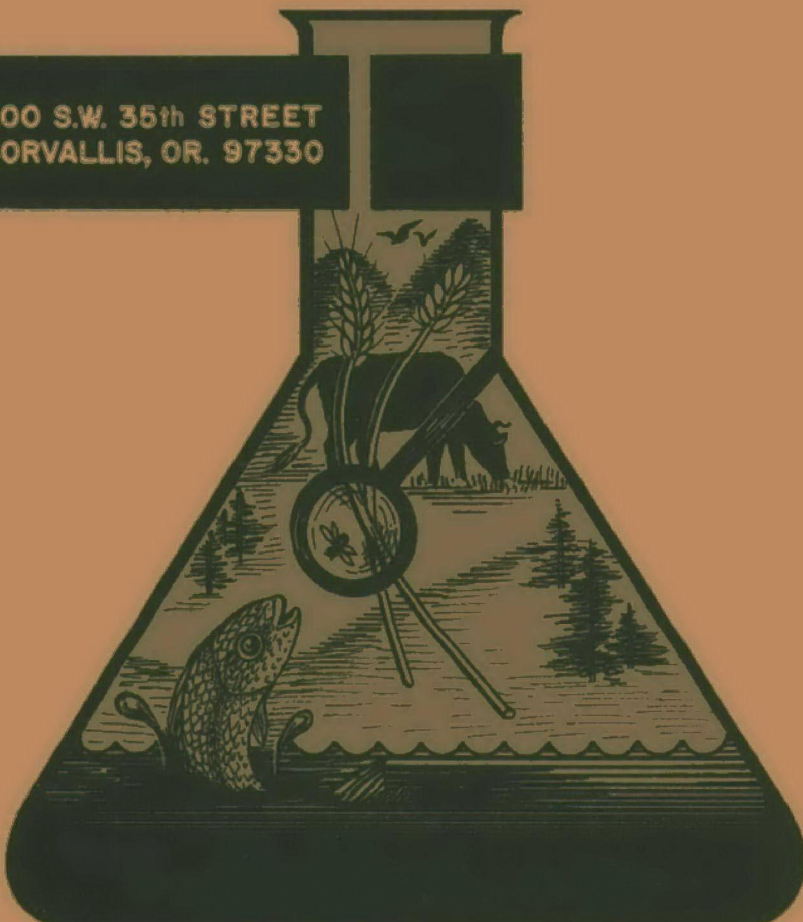
GUIDELINES FOR EVALUATION OF LAKE
RESTORATION DEMONSTRATION PROJECTS

By Thomas E. Maloney
Eutrophication and Lake
Restoration Branch

CERL-001

Corvallis
Environmental
Research
Laboratory

200 S.W. 35th STREET
CORVALLIS, OR. 97330



GUIDELINES FOR EVALUATION OF LAKE RESTORATION DEMONSTRATION PROJECTS

By Thomas E. Maloney
Eutrophication and Lake
Restoration Branch

CERL-001

GUIDELINES FOR EVALUATION OF LAKE RESTORATION DEMONSTRATION PROJECTS

by

Thomas E. Maloney
Eutrophication & Lake Restoration Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

ENVIRONMENTAL RESEARCH LABORATORY
U.S. ENVIRONMENTAL PROTECTION AGENCY
CORVALLIS, OREGON 97330

Guidelines for Evaluation of Lake Restoration Demonstration Projects

INTRODUCTION

Section 104(h)(A) of P.L. 92-500 authorized the Administrator of the Environmental Protection Agency to enter into contracts with or make grants to public and private agencies, and organizations and individuals for the purpose of developing and demonstrating new or improved methods for the prevention, removal, reduction and elimination of pollution in lakes, including the undesirable effects of nutrients and vegetation.

P.L. 92-500 provides several mechanisms for obtaining information on the condition of publicly owned lakes. These include: Section 303 (e), 106, 314, as well as Section 104(h). Section 303(e) requires that State program plans include a classification of publicly-owned freshwater lakes according to their eutrophic condition along with an identification of restorative measures to restore the quality of problem lakes. Supporting information is to be provided by the States in response to Appendix A of Section 106. Information on each lake will include the nature of the problem, identification of the cause, the identification of the possible restorative actions and a numerical priority for restoration assigned to each lake.

Section 314 (Clean Lakes) mandates that the States prepare and submit to the Administrator information similar to that required by Section 106, but goes beyond just the gathering of information and directs the Agency to provide financial assistance to States in order to restore the quality of publicly owned fresh-water lakes. As such, it is the principle mechanism by which actual restoration of lakes will be undertaken.

