Aquatic Pesticide Monitoring Program

Determining Economic Impacts of Aquatic Plant Management in California Waters

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Disclosure and Acknowledgements

This report is the result of feedback by the Aquatic Pesticide Monitoring Program Steering Committee that there is a need for more information on the comparative costs of different aquatic pest control methods in California waters. Discussions of the Environmental Economic Work Group of the Aquatic Pesticide Monitoring Program lead to a general framework for assessing cost-effectiveness, upon which the report is partially based. This work is intended as an educational tool, including case study examples, on the methodology for evaluating the relative costs of aquatic plant control methods in different management scenarios. No policy or regulation is expressed or intended.

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Chapter 1: Methodology For Aquatic Plant Management Economics.

Roger Mann, RMEcon, Davis, CA

1.1 Introduction

This chapter provides a methodology for aquatic plant management economics (APME). The methodology is designed to help managers and practitioners understand the costs and benefits of alternative management practices for aquatic plants. The methodology can be applied to develop comparisons of generic management strategies as well as specific aquatic plant management problems.

Many weed scientists and aquatic plant management practitioners in California have expressed a need for clear economic cost comparisons of different methods of aquatic plant control. This methodology provides a first step towards addressing that need. Scientists with the Aquatic Pesticide Monitoring Program are using this formal methodology to quantify economic differences among plant control options. The methodology may also be used by field practitioners to clarify their management options for a given water body and estimate which ones or which integrated practices will be most effective.

The chapter is structured as follows. First, the methodology is provided. Development of the structure and scope of the methodology is provided concurrently with definitions of terms and explanation of concepts. This structure allows concepts to be applied as they are described. Important definitions are provided in bold italic text. For example, tables that provide information for use in the analysis are called ***Economic Information Tables***. Tables that are used for entering data about a specific aquatic plant problem are called ***Entry Tables***.

Second, recommendations for documenting an analysis are provided. The main sections of the APME report are a summary, a discussion of remaining uncertainties and issues, and a description of how the APME process was applied to the unique APME problem at hand.

Third, an example is provided. The selected example involves Lake Van Ness, a 28 acre lake near Fresno, California. Three management alternatives are evaluated.

Fourth, information is provided to help a user estimate damage costs and environmental costs. These types of costs are typically more difficult to estimate and uncertain than control costs. Damage costs are those caused by the aquatic plants. Benefits are cost savings from aquatic plant damages that are avoided by aquatic plant management.

Environmental costs are those caused by the plant management and control practices, Environmental costs involve the unintended or external effects of plant management.

Environmental costs may also be addressed without formally converting them into dollar values. Non-economic evaluations of environmental hazards such as toxicity or health risk studies fall outside the scope of this document, but are an objective of the Aquatic Pesticide Monitoring Program.

The estimation of economic costs and benefits is often complicated by a lack of precedent, by a lack of data, by variations in economic perspective-whose benefits and costs should be counted, and many other factors. APME is not intended to completely cover all types of problems that might be encountered in estimating benefits and costs. Good background information is provided in benefit-cost textbooks and in guidance provided by federal agencies. Many citations and sources are discussed in Section 1.6.

1.2 Defining the Problem and Scope of the Analysis

This section outlines some economic and analysis concepts to consider in deciding if an analysis is justified. Some decisions about structure and scope that must be resolved include:

- Is there an aquatic plant problem that can and should be investigated?
- Are there at least two management alternatives?
- Whose costs and benefits should be counted?
- What types of costs and benefits can and should be counted, and what type of economic analysis then follows?
- What period of analysis and discount rate should be used?
- How should inflation be considered?

1.2.1 Identify the Aquatic Plant Problem

APME can be applied when 1) there is an aquatic plant problem, and 2) there are two or more feasible management alternatives, and 3) control costs can be estimated for each alternative. An ***aquatic plant problem*** is identified when a type of water body, a plant type, and potential economic costs can be identified. Entry Table 1 lists water body types, plant types and potential economic costs, and provides spaces for entering information for a specific problem.

1.2.1.1 Identify Potential Economic Costs and Benefits

If the aquatic plants can not be associated with any type of economic costs, then there is not an aquatic plant problem. ***Economic costs*** include control costs, damage costs and environmental costs. ***Control costs*** are the costs of aquatic plant management practices. ***Damage costs*** are costs caused by the plants – lost use values, lost recreation benefits, or flooding costs, for example – that are expected to be reduced or avoided by aquatic plant management. ***Benefits*** are reduced damage costs. Some types of damage costs are displayed in Entry Table 1. ***Environmental costs*** involve unintended, external impacts on non-target environmental resources or on people directly, caused by the control; for example, mortality of non-target species, health risks, or values associated with lost aquatic plant habitat.

From a purely economic perspective, the goal of aquatic plant management would be to minimize total economic costs. However, there may be other, non-economic considerations. These other considerations and information limitations may result in a plant management objective that the analysis will want to take as a given.

1.2.1.2 If Possible, Identify a Management Objective

Often, there will be a pre-existing management objective associated with a specified aquatic plant problem. A ***management objective*** is a definable goal for aquatic plant management that 1) is not expected to change and 2) all stakeholders can agree to. For purposes of APME, a ***stakeholder*** is any person or group of persons who can and might stop a management practice from being implemented. Stakeholders may include property owners, managers, financiers, and regulators. If there is no pre-existing management objective, then one might still be defined by stakeholders, or stakeholders may want to use APME as a method to help define a management objective. Entry Table 1 provides a space for describing the management objective, if any, and a space is provided for listing stakeholders associated with the aquatic plant problem.

The management objective should be specified as clearly as possible. The definition may include, for example, 1) measures of how much aquatic plant will be tolerated, such as percent plant cover or density, 2) dates at which control is expected, and/or 3) the potential type of damage costs that must be avoided.

A management objective is useful in that, if it is accepted as the basis for analysis, it will help reduce the number of feasible management alternatives that must be considered. On the other hand, if a management objective is selected, it must be recognized that the management objective itself may preclude a more economical alternative from being selected. More generally, if a management objective is accepted as a basis for analysis, then the possibility of a better management objective is not considered.

1.2.2 Identify Two or More Management Alternatives

The purpose of APME is to compare management alternatives in terms of their total economic cost, and to identify alternatives that may be preferred based on cost, management objectives, and other factors.

APME can be applied only when at least two management alternatives for an aquatic plant problem can be considered. A ***management alternative***, or alternative, is one or more ***management practices*** for aquatic plant control. A management practice is a particular type of treatment such as harvesting, use of sterile grass carp, or a chemical control such as with copper sulfate or glyphosate. Economic Information Table 1 lists types of management practices. A management alternative is the specific application of one or more management practices to a particular aquatic plant problem. Often, a management alternative will include just one management practice. However, an alternative could include one or more practices applied at different times or in different areas within the problem location. Much more detail on selecting and specifying alternatives is provided in Chapter 1.3 below.

1.2.3 Select One or More Economic Perspectives

Before conducting economic analysis, the analyst must select at least one economic perspective. The ***economic perspective*** defines whose benefits and costs will be counted by a benefit or cost analysis. An economic perspective can sometimes have the same definition as a stakeholder; for example, property owners who can unilaterally select a management alternative. The ***private perspective*** might be selected when a private group or individual can decide which management alternative to select. The analysis will determine which one they should select, given their benefits and costs. The private perspective overlooks environmental costs that may adversely impact other people, such as toxicity to nontarget organisms that other people care about, or spreading of noxious weeds outside the system. The private perspective also excludes any share of the control cost paid by the public.

The ***public perspective*** includes all people who are affected by the aquatic plant and its control. The public perspective is included when there is a public interest in the selection of a management alternative or there are external benefits, costs, or subsidies paid by persons other than the private group or individual. The public perspective is often used when a public agency must decide whether or not to participate in an action such as aquatic plant management.

The economics of a management alternative may differ between the two perspectives when external benefits, costs and subsidies are large. In general, the public perspective will include more of the "environmental costs" category. If both perspectives are to be included, it is often easiest to first count economic costs from the private perspective. Then, the analysis should include the external benefits, costs, or subsidies to obtain results for the public perspective.

1.2.4 Select a Type of Analysis

There are three types of analysis defined for APME. The types are differentiated by whether or not all alternatives should meet a management objective, and according to whether or not data on damage costs and environmental costs should be and can be counted. Any of the three types of analysis can be conducted from the public or private perspective, or both.

Type A. Meet a Management Objective, Control Costs Only

The Type A analysis is the minimum economic analysis possible given the types of economic data that are likely to be available. The analysis simply estimates and compares control cost across the management alternatives. A Type A analysis is appropriate for selecting an alternative when all alternatives meet a management objective and one of the following conditions holds:

- costs other than control costs don't matter, or
- all alternatives have the same damage and environmental costs, or
- damage and environmental costs are very small compared to control costs in any alternative

The Type A analysis will often be used merely because control cost data are likely to be more available and accurate than damage cost data or environmental cost data. A Type A analysis can also be used if damage costs or environmental costs are important, but they cannot be estimated. In this case, however, the economic analysis alone will not be sufficient for selecting an alternative. Qualitative or physical information about aquatic plant damages and environmental impacts should also be considered when an alternative is selected. The qualitative of physical information might include narrative descriptions, rankings of expected impacts, or by expressing environmental or damage variables in physical or biological units.

If there are expected to be important differences in damage or environmental costs between alternatives, and some damage or environmental costs can be quantified in dollars, then a Type B or C analysis should be pursued.

Type B. Meet a Management Objective, Include Some Damage Costs or Environmental Costs

This analysis is used when there is a management objective, and all management alternatives are designed to meet the objective, but there are still differences in damage costs or environmental costs between management alternatives, and some of these differences can be economically quantified in a meaningful way. The analysis estimates and compares total cost across the management alternatives. The selected alternative might not be the least costly alternative because the management objective may preclude the least costly alternative from being selected.

This type of analysis has a large amount of information required. In general, information on damage costs and environmental costs is more difficult to develop than control costs. If all damage and control costs cannot be quantified, then they should be described to the extent possible. Additional guidance for damage costs and environmental costs is provided in Chapters 1.6 through 1.8.

Type C. Full Benefit/Cost Analysis

This analysis is used when there is no management objective, or the management objective is not yet determined. The analysis estimates and compares total cost across the management alternatives. The analysis is used to determine which management alternative has the smallest combined control, damage and environmental cost, to the extent that information is available. This type of analysis has the most amount of information required. This type of analysis could be used to select the best management objective from a range of potential management objectives.

The three types of analysis are meant to encompass the entire range of problems that a user is likely to encounter. A Type A analysis is the most simple, because the management objective may eliminate some range of management alternatives, and detailed consideration of damage costs and environmental costs - costs that are hard to quantify - is not required. A Type B analysis allows that quantification of these costs is important for the case at hand. A Type C analysis is most ambitious in that it explicitly seeks a "global optimum;" the best possible economic outcome.

1.2.5 Select a Period of Analysis, Discount Rate, and Price Level

In some cases, each management alternative will be repeated at the same interval, perhaps once per year, and damage and environmental costs are expected to be the same each year in the future. In this instance, a period of analysis and discounting are not required. The analysis can estimate and compare annual costs of the alternatives.

Some aquatic plant management alternatives have costs and benefits that extend years into the future. For example, control by insects may increase over years as populations increase, or plants may grow back over years following a herbicide application. One alternative might have the same costs every year, while another requires large costs up-front but few costs in the future. In this case, economic analysis requires discounting of future costs over a period of analysis. Examples of discounting in APME are provided in Entry Table 6.

The ***period of analysis*** defines how many future years should be included in the analysis. The analyst must decide how many future years should be included.

The period of analysis should be selected to avoid bias in the comparison of alternatives. At the end of the period of analysis, the condition of the aquatic plants and the level of damage costs should be about the same under each alternative. If this is not possible, then the period of analysis should be carried so far into the future that discounting makes the future costs very small.

For example, suppose that we are comparing two management alternatives in a benefit/cost type of analysis. In one alternative, control occurs every 3 years; in the other, every 2 years. If both alternatives result in the same plant density immediately prior to control, then the period of analysis should be 6 years, because both alternatives result in the same plant density at the beginning of year 7. However, if one alternative allows for a much higher plant density regime, then 6 years would not be enough years, because the alternative that allows the higher plant density would have larger damage costs in year 7.

Rather than using a longer period of analysis, the high-density alternative could be modified to include an action in year 6 to make the ending densities comparable.

Economic analysis of a period of future years can be conducted as either a constant dollar analysis or a nominal dollar analysis. A nominal dollar analysis includes expected inflation in all future prices and interest rates. A constant dollar analysis takes out effects of inflation from all dollar values and interest rates before they are used in the analysis. If nominal dollar analysis is selected, then nominal discount rates should be used. If constant dollar analysis is selected, then real discount rates should be used. For APME, a constant dollar analysis is recommended.

The ***price level*** is the year selected for which all constant dollar values are expressed; for example, 2001 dollars. Economic data from prior years must be adjusted to the selected price level using price indices, such as the producer or consumer price index, that measure past inflation. Some potentially useful price indices are provided as Appendix A.

The ***real discount rate*** is the real rate of interest per year at which future benefits and costs should be discounted. It is an inflation-free interest rate. The discount rate is used to account for the time preference for money. People tend to prefer money in the present rather than the future.

Discounting means that, with a discount rate of d, dollar costs or benefits expected to occur Y years in the future must be divided by a factor of $(1+d)^Y$ before they are added together to obtain net present value of cost. For example, a real discount rate of 5 percent can be used as a reasonable default value. With a 5 percent discount rate, costs that occur exactly 50 years in the future are discounted (divided) by a factor of 11.47. $(1+.05)^{50}$ Discounting calculations can be simplified using spreadsheet functions such as NPV or PMT.

The purpose of ***sensitivity analysis*** is to determine how results are affected if some of the initial assumptions change. There are several reasons why the analyst might want to conduct sensitivity analysis using different interest rates. For problems that involve benefits or costs far in the future, a range of discount rates can be tested to see if results are sensitive to the selected rate. The real discount rate may need to differ between economic perspectives because different groups of persons have different rates of discounting the future. Economists often argue that the public discount rate should be smaller than the private discount rate. . The federal government provides discount rates for cost-effectiveness, lease purchase, and related federal analyses (OMB, 2002). The year 2003 discount rate ranges from 1.6 to 3.2 percent, depending on the number of years (3 to 30) in the analysis. The federal government also sets a discount rate each year that must be used for certain water resource project evaluations. That rate is 5.875 percent in 2003.

1.3 Specifying and Evaluating Management Alternatives

This section describes how to develop, display and analyze management alternatives. The methodology is presented and example tables for compiling economic information are provided.

1.3.1 Specify Management Alternatives

One of the most important inputs to APME is to specify the management alternatives that should be analyzed. To specify, in this case, means to provide enough information about the alternative to accomplish three things:

Estimate costs that are needed for the type of analysis selected;
Determine if the management objective, if there is one, is accomplished; and
Determine whether the alternative is technically, legally, and socially feasible

The information that will be needed is, typically, what practices are included, their costs, the area or amount of treatment, and the result in terms of amount of immediate control and the timing and extent of re-growth. To some extent, specification must be an iterative process. The alternatives to be analyzed are changed as more information about them is developed.

Unless the status quo is unacceptable to any stakeholder, a status quo management alternative should be one of the alternatives considered. The analyst should understand why the status quo alternative was used in the past in terms of what factors caused this alternative to be selected. Also, the opinions of any stakeholders regarding the potential for other management alternatives should be understood.

Entry tables 2 to 6 provide a template to use for specifying management alternatives and reporting economic costs by practice. Entry Table 2 provides a format for compiling a list of management practices for a management alternative. The remaining tables are described below.

In Entry Table 2, each practice should be entered in the order it is expected to occur. All practices expected during the period of analysis should be entered. There will be a version of Entry Table 2 for each management alternative to be considered. Chapter 1.4 provides an example that shows how Entry Table 2 can be used.

The fourth column of Entry Table 2 provides a place to check those practices that are identical in every management alternative considered. This check can only be completed when all management alternatives are specified. Only practices that are exactly the same, meaning they have the same cost in the same years, in all alternatives should be checked. These practices do not need to be considered in the economic evaluation, so the effort of collecting costs for them can be avoided. However, if financial feasibility is a potential issue, then the costs of all practices must be counted, even if they are the same in every management alternative. Therefore, if information on all costs must be collected to check financial feasibility, then the fourth column can be ignored.

1.3.2 Feasibility Tests

Any management alternative may have to meet a number of feasibility tests. Based on expert opinion, if the alternative cannot meet all of these tests, then it must be modified or discarded as an alternative. General guidance on feasibility is provided in the APMP Alternatives Literature Review and Field Evaluations. APME does not provide guidance on conducting checks to ensure that each management alternative is feasible for a given management scenario. However, the analyst should be aware that these other factors should be considered and that analysis time should not be wasted evaluating the costliness of management alternatives that are doomed to failure.

The tests are:

- Technical feasibility. The practice must be physically possible to perform in a management scenario. Performance parameters include the physical ability to apply the control given unique site conditions, the amount of the control to be applied, the success of the control, and the expected rate of re-growth of the aquatic plant. Practices not technically feasible include, for example, mechanical harvester operation in areas too shallow for boat movement, or grass carp addition to water bodies where fish won't survive.
- Legal Feasibility. The practice must be allowed by local, State and federal laws, and all necessary permits can be obtained.
- Financial Feasibility. The practice must be affordable within budget constraints. This test may not be possible until after economic costs are estimated (Chapter 1.3.3 below).
- Social/cultural Feasibility. The practice must be able to be approved by any stakeholder.

The analyst should take steps to ensure that all management practices included in the analysis are feasible. This may require meetings and assurances from other types of aquatic plant specialists and interests including applicators, contractors and operators, regulators, districts or other sources of finance, and public interest groups. Entry Table 2 includes a row to keep track of feasibility tests. If a particular management alternative fails one of the feasibility tests, cost benefit or cost-effectiveness analysis should not be conducted for that alternative.

If an alternative fails a feasibility test, this does not mean that the alternative should not be completely discarded. The alternative could be modified. If a practice passes a feasibility test, this does not imply that all technical, legal, financial and social/cultural considerations have been covered. These considerations may still have important roles in designing and evaluating alternatives.

1.3.3 Estimate Costs of Each Practice in Each Management Alternative

Each management practice in Entry Table 2 must be assigned a cost. Entry Table 3 provides a format for entering information about each practice in the management alternative. First, a description of each management practice is provided. The specification should include when, where and how much of each management practice will be applied.

Next, if the total cost of the practice is known, perhaps from a bid or past experience, it can be entered. If the analysis is a Type A, the entries for Entry Table 3 for this practice can end here.

Sometimes, the cost of a practice is unknown, but the cost can be estimated with information about the attributes of the practice. For example, the cost of chemical control can be estimated if the cost per acre and the number of acres to be treated is known. The acreage to be treated should be entered in Entry Table 3 unless cost is independent of acreage.

Some factors that affect cost, and other information that may be useful for estimating control costs, are provided in Economic Information Tables 2a (for chemical costs) and 2b (for mechanical costs). The estimates in Economic Information 2 were obtained from discussions with California contractors. It should be noted that the costs provided in Economic Information Table 2 are general estimates, and will not be applicable to all management scenarios. These costs should only be used in preliminary evaluations if local cost data are not available.

A table of control cost information from many studies and locations is provided as Appendix B. This information leads to an estimate of the control cost at the bottom of Entry Table 3. For a Type A analysis, the methodology can proceed to the next practice. For a Type B or C analysis, the methodology proceeds to Entry Tables 4 and 5.

One Entry Table 3 must be developed for each row in Entry Table 2 unless some management practices expected in different management alternatives or different times will be identical. If a management practice occurs more than once, then duplicate Entry Table 3s are not required.

1.3.4 For a Type B or C Analysis, Describe Damage Costs and Environmental Costs

For a Type B or C analysis, Entry Table 4 provides information on any damage costs expected to be caused by aquatic plants following a practice, but before the next practice is applied. One Entry Table 4 must be developed for each damage cost identified for each practice in Entry Table 3. If more than one practice will have exactly the same damage costs, then this is noted and duplicate tables are not required. The amount of damage costs should be based on the expected density of aquatic plants with the management alternative in place. Information on how to estimate economic damage costs is provided in Chapters 1.6 and 1.7 below.

For a Type B or C analysis, Entry Table 5 provides information on any environmental costs expected to be caused by the management practice. One Entry Table 5 must be developed for each environmental cost identified for each practice in Entry Table 3. If more than one practice will have exactly the same environmental costs, then this is noted and duplicate tables are not required. Information on how to estimate environmental costs is provided in Chapters 1.6 and 1.8 below.

1.3.5 Arrange Data into the Period of Analysis and Compare Costs

Now that each management alternative has been specified and costs have been estimated to the extent possible, the economic analysis can be conducted. Results for each year and each management practice should be entered into Entry Table 6 up to the last year of the period of analysis. If all costs are expected to be the same in every year, then cost data can be entered in the first row only, and net present value analysis is not required.

The last two rows of Entry Table 6 calculate the net present value and annualized value of each annual series of costs. Entry Table 6 should be entered into a spreadsheet format to allow the use of financial formulas for these calculations. The persons in the economic perspective would be indifferent between the ***net present value*** of costs, a lump-sum cost paid in year one, and the future stream of economic costs. In Excel, net present value is calculated using the NPV function. The entry in the cell where the NPV should appear is: NPV(.discount rate, range of cells with annual dollar values).

The ***annualized value*** is used to express the net present value as an annual equivalent. The persons in the economic perspective would be indifferent between the net present value of costs, and a future stream of costs equal each year to the annualized value. In Excel, net present value is calculated using the PMT function. The entry in the cell where the NPV should appear is -PMT(discount rate, number of years, NPV).

As an example of net present value and annualized value, consider a loan to be paid off in equal annual payments. The annual payments are the annualized value of the loan amount, and the loan amount is the net present value of the annual payments.

Entry Table 7 provides a Table for summarizing and comparing costs for all management alternatives. For each alternative, an indication should be provided to show if it meets the management objective, if applicable. Control costs and total costs are entered, and qualitative information about other costs, benefits and other considerations can be provided. Spaces are provided to enter results of feasibility tests. Finally, the last row provides a space where the selected or preferred alternative can be named.

1.4 Document the Analysis and Describe Remaining Issues and Uncertainties

In most cases, written documentation of the analysis should be developed. The report should summarize results, describe remaining uncertainties and issues, and expand on the data in the entry tables. The structure of the report could follow the structure of APME as reproduced and augmented below.

1. Summary of Results
2. Remaining Uncertainties and Issues
3. Identify the Aquatic Plant Problem
4. Potential Economic Costs and Benefits
5. Management Objective
6. Identifying Management Alternatives
7. Economic Perspective
8. Type of Analysis
9. Period of Analysis, Discount Rate, and Price Level
10. Specifying Management Alternatives
11. Feasibility Tests
12. Costs of Each Practice in Each Management Alternative
13. Damage Costs and Environmental Costs
14. Entry Tables

The first section would simply summarize results of the analysis. Recommendations for any additional information, analysis required to confirm the results, or other next steps should be provided. Section 2. should summarize the remaining uncertainties in the analysis and describe any remaining issues that might bear on the results.

The remaining sections follow the structure of APME in terms of the required decisions and data entries. These sections provide information to augment the Entry Tables. The report should provide documentation and description of the process and thinking that went into each step of the analysis. It should describe the reasons why the analysis options and sources of information were selected. Remaining uncertainties associated with data inputs and results should be revealed.

An example of an analysis report is provided in Section 1.5 below. The report describes the example study for Lake Van Ness in Fresno County.

