X, the probability of long-term >>>
<<<   problems due to chemical or physical alterations in the water column >>>
<<<   or on the benthos is very high (DELPHI ISSUE) This information will  >>>
<<<   be utilized in the TARGET SENSITIVITY subroutine.                  >>>
<<<                                                                    >>>
<<<         ENTER Vt/Vwb (or At/Awb)                                   >>>
<<<                                                                    >>>
<<<                                                                    >>>
<<<                                                                    >>>
%
>> .02
  E
<<<                                                                    >>>
<<<   IAA.8 Enter cost and confidence ratings for Viaa and Vwb (or Aiaa  >>>
<<<   and Awb)Ab), and Awb.                                              >>>
<<<                                                                    >>>
<<<         ENTER Viaa Cost.                                           >>>
<<<         ENTER Viaa Conf.                                           >>>
<<<         ENTER Vwb  Cost.                                           >>>
<<<         ENTER Vwb  Conf.                                           >>>
<<<         ENTER Aiaa Cost.                                           >>>
<<<         ENTER Aiaa Conf                                            >>>
<<<         ENTER Awb  Cost.                                           >>>
<<<         ENTER Awb  Conf                                            >>>
<<<                                                                    >>>
<<<                                                                    >>>
%
>> 3
>> 3
>> 4
>> 2
>> -
>> -
>> -
```

Other power plants generally do not have jet diffuser discharges; thus, only SONGS was considered.

```
>> -
  E

    IAA 9 Choose from the following menu

            IAA - return to consider additional subcategories within
                  this impact agent group
            IAB - return to 3 4 to consider impact agent questions for
                  IAB: Impingement/Entrainment
            IAC - return to consider impact agent questions for IAC:
                  Water quality degradation
            IAD - return to consider impact agent questions for IAD:
                  Habitat modification

            IS    all impact agents have been evaluated  Go to
                  TARGET SELECTION

     Type the appropriate letters and press RETURN

%
>> IAB
  E

    3 4   Select a specific impact agent among those you selected above
          Type the letters corresponding to the group in which it lies

               IAA - physical/chemical alteration (abiotic effects)
               IAB - impingement/entrainment (biotic effects)
               IAC - water quality degradation (biotic effects)
               IAD - habitat modification (biotic effects)

         Type the appropriate letters and press RETURN

%
>> IAB
  E

         IAB  Impact Agent B - Impingement/Entrainment

         You are in Impact Agent B  You will need to collect some
         information in order to proceed with the program  If you know
         what information is needed, answer N to the first question
         If you do not know, answer Y

         IAB 1 EPAM needs information to define the portion of the
         waterbody that will be entrained during cooling system
         operation (i e  that will be used for cooling), the total
         volume of water used in an annual cycle during plant
         operation and the total volume of the water body from which
         the water is drawn.          HELP Y/N?
```

IAB 2 Do you know the spatial dimensions of the entrainment envelope for n conditions that occur over an annual cycle?

Y - yes (go on)
N - no (go to TECHNIQUES)

%

IAB 3 Insert the necessary information* in the table below. This information will be used to define the extent of physical overlap between a monitoring program target and the impact agent.

* Information may be available to you (through previous measurements or modeling) to define the entrainment envelope more exactly. If you have such information (e g the spatial distribution of the entrainment parcel in 3 dimensions) use it to estimate the location and volume of the entrainment envelope. Otherwise, the spatial distribution will be assumed to be relatively uniform (see IAB 4 below)

After you have completed the table, press RETURN to continue.
If you wish to recall this table later enter IAB TABLE.

*

E

Fraction of year over which condition holds ? 1

Dimension	Distance from intake	Degree of Certainty (1-5)	Cost of Obtaining Information Having Greater Certainty (1 unit) ($)
-x	78	3	3
+x	78	3	3
-y	78	3	3
+y	78	3	3
-z	9	4	3
+z	0	5	1

E

See note associated with IAA 3 above. Intake data also were drawn from McGroddy et al. (1979) and Southern California Edison Company (1983).

```
<<<<                                                                    >>>>
<<<<    IAB 4 Given the information available, make a rough estimate    >>>>
<<<<    of the "volume" of the entrainment envelope; or draw            >>>>
<<<<    3-dimensional spaces on maps that can be used to estimate       >>>>
<<<<    overlap (in TARGET OVERLAP) in McHargian fashion.               >>>>
<<<<                                                                    >>>>
<<<<    VIAB = X x Y x Z                                                >>>>
<<<<                                                                    >>>>
<<<<          This "V" will be an rough estimate of the actual          >>>>
<<<<    volume, (i.e. "V" assumes a uniform distribution from +X to     >>>>
<<<<    -X, +Y to -Y, and +Z to -Z).  "V" will suffice for the current  >>>>
<<<<    application.  (DELPHI ISSUE)                                    >>>>
<<<<                                                                    >>>>
<<<<    ENTER V in units of cubic meters                                >>>>
```

```
%
>> 170000
   E
<<<<                                                                    >>>>
<<<<    IAB 5 Determine the total volume of cooling water (Vcw) used    >>>>  See note associated with IAB 3 above.
<<<<    during an annual cycle                                          >>>>
<<<<                                                                    >>>>
<<<<    Vcw = flow rate (vol/time) X time of plant operation            >>>>
<<<<                                                                    >>>>
<<<<    ENTER Vcw in units of cubic meters.                             >>>>
<<<<                                                                    >>>>
%
  2000000000
  E
<<<<                                                                    >>>>
<<<<    IAB 6 Determine the total volume of the waterbody (Vwb)from     >>>>  See note associated with IAA 5 above.
<<<<    which the cooling water is removed and into which spent cooling >>>>
<<<<    water is discharged.  Use whatever data are available           >>>>
<<<<    (e.g. hypsographic curves, depth contour information, maps, etc.)>>>>
<<<<    If the water body is an  open system (e.g. coastal site;        >>>>
<<<<    riverine site) use an estimate of effective volume.             >>>>
<<<<    Effective volume is that water that is likely to be entrained   >>>>
<<<<    during plant operation, e.g. the water above a certain depth    >>>>
<<<<    contour, the mean daily flow past the site in question, an daily>>>>
<<<<    and so forth.                                                   >>>>
<<<<                                                                    >>>>
<<<<    ENTER Vwb in units of cubic meters.                             >>>>
<<<<                                                                    >>>>
%
>> 20000000000
```

```
 E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<                                                                                  >>>>
<<<<      IAB 7 If more than one power plant exists on the waterbody                 >>>>
<<<<      within an X km area, calculate IAB 5 for each of the                        >>>>
<<<<      individual plants and sum for an estimate of the total volume               >>>>
<<<<      entrained during an annual cycle in this water body (Vt).                   >>>>
<<<<                                                                                  >>>>
<<<<      ENTER Vt in units of cubic meters.                                          >>>>
<<<<                                                                                  >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> 10000000000
 E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<                                                                                  >>>>
<<<<      IAB 8 Determine the ratio of Vt/Vwb.  If the ratio is greater               >>>>
<<<<      than X, the probability of long-term problems due to                        >>>>
<<<<      impingement or entrainment is very high.   (DELPHI ISSUE)                   >>>>
<<<<      This information will be utilized in the TARGET SENSITIVITY                 >>>>
<<<<      subroutine.                                                                 >>>>
<<<<                                                                                  >>>>
<<<<                                                                                  >>>>
<<<<      ENTER Vt/Vwb                                                                >>>>
<<<<                                                                                  >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> .5
 E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<                                                                                  >>>>
<<<<      IAB 9 Enter cost and confidence ratings for Vcw and Vwb                     >>>>
<<<<                                                                                  >>>>
<<<<            ENTER Vcw cost                                                        >>>>
<<<<            ENTER Vcw confidence                                                  >>>>
<<<<            ENTER Vwb cost                                                        >>>>
<<<<            ENTER Vwb confidence                                                  >>>>
<<<<                                                                                  >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> 3
>> 3
>> 4
>> 2
```

Data on water intake by all power plants in the effective water volume (as defined above) was taken from McGroddy et al. (1979), Los Angeles Department of Water and Power (1980), and Dietz (personal communication).

```
E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<                                                                    >>>>
<<<<      IAB.10 Choose from the following menu.                        >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<      IAA - return to 3.4 to consider impact agent questions for    >>>>
<<<<            IAA, Physical/Chemical Alterations                      >>>>
<<<<      IAB - return to consider additional subcategories within      >>>>
<<<<            this impact agent group                                 >>>>
<<<<      IAC - return to consider impact agent questions for IAC,      >>>>
<<<<            Water Quality Degradation                               >>>>
<<<<      IAD - return to consider impact agent questions for IAD,      >>>>
<<<<            Habitat Modification                                    >>>>
<<<<      TS  - all impact agents have been evaluated  Go to TARGET     >>>>
<<<<           SELECTION.                                               >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<      Type the appropriate letters and press RETURN                 >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
%
>> TS
  E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<                                                                    >>>>
<<<<      You are in TARGET SELECTION                                   >>>>
<<<<                                                                    >>>>
<<<<      TS1.2  Enter the letters and numerals for the impact          >>>>
<<<<      agent subcategory you want to consider.  Names up to 40       >>>>
<<<<      characters may also be entered to provide further             >>>>
<<<<      identification                                                >>>>
<<<<                                                                    >>>>
```

```
>> IAA>/IADJ-TURBIDITY
  E
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<          You will evaluate each target for this                    >>>>
<<<<          subcategory (through TARGET CHOICE) before you            >>>>
<<<<          begin on the next subcategory or the next impact          >>>>
<<<<          agent                                                     >>>>
<<<<                                                                    >>>>
<<<<          When you finish all targets for this                      >>>>
<<<<          subcategory, you will be directed to the next one         >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
^
>>
  E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<          TS1 2 You will be asked to consider potential targets     >>>>
<<<<          for the impact agent (and subcategory) under              >>>>
<<<<          consideration.                                            >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<          HELP Y/N?                                                 >>>>
<<<<                                                                    >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
%
>> N
  E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<                                                                    >>>>
<<<<          Do you have a list of potential targets for               >>>>
<<<<          the impact agent (and subcategory) under                  >>>>
<<<<          consideration?                                            >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<                Y - yes (go on)                                     >>>>
<<<<                N - no (go to TECHNIQUES)                           >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<                                                                    >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
%
>> Y
  E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<
<<<<          TS1 3 Using the table below, insert information into the
<<<<          appropriate columns (1 - 5) be responding to the questions
<<<<

<<<<      HELP Y/N ?                                                    >>>>
<<<<                                                                    >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
%
>> N
```

```
>> N
  E

<<<<      TS1.4 Column 1: list all potential targets by sequential code     >>>>
<<<<      number and either by species name, ecological group, or           >>>>
<<<<      whatever identification is deemed appropriate. Name must be       >>>>
<<<<      less than 12 characters. It may be useful to develop this         >>>>
<<<<      potential list for all impact agents you intend to consider       >>>>
<<<<      before going any farther in the program. In this way you can      >>>>
<<<<      identify targets that are likely to be affected by more than      >>>>
<<<<      one impact agent in the early stages of program development.      >>>>
<<<<      These targets will receive extra weight in TARGET SENSITIVITY.    >>>>
<<<<                                                                        >>>>
<<<<      ENTER THE NUMBER OF TARGETS                                       >>>>
<<<<                                                                        >>>>

%
>> 5
$          Target No.  1  is
>> CAL. HALIBUT
$          Target No.  2  is
>> KELP BASS
$          Target No.  3  is
>> BARRED SANDBASS
$          Target No.  4  is
>> KELP
$          Target No.  5  is
>> SUBTIDAL COMMUNITY
  E

<<<<                                                                        >>>>
<<<<      TS1.5 Column 2: give all targets for which a strong public        >>>>
<<<<      interest* exists a score of 1. Give all other targets a score     >>>>
<<<<      of 0. Any targets that have substantially greater interest        >>>>
<<<<      than the others may be assigned a score of 2 or higher.           >>>>
<<<<                                                                        >>>>
<<<<      HELP Y/N?                                                         >>>>
<<<<                                                                        >>>>

%
>> N
  E

                       /PUBLIC INT/
  1)CAL. HALIBUT           1
  2)KELP BASS              1
  3)BARRED SANDBASS        1
  4)KELP                   1
  5)SUBTIDAL COMMUNITY     1
  E
```

Target list includes kelp, which may be affected by light reduction, the subtidal community, which is subject to a siltation impact, and three fish species which rely to an extent on kelp bed habitat (DeMartini, 1981). It should be noted that the Southern California coastal fish species generally do not have obligate kelp habitat requirements, however (Feder et al., 1974).

All targets are considered to have public recognition as a result of fishing or shellfish harvesting interest or, in the case of kelp, prominence in the ecosystem.

```
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<     TS1 6 Column 3  give all targets which have a direct economic
<<<<     value in either commercial or sports/recreational markets a
<<<<     score of 1  Give all other targets a score of 0  Any targets
<<<<     that have substantially greater value than the others may be
<<<<     assigned a score of 2 or higher
<<<<
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
*
  E

                     /PUBLIC INT//ECON VALUE/
  1)CAL. HALIBUT          1          1
  2)KELP BASS             1          1
  3)BARRED SANDBASS       1          1
  4)KELP                  1          0
  5)SUBTIDAL COMMUNITY    1          1
  E
```

California halibut and the bass species represented the largest commercial and partyboat (sport) catches, respectively, in the SONGS region in 1975 (DeMartini, 1981). California halibut also served a smaller sport fishery.

