PLANNING FOR THE RESTORATION, MAINTENANCE, AND MANAGEMENT OF CRYSTAL LAKE

Dept. of Urban and Regional Planning
Environmental Land-Use Workshop Class
UP 338-L(1983)
University of Illinois at Urbana-Champaign

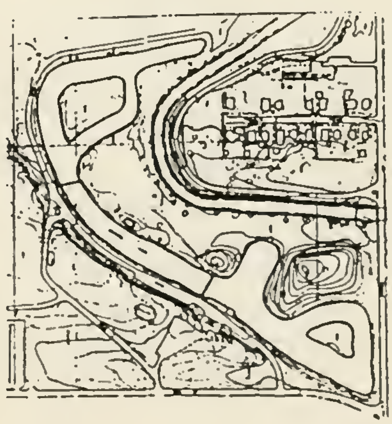


TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

SECTION I. RECOMMENDATIONS

After thorough evaluation of the information obtained during the study, the following recommendations are proposed for implementation by the Urbana Park District to restore Crystal Lake to a more appropriate recreational facility:

1. Based upon economic, environmental, and social costs, complete drainage and sediment excavation is recommended to deepen and re-contour the lake bottom.

2. If complete drainage is not possible, due to inclement weather conditions or the location of groundwater aquifers, the hydraulic dedege-dragline crane alternative, described within the report, is recommended as an alternative to sediment removal.

3. The Champaign County Fairgrounds should be used for final disposal of the lake sediment. Temporary disposal during the fair period (ie. June 1 - August 1) in the vicinity of the Crystal Lake Park playground area is recommended.

4. A well and pump are recommended to provide a new water supply for Crystal Lake.

5. A professional evaluation of the existing lake outflow structure should be made to determine its potential for rehabilitation to meet the needs of the Park District. If results warrant, a new structure should be installed during the first phase of the project.

6. A combination of technical and revegetation methods should be implemented to control slope erosion along the banks of Crystal Lake. Geo-textiles and gabion mattresses are recommended technical methods. T-shaped docks are suggested to provide access and control over-use of critical shoreline areas.

7. Shoreline revegetation, according to suggested plant species contained within the report, should begin in late summer or early fall after dredging is completed. Dead or dying trees along the shoreline need to be removed.

8. Following dredging and refilling an initial test for chemical constituents of lake water should be conducted.

9. Water quality testing for phosphorus, nitrogen, dissolved oxygen, and transparency should be performed monthly from October through April and twice a month from May through September.

10. Water samples for chemical analysis should be collected from at least three permanent locations within the lake; a) a deep station; b) a shallow station; and c) a station near the outflow structure.

11. A Hach Chemical Test Kit should be purchased by the Park District to be used by Park District personnel for testing water samples collected from Crystal Lake. Continued use of a secchi disk is recommended to measure lake transparency.

12. Planting of cattails and arrowheads is recommended at specific locations to provide bank and bottom stabilization, fish habitat, and to guard against erosion.

13. A plant management program should be implemented as soon as possible. Pulling of new shoots, algae raking, and use of specific herbicides are suggested.

14. Prior to lake dredging, larger game fish should be removed from Crystal Lake, retained in a local pond, and eventually returned to the lake following restoration. All other fish should be destroyed; Rotenone is the suggested toxicant for fish removal.

15. Following restoration, Crystal Lake should be restocked with fish. The recommended fish for restocking are: Largemouth Bass, Smallmouth Bass, Redear Sunfish, Fathead Minnow, and Channel Catfish.

16. During dredging, the lake bottom should be irregularly contoured, with depths over 12 feet in at least 25% of the lake.

17. Artificial structures, including brush and tire reefs of varying sizes, should be utilized to provide adequate fish habitat.

18. A fisheries monitoring program, consisting of annual inventories of each population, is recommended as a component of the fish management program.

19. Fish size limits are not initially recommended for bass.

20. It is recommended that the Park District continue to seek external funding from private as well as public sources. It is not recommended that the Park District delay restoration until such funding is attained.

SECTION II. INTRODUCTION TO UP 338-L WORKSHOP REPORT

by

L. L. Osborne, Ph.D.

INTRODUCTION

Many lakes throughout the world are undergoing accelerated aging which can be attributed to poor land use practices within the watershed and to insufficient management of the lake system. Lakes are important to urban inhabitants, providing not only a recreational center, but also contributing to flood control, and in some instances serving as a source of potable water supplies.

Illinois has over 80,000 surface water impoundments, totaling over 280,000 acres. The majority of Illinois lakes are very small, generally less than 10 acres in size and are generally man-made. Stout (1980) reported that less than six percent of the water impoundments within the state of Illinois are natural, but rather potholes excavated during construction, or are former bends (oxbows) of a river channel (as in the case of Crystal Lake) which have been effectively blocked at both the inflow and outflow. More importantly, the soils of much of Illinois are very fertile which provides a more than adequate natural source of nutrients to most lakes. This natural nutrient supply in conjunction with intensive agricultural activities such as fertilization and tillage contributes excessive amounts of nutrients and sediment to these natural catch basins.

Despite the relatively large amount of water impoundments within the state of Illinois, the immediate vicinity of Urbana-Champaign is substantially below the state average for aquatic recreational facilities (Clark, Dietz, and Assoc., 1978). The primary aquatic recreational area for Urbana residents is Crystal Lake (Section 8, Township 19, Range 9 East, 3rd Principal Meridian) located in the north-north-west portion of the city of Urbana, Illinois.

Crystal Lake is typical of most Illinois lakes; it is relatively small (approximately 7 acres), it is a man-made oxbow lake, and suffers from rapid anthropogenic induced lake aging. Lake aging is a natural process which is the basis of study of many freshwater ecologists. Man-induced nutrient loading (primarily phosporus and nitrogen based nutrients) and increased sedimentation greatly accelerates the natural aging process of lakes. This process is referred to as eutrophication. Eutrophication is characterized by a reduction in the quality of lake water due to the accumulation of decaying organic matter, decreased lake volume attributable to increased sedimentation and the deposition of partially decomposed organic materials, and increases in the production and standing crop of nuisance weeds, algae, and aquatic plants (Figure II-1).

Associated with the above water quality changes are an increased probability of fish kills due to diurnal fluctuations in the oxygen concentration of the water and the build-up of toxic compounds from decomposition of organic materials and the metabolism of various species of blue-green algae (Cyanophyta). The latter are primarily responsible for the foul odor associated with eutrophic lakes. Depletion of oxygen is generally insufficient to kill all species of fish within the lake. Rather, only the most oxygen sensitive species are eliminated from the system. Unfortunately, the oxygen sensitive species in this area are generally the primary game fish.

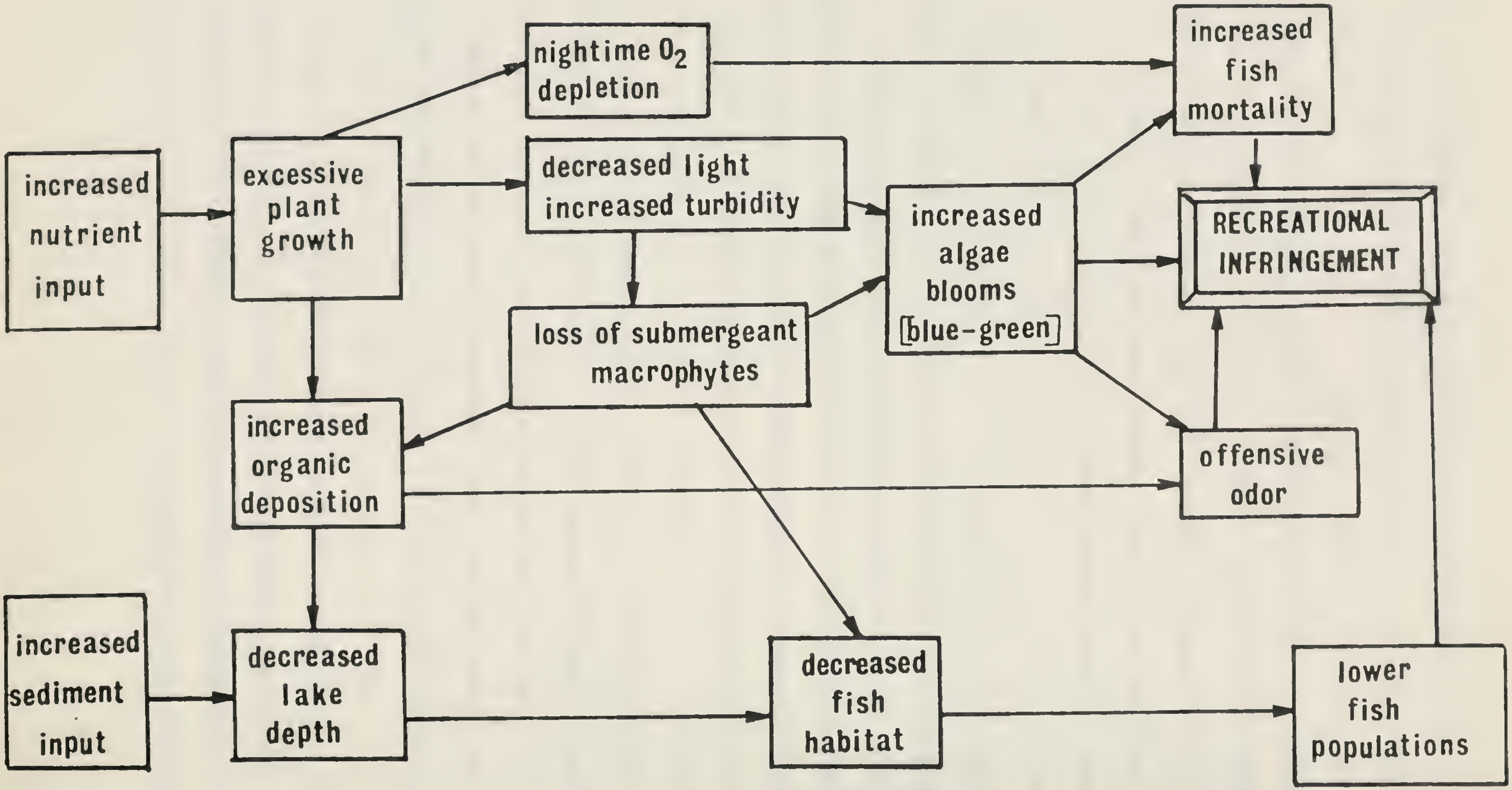


Figure II-1. Diagram of steps leading to eutrophication of a lake and the subsequent infringement on recreational potential.

Successful restoration of lakes suffering from intense eutrophication has been performed (eg. Lake Paradise, Illinois). Many times, however, the cost of such efforts are prohibitive. Thus, it is important that any individual or organization undertaking such a project be aware of the costs and more importantly, be provided with adequate information on the various approaches to restoration.

The appropriate approaches for the successful restoration of a lake are in most instances site specific, requiring consideration of the surrounding land-use activities, a knowledge of the sources of the problem and consideration of the costs, and ultimate uses of the lake. The following report contains a detailed plan for the restoration of Crystal Lake conducted by the UP 338-L Environmental Land Use Workshop class from the University of Illinois, Department of Urban and Regional Planning. The class was under the supervision of Prof. Lewis L. Osborne. A list of workshop participants is contained within the report.

The principle objectives of this study were:

1. to provide an evaluation of the procedures available for the restoration of Crystal Lake, and a course of action for restoring the lake to a condition that will provide a reasonable and lasting recreationally and aesthetically pleasing public use area;

2. to provide an estimate of present lake use and provide an estimate of future lake use through 1993 of the lake following restoration;

3. to develop a water quality monitoring program to be used as an early warning system by the Urbana Park District;

4. to provide an initial fish restocking and subsequent management program with a habitat development protocol.

In conducting this investigation, attention was given to the needs of local residents, and considerations given to the potential environmental and economic concerns of the Urbana Park District. Further, particular attention was given to the development of a water quality and fish monitoring program to be implemented by the Park District. The latter was felt to be of particular importance so as to provide the Park District with the capabilities of assessing future lake quality deterioration before costly mitigating and restorative measures had to once again be taken. Throughout the report, our research group worked on the assumption that the three city storm sewers entering the lake will be removed and discharged into the Saline River as recommended in the Clark, Dietz, and Associate report. Without such changes in storm sewer discharges, it is felt that the procedures outlined within this report are of only very temporary value. Furthermore, the need for a specially designed levee to reduce the amount of flood water overflow from the Saline River was also deemed appropriate (see Clark, Dietz, and Assoc. Report). Unfortunately, personnel with the appropriate expertise were not available within the class to adequately assess the necessary engineering requirements.

In conducting this study, the ten member class broke up into one of four separate working groups, each of which was assigned one of the principle project objectives previously listed. The students gathered information through verbal and written correspondence with recognized experts, readings of scientific literature, and by contacting various contractors and local authorities. The following report is a compilation of that information. The recommendations contained within the report are based upon the data obtained and an evaluation of the information as it related to the needs of the Urbana Park District within the capabilities of the class members.

Figures II-2 through II-5 contain an overall restoration plan and a time sequence for implementation of each project component discussed within the text for the four means of lake sediment removal examined within the report. Sections III through VI contain detailed assessments of major study categories from the four project objectives outlined earlier. Discussions of the information accumulated on each specific aspect of the study are contained within each of the report sections.