Entry Table 1. **Define the Aquatic Plant Problem.**
Name of Water Body:
1a. Location: (name of water body and its location. Identify water sources and destinations)
1b. Water Body Type (identify and describe at least 1)
Small pond
Large lake
Delta
Irrigation canal
Stormwater
EstuarineWetlands
Wildlife Refuges
1c. Aquatic Plant Type (identify and describe at least 1)
Floating
Submerged
Emergent
Algae
1d. Potential Economic Costs (identify and describe at least 1)
History of Control costs, or Control Expected (Name Practice from Information Table 1)
Types of Damage Costs
Contributes to flooding/drainage/storm water problems
Water supply quantity
Water supply quality
Impedes navigation
Impedes/limits recreation/parks values
Reduces environmental values
1e. Management Objective (if there is one)
1f. Stakeholders (if applicable)

<table>
<tr><th colspan="5">Entry Table 2.
Define a Management Alternative, with Checks.
For a Management Alternative, List of Expected Management Practices</th></tr>
<tr><td colspan="5">Management Alternative Name:</td></tr>
<tr><th>Year or years of Period of Analysis</th><th>Order of Practices When Applied During the Year (1^{st}, 2^{nd} etc)</th><th>Name of Practice to be applied (See Information Table 1)</th><th>If this practice repeats in all mgmt alts, check [1]</th><th>Notes</th></tr>
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<tr><td>Add more rows if needed</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Is this management alternative expected to meet the management objective?</td><td>Yes No DNA</td></tr>
<tr><td colspan="5">Is this management alternative expected to be feasible?</td></tr>
<tr><td>Feasibility Test Type</td><td>Technical</td><td>Legal</td><td>Financial</td><td>Social/cultural</td></tr>
<tr><td>(circle 1)</td><td>Yes No</td><td>Yes No</td><td>Yes No</td><td>Yes No</td></tr>
<tr><td colspan="5">[1] These checks are used to determine practices that do not need to be included in the analysis because they will be conducted in any case. The costs of these practices should be included in any consideration of financial feasibility</td></tr>
</table>

Entry Table 3. Number_____ Costs of a Management Practice. For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.		
Management Alternative Names:		
Name of Practice:		
General description of Practice		
When during the season will practice be applied?		
Where within the location this practice is to be applied?		
How much will be applied?		
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	Dollars	
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	
Total Estimated Cost	Range, Dollars	
Total Estimated Cost	Average, Dollars	
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

<table>
<tr><td colspan="3">Entry Table 4. Number_____
Damage Cost Data
Type B or C Analysis. For Each Damage Cost Type Expected, Complete One of These Tables</td></tr>
<tr><td colspan="3">Row Numbers from Entry Table 2 (1st, 2nd, etc) ____</td></tr>
<tr><td colspan="3">Management Alternative Name:</td></tr>
<tr><td colspan="3">Name of Practice:</td></tr>
<tr><td colspan="3">Type of Damage Cost:</td></tr>
<tr><td>Describe how this damage affects users of this water body</td><td colspan="2"></td></tr>
<tr><td>Describe location of damage</td><td colspan="2"></td></tr>
<tr><td>Measurable Attributes of this Damage</td><td>Measure</td><td>Amount</td></tr>
<tr><td>When following practice will damage occur</td><td>Approx. date(s)</td><td></td></tr>
<tr><td>Damaging acreage</td><td>Acres</td><td></td></tr>
<tr><td>Dollar cost of economic damage, if it can be measured (see Section 1.7)</td><td>Dollars</td><td></td></tr>
</table>

<table>
<tr><td colspan="3">Entry Table 5. Number___
Environmental Cost Data
Type B or C Analysis. For Each Environmental Cost Type Expected Following a Practice, Complete One of These Tables</td></tr>
<tr><td colspan="3">Row Numbers from Entry Table 2 (1st, 2nd, etc) ____</td></tr>
<tr><td colspan="3">Management Alternative Name:</td></tr>
<tr><td colspan="3">Name of Practice:</td></tr>
<tr><td colspan="3">Type of Environmental Cost:</td></tr>
<tr><td>Describe the environmental cost</td><td colspan="2"></td></tr>
<tr><td>Describe linkages between the affected resource and human interests</td><td colspan="2"></td></tr>
<tr><td>Describe the persons affected</td><td colspan="2"></td></tr>
<tr><td>Measurable Attributes of this Environmental Cost</td><td>Measure</td><td>Amount</td></tr>
<tr><td>When following practice will environmental cost occur</td><td>Time Units____</td><td></td></tr>
<tr><td>Approximate number of persons affected</td><td></td><td></td></tr>
<tr><td>Dollar amount of environmental cost, if it can be measured (see Section 1.8)</td><td>Dollars</td><td></td></tr>
</table>

Entry Table 6.
Costs of Management Practices by Year for a Management Alternative

Management Alternative:

		Quantified Control Costs, Damage Costs, and Environmental Costs, In ____ Dollars (enter year)						
Year	Source of Data (Tables, number)	Name of Control Cost, Damage Cost, or Environmental Cost						Total Cost of Alter-native by Year
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
Etc								
Last Yr								
NPV(.05, Yr1..,Yr20), 1000 $								
-PMT(.05,Last Yr.,NPV), 1000 $								

Entry Table 7.
Comparison of Management Alternatives for Aquatic Plant Management

Type of Analysis

	Economic Costs from Entry Table 6				Meets Management Objective?	Describe Other Benefits and Costs and Other Considerations that Affect the Selection of a Management Alternative	Results of feasibility Tests			
	Control Costs		Total Costs							
Management Alternative	NPV, 1000$	Annual Value, 1000$	NPV, 1000$	Annual Value, 1000$			Tech	Legal	Finance	Soc/C

Management Alternative Selected:

Economic Information Table 1.
List of Selected Aquatic Plant Management Practices

Practice	Description
No Practice	No intentional actions to reduce aquatic plants
Harvesting	Cut, harvest and disposal
Cutting	Cutting only
Excavation	Remove sediments and overlying plants. Methods include chaining, diver dredging, raking
Handpull	Individuals "weed" bottoms, may require divers
Bottom Barriers	Semi-permanent materials laid over plant beds
Rotovation	Submerged aquatic rototilling
Water level drawdown	Dewater system to kill plants
Sterile Grass Carp	Stock juvenile carp
Insect	Introduce insects that specialize in consuming target plants
Copper sulphate	Primarily for algae and hydrilla
Acrolein	Primarily for submersed plants in irrigation systems
Glyphosate	Primarily for emersed plants
Fluridone	Used for a variety of plant types
Diquat dibromide	
2,4-D	
Triclopyr	
Endothall	Primarily for submersed plants
Chelated Copper	Primarily for algae

Economic Information Table 2a.
Data for estimating costs for selected chemical aquatic plant control methods in northern California*

Cost Component	Units	Amount	Notes
Set-Up Costs	$ per application	$1,250	4 hour minimum. Includes 2-man crew, boat and spray equip
NPDES Permitting Costs	$ per site per year	$8,500	
Material and Application	$ per acre		
Renovate			
Glyphosate		$639	
Fluridone			
Chelated Copper		$540	
Copper Sulphate		$540	
Endothall		$639	
Sampling Requirements	$ per Sample		
Pre-treatment		$1,250	
Post-treatment		$1,250	
30 days post-treatment		$1,250	
If detectable at 30 days, additional until not detected		$1,250	

* The estimates in Economic Information 2 were obtained from discussions with California contractors. These are general estimates, will not be applicable to all management scenarios, and should only be used in preliminary evaluations if specific cost data are not available.

Economic Information Table 2b.
Data for estimating costs for selected non-chemical aquatic plant control methods in northern California*

Cost Component	Units	Type of Non-Chemical Method: Harvest-Large Water Body	Harvest-Small Water Body	Cutting	Rotovation	Excavation	Notes
Equipment	Type	H-7 400 cu ft	H-5 200 cu ft	H-5 200 cu ft	PRX 12' wide	hydraulic bucket	
Set-Up Costs							
Base Set-Up Cost	Dollars per Job	$800	$350	$350	$1,250	$1,250	If transport and mobilization takes 4 hours or less
Additional Cost if More than 4 Hours	Dollars per hour	$125					
Overhead	Additional % of Total Costs	22% to 28%	22% to 28%	22% to 28%	22% to 28%	22% to 28%	
Regulatory	Additional % of Total Costs	0% to 5%	0% to 5%	0% to 5%	15%	15% to 25%	For excavation, 15% if under 1000 cu yds, 25% if over
Operating Costs							Does not include any disposal
Base Operating Cost	Dollars per Day	$800	$500	$500	**	**	
Labor Operating Cost	Dollars per Day	$520	$520	$520	$520	$520	$65 an hour

Operating Speed	Acres per Day						
General submerged Vegetation					6 to 8		
General floating vegetation						0.17	
Pondweeds, widgeon grass, niads, milfoil		4	2	4	***	***	
Egeria, hydrilla, coontail, fanwort		2 to 3	1 to 1.5	4	***	***	
Floating plants: hyacinth, ezold		1 to 2	0.5 to 1.0	4	***	***	
Dense emergent vegetation (Thick tules or cattails)					0.25 to 1.25		
Hauling Costs							
If on-site disposal is available		$0	$0	$0	$0	$0	If no trailer is needed; i.e., disposal on shore
If on-site disposal is not available							
Trailor Labor Cost	Dollars per Day	$440	$440	$0	$440	$440	$55 an hour
Truck Labor Cost	Dollars per Day	$400 to $600	$400 to $600		$400 to $600	$400 to $600	
	Tons per Load	15-30	15-30		15-30	100	15 if dry, 30 if wet
	Loads per day	4	4		4	4	Depends on miles to disposal
Weight of material:							
If on-site drying is available	tons/acre	1.5 to 2	1.5 to 2		1.5 to 2		
If on-site drying is not available	tons/acre	2 to 4	2 to 4		2 to 4	2,097 to 2,420	2 if dry, 4 if wet. May require crushing

Disposal Costs				0			
If on-site disposal is available	$0	$0	$0			$0	
If green waste disposal is available	Dollars per Ton	$8 to $9	$8 to $9		$8 to $9		
If not available	Dollars per Ton	$0 to $40	$0 to $40		$0 to $40	$0 to $40	

* The estimates in Economic Information 2 were obtained from discussions with California contractors. These are general estimates, will not be applicable to all management scenarios, and should only be used in preliminary evaluations if specific cost data are not available.
** Data not available at time of report release; *** Costs not well characterized for specific vegetation categories.

1.5 Example of a Type A Analysis: Lake Van Ness

The example is provided through the analysis report and entry tables below.

1. Summary of Results

Lake Van Ness is a 28-acre lake near Fresno, California. The lake is used for recreation and aesthetic purposes by homeowners around the lake. The status quo management regime includes annual harvesting and chemical treatment for algae. The APME analysis considered three management alternatives; Status Quo, Sterile Grass Carp, and Bacterial Treatment. All of these alternatives would continue chemical treatment for algae.

The Status Quo and Bacterial Control alternatives both have the same costs every year. Since the Status Quo alternative costs less every year, it is obvious that the Status Quo alternative is more cost effective. Results are not so obvious for the Grass Carp alternative. Costs are more than Status Quo in the early years but less in future years. The discounting procedure is needed to determine which is less costly. With a five percent discount rate, it appears that the Grass Carp alternative is much preferred to the Status Quo. The annualized cost of the Grass Carp Alternative is $6,780 per year, much less than the annualized cost of $20,066 for the Status Quo. Additional development of the grass carp alternative appears warranted.

2. Remaining Uncertainties and Issues

The Sterile Grass Carp alternative may not be legally feasible in this case. If the lake is within the 150-year floodplain, planting of sterile grass carp might not be allowed. Additional information will be needed to clarify this point. Also, additional screening and permitting costs might be required. Eurasian Milfoil is not a preferred food type for Grass Carp, but it is thought that they can thrive and provide good control of milfoil. It is likely that the grass carp would eliminate any other aquatic plant species from the lake.

3. Identify the Aquatic Plant Problem

The aquatic plant problem in Lake Van Ness is described in Entry Table 1. Information was provided by Aquatic Environments Inc.

4. Potential Economic Costs and Benefits

The history of aquatic plant control in Lake Van Ness is sufficient to establish potential economic costs. Uncontrolled plant growth would diminish the lake's aesthetic qualities and diminish ability of residents to use small boats and practice catch-and-release fishing.

5. Management Objective

The management objective for Lake Van Ness is to provide aquatic plant control and maintain water quality consistent with the site aesthetics and lake management plan (LMP). The LMP restricts the range of permissable practices.

6. Identifying Management Alternatives

The management alternatives in Entry Table 2 were identified with the help of AEI.

7. Economic Perspective

A private perspective is used because the costs of control are paid privately, and there are no external costs or benefits outside of the local homeowner's group.

8. Type of Analysis

The analysis is a Type 1 analysis because the management objective is met in all cases, and there is no reason to believe that damage costs or environmental costs would be different among the three management alternatives.

9. Period of Analysis, Discount Rate, and Price Level

The analysis uses a fifty-year period of analysis, a 5 percent discount rate, and a 2002 price level.

10. Specifying Management Alternatives

The management alternatives in Entry Table 2 were specified with the help of AEI. For the Sterile Grass Carp alternative, it is assumed that a drum screen would be installed at the outflow to keep any carp from escaping.

11. Feasibility Tests

The economic analysis does not include algae control costs because algae control practices are identical in every management alternative. This means that financial feasibility tests can not be conducted. Financial feasibility does not seem to be an issue in this case. The large initial costs needed for sterile grass carp could be an issue. There is an outstanding issue regarding the legal feasibility of sterile grass carp. If the lake is not within a 150 year floodplain, then stocking of sterile grass carp should be allowed. There are no known social or cultural issues.

12. Costs of Each Practice in Each Management Alternative

Costs were estimated with help from AEI. For harvesting, costs were estimated based on the number of acres to be harvested, the cost per day, and the number of acres per day. The grass carp practice is assumed to include $10,000 in permitting and $39,900 in screening costs. All costs were developed from a range of assumptions, and the midpoint of the range of results was used to draw preliminary conclusions. For example, costs per grass carp were $15 to $35, and 2 to 4 fish would be planted per acre, so grass carp costs would be $840 to $3,920 every five years. In addition, a cost of $7.50 per fish per year is paid to CDFG for monitoring.

13. Damage Costs and Environmental Costs

All alternatives are designed to provide aquatic plant control consistent with the management objective. Therefore, no estimate of damage costs is required. There is some doubt as to the ability of bacterial control to function as planned.

None of the alternatives include herbicide application, but all include algaecide. Status Quo harvesting has raised issues with fragmentation. Sterile Grass carp would probably eliminate all aquatic plant species except Eurasian milfoil. Screening would ensure that there would be a negligible chance that sterile grass carp could escape Lake Van Ness.

14. Entry Tables

The Entry Tables for this case study are provide below. There are three versions of Entry Table 2, and four versions of Table 3. Four versions of Table 3 are required because the Bacterial Control alternative requires a limited amount of harvesting. There are three versions of Table 6 provided, one for each alternative.

Entry Table 1. Define the Aquatic Plant Problem.
Name of Water Body: Lake Van Ness
1a. Location: (name of water body and its location) Fresno (Central California Valley)
1b. Water Body Type (Identify and describe at least 1. Identify water sources and destinations)
Small pond
Large lake. 28 acre irregularly shaped freshwater lake. System takes storm water (street/landscape runoff) during events and has an overflow that ultimately feeds into the City of Fresno storm drain system Make up water is by underground well and is required in the absence of precipitation. The lake has a "fixed" or hard-plumbed aeration system, with twenty-four (24) subsurface diffusers located (immovable) in various spots around the lake.
Delta
Irrigation canal
Stormwater. The lake receives stormwater
EstuarineWetlands
Wildlife Refuges
1c. Aquatic Plant Type (identify and describe at least 1)
Floating
Submerged The dominant plant species within the lake is Milfoil (*Eurasian watermilfoil*), which accounts for approximately 80% of the total vegetation growth management. Secondary species found within the system are Coontail (*Ceratophyllum*), and Sago pondweed (*Potamogeton*). The resident (non-migratory) waterfowl population, consisting of Coots, Canada Geese as well as a mixture of other native and non-native avian species, has reached overcrowded proportions. The influx of nutrients as a result of the water fowl overpopulation is a significant contributor to the water quality degradation and primary food source for plants and algae.
Emergent
Algae The lake experiences large algal blooms (planktonic, *Anabaena*) during the warmer months, which are now requiring some form of control. These blooms are most likely as a result of the loss of (quality) nutrient absorbing vegetation (*Milfoil* has a poor uptake) and water fowl influx.
1d. Potential Economic Costs (identify and describe at least 1) Lake's primary function is that of aesthetics. Surrounded by $500,000 plus homes which back up to the lake bulkhead.
History of Control costs, or Control Expected (Name Practice from Information Table 1). Harvesting and more recently, chemical applications have been performed more as a reactive (as opposed to maintenance) measure to control plant and algae growth. Harvesting, in conjunction with chemical (algaecide only; past two years) applications have been the standard operating procedure for the site lake management. The plant population has been decimated by the overrun of waterfowl, creating "clean up work" for the harvester.

More recently (FY 2002), some experimentation with the use of Alum (Aluminum sulfate) has been utilized for nutrient (and algae) control measures. The Alum binds up nutrients (phosphorous & nitrogen) and other suspended solids within the water column, making them unavailable for plant/algal uptake. Initially, a cove on the lake was "boomed" off to control water exchange and an application performed. The area was measured and once an acceptable product (water quality) was achieved, the pounds of Alum per acre was then transferred to the rest of the lake. Two full lake applications were performed during the 2002 season, which resulted in lower chemical (primarily Cu) usage. Harvesting was still used to maintain "acceptable" plant populations. Only recently (past 2-3 years) have algaecide (Copper) applications been used, which are fairly inexpensive for the control of nuisance algal blooms. No herbicide applications have been used in the history of the lake. Harvesting has been the historical strategy, however, it is less cost effective due to the depletion of the plant growth (i.e. waterfowl disruption and fragmentation) and actual cost of the operation (labor, fuel/maintenance and overhead). The lake HOA owns a larger harvester (H-7 420), which is an "open water cutter, making maneuverability an issue.
Types of Damage Costs
Contributes to flooding/drainage/storm water problems
Water supply quantity
Water supply quality
Impedes navigation
Impedes/limits recreation/parks values mixed recreational usage (paddle and electric boats, catch and release fishing).
Reduces aesthetic/environmental values Home sites are very limited and the average (on the water) home is in excess of $500,000. The owners of such property purchased these sites primarily for the view and access to the water; If or when the water (quality or aesthetics) is degraded, the property owners become upset for obvious reasons, not the least being the erosion of home value/equity.
1e. Management Objective (if there is one). Maintain water quality consistent with the site aesthetics and lake management plan. LMP restricts range of permissable practices
1f. Stakeholders (if applicable) Lake Van Ness Homeowners Association, Dept. Pesticide Regulation, NPDS National Pollution Discharge System, CDFG (grass carp)

Entry Table 2.
Define a Management Alternative, with Checks
For a Management Alternative, List of Expected Management Practices

Management Alternative Name: Status Quo

Year or years of Period of Analysis	Order of Practices When Applied During the Year (1st, 2nd etc)	Name of Practice to be applied (See Table 5)	If this repeats in all mgmt alts, check	Notes
Every	1st	Inspections/ Assessment	√	
Every	2nd	Harvest 4 times		
Every	3rd	Increase Aeration	√	
Every	4th	Alum	√	
Every	5th	Copper Sulphate 2 times	√	
Add more rows if needed				

Is this management alternative expected to meet the management objective?	Yes No DNA
Is this management alternative expected to be feasible? Yes	

Feasibility Type	Technical		Legal		Financial		Social/cultural	
Test (circle 1)	Yes	No	Yes	No	Yes	No	Yes	No

Entry Table 2.
Define a Management Alternative, with Checks
For a Management Alternative, List of Expected Management Practices

Management Alternative Name: Sterile Grass Carp

Year or years of Period of Analysis	Order of Practices When Applied During the Year (1st, 2nd etc)	Name of Practice to be applied (See Table 5)	If this repeats in all mgmt alts, check	Notes
Every	1st	Inspections/Assessment	√	
1	1st	Screen Outflow and permitting		Permit needed from CDFG. Install drum screen identical to one at Lake Leland, WA (see Appendix B)
1	2nd	Plant Grass Carp		Eurasian watermilfoil is not a preferred food.
1	3rd	Harvest 4 times		
1	4th	Increase Aeration	√	
1	5th	Alum	√	
1	6th	Copper Sulphate 2 time	√	
2-3	2nd	Harvest 4 times		
2-3	3rd	Increase Aeration	√	
2-3	4th	Alum	√	
2-3	5th	Copper Sulphate 2 time	√	
4-50	2nd	Increase Aeration	√	
4-50	3rd	Alum	√	
4-50	4th	Copper 2 times	√	

Is this management alternative expected to meet the management objective?				Yes No DNA
Is this management alternative expected to be feasible? Yes, but some doubt				
Feasibility Type	Technical	Legal	Financial	Social/cultural
Test (circle 1)	Yes No	Yes No	Yes No	Yes No

Entry Table 2.
Define a Management Alternative, with Checks
For a Management Alternative, List of Expected Management Practices

Management Alternative Name: Bacterial Control

Year or years of Period of Analysis	**Order of Practices When Applied During the Year (1st, 2nd etc)**	**Name of Practice to be applied (See Table 5)**	**If this repeats in all mgmt alts, check**	**Notes**
Every	1st	Inspections/Assessment	√	
Every	2nd	Bacteria		
Every	3rd	Harvest 1 time		
Every	4th	Increase Aeration	√	
Every	5th	Alum	√	
Every	6th	Copper Sulphate 2 times	√	

Is this management alternative expected to meet the management objective?	Yes No DNA
Is this management alternative expected to be feasible? Yes, but uncertain	

Feasibility Type	Technical	Legal	Financial	Social/cultural
Test (circle 1)	Yes No	Yes No	Yes No	Yes No

Entry Table 3. Number 1 **Costs of a Management Practice.** **For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.**		
Management Alternative Names: Status Quo, Grass Carp		
Name of Practice: Harvest 4 times		
General description of Practice	Large harvester H-7 420	
When during the season will practice be applied?	Following Inspections/Assessment	
Where within the location this practice is to be applied?	Average of 14 acres each time	
How much will be applied?	4 times per year	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	Dollars	
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	14
Cost per day	$/day	$650-$1,000
Acres per Day	Acres	2-3
Treatments	Number per year	4
Total Estimated Cost	Range, Dollars/year	$12,133 to $28,000
Total Estimated Cost	Average, Dollars/year	$20,066
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 2 Costs of a Management Practice. For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.		
Management Alternative Names: Grass Carp		
Name of Practice: Plant Grass Carp		
General description of Practice	Plant Sterile Grass Carp. Permit may be hard or impossible to obtain, and/or compliance costs may be large. Eurasian watermilfoil is not a preferred food.	
When during the season will practice be applied?	Before first harvest	
Where within the location this practice is to be applied?		
How much will be applied?	Plant 2-4 juveniles per acre.	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	Dollars	
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	28
Stocking rate	Carp/acre	2-4
Frequency of Stocking	Once every X years	5
Dollar cost per carp	$/carp	$15-$35.00
Total Estimated Cost	Range, Dollars, once per 5 years	$840-$3,920
Total Estimated Cost	Average, Dollars, once per 5 years	$2,380
Annual monitoring cost	Dollars per year ($7.50 times 3 times 28)	$630
One-time screening cost	Dollars, Once	$39,900
One-time Compliance cost	Dollars, Once	$10,000
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 3 Costs of a Management Practice. For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.		
Management Alternative Names: Bacterial Control		
Name of Practice: Apply Bacteria		
General description of Practice	Beneficial aerobic bacteria or microbes consume nutrients and reduce reduce rate of growth. Water quality and alkalinity is important. Once alkalinity drops below about 100, won't do well.	
When during the season will practice be applied?	Following Inspections/Assessment	
Where within the location this practice is to be applied?	Whole lake	
How much will be applied?		
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	Dollars	$12,000-$24,000
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	
Total Estimated Cost	Range, Dollars/year	$12,000-$24,000
Total Estimated Cost	Average, Dollars/year	$18,000
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 4 **Costs of a Management Practice. For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.**		
Management Alternative Names: Bacterial Control		
Name of Practice: Harvest 1 time		
General description of Practice	Large harvester H-7 420	
When during the season will practice be applied?	Following Inspections/Assessment	
Where within the location this practice is to be applied?	Average of 14 acres each time	
How much will be applied?	1 time per year	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	Dollars	
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	14
Cost per day	$/day	$650-$1,000
Acres per Day	Acres	2-3
Treatments	Number per year	1
Total Estimated Cost	Range, Dollars/year	$3,033.-7,000
Total Estimated Cost	Average, Dollars/year	$5,016
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 6. Costs of Management Practices by Year for a Management Alternative								
Management Alternative: Status Quo								
		Quantified Control Costs, Damage Costs, and Environmental Costs, In 2000 Dollars (enter year)						
Year	Source of Data (Tables, number)	Name of Control Cost, Damage Cost, or Environmental Cost						Total Cost of Alter-native by Year
		Harvest 4 times						
1		20,066						20,066
2		20,066						20,066
3		20,066						20,066
4		20,066						20,066
5		20,066						20,066
6		20,066						20,066
7		20,066						20,066
8		20,066						20,066
9		20,066						20,066
10		20,066						20,066
11		20,066						20,066
12		20,066						20,066
13		20,066						20,066
14		20,066						20,066
15		20,066						20,066
16		20,066						20,066
17		20,066						20,066
18		20,066						20,066
19		20,066						20,066
Etc		20,066						20,066
50		20,066						20,066
NPV(.05, Yr1..,Yr20), 1000 $								$366.32
-PMT(.05,Last Yr.,NPV), 1000 $								$20.07