```
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<                                                            >>>>
<<<<     TS1 7 Column 4: give all targets which have particular >>>>
<<<<     environmental value a score of 1. Give all other targets a >>>>
<<<<     score value of 0  Any targets that have substantially greater >>>>
<<<<     environmental value than the others may be assigned a score >>>>
<<<<     of 2 or higher                                         >>>>
<<<<                                                            >>>>
<<<<     HELP Y/N?                                              >>>>
<<<<                                                            >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> N
  E

                     /PUBLIC INT//ECON VALUE//ECOL VALUE/
  1)CAL. HALIBUT          1          1          0
  2)KELP BASS             1          1          0
  3)BARRED SANDBASS       1          1          0
  4)KELP                  1          0          1
  5)SUBTIDAL COMMUNITY    1          1          0
  E
```

Kelp is recognized for its function as a habitat-former.

```
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<                                                            >>>>
<<<<     TS1 8 Column 5: sum the scores of each target  (Column 2 + >>>>
<<<<     Column 3 + Column 4);                                  >>>>
<<<<                                                            >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
*
>>
  E

                     /PUBLIC INT//ECON VALUE//ECOL VALUE//SUM VALUE/
  1)CAL. HALIBUT          1          1          0          2
  2)KELP BASS             1          1          0          2
  3)BARRED SANDBASS       1          1          0          2
  4)KELP                  1          0          1          2
  5)SUBTIDAL COMMUNITY    1          1          0          2
```

```
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<      TS1.9 Delete those targets which received a total score of 0
<<<<      in TS1.8
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

>>
  E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<                                                                  >>>>
<<<<      TS1.10 Record the code number of the last target to use as  >>>>
<<<<      the starting number for the next subcategory or impact agent. >>>>
<<<<                                                                  >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
*
>>
  E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<                                                                  >>>>
<<<<      TS1.11 Take the remaining targets one-by-one through TARGET >>>>
<<<<      OVERLAP. (type TARGET OVERLAP and press RETURN)             >>>>
<<<<                                                                  >>>>
<<<<      You may not complete EPAM with this target; you can return to >>>>
<<<<      TARGET SELECTION at any time and choose the target with the >>>>
<<<<      next highest score if you wish, for any reason.             >>>>
<<<<                                                                  >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> TARGET OVERLAP
  E
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
  <<                                                               >>
  <<                You are in TARGET OVERLAP.                     >>
  <<                                                               >>
  <<                  Do you need HELP? Y/N                        >>
  <<                                                               >>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> N
  E
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
  <<                                                               >>
  <<  TO.1 Do you know the overall geographic range in 3           >>
  <<       dimensions, x, y, and z (alongshore, offshore and       >>
  <<       vertically with depth) of the target for the n conditions >>
  <<       defined as representing significant differences in the >>
  <<       range?                                                  >>
  <<                                                               >>
  <<                 Y - yes (go on)                               >>
  <<                 N - no (go to TECHNIQUES)                     >>
  <<                                                               >>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
```

One example of TARGET OVERLAP, for California habitat, is shown in full. Detail on other targets was eliminated from the recorded computer file to save space, but final rankings for all targets are included in the Target Table.

```
TO 2 Collect the necessary information for n conditions
     (as defined for impact agents) for the table below and
     save; do not insert on screen

       Information Class          Degree of          Cost of
                                  Confidence         Obtaining Data
                                  (1 to 5)           ($)

       Geographic Range
              distance
            from the intake     time during
                 (m)            which condition
                                holds

     n=1,n
     -x      CAL. HALIBUT: BRITISH COLUMBIA-MAGDALENA BAY, BAJA
       CAL.
     +x
     -y                              4                  2
     +y
     -z            30 (PRIMARILY 1-20)
     +z             0
```

Feder et al. (1974) provided descriptive information and some specific data on target distributions.

```
E
```

```
TO 3 Calculate the relative overlap (RGO) of the target's
     geographic range with the impact agent envelope during all
     n conditions. If data are presented in qualitative terms,
     make the best estimate possible using maps of the area.
     Save information; do not insert on screen

                 IAx    IAy    IAz
          RGO = ---- X ---- X ----   for n=1 ... n     (DELPHI ISSUE)
                 GRx    GRy    GRz
                                    (CAL. HALIBUT: << .001)
   where RGO = relative geographic overlap
     IAx,y,z = the extent of the impact agent's range in the x,
               y, or z dimension (in meters) from IAATABLE,
               IABTABLE, etc. (recall by entering this
               designation if needed)
     GRx, y, or z = the extent of the target's geographic
               range in the x, y, or z dimension (in meters)
```

All fish species had very extensive ranges, for greater than the impact agent distributions, resulting in very low RGO values.

```
%
E
```

```
TO 4 Compute a composite RGO for the n conditions on a
     time-weighted basis. Save information; do not insert on
     screen

          RGOcomp = Sum(time RGOi applies/total time)RGOi

                                   (DELPHI ISSUE)
```

E

TO.5 Do you have information on the temporal fluctuations in target density in the immediate vicinity of the impact agent in the x, y, and z dimensions for the n conditions defined as representing significant differences in the range?

Y - yes (go on)
N - no (go to TECHNIQUES)

%
E

TO.6 Compute the percentage of the time the target is in the impact agent field as a density fluctuation rating. Collect information and save in a table as shown below; do not insert on screen

DFR	Degree of Confidence (1-5)	Cost($) of Data to increase confidence rating (1 unit)
n=1,n		
1	3	3

Y
E

TO.7 Compute a composite DFR for the n conditions on a time - weighted basis. Save information; do not insert on screen

DFR comp = Sum (time DFRi applies / total time)DFRi

(DELPHI ISSUE)

California halibut evidences little density fluctuation diurually or seasonally; hence DFR = 1. Certain other species are less uniform and overlap with the impact agent more at some times and less at others.

TARGET OVERLAP was repeated for all targets but was eliminated from recorded file for presentation of example.

```
%
>> 109
  E
  <<
  <<  TO 9 Rank the RGO and DFR values for all targets considered
  <<       for this impact agent, assigning 1 to the target having the
  <<       lowest value, 2 to that with the next lowest, and so on
  <<       Assign the same rank to targets having equal values  Enter
  <<       in columns 6 (GO) and 8 (DF) in the target lable developed
  <<       in TARGET SELECTION.  Enter TT to recall the table
  <<
%
>> TT
  E

                    /PUB IN/EC VAL/EN VAL/SUM VA/GEO OV
 1)CAL. HALIBUT        1     1      0      2      1
 2)KELP BASS           1     1      0      2      1
 3)BARRED SANDBASS     1     1      0      2      1
 4)KELP                1     0      1      2      4
 5)SUBTIDAL COMMUNITY  1     1      0      2      2
 E

                    /PUB IN/EC VAL/EN VAL/SUM VA/GEO OV/GO CON/DEN FL
 1)CAL. HALIBUT        1     1      0      2      1             1
 2)KELP BASS           1     1      0      2      1             1
 3)BARRED SANDBASS     1     1      0      2      1             1
 4)KELP                1     0      1      2      4             2
 5)SUBTIDAL COMMUNITY  1     1      0      2      2             2
 E
  <<
  <<  TO.10 Enter confidence ratings for GO and DF in columns 7
  <<        and 9, respectively (5 = high confidence; 1 = low
  <<        confidence).
  <<
  <<
  <<
  <<
  E
                    /PUB IN/EC VAL/EN VAL/SUM VA/GEO OV/GO CON
 1)CAL. HALIBUT        1     1      0      2      1      5
 2)KELP BASS           1     1      0      2      1      5
 3)BARRED SANDBASS     1     1      0      2      1      5
 4)KELP                1     0      1      2      4      5
 5)SUBTIDAL COMMUNITY  1     1      0      2      2      4
  E
```

Assigned values represent rankings of RGO and DFR, respectively.

```
 1)CAL. HALIBUT          1    1    0    2    1    5    1    5
 2)KELP BASS             1    1    0    2    1    5    1    5
 3)BARRED SANDBASS       1    1    0    2    1    5    1    5
 4)KELP                  1    0    1    2    4    5    2    5
 5)SUBTIDAL COMMUNITY    1    1    0    2    2    3    2    5
 E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<                                                                            >>>>
<<<<   3.5  EPAM needs information to define the sensitivity of this            >>>>
<<<<        target.  Go to TARGET SENSITIVITY.                                  >>>>
<<<<                                                                            >>>>
<<<<        ENTER <RETURN>                                                      >>>>
<<<<                                                                            >>>>
<<<<                                                                            >>>>
<<<<                                                                            >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
*
>>
 E
       <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
       <<                                                                >>
       <<                                                                >>
       <<        You are in TARGET SENSITIVITY.   HELP Y/N?              >>
       <<                                                                >>
       <<                  Help Y/N ?                                    >>
       <<                                                                >>
       <<                                                                >>
       <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> N
 E
   <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
   <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
   <<                                                                         >>
   <<   TS.1 Do you know what proportion of the target (population) is        >>
   <<        sensitive to the hypothesized impact, or, do you know how        >>
   <<        to obtain this information?                                      >>
   <<                                                                         >>
   <<              Y - yes (go on)                                            >>
   <<              N - no (go to TECHNIQUES)                                  >>
   <<                                                                         >>
   <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
   <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> Y
 E
```

One example of TARGET SENSITIVITY, for California halibut, is shown in full. Detail on other targets was eliminated from the recorded computer file to save space, but final rankings for all targets are included in the Target Table.

TS 2 Insert information in the table below, do not insert on screen

Type of Information	Degree of Confidence (rank on a scale of 1 to 5, 5 = complete confidence, 1 = no confidence)	Cost to increase confidence rating (1 unit) ($)
Examples:		
Survival during passage field survey		
Estimate of the effect of selective mortality on adult pop size, simulation model		

TS 3 Given information available, what proportion of the target is sensitive to the hypothesized impact?
If possible, express the data on a numerical scale from 0 to 1 where
0 = no sensitivity
1 = all targets are sensitive to the hypothesized impact agent.

For example, if R is estimated for impingement sensitivity, give actual R values. If data are qualitative, score as shown below.
0 = no or very low sensitivity
0.25 = some sensitivity
0.5 = significant sensitivity
0.75 = high sensitivity
1.0 = extreme sensitivity (all targets are sensitive)

Collect information but do not enter on screen.

Sensitivity of California halibut to turbidity was considered to range 0 - 0.25, since the species has a considerable amount of habitat alternative to the kelp beds and is not directly affected by the impact agent.

TS 4 Do any of the meteorological, environmental and/or biotic (life history) conditions associated with this target have an affect on its sensitivity rating?

Examples: increased turbidity during spring runoff periods will increase entrapment coefficient, seasonal changes in target distribution will change the sensitivity of mobile populations

Y - yes, adjust the rating up or down to reflect the differences; go to TS 5
N - no, go to TS 5

Additional sensitivity may occur during periods of high turbidity originating in river runoff and wave action.

TARGET SENSITIVITY was repeated for all targets but was eliminated from recorded file for presentation of example.

```
>> Y
 E
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
  <<
  <<              TS 5  Choose from the following options
  <<
        (1  go to TS 1 to re-evaluate the sensi[illegible]ity of additional
            targets of this impact agent
        (2  [illegible] targets
            [illegible]

  <<
  <<    Type the appropriate letters and press RETURN
  <<
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> TS6
 E
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
  <<                                                                                   >>
  <<    TS 6 Rank the target sensitivity ratings for all targets                       >>
  <<         considered for this impact agent, assigning 1 to the                      >>
  <<         target having the lowest sensitivity, 2 to the one with                   >>
  <<         the next lowest and so on. Assign the same rank to targets                >>
  <<         having equal sensitivity. Enter in column 10 in the Target                >>
  <<         Table. type TT <RETURN> to recall the table.                              >>
  <<                                                                                   >>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> TT
 E
```

Assigned values represent rankings of sensitivity ratings.

	/PI/	/EC/	/EN/	/SM/	/OO/	/GC/	/DF/	/DC/	/TR/
1)CAL. HALIBUT	1	1	0	2	1	5	1	5	1
2)KELP BASS	1	1	0	2	1	5	1	5	1
3)BARRED SANDBASS	1	1	0	2	1	5	1	5	1
4)KELP	1	0	1	2	4	5	2	5	2
5)SUBTIDAL COMM	1	1	0	2	2	3	2	5	3

```
 E
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
  <<                                                                                   >>
  <<    TS 7 Enter confidence ratings for TS in column 11.                             >>
  <<                                                                                   >>
  <<            5 - high confidence;                                                   >>
  <<            1 - low confidence                                                     >>
  <<                                                                                   >>
  <<                                                                                   >>
  <<                                                                                   >>
  <<    Type TT <RETURN> to recall table and enter                                     >>
  <<                                                                                   >>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> TT
 E
```

	/PI/	/EC/	/EN/	/SM/	/OO/	/GC/	/DF/	/DC/	/TR/	/TC/
1)CAL. HALIBUT	1	1	0	2	1	5	1	5	1	5
2)KELP BASS	1	1	0	2	1	5	1	5	1	5
3)BARRED SANDBASS	1	1	0	2	1	5	1	5	1	5
4)KELP	1	0	1	2	4	5	2	5	2	4
5)SUBTIDAL COMM	1	1	0	2	2	3	2	5	3	4

```
 E
```

```
   IS 8 Assign a rating for potential long term problems in column
        2 of the target table as follow

                1   Go to 2 if no chemically problems are treated
                2   If one or more chemicals are treated or one or more power

                  plants or other industrial or municipal impact agents
                  within a 200 km distance on the same water body
                                    OR
                  sensitive targets of the following types
             i    juvenile life stages of any finfish or shellfish
                  target
            ii    chemical sensitivity to trace elements in a dominant
                  food organisms (manifested either through increased
                  mortality or bioaccumulation)
           iii    thermal or chemical sensitivity of a major habitat
                  former (e.g. macroalgae, filamentous algae,
                  macrophytes)

  E

                                    OR
              ratio of Vcw/Vwb as estimated in IMPACT AGENT was
              greater than X.
                                    OR
              other problems to be developed

            3 - the occurrence of both multiple plants and sensitive
                targets in the above list

     Type TT <RETURN> to recall the table and enter

%
>> TT
  E
                 /PI/ /EC/ /EN/ /SM/ /GO/ /GC/ /DF/ /DC/ /TR/ /TC/ /LP/
 1)CAL. HALIBUT    1    1    0    2    1    5    1    5    1    5    1
 2)KELP BASS       1    1    0    2    1    5    1    5    1    5    1
 3)BARRED SANDBASS 1    1    0    2    1    5    1    5    1    5    1
 4)KELP            1    0    1    2    4    5    2    5    2    4    2
 5)SUBTIDAL COMM.  1    1    0    2    2    3    2    5    3    4    1
  E

    3 6  EPAM will prioritize targets for the impact agent in
         question according to the data collected in the LEVEL 3
         subroutines   Go to TARGET CHOICE

         Enter <RETURN

 *
 >>
```

Kelp was assigned a higher long-term ranking in recognition of its status as a habitat-former.