The Agency has determined that clean lakes funds will not be used for construction of treatment facilities for point source wastes contributing to lake eutrophication. These sources should be controlled through the issuance of permits pursuant to Section 402 of the Act, or through construction of wastewater treatment facilities pursuant to Section 201 of the Act. In addition, such funds will not be used for harvesting of aquatic vegetation, chemical treatment (algicides and herbicides) to alleviate temporarily the symptoms of eutrophication, maintenance of lake aeration devices, or similarly palliative methods and procedures, except as a necessary preliminary part of other, permanent restorative actions.

The Agency has further determined that the efficacy of certain demonstrations so funded be thoroughly documented and evaluated in a scientific manner acceptable to EPA. Responsibility for such evaluation has been delegated to the Office of Research and Development, Corvallis Environmental Research Laboratory. The purpose of these guidelines is to (1) assist potential grant or contract recipients in the selection of rehabilitation systems specific to their unique problems and (2) provide evaluation requirements. The yet experimental status of some rehabilitation techniques is obvious - hence underscoring the need for evaluation. It is contemplated that the evaluation be external to the restoration grant or contract and be performed by a technically competent State agency, university, contractor or by EPA.

RESTORATIVE PROCEDURES

The approach to the rehabilitation of degraded lakes is twofold: (1) restricting the input of undesirable materials and (2) providing in-lake treatment for the removal or inactivation of undesirable materials. Reducing or eliminating the sources of waste loading is the only restorative measure needed to achieve the desired level of improvement in certain lakes in which natural flushing results in substantial improvements in quality. However, in many lakes, particularly those with slow flushing rates, in-lake schemes are also required before significant improvements will be realized.

Lake restoration techniques are, numerous, but essentially unproven with much of the technology still in the experimental stages in laboratories or small lakes. Certain technologies have met with varying degrees of success on individual lakes, but their applicability to other lakes is unknown. At this point in time it is impossible to recommend reliable remedial measures for all problem lakes or even for particular classes of lakes. Advanced waste treatment (AWT) probably represents the best method available for curbing nitrogen and phosphorus input to waterways at moderate costs. However, since AWT is specifically excluded in Section 314 it is not under consideration here.

Nutrient Diversion

Nutrient diversion offers a possible restoration technique in situations where the incoming nutrient load is entering from a point source. This technique has been used successfully in Lake Washington and has resulted in some improvement in the Madison, Wisconsin lakes. Preliminary studies on several lakes indicate that the effects of diversion may not be readily effective in some eutrophic lakes, due to the remobilization of nutrients from the sediment pool and the continued influx of nutrients from non-point sources. The applicability of this technique is restricted by physical considerations and lake conditions.

One of the major disadvantages of nutrient diversion is the monetary costs; i.e. the expense of installing the collection system for many lakes may be prohibitive. Environmental costs may create another problem.

The diversion of nutrients from one lake to another waterway may result in the degradation of that waterway and the substitution of one problem for another. The morphometry of the lake must be looked at carefully. If the lake basin is shallow, nutrient exchange between sediment and the overlying water may recycle nutrients to the extent that no recovery is discernible. Also, if the groundwater influx is significant with respect to the total hydraulic budget and it is high in nutrients, recovery may be very slow or no recovery may occur. The hydraulic residence time, the rate at which high nutrient water leaves the basin, should also be considered; the shorter the residence time, the better chance for more rapid recovery.

Dredging

Lake dredging not only removes sediments, but also serves to remove a potential nutrient source. Little information is available on the chemical and biological effects of dredging, but projects are now underway which will evaluate the total environmental effects. When all the costs are included, contract unit prices for dredging range from $0.45 to $1.00 per cubic yard. The major factors influencing costs are: (1) the project size; (2) type of material to be excavated; (3) distance to disposal sites; and (4) the availability of properly equipped dredging contractors. The relatively high costs of dredging make this technique prohibitively expensive on large lakes, but dredging is a restorative technique that has been used for years on small lakes and ponds.

Nutrient Inactivation

Under certain conditions the best means of improving water quality is by direct treatment. This is particularly true for water bodies that inherently possess long hydraulic residence times and would thus not exhibit natural flushing characteristics. This type of treatment can be accomplished operationally by either treating the water directly in a water body or by pumping the water to an external treatment process and then returning it. Phosphorus is generally the preferred target because of the greater probability of reducing its concentration to growth-limiting proportions. Alum, sodium aluminate, fly ash, zirconium and various other materials have been investigated as nutrient inactivation agents. Although some pilot results with this technique have been encouraging, its applicability on a large-scale, with the exception of alum, has not been determined.

If the water is to be removed to an external process any degree of treatment can be achieved, depending upon the treatment process selected. Appreciable improvement can be achieved, for example, with chemical coagulation followed by plain or high rate (tube type) sedimentation. Such a treatment process can be expected to remove large amounts of color, turbidity, algae, bacteria, viruses and some dissolved organic impurities as well as phosphorus. If a higher degree of treatment is required, additional processes such as granular filtration and activated carbon absorption can be included.