Entry Table 6.
Costs of Management Practices by Year for a Management Alternative

Management Alternative: Grass Carp

		Quantified Control Costs, Damage Costs, and Environmental Costs, In 2000 Dollars (enter year)						
Year	Source of Data (Tables, number)	Name of Control Cost, Damage Cost, or Environmental Cost						Total Cost of Alter-native by Year
		Plant Grass Carp	Harvest 4 times	Annual DFG Fee				
1		52,280	20,066	630				72,976
2		0	20,066	630				20,696
3		0	20,066	630				20,696
4		0	0	630				630
5		2,380	0	630				3,010
6		0	0	630				630
7		0	0	630				630
8		0	0	630				630
9		0	0	630				630
10		2,380	0	630				3,010
11		0	0	630				630
12		0	0	630				630
13		0	0	630				630
14		0	0	630				630
15		2,380	0	630				3,010
16		0	0	630				630
17		0	0	630				630
18		0	0	630				630
19		0	0	630				630
Etc			0					
50		2,380	0	630				3,010
NPV(.05, Yr1..,Yr20), 1000 $								$123.8
-PMT(.05,Last Yr.,NPV), 1000 $								$6.78

Entry Table 6. Costs of Management Practices by Year for a Management Alternative								
Management Alternative: Bacterial Control								
		Quantified Control Costs, Damage Costs, and Environmental Costs, In ____ Dollars (enter year)						
Year	Source of Data (Tables, number)	Name of Control Cost, Damage Cost, or Environmental Cost						Total Cost of Alter-native by Year
		Apply Bacteria	Harvest 1 time					
1		18,000	5,016					23,016
2		18,000	5,016					23,016
3		18,000	5,016					23,016
4		18,000	5,016					23,016
5		18,000	5,016					23,016
6		18,000	5,016					23,016
7		18,000	5,016					23,016
8		18,000	5,016					23,016
9		18,000	5,016					23,016
10		18,000	5,016					23,016
11		18,000	5,016					23,016
12		18,000	5,016					23,016
13		18,000	5,016					23,016
14		18,000	5,016					23,016
15		18,000	5,016					23,016
16		18,000	5,016					23,016
17		18,000	5,016					23,016
18		18,000	5,016					23,016
19		18,000	5,016					23,016
Etc		18,000	5,016					23,016
50		18,000	5,016					23,016
NPV(.05, Yr1..,Yr20), 1000 $								$420.18
-PMT(.05,Last Yr.,NPV), 1000 $								$23.02

Entry Table 7.
Comparison of Management Alternatives for Aquatic Plant Management
Type of Analysis

	Economic Costs from Entry Table 6				Meets Management Objective?		Results of feasibility Tests			
	Control Costs		Total Costs							
Management Alternative	NPV, 1000$	Annual Value, 1000$	NPV, 1000$	Annual Value, 1000$		Describe Other Benefits and Costs and Other Considerations that Affect the Selection of a Management Alternative	Tech	Legal	Finance	Soc/C
Status Quo	$366.32	$20.07	$366.32	$20.07	√		√	√		√
Grass Carp	$123.8	$6.78	$123.8	$6.78	√	May not be able to obtain a permit for grass carp. Must be outside of a 150 year floodplain	√			√
Bacterial Control	$420.18	$23.02	$420.18	$23.02	√		√	√		√

Management Alternative Selected: Status Quo, but grass carp worthy of further development

1.6 Principles and Methods of Economic Valuation

APME is a form of economic benefit-cost analysis. This section provides more background information on benefit-cost analysis and provides general guidance and sources for problems likely to arise in a damage cost or environmental cost assessment. In particular, there are three categories of costs that can be either damage costs − caused by aquatic plants, or environmental costs − caused by aquatic plant control. These are:

- Water-based recreation
- Fish and wildlife
- Drinking water quality

There is a long history of benefit-cost analysis for beneficial uses of fresh water, and much of this work can be extended to the problem of freshwater aquatic plant management. There are numerous textbooks on benefit-cost analysis, for example Boardman, Greenberg and Vining (2001); Brent (1996); Dinwiddy and Teal (1996); Fuguitt, Diana and Wilcox (1999); Perkins (1994) and Zerbe and Dively (1984).

The most accepted procedural guide in the United States is probably the U.S. Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (USDI, 1983), commonly known as the P&G's. The P&G's are specifically mentioned as a basis for benefits estimates in one review of economic valuation of aquatic plant control (Thunberg, 1991). The P&G's are implemented through more specific direction provided in agency manuals such as the Army Corps of Engineer's Policy and Planning Guidance for Conducting Civil Works Planning Studies ER 1105-2-100 (USACE, 2000).

Many other sources may provide procedural help for damage cost or environmental cost estimation. Natural Resource Damage Assessments are used to estimate economic losses for environmental resources harmed by release of a hazardous substance into the environment. NRDA procedures and precedents may be most useful for environmental cost estimation. The U.S. Army Corps of Engineers has published guidance for cost-effectiveness analysis and incremental cost analyses that may be useful (USACE 1995).

The discussion below makes extensive use of the P&G's, and the ER 1105-2-100. An analyst seeking to quantify damage costs or environmental costs may need to acquire these references and other technical assistance, as discussed below.

Economic benefits are based on willingness to pay. Economic costs are just lost willingness to pay. Damage costs or environmental costs can be measured as the willingness to pay to avoid the aquatic plant damages or aquatic plant control impact, respectively. If those persons actually damaged have paid in the past to avoid the damages, then their payments might be taken as a measure of their willingness to pay. In general, a history of actual costs or other real experience should be used when available.

Under certain conditions, market prices of goods and services represent real experience, and they are a good measure of willingness to pay. In general, market prices should be used when the goods are traded in a reasonably competitive environment. In some cases, however, prices may not reflect willingness to pay, or there may be no price information at all. As an example of the former, prices should reflect competition among sellers, and price should be set to recover marginal (incremental) costs. Monopoly prices, or prices set to recover average costs may not be good measures of economic value. There is no price information when goods are provided for free. Many environmental goods such as viewing fish and wildlife and lake access are provided to the public free of charge. In these cases, non-market valuation techniques must be used to value the non-market goods.

Non-market valuation may be required for water-based recreation, fish and wildlife, and drinking water quality. Water-based recreation and fish and wildlife are usually provided publicly, and prices, if they exist, are not indicative of willingness to pay. In the case of drinking water quality, there is no market where specific water quality attributes can be purchased. The remainder of this section discusses these three types of costs.

1.6.1 Empirical Methods for Valuing Water- Based Recreation

Recreation benefits analysis has a long history in water resource development benefit-cost analysis. If the recreation service is provided privately in a competitive environment, then the prices charges might be used as a measure of benefit. Outdoor recreation, however, is usually provided publicly. Five valuation methods are commonly used: 1) the travel cost method, 2) hedonic pricing, 3) contingent valuation, 4) benefits transfers, and 5) unit values. Smith (1993) provides a summary and discussion of these methods.

In some cases, recreation prices are not available, but there are other recreation costs that provide information about willingness to pay. The travel cost method uses information about the place or origin of recreationists to determine how much they paid for their recreation, and this information provides a basis for willingness to pay. An example of the travel cost method related to recreational water quality is provided by Bouwes and Schneider (1979).

Hedonic pricing uses data on property values to infer the economic value of recreational opportunities and quality. The method works best when the recreation opportunity is associated with private lands; for example, a lake privately owned by lakefront homeowners. An example where land prices are a function of perceived water quality is provided by Epp and Al-Ani (1979). In another example, perceived health risk associated with a landfill site was estimated to affect property values (McClelland et al, 1990).

Contingent valuation queries recreationists directly about their willingness to pay for their recreation experience. The method can be used where there is no actual price, cost or expenditure data. Messonnier et al, (2000) provide an example where recreationists and lake residents are queried about their willingness to pay for five plant management alternatives. Several examples are available where contingent valuation was applied to evaluate recreational water quality (Green and Tunstall, 1991; Eisen-Hecht and Kramer, 2002; Lant and Mullens, 1991). Bergstrom et al. (1990) apply contingent valuation to estimate recreational value of wetlands. Morey et al (2002) estimate recreational trout fishing value in Montana's Clark Fork River as affected by mining wastes.

Benefits transfers uses benefit estimates from other, similar recreation areas and extrapolates to the location of interest. Some of the issues and potential problems with this approach are described by Brookshire and Neill (1992), Boyle and Bergstrom (1992) and Desvousges et al. (1992).

One simple type of benefits transfer involves the use of unit values. Unit values are just dollar per recreation unit values that can be used for a specified type of recreation. The units may be recreation days, or recreation trips, or recreational fish caught.

The USACE provides unit day values for recreation for use in benefits estimation, updated annually (USACE, 2002). The method providers a range of dollar values per day for general recreation and specialized recreation, and a system of point values is used to determine the exact value within the range that should be used. The point system considers the quality, availability, carrying capacity, accessibility and aesthetic qualities of the recreation experience. For 2002, general recreation is valued between \$2.90 and \$8.69 per day, and specialized recreation between \$11.46 and \$34.41 per day.

Southwick Associates (1993) and the American Fisheries Society (1993) provide unit values (value per fish) for many species of recreationally-caught fish at different sizes. Unit fish values can be expressed as unit day values if catch rate per day is known. Southwick Associates (1993) also provides an annotated bibliography of fish valuation studies and summarizes some unit day values for recreational fishing by State.

The four primary data methods – travel cost, hedonic pricing, contingent valuation and benefits transfers - generally require help from a specialist. All of these methods are able to generate substantially biased results if used incorrectly. The unit day value approach could also generate a substantial amount of bias for any unique situation.

Recreation losses can also be paid by businesses that serve recreationists. If sales are reduced, the amount of gross revenue is not a good estimate of economic benefit. Only the net revenue from the lost sales should be counted. This net revenue equals gross revenue minus the cost of goods sold and any other incremental costs that are no longer required when the sales are lost

1.6.2 Empirical Methods for Valuing Fish and Wildlife

Economic values associated with fish and wildlife losses include recreational fisheries, commercial fisheries, recreational non-consumptive use of fish and wildlife, ecological services and existence values.

Recreation methods were described in Section 1.6.1 above. In general, recreation valuation techniques should be used for organized recreational activities that have fish and wildlife as their primary focus. Organized bird-watching, for example, can be handled like any recreation in Section 1.6.5. If the fish and wildlife values are purely incidental and aesthetic, then the travel costs or hedonic pricing methods are not likely to be useful. Recreation losses may also include losses to commercial operators such as marinas, guides, and lodging operations. These losses are the net revenue losses of the operators.

For species having commercial value, economic benefits are net revenues from the sale of catch. Net revenues are gross revenues, being sales of fish, minus costs required to obtain the catch. Typical costs include labor and boat fuel.

For recreational or commercial fisheries, if the environmental impacts involve juvenile fish, then expected survival rates to catchable size need to be considered. For species that are food for recreational or commercial species, food web studies might be useful.

In some cases, fish and wildlife losses can be valued as the cost required to replace them. The American Fisheries Society (1993) provide unit values for many species of fish at different sizes based on hatchery costs. Southwick Associates (1993) also provides an annotated bibliography of fish valuation studies.

Recreational non-consumptive use of fish and wildlife, ecological services, aesthetic values and existence values are generally harder to place dollar estimates on than recreation values. Ecological services may include water quality improvements, wastewater assimilation, or production of fish and wildlife. The value of these services may be estimated as the cost to provide them by other means; for example, wastewater treatment. Aesthetic values apply when fish and wildlife are enjoyed because they are seen or heard. If not an organized recreational activity, then contingent valuation or benefits transfers may be applied. Existence values apply if people value the wildlife even if there is no expectation that the wildlife will be seen, caught or otherwise experienced. Usually, contingent valuation or benefits transfers studies must be used.

Natural Resource Damage Assessments (NRDAs) have been conducted to provide damage estimates for use in recovering public losses from chemical spills in California. Most cases have involved oil spill in marine environments and therefore have limited applicability to freshwater systems. In some cases, economic valuation studies and negotiated settlements can provide useful information for use in valuing fish and wildlife.

In the case of Cantara Loop, a metam sodium spill into the Sacramento River near Dunsmuir impacted instream habitat and wildlife (fish, amphibians, macroinvertebrates), riparian habitat, and recreational use. The NRDA portion of the case was settled for $14 million. In the case of the Iron Mountain site, acid mine drainage into Spring Creek and the Sacramento River impacted instream habitat and wildlife. The NRDA portion was settled for $9 million. Other NRDAs in progress that might yield useful information include Leviathan and Bryant Creeks, in Alpine County, an oil spill into the East Walker

River, Mono County, and acid mine drainage from the New Almaden Mine into the Guadalupe River and south San Francisco Bay.

1.6.3 Empirical Methods for Valuing Drinking Water Quality

Drinking water quality improvements are hard to value because there is not a competitive market for water of different qualities. Some theoretical aspects of the economics of water quality protection are provided by Shogren (1991) and Raucher (1983).

Often, water treatment costs are affected by water quality. If this is true, then economic costs are the difference between water treatment costs with and without the aquatic plants of aquatic plant control. These costs should be determined with help from treatment plant operators or qualified engineers. In some cases, water quality degradation may require that the water supply source can no longer be used. If water supply is reduced, then appropriate methods are described in Section 1.7.2.

Sometimes, households buy purified water or install water purifiers to avoid undesirable contaminants. Abdalla (1994) provides some examples. Household avoidance expenditures are definitely a cost associated with impure drinking water, but it may not be possible to determine how much cost to assign to individual contaminants.

Contingent valuation can be used to query water users about their willingness to pay for water quality improvements. Alternatively, it can be used to determine willingness to pay to avoid water quality degradation. Some examples are available (Bergstrom and Dorfman, 1994; Edwards, 1988). Expert advice should be obtained for use of contingent valuation methods.

1.7 Damage Cost Analysis

This section describes some considerations and methodologies that could be used to develop damage cost estimates for a Type B or C analysis. Damage costs are the losses caused by aquatic plants, and benefits are the reduction in damage costs obtained by management of the aquatic plant.

In any case, the goal of the damage cost analysis is to estimate the annual average amount of damage costs in each management alternative. In general, the economic estimation of damage costs for each management alternative should proceed in these steps:

1. Determine the growth and distribution of the undesirable aquatic plants expected;
2. Determine the types of damage caused by the aquatic plants;
3. For each type of damage, quantify the range and probability of damaging events;
4. For each type of damage, determine and describe how people will respond to it, but within the definition of the management alternative.

5. For each type of damage and event, estimate the economic loss associated with the damage given people's response to it. What would people in the accounting perspective be willing to pay to avoid these events?
6. Determine the expected annual value of damages as the discounted sum of future damages, each weighted by its probability, for all types of damages and events.

There are many types of damages that could be caused by aquatic plants. The sections below correspond to the types of damages displayed in Entry Table 1. Generally, these types correspond to beneficial uses of water that are impaired by the aquatic plants.

1.7.1 Contributes to flooding/drainage/storm water problems

Aquatic plants can impede the normal functioning of flood control facilities. Aquatic plants in channels can reduce the velocity of water and thereby reduce the effective rate of discharge. With plants, flooding may occur during less intense precipitation events, floods may cover a larger area, and the depth and duration of flooding may be longer. All of these results will increase economic costs, and risks to health and life increase.

The USACE's ER 1105 (USACE 2000) provides detailed guidance. Generally, flooding damages are either physical damages, which are damages to buildings, structures, or crops, or nonphysical losses, being income losses, cleanup costs, and emergency costs. "Inundation damages are computed as the difference in flood damages with and without the project." In this case, the difference should be determined by comparison of two or more management alternatives.

To estimate the expected annual amount of damage cost, the probability distribution of damaging flood events must be estimated. First, the storm events that would cause flood damage in the various management alternatives must be identified. Storm events that would not cause damages in any alternative do not need to be considered. Usually, damaging events are characterized by their frequency; for example, a 1 in 100 year flood, a 1 in 50 year flood, etc. These probabilities are usually estimated from the probabilities of such events in the past. Engineering studies of channel characteristics with and without aquatic plants may be required.

Second, the damaging events are characterized in terms of the area flooded and the depth and duration of the flood. Presumably, events with aquatic plants would result in more area flooded, greater flood depth, and a longer flooding duration. Other characteristics of the flood such as the amount of sediment and floodwater velocity may also affect damages.

Third, the dollar amount of damage to be expected for each event is estimated. This dollar amount is usually based on mapping of the area flooded by the event, an inventory of structures or crops within that area, and functions that describe the amount of economic damage given the depth and duration of the flooding event. Cleanup costs and emergency costs should be included. This step can be difficult. Technical assistance is recommended.

Finally, the expected amount of annual damage for a management alternative is the amount of damage expected for each damaging event, times its probability, summed over all possible damaging events.

Thunberg et al (1992) provide an example of these methods applied to estimate residential flood damage from aquatic plants. Thunberg and Pearson (1993) provide an example for aquatic plant control in canals serving citrus orchards.

1.7.2 Water supply quantity

Aquatic plants may reduce water supply by reducing the rate of water flow in channels, or by clogging intake structures. Aquatic plants can affect water quality (section 1.6.3) so that the water is unusable. Damages can occur because the benefits of water use are lost, or because alternative water supplies must be acquired.

Often, the potential for loss of water supplies will result in increased cleaning and maintenance costs. These activities may be enough to avoid water supply losses, but the costs of these activities must be included. Water supply districts and water users may keep records on the amount of time and effort required to remove aquatic plants from their water supply systems. That is, a management alternative without a proactive plant management strategy may require costs as water users react to the aquatic plants.

If water supply is actually lost, there are circumstances under which the price of water can be used as an estimate of lost benefit. Sometimes, water suppliers will charge a price for water that approximately equals the incremental cost of supplying that water. Given a price of water, water users should adjust their water use so that the incremental value of additional use, to them, just equals the price. If these efficiency conditions hold, then the price of water can be used as an estimate of incremental damage cost per unit water.

If the efficiency conditions do not hold, then other methods may be required. In any case, the response of water users faced with shortage must be determined. If they will choose to reduce water use, then the costs of conservation and the benefits of lost water use should be counted. There may be damage costs associated with lost stocks of goods such as landscaping or trees. If they will choose to acquire alternative water supplies, then the costs of the alternative supplies should be counted.

1.7.3 Water supply quality

Aquatic plants can impair water quality in many ways. Taste and odor may be affected. Aquatic plants may affect uptake or release of nutrients into the water.

1.7.4 Impedes navigation

Aquatic plants can impair navigation by clogging waterways, fouling propellers, and reducing the speed of navigation. If navigation will be impaired, then damage cost estimates should consider the volume of boat traffic, the types of boats and the nature of their business, and the specific pathways by which the aquatic plants impede navigation. Economic damages in commercial navigation are lost net revenues or increased operating costs. Recreational navigation is considered in Section 1.6.5 below.

1.7.5 Impedes/limits recreation/parks values

Aquatic plants can impair recreational use of water bodies in many ways. Recreational boat use can be impaired by fouling of propellers and reduced boat speed. On lakes, water-skiing, wakeboarding, tubing and similar activities can be eliminated from infested areas. Aquatic plants can have more complex relationships with fishing. Dense aquatic plants can make recreational fishing impossible. On the other hand, some aquatic plants are beneficial to some types of fish, and the fishing activity can focus around aquatic vegetation used as cover by the desirable fish. Similarly, some types of aquatic plants in some densities are beneficial for aesthetic purposes.

A number of examples of recreation valuation related to aquatic plants are available. Bergstrom et al (1996) estimate number of visits by fishers and non-fishers under four management alternatives and show that the best alternative for each group is different. Kahn and Kemp (1983) estimate benefits losses associated with loss of submerged aquatic vegetation in the Chesapeake Bay. Kirk and Henderson (2000) estimate amount of fishing and expenditures under three aquatic plant scenarios.

1.7.6 Reduces environmental values

Aquatic plants may reduce environmental values associated with a water body. In particular, infestation of a species may crowd other species and reduce diversity at the site. In this case, the damage cost estimate must consider what the quality of the system would be without the infestation. The types and diversity of species should be characterized, and the relationships among them described. Contingent valuation might be used to determine willingness to pay for environmental or aesthetic values. People could be provided with photographs and qualitative information and asked to state their willingness to pay for the reduced plant density.

1.7.7 Property Values

Aquatic plants may affect waterfront property values. It is important to note that changes in property values are not additive with the other types of values mentioned above. To the contrary, property values are usually a reflection of the other types of values. Property values represent the net present values of expected benefits of property owners for the aesthetic, recreational and environmental attributes of the water body. In general, when counting benefits from the perspective of property owners, either their annual benefits or their change in property values should be counted, but not both.

1.8 Environmental Cost Analysis

This section describes some considerations and methodologies that could be used to develop environmental cost estimates for a Type B or C analysis. Environmental costs are damages or loss of benefits caused by the aquatic plant management practices. Environmental costs do not include control costs such as permitting or environmental compliance costs. In general, environmental costs are incidental to the aquatic plant management practice, they are unintended consequences, and they often affect resource values at locations other than the aquatic plant site. The APMP Alternatives Literature Review provides tables that describe specific environmental costs that can be expected for different control methods. A good understanding of the physical environmental impact is a prerequisite for good economic analysis.

In any case, the goal of the environmental cost analysis is to estimate the annual average dollar amount of environmental costs in each management alternative. In general, the economic estimation of environmental costs should proceed in these steps:

1 Determine the physical or biological impact of the management practices in the alternative to be evaluated.
2 For each type of impact, quantify the range and probability of events that have environmental costs;
3 For each type of impact and event, determine and describe how people will respond to it, but within the definition of the management alternative. This response may include mitigation measures, clean-up and restoration activities.
4 For each type of impact and event, estimate the economic loss associated with the impact given people's response to it. What would people in the accounting perspective be willing to pay to avoid the impact events?
5 Determine the expected annual value of environmental costs as the annualized value of future costs, each weighted by its probability, for all types of impacts and events.

Environmental costs may involve risk of chemical spills or other unlikely events, as well as normal use. For events such as spills, the probability of spills of different sizes should be estimated. If economic costs associated with each spill event can be estimated, then the annualized cost can be estimated through steps 1 through 5 above.

The California Department of Boating and Waterways (CDBW 2001) provides a summary of the types of environmental impacts associated with chemical and mechanical aquatic plant control in the Delta. In general, costs arise from three types of physical or biological impacts.

- water quality
- fish and wildlife losses
- water supply and agricultural crops

The discussion below is organized around these categories

1.8.1 Water Quality Effects

Water quality effects associated with aquatic plant control may include introduction of toxic chemicals, reduction in dissolved oxygen caused by decaying plant material, increases in turbidity from mechanical harvesting operations, herbicides in drinking water, and increases in trihalomethane formation near drinking water treatment facilities.

If the water quality effect will cause recreation losses, appropriate methods were described in Section 1.6.1 above. If the water quality effect will cause fish and wildlife losses, appropriate economic methods are discussed in 1.6.2 above. If the water quality effect will cause water supply losses, then methods are discussed in 1.8.2 below.