```
  E
<<
                You are in TARGET CHOICE

                HELP Y/N
<<
<<
%
>> N
  E
<<     TS2.1 Check that the following information is in the             >>
<<           appropriate columns in ALL the Target Tables. You should   >>
<<           have one table for each impact agent subcategory you       >>
<<           considered.  If information is missing, insert as needed   >>
<<                                                                      >>
<<     Recall tables by typing IAA1, IAA2, etc   RETURN  for checking.  >>
<<                                                                      >>
<<                                                                      >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>>
  E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                      >>
<<    TS2.9 Conduct a final screening using TARGET SCREENING CHOICE     >>
<<          for each impact agent subcategory                           >>
<<                                                                      >>
<<                                                                      >>
<<                                                                      >>
<<    Call the CHOICE subroutine by typing CHOICE <RETURN>              >>
<<                                                                      >>
<<                                                                      >>
<<                                                                      >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> CHOICE
     E

 THIS IS THE CHOICE PROGRAM

 ENTER TITLE OF MATRIX ANALYSIS OR MAIN OBJECTIVE
>> TURBIDITY TARGET CHOICE
 ENTER NUMBER OF CRITERIA
>> 4
 ENTER VARIABLE NAME FOR CRITERIA          1
>> GEOG  OVERLAP
 ENTER VARIABLE NAME FOR CRITERIA          2
>> DENSITY FLUCTUATION
 ENTER VARIABLE NAME FOR CRITERIA          3
>> TARGET SENSITIVITY
 ENTER VARIABLE NAME FOR CRITERIA          4
>> LONG TERM
```

Steps TS2.2 - TS2.8 are guides for checking the Target Table and were eliminated from the recorded file.

Only the set-up and output are presented for Turbidity TARGET CHOICE.

Criteria are rankings in GO, DF, TR, and LP columns on Target Table. SM rankings normally would be included but are equal for all targets in this case.

```
ENTER THE NAME OF ELEMENT
  CAL HALIBUT
ENTER THE NAME OF ELEMENT
  KELP BASS
ENTER THE NAME OF ELEMENT        3
  BARRED SANDBASS
ENTER THE NAME OF ELEMENT        4
  KELP
ENTER THE NAME OF ELEMENT        5
  SUBTIDAL COMM

   FROM THE MULTIPLICATION OF THESE MATRICES WE GET

   CAL. HALIBUT                                  0 08435625
   KELP BASS                                     0 08435625
   BARRED SANDBASS                               0 08435625
   KELP                                          0 48803556*
   SUBTIDAL COMM.                                0 26287055*

   PRESS RETURN TO CONTINUE
>>
 E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<                                                                    >>>>
<<<<   3.7  Choose from the following options                           >>>>
<<<<                                                                    >>>>
<<<<        TS1 - go to TARGET SELECTION to evaluate targets            >>>>
<<<<              for another impact agent.                             >>>>
<<<<                                                                    >>>>
<<<<        2.3 - go to LEVEL 2.  All impact agents and their targets   >>>>
<<<<              have been evaluated and prioritized.                  >>>>
<<<<                                                                    >>>>
<<<<        Type the appropriate letters and press RETURN               >>>>
<<<<                                                                    >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> TS1
 E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<                                                                    >>>>
<<<<     You are in TARGET SELECTION                                    >>>>
<<<<                                                                    >>>>
<<<<     TS1.2  Enter the letters and numerals for the impact           >>>>
<<<<     agent subcategory you want to consider.  Names up to 40        >>>>
<<<<     characters may also be entered to provide further              >>>>
<<<<     identification                                                 >>>>
<<<<                                                                    >>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> TAB IMPINGEMENT/ENTRAINMENT
   II
 E
                    ZP1/  ZEN/ ZSM  ZGO   ZDC/ ZDC/ ZIR/ ZIC/ ZEP/
 1)GOLDENFISH        1          1     1          3          4
```

*Targets selected for further consideration.

Only the final Target Table and TARGET CHOICE are presented for the second impact agent. TARGET SELECTION, TARGET OVERLAP, and TARGET SENSITIVITY were employed for each target in developing the table but were eliminated from the file for this presentation.

The target list was derived from Thomas et al. (1980a), DeMartini (1980, 1981), and Southern California Edison Company (1982; 1983 a,b). The primary basis was historical data on impingement and entrainment at SONGS. These references, along with Feder et al. (1974) provided the data on target values, overlap, and sensitivity. In this list kelp bass, barred sandbass, and spotted sandbass are grouped as <u>Paralabrax spp</u>. All targets are considered to be subject to long-term impingement/entrainment impacts due to the presence of numerous other thermal electric plants on the Southern California coast, an issue under exploration with the Delphi panel. The ichthyoplankton subject to entrainment were assigned a higher

```
  4)SILVERSIDES          0    1    1    2    1    5    .    .    2    2    2
  5)WALLEYED SURFPER     0    0    1    1    1    .    1    1    1    4    .
  6)SARGO                0    1    0    1    1    .    2    2    2    3    2
  7)WHITE SURFPERCH      0    0    1    1    1    .    1    1    1    4    2
  8)FAL. HALIBUT 1P      1    2    0    3    1    5    2    3    4    3    3
  9)PARALABRAX SPP       1    2    0    3    1    5    2    3    4    3    3
  E
<<                                                                          >>
<<                                                                          >>
<<                                                                          >>
<<   3.6  EPAM will prioritize targets for the impact agent in             >>
<<        question according to the data collected in the LEVEL 3          >>
<<        subroutines.  Go to TARGET CHOICE                                >>
<<                                                                          >>
<<        ENTER <RETURN                                                     >>
<<                                                                          >>
<<                                                                          >>
<<                                                                          >>
*
>>
  E
<<                                                                          >>
<<                                                                          >>
<<            You are in TARGET CHOICE                                      >>
<<                                                                          >>
<<                                                                          >>
<<            HELP Y/N?                                                     >>
<<                                                                          >>
<<                                                                          >>
<<                                                                          >>
%
>> N
  E
<<                                                                          >>
<<                                                                          >>
<<     TS2 1 Check that the following information is in the                 >>
<<           appropriate columns in ALL the Target Tables.  You should      >>
<<           have one table for each impact agent subcategory you           >>
<<           considered.  If information is missing, insert as needed.      >>
<<                                                                          >>
<<     Recall tables by typing IAA1, IAA2, etc.  <RETURN> for checking.     >>
<<                                                                          >>
<<                                                                          >>
>
```

long-term rating to reflect both the concentration of plants and their juvenile status.

Steps TS2.2 - TS2.8 were deleted.

```
>>
 F
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>

     TS2.9 Conduct a final screening using TARGET SCREENING CHOICE
           for each impact agent subcategory

%
>> CHOICE
    F

THIS IS THE CHOICE PROGRAM

ENTER TITLE OF MATRIX ANALYSIS OR MAIN OBJECTIVE
>> IMPING/ENTRAIN TARGET CHOICE
ENTER NUMBER OF CRITERIA
>> 4
ENTER VARIABLE NAME FOR CRITERIA          1
>> VALUE SCORE
ENTER VARIABLE NAME FOR CRITERIA          2
>> DENSITY FLUCTUATION
ENTER VARIABLE NAME FOR CRITERIA          3
>> TARGET SENSITIVITY
ENTER VARIABLE NAME FOR CRITERIA          4
>> LONG-TERM
ENTER THE NUMBER OF ELEMENTS. AN ELEMENT IS A
TARGET, HYPOTHESIS, ETC
>> 9
ENTER THE NAME OF ELEMENT            1
>> QUEENFISH
ENTER THE NAME OF ELEMENT            2
>> N  ANCHOVY IP
ENTER THE NAME OF ELEMENT            3
>> WHITE CROAKER
ENTER THE NAME OF ELEMENT            4
>> SILVERSIDES
ENTER THE NAME OF ELEMENT            5
>> WALLEYE SURFPERCH
ENTER THE NAME OF ELEMENT            6
>> SARGO
ENTER THE NAME OF ELEMENT            7
>> WHITE SURFPERCH
ENTER THE NAME OF ELEMENT            8
>> CAL  HALIBUT IP
ENTER THE NAME OF ELEMENT            9
>> PARALABRAX SPP.  IP

  FROM THE MULTIPLICATION OF THESE MATRICES WE GET

  QUEENFISH                                              0 14865297*
  N  ANCHOVY IP                                          0 24433433*
  WHITE CROAKER                                          0 07538027
  SILVERSIDES                                            0 0471274[illegible]
  WALLEYE SURFPER                                        0 03106008
  SARGO                                                  0 [illegible]
  WHITE SURFPERCH                                        0 029[illegible]030
  CAL  HALIBUT IP                                        0 19[illegible]*
  PARALABRAX SPP                                         0 1[illegible]01256*
```

Only the set-up and output are presented for Impingement/Entrainment TARGET CHOICE.

Criteria are rankings in SM, DF, TR, and AP columns on Target Table. GO rankings normally would be included but are equal for all targets in this case.

*Targets selected for further consideration.

```
   3 /  Choose from the following options

        TGT   go to TARGET SELECTION to evaluate targets
              for another impact agent

        2.3   go to LEVEL 2.  All impact agents and their targets
              have been evaluated and prioritized

        Type the appropriate letters and press RETURN

%
>> ? 3
  E

  2.3 You must decide whether to enter the HYPOTHESIS GENERATION
      subroutine.  Do you want HELP Y/N?

%
>> N
  E

   Do you wish to enter the HYPOTHESIS GENERATION subroutine?

                Y - yes (go to HYPOTH)
                N - no (go to 2.4)

%
>> Y
  E

       You are in HYPOTHESIS GENERATION SUBROUTINE

                          (HYPOTH)