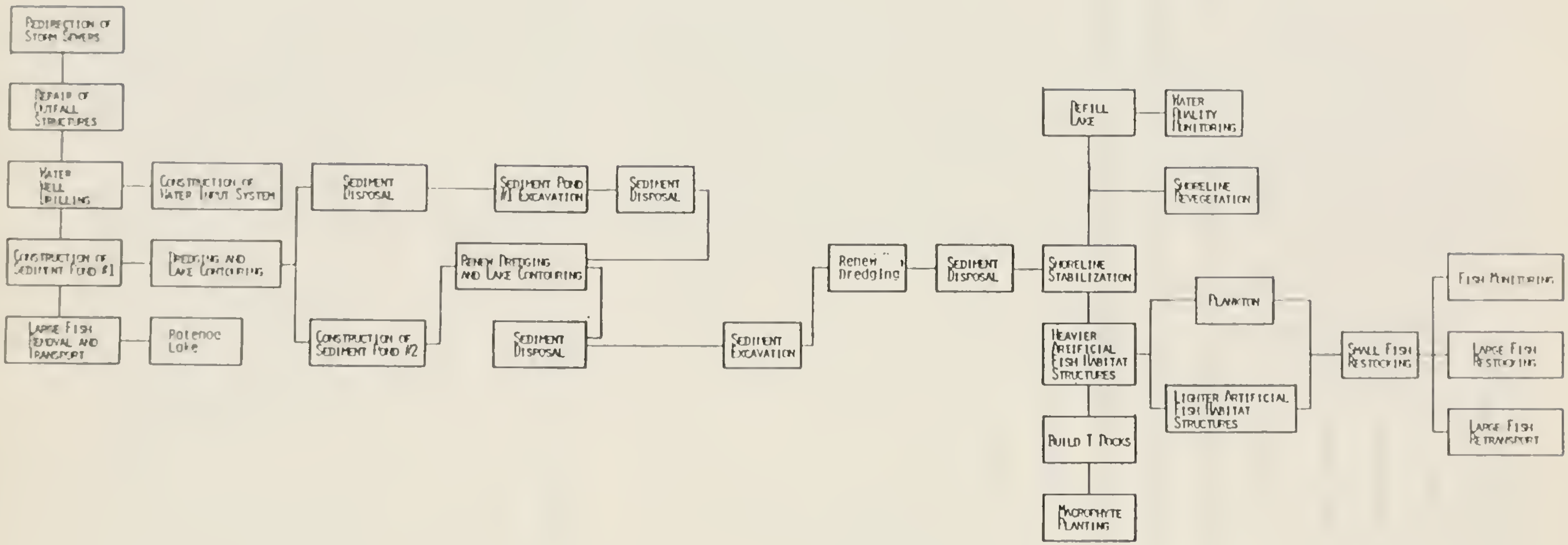


FIGURE II-2
HYDRAULIC METHOD

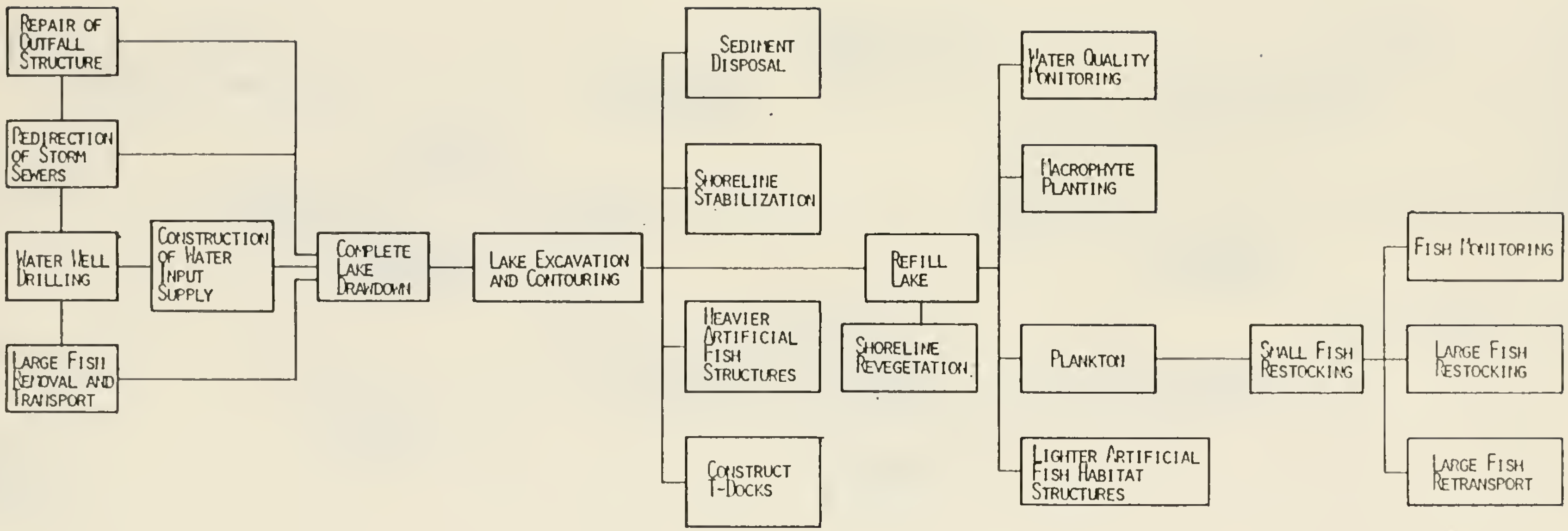


Figure II-3:
Complete Drawdown and Excavation Method

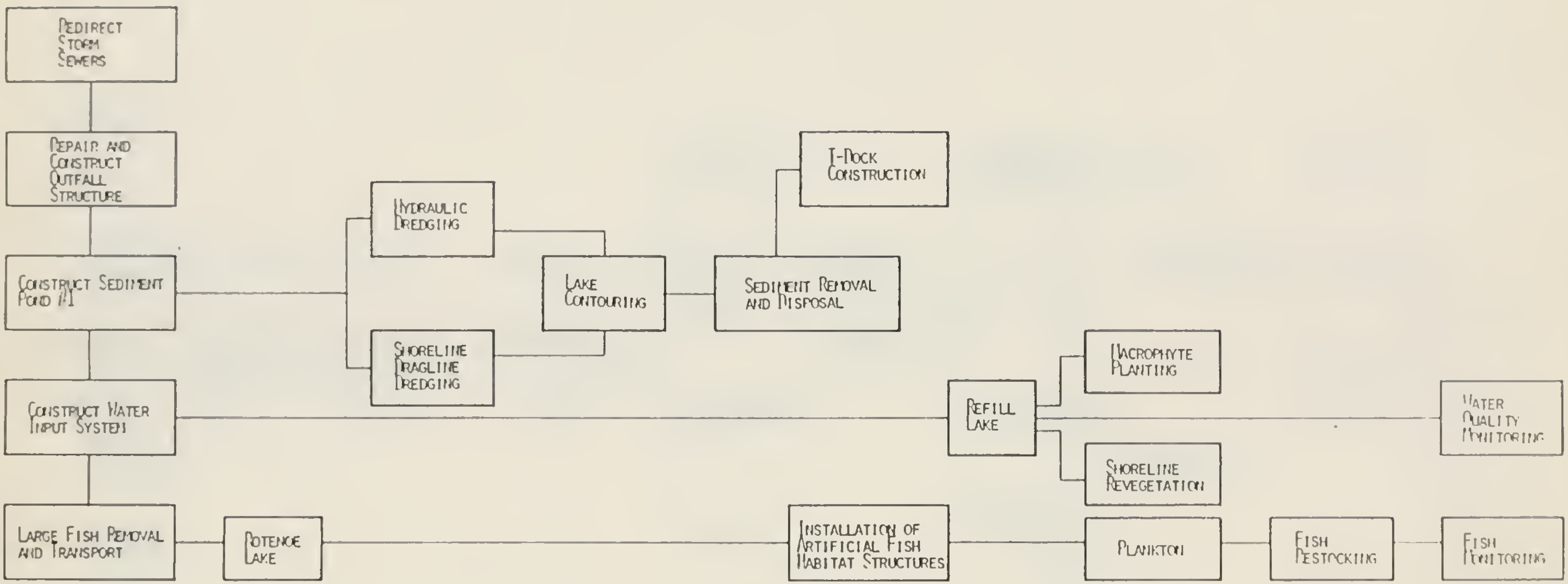


Figure II-4:
Hydraulic and Shoreline Dragline Method

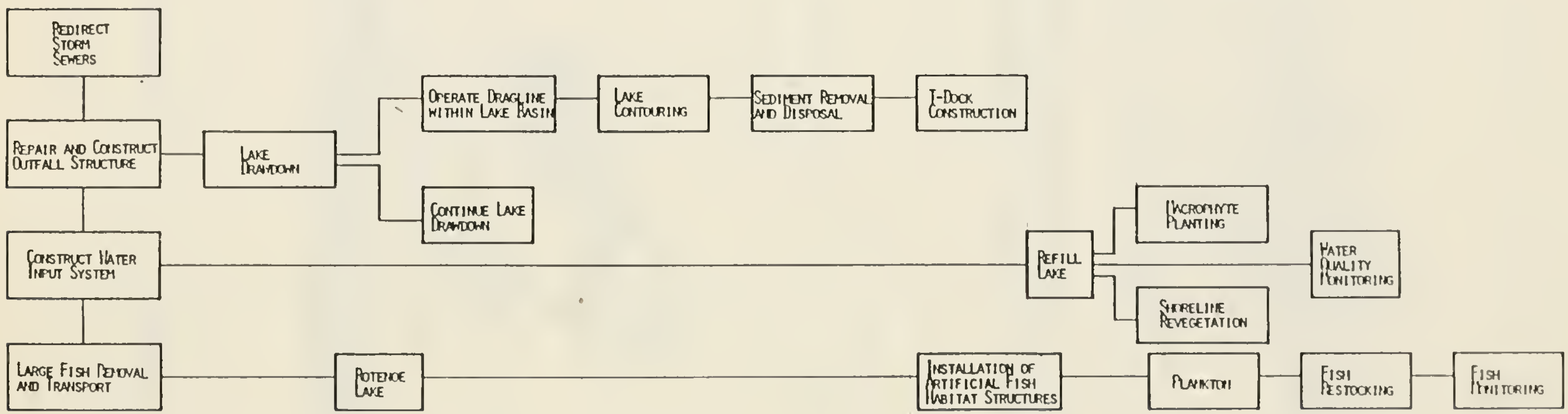
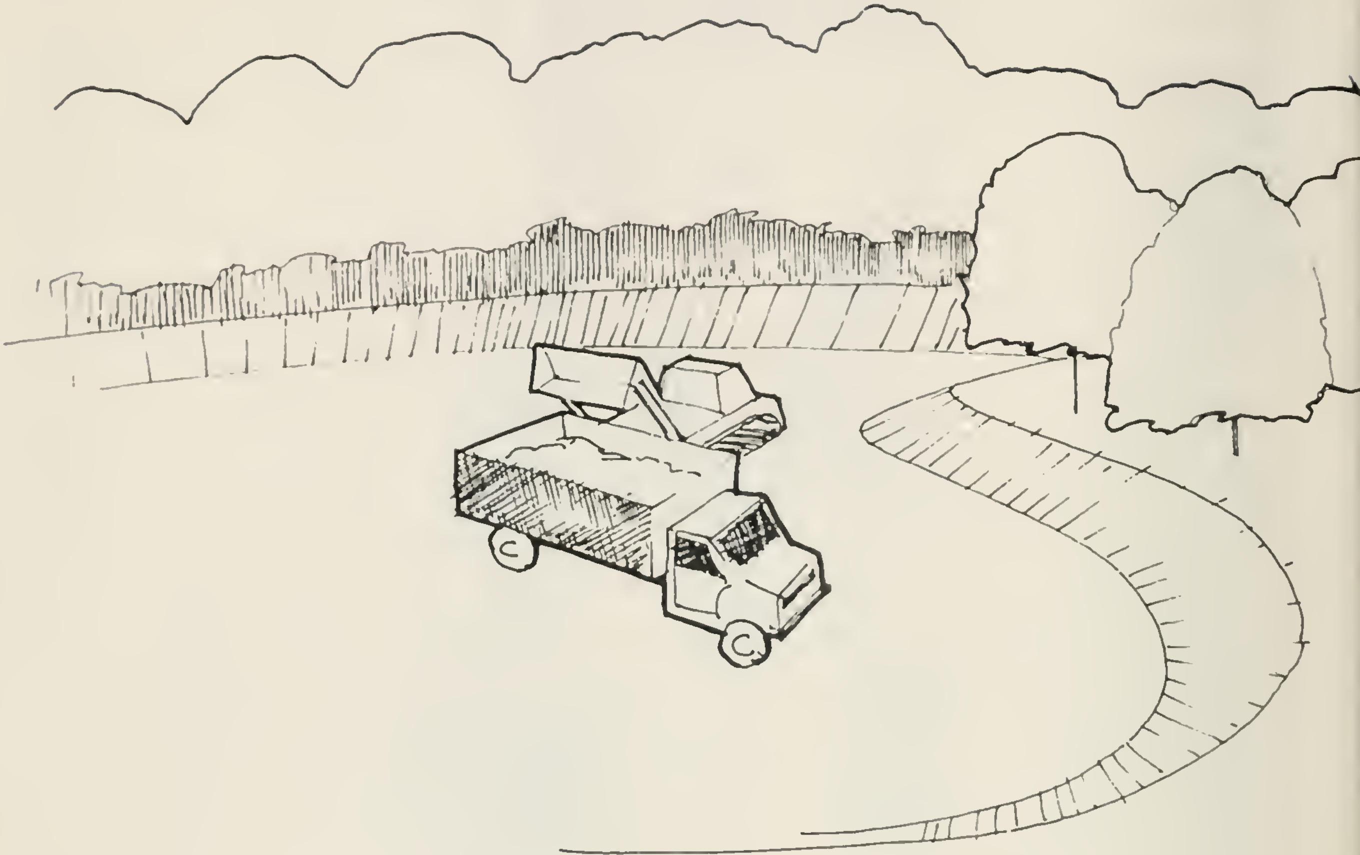


Figure II-5
Partial Drawdown and Dragline within Shoreline Basin Method



SEDIMENT EXCAVATION AND DISPOSAL
BANK STABILIZATION AND REVEGATATION

SECTION III - SEDIMENT REMOVAL-DISPOSAL AND BANK STABILIZATION

by

K. Guiney, L. Marshall-Lewis, B. Lewis, and L. Raymon

INTRODUCTION

Crystal Lake is no longer a high quality water resource for the city of Urbana. It has rapidly deteriorated, filling in with sediments resulting from storm sewers and urban runoff. As it is the only public freshwater lake in Urbana, its importance to the community cannot be understated.

The workshop's goal of preparing a plan to rehabilitate Crystal Lake began with the development of objectives aimed at upgrading its aesthetic and recreational qualities. The objectives are:

1. How to remove and dispose of the existing sediments.
2. Methods to stabilize highly eroded areas along the shoreline.
3. Limit access to control erosion.
4. Review maintenance techniques such as outflow structure and water source.

To meet these objectives, the lake's problems were assessed, solutions developed, and alternatives were proposed and evaluated. Criteria used to evaluate these were cost, environmental impacts, time, and effectiveness. A comprehensive view was taken in developing alternatives. Particular emphasis was placed on environmental damage, sociological effects on nearby residents, and the needs of special groups such as the elderly and handicapped.

METHODS

The first phase of the methodology was a literature search. Material directly related to the subject was scarce. What material was found was generally in the form of case studies which made it difficult to relate to the Crystal Lake Project. One good source was found on the subject of slope stabilization, along with another on revegetation. Material on dredging, sediment removal, water supply, etc. was usually vague and not relevant to this study.

The majority of the information used in Section III was obtained from personal communications. Contacts within the areas of construction, engineering, academia, the public sector, trucking, and waste management were made. Some were interviewed in person while others were contacted by telephone. In the case of dredging and slope stabilization, information was sent by mail. Frequent trips to Crystal Lake for observations were interspersed after information was acquired. Adjustments in proposals and/or work-in-progress were made if necessary. Areas requiring additional information were pinpointed and the information gathering process repeated.