If drinking water quality is affected, methods are described in section 1.6.3. If water treatment would be changed to cope with the water quality change, then the change in cost of treatment is the measure of economic cost. If water quality for end-users is changed, then their willingness to pay to avoid the water quality degradation must be determined. California EPA (1997, 2002) provides public health goals for chemicals in drinking water; diquat, endothall, copper, glyphosate and 2,4-D. These documents set standards and discuss the types of health effects that might be expected.

1.8.2 Fish and Wildlife Losses

These losses include mortality of valuable species or biological communities caused directly by the treatment, or less directly through loss of habitat or food sources or through water quality changes. In the Delta, CDBW (2001) cites loss of special status intertidal wetland communities, reduced aquatic invertebrate abundance, harm to special status species such as Valley elderberry beetle and a number of fish species, and loss of aquatic invertebrates, reptiles, amphibians and birds. Many mitigation measures are proposed that would lessen these effects. Economic costs should include these mitigation measures as a response, and the costs of the mitigation measures should be included either as control costs or environmental costs.

Economic methods were discussed in section 1.6.2. If mitigation does not completely eliminate the adverse effect, then additional environmental costs should be included. If the environmental cost must be corrected by clean-up, restoration or replacement activities, or these activities are the least-cost alternative for coping with the damages, then the costs of these activities should be included. If environmental impacts continue after restoration, or if the impacts occur before restoration can be completed, then the costs of these impacts should also be included.

1.8.3 Water Supply and Agricultural Crops

Adverse effects include intake clogging caused by fragmentation following mechanical harvest and effects of herbicides on irrigated crops. Intake clogging may be reduced by additional activities undertaken to clear intakes. To the extent this is true, then the cost of these activities should be counted. If intake clogging can not be eliminated, then water supply losses should be counted.

The appropriate measure of losses to irrigated farming operations is net revenue losses. Any additional costs are net revenue losses, and lost sales, net of cost savings, are net revenue losses. The cost of water supply losses is either the cost of alternative supply or the damages from lost water use.

Mechanical harvesting or cutting methods may result in infestations in other locations. The costs of additional infestations might be counted as a damage cost. The cost of controlling these infestations to non-economic levels can be used as a measure of cost.

1.9 References Cited

Abdalla, Charles W. 1994. “Groundwater Values from Avoidance Cost Studies: Implications for Policy and Future Research.” American J. of Agricultural Economics 76(1062-1067)

American Fisheries Society, 1993. “Investigation and Valuation of Fish Kills.” American Fisheries Society Special Publication 24. Prepared by the Pollution Committee, Southern Division and The Socioeconomics Section, American Fisheries Society. For: American Fisheries Society, Bethesda.

Aquatic Environments Inc. 2003. Subject: February 21 2003 Making Follow Up Information. To: Mr Ben Greenfield, Mr. Roger Mann. From: George P. Forni. Alamo, CA, March 1.

Bergstrom, John C., R. J. Teasley, H. K. Cordell, R. Souter and D. B. K. English. 1996. “Effects of Reservoir Aquatic Plant Management on Recreational Expenditures and Regional Economic Activity.” J. Agricultural and Applied Economics: 28(2) 409-422. December.

Bergstrom, J. C., J. R. Stoll, J. P. Titre and Vernon L. Wright, 1990. “Economic Value of Wetlands-Based Recreation.” Ecological Economics 2(1990) 129-147.

Bergstrom, J. C. and J. H. Dorfman, 1994. “Commodity Information and Willingness to Pay for Groundwater Quality Protection.” Review of Agricultural Economics 16 413-425.

Boardman, Anthony E., D. H. Greenberg, D. Weimer and, A.Vining. 2001. Cost-Benefit Analysis: Concepts and Practice. 2nd edition, Pearson Education, Prentice Hall.

Bouwes, Nicolas W. and R. Schneider. 1979. “Procedures in Estimating Benefits of Water Quality Change.” American J. of Agricultural Economics. August. 535-539.

Boyle, Kevin J. and J. C. Bergstrom, 1992. "Benefit Transfer Studies: Myths, Pragmatism and Idealism." Water Resources Research 28(3) 657-663.

Brent, Robert J. 1996. Applied Cost-Benefit Analysis, Northampton, MA, Edward Elgar.

Brookshire, David S., and H. K. Neill. 1992. "Benefit Transfers: Conceptual and Empirical Issues." Water Resources Research 28(3) 651-655.

California Department of Boating and Waterways. 2001. Final Environmental Impact Report. Section IV. Findings on Specific EDCP and Two-Year Komeen Trial Impacts. March.

California Environmental Protection Agency. 2000. Diquat. Public Health Goals for Chemicals in Drinking Water. Pesticide and Environmental Toxicology Section, Office of Environmental Health Hazard Assessment. September.

Ibid. 1997. Endothall. December.

Ibid. 1997. Glyphosate. December.

Ibid. 1997. 2,4-D. December

Ibid. 1997. Copper. December.

Crocker, Thomas D., B. A. Forster and J. F. Shogren. 1991. "Valuing Potential Groundwater Protection Benefits." Water Resources Research 27(1) 1-6.

Desvousges, William H., M. C. Naughton and G. R. Parsons, 1992. "Benefit Transfer: Conceptual Problems in Estimating Water Quality Benefits Using Existing Studies." Water Resources Research. 28(3) 675-683.

Edwards, Steven F. 1988. "Option Prices for Groundwater Protection." J. Environmental Economics and Management. 15 475-487.

Eisen-Hecht, Jonathan I. and R. A. Kramer. 2002. "A Cost-Benefit Analysis of Water Quality Protection in the Catawba Basin." J. of the American Water Resources Association 38(2) 453-465.

Epp, Donald J. and K. S. Al-Ani. 1979. "The Effect of Water Quality on Rural Nonfarm Residential Property Values." American J. of Agricultural Economics. August 529-534.

Fuguitt, Diana and S. J. Wilcox, 1999. Cost-Benefit Analysis for Public Sector Decision-Makers. Westport, CT, Quorum Publishers.

Gibbons, Maribeth V., Harry L. Gibbons, Jr. and Mark D. Sytsma. 1994. A Citizen's Manual for Developing Integrated Aquatic Vegetation Management Plans. Appendix D: Aquatic Plant Control Methods. Ecology Publication 93-93. January.

Green, C. H. and S. M. Tunstall. 1991. "The Evaluation of River Water Quality Improvements by the Contingent Valuation Method." Applied Economics 23. 1135-1146.

Harris, P. "Costs of Biological Control of Weeds by Insects in Canada." Weed Science 27(2) 242-250.

Hinkle, Joe. 2002. "Mowing and Rotovator Testing on Orange Lake, Florida." Aquatics 24(4) Winter 12-13.

Jaggers, Bruce V. "Economic Considerations of Integrated Hydrilla Management. A Case History of Johns Lake, Florida." Proceedings, Grass Carp Symposium.

Kahn, James R. and W. M. Kemp. 1985. "Economic Losses Associated with the Degradation of an Ecosystem: The Case of Submerged Aquatic Vegetation in Chesapeake Bay." J. Environmental Economics and Management 12. 246-263.

Kellet, Troy. 2003. Personal Communications with SFEI. Richvale Irrigation District.

Kirk, James P. and Jim E. Henderson. 2000. Economic Value of Aquatic Vegetation. Aquatic Plant Control Research Program Vol A-00-1. December.

Lake County, Water Resource Division Website. 1999. 1999 Aquatic Weed Pilot Project. http://watershed.co.lake.ca.us/programs/aquaticplants/pilotproject.html

Lant, Christopher L. and Jo Beth Mullens. 1991. Lake and River Quality for Recreation Management and Contingent Valuation. Water Resources Bulletin 27(2) 453

Lembi, C.A. 2002. Assessment of 2,4-D Use in Aquatic Systems in the United States. Chapter 12. Department of Botany and Plant Pathology, Purdue University, West Lafayette, IN 47907.

Madsen, John D. 1997. "Methods for Management of Nonindigenous Aquatic Plants." In: Luken, J. O. and J. W. Thieret, Eds. Assessment and Management of Plant Invasions. Springer.

McClelland, Gary H., W.D. Schulze and B. Hurd, 1990. "The Effect of Risk Beliefs on Property Values: A Case Study of a Hazardous Waste Site." Risk Analysis 10(4) 485-487.

Messonnier, Mark L., J. C. Bergstrom, C. M. Cornwell, R. J. Teasley and H. K. Cordell. 2000. "Survey Response-Related Biases in Contingent Valuation: Concepts, Remedies and Empirical Application to Valuing Aquatic Plant Management." American J. of Agricultural Economics 83. 438-450.

Morey, Edward R., W. S. Breffle, R.D. Rowe and D. M. Waldman. 2002. "Estimating Recreational Trout Fishing Damages in Montana's Clark Fork River basin: Summary of a Natural Resource Damage Assessment." J. Environmental Management 66. 159-170.

Office of Management and Budget. 2003. Circular No. A-94. Appendix C. Discount Rates For Cost-Effectiveness, Lease Purchase and Related Analyses. Revised January 2003.

Perkins, F. 1994. Practical Cost Benefit Analysis: Basic Concepts and Applications. Macmillan Education Australia, Melbourne.

Raucher, Robert L. 1983. "A Conceptual Framework for Measuring the Benefits of Groundwater Protection." Water Resources Research 19(2) 320-326.

Sassic, N.M. Undated. "Harvesting." Aquatics 4(1):14-16.

Seagrave, Chris. 1988. Aquatic Weed Control. Fishing News Books Ltd. Farnham, England.

Shireman, Jerome V., Douglas E. Colle and Daniel E. Canfeld, Jr. 1986. "Efficacy and Cost of Aquatic Weed Control in Small Ponds." Water Resources Bulletin 22(1) 43-48. February.

Smith, V. Kerry. 1993. Nonmarket Valuation of Environmental Resources: An Interpretive Appraisal. Land Economics 69(1) 1-26.

Southwick Associates, 1993. "Sourcebook for Investigation and Valuation of Fish Kills." Supplement to American Fisheries Society Special Publication 24. For: American Fisheries Society, Bethesda.

Stocker, Randall K. Undated. "Agricultural Canal Systems." In: Managing Aquatic Vegetation with Grass Carp. A Guide for Water Resource Managers. J. R. Cassani, eds. American Fisheries Society, Introduced Fish Section.

Taylor, Susan and Glenn Gately. 1998. Lake Leland Integrated Aquatic Plant Management Plan. For Lake Leland Steering Committee. Funded by Washington Department of Ecology and Jefferson Parks and Recreation. December.

Thunberg, Eric M. 1991. Literature Review of Economic Valuation of Aquatic Plant Control. Aquatic Plant Control Research Program Miscellaneous Paper A-91-1. Final Report. February.

Thunberg, Eric M. and C. N. Pearson Jr. 1993. “Flood Control Benefits of Aquatic Plant Control in Florida’s Flatwoods Citrus Groves.” J. Aquatic Plant Management. 31, 248-254

Thunberg, Eric M. and C. N. Pearson and J. W. Milon. 1992. “Residential Flood Control Benefits of Aquatic Plant Control.” J. Aquatic Plant Management 30. 66-70.

U.S. Army Corps of Engineers. 1995. Evaluation of Environmental Investments Procedures Manual. Interim: Cost Effectiveness and Incremental Cost Analysis. Evaluation of Environmental Investments Research Program. IWR Report #95-R-1. May.

USACE. 2000. Policy and Planning Guidance for Conducting Civil Works Planning Studies. USACE ER 1105-2-100.

USACE 2002. Economic Guidance Memorandum 02-04. Unit Day Values for Recreation, Fiscal Year 2002.

USACE, 1995. Evaluation of Environmental Investments Procedures Manual. Interim: Cost Effectiveness and Incremental Cost Analyses. IWR Report #95-R-1. May.

USDI, U.S. Water Resources Council, 1983. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. Washington.

Westerdahl, Howard E. and Kurt D. Getsinger, Eds. Aquatic Plant Identification and Herbicide Use Guide. USACE Technical Report A-88-9.

Weed Control Manual 2000. Volume 32. Section 10. Aquatic

Zerbe, Richard O. and and D. D. Dively. 1984. Benefit Cost Analysis in Theory and Practice. Harpercollins.

Chapter 2: Cost Effectiveness of Different Control Methods In California Waters

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Abstract

This chapter compares the cost-effectiveness of various aquatic plant control methods in different management scenarios. It uses the "Type A" methodology, outlined in Chapter 1. The Type A analysis is a cost-effectiveness analysis which only considers control costs paid to meet a management objective. This chapter does not include estimates of damage or environmental costs, nor does it present benefit/cost analyses. The methodology used to acquire cost information includes an initial establishment of contact with managers and practitioners, the creation of a survey to guide the phone interviews, and explanatory letters describing the project, which were sent out to the practitioners. Phone interviews were conducted to collect the information, which were assembled and analyzed according to the methodology. This study found that a variety of non chemical and chemical alternatives can be the most cost-effective methods for the treatment of the aquatic plant problem, depending on the management circumstances. For chemical management techniques, control costs per surface acre are very high for a low acreage area and decrease with increasing area, resulting from the set-up and NPDES permitting costs incurred for any pesticide application that occurs. For non-chemical techniques, the rates of control cost per unit area are similar for both small and large acreage, as there are no permitting or monitoring costs that are required using these techniques.

Four management problems are evaluated in detail using formal cost-effectiveness analysis: (1) the control of emergent vegetation at the Kern National Wildlife Refuge, (2) the control of Eurasian Water Milfoil, Curly Leaf Pondweed, and algae at the Big Bear Lake Municipal Water District, (3) the control of Eurasian water milfoil and Water Hyacinth at the Stone Lakes National Wildlife Refuge (Elk Grove, CA), and (4) the control of Eurasian Water milfoil and Water Hyacinth at Big Break, located on the Sacramento-San Joaquin Delta in Antioch, CA. The most cost effective management technique for the Kern NWR is mowing, given that no more than four mowing events per season occur. The most cost effective management technique for Big Bear Lake is the application of Sonar (Fluridone), in combination with some harvesting. The most cost effective technique at both Stone Lakes NWR and Big Break are the application of herbicides with additional surfactants.

Introduction

The purpose of this analysis is to explore the feasible options that aquatic plant managers have at their disposal based on estimation and comparison of control costs for several management alternatives. The "Type A" analysis is one of three types of analysis as outlined in Chapter 1 "Methodology for Aquatic Plant Management Economics" by Roger Mann, which was designed to help managers and practitioners understand the costs and benefits of alternative management practices for aquatic plants. The Type A analysis is a cost-effectiveness analysis. It was designed to consider only control costs paid to meet a management objective. It does not include estimates of damage or environmental costs, nor is it a benefit/cost analysis.

This chapter includes a description of the methods used to acquire the data used in the analysis. These methods include an initial establishment of contact with managers and practitioners, the creation of a survey to guide the phone interviews, and explanatory letters describing the project, which were sent out to the practitioners. Finally, phone interviews were conducted and the data was assembled and analyzed according to the methodology. Also included in the chapter is a discussion of trends of aquatic plant management as a result of this data collection. Results are presented, including data gathered from practitioners which may not qualify as a management scenario that is in need of a type A investigation.

Finally, a presentation of four selected study sites, which have been chosen based on the characteristics of the aquatic plant problem and need for a management objective, for which a thorough "Type A Analysis" has been carried out. The selected site analyses consider: (1) the control of Alkalai Bulrush (*Scirpus maritimus*) and Cattail (*Typha latifolia*) at the Kern National Wildlife Refuge; (2) the control of Eurasian Water Milfoil (*Myriophyllum spicatum*), Curly Leaf Pondweed (*Potamogeton crispus*), and various species of planktonic, filamentous and blue green algae at the Big Bear Lake Municipal Water District; (3) the control of Eurasian water milfoil and Water Hyacinth at the Stone Lakes National Wildlife Preserve in Elk Grove, CA; and (4) the control of Eurasian Water milfoil and Water Hyacinth at Big Break, located on the Sacramento-San Joaquin Delta in Antioch, CA. These sites qualify as Type A subjects according to the Chapter 1 methodology because they pass all feasibility tests and have a well-defined management objective.

Methods: Preparation and Data Collection

In this section the steps taken in the preparation and collection of the data to be used for the Type A Analysis are outlined.

Establishing Contact with Managers and Practitioners

An initial contact with practitioners or managers was established through the Aquatic Plant Monitoring Program (APMP) via phone calls and meetings attended by Ben Greenfield, Nicole David and Geoff Siemering. This contact information was collected while gathering information to investigate the needs and practices of aquatic plant managers in and outside of California. In addition, practitioner contacts were also acquired via NPDES permit applicant listings.

List of Possible Managers to Contact

Based on these initial contacts, a database of potential practitioners to contact for cost related information based was compiled including information on their aquatic plant concerns, location, past and present management practices, and interests in management strategies. Approximately 50 practitioners in California and Washington were identified as possible contacts for Type A information. The range of practitioners or managers included groups and individuals from a variety of water and aquatic plant management organizations such as various irrigation districts, lake managers, State and Federal Wildlife refuges, California Department of Boating and Waterways, California Department of Fish and Game, California Department of Food and Agriculture, private aquatic plant contractors, homeowner associations, and research centers.

Survey and Letter Design

In order to acquire the most useful information possible, a survey was designed to guide the analyst through a call or meeting with the practitioner. The main objectives of the survey were to gain an understanding of a few basic aspects of each manager's practice including:

- target pest
- location-specific details such as system type or use characterization of the water body
- elements of chemical and/or non chemical controls of aquatic macrophytes
- methods for algae control
- the feasibility and variability of each of the techniques and their possible alternatives.

Once these items were determined, the analyst would make inquiries regarding the costs of each of the control methods including elements such as equipment, materials, labor costs, disposal, permitting fees, monitoring, and research. Essentially, any costs involved in the management of the aquatic plant problem were to be accounted for.

The survey was designed to gather specific cost information in a form that would allow the analyst to present it as a rate, specifically as cost of area treated per hour/season. In addition the *total* cost per season was elicited. Total cost includes initial fixed costs, set-up costs, as well as ongoing costs per treatment strategy.

The survey differentiates between chemical, non chemical and algae techniques, and handles them as three unique strategies.

The survey is attached as **Appendix C**.

A letter was created to invite practitioners and managers to the phone interview and/or personal meeting where the survey was administered to acquire the cost related information regarding their management technique. The letter describes the position of the analyst and relation to the APMP as well as explaining what the objective of the "Type A" analysis. The letter also informs the recipient of the person who recommended them as a participant in the project and also offers a summary of findings from the project.

The letter was sent either as hard copy or electronically to most managers on the contact list. A generic copy of the letter is attached as **Appendix D**.

Interviews

The phone interviews were conducted over an estimated one month period during July and August. Calls lasted from 15 minutes to more than one hour.

Data Assemblage

The data were assembled in an effort to estimate the unit and total costs of each management alternative. Where possible, the data were expressed in terms of cost per treatment per season per area. This allowed for a comparison of costs across different techniques.

The data are summarized in tabular form as **Appendix E**.

Results

Cost Effectiveness Information Gathered

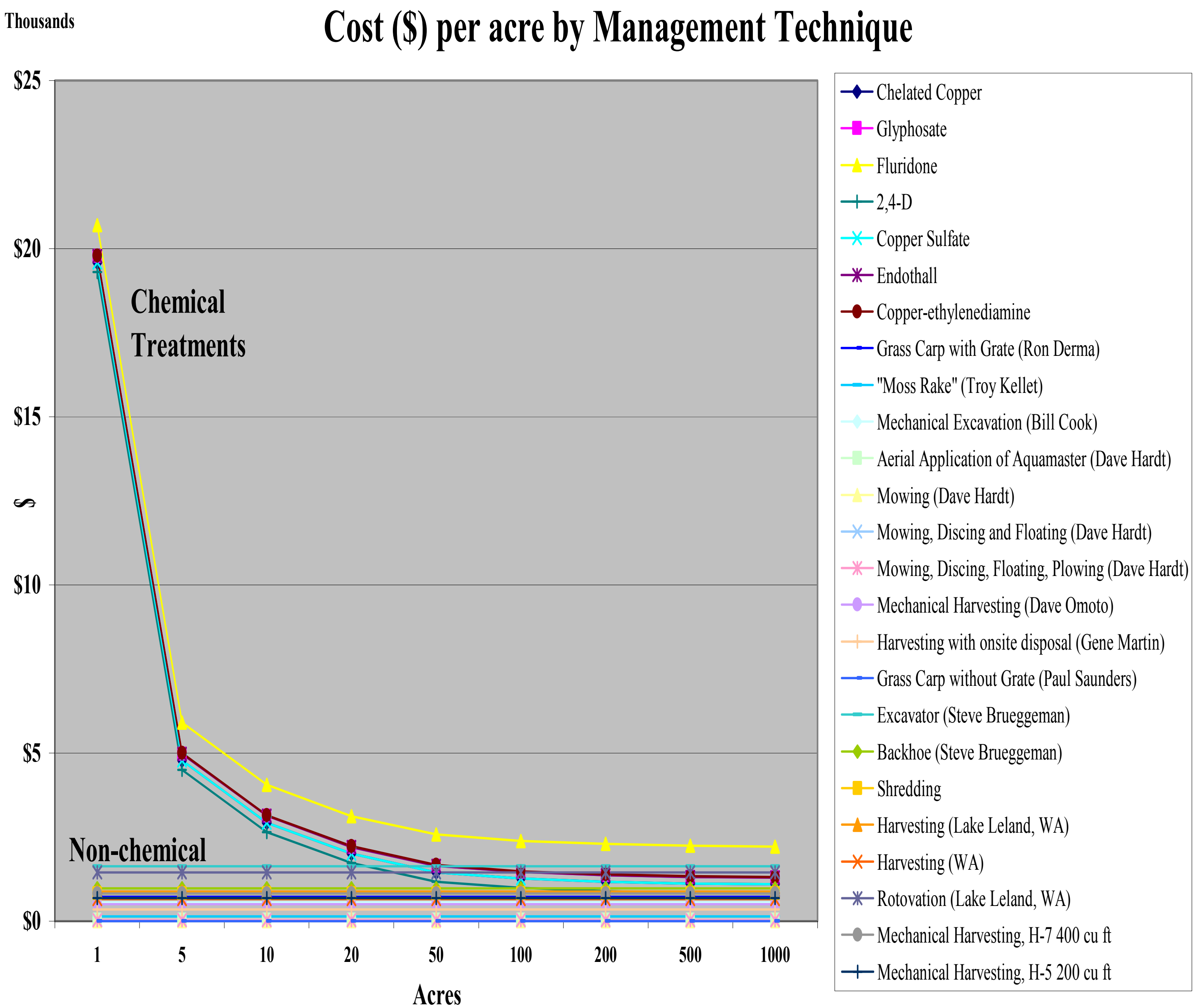
There were approximately 35 data points for cost estimations collected. Many methods, pests and system types were represented as a result of the surveys completed during the summer period. See Appendix E for a full list of the data collected and accompanying notes regarding elements such as special circumstances and the success of varying control techniques given variable environmental conditions. In an effort to standardize the data, data were categorized by method and pest, and costs were converted to a cost per treatment per season per area for the available techniques. In addition, the total cost per season is included for each management alternative as rate information may not accurately address the effectiveness of each cost per alternative. Total costs per season ranged from approximately $1,000 to $300,000 and per area costs ranged from $6 per surface acre to greater than $12,000 per surface acre.