       HELP Y/N?
```

```
%
>> N
  E
  <<                                                                    >>
  <<     H1  From the following listing, please make the choices that   >>
  <<     correspond most closely to what you think will happen at       >>
  <<     this site, under the hypothesized conditions, to this         >>
  <<     target  For each choice you make, type the appropriate         >>
  <<     letter and press RETURN                                        >>
  <<                                                                    >>
  <<     Type of Response  DIRECT - target is directly affected by      >>
  <<     impact agent.                                                  >>
  <<                                                                    >>
  <<     DI - individual response (bioaccumulation, disease             >>
  <<          propagation, behavioral change, etc )                     >>
  <<     DP - population response (numbers, age structure, growth,      >>
  <<          fecundity, reproductive strategy, sex ratio, length-      >>
  <<          weight ratio, etc.)                                       >>
  <<     DC - community response (species composition, diversity,       >>
  <<          total biomass, total abundance, relative abundance,       >>
  <<          percent similarity, etc.)                                 >>
  <<     DE - ecosystem response (change in trophic dynamics,           >>
  <<          nutrient cycling, energy flow, etc )     MORE ON NEXT PAGE >>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
^
  E
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
  <<                                                                    >>
  <<     Type of Response: INDIRECT - target is affected indirectly,    >>
  <<     i.e. as a result of a direct effect on another ecosystem       >>
  <<     component.                                                     >>
  <<                                                                    >>
  <<     II - individual response                                       >>
  <<     IP - population response                                       >>
  <<     IC - community response                                        >>
  <<                                                                    >>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
%
>>
  E
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
  <<                                                                    >>
  <<     User is routed to the variables identification subsection of   >>
  <<     HYPOTH for the response type that is identified )              >>
  <<                                                                    >>
  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
*
>> DP
>>
```

Full detail is presented for development of only one hypothesis. The steps were repeated for all other hypotheses but were eliminated from the recorded computer file for this presentation.

The subject of the first hypothesis is Northern Anchovy ichthyoplankton, which is potentially affected by entrainment. The effect would be noted as a direct population response.

E

VARIABLES IDENTIFICATION

This section of HYPOTH presents ... compilation of variables that have be ... in impact ... monitoring ... according to the impact target as identified previously (e.g. finfish, phytoplankton, etc.). Within these categories, each variable is considered in terms of its general or specific applicability, the availability of techniques for measurement, the general dollar cost associated with measurement, and the expected accuracy (variance) of the measurement.

The choice of appropriate variable is a decision made by the user. The information is presented to prompt consideration of characteristics that have been found to be important. Read the information given below and respond to the instructions.

E

VI In what ecological group does your target occur? Choose from the following menu

- F - finfish
- S - shellfish
- IC - ichthyoplankton
- IN - benthic macroinvertebrates
- Z - zooplankton
- PH - phytoplankton
- PE - periphyton
- MA - macrophytes/macroalgae
- MI - microbes (bacteria, fungi, etc.)
- D - detritus

Type the appropriate letter and press RETURN. Only one target will be considered at a time. If more than one target ranked highly in TARGET SCREENING, consider each one in turn.

%

F

E

NOTE. VARIABLES IDENTIFICATION will use the format shown below. Detail will be entered as it is developed by the project team members and reviewed through the Delphi process.

F

Population Response

Finfish

Variable List: Abundance (#/unit effort)
[illegible] #/unit water; #/surface area)
[illegible] of
Biomass (metric/volume; water)
Population Statistic (weight per as weight)
Population Statistic (age per as ratio/percentage)

E

(user is routed to this question)

V2 From the compilation presented to you, what variable do you choose? Enter variable name and units

Variable : __ABUNDANCE_____

Units: _NO /UNIT VOLUME _____

(information is stored and user is routed to consideration of the spatial dimensions of the anticipated effect)

%

E

H2 Based upon your knowledge of the interaction in space between the impact agent and the target and your knowledge of the spatial distribution of the target itself, what spatial dimension do you think the expected impact will have? Choose from the following menu:

M - effect is manifested on a spatial scale of meters (e.g effect and/or repercussions of the effect are observed only in the immediate area of the impact agent) Scale is less than the local range of the target

K - effect is manifested on a spatial scale of kilometers (e.g effect and/or repercussions of the effect are observed in the vicinity of the impact agent and in other areas of the water body and/or in the water body as a whole) Scale is equal to the local range of the target

E

thousands of kilometers (e.g. effect and/or repercussions or effect are observed in widely separated areas, perhaps beyond the receiving water body if diff. Scale is equal to the geographic range of the target greater than the local range

Type the appropriate letter and press RETURN

(information is stored and user is routed to next question)

%

>>

E

>> K

A spatial scale of kilometers is hypothesized.

H3 Based on your knowledge of the target and the impact agent, over what time scale do you anticipate the effect will continue to be observed?

Consider the conditions below (all of which decrease the severity of an observed effect).

1. positive response capacity of target has high probability of occurring due to:
   a. high reproductive rate;
   b. large capacity for adaptation to altered conditions;
   c. other (Delphi-ed)
2. compensatory response of non-affected life stages of target counteract consequences of effect.
3. organisms are highly mobile and able to move away from impact agent, thereby decreasing probability of continuous effects.
4. generation time is very short.
5. other (Delphi-ed)

>>

E

Choose from the following options:

L - less than a generation time (usually less than a year)

E - equal to a generation time (usually within 1 to 5 years)

G - greater than one generation time (usually more than 5 years)

(DELPHI ISSUE)

Type the appropriate letter and press RETURN

(information is stored and user is routed to next question)

A temporal scale of years is hypothesized in consideration of the juvenile stage involved in this hypothesis.

```
>> G
<<
<<   H4  Using the following matrix, pinpoint the relative severity of
<<       the hypothesized effect under consideration
<<                          (DELPHI ISSUE)
<<
```

```
>>
  E
<<                                    TIME
<<                        : GENERATION    = GENERATION    > GENERATION
<<                        +---------------+---------------+---------------+
<<          METERS        |               |               |               |
<<                        |  not severe   |  not severe   |  may be severe|
<<                        |               |               |               |
<<                        +---------------+---------------+---------------+
<<  S                     |               |               |               |
<<  P     KILOMETERS      |               |               |               |
<<  A                     |  not severe   |  may be severe|    severe     |
<<  C                     |               |               |               |
<<  E                     |               |               |               |
<<                        +---------------+---------------+---------------+
<<       100 - 1000'S     |               |               |               |
<<        KILOMETERS      |not applicable |  may be severe|    severe     |
<<                        |               |               |               |
<<                        +---------------+---------------+---------------+
<<  NOTE: matrix is prototype.  Detail will be presented to Delphi panel.
```

```
%
  E
<<
<<          Based on the location of the target under consideration
<<     in the matrix above, choose from the following options:
<<
<<     NOT SEVERE: reject this hypothesis and
<<
<<          H1 - return to H1 and consider the next target
<<          H9 - go to H9 to consider the CHOICE subroutine in
<<               HYPOTHESIS SCREENING
<<               (this was the last target and the last impact agent)
<<
<<     MAY BE SEVERE: reconsider this target in terms of relative
<<     overlap
<<
<<          TS - return to TARGET SCRLENING and reconsider the
<<               relative overlap of target,
<<     (More choices on next page)
```

```
>>
>>
```

```
E

SEVERE  Target should be evaluated, continue to HS to
formulate Ho

Type the appropriate letters and press RETURN

%
  E
>> SEVERE

   H5   You now have enough information to formulate this primary
        hypothesis(Ho).

     Using the following prototype, enter your Ho in words.  If the
     Ho does not fit into the given format, enter it in the space
     given below.

     Ho: the NO /UNIT VOLUME____ of N  ANCHOVY ICHTHYOPLAN  will
     change     (variable)              (target)
     on a spatial scale of KILOMETERS_____ and a temporal
     scale ofYEAARS_____ (hours,days or years) due to the
     action of ENTRAINMENT_____
                          (impact agent)

%
  E
%
  E

     Describe the hypothesized distribution of the effect as
     a guide to sampling program design, using data from
     TARGET OVERLAP, or equivalent, as a basis

         Spatial distribution - WITHIN 3 KM OF SHORE AND WITHIN 3 KM
           OF SONGS



         Temporal distribution - FEBRUARY-MAY AND SEPTEMBER-OCTOBER
```

The information gathered in LEVEL 3 was considered to propose spatial and temporal occurrences for the effect, if any. This description is intended to guide the placement of sampling stations for testing the hypothesis in LEVEL 1.

E

effects on other targets associated with the above hypothesized impact

Y - yes, develop into hypotheses
N - no, go on to H7

Insert complementary hypotheses in space below

%

E

H7 Consider any alternative explanations and assumptions that might invalidate acceptance of this Ho. These will be used to formulate possible alternative hypotheses to be tested as a means of strengthening a decision based on acceptance or rejection of this Ho, or as a partial basis for discarding this Ho as part of the monitoring program.

Conditions (in the vicinity of the power plant or in the range of the target being considered) likely to result in alternative explanations for acceptance or rejection of the Ho:

Full detail is presented for development of only one alternative hypothesis. The steps were repeated for other H_a's associated with this Ho and for other primary hypotheses but were deleted from the file for this presentation.

E

1. significant upwelling events;
2. major changes in tidal flux during an annual cycle;
3. major changes in river runoff which affect discharge, turbidity, salinity, chemical environment, due to the natural annual cycle or annual fluctuations in reservoir storage and release patterns;
4. significant changes in meteorological conditions;
5. large annual variation in natural population;
6. resource extraction activity:
   - commercial fisheries
   - oil/gas
   - other mining activity
   - forestry
   - drilling

7. resource renewal activity:
   - reforestation
   - waste recycling
   - dredging for navigation
   - hatchery activity
   - nursery grounds
   - flood control (water storage) reservoir - age; size

8. industrial activity
   - pulp and paper mills
   - petrochemical plants
   - food processing plants
   - iron and steel mills
   - manufacturing plants
   - smelters

9. other energy facilities
   - oil
   - gas
   - coal
   - nuclear
   - hydroelectricity

10. waste disposal facilities
   - municipal discharge
   - ocean dumping
   - landfills
   - environmental contaminants and toxic substances
   - storage
   - biological emissions

11. recreational activity
- sport fishing
- parks
- resorts
- boating
- swimming
- aesthetic amenities (scenic)

12. land use and transportation
- urban
- agricultural
- airport
- transportation
- transmission lines
- other structures
- history of recovery (e.g., eg 'am is recovering from a period of degradation and observed changes in biota may be due to the altered nutrient regime and not the power plant operation or design).

E

Formulate the alternative hypotheses (Ha's) following the prototype given above for the Ho's. An Ha will be appropriate if any of the above activities occur near the plant, or in the range of the target being considered, at a significant level.

Significance can be judged by comparing (categories to be reviewed by Delphi process)

1. the ratio of flow into or out of the water body due to the alternative activity relative to the flow due to the impact agent being considered.
2. the ratio of resource extracted relative to the total resource present, or to the resource likely to be affected (see TARGET SENSITIVITY).
3. other

E

If any of these ratios is greater than X, the Ho should be discarded. Change due to the hypothesized impact agent will be indistinquishable from change due to other factors.

(DELPHI ISSUE)

If you decide to retain an Ho in spite of one or more existing Ha's, these Ha's will be evaluated as part of the full monitoring program. Type the Ha's below and give them the same number as the associated Ho (e.g., Ho-1, Ha-1a, Ha-1b).

```
>>
 E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<     Ha's, if any, should be inserted in prototype or in lines                >>
<<     provided.                                                                >>
<<                                                                              >>
<<     The NO /UNIT VOLUME ________ of N. ANCHOVY ICHTHYOPLAN _ will            >>
<<              (variable)                 (target)                             >>
       change on a spatial scale of KILOMETERS ______________ and
<<     a temporal scale of YEARS ____________________ due to                    >>
<<     the action of OTHER SOUTHERN CALIFORNIA POWER PLANTS ______              >>
<<     ______________________________ (alternative agent)                       >>
<<                                                                              >>
<<     _________________________________________________________________       >>
<<     _________________________________________________________________       >>
<<     _________________________________________________________________       >>
<<     _________________________________________________________________       >>
<<     _________________________________________________________________       >>
<<     _________________________________________________________________       >>
<<                                                                              >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
 E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                              >>
<<     H8     Choose from the following options.                                >>
<<                                                                              >>
<<            H7 - return to H7 (there are more Ha's to consider for            >>
<<                 this Ho).                                                    >>
<<            H9 - go to H9 (all Ha's have been considered for this Ho).        >>
<<                                                                              >>
<<                                                                              >>
<<     Type the appropriate letters and press RETURN.                           >>
<<                                                                              >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<                                                                              >>
<<     H9    Choose from the following options:                                 >>
<<           H1 - return to H1 (there are more targets to consider              >>
<<                for this impact agent or other impact agents).                >>
<<           CHOICE _ go to the HYPOTHESIS CHOICE subroutine                    >>
<<           (there are no more impact hypotheses to be developed).             >>
<<                                                                              >>
<<     Type the appropriate letters and press RETURN.                           >>
<<                                                                              >>
<<                                                                              >>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
%
>> CHOICE
     E

 THIS IS THE CHOICE PROGRAM

 ENTER TITLE OF MATRIX ANALYSIS OR MAIN OBJECTIVE
 ENTER NUMBER OF CRITERIA
>> HYPOTHESIS CHOICE
>> 7
 ENTER VARIABLE NAME FOR CRITERIA              1
   SEVERITY
 ENTER VARIABLE NAME FOR CRITERIA              2
```

Step H7 was repeated for other H_a's associated with this Ho but was eliminated for presentation of the example.

Steps H1-H8 were repeated for other Ho's but were deleted from the recorded computer file for presentation.

<u>Candidate</u> <u>Hypotheses</u>

H_o1: The number/unit volume of northern anchovy ichthyoplankton will change on a spatial scale of kilometers surrounding SONGS and a temporal scale of more than one generation due to entrainment.

- H_a1A: The described change will occur as a result of operations at other Southern California power plants.
- H_a1B: ... As a result of oceanographic events such as current variations and/or upwelling
- H_a1C: ... As a result of fishing.

H_o2: Bass Ip Entrainment

- H_a2A: Other plants
- H_a2B: Oceanographic
- H_a2C: ... As a result of kelp habitat loss.
- H_a2D: Fishing

H_o3: California halibut Ip Entrainment

- H_a3A: Other plants
- H_a3B: Oceanographic
- H_a3C: Fishing

```
 ENTER VARIABLE NAME FOR CRITERIA              3
>> NO. Ha'S
 ENTER VARIABLE NAME FOR CRITERIA              4
>> Ha PROBABILITY
 ENTER VARIABLE NAME FOR CRITERIA              5
>> COST
 ENTER VARIABLE NAME FOR CRITERIA              6
>> TECH. AVAILABILITY
 ENTER VARIABLE NAME FOR CRITERIA              7
>> CONTINUITY
 ENTER THE NUMBER OF ELEMENTS, AN ELEMENT IS A
 TARGET, HYPOTHESIS, ETC
>> 7
 ENTER THE NAME OF ELEMENT                     1
>> Ho1-N. ANCHOVY IP
 ENTER THE NAME OF ELEMENT                     2
>> Ho2-PARALABRAX IP
 ENTER THE NAME OF ELEMENT                     3
>> Ho3-CAL. HAL. IP
 ENTER THE NAME OF ELEMENT                     4
>> Ho4-QUEENFISH
 ENTER THE NAME OF ELEMENT                     5
>> Ho5-KELP
 ENTER THE NAME OF ELEMENT                     6
>> Ho6-SUBTIDAL COMM.
 ENTER THE NAME OF ELEMENT                     7
>> Ho7-PARTICLE CONC.