The costs of these treatment processes can be fairly high with operating costs approaching those of municipal waste treatment [$0.10 - 20/1000 gallons (3.8m^3); $30 - 60/acre-ft (1,233m^3)].

<u>Dilution and Displacement</u>

The water quality of some lakes can be improved by diluting or replacing the existing water with that of a higher quality. In using this method the replacement water must be readily available, and there must be a convenient and acceptable means of discharging the displaced water. Water replacement can be accomplished in two ways: (1)

by introducing high quality water directly into the lake, thus displacing an equal volume of lower quality water or (2) by removing a given volume of the existing water and replacing it with water of higher quality.

Bottom deposits may play an important role in determining nutrient levels within a lake and leaching can negate the potential effects of the influx of nutrient poor water. This is an important consideration for lakes with extensive shallow areas and in situations where dilution is not continuous.

Although economic considerations and logistics may severely limit the number of applications, the technique can and has been used effectively. Certain in-lake phenomena have been identified as important and thorough pre-treatment investigations should increase the degree of success in future dilution and displacement projects.

Aeration

The basic objectives behind virtually all aeration projects are to maintain an aerobic system above the bottom sediments to impede the recycling of phosphorus and to improve the dissolved oxygen for fishery or water quality management. However, because of the differences in technique and the effects of aeration on the thermal regime of a lake, it is convenient to recognize two separate categories - total aeration and hypolimnetic aeration. These methods are of particular value in improving the water quality of lakes in which the hypolimnion is void of dissolved oxygen and thus uninhabitable by aerobic organisms. The effective actions of both of these processes are to increase the oxygen concentrations, promote the oxidation of reduced organic and inorganic substances and enhance biotic distribution. Aeration techniques generally treat the symptoms of overfertilization rather than the source of nutrients. Permanent restoration will best be accomplished by removing or significantly reducing the primary nutrient inputs to the lake. Following such a reduction, aeration methods may be effective in increasing the rate of recovery.

Control of allochthonous sediments

Sedimentation of lakes and reservoirs is a major factor restricting the available acreage of the Nation's recreational waters. In terms of volume, sediments are the greatest pollutant. Sedimentation rates can frequently be retarded by prudent land use management practices within the watershed. Agricultural practices such as strip cropping, contour plowing and proper grazing practices prevent rural erosion and consequent sedimentation. Construction and logging activities should avoid the steepest slopes and projects which denude the landscape should be timed to avoid seasonal rainy periods.

Mechanical measures can be used to intercept, divert, retard or otherwise control runoff. These include such practices as land grading, bench terracing, construction of diversion and waterway stabilization structures, and installation of sediment basins or traps. `Vegetative measures include the use of mulches, and temporary and permanent cover crops. Erosion control and stabilization of lake shorelines can be accomplished by both vegetative and structural means.

Drawdown

Water level manipulation exists as a potential mechanism for enhancing the quality of certain lakes and reservoirs. Lake drawdown has been investigated as a control measure for submersed rooted aquatic vegetation, as a means to retard nutrient release from the sediment nutrient pool, and as a mechanism for lake deepening through sediment consolidation.

Observations from natural drawdown and subsequent exposure of the bottom sediments have indicated marked improvement in some Florida lakes. Before drawdown the lakes produced heavy algal crops. After drawdown and sediment drying, rooted aquatic plants replaced the algal community making the lakes more amenable to game fish.

Bottom Sealing

Covering of bottom sediments with sheeting material (plastic, rubber, etc.) or particulate material (clay, fly ash, etc.) can theoretically perform two functions. First it can prevent the exchange of nutrients from the sediments to the overlying water, and second, it can prevent or retard the establishment of rooted aquatic plants.

One problem encountered when covering sediments is the ballooning of the sheeting or rupturing of the seal of particulate matter when gas is produced in the underlying sediments.

For particulate material, the small sizes which have relatively low specific gravity (i.e. clays and fly ash) appear to be best suited for sediment covering. Materials of larger size (sands and silts) tend to sink below flocculant sediments. Sands and silts, however, can be effective in areas where the sediments are more consolidated. Materials such as Kaolinite and fly ash, which have a high water soluble lime content, have the added advantage that they remove phosphorus from the water as they settle and carry it to the bottom in a relatively insoluble form.

Summary

For all the potential lake restoration techniques mentioned above, there needs to be more large-scale evaluation. Several of the techniques have been tested in the laboratory or in small experimental ponds. In rare instances where some manipulation has been carried out on a larger lake, sufficient baseline data were usually not obtained to allow for a good evaluation of the technique used.

More information needs to be available in order to determine if a restorative technique, which was successful on one lake in a particular geographic area, would be applicable to other lakes located in different geographic areas. Also, firmer data have to be obtained relating to the costs and benefits of the various lake restoration procedures.