Figure 1.
Estimates of Costs per Surface Acre for Various Aquatic Weed Management Techniques

Practice	Target Pest	$/surface acre
Pulling and Komeen (Ross O'Connell)	Hydrilla	$12,190.39 (Handpulling) $642.69 (Komeen)
Mechanical Harvesting	Eurasian Water Milfoil	$1818
Grass Carp including Grate (Ron Derma)	Submersed vegetation	$722.99
Grass Carp without Grate (Paul Saunders)	Pondweed, milfoil, Hydrilla, salvinia	$2
Excavator, "Moss Rake" (Troy Kellet)	Curly leaf pondweed, Elodea	$137.40
Aerial application of AquaMaster (Dave Hardt)	Alkalai Bulrush, Cattail	$47.87
Mowing (Dave Hardt)	Alkalai Bulrush, Cattail	$6.79 (requires many passes)
Mowing, Discing and Plowing (Dave Hardt)	Alkalai Bulrush, Cattail	$23.89 (requires many passes)
Mowing, Discing, Plowing and Floating (Dave Hardt)	Alkalai Bulrush, Cattail	$30.56 (requires frequent passes)
Mechanical Harvesting (Dave Omoto)	Elodea, Milfoil, pondweeds, Primrose, Coontail, Naiad	$500
Harvesting (Gene Martin)	Milfoil	$344
Sonar (Fluridone) (Gene Martin)	Milfoil	$1000
Excavator (Steve Brueggeman)	Water Primrose	$1,636
Backhoe with fabricated rake (S. Brueggeman)	Water Primrose	$979
Round-Up Pro 2.5% (S. Brueggeman)	Water Primrose	$94-$178
Mechanical Excavation (Bill Cook)	Submersed weeds	$557
Shredding (Dave Penny)	Water Hyacinth	$817
Mechanical Harvesting (Lake Leland, WA)	Floating plants	$875
Mechanical Harvesting (WA)	Floating plants	$650
Rotovation (Lake Leland, WA)	Hydrilla	$1450
Mechanical Harvesting H-7, 400 cu ft. (AEI)	Floating and submersed plants	$700-1000
Mechanical Harvesting H-5, 200 cu ft. (AEI)	Floating and submersed plants	$500-$700

System types ranged from irrigation canals, reservoirs, “afterbays”, seasonal wetlands, lakes, lagoons, service ditches and ponds. Many of the data are based on an estimation of total control costs per season and their relation to the number of acres treated per season. There are fixed costs and set up fees which have been included in the rates. Figure 2 shows a cost per acre by management technique.

Figure 2.



Estimations of the cost components of the various chemical treatments (glyphosate, fluridone, chelated copper, copper sulphate, endothall, and copper-ethylenediamene) shown in Figure 2 were taken from “Economic Information Table 2” of Chapter 1 of this report. The costs of chemical treatments include set-up costs, NPDES permitting costs, materials and application and sampling requirements for both pre- and post treatment. Estimations of cost/acre for non-chemical techniques were provided by various managers and practitioners and include operation and material costs, fixed costs, and labor costs. In some cases, these rates were estimated based on a total cost per season divided by the acreage managed, without a thorough breakdown of the various component costs described above.

There were four management scenarios that have been selected from this set of data points to investigate using the Type A analysis. These are the Kern National Wildlife Refuge, the Big Bear Municipal Water District, Stone Lakes National Wildlife Refuge, and Big Break on the Delta. They were chosen by virtue of the management scenario that is presently in place at each site, as well as the fullness and availability of the data set with regard to costs and options for each manager. Each site shows the need for a successful management scenario to be implemented where a variety of techniques are currently being used in an experimental theme. This is to say, a variety of methods are being used without a complete understanding of which is most cost effective, considering the limitations of the respective systems. Results are presented below.

Type A Analysis: Kern National Wildlife Refuge

Characterization of Kern NWR scenario (from USFWS):

The Kern National Wildlife Refuge (KNWR) is located 18 miles west of the city of Delano at the southern end of the San Joaquin Valley of California. The 10,618-acre Kern refuge consists of natural valley grasslands, a relict riparian corridor, and developed marsh.

The refuge is south of the original Tulare Lake Bed in the southern San Joaquin Valley of California. This lake covered almost one half million acres during flood years and was home to millions of fish, amphibians, reptiles, birds, and mammals. One hundred-fifty years ago, this area was covered by an inland lake and wetland system totaling up to 625,000 acres. Each year the arrangement of marshes and lakes would vary due to drought and flood cycles. The refuge was the first effort to preserve wetland habitat in the area. In addition, this area was important habitat for wintering birds along the Pacific flyway in the southern San Joaquin Valley.

The refuge is intensively managed to produce habitat for migrating and wintering waterfowl and other water birds. Marsh habitat is maintained to provide a continuing food source for the birds and other wildlife. About 50% of the refuge is currently maintained with diked impoundments. Grain plantings of wild millet (watergrass) and swamp timothy are managed in a 1,200-acre area.

The Type A analysis example is provided through the analysis report and the entry table below.

1. *Summary of Results*

The area of concern in the Kern National Wildlife Refuge (KNWR) includes 800 acres of seasonal wetland “management units” which are shallow, flooded areas irrigated in the spring and summer seasons. Alkali bulrush and Cattail are the problem species which overgrow in these areas during the warmer months of the year.

The APME "Type A" analysis concluded that the best alternative for this entire area is mowing four times per season as it produces an annualized cost of $21,730 per year, achieving the same management objective for less than the other two mechanical options despite being more time consuming.

2. Remaining Uncertainties and Issues

The use of AquaMaster once every five years and one mowing event per year is most effective in terms of control and costs. However, the KNWR manager suggests that "Due to Fish and Wildlife Service internal regulations, the use of aerially applied herbicides is very time consuming to implement…doubt[s] that herbicides will ever become [the] first choice of control options…" (Personal communication, 7/15/03)

If implementation time should acceptably decrease, this could become a very viable management alternative.

An integrative approach might work best for this area as some regions are more overgrown than others. Only mowing might be the most viable alternative for the sparse areas, herbicide treatment in addition to mowing might be more suitable for areas with denser growth. Amount of growth in each area is dependant on environmental conditions of the season. A survey of which areas are prone to higher growth might be of use in determining how much management is applied in which areas.

In addition, there will be 1100 additional acres of moist soil wetlands added to the management program next scheme, which, according to Dave Hardt, Kern NWR manager, could increase rates of control costs per acre.

3. Identify the Aquatic Plant Problem

There is an extensive aquatic plant problem on the wetland areas of the Kern NWR. The pest species are Cattail, Alkali Bulrush, and Tamarisk in the upland areas. This analysis will deal only with the control of Cattail and Bulrush.

In the past, chemical controls such as Arsenal, Round Up and Garland 4 have been successfully implemented, although it had been found to be very costly and time consuming.

The refuge managers have switched to more extensive use of mechanical control because exclusive chemical control has been found to be too expensive at this site. In some cases, chemical control was not effective at label recommended concentrations. In addition, most applicators do not have aircraft permitting for herbicide application to USFWS refuges.

There have been mixed results with integrated approaches on cattail control. Managers at Kern NWR have combined aerial "fly-overs" of Rodeo with wetland draining, followed by mowing and disking. It has been found that the most effective control occurs after the area is left dry for 3 months, which is not feasible because of the need to maintain sufficient waterfowl habitat. Also, plowing followed by drying is more effective than disking. They are currently using the disking technique on the main unit to maintain lower biomass; this practice is likened to "mowing the lawn" by Kern NWR managers. It is not possible to keep the main unit dry for more than 3 or 4 weeks because some sensitive bird species need the wetlands.

They have a number of different treatments that have already been conducted. These include areas mowed and disked but not sprayed, areas sprayed two years ago, and areas not treated at all.

4. Potential Economic Costs and Benefits

Uncontrolled plant growth diminishes the value of the area as a wildlife refuge as overgrowth impedes the area where sensitive waterfowl species inhabit.

5. Management Objective

The management objective for the Kern NWR is to control but not eradicate the growth of cattail and alkali bulrush so as to preserve sufficient waterfowl habitat.

6. Identifying Management Alternatives

Management alternatives are specified in Entry Tables 3, Numbers 1-5 with the help of David Hardt, Kern NWR manager.

7. Economic Perspective

A public perspective is used as the costs of control are federally funded.

8. Type of Analysis

The type of analysis performed is a Type A, where only control costs are considered.

9. Period of Analysis, Discount Rate, and Price Level

The analysis uses a fifty-year period of analysis, a 5 percent discount rate and a 2002 price level.

10. Specifying Management Alternatives

Management alternatives are specified in Entry Tables 3, Numbers 1-5 with the help of David Hardt, Kern NWR manager.

11. Feasibility Tests

- Technical Feasibility: All five alternatives are physically possible to perform on the areas of concern.
- Legal feasibility: All five alternatives area allowed by local, State and federal laws, and all necessary permits can be obtained.
- Financial feasibility: All five alternatives are financially feasible under the budget constraints for the area.
- Social/cultural feasibility: The two alternatives that involve the aerial application of AquaMaster have been found to be [too??] time consuming to implement the permit and helicopters necessary for application.

12. Costs of Each Practice in Each Management Alternative

Estimations of cost were offered by David Hardt, manager Kern NWR.

The cost of the aerial application of AquaMaster is estimated to be **$47.87** per acre and includes rates per acre of helicopter time (2000 rates), AquaMaster (2003 costs), surfactant, Load Management Staff, and planning/permits. Dave Hardt estimates that AquaMaster needs to be applied once per five years. The cost of mowing includes labor, fuel and equipment service and is **$6.97** per acre, and can be needed anywhere from 1-4 times per season dependant on seasonal conditions. The cost of mowing, disking, and floating only is **$23.89** per acre and includes labor to disc, fuel, equipment service and floating costs. Finally, the cost to mow, disk, plow, and float is **$30.56** per acre. The cost of management alternative 2, AquaMaster with one plowing event is **$54.84** per acre and was estimated by combining costs listed above ($47.87+$6.97). As mentioned above, the frequency of each treatment varies with differing environmental conditions in the reserve.

The net present and annual payment values were derived over a 50 year period by implementing a cost per season, depending on treatment method and frequency requirement, and using a 5% discount rate to calculate the value in terms of a 2003 dollar value.

13. Damage Costs and Environmental Costs

No damage or environmental costs have been assessed for this analysis.

14. Entry Tables

The final entry table for this analysis is provided below; the back-up entry tables for this analysis are provided as **Appendix F**.

Entry Table 7[3]. Comparison of Management Alternatives for Aquatic Plant Management

Type of Analysis: A

	Economic Costs from Entry Table 6				Meets Management Objective?	Describe Other Benefits and Costs and Other Considerations that Affect the Selection of a Management Alternative	Results of feasibility Tests			
	Control Costs		Total Costs							
Management Alternative	NPV, 1000$	Annual Value, 1000$	NPV, 1000$	Annual Value, 1000$			Tech	Legal	Finance	Soc/C
AquaMaster	**$153.79**	**$8.42**	**$153.79**	**$8.42**	**yes**	The use of aerially applied herbicides is very time consuming to implement due to Fish and Wildlife Service internal regulations; the refuge manager doubts it will ever become first choice of control.	x	x	x	
AquaMaster and Mowing (1 times/season)	**$252.96**	**$13.86**	**$252.96**	**$13.86**	**yes**	This option produces better results than just mowing, is less labor intensive. See Comments for "AquaMaster" alternative.	x	x	x	
Mowing (4 times/season)	**$396.66**	**$21.73**	**$396.66**	**$21.73**	**yes**	Could operate more or less times per season depending on conditions—costs increase significantly with increased mowing events. See sensitivity analysis.	x	x	x	x
Mowing, Discing, Floating (2 times/season)	**$697.81**	**$38.22**	**$697.81**	**$38.22**	**yes**	Could operate more or less times per season depending on conditions—costs increase significantly with increased mowing events. See sensitivity analysis.	x	x	x	x
Mowing, Discing, Plowing, Floating (1 times/season)	**$446.32**	**$24.45**	**$446.32**	**$24.45**	**yes**		x	x	x	x

Management Alternative Selected: Mowing, given that there are no greater than 4 mowing events per season. If conditions are such that growth is extreme, the "Combined Mowing, Discing, Plowing, Floating" option is most cost effective. "AquaMaster and mowing once per season" is the most effective, possibly not feasible because of permitting time constraints.

[3] See sections 12 and 14 of "Type A Analysis: Kern NWR" for the derivation of the values on this table

Type A Analysis: Big Bear Lake Municipal Water District

Characterization of Big Bear Lake scenario (from BBMWD website[4]):

Big Bear Lake is located in San Bernardino County within the San Bernardino Mountains. The water body is a reservoir with a dam located at the west end of the lake. Big Bear like is widely used as a recreational area supporting boating, fishing and other recreational activities. In addition, there are large areas of the shoreline developed as residential or resort property, including many privately owned docks. The lake has experienced a major aquatic weed problem for many decades, as it provides an ample habitat for submersed aquatic plants. At some point in the 1970's, the invasive aquatic species Eurasian Water Milfoil was introduced to the lake and is a major plant of concern in addition to various pondweeds and other algae (ReMetrix, 2001). Eight types of aquatic plants have been identified in Big Bear Lake, of which coontail and milfoil are the most abundant and the most troublesome to navigation, fishing and aesthetics. District records indicate that of the weeds harvested, 73% is coontail, 20% is milfoil and the remaining 7% is a combination of other types.

Big Bear Municipal Water District operates three aquatic weed harvesters and one Aquamog on the Lake for the purpose of removing weeds, primarily from around docks and major boating areas. Approximately 86% of the weed cutting occurs around private docks, with the remaining 14% occurring in areas where improved public access is needed or navigational hazards must be removed. The harvesting program currently removes about one-thousand tons of weeds from the Lake annually. Some chemical weed treatment has been performed in the past; however the method of mechanical harvesting has been determined to have less adverse impacts and is now the preferred method used by District Staff. Occasionally, when the situation demands, chemicals are used to treat excessive algae blooms.

The Aquamog, a 10' wide barge with a cab for the operator, is paddle wheel driven, 35' in length and has an excavator arm which accepts a number of different attachments. The attachment used for this program is the tiller which is similar to the rototiller used in the garden, except on a larger scale. It is 10' wide and weighs about 2,000 pounds. It has 4 rows of spring steel tines that are off-set to get maximum digging on the bottom of the Lake to dislodge the aquatic plants. Each dock area takes about 30 minutes to complete and one lap around the Lake is completed each spring.

In the summer of 1996, the District completed an experimental application in Grout Bay of a product called Sonar (Fluridone). Grout Bay, on the north shore of the Lake, was selected as the test area as it is protected from the wind and also from weed harvesting operations. This 35 acre area was initially treated during the first week of August 1996, with additional applications approximately every three weeks throughout the remainder of the summer. District staff monitored the test area following the applications and

[4] www.bbmwd.org

concluded that the product results were unsatisfactory. Upon further evaluation, it was determined that the applications occurred too late in the growing season to achieve maximum results. A second series of applications took place in 1998 in the same area of the Lake. The cost for these treatments was approximately $1,000 per acre and the result was nearly three years of weed-free access in Grout Bay. Based on these results, the District developed a plan to treat specific areas of the Lake again in 2000.

In December of 2001, the District decided to move forward in the spring of 2002 with an aggressive program for herbicide treatments. Following three dry years with less than normal inflow to the Lake, and a Lake that was 9'6" below full, it was determined that applications in the east end of the Lake, in Boulder Bay and in the Mallard Lagoon/Canvasback Cove areas could achieve many years of relief from the infestation of Eurasian water milfoil. A consultant was retained to coordinate the permit process work with the Santa Ana Regional Water Quality Control Board. The cost of the applications was projected at $264,000 with funding provided from the District's Lake Improvement Fund. (BBMWD website)

The Type A analysis example is provided through the analysis report and the entry table below.

1. Summary of Results

According to the APME type A analysis, Management Alternative 2: Sonar and some harvesting is the best management alternative for the control of Eurasian Water Milfoil and Curly Leaf Pondweed on Big Bear Lake with an annual cost of $249,000. Gene Martin, manager BBMWD, suggests that this option is the most effective in terms of control of milfoil and requires a lesser time commitment during the management season at Big Bear Lake.

2. Remaining Uncertainties and Issues

One issue raised was that in years of low water level at the lake (this year reached a record 14 feet below the full elevation) allows for a natural drawdown. In this case, it is both cost saving and effective to follow the drawdown and apply Sonar to the exposed milfoil for a thorough eradication of the milfoil in those areas. Performing a manual drawdown during wetter periods would not be possible as a result of the water rights and purchases that the BBMWD is responsible for.

A second concern brought up by Mr. Martin is that as a result of the extreme effectiveness of the Sonar treatment on Eurasian water milfoil, a resultant abundance of curly leaf pondweed has grown in place due to the lack of biological competition. A management strategy is necessary to control for both target pests.

3. Identify the Aquatic Plant Problem

The lake has experienced a major aquatic weed problem for many decades. During the 1970's, the invasive aquatic species Eurasian Water Milfoil was introduced to the lake and is a major plant of concern in addition to various pondweeds and other algaes (ReMetrix, 2001). Eight types of aquatic plants have been identified in Big Bear Lake, of which coontail and milfoil are the most abundant and the most troublesome to navigation, fishing and aesthetics. District records indicate that of the weeds harvested, 73% is coontail, 20% is milfoil and the remaining 7% is a combination of other types.

4. Potential Economic Costs and Benefits

The presence of the vascular rooted aquatic plants has some environmental benefits to Big Bear Lake. They can serve to provide essential habitat for fish life, as well as producing an abundance of food organisms for all species of fish present. Aquatic plants are also utilized to a significant extent as food by migratory waterfowl and often serve as some control of shoreline erosion. (BBMWD website)

However, the overgrowth of these aquatic plants inhibits navigation, fishing, recreation and aesthetic values on the lake. Control without complete eradication is central to the management technique at this site.

5. Management Objective

The objective of aquatic plant removal is to eliminate overgrowth of the plants and to facilitate access to the lake. The short-term objective of aquatic plant management in the lake should be to maintain beneficial uses. The long-term objective, whenever feasible, should be to substantially reduce the Eurasian Milfoil populations in the lake and encourage the reestablishment of native aquatic plant communities. (ReMetrix, 2001)

6. Identifying Management Alternatives

Management alternatives available in the Big Bear Lake include harvesting, AquaMogging, Sonar (Fluridone) application, and suction dredging using divers and vacuums. (Remetrix, 2001)

Drawdown is not an available technique as the manipulation of water levels in Big Bear Lake is not under the control of the Big Bear Municipal Water District. (Gene Martin, Personal Communication, 8/03)

7. Economic Perspective

A public and private perspective will be used because costs of control are paid both publicly and privately.

8. Type of Analysis

This is a type A analysis because only control costs and not damage or environmental costs are being considered.

9. Period of Analysis, Discount Rate, and Price Level

A 50 year period, a 5% discount rate and a 2003 price level are being used for this analysis.

10. Specifying Management Alternatives

See entry table 3, numbers 1-3 for the specification of management alternatives.

11. Feasibility Tests

- Technical Feasibility: All three alternatives are physically possible to perform on the areas of concern.
- Legal feasibility: All three alternatives area allowed by local, State and federal laws, and all necessary permits can be obtained.
- Financial feasibility: All three alternatives are financially feasible under the budget constraints for the area.
- Social/cultural feasibility: All three alternatives are socially and culturally feasible in the Big Bear Area. However, the environmental impacts of suction dredging are more severe than the other alternatives. This may have an effect on a decision of whether or not to use this technique. This element can be further explored via a Type B analysis.

12. Costs of Each Practice in Each Management Alternative

Costs were estimated with the help of Gene Martin, Manager BBMWD and a ReMetrix report titled, "Vegetation Assessment and Management Plan for Big Bear Lake (San Bernardino County, California)", completed 2001. For harvesting, per season costs were estimated to be **$250,000 to $300,000**. The costs for the application were estimated to be $1000 per acre for a 240 acre area, with additional costs for permitting and monitoring to give a season total of **$225,000 to $270,000** depending on year of application. The costs for suction dredging range from $1,500 to $2000 a day with actual removal rates varying from 0.25 to 1 acre per day to give an average season total of **$285,000**. See entry tables in Appendix G for a complete cost break down.

13. Damage Costs and Environmental Costs

No damage costs or environmental costs were assessed for this analysis.

14. Entry Tables

Entry Table 7 is provided below, back-up entry tables are provided as **Appendix G.**

Entry Table 7.
Comparison of Management Alternatives for Aquatic Plant Management
Type of Analysis: Type A

	Economic Costs from Entry Table 6				Meets Management Objective?		Results of feasibility Tests			
	Control Costs		Total Costs							
Management Alternative	NPV, 1000$	Annual Value, 1000$	NPV, 1000$	Annual Value, 1000$		Describe Other Benefits and Costs and Other Considerations that Affect the Selection of a Management Alternative	Tech	Legal	Finance	Soc/C
Harvesting, Aquamog	**$5020.38**	**$275.00**	**$5020.38**	**$275.00**	**yes**	Harvesting allows some fragments of plant material to escape which can contribute to re-growth. Yearly application of harvesting is necessary and time consuming.	x	x	x	x
Sonar and some harvesting	**$4548.96**	**$249.18**	**$4548.96**	**$249.18**	**yes**	Sonar has to be applied at the correct time, otherwise is ineffectual.	x	x	x	x
Suction Dredging	**$5202.94**	**$285.00**	**$5202.94**	**$285.00**	**yes**	Has many undesirable effects on environmental quality of the water body by increasing turbidity and nutrient release from disturbed sediments. Sediment curtains can curb this problem, but is very costly.	x	x	x	x

Management Alternative Selected: Sonar and some harvesting (8-10 days per season to control curly leaf pondweed which arises as a result of the eliminated milfoil).

Type A Analysis: Stone Lakes National Wildlife Refuge

Characterization of Stone Lakes NWR Scenario (from SLNWR website)

The Stone Lakes National Wildlife Refuge is located south of Sacramento in Elk Grove California. In 1972, the U.S. Army Corps of Engineers recommended establishing a national wildlife refuge in the Stone Lakes Basin after completing a flood control study of Morrison Creek, Sacramento County's largest creek system. Stone Lakes NWR was established in 1994 by the U.S. Fish and Wildlife Service and is one of a few urban refuges that have the potential to attract and educate thousands of visitors in the Central Valley of California. The refuge is situated within the Sacramento-San Joaquin Delta along the Pacific Flyway, the destination of thousands of migrating waterfowl, shorebirds, and other water birds.

Through a number of innovative partnerships such as the California Departments of Transportation, Parks and Recreation, Water Resources and the National Audubon Society, the refuge is protecting scarce natural habitats and agricultural resources in an area threatened by urban sprawl and agricultural changes. Stone Lakes Refuge contains both seasonal and permanent wetlands, riparian forest, and grasslands, as well as some of the last remaining freshwater lakes in the central valley. These areas provide habitat for large populations of migratory water birds, also a major rookery for several colonial nesting species such as great blue herons, and a warm water fishery. Several endangered, threatened, and special-status species benefit from these habitats such as the valley elderberry longhorn beetle, Swainson’s hawk, and greater Sandhill crane.

Visitor numbers increase every year; they topped 8,500 in 2001, despite a lack of developed facilities such as a visitor education center and restrooms. Volunteers from the local area dedicate their time on weekends guiding visitors through grasslands and tree-lined waterways to educate the public about the refuge in their backyard.

In both the North and South Stone Lakes, as well as surrounding sloughs there are major infestations of Water Hyacinth. Traditionally, managers at Stone Lakes have controlled the hyacinth by means of herbicide treatment. With the aid of supplemental labor during the management season, employees have spent approximately four days per week during a 5 month period manually applying Weedar64® and AquaMaster®. In addition, handpulling has also been used as a management technique in places where infestations are very dense. This year, 2003, has been the first time that “shredding” has been used on the Stone Lakes as a management technique. A pilot study to test out this technique was arranged and carried out by the San Francisco Estuary Institute and Master’s Dredging, Incorporated, in conjunction with the Stone Lakes Refuge Managers and Vino Farms.

The Type A analysis example is provided through the analysis report and the entry table below.

15. Summary of Results

Out of the four management alternatives considered (herbicide treatment, shredding, handpulling and harvesting) herbicide treatments with Weedar64®, AquaMaster® with surfactant R-11 is the most cost effective strategy for the Stone Lakes NWR at this time.

16. Remaining Uncertainties and Issues

This is the first time that shredding has been carried out at the Stone Lakes. It was noted by operators that the shredding was done too late in the season, as the plants had grown too large for shredding to be effective. This could have a significant effect on the cost and effectiveness of this strategy. There will be another shredding event carried out in spring of 2004 on younger, less mature plants.

17. Identify the Aquatic Plant Problem

The aquatic species of concern in the Stone Lakes NWR is the Water Hyacinth (*Eichornia crassipes*). As a result of the invasion and overgrowth of the Hyacinth, there has been a decrease in the amount of flow in surrounding sloughs and waterways because of physical clogging as well as uptake. As a result of Water Hyacinth's high rate of water use, one acre of the plants cause a loss of up to 39 acre inches of water per month over the rate of an acre open water. (CDBW)

18. Potential Economic Costs and Benefits

One benefit of the growth of water hyacinth on Stone Lakes proper is that it may provide habitat for various species of fish and invertebrates which could support the ecosystem that is present on the refuge. Stone Lakes NWR is a major stop along the Pacific Flyway, a popular spot for migratory birds in the western coast region.