     FROM THE MULTIPLICATION OF THESE MATRICES WE GET:

     Ho1-N  ANCHOVY                    0.18088464
     Ho2-PARALABRAX                    0.13240702
     Ho3-CAL. HAL. I                   0 14639604
     Ho4-QUEENFISH                     0.05777458
     Ho5-KELP                          0.28026164
     Ho6-SUBTIDAL CO                   0 07112452
     Ho7-PARTICLE CO                   0.13115147

     PRESS RETURN TO CONTINUE
```

H_o4: Queenfish Impingement/Entrainment

- H_a2A: Other plants
- H_a2B: Oceanographic
- H_a2C: ... As a result of increased sediment transport by river runoff, bluff erosion and wave action, decreasing light and increasing vulnerability to inpingement.

H_o5: Kelp

- H_a5A: Runoff and waves
- H_a5B: ... As a result of storm damage
- H_a5C: ... As a result of current and consequent substrate shifts.

H_o6: Subtidal Community

- H_a6A: Other plants
- H_a6B: Runoff and waves
- H_a6C: Current and substrate
- H_a6D: ... As a result of municipal wastewater discharges.

H_o7: A statistically significant change will occur in mean and maximum values of a measure of turbidity on a spatial scale of meters surrounding SONGS due to diffuser action.

- H_a7A: Runoff and waves

The criteria for HYPOTHESIS CHOICE were the severity and irreversibility of the proposed primary hypotheses, the number and probability of occurrence of H_a's associated with each, cost, availability of measuring technology, and continuity of past monitoring efforts.

The priority ranking of the candidate hypotheses through CHOICE was:

H_o5 (Kelp)	H_o7 (Particle Conc.)
H_o1 (N. Anchovy IP)	H_o6 (Subtidal)
H_o3 (Cal. Halibut IP)	H_o4 (Queenfish)
H_o2 (Paralabrax IP)	

From this point EPAM would continue to step 1.4 in LEVEL 1 to consider sampling design. This portion of the analysis has not been completed for SONGS, since the optimization algorithms have not been programmed, but will be demonstrated for this and each other case study in Phase III.

APPENDIX D

STATISTICAL METHODS: RELATIONSHIPS, ALGORITHMS AND TESTS

D.1 Relationship Between Autocorrelation At Stations and Autocorrelation in Station Pair Differences

D.2 Relationship Between Cross-correlation Among Errors at Stations and Cross-correlation Among Errors in Station Pair Differences

D.3 Algorithm to Generate a Multivariate AR(1) Process

D.4 Estimation of Σ_{ε}^{2} and $\Sigma_{c/}^{2}$ from LACSD Benthic Data

D.5 Recommended Procedures for Testing for Short-term Impact That Allow for Spatial and Temporal Correlation

D.6 Recommendation Procedures for Testing for Long-term Impact That Allow for Spatial and Temporal Correlation

D.7 Power of Tests to Detect Long-term Impact

Appendix D.1

RELATIONSHIP BETWEEN AUTOCORRELATION AT STATIONS AND AUTOCORRELATION IN STATION PAIR DIFFERENCES

This appendix shows how autocorrelation in the error terms at a treatment station and its paired control station can induce autocorrelation in the differences between the observations at the treatment and control station.

Assume the observations after subtracting out the mean (i.e. the error terms) at a treatment station and its paired control station both follow AR(1) processes, so that we can write:

$$C(t) = \phi_1 C(t-1) + \varepsilon_1(t)$$

$$T(t) = \phi_2 T(t-1) + \varepsilon_2(t)$$

where $\begin{matrix}\varepsilon_1(t)\\ \varepsilon_2(t)\end{matrix}$ are i.i.d. $N_2(0,\Sigma)$, $\Sigma = \begin{bmatrix} \sigma^2 & \rho_e \sigma^2 \\ \rho_e \sigma^2 & \sigma^2 \end{bmatrix}$,

$C(t)$ = the error at the control station at time t,

$T(t)$ = the error at the treatment station at time t.

Thus,

$$Cor[C(t-1),C(t)] = \phi_1,$$

$$Cor[T(t-1),T(t)] = \phi_2,$$

$$Var[C(t)] = \sigma^2/(1-\phi_1^2),$$

$$Var[T(t)] = \sigma^2/(1-\phi_2^2),$$

$$Cov[C(t),T(t)] = \rho_e\sigma^2/(1-\phi_1\phi_2).$$

Let $d(t) = C(t) - T(t)$.

By definition,

$$\mathrm{Cor}[d(t-1),d(t)] = \mathrm{Cov}[d(t-1),d(t)]/\{\mathrm{Var}[d(t-1)]\mathrm{Var}[d(t)]\}^{1/2}. \tag{1}$$

Now

$$\begin{aligned}\mathrm{Cov}[d(t-1),d(t)] &= \mathrm{Cov}[(C(t-1)-T(t-1)),(C(t)-T(t))] \\ &= \mathrm{Cov}[C(t-1),C(t)] - \mathrm{Cov}[C(t-1),T(t)] \\ &\quad - \mathrm{Cov}[C(t),T(t-1)] + \mathrm{Cov}[T(t-1),T(t)],\end{aligned} \tag{2}$$

and

$$\mathrm{Cov}[C(t-1),C(t)] = \phi_1 \mathrm{Var}[C(t)], \tag{3}$$

$$\mathrm{Cov}[T(t-1),T(t)] = \phi_2 \mathrm{Var}[T(t)], \tag{4}$$

$$\mathrm{Cov}[C(t-1),T(t)] = \phi_2 \mathrm{Cov}[C(t),T(t)], \tag{5}$$

$$\mathrm{Cov}[C(t),T(t-1)] = \phi_1 \mathrm{Cov}[C(t),T(t)]. \tag{6}$$

Hence,

$$\mathrm{Cov}[d(t-1),d(t)] = \frac{\phi_1\sigma^2}{(1-\phi_1^2)} + \frac{\phi_2\sigma^2}{(1-\phi_2^2)} - (\phi_1+\phi_2)\frac{\rho_e\,\sigma^2}{(1-\phi_1\phi_2)} \quad . \tag{7}$$

Also,

$$\mathrm{Var}[d(t)] = \mathrm{Var}[C(t)-T(t)] = \mathrm{Var}[C(t)] + \mathrm{Var}[T(t)] - 2\,\mathrm{Cov}[C(t),T(t)]$$

$$= \frac{\sigma^2}{1-\phi_1^2} + \frac{\sigma^2}{1-\phi_2^2} - 2\frac{\rho_e\,\sigma^2}{(1-\phi_1\phi_2)} \quad . \tag{8}$$

Hence,

$$\mathrm{Cor}[d(t-1),d(t)] = \frac{\dfrac{\phi_1\sigma^2}{1-\phi_1^2} + \dfrac{\phi_2\sigma^2}{1-\phi_2^2} - (\phi_1+\phi_2)\dfrac{\rho_e\,\sigma^2}{(1-\phi_1\phi_2)}}{\dfrac{\sigma^2}{1-\phi_1^2} + \dfrac{\sigma^2}{1-\phi_2^2} - 2\,\dfrac{\rho_e\,\sigma^2}{(1-\phi_1\phi_2)}} \quad . \tag{9}$$

If $\phi_1 = \phi_2 = \phi$, then (9) becomes:

$$\text{Cor}[d(t-1), d(t)] = \emptyset. \tag{10}$$

That is, if there is autocorrelation in the error terms at both the treatment and the contol station, and the autocorrelation parameter is the same at both stations, then autocorrelation exists in the differences between the treatment and control station, and the autocorrelation parameter for the differences is the same one as for the treatment error terms and control error terms.

Appendix D.2

RELATIONSHIP BETWEEN CROSS-CORRELATION AMONG ERRORS AT STATIONS AND CROSS-CORRELATION AMONG ERRORS IN STATION PAIR DIFFERENCES

This appendix shows how instantaneous correlations in the error terms among two treatment and two control stations (spatial correlation) can induce instantaneous correlation between the two station pair differences derived from these four stations.

Let

$\rho_C = Cor[C(1),C(2)]$,

$\rho_T = Cor[T(1),T(2)]$,

$\rho_{ij} = Cor[C(i),T(j)]$ for $i,j = 1,2$,

$\sigma^2 = Var[C(i)] = Var[T(i)]$ for $i = 1,2$,

$d(i) = C(i) - T(i)$ for $i = 1,2$,

where $C(i)$ = the error at the control station for pair i,
$T(i)$ = the error at the treatment station for pair i,
$i = 1,2$.

By definition,

$$Cor[d(1),d(2)] = Cov[d(1),d(2)] / \{Var[d(1)]\ Var[d(2)]\}^{1/2}.$$

Now

$$Cov[d(1),d(2)] = Cov[(C(1)-T(1)),(C(2)-T(2))]$$

$$= Cov[C(1),C(2)] - Cov[C(2),T(1)] - Cov[C(1),T(2)]$$

$$+ \mathrm{Cov}[T(1),T(2)]$$

$$= \sigma^2 [(\rho_C+\rho_T) - (\rho_{12}+\rho_{21})].$$

Also,

$$\mathrm{Var}[d(1)] = \mathrm{Var}[C(1)-T(1)] = \mathrm{Var}[C(1)] + \mathrm{Var}[T(1)] - 2\,\mathrm{Cov}[C(1),T(1)]$$

$$= 2\sigma^2(1-\rho_{11}),$$

and similarly,

$$\mathrm{Var}[d(2)] = 2\sigma^2(1-\rho_{22}).$$

Thus,

$$\mathrm{Cor}[d(1),d(2)] = \frac{(\rho_C+\rho_T) - (\rho_{12}+\rho_{21})}{2[(1-\rho_{11})(1-\rho_{22})]^{1/2}} \quad .$$

If correlation in the error terms between stations is positive and a function of distance, and the control stations are closer to each other than to their paired treatment stations (as in Figures 4.3 and 4.4), then $(\rho_C+\rho_T) > (\rho_{12}+\rho_{21})$, and hence $\mathrm{Cor}[d(1),d(2)] > 0$

Appendix D.3

ALGORITHM TO GENERATE A MULTIVARIATE AR(1) PROCESS

This appendix describes the algorithm that was used to generate the observations for the Monte Carlo studies described in the subsection Effects of Correlated Errors on ANOVA of Chapter 4.

The model is given by:

$$\underline{y}(t) = \underline{\mu}(t) + \underline{n}(t)$$
$$\underline{n}(t) = \underline{\emptyset}\, \underline{n}(t-1) + \underline{\varepsilon}(t)$$

where

$\underline{y}(t)$ = a p x 1 vector of observation at time t,

$$E[\underline{y}(t)] = \underline{\mu}(t),$$
$$E[\underline{n}(t)] = \underline{0}$$

$$\underline{\emptyset} = \begin{bmatrix} \emptyset_1 & & & 0 \\ & \emptyset_2 & & \\ & & \ddots & \\ & & & \ddots \\ 0 & & & \emptyset_p \end{bmatrix}$$

$\underline{\varepsilon}(t)$'s are i.i.d. $N_p(\underline{0},\Sigma)$ random variables for all times t.

It follows that

$$\mathrm{Var}[\underline{n}(t)] = V,$$

$$\mathrm{Cor}[\underline{n}(t)_i, \underline{n}(t-1)_i] = \emptyset_i \text{ for } i=1, \ldots, p,$$

where

$v_{ij} = \sigma_{ij}/(1-\phi_i\phi_j)$

v_{ij} = the ij^{th} element of V,

σ_{ij} = the ij^{th} element of Σ,

$\underline{\eta}(t)_i$ = the ith element of $\underline{\eta}(t)$.

An algorithm to generate data that follow this model is given by:

1) Decompose Σ as $\Sigma = U'U$, where U is an upper triangular matrix (Seber, 1977).

2) Generate $\underline{\pi}(t)$, where $\underline{\pi}(t)$ is distributed as $N_p(\underline{0},I)$, and I is the p x p identity matrix (Knuth, 1981).

3) Let $\underline{\varepsilon}(t) = U'\underline{\pi}(t)$. Then $\underline{\varepsilon}(t)$ is distributed as a $N_p(\underline{0},\Sigma)$ random variable.

4) Let $\underline{\eta}(t) = \underline{\phi}\,\eta(t-1) + \underline{\varepsilon}(t)$.

5) Let $\underline{y}(t) = \underline{\mu}(t) + \eta(t)$

APPENDIX D.4

ESTIMATION OF σ^2_ε AND $\sigma^2_{C/AB}$ FROM THE LACSD BENTHIC DATA

In order to apply the optimization algorithm described in the section Short Term Sampling Network Optimization - Indepdendent Residuals, the user must supply the parameters σ^2_ε and $\sigma^2_{C/AB}$. Benthic data from the LACSD sampling program (Garrison, 1981) were used to derive estimates of these parameters for the example described in the subsection Example of Application of Optimization of Chapter 4. The type of data that the algorithm is designed for is observations of station pair differences. Because the LACSD sampling program did not use station pairs, it was only possible to estimate the variability due to measurement error and natural variability at each station (denoted σ^2_1 and σ^2_2, respectively). Upper bounds on σ^2_ε and $\sigma^2_{C/AB}$ are then given by:

$$\sigma^2_\varepsilon \leq 2\sigma^2_1,$$

$$\sigma^2_{C/AB} \leq 2\ \sigma^2_2$$

because Var(X-Y) = Var(X) + Var(Y) - 2Cov(X,Y) for two random variables X and Y.

The total number of benthic organisms per sample at stations 0_B, 0_C, 0_D, 1_C, 2_C, 3_B, 4_C, and 5_C for the years 1978-1979 was used as the variable from which to estimate σ^2_ε and $\sigma^2_{C/AB}$. The data took the form:

X_{ijkl} = the lth observation at station i in semester j of year k,

where

i = 1,...,8
j = 1,2
k = 1,2
l = 1,2,3.

The X_{ijkl}'s were taken to be the natural logarithms of the original observations.

The unbiased estimate of measurement error at each station is:

$$\sigma_1^2 = \sum_{ijkl} (X_{ijkl} - \bar{X}_{ijk\cdot})^2 / [8 \cdot 2 \cdot 2 \cdot (3-1)],$$

where

$$\bar{X}_{ijk\cdot} = (1/3) \sum_{i=1}^{3} X_{ijkl\cdot}$$

The unbiased estimate of natural variability at each station is:

$$\sigma_2^2 = (MS - \sigma_1^2)/3,$$

where

$$MS = \sum_{ijk} (\bar{X}_{ijk\cdot} - \bar{X}_{ij})^2 / [8 \cdot 2 \cdot (2-1)].$$

(MS is the unbiased estimate of $\sigma_1^2 + 3\sigma_2^2$.) The estimates of σ_1^2 and σ_2^2 were 0.12 and 0.03, respectively, so the estimates of σ_ε^2 and $\sigma_{C/AB}^2$ were 0.24 and 0.06, respectively.

It should be noted that the data used to derive these estimates were gathered about 40 years after the discharge of wastewater had commenced. It is possible, therefore, that a trend in the mean at each station is present, although inspection of the estimates of the means revealed no clear trend in one direction at all stations. A trend in the mean would not affect the estimate of σ_1^2, but could greatly inflate the estimate of σ_2^2. It is therefore possible that the ratio $\sigma^2/\sigma_{C/AB}^2$ is much larger than the estimated 4.0.

Appendix D.5

RECOMMENDED PROCEDURES FOR TESTING FOR SHORT-TERM IMPACT THAT ALLOW FOR SPATIAL AND TEMPORAL CORRELATION

Design and General Model

Consider the following lay-out of data gathered for aquatic monitoring:

PLANT STATUS	SEASON 1	SEASON 2	. . .	SEASON S
1	$\underline{y}_{111} \cdots \underline{y}_{11n}$	$\underline{y}_{121} \cdots \underline{y}_{12n}$	. . .	$\underline{y}_{1S1} \cdots \underline{y}_{1Sn}$
2	$\underline{y}_{211} \cdots \underline{y}_{21n}$	$\underline{y}_{221} \cdots \underline{y}_{22n}$	. . .	$\underline{y}_{2S1} \cdots \underline{y}_{2Sn}$

where

$\underline{y}_{ijk}$ = a pxl vector of differences between treatment and control stations,

p = number of station pairs,

i = 1,2 (plant status),

j = 1,2,...,S (time of sampling, or season),

k = 1,2,...,n (year number for that level of plant status),

S = number of seasons,