CRITERIA FOR SELECTION OF RESTORATIVE PROCEDURE

Criteria for the selection of the type of restorative procedure to be used on a particular lake will be based upon limnological and nutrient loading data, lake use, and the results obtained from laboratory and small scale experimentation. The techniques chosen for particular lakes will be based upon past experience, their potential for success, their potential applicability to other lakes and their potential for long-term effectiveness.

Evaluating the effectiveness of a restorative procedure will be essential and, therefore, it is necessary to have good baseline data on the lake or reservoir. As a minimum, the type of baseline data should be similar to that gathered by the National Eutrophication Survey. These should include the present trophic condition of the water body as well as its surface area, maximum depth, average depth, area of the watershed draining into the water body and how many tributaries feed into it. Ground water inflow data are also valuable. If bathymetric maps are available, they should be provided as well as tributary flow volumes and transects or sections showing bottom features, shape and multiple basins.

It is desirable to know the nutrient budget, especially that for nitrogen and phosphorus, as well as the hydraulic residence time of the water body. If thermal stratification occurs, it should be determined if the hypolimnion becomes anaerobic and, if so, for how long and over what extent of the bottom. However, temperature and dissolved oxygen data are essential parameters whether the water body is stratified or not.

The extent of algal blooms as well as the species involved should be listed. That portion of the shoreline and lake bottom that is covered by aquatic weeds should be estimated and speciation determined.

Any other limnological or biological studies that have been conducted on the water body should be described. Additional baseline data, if available should include transparency (Secchi disc) readings, dissolved oxygen concentration, dissolved phosphorus, total phosphorus, ammonia nitrogen, Kjeldahl nitrogen, nitrate nitrogen, pH, alkalinity and chlorophyll *a*. Algal assay data relating to the growth-limiting nutrient and to what concentration a nutrient must be lowered to in order to improve the lake to an acceptable trophic state are extremely valuable.

EVALUATION MEASUREMENTS AND PROCEDURES

Following the restorative manipulation, studies should be conducted for one or more years in order that the effectiveness of the procedure can be properly evaluated. Some lakes will be studied more intensively than others, but post-manipulation data will be required on all lakes in order that the rate and extent of recovery, as well as the effectiveness of the selected treatment technique, can be evaluated. As a minimum, these data should include inorganic nitrogen, ortho and total phosphorus, temperature, transparency, dissolved oxygen and chlorophyll *a*. These measurements should be made at least monthly and the number of sampling and test sites will be determined by the size, morphometry and stratification characteristics of the lake.

No more than 10 percent of the available funds appropriated for lake restoration will be used for field evaluation of the methods and procedures used. Therefore, only a limited number of lakes undergoing a restorative manipulation will be studied intensively. Those which will undergo intensive evaluation will be those where extensive baseline data are available and when it is desirable to compare the effectiveness of the various types of lake restoration procedures. On these lakes more extensive biological, chemical and physical tests will be conducted. Dominant phytoplankton and zooplankton species should be identified every two weeks during the "growing" season and monthly during the "non-growing" season. Benthic species should be identified on a monthly basis. Fish species composition, size distribution and numbers should be determined at least once a year. Also, an assessment of higher aquatic plant species and standing crop should be made at least once a year during the height of the "growing" season. If the problem is primarily macrophytes, however, this would be modified.

Chemical and physical tests should include those for nitrogen and phosphorus species, alkalinity, chlorophyll a, pH, dissolved oxygen, conductivity, temperature and productivity measurements. These should be carried out bi-weekly during the growing season and monthly at other times. Again, the number of sampling and testing sites will be determined by those mentioned previously. Depending upon the type of lake restorative procedure used and the nutrient controls implemented, a post-treatment nutrient budget may also be recommended to assess the effectiveness of the procedure in reducing the nutrient load to the lake.

SELECTED REFERENCES

Dunst, R. C. et al. 1974. Summary of Lake Rehabilitation Techniques and Experiences. Technical Bulletin No. 75. Dept. of Natural Resources, Madison, Wisconsin.

Girman, S. T. 1974. Cost-Benefit Evaluation of Lake Reclamation Techniques. M.S. Thesis in Environmental Health Engineering, Dept. of Civil Engineering, University of Notre Dame, Notre Dame, Indiana.

Tenney, M. W., S. M. Yachsich and J. V. De Pinto. 1974. Restoration of Water Bodies, Environmental Engineers Handbook, Vol I, B. G. Liptak, Editor, McGraw - Hill, New York.

U. S. Environmental Protection Agency. 1973. Measures for the Restoration and Enhancement of Water Quality, EPA-430/9-73-005.

U. S. Environmental Protection Agency. 1974. National Eutrophication Survey Methods for Lakes Sampled in 1972. Working Paper No. 1. Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon and National Environmental Research Center, Las Vegas, Nevada.