Among the first contacts were professors at the University of Illinois. It was anticipated that these professionals would have information on the most up-to-date techniques and procedures. This was not as prevalent as had been anticipated. One important contact was Dr. R.C. Hiltibran, retired professor, Natural History Survey. He provided leads to other lakes in the Champaign-Urbana area that have employed dredging and sediment removal, what methods were used, and an idea of the probable success of each method. Another contact within the University was Professor A. Nieto, civil engineering. A discussion on methods of slope stabilization produced simple, feasible, and economical ways to deal with the erosion problem. Professor Nieto was also cited by another contact as the expert in the field of the engineering capacity of the soils in the Champaign-Urbana area (in conjunction with the construction of the sediment ponds).

Others contacted outside the University included: Gene Sanks, Urbana Park District, Keith Kessler, director, Champaign County Fairgrounds, Richard Sheets, Western Lion (waste management). Still other contacts included businesses and sales representatives from the Champaign-Urbana area and out-of-state. For a complete listing of all contacts, see the Reference section at the end of this report.

FINDINGS

Sediment Removal

This section comprises one component of an overall effort to develop a plan for the successful restoration of Crystal Lake. The objectives of this section were to:

1. Examine methods of lake sediment removal; and
2. Evaluate the applicability of each method in relation to the particular needs and physical characteristics of Crystal Lake.

The criteria employed in the evaluation of each method were the costs of implementation and completion of sediment removal, the possible environmental impacts to the surrounding area during the removal operation, and the social concerns of local residents and park users, such as noise, aesthetics, and period of lake inavailability.

The three sediment removal methods considered for the project were were hydraulic floating dredging, lake drawdown and sediment excavation, and shoreline dredging. Due to the location of roads and the probable damage to vegetation and landscape, shoreline dredging was eliminated as a principle removal technique. Shoreline dredging with a dragline crane was, however, considered for use in conjunction with the other two sediment removal techniques.

Four alternatives were developed using the above sediment removal techniques. The alternatives evaluated in this findings section are: hydraulic dredging alone, Alternative 1; hydraulic dredging combined with shoreline dredging, Alternative 2; partial drainage followed by shoreline dredging in the lake basin, Alternative 3; and complete drainage and sediment excavation, Alternative 4. The principle methods of sediment removal will now be discussed.

Hydraulic dredging consists of the use of a floating dredge operated on the lake surface, as illustrated in Figure III-1. The barge-like structure has an extendable arm apparatus with an attached cutting device which removes the sediment from the lake bottom. The sediment, along with water drawn from the lake (five to six times the amount of water as sediment), is sucked into a pipe and travels to either a dewatering pond, sediment pond, or containment pond (sturcture). There, the water level is allowed to rise, and the sediment settles to the bottom. Cleaner water from the top flows back to the lake by gravity, either through pipes (tile) or other means. After filling, the sediment takes approximately one and one-half to three months to dry to a transportable condition.

Lake drawdown and sediment excavation is a fairly simple removal technique. Water in a lake is removed through a large water pump. If necessary, pits are dug or constructed (natural or artificial reservoir), that draw all of the water to where the water pump operates. After a

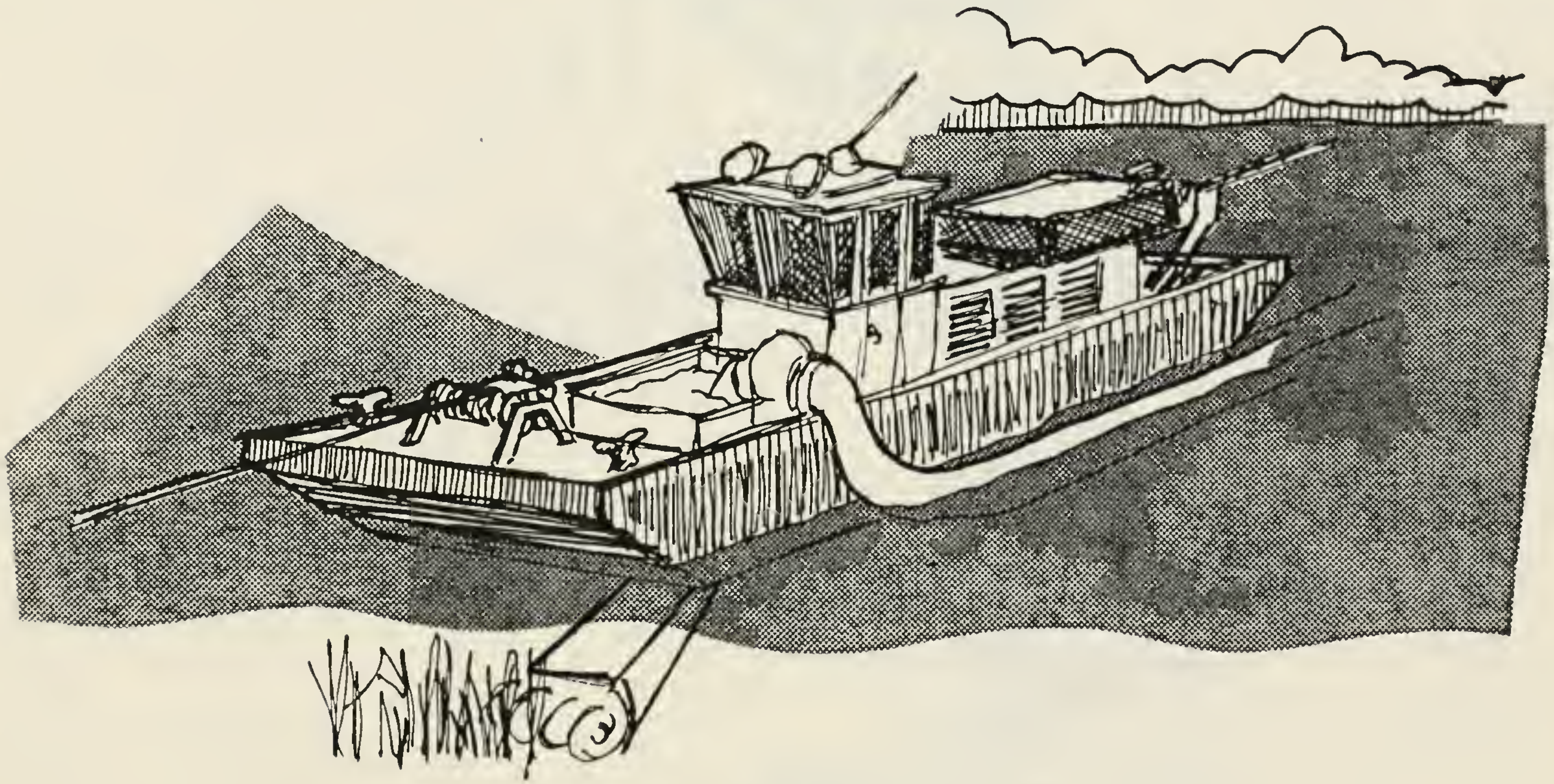


Figure III-1. Illustration of a hydraulic dredge in use.

drying period, the lake basin is suitable for excavation with bulldozers and endloaders. The desired depths and contours are then excavated and the lake refilled.

Shoreline dredging, used in the combination Alternatives 2 and 3, described above, involves use of a mechanical dredge such as illustrated in Figure III-2. The shoreline dredge operates by scraping the bottom of the lake with a scoop bucket pulled by lines attached to the dredge and the opposite side of the lake. The use of shoreline dredging will be described in more detail for each of the alternatives that combine shoreline dredging with the other two principle sediment removal methods.

The following section describes the four previously mentioned alternatives, and the implications involved with the implementation of each; their economic, social, and environmental advantages and disadvantages. The alternatives are evaluated in sequential order.

Alternative 1, Hydraulic Dredge

The volume of water in Crystal Lake will not likely be great enough to complete sediment removal with hydraulic dredging as a sole means of removal. Thus, were Alternative 1 employed, an additional water source would be necessary. Because of the large sediment pond(s) size(s) required, and the additional costs involved, the alternative of using two rotating dewatering ponds was developed. Each of the two structures would hold and drain one month's dredged product if made at a capacity of 15,000 cubic yards. The operation would utilize two removal periods of three to four months. Thus, the entire operation time for this alternative is between six and eight months.

Figure III-2. Illustration of a dragline crane in use.

The procedures involved in hydraulic dredging for Crystal Lake include: constructing the dewatering ponds (two weeks construction time), and supplying an additional water source, discussed in the Water Source FINDINGS section, prior to operating the dredge. A sediment survey would be necessary in the beginning as well, as with all of the alternatives, to determine the amount of sediment to be removed. For comparative purposes, a conservative estimate of 50,000 cubic yards of sediment was made. There are many options in the size and number of sediment ponds that would be used to dewater the removed sediment. The containment ponds mentioned for Alternative 1 take into account the anticipated size of the disposal site.

The type of dewatering ponds which follow are designed to moderately reduce erosion. Cost estimates, listed in Tables III-1 and III-2, are for construction of the following dewatering structures: Tyce C basins, drained through manholes sitting upright at the top level of the water (additional manholes are stacked when the sediment level rises), into 48 inch pipes (tile) routed back to the lake.

The various alternatives that the Park District has to operate a hydraulic dredge are: purchase and operation by Park District personnel; rental and operation by Park District personnel; and, obtaining the service from area contractors. Purchase or rental of a new dredge would be prohibitively expensive, so these figures are not shown, to make comparison of the other options clearer. The cost estimates for each option are provided in Table III-1.

With the purchase option there is the cost advantage if the resale of the dredge is successful. The dredge's value will depreciate by

Option	Dredge and Labor	Sediment Pond Construction and Excavation	Fuel, Oil and Accessories	Set-up, Take-down	Insurance (I) Depreciation (D) Security Deposit (S)	Recovered Costs	Total Costs
Purchase dredge with 6,000 hrs. of operation remaining	$101,611	$147,000	$10,679	$5,000	(I) $625	$45,000-$65,000	$200,000-$220,000
Rental of reconditioned dredge (Mudcat)	$73,123	$147,000	$18,308	$10,000	(I,D,S) $20,625	$10,000	$259,000
Service by Contractor	$138,500	$147,000	N/A	$10,000	N/A	N/A	$285,000

TABLE III-1. Hydraulic dredging cost estimates.

Job and/or Equipment	Service Costs
Hydraulic Dredging	$41,500
Launching and Removing Dredge	$10,000
Dragline Dredging inc. Trucks	$126,000
Dewatering Pond construction @19,000 cy	$53,200
Total Costs	$230,700

TABLE III-2. Cost estimates for hydraulic dredging (15,000 cy) supplementing dragline dredging (35,000 cy) of sediment.

roughly $10,000 after the approximately 625 hours of operation at Crystal Lake. Thus, the dredge could possibly be sold for $45,000 - $65,000. If resale is feasible and timely, Alternative 1, purchase, would be cost-competitive with the other alternatives.

The use of hydraulic dredging involves a few serious environmental concerns. Although little erosion will occur to the lake, there is a good possibility of water damage at the dewatering site. The velocity of the water-sediment mixture, regardless of how well controlled, will result in extensive erosion to the dewatering area. Additional environmental and social disadvantages and advantages are listed in Table III-4.

Another concern in relation to sediment ponds is safety. Renters of hydraulic dredges usually require that the containment ponds be fenced in to restrict access. The costs of fencing for the pond(s) would need to be added to those of Alternatives 1 and 2.

Alternative 1 does have a significant social advantage, as the operation could take place during the winter.

<u>Alternative 2, Hydraulic and Shoreline Dredging</u>

To minimize erosion and costs associated with hydraulic sediment removal, shoreline dredging can be used to reduce the amount of hydraulically dredged water-sediment materials. The hydraulic dredge could be used on areas inaccessible to the dragline crane dredge. The shoreline dredge would, in Alternative 2, operate behind the trees of the shoreline, by dragging a bucket across the bottom of the lake. The sediment is scooped into the bucket and deposited in trucks. Implementation of this alternative would require an evaluation of the shoreline to determine the best access points for the dragline crane. Where vegetation is too dense or areas are not wide enough, the hydraulic dredge will have to be used. Construction of a sediment pond(s) will be necessary if Alternative 2 is used, as was previously discussed. The cost estimates given in Table III-2 allow for 15,000 cubic yards to be removed with the hydraulic method and 35,000 cubic yards by the dragline crane.

Utilization of the above alternative will involve lower costs, as hydraulic dredging is more expensive per cubic yard and the cost of construction of the sediment pond(s) required with hydraulic dredging is high. With Alternative 2, the majority of the sediment can be removed at a lower cost, without costs for dewatering pond construction that are incurred in Alternative 1.

The environmental considerations for Alternative 2 are presented in Table III-4. Because shoreline dredging does not involve the transport of the volume of water that is required in Alternative 1, the environmental impacts to the dewatering area will be reduced. However, some erosion will occur to the shoreline.

Socially, this alternative is advantageous as it takes two to three months and can be undertaken in the winter. Additional social advantages and disadvantages can be found in Table III-4.

<u>Alternative 3, Partial Drainage and Dragline Dredging in Lake Basin</u>

For Alternative 3, the lake can be drained to dry the in-lake shoreline banks a distance of 25 feet into the middle of the lake. The reduced water volume would increase the operation's efficiency, as less water will be involved in the removal process. Most vegetation areas along the

Job and/or Equipment	Service Costs
Drainage	$25,000
Sediment Removal @ $3.60/cy	$180,000
Total Costs	$205,000

TABLE III-3. Cost estimates for dragline dredging after partial drawdown.

Alternative	Advantages	Disadvantages
#1 Hydraulic Dredging	1. Costs deferred through resale of dredge (applies to purchase of dredge 2. Little shoreline destruction 3. Implementable in any season	1. Obstructions mav damage equipment 2. Fences required for safety at dewatering ponds 3. Dredge storage (applies to purchase of dredge 4. Extensive soil erosion
#2 Hydraulic and Shoreline dredging	1. Cost-efficiency, as sediment is pumped to permanent disposal site 2. Less erosion from water transport 3. Shortest operation time: 3-6 months	1. Additional shoreline reconstruction costs 2. Some erosion from sediment pond, shoreline dredging, and trucking of wet silt 3. Disturbance to shoreline vegetation 4. Noise and traffic from trucks 5. Pipelines obstructing roads and paths

TABLE III-4. Advantages and disadvantages of sediment removal alternatives.

Alternative	Advantages	Disadvantages
#3 Partial Drainage and Dragline Dredging in Lake Basin	1. Productivity is increased, reducing costs 2. Less water involved in dredging, reduction in erosion 3. Less shoreline disturbance than with shoreline dredging operating out of the lake basin	1. Additional bank reconstruction costs 2. Some erosion from sediment transfer, heavy equipment on banks, and drainage into the Saline
#4 Complete Drawdown and Sediment Excavation	1. Dry excavation and transport is most productive and cost-efficient 2. Fewer truck trips 3. Avoid erosion to banks and lake by removing and transporting dry sediment 4. No water leakage from trucks	1. Costs increase; approaching those of Alternative 3 if lake basin does not dry sufficiently 2. Some erosion into Saline Ditch 3. Noise and traffic from trucks 4. Safety considerations 5. Longest completion period: 10-20 months 6. Previously undisturbed islands may be accessible, detrimental to wildlife

TABLE III-4. (continued)

shore will remain undisturbed. Two to four areas of 20–25 feet wide will be required for equipment access.