n = number of years of sampling for each level of plant status.

Let $\underline{\emptyset} = \begin{bmatrix} \emptyset_1 & & & 0 \\ & \emptyset_2 & & \\ & & \ddots & \\ 0 & & & \emptyset_p \end{bmatrix}$

A general model that allows for both spatial correlation and temporal correlation (in the form of an AR(1) process at each station) is given by:

MODEL 1: $(\underline{y}_{ijk} - \underline{u}_{ij}) = \underline{\emptyset}(\underline{y}_{i(j-1)k} - \underline{u}_{i(j-1)}) + \underline{\varepsilon}_{ijk}$, for $j=2,\ldots,S$

$(\underline{y}_{i1k} - \underline{u}_{i1}) = \underline{\emptyset}(\underline{y}_{iS(k-1)} - \underline{u}_{iS}) + \underline{\varepsilon}_{i1k}$, for $k=2,\ldots,n$

$(\underline{y}_{211} - \underline{u}_{21}) = \underline{\emptyset}(\underline{y}_{1Sn} - \underline{u}_{1S}) + \underline{\varepsilon}_{211}$

where $\underline{\varepsilon}_{ijk}$ are i.i.d. $N_p(\underline{0},\Sigma)$ random variables.

It should be noted that if $\emptyset_1 = \ldots = \emptyset_p = 0$ and $\Sigma = \sigma^2 I_p$, where I_p is the pxp identity matrix, then this model is exactly the same as the example given by Skalski and McKenzie (1982) shown in Table 4.5, except that the factors depth contour (3 levels) and location (2 levels) have been combined into one factor: station pair (6 levels).

Hierarchical Procedure for Testing for Short-Term Plant Impact

1) Test for the presence of temporal correlation.

   a) Test H_0: $\emptyset_1 = \ldots = \emptyset_p = \emptyset$ via the likelihood ratio test (Bickel and Doksum 1977). If HO is rejected, go to 2)a), otherwise go to 1)b).

   b) Test H_0: $\emptyset = 0$ via the likelihood ratio test. If H_0 is rejected, go to 2)b), otherwise go to 3).

2) Filter the temporal correlation out of the data

a) Use the maximum likelihood estimates (MLE's) of $\emptyset_1, \ldots, \emptyset_p$ derived in step 1)a) to pre-whiten the data (Jenkins and Watts 1968). Go to 3).

b) Use the MLE of $\emptyset$ derived in step 1)b) to pre-whiten the data. Go to 3).

3) Test for the presence of spatial correlation.

The new model for the data is given by:

MODEL 2: $\underline{y}^*_{ijk}$ are distributed independently as $N_p(\underline{u}_{ij}, \Sigma)$,

where $\underline{y}^*_{ijk} = \begin{cases} \underline{y}_{ijk} \text{ if } H_0 \text{ was not rejected in step 1)b),} \\ \text{the pre-whitened data, otherwise.} \end{cases}$

For ease of notation, the * will be dropped on the $\underline{y}^*_{ijk}$.
The null hypothesis of no spatial correlation is given by

H_0: Σ is diagonal, or equivalently

H_0: RHO = I_p, where RHO = $\mathrm{Cor}(\underline{y}_{ijk}, \underline{y}_{ijk})$.

Let $A_{ij} = \sum_{k=1}^{n} (\underline{y}_{jk} - \bar{\underline{y}}_{ij.})(\underline{y}_{ijk} - \bar{\underline{y}}_{ij.})'$,

$$A = \sum_{i=1}^{2} \sum_{j=1}^{S} A_{ij}$$

$$\bar{\underline{y}}_{ij.} = (1/n) \sum_{k=1}^{n} \underline{y}_{ijk}.$$

Now each A_{ij} is distributed with a Wishart distribution with parameters Σ and (n-1) (hereafter abbreviated as $A_{ij} \sim W(\Sigma, n-1)$),

and $A \sim W(\Sigma, 2S(n-1))$ (Morrison, 1976).

Let $D = \begin{bmatrix} 1/\sqrt{a_{11}} & & \\ & \ddots & \\ & & 1/\sqrt{a_{pp}} \end{bmatrix}$,

$R = DAD$ (this is $\widehat{RHO}$, the maximum likelihood estimate of RHO),

$X^2 = -2S(n-1) - [(2p+5)/6] \ln |R|$.

Reject H_0 at level α if $X^2 > \chi^2_\nu(\alpha)$,

where $\nu = p(p-1)/2$,

$\chi^2_\nu(\alpha)$ = the $(1-\alpha)$th percent point of a χ^2 distribution with ν degrees of freedom.

If H_0 is rejected, go to 4)b), otherwise go to 4)a).

4) Carry out the test for plant status effect.

a) Assume Σ is diagonal.
The new model for the data is given by a standard 3-way ANOVA model:

MODEL 3: $y_{ijkl} = \mu + A_i + B_j + C_k + AB_{ij} + AC_{ik} + BC_{jk} + ABC_{ijk} + e_{ijkl}$,

where A_i = Plant status effect at level i,

B_j = Season effect at level j,

C_k = Station pair effect for station pair k,

$i = 1,2$

$j = 1,2,\ldots,S$

$k = 1,2,\ldots,p$

$l = 1,2,\ldots,n$

ε_{ijkl} are i.i.d. $N(0, \sigma^2)$ random variables.

NOTE: By not rejecting H_0 in step 3), it is actually proper to only assume that ε_{ijkl} are independent $N(0, \sigma_k^2)$. The assumptions of ANOVA, however, require that $\sigma_1^2 = \ldots = \sigma_p^2 = \sigma^2$.

Now test for the significance of season effect. The null hypothesis of no season effect is given by:

$$H_0: B_1 = \ldots = B_S = 0,$$
$$\text{assuming } ABC_{ijk} = 0 \text{ for all } i,j,k$$
$$AB_{ij} = 0 \text{ for all } i,j$$
$$BC_{j,k} = 0 \text{ for all } j,k.$$

If H_0 is rejected, go to 4)a)i), otherwise go to 4)a)ii).

i) The test for plant status effect with seasons present.

The test for no plant status effect is given by:

$$H_0: A_1 = A_2 = 0,$$
$$\text{assuming } ABC_{ijk} = 0 \text{ for all } i,j,k$$
$$AB_{ij} = 0 \text{ for all } i,j$$
$$AC_{ik} = 0 \text{ for all } i,k.$$

The F-statistic used to test H_0 is distributed as $F_{1,2}$ under H_0, where $\nu_1 = 1$, and $\nu_2 = 2Sp(n-1)$.

STOP.

ii) The test for plant status effect with seasons absent.

The new model for the data is now:

Model 4: $y_{ik} = u + A_i \quad C_k \quad AC_{ik} \quad \varepsilon_{ikl}$

where A_i = Plant status effect at level i

C_k = Station pair effect for station pair k

$i = 1,2$

$k = 1,\ldots,p$

$l = 1,\ldots,(Sn)$

ε_{ikl} are i.i.d. $N(0,\sigma^2)$ random variables.

The test for no plant status effect is given by:

H_0: $A_1 = A_2 = 0$,

assuming $AB_{ik} = 0 \quad i,k$.

The F-statistic used to test H_0 is distributed as F_{ν_1,ν_2} under H_0, where $\nu_1 = 1$, and $\nu_2 = 2p(Sn-1)$.

STOP.

b) Assume Σ is general.

Put the model in a 2-way multivariate ANOVA framework. The model for the data is now:

MODEL 5: $\underline{y}_{ijk} = \underline{\mu} + \underline{A}_i + \underline{B}_j + \underline{AB}_{ij} + \underline{\varepsilon}_{ijk}$.

This is just another way of writing MODEL 2, with

$\underline{\mu}_{ij} = \underline{\mu} + A_i + \underline{B}_j + \underline{AB}_{ij}$.

Now test for the significance of the season effect. The null hypothesis of no season effect is given by:

H_0: $\underline{B}_1 = \ldots = \underline{B}_S = \underline{0}$,

assuming $\underline{AB}_{ij} = \underline{0} \quad i,j$.

If H_0 is rejected, go to 4)b)i), otherwise go to 4)b)ii).

i) Test for plant status effect with seasons present.
Model 5 can be rewritten as:

MODEL 5': $\underline{y}_{1j1}, \cdots, \underline{y}_{1jn}$ independent $N_p(\underline{\mu}_j, \Sigma)$,

$\underline{y}_{2j1}, \cdots, \underline{y}_{2jn}$ independent $N_p(\underline{\mu}_j + \underline{\Delta}, \Sigma)$.

The test for no plant status effect is given by:

$H_0: \underline{\Delta} = \underline{0}$.

Let $\underline{X}_j = \sqrt{n}/2\ (\bar{\underline{y}}_{2j} - \bar{\underline{y}}_{1j})$

$$\bar{\underline{X}} = (1/S) \sum_{j=1}^{S} \underline{X}_j$$

$$\hat{\Sigma} = [1/2S(n-1)]A$$

A = A as defined in step 3).

The statistic used to test H_0 is given by:

$$F = \frac{2S(n-1)-p+1}{p2S(n-1)}\ T^2,$$

where $T^2 = S\bar{\underline{X}}'(\hat{\Sigma})^{-1}\bar{\underline{X}}$.

F is distributed as F_{ν_1,ν_2} under H_0, where $\nu_1 = p$, and $\nu_2 = 2S(n-1)-p+1$.

STOP.

ii) Test for plant status effect with seasons absent.

The model for the data now becomes:

MODEL 6: $\underline{y}_{1jk}$ are i.i.d. $N(\underline{\mu}, \Sigma)$,

$\underline{y}_{2jk}$ are i.i.d. $N(\underline{\mu}+\underline{\Delta}, \Sigma)$.

The test for no plant status effect is given by:

$H_0: \underline{\Delta} = \underline{0}$.

Let $A_i = \sum_{j=1}^{S} \sum_{k=1}^{n} (\underline{y}_{ijk} - \bar{\underline{y}}_{i..})(\underline{y}_{ijk} - \bar{\underline{y}}_{i..})'$, for i=1,2

$A = (A_1 + A_2) \mid W(\Sigma, 2(Sn-1))$

$\hat{\Sigma} = [1/2(Sn-1)]\ A$

$\bar{\underline{X}} = (\bar{\underline{y}}_{2..} - \bar{\underline{y}}_{1..})$.

The test statistic to test H_0 is given by:

$$F = \frac{2(Sn-1)-p+1}{p2(Sn-1)}\ T^2,$$

where $T^2 = (Sn/2)\bar{\underline{X}}'(\Sigma)^{-1}\bar{\underline{X}}$.

F is distributed as F_{ν_1,ν_2} under H_0, where $\nu_1 = p$, and $\nu_2 = 2(Sn-1)-p+1$.

STOP.

APPENDIX D.6

RECOMMENDED PROCEDURES FOR TESTING FOR A LONG-TERM IMPACT THAT ALLOW FOR SPATIAL AND TEMPORAL CORRELATION.

Design and General Model

The ANOVA design and procedure described for detecting short term impacts is suitable for detecting an impact that takes the form of a step intervention response function (IRF), shown in Figure 4.14a. It is not suitable for detecting a subtle impact that is chronically increasing in magnitude, one that takes the form of a linear trend IRF shown in Figure 4.14b. To detect such an impact, an intervention analysis model must be used, but the same design of paired control-treatment stations will be used. A general model is given by:

MODEL 1: $(y_t-\mu_t) = \emptyset(y_{t-1}-\mu_{t-1}) + \varepsilon_t$,

for t=2,. . .,n1, and

$(y_t-[\mu_t+(t-n1)\omega]) = \emptyset(y_{t-1}-[\mu_{t-1}+(t-1-n1)\omega]) + \varepsilon_t$,

for $t=n_1+1,. . .,T$

where $y_t = (1/p)\sum_{i=1}^{p}(\underline{y}_t)_i$

$\underline{y}_t$ = the pxl vector of differences between the treatment and control stations at time t

$\mu_t = \mu^*_{(t \bmod S)+1}$

μ^*_j = the mean for season j, j=1,. . .,S

ε_t are i.i.d. $N(0,\sigma^2)$ random variables

$\sigma^2 = (1/p)\sum_{1}^{p}\sum_{1}^{p}\sigma_{ij}$

σ_{ij} = the ij^{th} element of Σ

$\Sigma = \mathrm{Cov}(\underline{y}_t,\underline{y}_t)$

S = the number of times samples are taken per year (the number of seasons)

n_1 = the number of sampling periods before intervention

n_2 = " " " " " after "

$T = n_1+n_2$.

The test for no plant impact is given by H_0: $\omega = 0$. Procedures to test H_0 are given in the next section.

Hierarchical Procedure to Test for Plant Impact

1) Determine whether seasonality exists.

From the results of a pilot study, the investigator will have determined whether seasonality is present in the station pair differences or not (i.e. whether the station pairs track each other as in Figure 4.11a or Figure 4.11b).

If seasons are present, go to 2)a), otherwise go to 2)b).

2) Test for no plant impact.

The test of H_0: $\omega = 0$ can be carried out by calculating the MLE of ω, and then performing the Wald test (Silvey 1975). $\hat{\omega}$ (the MLE of ω) is distributed as approximately a $N(\omega,V)$ random variable when T is large, where V is the element corresponding to ω in the inverse of the Fisher information matrix. Thus $z = \hat{\omega} / \sqrt{V}$ is distributed as approximately a $N(0,1)$ random variable under H_0.

a) Assume seasons present.

In the following procedure, assume one set of observations

per season are taken, so that in the notation of Model 2,

$n_1 = Sn_b$

$n_2 = Sn_a$

$n_t = n_b + n_a$

$T = n_1 + n_2 = Sn_t$

where n_b = the number of years of sampling before intervention

n_a = " " " " " " after " .

Test for the presence of temporal correlation. The null hypothesis of no temporal correlation is given by $H_0: \emptyset = 0$. We can test H_0 via the likelihood ratio test. If H_0 is rejected, go to 2)a)i), otherwise go to 2)a)ii).

i) Assume $\emptyset > 0$.

In this case, $V = f_1(\sigma, \emptyset, S, n_b, n_a, \mu_1, \ldots, \mu_s)$

Thus, reject $H_0: \omega = 0$ at level α if $z = \hat{\omega}/\sqrt{V} > z(\alpha)$, where $z(\alpha)$ is the $(1-\alpha)$th percent point of the N(0,1) distribution.

STOP.

ii) Assume $\emptyset = 0$.

In this case,

$$V = \sigma^2 \left[\frac{S\, n_a}{12\, n}(S^2 n_a^3 + 4\, S^2 n_a^2\, n_b - S^2 n_a + 6\, S\, n_a\, n_b + 2\, n_b)\right]^{-1}.$$

STOP.

b) Assume seasons absent.

This case was worked out by Lettenmaier and Murray (1977). Test H_0: $\phi = 0$ via the likelihood ratio test. If H_0 is rejected, go to 2)b)i), otherwise go to 2)b)ii).

i) Assume $\phi > 0$.

In this case, $V = \dfrac{T(1-\phi)^2/\sigma^2}{D(\phi, n_1, n_2, {}^2)}$

where

$$D(\phi, n_1, n_2, {}^2) = \{(1/\sigma^2)\left[\frac{n_2(n_2-1)(2n_2-1)(1-\phi)^2}{6} + n_2^2\,(1-2\phi) + \phi n_2(n_2+1)\right]$$

$$(T(1-\phi)^2/\sigma^2) - \left[\frac{n_2^2\,(1-\phi)^2 + n_2\,(1-\phi^2)}{2\sigma^2}\right]^2$$

STOP.

ii) Assume $\phi = 0$.

In this case, $V = \dfrac{12\, T\, \sigma^2}{n_2^2\left[(4T-3n_2)n_2 - (3n_2 - 2T)\right]}$

STOP.

APPENDIX D.7

POWER OF TESTS TO DETECT LONG-TERM IMPACT

This appendix gives the powers of the different tests for a long-term impact described in appendix D.5.

The power of the test of the null hypothesis of no plant impact is given by:

$$H(NCP - z(\alpha))$$

where H is the cumulative distribution function of a N(0,1) random variable, $z(\alpha)$ is the $(1-\alpha)$th percent point of a N(0,1) distribution, and NCP is a non-centrality parameter that depends on whether seasons is a factor in the time series analysis, whether temporal correlation is present, and whether spatial correlation is present. The values of NCP for the 8 possible situations are given below.