However, much of the overgrowth occurs in the canals and sloughs in the area, therefore hindering flow to surrounding agriculturalists.

19. Management Objective

The objective is to eradicate the weeds in functional waterways, and to control (not necessarily eliminate) the weed on Stone Lakes proper.

20. Identifying Management Alternatives

There are four management alternatives to be considered on Stone Lakes NWR (1) herbicide application using Weedar64® and AquaMaster® with surfactant, (2) Shredding, (3) Harvesting, and (4) Hand-pulling.

21. Economic Perspective

A public perspective shall be used because the refuge is a federal holding, managed by the US FWS.

22. Type of Analysis

This is a type A analysis because only control costs and not damage or environmental costs are being considered.

23. Period of Analysis, Discount Rate, and Price Level

A 50 year period, a 5% discount rate and a 2003 price level are being used for this analysis.

24. Specifying Management Alternatives

See Appendix H, entry table 3, numbers 1-3 for the specification of management alternatives.

25. Feasibility Tests

- Technical Feasibility: All four alternatives are physically possible to perform on the areas of concern.
- Legal feasibility: All four alternatives area allowed by local, State and federal laws, and all necessary permits can be obtained.
- Financial feasibility: All four alternatives are financially feasible under the budget constraints for the area.
- Social/cultural feasibility: All four alternatives are socially and culturally feasible on the reserve. However, managers at Stone Lakes would like to find non-chemical alternatives for treatment of water hyacinth in the interest of ecosystem health. This may have an effect on future decisions of whether or not to use this technique. This element can be further explored via a Type B analysis.

26. Costs of Each Practice in Each Management Alternative

Costs were estimated with the help of Clay Courtwright, US FWS Biologist at the Stone Lakes NWR. For herbicide treatment, per season costs for 2003 were estimated to be **$55,012.03** at a rate of **$183/acre** with a predicted increase of 23% for 2004, going forward. Shredding costs were estimated to be **$245,106** or **$817/acre** for the 300 acre area. The costs for harvesting range from **$205,016** to **$208,177** per season at a rate of **$683-693/acre** based on variable disposal costs associated with the removal of the hyacinth from the water body.

27. *Damage Costs and Environmental Costs*

No damage costs or environmental costs were assessed for this analysis.

14. Entry Tables

Entry Table 7 is provided below, back-up entry tables are provided as **Appendix H.**

Entry Table 7. Comparison of Management Alternatives for Aquatic Plant Management

Type of Analysis: A

	Economic Costs from Entry Table 6				Meets Management Objective?		Results of feasibility Tests			
	Control Costs		Total Costs							
Management Alternative	NPV, 1000$	Annual Value, 1000$	NPV, 1000$	Annual Value, 1000$		Describe Other Benefits and Costs and Other Considerations that Affect the Selection of a Management Alternative	Tech	Legal	Finance	Soc/C
Herbicide Treatment (Weedar64® and AquaMaster® plus surfactant R-11)	**$129.02**	**$7.07**	**$129.02**	**$7.07**	**yes**	The use of applied herbicides is time consuming for managers, but seems to be the most inexpensive option. Refuge manager is interested in non-chemical options for the preservation of natural status of the reserve.	x	x	x	x
Shredding	**$471.97**	**$25.85**	**$471.97**	**$25.85**	**yes**	Very expensive option, dissolved oxygen in slough dropped to zero after treatment. In addition, operated very late in the season, will try again next year when plants are smaller and less mature.	x	x	x	x
Harvesting	**$394.77**	**$21.62**	**$394.77**	**$21.62**	**yes**	Harvested materials can sometimes be sold as composting materials	x	x	x	x
Handpulling	**$558.42**	**$30.59**	**$558.42**	**$30.59**	**yes**	Most expensive option	x	x	x	x

Management Alternative Selected: Herbicide treatment with Weedar64® and AquaMaster® and surfactant R-11.

Type A Analysis: Big Break, San Joaquin-Sacramento Delta

Characterization of Big Break Scenario

Big Break is a large tidally influenced water body located 40 miles inland from the Golden Gate in the Sacramento-San Joaquin Delta (Gordy 2003). It lies in Contra Costa County and is located directly north of the town of Oakley in the western Delta area (Small). Seventy-two years ago when a wall in an agricultural levee failed and flooded the bottomland with up to 10 feet of water it created Big Break. The water from the break is a 1,758-acre backwater that provides habitat for birds, fish, mammals, invertebrates, and endangered species (CSU Hayward 2000). The area consists of shallow water with abundant vegetation; supporting areas of tidal marsh, seasonally inundated floodplain, riparian forest, and Antioch dune scrub (Small).

Big Break is the third largest tidal marsh in the western delta (Small). The water in Big Break has less than 1 in 40 salinity, which allows it to provide habitat for many freshwater and andronomous fish species (CSU Hayward 2000). Native fish species include splittail, juvenile salmon, black rail, and pond turtles (Small). Many different species use Big Break as habitat. Mammals such as the river otter, beavers, and bats have all been observed there (Gordy 2003). Qualified biologists have recorded over 150 bird species including several CALFED and CVIPA priority targets at Big Break (Small). Birds like the Swanson's Hawk use the shoreline vegetation for nesting sites. Many fish species use Big Break either as their primary habitat (largemouth bass, striped bass, blue gill, prickly sculpin, and carp) while others use it as an migration routes to their spawning beds (Chinook salmon, splittail, and delta smelt) (DBW EIR 2001). Big Break is one of the only locations where adult splittail congregate in large numbers (Small). Big Break has an abundance of habitat for many invertebrates and some reptiles like the giant garter snake (Small). All animals mentioned above have the potential to be directly or indirectly harmed by the aquatic weed control in Big Break (DBW EIR 2001).

The main aquatic weed in the Big Break area is *Egeria densa,* which has infested large areas of open water. In addition, Water Hyacinth is also a weed of concern in the Big Break area. In 1997 the Department of Boating and Waterways in conjunction with the Romberg Tiburon Center for Environmental Studies began a program to study growth of *Egeria* at Big Break. That same year the *Egeria* infestation at Big Break had become such a problem that Assembly Bill 2193 was enacted, which enabled the Department of Boating and Waterways to create the *Egeria Densa* Control Program (EDCP) for the Delta (DBW 2001). During the first year of the study aerial photos revealed that *Egeria* covered 37.8% of the waters surface in Big Break (563.46 acres). Over the next three years the Department in conjunction with other interested parties created an EIR/EIS for the EDCP. By 2000 *Egeria* coverage had increased to 52.1% (723.77 acres) of the surface waters at Big Break (Romberg). In 2001 the Department had completed its initial EIR on the EDCP. In the EIR the Department investigates the impacts of using Sonar (Fluridone), Reward (Diquat), Komeen (chelated copper), and mechanical harvesting as options for control of *Egeria* and Water Hyacinth.

The Type A analysis example is provided through the analysis report and the entry table below.

1. Summary of Results

Currently the most feasible option for management of *Egeria* and Water Hyacinth at Big Break is herbicide application. While the Type A analysis shows that it is the most expensive option, it is the only successful method where the use of harvesters has proven to be difficult given the excessively windy conditions at Big Break.

2. Remaining Uncertainties and Issues

As mentioned above, Big Break is located at a very windy point along the Delta, making harvesting a less than optimal option for managers. In addition, *Egeria* fragments left behind as a result of harvesting further propagate the growth of the weed and render the treatment less effective.

Handpulling has also been used as an effective means of treatment for Hyacinth at Big Break. The difficulty with this option is that disposal of the plant remains can be expensive. This season's "pulled" hyacinth are currently laying on a barge in the middle of the Break, drying and waiting to be disposed of.

3. Identify the Aquatic Plant Problem

Both Water Hyacinth and *Egeria densa* are invasive species that are currently affecting navigation, recreational boating, and fishing at Big Break. In 1997 the Department of Boating and Waterways in conjunction with the Romberg Tiburon Center for Environmental Studies began a program to study growth of *Egeria,* the main pest, at Big Break. That same year the *Egeria* infestation at Big Break had become such a problem that Assembly Bill 2193 was enacted, which enabled the Department of Boating and Waterways to create the *Egeria Densa* Control Program (EDCP) for the Delta (DBW 2001). During the first year of the study aerial photos revealed that *Egeria* covered 37.8% of the waters surface in Big Break (563.46 acres). Over the next three years the Department in conjunction with other interested parties created an EIR/EIS for the EDCP. By 2000 *Egeria* coverage had increased to 52.1% (723.77 acres) of the surface waters at Big Break (Romberg). In 2001 the Department had completed its initial EIR on the EDCP. In the EIR the Department investigates the impacts of using Sonar (Fluridone), Reward (Diquat), Komeen (chelated copper), and mechanical harvesting as options for control of *Egeria*.

4. Potential Economic Costs and Benefits

Benefits of leaving the *Egeria* and Hyacinth in place include an increased habitat for various aquatic invertebrates as well as various species sport fish, which are sought by vacationers and fishers who visit Big Break. In addition, it has been postulated that hyacinth are efficient at the uptake and storage of contaminants, namely mercury, along with their required nutrients. Joy Andrews of California State University Hayward has been studying the role of hyacinth serving as contaminant accumulators at Big Break. She has learned that the weeds thought to be nuisance aquatic plants are taking up high levels of mercury from the sediments; essentially making them unavailable in the remainder of the ecosystem.

5. Management Objective

The management objective at Big Break is to control the weed for ease of navigation and to stop the increase in rate of growth of *Egeria*.

6. Identifying Management Alternatives

Currently there are three management alternatives for the control of *Egeria* including (1) the use of Sonar (Fluridone), Reward (Diquat), Komeen (chelated copper), (2) handpulling and (3) mechanical harvesting. For this analysis, I consider all chemical treatments under one heading as "Herbicide Treatment" because the cost data provided by Cynthia Gause, CDBW is available only at this level.

7. Economic Perspective

A public perspective shall be used because Big Break is managed by the California Department of Boating and Waterways and is accessible and used by members of the public.

8. Type of Analysis

This is a type A analysis because only control costs and not damage or environmental costs are being considered.

9. Period of Analysis, Discount Rate, and Price Level

A 50 year period, a 5% discount rate and a 2003 price level are being used for this analysis.

28. Specifying Management Alternatives

See Appendix I, entry table 3, numbers 1-3 for the specification of management alternatives.

29. Feasibility Tests

- Technical Feasibility: All three alternatives are physically possible to perform on the areas of concern. However, it is often difficult to carry out harvesting on Big Break as a result of windy conditions mentioned above.
- Legal feasibility: All three alternatives area allowed by local, State and federal laws, and all necessary permits can be obtained.
- Financial feasibility: All three alternatives are financially feasible under the budget constraints for the area.
- Social/cultural feasibility: All three alternatives are socially and culturally feasible on the reserve. However, managers at Big Break would like to find non-chemical alternatives for treatment of *Egeria* as the costs associated with chemical treatment are extremely high.

10. Costs of Each Practice in Each Management Alternative

According to the CDBW *Egeria densa* EIR, chemical treatments at Big Break include the use of Sonar™™ (fluridone), Reward™ (Diquat-dibromide), and Komeen™™ (chelated copper). The cost of Sonar™ is estimated to be **$800-1000/acre** {G., 2003 #144}, Reward™™ is **$75/acre** , and Komeen™™ at **$450/acre**. I assume that each acre treated requires one pass with each chemical, giving a season total of **$1,096,860** for the 724-acre management area at Big Break. Environmental costs for chemical treatments are estimated to be **$47,988**, which includes mitigation costs calculated in Section 6.7. Harvesting costs are also high at Big Break. Using estimates from George Forney, of AEI, the cost of having two H-7, 400 cubic foot harvesters operating full time, completing two passes over the Big Break area would have a cost of **$2033-2148/acre** with a total season cost of **$1,471,563-1,555,041** (the low estimates do not include disposal costs, the high estimates do)**.** When considering environmental costs, specifically fish kills and mitigation costs as a result of harvesting, total season costs are **$1,519,551-1,603,029.** Finally, hand pulling has an estimated cost of **$500-2400** per day (Gibbons et al, 1999), which gives a rate of **$695-$3229/acre** and a season total of **$503,536-$2,337,670.**

11. Damage Costs and Environmental Costs

No damage costs or environmental costs were assessed for this analysis.

12. Entry Tables

Entry Table 7 is provided below, back-up entry tables are provided as **Appendix I.**

Entry Table 7. Comparison of Management Alternatives for Aquatic Plant Management										
Type of Analysis: A & B										
	Economic Costs from Entry Table 6				Meets Management Objective?	Describe Other Benefits and Costs and Other Considerations that Affect the Selection of a Management Alternative	Results of feasibility Tests			
	Control Costs		Total Costs							
Management Alternative	NPV, 1000$	Annual Value, 1000$	NPV, 1000$	Annual Value, 1000$			Tech	Legal	Finance	Soc/C
Herbicide Treatment: diquat bromide, fluridone, chelated copper	**$21,121**	**$1157**	**$53,866**	**$2951**	**Yes**	This seems to be the only effective treatment method at Big Break for Egeria.	x	x	x	x
Harvesting	**$28,336-$29,943**	**$1552-$1640**	**$29,260-$30,868**	**$1603-$1691**	**Yes**	Harvesting is difficult to carry out at Big Break because of the extremely windy conditions that are unpredictable.		x	x	x
Hand pulling	**$27,355**	**$1498**	**$27,355**	**$1498**	**Yes**		x	x	x	x
Management Alternative Selected: Herbicide treatment if only control costs are considered, Harvesting if control and environmental costs are considered.										

Discussion

It is important to recall that the “Type A” analysis is the minimum economic analysis possible given the types of economic data that are likely to be available (Mann, 2003). This analysis has merely provided an approximation of relative control costs for a variety of different chemical and non-chemical techniques based mostly on the estimations of managers and practitioners.

Differing Chemical and Non-chemical Alternative Costs

As a result of this “Type A” analyses, it has been shown that a variety of non chemical and chemical alternatives are possible as cost effective methods for the treatment of an aquatic plant problem. For chemical management techniques, it is shown that the control costs per surface acre are very high for a low acreage area and decrease with increasing area. This trend can be attributed to the concept that set-up and NPDES permitting costs are incurred for any pesticide application that occurs, regardless of water body type or size. These fixed costs become distributed as the area of treatment increases, thus making chemical treatment more economically feasible for a large water body with a critical aquatic plant infestation. For non-chemical techniques, the rates of control cost per area are fairly constant for both small and large acreage, as there are no permitting or monitoring costs that are required for using these techniques. Total non-chemical control costs increase substantially with increased acreage.

Of the four management scenarios evaluated in detail, chemical control was determined to be most cost effective for two, non-chemical control (mowing) for one, and combined methods (chemical treatment plus harvesting) for one. The most cost effective management technique for the Kern NWR is mowing, given that no more than four mowing events per season occur. The most cost effective management technique for Big Bear Lake is the application of Sonar (Fluridone) and some harvesting. The most cost effective method for control of Water Hyacinth at Stone Lakes National Wildlife Refuge is application of chemicals. For Big Break, costs of chemical application for aquatic plant control is high, but harvesting is not a technically viable option at this site, and the total costs of hand removal are currently unknown.

A further investigation of the breakdown of non-chemical control costs is necessary to get a better understanding of how these rates differ with different acreage. The current limitation to acquiring this type of knowledge is based on the fact that most of the managers contacted were aware of the total amount spent for the technique used over a certain area with little or no record of different component costs.

Environmental Conditions

One consideration which may render aspects of the Type A analysis ineffectual as a predictor of future control costs given a particular technique is that of varied environmental conditions in any given season. Yearly fluctuations in temperature, precipitation and available have significant effects on the amount of growth and ease of control during the control season.

For example, Gene Martin, Manager at the Big Bear Municipal Water District, has stated that as a result of this year's particularly low water levels, the control of Eurasian water milfoil has been more effective regarding both time and cost because of the exposure of the plant in the absence of the usual submersion. During wetter years, this lowered water level is not available and therefore management costs will increase. In addition, the control season begins in Big Bear when temperatures reach 55 degrees and subsequently, plants begin to grow. This can alter the duration of the control season, and thus costs, significantly.

Another example of the environmental limitations of control cost considerations is apparent in the Kern NWR example. The most cost effective alternative selected was mowing, given that there are no greater than 4 mowing events per season on the wetland. Dave Hardt said that this year's plant problem has been especially bad due to the warm temperatures and wet conditions, creating a significant overgrowth that has not been easily controlled with the status quo management techniques. Should environmental conditions continue to be advantageous for the growth of bulrush and cattail on the management units, costs will likely increase and the mowing alternative would no longer be the optimal method for control. In addition, Mr. Hardt commented that the acquisition of an additional 1100 acres of moist soil wetlands will be added in the future, which will most likely increase the rates of control. He states that he will have to "…wait and see what kind of vegetative response [there is] before making any firm plans".

To summarize, the cost of a management technique can vary drastically depending on the amount of growth that occurs during any particular season, which is usually due to uncontrollable factors such as temperature, amount of precipitation or water levels in a particular water body/region.

The Grass Carp Issue

The grass carp (*Ctenopharyngodon idella*) feeds on aquatic plants and can be used as a biological tool to control nuisance aquatic plant growth. Once grass carp are stocked in a water body, it may take from two to five years for them to control the plant growth and decrease weeds to about 20% of the earlier plant cover (Washington State Department of Ecology, 2001).

Success with grass carp may vary from site to site. Sometimes identical stocking rates result in no control, control, or even complete elimination of all underwater plants. They should be stocked only in water bodies where complete elimination of all submersed plant species can be tolerated. Furthermore, due to the risk of adverse impacts on adjacent water bodies, stocked water bodies should be isolated or have screened inlets and outlets (Washington State Department of Ecology, 2001). Currently California Department of Fish and Game will allow grass carp to be used only in water bodies that can be completely isolated from and are outside of the 100-year floodplain.

It is difficult to estimate the exact cost per surface acre of control using the sterile grass carp method as the managers surveyed were unaware of the optimal number of fish to use for their area of concern. One study stocks fish ranging in weight between 350 and 550 grams at a rate of 357 fish per hectare to control various species of aquatic plants in different seasons in static and flowing canals (Pine et. al., 1989). Another study (Pine et. al., 1990) discusses the effect of size on the control of aquatic plants. The costs and permitting fees associated with the use of grass carp in California are relatively consistent among practitioners with a price of approximately $5-$10/fish with a $7.50/fish annual fee paid to the Department of Fish and Game. The difficulty arises where the carp are applied to a water body and managers cannot keep track of how many are still living and eating the target pest species. In this respect, it is difficult to assess how many fish per acre are necessary for control, thus effecting control costs. One manager surveyed installed 300 fish one year and 100 the following year with little or no knowledge of how many he will apply going forward. Another manager surveyed suggested just "…putting in 100 fish each year…" (Paul Saunders, personal communication 8/03). Further analysis of the optimal number of fish required per surface acre would improve the actual control costs necessary for the grass carp management alternative.

Acknowledgements

Many thanks to the managers and practitioners that took the time to speak with me about their management techniques and various costs and issues involved. Of particular help were Dave Hardt, Manager Kern National Wildlife Refuge and Gene Martin, Manager Big Bear Municipal Water District, Dave Omoto of the Contra Costa Irrigation District, Cynthia Gause and Marcia Caslock from the California Department of Boating and Waterways, Tom Harvey and Clay Courtwright from the Stone Lakes National Wildlife Refuge. In addition, thanks to Ben Greenfield, Roger Mann, and Karyn Moskowitz for their help and comments on the writing of this report.

References

Mann, Roger. 2003. “Methodology for aquatic plant management economics.” Third Draft prepared 3/01/03.

McNabb, Terry and Doug Henderson. 2001. “Vegetation Assessment and Management Plan for Big Bear Lake (San Bernardino County, California)”. ReMetrix report prepared for Big Bear Municipal Water District.

Pine, R.T., Lars W. Anderson, and Silas S.O. Hung, 1989. Effects of static versus flowing canal systems on aquatic plant preferences of triploid grass carp. Trans. Am. Fish Soc. 118:336-344.

Pine, R.T., L.W.Anderson, and S.O. Hung, 1990. Control of Aquatic Plants in Static and Flowing Water by Yearling Triploid Grass Carp. Journal of Aquatic Plant Management. 28: 36-40.

Washington State Department of Ecology. 2001. Final Supplemental Environmental Impact Statement for Freshwater Aquatic Plant Management. Publication Number 00-10-040.

Appendices.