The major advantage associated with this alternative is its low cost. Table III-3 shows estimated costs for Alternative 3. Because the sediment will be partially dried, dragline dredging will be more cost-efficient than Alternative 2. Erosion will be minimal also. Shoreline damage will result from the operation of the dragline, requiring bank reconstruction.

The Saline Ditch may experience flooding or erosion from the drainage of Crystal Lake. Damage that the Park District would be held liable for should be minimal if discharge from the lake is regulated in some manner, such as pumping, or if lake discharge is directed through the outflow structure.

Alternative 4, Complete Drawdown and Excavation

Complete drawdown and sediment excavation involves drainage similar to Alternative 3 and as described in the first summary of lake drainage and excavation. However, a longer drying period, continuous pumping of water, and possible reservoir construction might be necessary. The dry sediment will be removed with light and efficient equipment. The primary advantages, as listed in Table III-4, come from the use of smaller equipment, reducing costs and minimizing erosion. As with Alternative 3, there will be the possibility of environmental damage to the Saline Ditch.

The estimated total costs for Alternative 4 are approximately $200,000. The cost-efficiency and environmental advantages described earlier, as well as others, are presented in Table III-4.

The major disadvantage of Alternative 4 is the length of time required for completion. The drying time will depend, to an extent, on the amount of rainfall during the process. The majority of the slopes in the vicinity are minimal, so drainage of rainwater, after rerouting of the storm sewers, should not be excessive.

Conversion to Alternative 3 (i.e. partial drainage and dragline dredging) may be required if it is found that inclement weather conditions prohibit complete drying of the lake bed and sediments. If the Park District simply wanted to speed up the time for completion of the operation, the areas that were not drying thoroughly could be dredged with a dragline crane.

Most likely, the areas that might accumulate rainfall will be accessible from the steeper slopes that the water flowed into the lake off of. As the steepest slopes generally will need to be physically reconstructed and stabilized, operating a dragline crane from these locations should not increase bank reconstruction and stabilization costs.

In addition to the time required for completion of Alternative 4, the basin's condition while drying is a social concern. The above disadvantage would require that some measure be taken to restrict access to the lake.

If complete drainage is implemented, the Illinois State Geological Survey should be contacted and inquiries made as to the possibility of their personnel conducting core borings. Borings should reveal any geological characteristics which might prevent complete drainage. Complete drainage may not be possible if, in digging the reservoir or water drawing pit, a sand and/or gravel aquifer is encountered.

Each alternative has certain advantages and disadvantages associated with its use, which are outlined in Table III-4. The principle advantages and disadvantages of each method of sediment removal are summarized in the following list. (A - advantage, D - disadvantage.)

1. Hydraulic Dredging, Alternative 1.

   A - The most favorable aspect is that the shoreline banks of the lake remain undisturbed.

   D - The strongest negative aspect is the erosion related to drainage of the sediment-water mixture.

2. Hydraulic Dredge Supplemented with Shoreline Dredging, Alternative 2.

   A - Less erosion than hydraulic dredging.

   D - Disturbance to shoreline vegetation.

3. Partial Drainage and Dragline Dredging, Alternative 3.

   A - Cost-efficient, as well as less erosion than the two previous alternatives.

   D - Bank destabilization; additional reconstruction costs.

4. Complete Drainage and Sediment Excavation, Alternative 4.

   A - Cost-efficient, minimal erosion and disturbance to the shoreline.

   D - Length of park inavailability.

After comparison of the advantages and disadvantages related to each alternative, lake drawdown and excavation appears to offer the most net advantages. Most importantly, cost-efficiency and minimal erosion are the principle advantages of Alternative 4. If in the unfortunate circumstance that inclement weather prevents drying of the lake bed, Alternative 3 can be implemented by simply contracting a shoreline dredge.

Sediment Disposal

After the lake sediment is removed, it must be transported to either a temporary or permanent location. This can be accomplished by trucking or piping the sediment. If trucks are used, care should be taken to maintain clean streets, so area residents do not complain. Watertight trucks, along with street sweepers, may be necessary. The city of Urbana has an ordinance requiring trucks to have watertight beds, so enforcement will be imperative. If the sediment is piped, as in the case with the Mudcat alternative, the sediment can be located up to 5,000 feet from its ultimate destination without additional pumps or pipes. The sediment can be temporarily disposed of in drying ponds at the existing playground, on Park District land.

The Mudcat alternative will require partial drying of the sludge before it can be used or transported. Two ponds large enough to each contain a month's worth of sludge, or about 15,000 square yards, can be used in rotation. Sufficient drying will occur after 1½ to three months. It can then be transported to a permanent location.

Permanent locations, including Western Lion Ltd's Urbana landfill, the county fairgrounds, and farmers, are available for either the wet or dried sludge. To make disposal most cost-efficient for the Park District, it is preferable that the eventual user pay any trucking costs. Mr. Richard Sheets, operator of Western Lion, has agreed to accept all of the sediment, to be used as an additional layer of soil at the landfill. The existing layer of clay used to cover daily operations at the landfill is not conducive to vegetation, so Mr. Sheets has expressed the desire to use the sediment in his efforts to revegetate the site.

The Champaign County Fairgrounds is another final disposal site. Mr. Keith Kessler, fairgrounds manager, has agreed to take all the wet sediment provided operations cease between June 1 and August 1. The sediment can be retained in rectangular or square holding structures approximately three to five feet high, or a height necessary to confine the sediment. Mr. Kessler has proposed spreading the sediment in pastures around the track, or on the infield after it is dry.

Farmers are another possible disposal solution. The availability of the sediment could be publicized in local newspapers. To ensure that the sediment meets EPA standards, it must be tested for levels of heavy metals and other contaminants. Provided that the sediment meets these federal and state standards, it can be made available to local farmers or gardeners to utilize.

Cost estimates for trucks holding ten cubic yards range between $35-40 per hour. Assuming a round trip distance of two miles, it is anticipated that two to three trips per hour can be made between the lake and the landfill per truck.

Water Source

A new water source for Crystal Lake is needed to refill the lake and permit the flow through of water. The inflow of water combined with the outflow structure will create a current in the lake. This current will aid in preventing stagnation and associated algal blooms.

Alternative water sources for Crystal Lake include:

1. A well and pump

2. A connection to the city water supply

3. Diverting the Saline Ditch

4. Tertiary treated sewage effluent

In choosing a water source, water quality and cost were the basic criteria with reliability a secondary consideration. The water quality of alternatives two and four are expected to be detrimental to the lake. City water is chlorinated, which would be harmful to the aquatic life in the lake (Osborne, 1981). The sewage effluent would, in reality, contain too many nutrients. This would just aggravate the condition of the lake until a situation similar to the one faced now occurs. Also, tertiary treatment has a tendency to be unreliable, with frequent breakdowns of the system. The water from the Saline may deteriorate in the future, due to future urbanization, thereby forcing the Park District to find a new source. All three of the above alternatives are potentially costly and therefore not economically feasible.

Slope Stabilization

The erosion on the banks around Crystal Lake is caused by two factors:

1. Surface runoff, compounded by overuse; and
2. The natural wave action of the water.

The runoff carries sediment into the lake. The continuation of these processes over time can degrade the quality of the lake, resulting in a situation similar to the one being faced today. Therefore, it is important that surface runoff be controlled. To accomplish this there are two objectives:

1. To stabilize the banks through technical methods and/or revegetation; and

2. To control access to the banks to prevent overuse.

1. Technical Methods of Bank Stabilization

A. Rip Rap

Rip rap (Figure III-3) is a method where the shore is covered with a layer of stones and/or boulders. According to personal communication with Professor Nieto, the coverage needs to be two inches deep. This method is generally applicable under any conditions. One exception is on very steep slopes. Another advantage of this method is that it conforms to the contour of the bank, and if dark stones are used, a rather natural looking setting can be achieved.

The limitations of rip rap include the availability of suitable size stones and the associated costs of quarrying, transport, and placement of the material. The stones may need to be compacted by a truck or some other similar vehicle.

B. Geo-textiles

Geo-textiles are a type of fabric designed for use in the engineering field (Figure III-4). It is used for road construction and lining hazardous waste ponds. There is one type of fabric designed for slope stabilization. This fabric is specially designed to handle surface runoff while protecting the soil underneath. The fabric also allows seepage of water to the soil below. Although this fabric is relatively new, the lifespan is estimated to be in the fifty year plus range.

The major limitation of this method is that proper installation is essential to ensure effectiveness. Therefore, it may be necessary

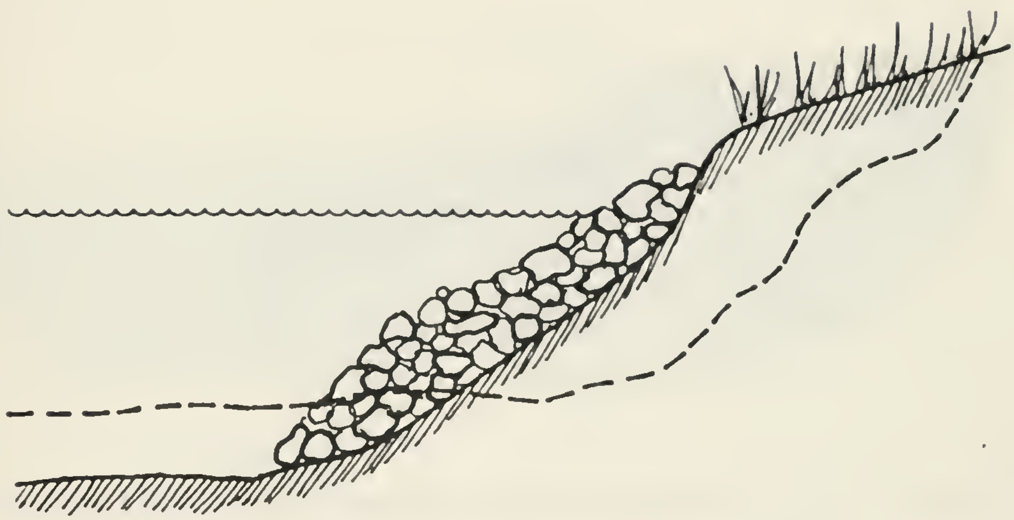


FIGURE III-3. Illustration of rip rap, a technical method for bank stabilization.

FIGURE III-4. Illustration of geo-textile, a technical method for bank stabilization.

to hire special personnel to install the product. A layer of dirt or rip rap may be needed on top of the fabric to conceal the unnatural appearance of the material.

C. Gabion mattresses

Gabion mattresses are wire boxes filled with rocks and boulders implanted along the shore with an apron (Figure III-5). Gabions are flexible and can withstand freeze-thaw conditions as well as contour along the bank. Although they are wire boxes, they can be filled with dirt to allow vegetation to grow out of the boxes to give them a more natural appearance.

There are some limitations to the use of gabion mattresses. First, very steep and very shallow slopes require special treatment such as grading the bank. The second major limitation is in regard to the soil type. Fine soil will wash out from underneath the gabion mattress unless special precautions are taken. These include the use of a permeable membrane placed behind the structure, at additional cost.

D. Miscellaneous methods

A number of other methods should also be mentioned. These include flagstones, railroad ties, steel sheet retaining walls, and concrete seawalls. Although the above methods are relatively inexpensive, each has distinct disadvantages relative to Crystal Lake's needs. Flagstones can develop a slippery surface, making them hazardous to the public. Railroad ties often contain creosote which is detrimental to aquatic life. Steel sheet and concrete retaining seawalls have an exaggerated unnatural appearance that would be difficult to camouflage with plants.

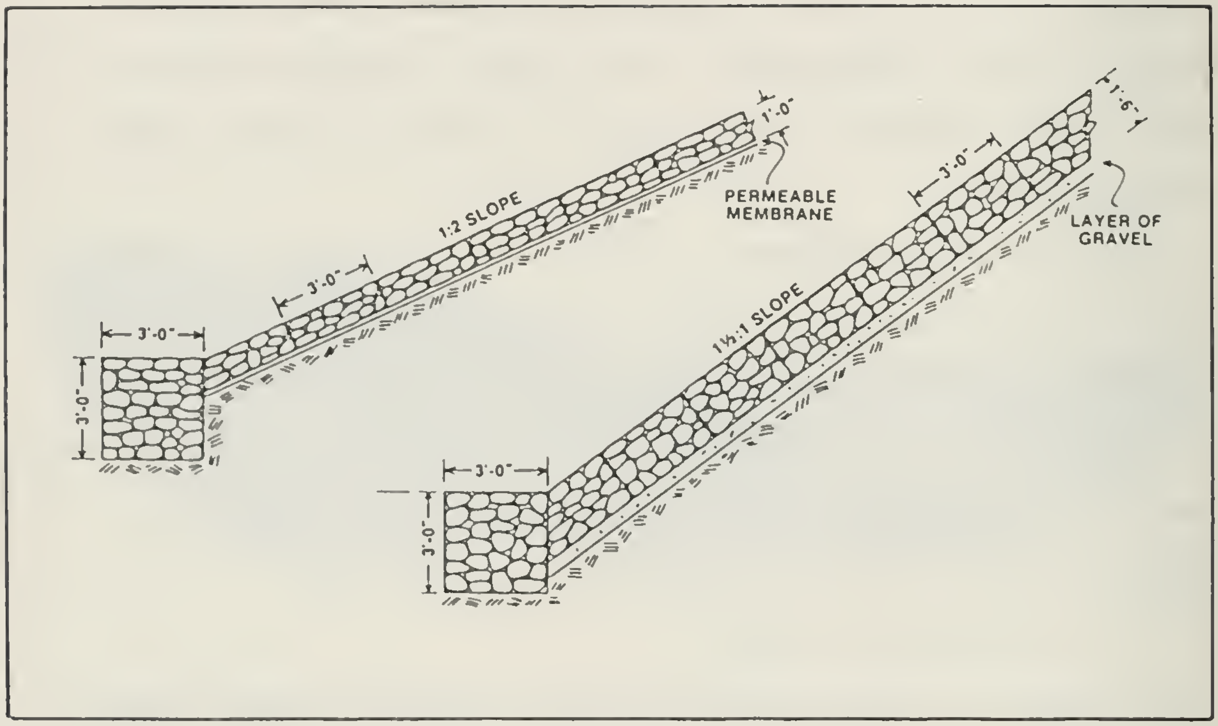


FIGURE III-5. Illustration of gabions, a technical method for bank stabilization.

2. Controlling access

Overuse is a prime contributor to the erosion of the banks along Crystal Lake. One of the objectives of this project is to develop a method of controlling access to the banks to prevent overuse and therefore future erosion problems. Since Crystal Lake is the only recreational body of water in Urbana, it is faced with a high level of use. This is especially true during fishing season (the warm months). Furthermore, results of our survey indicate that lake usage will likely increase following restoration (see section 6).