	NCP
Temporal Correlation Present	
Seasons Present	$f_2(\sigma, \emptyset, S, n_b, n_a, \omega, \ldots, \omega_s, \omega)$
Seasons Absent	$\frac{n_2 \omega}{12 \sigma^*} \left[\frac{2(n_2-1)(2n_2-1)(1-\emptyset)^2}{n_2} + 12(1-2\emptyset) + \frac{12\emptyset(n_2+1)}{n_2} - \frac{3\left[n_2(1-\emptyset)^2+(1-\emptyset^2)\right]^2}{T(1-\emptyset)^2} \right]^{1/2}$

Temporal Correlation Absent

Seasons Present $$\frac{S\, n_a \omega}{\sqrt{12}\,\sigma^*}\left[\frac{1}{n_t}\left(S\, n_a + 4\, S\, n_a\, n_b - S + 6\, n_b + \frac{2\, n_b}{S\, n_a}\right)\right]^{1/2}$$

Seasons Absent $$\frac{n_2\, \omega}{12\,\sigma^*}\left[\left(4 - 3\,\frac{n_2}{T}\right) n_2 - \left(3\,\frac{n_2}{T} - 2\right)\right]^{1/2}$$

where $$\sigma^* = \left[(1/p^2)\sum_{1}^{P}\sum_{1}^{P}\sigma_{ij}\right]^{1/2}$$

σ_{ij} = (ij)th element of Σ.

If spatial correlation is absent, σ^* becomes $\sigma^* = \sigma/\sqrt{p}$, where σ^2 is the variance of the station pair differences. Note that δ (the total change in magnitude; see Figure 4.11b) is given by $\delta = n_2\omega$ when season is absent as a factor, and $\delta = S\, n_a\omega$ when season is present. Thus, δ always appears in the numerator of NCP.

APPENDIX E

PHASE III WORK STATEMENT

APPENDIX E

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SAMPLING DESIGN FOR AQUATIC ECOLOGICAL MONITORING RESEARCH PROJECT 1729-1

Work Statement for Phase III

June 1983

Submitted by

Environmental Engineering and Science Program
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Proposed Phase III Project Period: August 1, 1983 - June 30, 1984
Proposed Phase III Budget: $149,842.00

PHASE III WORK STATEMENT

The objectives of the Phase III research are to demonstrate, evaluate and modify the Electric Power Aquatic Monitoring (EPAM) methodology developed in Phase II (see Attachment A) by:

1. Case study evaluation of EPAM subroutines developed in Phase II using complete data sets from at least two sites, and data subsets from a maximum of three sites. These supplementary data sets will be selected to represent the full range of plant and site conditions, impact agents, and targets necessary to fully evaluate the EPAM methodology.

2. Refinement of EPAM subroutines for monitoring program design as necessary following case study evaluations.

3. Finalization of the structure of EPAM to incorporate changes made following 1) and 2) above.

The final model structure, which will incorporate the Phase II methodologies, plus a demonstration of these methods in case study examples, will be communicated to the broad community interested in questions of environmental assessment (utility and regulatory agency personnel, industry personnel, academicians, and private consultants) in Phase IV.

The following tasks are proposed to accomplish these objectives:

TASK I SELECTION OF REPRESENTATIVE SITES-- Sites proposed in Phase II (see Attachment B) will be reviewed with the project manager and the review panel. Various criteria have been established for selection of the case histories to be used in Phase III to ensure that EPAM encounters the majority of site, operation and design characteristics of interest to EPRI-member utilities. These criteria include:

I.1. Representation of:

   a. All major cooling water sources and receiving waterbody types

(open coastal ocean, large lake, estuarine, free-flowing river, reservoir, cooling lakes and ponds).

b. Nuclear and coal plants (oil and gas not excluded) with open cooling systems. In the case of coal, all aspects of coal and ash handling, including unloading from barges, storage in coal piles, ash ponds, ash transport and land disposal, and SO_2 scrubber waste handling will be included if possible.

c. All major impact agents commonly operating at thermal electric power plants, including impingement, entrainment, chemical discharge, anti-biofouling agents, thermal loading, physical habitat disruption, and pollution due to nonpoint sources (site runoff, leaching, etc.).

d. Various anti-biofouling strategies, including at least intermittent and continuous chlorination and heat treatment.

e. The major targets typically affected by all impact agents, including at least plankton, benthic invertebrates, finfish, shellfish and macroalgae or macrophytes.

f. Situations in which nonplant-induced environmental conditions may provide alternative explanations for ecological change.

g. Situations which appear to have an increased potential for long-term, cumulative effects (as identified following Phase II Delphi review). Presently, conditions to be included are sites having multiple power plants on the same waterbody, and sites having a preponderance of organisms with long generation times.

I.2. Existence of substantial data bases from past monitoring efforts. For evaluation of the optimization subroutine (#9), two full data sets will be required. These data must be available on magnetic tape and be compatible with the University of Washington computer systems.

I.3. The expectation of cooperative assistance by the operating utility. The EPRI project manager will be requested to make the initial contact with the utility to secure assistance and permission for the use of data and reports.

A listing of the sites and an analysis of their fit with the criteria will be submitted to the project manager by the end of the third month of the phase.

TASK II EVALUATION OF EPAM-- For each site selected, the following subtasks will be conducted:

II.1. SITE VISIT -- A site visit will be conducted to collect monitoring data and design criteria, and to observe the physical site conditions. The EPAM procedure will be presented to site personnel to gain subjective insights and preferences.

II.2. ANALYSIS OF MONITORING DATA -- A program developed during Phase II will be used to examine the monitoring data for temporal and spatial correlation and to estimate the coefficients required by the EPAM sampling optimization subroutine (see II.5).

II.3. EVALUATION OF HYPOTHESIS GENERATION AND EXPERIMENTAL DESIGN SUBROUTINES -- The operation of subroutines 1-8 will be evaluated by application in the design of a monitoring program for each case study site. Criteria to be employed in the evaluation are the ability of EPAM to represent all aspects of the case study and to function smoothly to yield a sampling design.

For each case study the evaluation steps will be:

a. Catalog impact agent characteristics and distributions;
b. Catalog target characteristics and distributions;
c. Assemble target sensitivity data;
d. Use EPAM methodology to select targets, define hypotheses, and identify the initial experimental design;
e. Evaluate the sensitivity of EPAM results to input data.

II.4. DELPHI METHOD EVALUATION -- In combination with refining identified EPAM issues by the Delphi process, including evaluation of case history results (see II.6), the strengths and weaknesses of the method will be further evaluated by considering: (1) the

practicality and utility of specialized Delphi subpanels (i.e. panels formed to evaluate one or more subroutine within EPAM) and, (2) the potential utility of national computer mail systems for Delphi communication. A subgroup of the Delphi panel assembled during Phase II will be stratified into mail - and computer-response groups. The members of the initial subgroup will be chosen on the basis of expertise in the area for which further Delphi evaluation is mandated, while the mail- and computer-response group members will be chosen on the basis of having access to an interactive terminal. Criteria for judging panel performance in the various evaluations will be:

a. Extent of participation by the members
b. Timeliness of responses
c. Rate of reaching consensus
d. Consensus content
e. Cost of implementation

II.5. OPTIMIZATION -- The EPAM optimized design will be evaluated on the basis of the numbers of stations, observations, and replicates, as well as the power of the networks with respect to selected change levels. Effects on the power of the network due to spatial and/or temporal correlation between sites and/or patchiness of the biological populations will be noted. Subjective weighting functions will be used to test the allocation of effort among the hypotheses to be tested.

Evaluation steps will include:

a. Define actual sampling grid in case history;
b. Examine the objectives of minimizing cost for a given power and maximizing power for a given cost;
c. Develop the EPAM generated optimal sampling design with and without spatial and temporal correlation;
d. Identify design differences with and without recognition of spatial correlation to establish when these corrections are necessary;
e. Characterize objective and subjective criteria for use in

multiobjective monitoring designs using the CHOICE methodology. (See Attachment A, subroutine 5 for description of CHOICE).

II.6. CASE HISTORY -- The results of each site analysis will be documented and reviewed with the personnel at the examined site. These case history results will be submitted to a Delphi panel for evaluation (see II.4).

II.7 EVALUATION OF EPAM BY UTILITY PERSONNEL-- Selected utility personnel will be requested to apply EPAM at their site to evaluate:

a. Clarity of instruction
b. Ease of use
c. Scientific acceptability
d. Value of results

Progress on completion of this task will be reported to the project manager in the regular quarterly reports (see Schedule).

TASK III EPAM MODIFICATION PLANS-- Since EPAM was developed under a set of constraints that precluded the examination of either risk and uncertainty or sampling gear performance, there are modifications that could improve its comprehensiveness. While TASK II will incorporate improvements in the use of statistical analysis, the application of simulation models to design experiments, and hypothesis generation features, there are certain modifications that may be beyond the original scope of work. If these are identified and their importance demonstrated in the case studies, work plans for these modifications will be prepared and submitted.

TASK IV FINALIZATION OF EPAM STRUCTURE -- The structure of EPAM will be finalized to incorporate any changes indicated following completion of Tasks II and III as described above. A critical decision will be the balance between handbook narrative and interactive computer software.

A list of the modifications to EPAM instituted during this phase will be a Phase III deliverable and will be provided at the conclusion of the phase.

PHASE III PRODUCTS

The deliverable products of Phase III will be:

1. A list of modifications recommended and installed in EPAM.

2. Work plans for research on EPAM features that are beyond the scope of this project.

3. A summary of evaluations of the Delphi technique and the results developed through its application.

4. An outline for the final report and user manuals (full versions will be the Phase IV products).

These products will be provided to EPRI at the conclusion of Phase III.

Table D.1. Allocation of Phase III Effort

Task I - Selection of Representative Sites (including data collection)	10%
Task II - Evaluation of EPAM	70%
II.1 Site Visit	8%
II.2 Analysis of Monitoring Data	10%
II.3 Hypothesis Generation and Experimental Design	20%
II.4 Delphi Method Evaluation	5%
II.5 Optimization	20%
II.6 Case History	5%
II.7 Evaluation of EPAM by Utility Personnel	2%
Task III - EPAM Modification Plans	5%
Task IV - Finalization of EPAM Structure	15%

Table D.2. Phase III Schedule

Period of performance: August 1, 1983 - June 30, 1984

Months	1	2	3	4	5	6	7	8	9	10	11
Select sites and collect data	---	---	---	---	A						
Establish collection	set 1		=	set 2							
Evaluate Hypotheses	---	---	---	---	---						
Evaluate sampling design	set 1		=	set 2							
Evaluate monitoring program	---	---	---	---	---	---	---				
Prepare case history summary	set 1		=	set 2							
	---	---	---	---	---	---	---	---	---	---	---
											B
	Q				Q				Q		

A. Submission of listing and analysis of sites.

B. Submission of Phase III deliverable products.

Q. Quarterly report (note: the quarterly report schedule follows that implemented during previous phases).

Table D.3. Projected Allocation of Phase IV Effort

Period of performance: July 1, 1984 - November 24, 1984

Documentation	
Theory/Delphi	25%
Users' Manual	25%
Code	20%
Workshop	15%
Final Printing	15%

ATTACHMENT A

DESCRIPTION OF EPAM AND ITS SUBROUTINES