Appendix A. Price Indices

	GDP Deflator	Consumer Price Index
1980	53.19	47.84
1981	58.15	52.81
1982	61.75	56.05
1983	64.20	57.85
1984	66.58	60.34
1985	68.72	62.46
1986	70.25	63.67
1987	72.39	66.01
1988	74.86	68.67
1989	77.73	71.99
1990	80.76	75.88
1991	83.71	79.09
1992	85.75	81.49
1993	87.80	83.89
1994	89.62	86.07
1995	91.57	88.50
1996	93.36	91.10
1997	95.19	93.22
1998	96.39	94.65
1999	97.84	96.75
2000	100.00	100.00
2001	102.14	102.85
2002	104.56	105.01
2003	105.81	107.53

Appendix B. Aquatic Plant Management Economics Data. Control and Management Costs from Literature

Herbicides

Source (full citation below)	Year of Cost, if different	Location	Size	Type of Practice/Information Provided	Quantitative Information
Taylor and Gately, 1998		Lake Leland, WA	100 acres	Fluridone	$1,000 to $1,100. Budget of $116,000 for Sonar treatment included five treatments and samplings, permitting, public notification, bathymetric mapping, and volume calculations.
				Glyphosate	$300 per acre
				Endothall	$700 per acre
				Glyphosate, for 2000 feet of stream	$800 to $3,200
Gibbons et al, 1994		Washington		Sonar® (Fluridone)	$900 to $1,000 per acre
				Rodeo® (glyphosphate)	$250 per acre
				Endothall	$300 to $400 per acre
				Navigate (2-4,D)	$300 to $400 per acre
Lake County Water Resources Div., 1999				Copper	$65 per acre
Lembi, 2002				2,4-D for water hyacinth	$65 per acre
				Granular 2,4-D for Eurasian watermilfoil	$319 per acre
AEI, 2003	2003	Lake Van Ness	28 acres	Copper, for algae blooms	About $100 per acre, 4 times per year
Jaggers, 1995?	1986-1993	Lake John, FL	2,418 acres, 201 treated	Fluridone, $1,000/3.8 L, 201 acres (8.3%) each treatment, 1.9 L per acre treated	$500 per treated acre every 3 years, $167/ac/yr

					Total lake cost of $31,400 per year average
Shireman, Colle and Canfeld, 1986	1980-1983	Ponds, FL	0.5 acres	Diquat, granular 2 4D, Dichlobenil, glyphosate, chelated copper	$169 to $542 per acre per year
				Range represents three ponds	
				Cost/harvestable bluegill (>15 cm) or bass (>25 cm)	$2.89 to $11.20/fish or $8.26 to $21.93 per lb of fish
Sassic, 1982	1982	Florida	Many		$150 to $300 per acre per year
Seagrave, 1988		England		Assumed 1.5 $ per English pound	
				Still water	$300/ac/yr
				Drainage channels	$315/ac/yr

Grass Carp

Source (full citation below)	Year of Cost	Location	Acres	Type of Practice/Information Provided	Quantitative Information
Gibbons et al, 1994		Washington		Stocking rates, costs	10 to 25 fish per acre
					For 10,000 or more, $5.00 per fish
					For small air freight delivery, $10 to $20/fish
Taylor and Gately, 1998		Lake Leland, WA	100 acres	Stocking rates, costs, screening costs	10 to 25 fish per vegetated acre, 5 to 10 acres
					$10 per fish
					$39,300 to install a drum screen at the existing fish weir
AEI, 2003		Lake Van Ness	28 acres		$15 to $35 per fish
Jaggers, 1995?	1986-1993	Lake John	2,418 acres	Integrated system, carp and contact herbicide	$10,085 per year average cost
Shireman, Colle and Canfeld, 1986	1980-1983	Ponds, FL	0.5 acres	Range represents three ponds	$64 to $100 per acre per year
				Cost/harvestable bluegill (>15 cm) or bass (>25 cm)	$0.58/fish or $2.24 per lb of fish
Wattendorf and Phillippy, undated	1993-1994	Florida	"typical site"		A typical site was 10 acres and 50 carp
					Public permitting costs were about $4.00 per fish
Stocker, undated	1992	Imperial Co	irrigation canal	Fish only cost for a "small program" on heavily infested canals. 200 fish per mile, restock 10%/yr	$268 per mile of canal per year over 10 years
	1994			Additional cost for biologist	$25,000 to $40,000
				Additional screening costs	"several hundred dollars to several hundred thousand dollars"
Seagrave, 1988		England		Assumed 1.5 $ per English pound	
				Still water, cost at 222 lb per acre	$225/ac/yr (average over 4 years)

Mechanical Methods: Practices for Large Areas

Source (full citation below)	Year of Cost	Location	Acres	Type of Practice/Information Provided	Quantitative Information
Taylor and Gately, 1998		Lake Leland, WA	100	For mechanical harvesting	$750.00 per acre on non-prevailing wage rate projects
					$1000.00 per hour if prevailing wage is required.(per acre?)
Gibbons et al, 1994		Washington		For mechanical harvesting	Cost of equipment is $35,000 - $110,000, plus O&M
					Cost per acre is $500 - $800 not including mobilization
					Costs as low as $250 per acre have been reported.
AEI, 2003		Lake Van Ness	28 acres	Mechanical harvest, H-7 420 harvester	$650 to $1,000 per day, 2 to 3 acres per day
					Infer: $216 to $500 per acre
Hinkle, 2002	1977	Orange Lake, FL	163 acres harvested	Harvesting hydrilla	$495/acre/yr
				"Average costs in southern waters"	$405/acre/year
Sassic, 1982		East Co Water Control District, FL			$75/acre/yr
Taylor and Gately, 1998		Lake Leland, WA	100	Rotovation	$1,200 to $1,700 per acre, plus disposal
Gibbons et al, 1994		Washington		Rotovation	$1,500 to $2,000 per acre for a private contractor includes harvest, remove obstacles, rototill, and collect and disposal.
Hinkle, 2002		Orange Lake, FL		Rotovator on lakebed to eliminate floating islands, John Deer 5410, Howard HR 20 rotovator	23 acres, 20 hours, $104/acre

		Mowing, 6 ft mower, John Deer 5410	50 acres, 30 hours, $45/acre
Gibbons et al, 1994	Washington	Mechanical cutting	Portable boat-mounted unit costs $400 to $3,000 Specialized underwater cutters cost $11,000 The Swordfish battery operated cutter retails for $1,995

Mechanical Methods: Practices for Small Areas and Flowing Waters

Source (full citation below)	Year of Cost	Location	Acres	Type of Practice/Information Provided	Quantitative Information
Taylor and Gately, 1998		Lake Leland, WA	100	Hand cutting	$100 for Aquatic Weed Cutter
					$1,500 for mechanized underwater mower
Gibbons et al, 1994		Washington		Hand cutting	Commercial weed cutter costs about $130 with accessories.
					A commercial rake costs about $95 to $125
Gibbons et al, 1994		Washington		Weed roller	Cost about $2,000, minimal O&M
					Infer: for 30 ft roller, initial cost about $1 per sq ft. $\$2000/(3.14x30^2)*.75$
Taylor and Gately, 1998		Lake Leland, WA	100	Suction dredge	$1,100 to $2,000 per day, 1/4 to 1 acre per day
					Infer: $1,100 to $8,000 per acre
Gibbons et al, 1994		Washington		Suction dredge	$1,500 to $2,000 per day.
Taylor and Gately, 1998		Lake Leland, WA	100	Bottom barriers, burlap	$0.15 to $0.25 material cost per square ft
					$0.25 to $0.50 per sq. ft. for installation
				Bottom barriers, synthetic, 300' bv 12' or 15'	$0.07 to $0.10 material cost per sq ft
				Bottom barriers, tarp	$0.08 to $0.10 material cost per sq ft
Gibbons et al, 1994		Washington		Bottom barriers	$0.22 to $1.25 per square foot. Cost of commercial barriers may include installation fee
					$750 to have 1,000 sq, ft. of screen installed.
					Maintenance costs for a waterfront lot are about $120 each year

Taylor and Gately, 1998		Lake Leland, WA	100	Hand pulling	$500 to $2,400 per day
Gibbons et al, 1994		Washington		Hand pulling	$130 for average waterfront lot for a hired commercial puller.
Shireman, Colle and Canfeld, 1986	1980-1983	Ponds, FL	0.5 acres	Harvesting cost	$800 per acre per year
				Cost/harvestable bluegill (>15 cm) or bass (>25 cm)	$11.52/fish or $37.33 per lb of fish
Kellet, Troy. 2003		Richvale ID	Irrigation ditch	Clearing ditches, mechanical excavator	One mile per day, $75 per hour
					Once every 1 to 3 years
					Infer: $600 per mile, $200 to $600/mile/yr
Stocker, undated.	1992	Imperial Co	Irrigation canal	Anchor chain dragged along bottom, or disking	$60 to $100 per mile
				Hydraulic excavation	$600 to $1000 per mile
Seagrave, 1988		England	Drainage channels	Assumed 1.5 $ per English pound	
				Drainage channels, machine-mounted buckets	$1,214/ac/yr
				Drainage channels, weed cutting boats	$480/ac/yr

Other Biological Controls

Source (full citation below)	Location	Size	Type of Practice/Information Provided	Quantitative Information
AEI, 2003	Lake Van Ness	28 acres	bacterial	$12,000 to $24,000 per year on 28 acres Infer: $430 to $860 per acre
Harris, 1979	Canada		Costs in scientist-years for weed control	About 20 years per nuisance weed species
Madden, 1997			Table of biological management methods for control Advantages, disadvantages, systems where used	
Gibbons et al, 1994				Insects can sell for $1.00 or more per insect.

Appendix C. APMP Survey Questionnaire: Type A Analysis

Date:
Applicator Entity:
Contact Person:
Phone Number:

In conjunction with Geoff Siemering and Ben Greenfield at the San Francisco Estuary Institute, I am a UCSB graduate student conducting a research project to evaluate the cost effectiveness of various aquatic plant management control strategies as a part of a master's thesis project. We will compile a detailed analysis of control strategies across a range of water bodies and aquatic pests.

Since there have been few comprehensive studies, this survey is intended to capture a better understanding of how costs vary across different control strategies. It will serve as a framework to compile a guide for all water body managers so that they may use it as a management tool when deciding which pesticide or mechanical control method results in the greatest cost savings. As a result of your participation in this survey, we could present you a summary of our findings by March 2004.

We are calling based on the recommendation of ________________________ or from the listing of NPDES permit applicants. This call is a follow up to the letter we sent you on ____________. I was wondering if it would be possible to obtain information from you on the different costs involved in conducting distinct aquatic plant control methods.

How much time do you have for the survey?

Location Specific Details

1. Water body characterization – depth, size, and use classification:

2. What are your targeted pests, excluding algae? What are your normal pest management seasons? (Start and end month)

3. What are your control methods? Chemical, non-chemical, both? Do methods vary from year to year? If so, what does the variability depend on?

If Chemical Proceed as Follows

1. What is the size of the area where you will be applying pesticides this season?

2. Which pesticides will you apply?

3. What is the estimated amount? How often? (Find a rate: specifically area treated/gallon or hour, etc.) Are these pesticides different from last season?

4. What equipment and materials are used for the application? Is it owned or rented? If rented, how much are rental costs?

5. Do you hire laborers to apply the pesticides? How much does this cost? How many hours do they work? How frequently?

6. For water bodies designated for recreational use, is the water body closed after application or does it require a recovery period before recreation can resume?

7. Is water quality sampling included in your chemical control method? If so, what type of sampling? What are the costs of this sampling? How often do they occur throughout the season?

8. What type of surfactants do you use, if any? (Not Applicable for Fluridone, Acrolein, or Copper) What is the cost of the surfactant? How often? On what sized area?

For Non Chemical Control proceed as follows

1. Which method do you employ?

2. **For Grass Carp/Biological Users:** How much did your permit cost? How much does each fish cost? Set up costs? (Filters, barriers to escape) Maintenance costs?

3. What is the size of the area that you apply this method to?

4. **For mechanical/manual harvesting:** Are there any purchase or rental costs that are associated with related tools/machines that apply? Are there any typical maintenance costs associated with these tools?

5. Do you hire anybody to carry out this task? Are there any set up costs? Base costs? Overhead? How many labor hours does it require?

6. How long is a typical treatment period? How frequently are the treatments applied?

7. Are there other major operational or material costs associated with your method (gas, electricity, etc.)?

8. What is your method and cost of weed disposal? (Hauling, labor, drying, incineration…)

For Algae control proceed

1. Are algae a management concern in your water body? Do you monitor for algae problems? If so,

a) How?

b) How often?

c) What are costs associated with this monitoring? Have you hired anyone to assess algae?

2. Do you use chemical control methods such as copper sulfate (bluestone) or Cutrine-Plus to control any algae problem you may have? If so,

   a) Do you have any permitting costs?

   b) What are your application rates?

   c) How is it applied?

   d) How often must you apply chemicals during the season?

   e) What are your costs of application? Cost of chemical? Labor?

3. If chemical methods are not used, why not? What other strategies do you consider?

4. Do you use any non-chemical methods to control algae, such as aeration, barley straw, bacteria addition, nutrient limitation, application, gypsum, or any other techniques?

   a) What are the costs of control?

   b) How often must you apply or use these techniques in a season?

5. Could you recommend any other practitioners that would be willing to participate in this survey?

Appendix D. APMP Survey Letter to Practitioners

San Francisco Estuary Institute

7770 Pardee Lane, 2nd Floor
Oakland, CA 94621-1424
Office (510) 746-SFEI (7334)
Fax (510) 746-7300

March 15, 2004

Dear Ms. Practitioner:

I am a graduate student from University of California, Santa Barbara working with Geoff Siemering and Ben Greenfield of the Aquatic Pesticide Monitoring Program (APMP). We are carrying out an investigation of the respective costs and effectiveness of various aquatic management control strategies. One of the objectives of the APMP is to gather information related to non-chemical alternatives for chemical aquatic plant management.

To date, there have been few comprehensive studies related to this issue. Many practitioners have indicated a need for thorough determination of cost effectiveness where this information is not available. This survey is intended to capture a better understanding of how costs vary across different control strategies. It will lead to a guide for water body managers to help decide which pesticide or mechanical control method is most cost effective. In addition, we will compile a detailed analysis of control strategies across a range of water bodies and aquatic pests.

Ben Greenfield has provided us with your contact information and has indicated that you would be willing to provide our group with cost effectiveness information in order to help understand the effectiveness of different control strategies. The requested data will not be used for site-specific evaluations, but your organization would be formally recognized in our final report, unless you wish otherwise. We will honor any other requests you may have regarding the use of sensitive cost information. We would present you a summary of our findings by March 2004.

Unless I hear from you first, I will contact you by phone or email during the first week of _____, to set up a phone discussion with you. Please do not hesitate to contact me if you have any questions. Thank you for considering this data request.

Sincerely,

Marion Wittmann
Master's Student of Environmental Science and Management
(510) 746-7341

Appendix E. Aquatic Pest Control Data Collected From California Practitioners

Please contact the author for the latest version of the Excel file.

Appendix F. Entry Tables For Kern NWR Analysis

Entry Table 1. Define the Aquatic Plant Problem.
Name of Water Body: **Kern NWR**
1a. Location: **Kern National Wildlife Refuge (KNWR) is located 18 miles west of the city of Delano at the southern end of the San Joaquin Valley of California.**
1b. Water Body Type (identify and describe at least 1)
Small pond
Large lake
Delta
Irrigation canal
Stormwater
EstuarineWetlands: **7000 acres of Seasonal Wetlands**, **also, 2400 acres of "Management Units": shallow, flooded plains, 2-6 inches deep, units irrigated in Spring/Summer. Current concern is the management of 800 acres of marshland unleveled units. Will begin to manage an additional 1100 acres of moist soil wetlands next fall.**
Wildlife Refuges **The 10,618-acre Kern refuge consists of natural valley grasslands, a relict riparian corridor, and developed marsh**
1c. Aquatic Plant Type (identify and describe at least 1)
Floating
Submerged
Emergent **Alkalai Bulrush (*Scirpus maritimus*), Cattail (*Typha latifolia*)**
Algae
1d. Potential Economic Costs (identify and describe at least 1) **KNWR provides wintering habitat for migrating birds, shorebirds, marsh and waterfowl in the southern San Joaquin Valley. The refuge also provides habitat for upland species. Overgrowth of the bulrush and cattail cause "crowding" problems in the wetland areas. There are also hunting opportunities for waterfowl that are jointly managed by refuge staff and the California Dept. of Fish and Game that could be affected by general overgrowth problems.**
History of Control costs, or Control Expected: **Many different kinds of control methods have been used, including mowing, plowing, disking, floating, herbicide application—still trying to determine most effective method.** **The have switched to more extensive use of mechanical control because exclusive**

chemical control has been too expensive at this site. In some cases, chemical control wasn't effective at label recommended concentrations. Also, most applicators don't have aircraft permitting for herbicide application to USFWS refuges. **David Hardt (Kern NWR Manager) described extensive mechanical control for salt cedar, bulrush and cattail. They have had mixed results with integrated approaches on cattail control. They have combined aerial fly-over applications of Rodeo or AquaMaster with wetland draining, followed by mowing and disking. The most effective control occurs after the area is left dry for 3 months which isn't feasible because of the need to maintain sufficient waterfowl habitat. The also found that plowing followed by drying is more effective than disking. They are currently using disking on the main unit just to maintain lower biomass ("mowing the lawn"). It is not possible to keep the main unit dry for more than 3.4 weeks because some sensitive bird species need the wetlands.** **They have a number of different treatments that have already been conducted. These include areas mowed and disked but not sprayed, areas sprayed two years ago, and areas not treated at all.**
Types of Damage Costs
Contributes to flooding/drainage/storm water problems
Water supply quantity
Water supply quality
Impedes navigation
Impedes/limits recreation/parks values
Reduces aesthetic/environmental values **The refuge values the wetland "management units" as habitat for sensitive species; the overgrowth of pest plant species impedes these units as effective areas for fowl.**
1e. Management Objective **To control, not necessarily eliminate, target pests—there is value in keeping some of the plants around as habitat for sensitive bird species and other animals in the refuge**
1f. Stakeholders **Users of Kern NWR, ecosystem participants**

Entry Table 3. Number 1 **Costs of a Management Practice.** **For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.**		
Management Alternative Names: Mowing, Discing, Floating, Plowing		
Name of Practice: Aerial Application of AquaMaster		
General description of Practice	**Spray herbicide, AquaMaster, over open water and seasonal wetland**	
When during the season will practice be applied?	**During the management period late spring/early summer**	
Where within the location this practice is to be applied?	**800 acres of open water, wetland area**	
How much will be applied?	**Once per 5 years**	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	Dollars/years	$38,296/0.2
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	280
Helicopter Time	$/acre	$13.40
AquaMaster	$/acre	$30.00
Surfactant	$/acre	$0.90
Load Mgt. Staff	$/acre	$1.00
Planning/Permits	$/acre	$2.57
Total Estimated Cost	**Average, Dollars/acre**	**$47.87/acre**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 2 **Costs of a Management Practice.** **For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.**		
Management Alternative Names: Mowing, Discing, Floating, Plowing		
Name of Practice: Aerial Application of AquaMaster and One Mowing		
General description of Practice	**Spray herbicide, AquaMaster, over open water and seasonal wetland and mow once per season**	
When during the season will practice be applied?	**During the management period late spring/early summer**	
Where within the location this practice is to be applied?	**800 acres of open water, wetland area**	
How much will be applied?	**AquaMaster once per 5 years, Mowing each year**	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known		
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	280
Helicopter Time	$/acre	$13.40
AquaMaster	$/acre	$30.00
Surfactant	$/acre	$0.90
Load Mgt. Staff	$/acre	$1.00
Planning/Permits	$/acre	$2.57
Mowing	$/acre	$6.79/acre
Total Estimated Cost	**Average, Dollars/acre**	**$54.66/acre**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 3 **Costs of a Management Practice.** **For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.**		
Management Alternative Names: AquaMaster, Discing, Floating, Plowing		
Name of Practice: Mowing		
General description of Practice	**Mowing over seasonal wetland area to control bulrush, cattail**	
When during the season will practice be applied?	**During the management season, April-September**	
Where within the location this practice is to be applied?	**800 acres of seasonal wetland area**	
How much will be applied?	**Four applications per season**	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	Dollars/year	$21,728
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	700
Labor	$/acre	$5.52
Fuel	$/acre	$1.02
Equipment Service	$/acre	$0.25
Total cost per unit	**$/acre**	**$6.79**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 4 Costs of a Management Practice. For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.		
Management Alternative Names: AquaMaster, Discing, Floating, Plowing		
Name of Practice: Combined Mowing, Discing and Floating		
General description of Practice	**Mowing, Discing and Floating only**	
When during the season will practice be applied?	**During the management period late spring/early summer**	
Where within the location this practice is to be applied?	**800 acres of seasonal wetland area**	
How much will be applied?	**Twice per season**	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	**Dollars/year**	**$38,224**
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	150
Mowing	$/acre	$6.79
Labor to Disc	$/acre	$3.07
Fuel	$/acre	$0.57
Equipment Service	$/acre	$0.13
(Discing Subtotal x 2 passes)	$/acre	$7.54
Floating (leveling)	$/acre	$9.56
Total cost per unit	**$/acre**	**$23.89**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 5 Costs of a Management Practice. For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.		
Management Alternative Names: AquaMaster, Mowing, Discing, Floating, Plowing		
Name of Practice: Combined Mowing, Discing, Floating, and Plowing		
General description of Practice	**Mowing, discing, floating and plowing over seasonal wetland management units**	
When during the season will practice be applied?	**During the management period late spring/early summer**	
Where within the location this practice is to be applied?	**800 acres of seasonal wetland area**	
How much will be applied?	**Once per season**	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	Dollars/year	**$24,448**
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	100
Mowing	$/acre	$6.79
Plowing	$/acre	$6.67
Discing 2 Passes	$/acre	$7.54
Floating	$/acre	$9.56
Total cost per unit	**$/acre**	**$30.56**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 6.
Costs of Management Practices by Year for a Management Alternative

Management Alternative: Aerial Application of AquaMaster

Year	Source of Data (Tables, number)	Quantified Control Costs, Damage Costs, and Environmental Costs, In 2003 Dollars — Name of Control Cost, Damage Cost, or Environmental Cost: **AquaMaster**						Total Cost of Alter-native by Year
1		$38,296						$38,296
2		0						0
3		0						0
4		0						0
5		0						0
6		$38,296						$38,296
7		0						0
8		0						0
9		0						0
10		0						0
11		$38,296						$38,296
12		0						0
13		0						0
14		0						0
15		0						0
16		$38,296						$38,296
17		0						0
18		0						0
19		0						0
Etc		0						0
Last Yr		$38,296						$38,296
NPV(.05, Yr1..,Yr50), 1000 $								**$153.79**
-PMT(.05,Last Yr.,NPV), 1000 $								**$8.42**

Entry Table 6. **Costs of Management Practices by Year for a Management Alternative**								
Management Alternative: Aerial Application of AquaMaster and Mowing								
		Quantified Control Costs, Damage Costs, and Environmental Costs, In 2003 Dollars						
Year	Source of Data (Tables, number)	Name of Control Cost, Damage Cost, or Environmental Cost						Total Cost of Alter-native by Year
		AquaMaster and Mowing						
1		$43,728						$43,728
2		$5,432						$5,432
3		$5,432						$5,432
4		$5,432						$5,432
5		$5,432						$5,432
6		$43,728						$43,728
7		$5,432						$5,432
8		$5,432						$5,432
9		$5,432						$5,432
10		$5,432						$5,432
11		$43,728						$43,728
12		$5,432						$5,432
13		$5,432						$5,432
14		$5,432						$5,432
15		$5,432						$5,432
16		$43,728						$43,728
17		$5,432						$5,432
18		$5,432						$5,432
19		$5,432						$5,432
Etc		$5,432						$5,432
Last Yr		$43,728						$43,728
NPV(.05, Yr1..,Yr50), 1000 $								**$252.96**
-PMT(.05,Last Yr.,NPV), 1000 $								**$13.86**

Entry Table 6.
Costs of Management Practices by Year for a Management Alternative

Management Alternative: Mowing

		Quantified Control Costs, Damage Costs, and Environmental Costs, In 2003 Dollars						
		Name of Control Cost, Damage Cost, or Environmental Cost						Total Cost of Alter-native by Year
Year	Source of Data (Tables, number)	**Mowing (4 times)**						
1		$21,728						$21,728
2		$21,728						$21,728
3		$21,728						$21,728
4		$21,728						$21,728
5		$21,728						$21,728
6		$21,728						$21,728
7		$21,728						$21,728
8		$21,728						$21,728
9		$21,728						$21,728
10		$21,728						$21,728
11		$21,728						$21,728
12		$21,728						$21,728
13		$21,728						$21,728
14		$21,728						$21,728
15		$21,728						$21,728
16		$21,728						$21,728
17		$21,728						$21,728
18		$21,728						$21,728
19		$21,728						$21,728
Etc		$21,728						$21,728
Last Yr		$21,728						$21,728
NPV(.05, Yr1..,Yr20), 1000 $								**$396.66**
-PMT(.05,Last Yr.,NPV), 1000 $								**$21.73**

Entry Table 6. Costs of Management Practices by Year for a Management Alternative								
Management Alternative: Mowing, Discing and Floating								
		Quantified Control Costs, Damage Costs, and Environmental Costs, In 2003 Dollars						
Year	Source of Data (Tables, number)	Name of Control Cost, Damage Cost, or Environmental Cost						Total Cost of Alter-native by Year
		Mowing, Discing and Floating						
1		$38,224						$38,224
2		$38,224						$38,224
3		$38,224						$38,224
4		$38,224						$38,224
5		$38,224						$38,224
6		$38,224						$38,224
7		$38,224						$38,224
8		$38,224						$38,224
9		$38,224						$38,224
10		$38,224						$38,224
11		$38,224						$38,224
12		$38,224						$38,224
13		$38,224						$38,224
14		$38,224						$38,224
15		$38,224						$38,224
16		$38,224						$38,224
17		$38,224						$38,224
18		$38,224						$38,224
19		$38,224						$38,224
Etc		$38,224						$38,224
Last Yr		$38,224						$38,224
NPV(.05, Yr1..,Yr20), 1000 $								**$697.81**
-PMT(.05,Last Yr.,NPV), 1000 $								**$38.22**

Entry Table 6.
Costs of Management Practices by Year for a Management Alternative

Management Alternative: Combined Mowing, Discing, Floating and Plowing

		Quantified Control Costs, Damage Costs, and Environmental Costs, In 2003 Dollars						
Year	Source of Data (Tables, number)	Name of Control Cost, Damage Cost, or Environmental Cost						Total Cost of Alter-native by Year
		Mowing, Discing, Floating, Plowing						
1		$24,448						$24,448
2		$24,448						$24,448
3		$24,448						$24,448
4		$24,448						$24,448
5		$24,448						$24,448
6		$24,448						$24,448
7		$24,448						$24,448
8		$24,448						$24,448
9		$24,448						$24,448
10		$24,448						$24,448
11		$24,448						$24,448
12		$24,448						$24,448
13		$24,448						$24,448
14		$24,448						$24,448
15		$24,448						$24,448
16		$24,448						$24,448
17		$24,448						$24,448
18		$24,448						$24,448
19		$24,448						$24,448
Etc		$24,448						$24,448
Last Yr		$24,448						$24,448
NPV(.05, Yr1..,Yr20), 1000 $								**$446.32**
-PMT(.05,Last Yr.,NPV), 1000 $								**$24.45**