One problem that may have caused the overuse is the limited amount of shoreline and the large number of people requiring access to the shore. Another possibility is that the devoted fishermen were jockeying for position along the banks to find the best fishing spots. This project is assuming that the first situation mentioned above is the cause of overuse. A definitive study of the question is beyond the scope of this workshop. Whatever the reason, it must be recognized that Crystal Lake is a public lake and the whims of a few devoted fishermen must not take precedence over the requirements of the general public.

Therefore, the problem to be overcome included the following characteristics:

1. How to increase access to the lake while decreasing the amount of shoreline used;
2. How to make the changes in a "neutral" manner, so that they would not disrupt the natural appearance of the lake;
3. What would be the most economical and feasible method; and
4. To make the lake accessible to the handicapped.

With these considerations in mind, the solution became clear - docks.

The Clark, Dietz report mentioned these and it seems a logical conclusion to the problem. Docks are a universal solution to the problem of access to water and would seem to be an acceptable solution for Crystal Lake (Figure III-6).

There are special considerations that need to be dealt with in regard to the Crystal Lake project. The size of the lake is a prime consideration. The docks cannot be too large or they will be out of proportion with the lake. In keeping with federal and state guidelines, the docks will have to be made accessible to the handicapped. Additional consideration will be how the construction of the docks may affect the development of a quality fishing environment.

As previously mentioned, a study determining the exact amount of use the lake receives is not possible within the framework of this workshop. Because of this, a definitive number of docks needed cannot be determined. However, after examining the pattern of overused spots along the banks, the suggested number of docks to be constructed is five (Figure III-7).

The docks will utilize the same amount of space along the shoreline that two or three people would normally occupy. However, the docks will be designed to accomodate between five and ten people in the same amount of space. This will allow people access to the lake in a less environmentally destructive and more safe fashion (Figure III-7).

This method is more acceptable than an alternative of fencing off the areas. The docks will serve as a focus to direct traffic along the banks. This, in combination with the replanting of areas that have been designated off limits, will help discourage entrance to the banks.

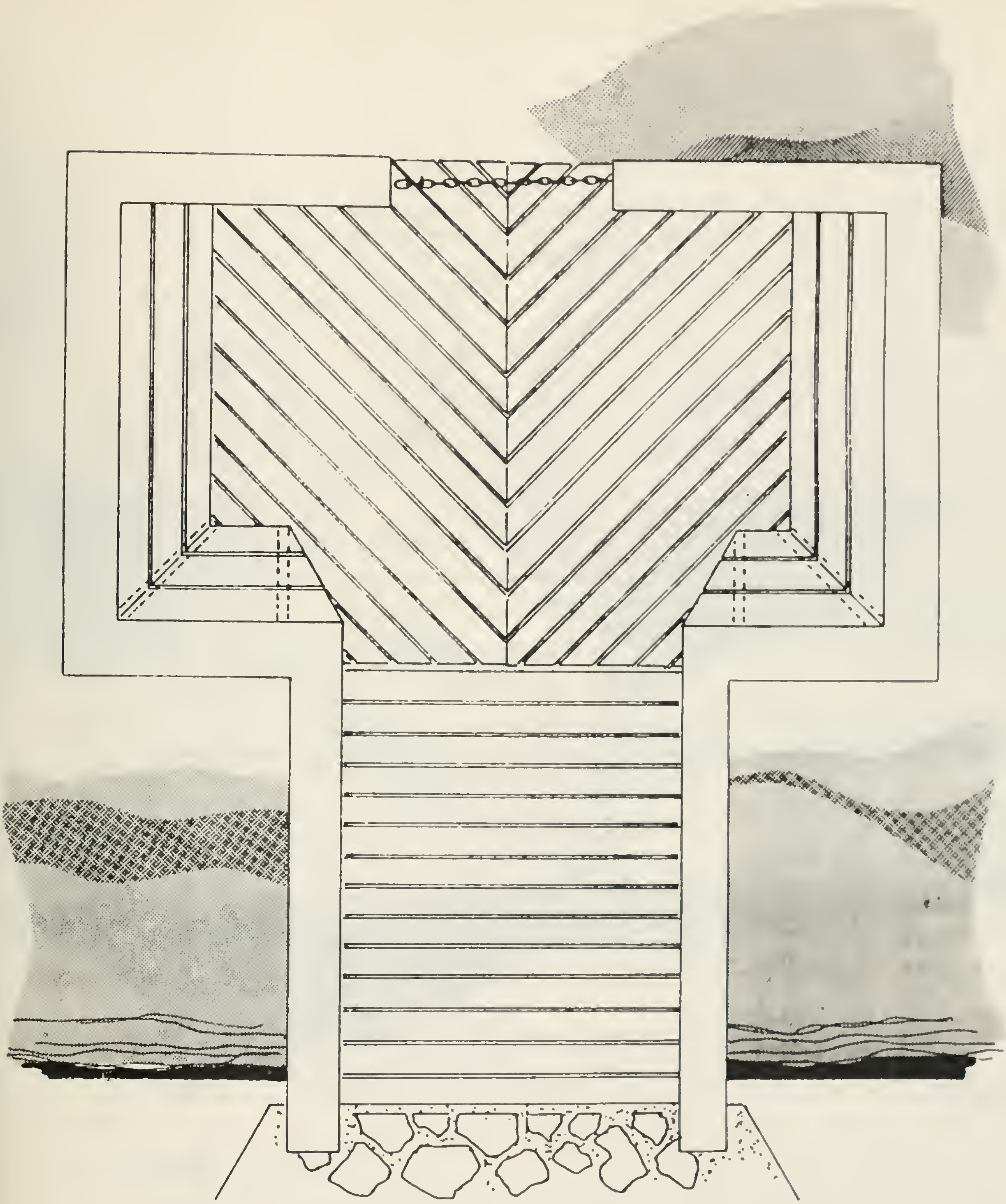


FIGURE III-6A. Top view of docks.

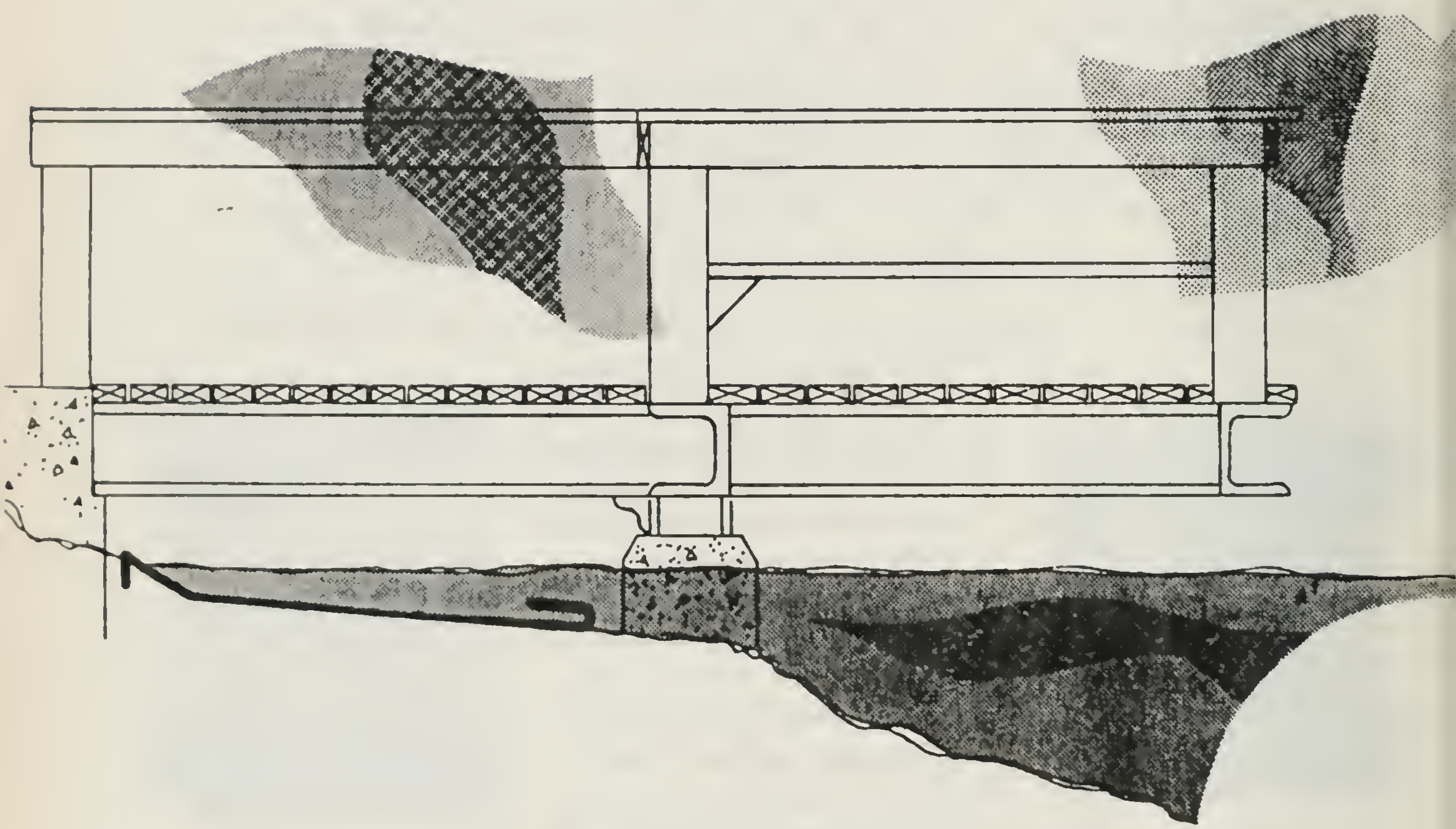


FIGURE III-6B. Side view of docks.

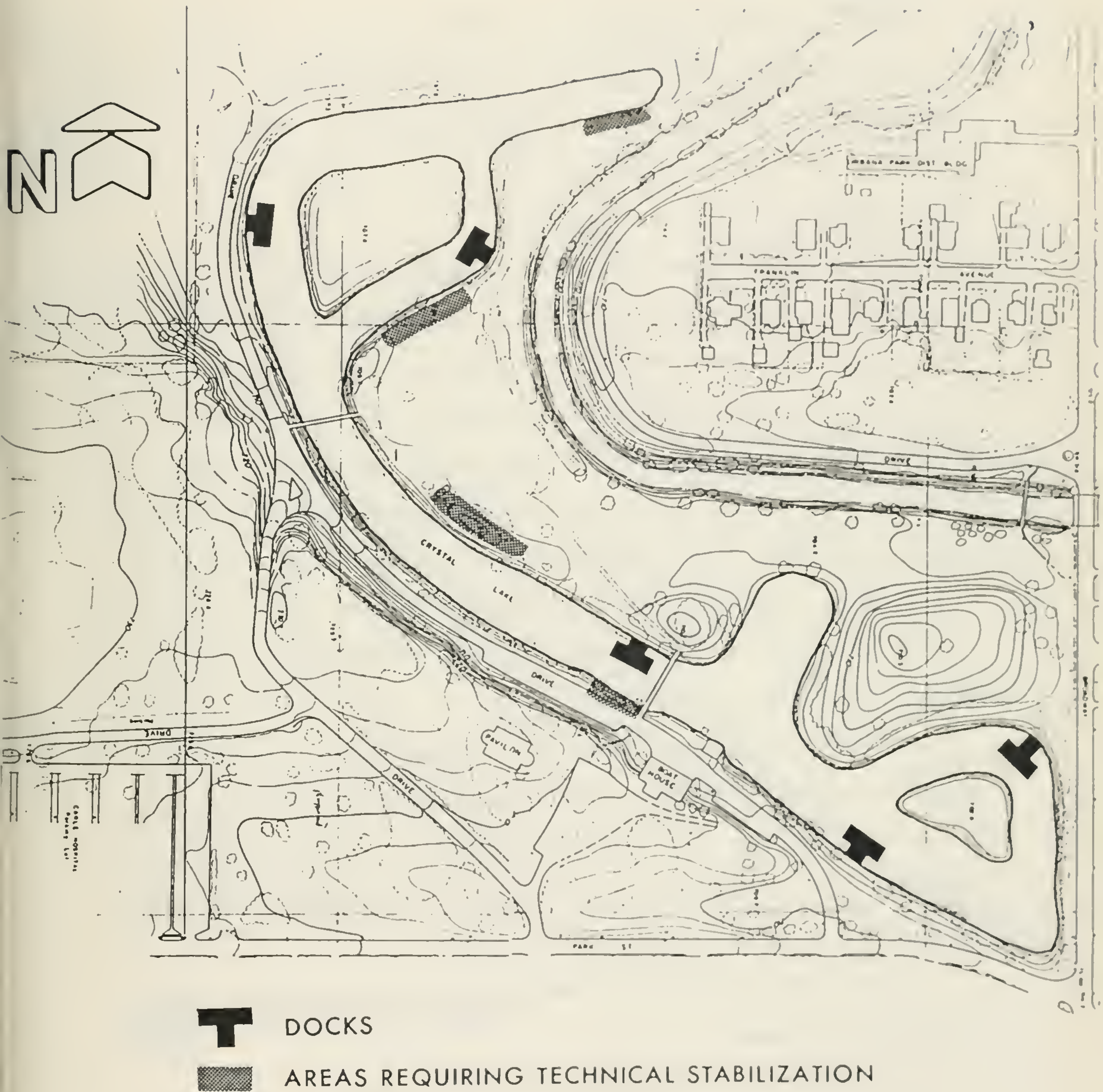


FIGURE III-7. Proposed locations for T-docks.

Revegetation

Many areas along the shoreline of Crystal Lake are not suffering from severe erosion, but could become so if steps are not taken to stabilize the soil. It is the purpose of this section to discuss the current conditions of the vegetation at Crystal Lake and what can be done to improve the aesthetic quality of the shoreline.

Inspection of the banks reveals many areas where there is a need for revegetation. Erosion has occurred at these points because of heavy foot traffic. Fishermen looking for new areas seem to be the main cause, and the primary purpose of revegetation would be to restrict access to the shoreline and to stabilize the banks to prevent excessive erosion. There are approximately 850 linear feet of shoreline that needs revegetation (Figure III-8). Some revegetation will take place in conjunction with structural methods to improve bank stabilization. Much of the planting will take place in areas where vegetation already exists, but groundcover has been worn away, exposing soil.

Plants possess several functions other than their aesthetic qualities. Furthermore, plants can screen unwanted views, act as barrires, and restrict the flow of runoff enabling the water to soak into the soil and not erode it. Plants also provide food and cover for wildlife, which is important in an urban area such as Urbana.