The University of Washington model, EPAM (an interactive guide for Electric Power Aquatic Monitoring) functions to guide a user (i.e. one who must design an aquatic monitoring program) in the development of a cost-effective and scientifically valid monitoring program to evaluate the existence, or lack thereof, of ecological change in an aquatic ecosystem due to electrical generation at a thermal power plant.

EPAM has four basic functions:

1. The development of a prioritized list of monitoring program targets (i.e. ecosystem components, including such things as individual species, community indicators, chemical parameters, etc.) that have potential for being affected by plant operation or design;

2. The development of a list of potential impact hypotheses which will serve to guide the structure of the monitoring program; it is assumed that a monitoring program will typically include one or more hypotheses of impact;

3. The development of the actual sampling program for testing each of the hypotheses that is incorporated into the monitoring program;

4. An optimization routine that designates targets, hypotheses, and sampling stations and/or replicates based on measurement capability (due to best techniques, a low variance component, low cost, etc.), sensitivity to impact, or scientific value. The final version of this subroutine optimizes the tradeoff between dollars expended (cost) and increased effectiveness of the monitoring program (power).

EPAM is structured into four hierarchical levels which correspond to: 1) the different stages in monitoring program design in which a user might find him- or herself (e.g. components to be considered are not known; components to be measured are known but program hypotheses are not established; hypotheses are defined but sampling design has not been identified:

design has been developed but user is uncertain that it is optimal in terms of dollars expended); and 2) the four functions of the design process (e.g. designation of what should be measured, development of hypotheses, development of the sampling design and optimization of the whole program, as described above.

EPAM is an interactive computer program which will be written in FORTRAN 77 and will be initially operational on a VAX/VMS system. Each level of the model (Figure 1) is structured into subroutines which ask the user to insert, or develop and insert, information about each of the functions described above. At each lower level (LEVEL 3 being the lowest level), it is assumed that less information about the monitoring program and the ecosystem under consideration is available to the user. EPAM guides the user to develop the necessary data base for each level entered. As all the information necessary at a lower level is inserted into EPAM, the user is moved to the next higher level. Eventually all users enter LEVEL 0 with a fully developed monitoring program in need of optimization.

The lowest level, 3, assumes that the user has no or minimal prior knowledge of the impacts which have potential to occur at the site, nor the targets likely to be affected. LEVEL 3 identifies impacts and potential targets by evaluating the interaction between plant characteristics and ecosystem components. The next higher level, 2, assumes the availability of this information and uses it to develop formal hypotheses of impact. LEVEL 2 also helps the user select from all hypotheses those that would be most effective in the developing monitoring program. In LEVEL 1, the sampling design and appropriate analytical techniques for testing the hypotheses are developed. The final level, 0, increases the cost-effectiveness of the monitoring program through the use of an optimization subroutine.

The model hierarchy (LEVELS 0, 1, 2, and 3) is designed to allow a user to benefit from EPAM's guidance regardless of how much prior information is available to describe the system. The flow chart (Figure 1) shows the nine main subroutines and their hierarchy. Several other auxiliary subroutines are also shown. A description of each follows:

INTRODUCTION - introduces user to EPAM, its goals, components and operational mode.

IMPACT AGENT (1) - allows user to identify the mechanisms which have potential to cause problems at the site in question. These so-called impact agents occur as a result of plant operation and design. They include such phenomena as the entrainment of organisms through the cooling system, toxicity due to the use of anti-biofouling agents, degradation of the benthic habitat due to outfall structures and flows, and so forth. At the moment, EPAM includes four impact agent categories: A. Chemical/Physical Alterations-Abiotic Effects; B. Impingement/Entrainment-Biotic Effects; C. Water Quality Change-Biotic Effects; D. Habitat Alteration-Biotic Effects. Other impact categories will be added if sufficient rationale arises during model testing or following the Delphi review. IMPACT AGENT employs a version of the CHOICE program (see TARGET SCREENING for a description of this program) to select those impact agents that need to be further evaluated in the monitoring program.

TARGET SELECTION (2) - allows user to identify a preliminary list of targets to be considered for inclusion in the monitoring program. A target is defined as any component of the ecosystem that can be measured in order to determine the existence, or lack thereof, of change. A target can be any quantifiable entity (e.g. nitrate, copper, salinity, phytoplankton, juvenile striped bass etc.) that has a potential to be affected by plant operation or design. The preliminary list of targets is evaluated on the basis of established criteria (currently under Delphi review) and, if possible, reduced in size.

TARGET OVERLAP (3) - allows user to identify those targets which demonsrate significant overlap with the impact agent in both time and space domains within their overall geographic range (relative to the impacted area) and on a local scale (within the local habitat available to the target in the impacted area). A user is required to designate the relative accuracy of these estimates, and the expected cost of collecting data having greater accuracy.

TARGET SENSITIVITY (4) - allows user to identify the relative sensitivity of each target to the hypothesized impact agent(s), given that the target has importance and is found in the area of potential impact. Again, the user must

designate the relative accuracy of each estimate, and the cost of increasing the accuracy of the estimate by further data collection.

TARGET SCREENING (5) - presents a pair-wise comparison choice program (CHOICE on the flow diagram) which allows the user to select among targets on the basis of their relative vulnerability to the impact agent (including the extent of physical overlap and sensitivity), and their importance relative to the criteria established in TARGET SELECTION. CHOICE ranks all targets for each impact agent (using a normalized scale, 0-1) on the basis of how each compares to all others for the criteria considered. CHOICE uses the eigen-value-method for choosing among a variety of options on the basis of different criteria as developed by Thomas L. Saaty (1977) in "A Scaling Method for Priorities in Hierarchical Structures" in the Journal of Mathematical Psychology 15:234-281.

HYPOTHESIS GENERATION (6) - allows user to generate an initial list of quantitative and testable hypotheses of impact for the monitoring program by considering:

1. The potential impact;

2. The spatial scale of the potential impact;

3. The temporal scale of the potential impact;

4. The severity of the potential impact (initially described as a function of spatial and temporal dimensions);

5. The type, cost and accuracy of the variable(s) necessary to measure the potential impact;

6. Complementary hypotheses (a complementary hypothesis is defined as a hypothesized change that occurs as an indirect result of another hypothesis, e.g. impingement mortality may cause a decline in population size of a planktivorous finfish species; this decline may, in turn, result in an increase in the size of the

zooplankton population due to reduced predation);

7. The potential for falsification of the hypothesis as a result of alternative explanations for the potential impact (e.g. a commercial fishery may be responsible for the decline in population size of a finfish species instead of mortality due to impingement).

HYPOTHESIS SCREENING (7) - presents a third version of the CHOICE program which allows the user to eliminate those hypotheses which rank poorly when compared against all others on the list on the basis of the criteria established in HYPOTHESIS GENERATION (2, 3, 4, 5, and 7 above), the first CHOICE score, established in TARGET SCREENING, and the confidence the user has in the data on which that score was based (i.e. data to describe target overlap, target sensitivity, etc.)

SAMPLING DESIGN (8) - uses the information collected in previous subroutines to develop a preliminary sampling design (station locations, sampling frequencies, and numbers of replicates) for each of the hypotheses that remain part of the monitoring program following HYPOTHESIS SCREENING. In particular, SAMPLING DESIGN calls for information about the spatial and temporal distribution of each target and the expected variance associated with a given technique for measuring the target. SAMPLING DESIGN also guides the user in designating appropriate methods for statistical analysis of the data base and considers conditions under which simulation models and/or specialized experimental studies might be implemented to improve the monitoring design.

OPTIMIZATION (9) - this final subroutine reevaluates the sampling design on the basis of its costs and the effectiveness (ability to detect change if it exists) of the monitoring program. Sampling stations, sampling frequencies and sampling replicates are eliminated, or added, to establish the tradeoff between cost and effectiveness for each hypothesis in the final monitoring program. The optimization routine is based on the Lagrangian multiplier method and optimizes either for minimum cost (with fixed effectiveness) or maximum effectiveness (with fixed cost). OPTIMIZATION present the user with a final version of the CHOICE program to establish criteria to evaluate individual sampling designs and their effectiveness.

TECHNIQUES - this subroutine presents a user with suggested methods for collecting the information base needed in the different subroutines. TECHNIQUES guides the user to consider both the cost expended and the accuracy gained when choosing among the different methods. This subroutine is developed in outline form only since its scope lies outside of the current project.

LEVEL OF CERTAINTY - this subroutine functions as a "policing" mechanism that helps to prevent a user from entering a given level or subroutine before the necessary background information has been assembled.

GLOSSARY - this subroutine defines all technical terms presented in EPAM.

HELP - this subroutine presents the user with instructions about the operational mode of EPAM's different sections. It also reminds the user of the function of each subroutine, its data needs and its final output.

ATTACHMENT B

Case Study Candidates for Phase III Testing

At the moment plants being considered for Phase III testing include:

1. St. Lucie, Florida Power and Light, coastal, nuclear
2. Big Bend, Tampa Electric, coastal, coal
3. Cook, Indiana and Michigan Electric, Great Lakes, nuclear
4. Waukegan, Commonwealth Edison, Great Lakes, coal and gas
5. Campbell, Consumers Power, Great Lakes, coal
6. Lakeview or Oswego, Ontario Hydro, Great Lakes
7. Chalk Point, Potomac Electric Power, estuarine, coal and oil
8. Morgantown, Potomac Electric Power, estuarine, coal
9. Brunswick, Carolina Power and Light, estuarine, nuclear
10. Calvert Cliffs, Baltimore Gas and Electric, estuarine, nuclear
11. Connecticut Yankee, Northeast Utilities, river, nuclear
12. Prairie Island, Northern States Power, river, nuclear
13. Sioux, Union Electric, river, coal
14. Muskingum River, Ohio Power, river, coal
15. Bull Run, TVA, reservoir, coal
16. Gallatin, TVA, reservoir, coal
17. Oconee, Duke Power, reservoir, nuclear
18. Allen, Duke Power, reservoir, coal
19. Diablo Canyon, Pacific Gas and Electric, coastal, nuclear (pending release of data)
20. Millstone, Northeast Utilities, coastal, nuclear
21. Zion, Commonwealth Edison, Great Lakes, nuclear
22. Brayton Point, New England Power, coastal, coal and oil
23. Nine Mile Point, Niagara Mohawk, Great Lakes, nuclear
24. Cedar Bayou, Houston Power and Electric, cooling lake with estuarine discharge, gas

A further list of 63 additional plants has been compiled. These plants will be considered pending the outcome of initial investigations into the 24 plants listed above.