Appendix G. Entry Tables For Big Bear Lake Analysis

Entry Table 1. Define the Aquatic Plant Problem.
Name of Water Body: **Big Bear Lake**
1a. Location: **Big Bear Lake is located in Southern California between the San Bernardino Mountains**
1b. Water Body Type (identify and describe at least 1)
Small pond
Large lake **Big Bear Lake is eight miles long and approximately one mile across at its widest point. It has about 23 miles of shoreline and is located at an elevation of 6,743.2 feet. The present dam, built in 1912, replaced the original dam, which was built in 1884. The new dam impounds more than 73,000 acre-feet of water with a height of 72'4". The Lake is not a source of water for the local water supply. The only water taken locally is by the two ski resorts for making artificial snow. They may each purchase up to 500-acre ft. per ski season. The Municipal Water District manages the lake. Private homes, several marinas, public parks and some hotels and lodges surround the south side of the lake.**
Delta
Irrigation canal
Stormwater
EstuarineWetlands:
Wildlife Refuges
1c. Aquatic Plant Type (identify and describe at least 1) **Eight types of aquatic plants have been identified in Big Bear Lake, of which coontail and milfoil are the most abundant and the most troublesome to navigation, fishing and aesthetics. District records indicate that of the weeds harvested, 73% is coontail, 20% is milfoil and the remaining 7% is a combination of other types.**
Floating **Smartweed (*Polygonum hydropiperoides Michx)***
Submerged **Coontail (*Ceratophyllum demursum*), Eurasian Water Milfoil (*Myriophyllum spicatum*), Curly leaf pondweed (*Potamogenton crispus*), American Elodea (*Elodea canadensis*) Sago pondweed (*Potamogenton pectinafus*), Leafy-pondweed (*Potamogenton foliosus*), Widgeon Grass (*Ruppia maritime*), Spikerush (*Eleocharis spp.*)**
Emergent
Algae **Planktonic Algae, common genera: Anabaena, Chlorella, Pediastrum, Scenedesmus, Oocystis; Filamentous Algae, common genera: Spirogyra, Cladophora, Rhizoclonium, Mougeotia, Zygnema and Hydrodictyon; Toxic Algae; Blue Green Algae (*Lyngbya spp.*)**
1d. Potential Economic Costs (identify and describe at least 1) **The lake is widely used as a recreational area supporting boating, fishing and other recreational activities.**

The overgrowth of aquatic plants inhibits the facilitation of access to the lake. Eight types of aquatic plants have been identified in Big Bear Lake, of which coontail and milfoil are the most abundant and the most troublesome to navigation, fishing and aesthetics. District records indicate that of the weeds harvested, 73% is coontail, 20% is milfoil and the remaining 7% is a combination of other types.
History of Control costs, or Control Expected: **Big Bear Municipal Water District operates three aquatic weed harvesters and one Aquamog on the Lake for the purpose of removing weeds, primarily from around docks and major boating areas. Approximately 86% of the weed cutting occurs around private docks, with the remaining 14% occurring in areas where improved public access is needed or navigational hazards must be removed. The harvesting program currently removes about one-thousand tons of weeds from the Lake annually. Some chemical weed treatment has been performed in the past; however the method of mechanical harvesting has been determined to have less adverse impacts and is now the preferred method used by District Staff. Occasionally, when the situation demands, chemicals are used to treat excessive algae blooms.** **The Aquamog, a 10' wide barge with a cab for the operator, is paddle wheel driven, 35' in length and has an excavator arm which accepts a number of different attachments. The attachment used for this program is the tiller which is similar to the rototiller used in the garden, except on a larger scale. It is 10' wide and weighs about 2,000 pounds. It has 4 rows of spring steel tines that are off-set to get maximum digging on the bottom of the Lake to dislodge the aquatic plants. Each dock area takes about 30 minutes to complete and one lap around the Lake is completed each spring.** **The Aquamog program is geared to remove the rooted weeds around residential docks to improve recreational access during the summer season. The District sends letters in the fall to each residential dock owner to advise them of the Aquamog program and schedule, and to recommend that they move their dock at least 50' off the shore or to a marina for storage. The Aquamog program begins on April 1 and continues until the water temperatures reach an average of 55 degrees, as determined by readings taken at a depth of two-feet of water at ten locations around the Lake.** **In the summer of 1996, the District completed an experimental application in Grout Bay of a product called Sonar. After many weeks of studying case histories regarding the use of Sonar and actually visiting sites where Sonar had been used, the District determined that a test in Big Bear Lake was the appropriate first step in analyzing Sonar's potential. Grout Bay, on the north shore of the Lake, was selected as the test area as it is protected from the wind and also from weed harvesting operations. This 35 acre area was initially treated during the first week of August 1996, with additional applications approximately every three weeks throughout the remainder of the summer. District Staff monitored the test area following the applications and concluded that the product results were unsatisfactory. Upon further evaluation, it was determined that the applications occurred too late in the growing season to achieve maximum results. A second**

series of applications took place in 1998 in the same area of the Lake. The cost for these treatments was approximately $1,000 per acre and the result was nearly three years of weed-free access in Grout Bay. Based on these results, the District developed a plan to treat specific areas of the Lake again in 2000. **In December of 2001, the District decided to move forward in the spring of 2002 with an aggressive program for herbicide treatments. Following three dry years with less than normal inflow to the Lake, and a Lake that was 9'6" below full, it was determined that applications in the east end of the Lake, in Boulder Bay and in the Mallard Lagoon/Canvasback Cove areas could achieve many years of relief from the infestation of Eurasian water milfoil. A consultant was retained to coordinate the permit process work with the Santa Ana Regional Water Quality Control Board. The cost of the applications was projected at $264,000 with funding provided from the District's Lake Improvement Fund. (BBMWD web site)**
Types of Damage Costs
Contributes to flooding/drainage/storm water problems
Water supply quantity
Water supply quality **The excessive vegetation leads to a change in localized levels of nutrients and turbidity in the lake (either as a result of management practices, or damages from the plants themselves).**
Impedes navigation **This is one of the main reasons for management; open areas where boaters traverse are impacted by heavy levels of vegetation, private dock owners pay an annual fee to cover the cost of mechanical harvesting to keep the areas free.**
Impedes/limits recreation/parks values **Coontail and milfoil are the most abundant and the most troublesome to boating, jet skiing, paddling, fishing, etc.**
Reduces aesthetic/environmental values **Yes.**
1e. Management Objective **To reduce the overgrowth of plants and to facilitate access to the lake without the eradication of all weeds.**
1f. Stakeholders **Big Bear Municipal Water District, The Fishing Association of Big Bear Lake, Santa Ana Regional Water Quality Control Board, Western Aquatic Plant Management Society, local property owners, private dock users, recreators on the lake**

Entry Table 3. Number 1 Costs of a Management Practice. For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.		
Management Alternative Names: Sonar		
Name of Practice: Status Quo: Harvesting, Aquamogging		
General description of Practice	**Have three harvesters (H-650), and one Aquamog which works similarly to a rototiller to remove weeds from around dock areas.**	
When during the season will practice be applied?	**Weed harvesting program begins June 15 with most heavily weeded areas being treated first, continues through end of season, September 15.**	
Where within the location this practice is to be applied?	**Aquatic plants cover about 800 acres around the perimeter of big bear lake. The district controls 240 acres of the growth with harvesters.**	
How much will be applied?		
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known		**$250,000-$300,000 per season**
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	240 (website) or 800 (Gene)
Maintenance/storage machines	Dollars/Year	$25,000
Operating costs	Dollars/year	$225,000-$275,000
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 2 **Costs of a Management Practice.** **For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.**		
Management Alternative Names: Harvesting, Aquamogging		
Name of Practice: Sonar and some Harvesting		
General description of Practice	**Application of herbicide, Sonar and use of harvester for curly leaf pondweed that grows once milfoil is eradicated**	
When during the season will practice be applied?	**Early in the growing season, June**	
Where within the location this practice is to be applied?	**Boulder Bay and Mallard Lagoon/Canvasback Cove**	
How much will be applied?	**145 acres one year, approximately 100 acres the following year**	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known		
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	145 acres
Cost per acre	$/acre	$1000
Permitting/Monitoring	$	$100,000
Department of F&G Permit	$	$154
Operation Costs for harvesters	$/season (8 days, Gene Martin)	$23,377-$28,571 (est. as a proportion of Gene Martin estimation of total control cost/season)
Total Cost	**$/season**	**$268,530-$273,725**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 3 Costs of a Management Practice. For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.		
Management Alternative Names: Sonar, Harvesting, Aquamogging		
Name of Practice: Diver Dredging		
General description of Practice	**Diver-operated suction dredging uses divers equipped with suction dredge hoses that vacuum the plant material out of the lake.**	
When during the season will practice be applied?	**During the growing season: late spring-late summer.**	
Where within the location this practice is to be applied?	**Along the 240 acres of treatment zone as indicated by the BBMWD and ReMetrix, Inc. consultants**	
How much will be applied?		
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known		
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	240
Cost	$/day	$1,500-$2,000/day
Removal Rates	acre/day	0.25-1.0
Total cost	**$/season**	**$90,000-$480,000**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 6.
Costs of Management Practices by Year for a Management Alternative

Management Alternative: Aerial Application of AquaMaster

		Quantified Control Costs, Damage Costs, and Environmental Costs, In 2003 Dollars						
Year	Source of Data (Tables, number)	Name of Control Cost, Damage Cost, or Environmental Cost						Total Cost of Alter-native by Year
		Harvesting/ Aquamogging						
1		$275,000						$275,000
2		$275,000						$275,000
3		$275,000						$275,000
4		$275,000						$275,000
5		$275,000						$275,000
6		$275,000						$275,000
7		$275,000						$275,000
8		$275,000						$275,000
9		$275,000						$275,000
10		$275,000						$275,000
11		$275,000						$275,000
12		$275,000						$275,000
13		$275,000						$275,000
14		$275,000						$275,000
15		$275,000						$275,000
16		$275,000						$275,000
17		$275,000						$275,000
18		$275,000						$275,000
19		$275,000						$275,000
Etc		$275,000						$275,000
Last Yr		$275,000						$275,000
NPV(.05, Yr1..,Yr50), 1000 $								**$5020.00**
-PMT(.05,Last Yr.,NPV), 1000 $								**$275.00**

Entry Table 6.
Costs of Management Practices by Year for a Management Alternative

Management Alternative: Mowing

		Quantified Control Costs, Damage Costs, and Environmental Costs, In 2003 Dollars						
Year	Source of Data (Tables, number)	Name of Control Cost, Damage Cost, or Environmental Cost						Total Cost of Alter-native by Year
		Sonar and some Harvesting						
1		$271,128						$271,128
2		$226,129						$226,129
3		$271,128						$271,128
4		$226,129						$226,129
5		$271,128						$271,128
6		$226,129						$226,129
7		$271,128						$271,128
8		$226,129						$226,129
9		$271,128						$271,128
10		$226,129						$226,129
11		$271,128						$271,128
12		$226,129						$226,129
13		$271,128						$271,128
14		$226,129						$226,129
15		$271,128						$271,128
16		$226,129						$226,129
17		$271,128						$271,128
18		$226,129						$226,129
19		$271,128						$271,128
Etc		$226,129						$226,129
Last Yr		$271,128						$271,128
NPV(.05, Yr1..,Yr20), 1000 $								**$4548.96**
-PMT(.05,Last Yr.,NPV), 1000 $								**$249.18**

Entry Table 6.
Costs of Management Practices by Year for a Management Alternative

Management Alternative: Combined Mowing, Discing, Floating and Plowing

		Quantified Control Costs, Damage Costs, and Environmental Costs, In 2003 Dollars						
Year	Source of Data (Tables, number)	Name of Control Cost, Damage Cost, or Environmental Cost						Total Cost of Alternative by Year
		Suction Dredging						
1		$285,000						$285,000
2		$285,000						$285,000
3		$285,000						$285,000
4		$285,000						$285,000
5		$285,000						$285,000
6		$285,000						$285,000
7		$285,000						$285,000
8		$285,000						$285,000
9		$285,000						$285,000
10		$285,000						$285,000
11		$285,000						$285,000
12		$285,000						$285,000
13		$285,000						$285,000
14		$285,000						$285,000
15		$285,000						$285,000
16		$285,000						$285,000
17		$285,000						$285,000
18		$285,000						$285,000
19		$285,000						$285,000
Etc		$285,000						$285,000
Last Yr		$285,000						$285,000
NPV(.05, Yr1..,Yr20), 1000 $								**$5202.94**
-PMT(.05,Last Yr.,NPV), 1000 $								**$285.00**

Appendix H. Entry Tables For Stone Lakes Analysis

Entry Table 1. Define the Aquatic Plant Problem.
Name of Water Body: **Stone Lakes National Wildlife Refuge**
1a. Location: **The Stone Lakes National Wildlife Refuge is located south of Sacramento in Elk Grove California. The refuge is situated within the Sacramento-San Joaquin Delta along the Pacific Flyway, the destination of thousands of migrating waterfowl, shorebirds, and other water birds.**
1b. Water Body Type (identify and describe at least 1)
Small pond
Large lake **The Stone Lakes Basin is located in the Cosumnes and Mokelumne River watersheds and the Sacramento-San Joaquin River Delta. Floodwaters from these river systems and the 180-square mile Morrison Creek watershed replenish the basin's large lakes, wetlands and riparian streams during winter storms. Construction of the Sacramento River flood control system has helped to reduce extensive flooding caused by heavy winter rains and spring thaws.**
Delta
Irrigation canal
Stormwater
EstuarineWetlands:
Wildlife Refuges **As of 1994; the Stone Lakes Basin has recently been converted into a national wildlife refuge.**
1c. Aquatic Plant Type (identify and describe at least 1) **Two types of aquatic plants have been identified as problem weeds in the Stone Lakes.**
Floating **Water Hyacinth (*Eichhornia crassipes*)**
Submerged **Eurasian Water Milfoil (*Myriophyllum spicatum*)**
Emergent
Algae
1d. Potential Economic Costs (identify and describe at least 1) **Clogged waterways: as a result of the invasion and overgrowth of the pest weeds, there have been a decrease in the amount of flow in surrounding sloughs and waterways. Because of Water Hyacinth's high rate of water use, one acre of the plants cause a loss of up to 39 acre inches of water per month over the rate of an acre open water. (CDBW)**
History of Control costs, or Control Expected: **Managers at Stone Lakes NWR have traditionally controlled these plants by spraying either 2,4-D or Glyphosate, or have done some harvesting and handpulling. This has proven to be costly and time-consuming. As a result of a pilot program, funded by the SFEI, shredding will be attempted at Stone Lakes on the East and West portions of Lambert Slough, as well as the Stone Lake proper.**

Types of Damage Costs
Contributes to flooding/drainage/storm water problems
Water supply quantity
Water supply quality
Impedes navigation
Impedes/limits recreation/parks values
Reduces aesthetic/environmental values
1e. Management Objective **To eliminate weeds in order to clear clogged waterways, irrigation canals, and to avoid the overgrowth of these invasive species on the lake.**
1f. Stakeholders **California Department of Transportation; California Department of Parks and Recreation; California Department of Water Resources; California Waterfowl Association; Ducks Unlimited; National Audubon Society; Sacramento Regional County Sanitation District; Sacramento County Department of Parks, Recreation and Open Space; Sacramento Open Space; Stone Lakes Alliance; The Nature Conservancy and Trust for Public Lands; US Bureau of Reclamation, Vino Farms**

Entry Table 3. Number 1 Costs of a Management Practice. For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.		
Management Alternative Names: Shredding, Handpulling		
Name of Practice: Herbicide/surfactant application		
General description of Practice	**Weedar64® and AquaMaster® are applied, in addition to a surfactant (R-11) with the labor from 2 additional employees hired for the hyacinth control program**	
When during the season will practice be applied?	**May-October, four days a week**	
Where within the location this practice is to be applied?	**Sloughs, waterways, canals, and Stone Lakes proper**	
How much will be applied?	**Approximately 160 gallons Weedar64, and 95 gallons AquaMaster**	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	**$55,012.03**	**$183/acre**
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	300
Equipment (USFWS)	Dollars/Year	$4,352.64
Labor/contract (USFWS)	Dollars/year	$2000.000
Chemicals (USFWS)	Dollars/year	$5,870.39
Labor/contract (CO. WRD)	Dollars/year	$13,600
Chemicals (CO. WRD)	Dollars/year	$5000
Chemical (BDW)	Dollars/year	$1500
Hours spent admin/field (USFWS)	Dollars/year	$22,689
Total	**Dollars/year**	**$55,012.03**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 2 **Costs of a Management Practice.** **For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.**		
Management Alternative Names: Herbicide Treatment, Handpulling		
Name of Practice: Shredding		
General description of Practice	**A large mechanical shredder mulches the plants as it makes its way through the waterways.**	
When during the season will practice be applied?	**Early in season when the plants are small enough to not clog shredding machine; spring**	
Where within the location this practice is to be applied?	**Sloughs, waterways, canals, and Stone Lakes proper**	
How much will be applied?	**Dependant on environmental conditions; most likely a few times per season**	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known		**$817/acre**
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	300
Treatment Rate	Acres/hour	0.5
Cost per acre	$/acre	$817
Total Cost	**$/season**	**$245,106**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 3 **Costs of a Management Practice.** **For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.**

<table>
<tr><td colspan="3">Management Alternative Names: Shredding, Herbicide Application</td></tr>
<tr><td colspan="3">Name of Practice: Harvesting, H-5 Harvester</td></tr>
<tr><td>General description of Practice</td><td colspan="2">A 200 cubic foot harvester removes the water hyacinth from the water body at a rate of approximately 1-2 acres per day</td></tr>
<tr><td>When during the season will practice be applied?</td><td colspan="2">Spring-late Summer during the treatment season</td></tr>
<tr><td>Where within the location this practice is to be applied?</td><td colspan="2">Sloughs, waterways, canals, and Stone Lakes proper</td></tr>
<tr><td>How much will be applied?</td><td colspan="2">Approximately 200 days are necessary for harvesting Stone lakes</td></tr>
<tr><td>Measurable Attributes of this Practice</td><td>Measure/Units</td><td>Answer/Number of Units</td></tr>
<tr><td>Total Control Cost, if known</td><td>$205,016</td><td>$683.39/acre</td></tr>
<tr><td colspan="3">If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.</td></tr>
<tr><td>If Total Control Cost not known, name factors that affect cost (See Information Table 2)</td><td>Measure/Units</td><td>Answer/Number of Units</td></tr>
<tr><td>Treatment Area</td><td>Acres</td><td>300</td></tr>
<tr><td>Set up (one time cost $967-1064 per job)</td><td>$/Job</td><td>$1,016</td></tr>
<tr><td>Operating Cost</td><td>$/Day</td><td>$500</td></tr>
<tr><td>Labor Cost</td><td>$/Day</td><td>$520</td></tr>
<tr><td>Treatment Rate</td><td>Acres/Day</td><td>1.5</td></tr>
<tr><td>Cost/Acre</td><td>$/acre</td><td>$683.39</td></tr>
<tr><td>Total Cost</td><td>$</td><td>$205,016</td></tr>
<tr><td>If Disposal Costs Considered</td><td>$</td><td>$208,177</td></tr>
<tr><td colspan="3">Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.</td></tr>
</table>

Appendix I. Entry Tables For Big Break Analysis

Entry Table 1. **Define the Aquatic Plant Problem.**
Name of Water Body: **Big Break**
1a. Location: **Big Break is located 40 miles inland from the Golden Gate in the Sacramento-San Joaquin Delta (Gordy 2003). It lies in Contra Costa County and is located directly north of the town of Oakley in the western Delta area (Small).**
1b. Water Body Type (identify and describe at least 1)
Small pond
Large lake
Delta
Irrigation canal
Stormwater
EstuarineWetlands: **The area is considered to be a shallow water body with abundant vegetation; supporting areas of tidal marsh, seasonally inundated floodplain, riparian forest, and Antioch dune scrub (Small).**
Wildlife Refuges
1c. Aquatic Plant Type (identify and describe at least 1)
Floating **Water Hyacinth (*Eichhornia crassipes*)**
Submerged ***Egeria densa* (Brazilian elodea)**
Emergent
Algae
1d. Potential Economic Costs (identify and describe at least 1) **Clogged waterways: as a result of the invasion and overgrowth of Egeria and Water Hyacinth, there has been a decrease in the amount of flow in surrounding sloughs and waterways. In addition, fishing and recreation have been impeded as a result of the vast amount of weed overgrowth.**
History of Control costs, or Control Expected:
Types of Damage Costs
Contributes to flooding/drainage/storm water problems
Water supply quantity
Water supply quality
Impedes navigation **Especially to fisherman, other boaters in the area**
Impedes/limits recreation/parks values **See above**
Reduces aesthetic/environmental values

1e. Management Objective **To eliminate weeds in order to clear clogged waterways, make navigation and recreation possible for users of the Big Break area**
1f. Stakeholders **California Department of Transportation; California Department of Parks and Recreation; California Department of Water Resources; California Department of Boating and Waterways, DeltaKeepers, BayKeepers**

Entry Table 3. Number 1 **Costs of a Management Practice.** For Each Unique Management Practice from All Entry Table 2s		
Management Alternative Names: Harvesting, Handpulling		
Name of Practice: Herbicide Treatment: Fluridone, Diquat bromide, and chelated copper application, with use of R-11 surfactants		
General description of Practice	**Aquatic plant herbicides and surfactants are applied to the Egeria and Water Hyacinth**	
When during the season will practice be applied?	**May-October, during the treatment season**	
Where within the location this practice is to be applied?	**In heavily infested areas in Big Break, approximately 724 acres need application**	
How much will be applied?		
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	**$1,096,860**	**$1515/acre**
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	724
Fluridone	Cost/acre	$900
Diquat bromide	Cost/acre	$75
Chelated Copper	Cost/acre	$540
Total	**Dollars/year**	**$1,096,860**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 2 Costs of a Management Practice. For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.		
Management Alternative Names: Herbicide Application, Handpulling		
Name of Practice: Harvesting, H-7 Harvester		
General description of Practice	**400 cubic foot harvester(s) removes the water hyacinth from the water body at a rate of approximately 2-3 acres per day (AEI, 2003)**	
When during the season will practice be applied?	**May-October, during the treatment season**	
Where within the location this practice is to be applied?	**In heavily infested areas in Big Break, approximately 724 acres need application**	
How much will be applied?	**Dependant on environmental conditions; most likely 2 passes per season**	
Measurable Attributes of this Practice	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	**$1,471,563-$1,555,041**	**$2032-2147/acre**
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Acreage to be treated	Acres	724
(Operation) Days required	Days	362
Set up	$/Job/Harvester	$1,064
Operating Cost	$/day/Harvester	$1000
Labor Cost	**$/day/Harvester**	**$520**
Total Cost with 2 harvesters, 4 passes per season (No Disposal costs)	**$**	**$1,471,563**
Total Cost w/2 harvesters, 4 passes per season (Disposal costs included)	**$**	**$1,555,041**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		

Entry Table 3. Number 3
Costs of a Management Practice.
For Each Unique Management Practice from All Entry Table 2s, Complete One of These Tables.

Management Alternative Names: Herbicide Application, Harvesting

Name of Practice: Handpulling (estimations according to Gibbons et al, 1999)

General description of Practice	**Manual removal of Hyacinth and Egeria plants from the area, placed on barge to dry out and disposed**	
When during the season will practice be applied?	**Spring-late Summer during the treatment season**	
Where within the location this practice is to be applied?	**Along the weed infested perimeter of the Big Break area**	
Measurable Attributes	**Measure/Units**	**Answer/Number of Units**
Total Control Cost, if known	**$503,536-$2,337,670**	**$695-$3229/acre**
If Total Control Cost was known, go to next practice, or if all practices are done, and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		
If Total Control Cost not known, name factors that affect cost (See Information Table 2)	**Measure/Units**	**Answer/Number of Units**
Treatment Area	Acres	724
Labor Cost	$/day	$500-2400
# of Treatment Days (according to harvesting estimate)	Days	241
Total Cost	**$/Treatment Season**	**$503,536-$2,337,670**
Go to next practice, or if all practices are done and this is a Type A analysis, go to Entry Table 6. If this is a Type B or C Analysis, go to Entry Table 4.		