The selection of plants for revegetation of the shoreline will depend on four criteria:

1. Hardiness to climatic conditions of Illinois;
2. Site-specific conditions;
3. Functional considerations; and

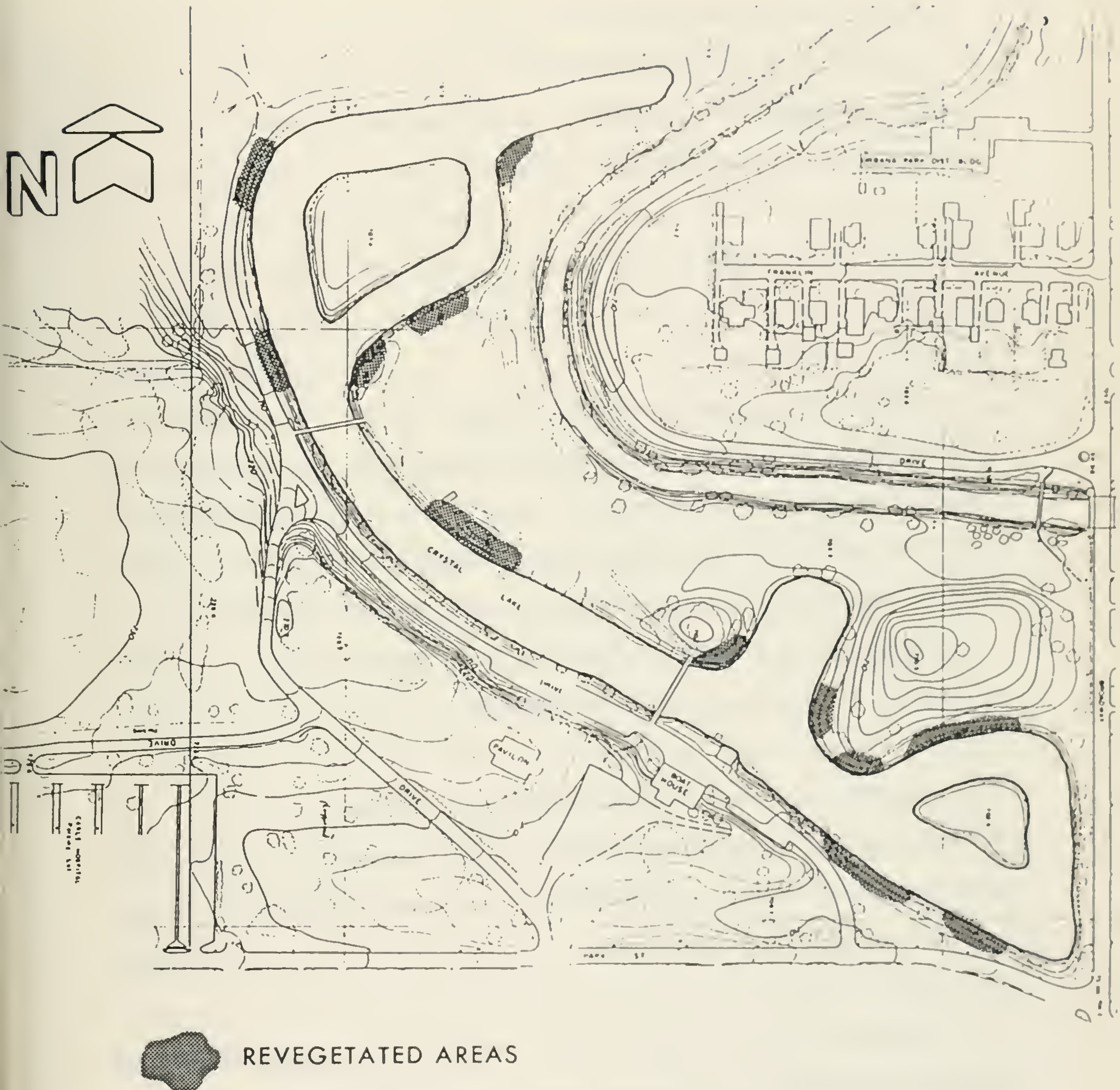


FIGURE III-8. Shoreline areas to be revegetated.

4. Aesthetic considerations.

Secondly, the individual conditions of the shoreline should be analyzed. Specific site conditions include the composition of the soil, and the amount of sun or shade that falls on the site. Information taken from a soil survey map indicates that the soils should permit most plants to be grown with a minimal amount of soil preparation. Each site is different with respect to sun or shade conditions and must be independently evaluated as such.

Plants will need to form a barrier against people walking up to and along the bank. The structure of each plant is a major consideration. In areas where bank degradation has occurred, plants with thorns or dense branching should be selected to act as a barrier. Since minimal care will be given to the plants, species should be chosen that are hardy and maintenance-free. During the first few growing seasons, all new plants should be protected from foot traffic until they have become established.

The selection of proper plants can add to the æsthetic quality already existing in the park. Although this aspect is not of primary importance, it is a benefit that should not be overlooked. Existing plantings are arranged in informal shapes, giving the park a natural character. Plants chosen should display the same natural feature in their form and their placement around the lake's edge. This should supplement the natural landscape that has matured there.

Costs for revegetating the shoreline will depend on two factors, the type of species chosen and the quality of plants used. On the average, plants will range from $10 to $15 per plant. Some species will be more expensive than others because of market supply. Generally, groundcovers are less expensive than shrubs. Prices will vary depending on the availability from nursery supplies. In addition to replanting, other costs to be considered are soil preparation before planting and maintenance during the early years.

RECOMMENDATIONS

Sediment Removal

Based on the criteria of costs, social impacts, and environmental considerations, it is recommended that the Park District proceed with lake drainage and sediment excavation to restore Crystal Lake. Although the process is lengthy, Alternative 4 promises to offer few negative environmental impacts, and also lower costs. Functional to the lower costs and less environmental damages, the fewer truck trips and less leakage of water from the trucks are also social advantages.

Alternatively, if the Park District does not want to put the lake out of commission for any summer season at all, Alternative 2, Hydraulic Dredge Supplemented with Dragline Crane, is recommended. The main advantage of Alternative 2 is that it is relatively cost-efficient and minimizes erosion.

Sediment Disposal

Based on these findings, it is recommended that the fairgrounds be utilized for final disposal of the sediment. As the park and fairgrounds are both public, it is recommended that the sediment be used for a public benefit. It will be more cost-efficient to do this, as Mr. Sheets has not committed himself to pay for disposal. The fairground land is also much closer than the landfill, which will save time and energy involved with transportation to the landfill. This alternative has the additional advantage of eliminating the problem of street cleaning. It will, however, necessitate the operation of the project during times when the fair is not going on. This appears to be the principle drawback. The sediment removed during the two months during which the fair is being held could be temporarily stored at the present Park District playground, and then trucked to the fairgrounds after the fair is over. The sediment will have to be partially dried, which would require the construction of drying beds, within the confines of the Park. Furthermore, the disposal of sediment at the fairgrounds must be artificially retained until sufficient vegetation can be established to prevent sediment erosion onto surrounding areas and eventually into the Saline Ditch. Such retainers are, however, simple to construct and operate.

Water Source

After evaluating the available options for a new water source, it is recommended that the first alternative, a well and pump, be used.

As discussed in the Clark, Dietz report, the well should be drilled into either the lower or middle aquifer (Figure III-9). Discussions with two private contractors indicated that a flow of 200 to 225 gallons per minute is the amount needed to create a current in the lake. This is the same as in the Clark, Dietz report. The three estimates for this rate obtained from local drilling contractors ranged from $3,000 to $4,000 for a 200 feet deep well and pump. However, if it is determined that a

Scientific Name	Common Name
Groundcover	
	Crownvetch
Hypericum prolificum	Shrubby St. Johnswart
Pachysandra terminalis	Japanese Spurge
Vinca minor	Periwinkle
Shrubs	
Berberis julianae	Wintergreen Barberry
Crataegus oxycantha	English Hawthorn
Elaeagnus umbellata	Cardinal Autumn Olive
Ligustrum amurense	Amur Privet
Pyracantha coccinea	Scarlet Firethorn
Robina hispida	Bristly Locust

TABLE III-5. A list of plants recommended for planting along the shoreline of Crystal Lake.

greater flow is necessary, the costs will increase accordingly. It is possible, with a large pump, to see flows up to 3,000 gallons per minute.

Other factors that should be taken into consideration before pumping the water into the lake include:

1. The chemical composition of the water (i.e. are there traces of heavy metals or other signs of contamination?); and

2. The temperature of the water - is the water in a temperature range that will accomodate the desired aquatic life in the lake?

This type of information will only be available after consulting with an engineer or a drilling contractor, or by examining groundwater chemical data at the Illinois State Water Survey.

Outflow Structure

An outflow structure is important to assist in creating a current in Crystal Lake. The current structure at the north end of the lake is in poor repair. Due to this, it is difficult to assess the condition of the structure and its potential for rehabilitation. It is recommended that the structure be cleaned up and that a professional engineer be hired to fully evaluate the condition of the existing structure. If a new outflow structure is needed, the construction would have to take place in the first phase of the project. It is possible that it could be done in conjunction with draining the lake, if that dredging method is approved. There is also the possibility of inflow of water from the Saline Ditch and the accompanying trash fish. This inflow would degrade the quality of the water and aquatic life in the restored lake.

Although the present workshop does not have the technical knowledge to fully evaluate the outflow structure, there are at least two factors that this structure should possess. The first is a backflow valve to prevent the introduction of water and fish from the Saline into Crystal Lake while still allowing water from Crystal Lake to flow into the Saline. A filter system should also be investigated. This system would prevent the clogging of the pipe between the lake and the Saline with sediment and other debris. The filter could be placed outside the pipe where routine cleaning would be possible.

Bank Stabilization

It is recommended that a combination of technical methods and re-vegetation be used to control slope erosion on the banks of Crystal Lake. There should be two technical methods used: the geo-textiles and gabion mattresses. The geo-textiles are recommended due to their long lifespan and because they were designed specifically to handle surface runoff and because of their low costs. The fabric should be used on the areas under the docks where it will not be seen, therefore removing the need to cover it with rip rap. Gabions can be used in areas that have been designated in need of technical stabilization but that will not be a dock access area. The geo-textile fabric can be placed underneath the gabions if it is determined that there is silty soil along the banks. The docks combined with revegetation will control access to the shore and control bank erosion (Figure III 10).

Shoreline Revegetation

A suggested plant list which meets the above criteria is included in Table III-5. Although incomplete, the list provides a starting point which can be added on to. Several plants should be used from the list to provide a variety of texture and form to the existing landscape in the park.

Replanting should take place in late summer or early fall after the dredging has finished. Only after all construction along the shoreline is completed should preparation start for replanting. This will avoid costly mistakes of destroying shrubs that were planted beforehand.

From the observations made at the park, it is suggested that dead or dying trees be cleared along the shoreline. It is clear that the visual appeal is from views across the lake to other areas of the park. A balance should be maintained between existing trees and new vegetation being planted. A Landscape Architect or Horticulturist is recommended to mark these trees for removal before dredging takes place.

WATER QUALITY MONITORING AND VASCULAR PLANTS

SECTION IV. WATER QUALITY MONITORING AND VASCULAR PLANTS
by
B. Begolka and M. Chawla

INTRODUCTION

A water quality monitoring program, and a plan for the use and control of aquatic vascular macrophytes following sediment removal, were developed for Crystal Lake.

The purpose of lake monitoring is to develop an early warning system which can be used to detect excessive nutrient loading within the lake. Water quality is affected by all watershed activities and characteristics which substantially dictate what aquatic life forms can exist within the lake. Water quality is reflected in the species composition and diversity, population density, and physiological condition of indigenous communities of aquatic organisms (Cairns and Dickson, 1973). The present poor water quality of Crystal Lake can be primarily attributed to an overloading of nutrients, i.e. phosphorus and nitrogen, and excessive sediment inputs. A water quality monitoring system is therefore of prime importance as it can serve as an early warning system to detect chemical imbalances in the lake ecosystem.

Phosphorus, nitrogen, dissolved oxygen, and transparency are most indicative of the trophic condition of a lake (Kothandaraman and Evans, 1983). Phosphorus is usually the most important nutrient controlling lake productivity (U.S. EPA, 1980), and the orthophosphate form is an important measure of trophic state. Dissolved orthophosphate approximates the soluble reactive phosphorus that can be immediately used by photosynthetic organisms. Phosphorus depletion usually occurs during algal blooms in eutrophic lakes, when concentrations are reduced by excessive consumption, by algal cells.

Nitrogen is also an important plant nutrient as it is both required by photosynthetic organisms and sometimes in limited supply within lakes. When the weight ratio of total nitrogen to total phorphorus (N:P) is less than 15:1, nitrogen is likely to be the limiting nutrient (U.S. EPA, 1980).

Dissolved oxygen is required by all aerobic aquatic organisms for survival. Measurement of dissolved oxygen and vertical temperature provides information on layering of water bodies, mixing, and on the occurrence and extent of potential oxygen deficits. Dissolved oxygen is the amount of oxygen in solution in the water and thus available to aquatic organisms. If sufficiently depleted, fish and other organisms may suffocate, and the quality of their habitat will be adversely affected. Oxygen depletion occurs when decay of organic matter such as fallen leaves, macrophyte kills, and normal respiration of aquatic organisms remove dissolved oxygen from water faster than it is replaced by reaeration or photosynthesis (U.S. EPA, 1980).

Lake transparency can indicate the amount of suspended matter within the lake, may present an indirect measure of algal blooms or the degree of eutrophication, and approximates the depth at which photosynthesis can occur.

A plan for the use and control of aquatic vascular macrophytes following restoration was developed. Presently, the turbid water of Crystal Lake has substantially reduced the amount of light reaching the lower portions of the lake; therefore, submerged vascular macrophytes are virtually non-existent and the emergent species are limited to a few shoreline areas. Aquatic macrophytes are an important part of a lake's ecosystem providing fish habitat, bank stabilization, and lake bottom stabilization. Although vascular macrophytes are important to the lake, they can become a problem if their growth becomes excessive.

Management techniques, if started at the completion of lake restoration, should control the growth of vascular macrophytes. If such growth becomes excessive, the control measures discussed in a later section of this report (see FINDINGS) can be implemented.

METHODS

The information contained in this report was obtained through a variety of sources including a literature review of pertinent information, and through personal communications.

Information regarding the critical nutrient levels (phosphorus and nitrogen), dissolved oxygen, and transparency was obtained from Donna Sefton (1983). These critical levels can provide an early warning to possible future nuisance growths of aquatic plants. Information on the use of a Hach-kit was obtained from Culligan, Inc. (Champaign, IL). Additional information about Hach-kits was also received from Prof. Osborne (1983). A Hach-kit provides a battery of tests that can be performed to test water quality.

Information on aquatic plants was obtained from Pam Tazik (1983), who provided various articles on the use of management techniques; a handbook on aquatic plants of Illinois, differentiating native from exotic species; as well as specific planting instructions for cattails and arrowheads. Additional information on aquatic plant control was obtained from Dr. Hiltibran (1983) who cited both benefits and limitations of various control measures, and literature on the use of endothal (chemical control). The information obtained from these valuable sources was carefully evaluated and is presented here as it applies to Crystal Lake.

FINDINGS

Water Quality Monitoring

Lake monitoring involves the measurement of such basic physical and chemical parameters as phosphorus, nitrogen, dissolved oxygen, and water transparency. These parameters describe lake trophic state (U.S. EPA, 1980). If acceptable lake trophic conditions are to be maintained, parameter levels should be maintained in accordance with Illinois EPA regulations. The appropriate parameter levels are described below.

Phosphorus may exist within lake systems as orthoinoganic phosphate, metaphosphate, and organic phosphorus. Of these, only inorganic orthophosphate (PO_4^{3-}) is commonly measured. Orthophosphate supplies an essential nutrient necessary to aquatic plant growth (Baas, Westerdahl, and Perrine, 1976). Total lake phosphorus level should not exceed .05 mg/l to maintain acceptable trophic condition. However, it should be noted that nuisance algae and plant growths may result from .02 mg/l phosphorus (Sefton, 1983).

The production level refers to the total amount of living matter produced in a lake per unit time (Sefton, 1982). Because phosphorus frequently controls lake production level, it is an important measure of trophic state. During the summer, phosphorus in the uppermost layer of a lake (epilimnion) is present in its bound form (i.e. metaphosphate) as part of living organisms. Organic phosphorus from fallen leaves, decaying plants, and dead organisms is often converted to inorganic forms by bacteria in the upper layers (Baas, et.al., 1976). Additional sources of phosphorus include urban runoff, use of fertilizers in the area, and animal wastes. As sediments settle during lake stratification, phosphorus concentrations in surface waters gradually decline. Phosphate returns to the epilimnion primarily during spring and fall turnovers when massive lake mixing occurs. There it may contribute to algal blooms (Baas, et.al., 1976).

Nitrogen, as a basic constituent of amino acids, is essential to all living organisms (Baas, et.al., 1976). The most abundant gas in the atmosphere, nitrogen can undergo various transformations in nature. Nitrogen in natural waters generally occurs as nitrate, organic nitrogen, and ammonia nitrogen (Kothandaraman and Evans, 1983). Nitrate nitrogen (NO_3^-), and to a lesser extent, ammonia (NH_4^+) can be utilized by aquatic plants and algae to support growth. Sewage discharges, nitrogen-based fertilizers, nitrogen-rich soil, and contaminated runoff all produce excessive in-lake levels of ammonia and organic nitrogen. Levels of nitrate nitrogen should not exceed 0.3 mg/l. Nuisance growths may occur at levels as low as 0.1 mg/l (Sefton, 1983), according to Illinois EPA.

Dissolved oxygen is necessary to maintain aerobic conditions in waters and is considered a primary indicator of the suitability of surface waters for support of aquatic life (Krenkel and Novotny, 1980). Because low levels of dissolved oxygen in water usually indicate the presence of decomposing organic matter, dissolved oxygen is an important indicator of lake condition. Dissolved oxygen enters the water through gas exchange at the water surface (aeration), and is distributed throughout the lake by vertical mixing and diffusion (Baas, et.al., 1976). In-lake oxygen concentration decreases when the decomposition of such organic matter as fallen leaves, macrophyte kills, and the normal respiration of aquatic organisms, removes dissolved oxygen from water faster than it can be replaced by reaeration or photosynthesis. Dissolved oxygen generally ranges from 0-15 mg/l. The Illinois Pollution Control Board general use standard states that dissolved oxygen should not be less than 6 mg/l during at least 16 hours of every 24 hour period, nor less than 5 mg/l at any time (Sefton, 1983).

Transparency is an indication of light penetration into water bodies. It provides a general index of water clarity, and physical properties including water color, turbidity, dissolved and suspended organic and inorganic material. Severe erosion of urban runoff can greatly reduce water clarity. Spring and fall turnovers, which contribute to algal blooms, also lessen transparency. This reduction in lake transparency limits the amount of light available to aquatic plants for photosynthesis.

Quantitative analysis of nutrient concentrations (phosphorus and nitrogen) and dissolved oxygen can be conducted by use of a Hach-kit, while transparency can be measured using a secchi disk. These analyses should be conducted at regular intervals at the same locations each time.

Hach-kit model DR/1 is compact, easy to operate, and completely portable. It comes with a colorimeter and a pH meter. It has been designed for more than 50 different water and wastewater tests. A list of tests that can be performed by this model is given in Table IV-1.(Hach, 1982).

TEST	RANGE
Aluminum	0-1 mg/l
Barium	0-300 mg/l
Boron	0-15 mg/l
Bromine	0-4 mg/l
Cadium	0-70 ug/l
Chlorine, Free	0-1.7 mg/l
Chlorine, Total	0-1.7 mg/l
Chromate, Sodium	0-1000 mg/l
Chromium, Hexavalent	0-0.5 mg/l
Chromium, Total	0-0.5 mg/l
Cobalt	0-1.2 mg/l
Color	0-500 units
Copper	0-3 mg/l
Copper, Dissolved and Total Recoverable	0-2 mg/l
Cyanide	0-0.2 mg/l
Cyanuric Acid	0-50 mg/l
Detergents	0-0.2 mg/l
Fluoride	0-2 mg/l
Hydrazine	0-0.3 mg/l
Iodine	0-6 mg/l
Iron, Ferrous	0-2 mg/l
Iron, Total (2 ranges)	0-2 mg/l, 0-0.9 mg/l
Lead	0-150 ug/l
Manganese, High Range	0-10 mg/l
Manganese, Low Range	0-0.6 mg/l
Mercury	3 ug/l and up
Molybdenum, Molybdate	0-50 mg/l
Nickel (2 ranges)	0-2 mg/l, 0-0.6 mg/l
Nitrogen, Ammonia	0-3 mg/l
*Nitrogen, Nitrate	0-30 mg/l
*Nitrogen, Nitrate, Low Range	0-0.3 mg/l
Nitrogen, Nitrite, Low Range	0-150 mg/l
Nitrogen, Nitrite, High Range	0-0.2 mg/l
Oil in Water	0-80 ppm
Oxygen Demand, Chemical (COD)	0-900 mg/l

TABLE IV-1. A list of tests that can be performed by model DR/1 (Hach, 1982).

TEST	RANGE
Oxygen Demand, Chemical	0-150 mg/1, 0-1500 mg/1
Ozone	0-1.2 mg/1
pH	2-12 pH units
Phenol	0-0.2 mg/1
*Phosphate, Ortho, High Range	0-20 mg/1
*Phosphate, Ortho, Low Range	0-3 mg/1
Phosphate, Total Inorganic	0-20 mg/1, 0-3 mg/1
Phosphate, Total Organic and Inorganic	0-20 mg/1, 0-3 mg/1
Potassium	0-10 mg/1
Selenium	0-1.0 mg/1
Silica, High Range	0-70 mg/1
Silica, Low Range	0-3 mg/1
Sulfate	0-150 mg/1
Sulfide	0-0.9 mg/1
Tannin, Lignin	0-6 mg/1
Turbidity	0-500 FTU
Volatile Acids	0-2500 mg/1
Zinc	0-1.5 mg/1

TABLE IV -1. Continued.

This model is priced at $585.00. A second, more sophisticated model, DREL/4 includes spectrophotometer, digital titrator and titration cartridges, a built-in conductivity meter, and a portable pH meter. The basic DREL/4 is priced at $1180.00 and DREL/4 with conductivity meter is priced at $1350.00 (Hach, 1982). A list of the tests that can be performed by this model is provided in Table IV-2 (Hach, 1982).

Both of these models perform similar tests with the exception of DREL/4 measuring dissolved oxygen and DR/1 measuring chemical oxygen demand. Since DREL/4 has a built-in spectrophotometer, digital titrator, and a conductivity meter, it is priced higher than DR/1. Both of these models can be purchased from Hach Chemical Company in Ames, Iowa (1-800-247-3990). For the water quality tests needed to be performed for Crystal Lake, model DR/1 would suffice.

Secchi disk visibility is a measure of lake water transparency - its ability to allow vertical light penetration. Even though the secchi disk transparency is not an actual quantitative indication of light transmission, it provides both an index and a means of comparing similar bodies of water, or the same body of water at different times (Kothandaraman and Evans, 1983). Secchi disk is a white disk, 20 cm in diameter, which can be lowered into the water on a calibrated line to the point where it disappears. It is then raised until it just reappears. The average of the two depths is the secchi disk transparency (U.S. EPA, 1980). The secchi disk transparency of the Illinois lakes sampled in the past by Illinois EPA ranged from 3 inches (7.62 cm) to 17 feet (5.19 m). The majority have average transparencies of less than 4 feet (1.22 m) (Sefton, 1983).

TEST	RANGE
Acidity	0-250 mg/1
Alkalinity	0-250 mg/1
Bromine	0-40 mg/1
Calcium	0-100 mg/1
Carbon Dioxide	0-100 mg/1
Chloride	0-125 mg/1
Chlorine, Total	0-1.7 mg/1, 0-2.0 mg/1
Chromate, Sodium	0-1000 mg/1
Chromium, Hexavalent	0-0.5 mg/1
Color	0-500 units
Conductivity	0-20,000 mhos/cm
Copper	0-3.0 mg/1
Fluoride	0-2.0 mg/1
Hardness, Total	0-250 mg/1
Iodine	0-6 mg/1, 0-70 mg/1
Iron, Total	0-2.0 mg/1
Manganese	0-10 mg/1
Nitrogen, Ammonia	0-2.0 mg/1, 0-3.0 mg/1
*Nitrogen, Nitrate	0-30 mg/1
*Nitrogen, Nitrate	0-.02 mg/1
*Oxygen, Dissolved	0-4 mg/1, 0-20 mg/1
pH	0-14 units, 2-12 units
pH, Wide Range	4-10 units
Phosphorus, Reactive	0-2.0 mg/1, 0-3.0 mg/1
*Phosphorus, Acid Hydrolyzable	-----
*Phosphorus, Organic and Acid Hydrolyzable	-----
Residue, Nonfiltrable	0-500 mg/1
Silica	0-2.0 mg/1, 0-3.0 mg/1
Sulfate	0-150 mg/1
Sulfide, Hydrogen	0-5.0 mg/1
*Turbidity	0-500 NTU

TABLE IV-2. A list of tests that can be performed by model DREL/4 (Hach, 1982).

Monitoring of lake trophic condition using the indicators described above is necessary if the effects of lake restoration are to be maintained.

Vascular Plants

The second component of this study deals with the use and control of vascular plants following restoration. Mulligan (1969) states that vascular plants are important to the aquatic environment for the following reasons.

1. Produce oxygen through photosynthesis;
2. Slow water movements and provide habitats for sessile benthic organisms (those living on the bottom of the lake);
3. Provide surfaces for attachment by bacteria and aquatic insects;
4. Serve as food, nest-building material, and sites for egg attachment for aquatic insects and fish;
5. Provide nesting sites for fish;
6. Protect small fish from predation;
7. Convert inorganic material to organic matter;
8. Anchor the soil in place by means of their root systems, thereby providing lake bottom stabilization;
9. Provide controlled access to fishing in certain areas of the lake.

This investigation into the use of vascular macrophytes in the lake has led to the conclusion that native species will colonize and grow on their own, but specific species' planting was recommended for bank stabilization, fisheries, and deterrents to fishing in critical areas. Species found to be native to this region are listed in Lueschow (1972). From this list cattails and arrowheads were found suitable for Crystal Lake.

We recommend that cattails and arrowheads be planted in the areas indicated in Figure IV-1.

Cattails (Typha spp.) are tall, erect, perennial plants with jointless stems, 2-ranked, linear, sheathing leaves, and thick branching rootstocks (Muenscher, 1944). They usually produce a long stalk with a seed spike at the end. The two types of cattails found in Illinois are narrow-leaf and broad-leaf. Cattails grow along the water's edge in shallow waters, provide shallow lake bottom stabilization, and guard against soil erosion.

Cattails must be transplanted from an existing area into the new lake by digging up the root balls of the young plants. They are then planted in several inches of silt about one to two feet apart, up to two feet out from the shore (Tazik, 1983). The plants must be continually covered with water at the new site.

Arrowhead plants (Sagittaria spp.) usually have arrowhead-shaped leaves and tiny white flowers. This perennial plant grows along the edge of lakes and ponds in shallow water and is sometimes known as duck potato because of its tuberlike root (Illinois DOC, 1983). Arrowhead plants also provide shallow bottom stabilization, and guard against soil erosion.

Arrowheads can be planted in the same manner as cattails, but care must be taken because of its small root system. Arrowheads can also be propagated by planting seeds in the same manner as the root ball (Tazik, 1983). Both cattails and arrowheads can be obtained from lakes or rivers in this area (i.e. Lake of the Woods, Homer Lake, Sangamon River, etc.).

Control of aquatic vascular macrophytes is very important in maintaining

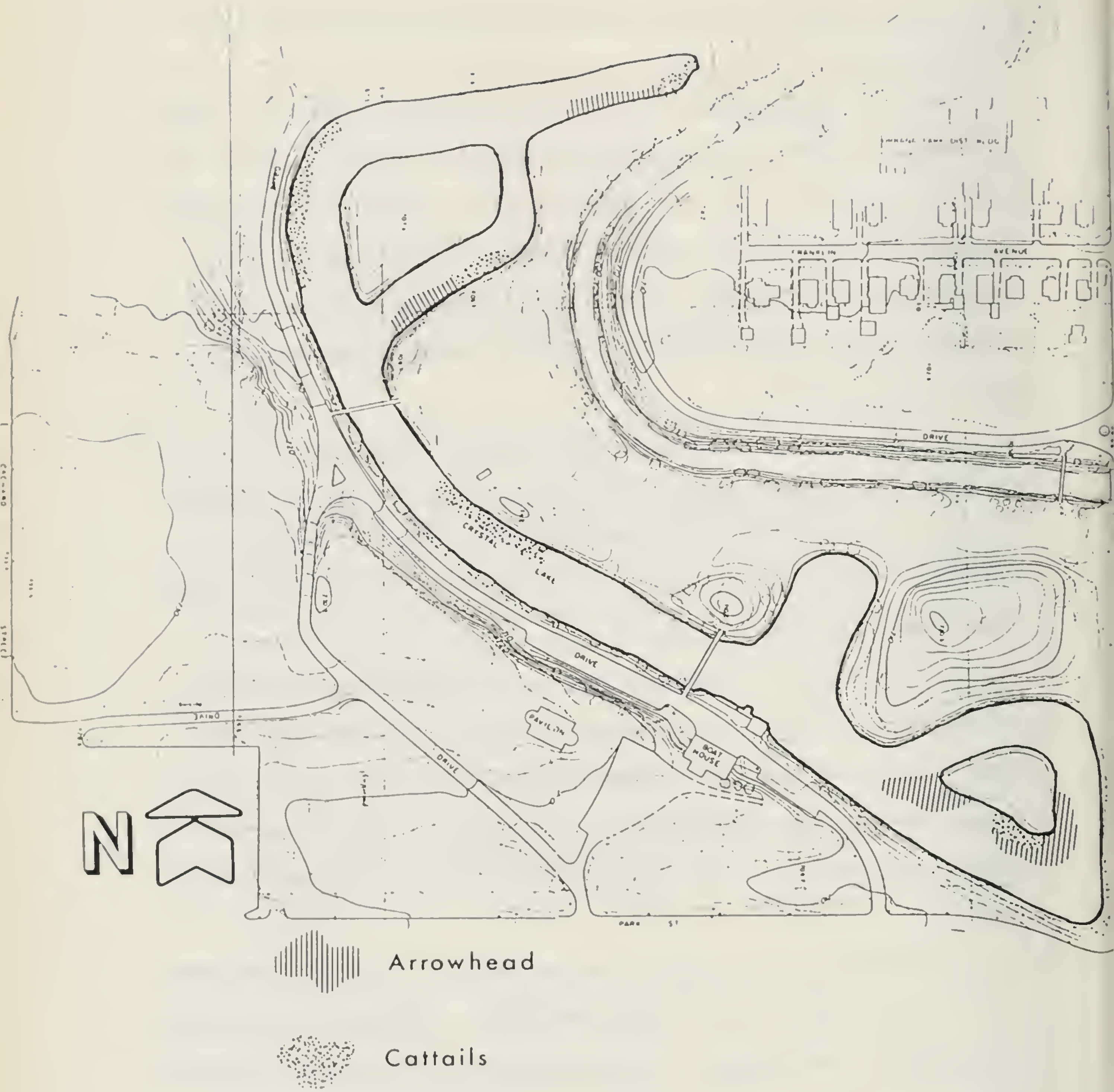


FIGURE IV-1. Recommended planting locations for cattails and arrowheads.

the lake in its restored condition. If left uncontrolled, vascular macrophytes will grow and spread throughout the lake, causing a major reduction in lake use. Therefore a management program begun at the completion of restoration will be the best and most economical form of aquatic plant ("weeds") control in Crystal Lake over a long period of time. The management program would consist of keeping new aquatic vascular macrophyte growths to a minimum in most of the lake and allowing them to grow to a certain density in specific areas where shoreline stabilization or fish habitats are needed. The management techniques can be divided into three categories: mechanical, chemical, and biological.

Mechanical control consists of pulling, raking, cutting, and removal of nuisance growths. The simplest method entails pulling off new shoots of emergent and submergent growths, and raking algae from the surface of the water. Other mechanical control methods consist of cutting and raking of nuisance plant growths with the help of commercial harvesting equipment. The benefits and limitations of these are listed in Table IV-3 (Bates, 1976).

The second management technique involves the use of chemical controls. Of the numerous techniques which have been employed as control measures, chemical control has been the most widely used method. It has the greatest utility and justification in highly eutrophic lakes in which the nutrient supply cannot be effectively controlled and where other management alternatives are infeasible (Dunst, et.al., 1974). Chemical controls of aquatic weeds make use of herbicides. An ideal aquatic herbicide must meet the following criteria (Lueschow, 1972):

1. Quick and efficient destruction of the nuisance plant;

BENEFITS	LIMITATIONS
Non-polluting	Very expensive
Do not harm fish	Slow
Target-specific	Less desirable species may succeed
Add no toxic materials	Problem of transporting and storing harvested plant matter
No license required	Labor intensive
Remove nutrients	Rapid growth of cut weeds
Lake can remain open during such an operation	

TABLE IV-3. Benefits and limitations of mechanical controls (Bates, 1976).

2. Non-toxic to other desirable organisms (fish, arthropods, etc.);

3. Non-toxic to water users;

4. Easy and safe to apply;

5. Readily confined to specific areas;

6. Breakdown to harmless products with no residue potential.

Five suitable aquatic herbicides were considered for use in recreational waters. These are: 2,4-D (2,4-dichlorophenoxy acetic acid), Silvex (2-2,4,5-trichlorophenoxy propionic acid), the potassium salt of endothal (1,2-dicarboxy-3,6-endoxoxy cyclohexane) marked as Aquathol, Diquat, and Copper Sulfate ($CuSO_4$).

2,4-D is a common agricultural herbicide. It kills by disrupting the pattern of cell division in the actively reproducing portions of leaf, stem, and roots (Lueschow, 1972). Herbicides of this type usually take four to six weeks to kill a plant. Most applications of 2,4-D are made in late May or early June, and best results are achieved when the plants are most actively growing (Lueschow, 1972).

Silvex, like 2,4-D, is a phenoxy compound that kills a plant by overstimulation of the meristem regions of the root, leaves, and stem (Lueschow, 1972). It is usually used in combination with endothal compounds to produce a more effective kill. Labeling restrictions for both 2,4-D and Silvex restrict swimming for one day, and three days for other water uses (Lueschow, 1972).

Aquathol is perhaps the most widely used aquatic herbicide in this area (Hiltibran, 1983). The endothal compounds are contact herbicides that cause the plants to die and go down three to five days after treatment (Lueschow, 1972). A wide margin of safety exists between the use rates and toxicity to desirable fish and fish-food organisms (Lueschow, 1972). The addition of silvex to endothal effectively broadens the species spectrum and adds to efficiency by preventing regrowth from roots that are difficult to control with a contact herbicide (Lueschow, 1972).

Diquat is a quaternary ammonia compound that is particularly safe for fish and fish-food organisms (Lueschow, 1972). Like aquathol, diquat acts as a contact herbicide and is rapidly absorbed by the plant tissue causing a rapid kill. Diquat is effective on filamentous algae and is most efficient on plants without extensive root systems (Lueschow, 1972). It is particularly successful on floating plants. The Urbana Park District presently uses diquat to control duckweed on Crystal Lake.

Since the early part of this century, copper sulfate has been used for algae control. When copper sulfate is applied directly to the surface algae, it acts to interfere with vital physiological processes. Often the algal cells turn grey shortly after treatment (Lueschow, 1972). Copper sulfate is also toxic to fish and fish-food organisms at approximately 1 ppm (Lueschow, 1972). The benefits and limitations of chemical control measures are listed in Table IV-4 (Bates, 1976).

Herbicide applications should be done in the spring when plants are young, before they reach the seeding stage (Illinois DOC, 1983). Most applications should be performed before July 1, except for algae, which can be treated through the summer months (Illinois DOC, 1983). One treatment is usually necessary during each growing season.

Biological control is a third management technique used in the control of aquatic vascular macrophytes. The common biological controls are non-selective weed-eaters such as herbivorous fish (Chinese grass carp),

BENEFITS	LIMITATIONS
Ease of application	High initial cost
Rapid die-off	Some agents are toxic to fish and other aquatic organisms
Safe when used correctly (i.e. when label restrictions are followed)	May be followed by algal bloom
Labor-conserving	Repeated application necessary
Some are target-specific	May damage desirable species

TABLE IV-4. Benefits and limitations of chemical control measures (Bates, 1976).

which have been successful in controlling plant growth in Arkansas lakes, crayfish, and snails. Crayfish and snails will enter the lake on their own. The hybrid and Chinese grass carp might be introduced, but are at this time illegal, although they are present in the Mississippi River. These biological controls require periodic surveillance and manipulation in order to avoid unwanted side effects and costs. The cost-efficiency of biological control depends on type of plants, densities, area to be controlled, and the specificity of control measures. The benefits and limitations of biological control measures are listed in Table IV-5 (Bates, 1976).

RECOMMENDATIONS

For the first objective, to provide a water quality monitoring program to be used as an early warning system, the following recommendations are proposed for implementation by the Urbana Park District.

1. Phosphorus, nitrogen, dissolved oxygen, and transparency should be tested.

2. These tests should be conducted once a month from October to April and more often (i.e. at least twice a month) from May to September.

3. The tests to be performed during the months of May through September should be conducted once between the first and fifteenth and once between the sixteenth and thirty-first of each month (Sefton, 1982).

4. Water samples for chemical analysis should be collected from at least three proposed locations: a) a deep station, b) a shallow station, and c) a station near the outflow. These samples should be collected from the same stations each month.

5. Water samples for chemical analysis should be obtained at one meter intervals commencing from the surface of the lake.

6. A Hach-kit should be purchased (model DR/1 or DREL/4) to test for inorganic orthophosphate, nitrate nitrogen, and dissolved oxygen.

BENEFITS	LIMITATIONS
Low application cost and persistence	Host specificity is very critical to establish correctly
Nutrient removal	May damage desirable species
May yield economic by-products	Suitable species are relatively new
Reach unaccessible areas	

TABLE IV-5. Benefits and limitations of biological control measures (Bates, 1976).

7. Continued use of a secchi disk is suggested to measure lake transparency as presently utilized by the Urbana Park District.

8. An initial test for chemical constituents of lake water following restoration should be conducted. This test could be carried out by the Natural History Survey (Aquatic Chemistry), Illinois State Water Survey (Aquatic Chemistry), or by a limnology class offered at the University of Illinois (Prof. Lynch, Dept. of Ecology, Etology, and Evolution).

For the second objective, the use and control of vascular plants, the following recommendations are proposed for implementation by the Urbana Park District.

1. Planting of cattails and arrowheads is suggested at specific locations (Figure IV-1) to provide bank and bottom stabilization, fish habitat, and guard against soil erosion.

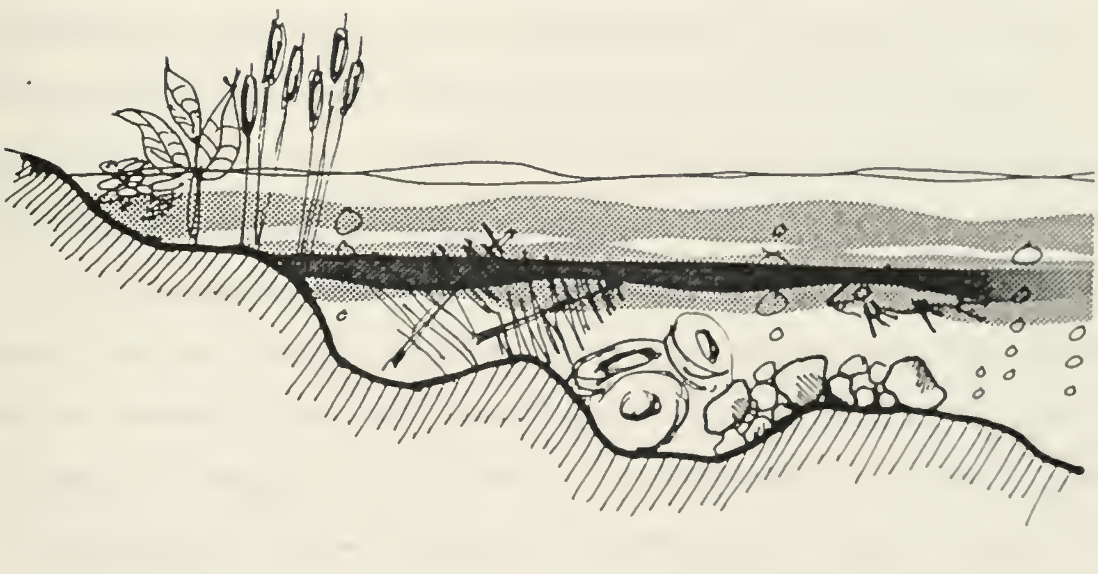
2. Cattails and arrowheads should be planted during their reproductive cycle (i.e. early spring).

3. The planting for cattails and arrowheads should start at the shoreline and go out about two feet. These plants could be spaced one to two feet apart depending on how quickly the established population is desired (Tazik, 1983).

4. For management techniques, the pulling of new shoots and raking of algae; use of Aquathol, Diquat, and Copper sulfate; crayfish and snails; should be considered if growth of aquatic plants becomes excessive.

5. A combination of these three management techniques is suggested to provide a balanced management approach.

FISHERIES STOCKING
AND
MANAGEMENT



SECTION V: FISHERIES STOCKING AND MANAGEMENT

by

M. I. Braga and D. Fields

INTRODUCTION

Lakes, like living organisms, go through an aging process (eutrophication), characterized by an increase in the fertility of the water, attributable to the addition of plant nutrients.

Natural eutrophication is usually a very slow process and the enrichment of the water is caused by plant and animal matter, as well as soil particles, being carried into the lake by natural runoff. As time goes on, the lake will become more shallow due to sedimentation and will develop algal blooms as a result of increased fertility.

The action of man in the environment may significantly accelerate the eutrophication process, through drainage of municipal and industrial waste waters and agricultural and urban runoffs. "As a result, lakes become unattractive for bathing, boating, and other water-oriented recreations and result in severe economic loss to established resorts. The former users of such lakes are forced to travel elsewhere at added expense. Fish production often increases but the species composition changes. Economically important species such as trout decline or disappear and are often replaced by coarser fish of lower economic value" (OECD, 1982).

The fish community in Crystal Lake is presently suffering from the effects of man-induced eutrophication. The sediments and nutrients brought in by urban runoff and bank erosion have changed the environmental structure of the lake; it is now more shallow and contains excessive growths of aquatic plants. The water is more turbid and less oxygenated (especially in summer), which constitutes a less than optimal condition for warm-water fish. As a result, fish species that require water of a better quality are not able to maintain healthy populations in Crystal Lake.

The fish remaining in eutrophic lakes often become stunted, which means that they will still reproduce but do not grow to their full potential. Stunted fish are characterized by large heads and small bodies, which is indicative of insufficient food supply or intense competition for a limited resource.

Appropriate lake management can slow down the eutrophication process. The reduction of sediment and nutrient inputs into the lake provides an obvious starting place. Fish populations should also be managed to help maintain a balanced relationship among the different species. The condition of the fish community in the lake can also be used to evaluate the degree of success achieved by any restoration efforts.

The implementation of a fisheries program and its long-term management is part of a larger project concerning the rehabilitation of Crystal Lake as a recreational resource for the Champaign-Urbana area. Fish restocking and management programs will be coordinated with other aspects of the restoration process in such a manner that good recreational fisheries will become available by the time the lake is re-opened to public use.

The four major objectives of the proposed fisheries program are:

1. Removal of all existing fish from the lake.
2. Restocking the fish populations of Crystal Lake.
3. Improvement of the fish habitat structure within the lake.

4. Design of a fisheries management program for Crystal Lake. It is anticipated that implementation of the following recommendations will result in an enhanced fisheries within Crystal Lake. This, in turn, should provide an additional recreational resource for Champaign-Urbana area residents.

Recommended actions and procedures necessary to meet these objectives are outlined below.

Removal of all existing fish from the lake

This objective involves two different actions. First, as many as possible of the adult desirable fish will be removed alive and transferred to temporary holding ponds until they may be returned to Crystal Lake, following completion of construction work. The second step entails removing all remaining fish from the lake. This action is important to insure that no undesirable fish species will remain in Crystal Lake after the restoration work is completed, thus providing the restocked fish with a habitat free of undesirable competitors, and lake managers with a better chance to develop healthy fish populations. Two alternative methods of accomplishing this task were considered: 1) the introduction of predator fish into the lake, and 2) the use of a fish toxicant to kill all the remaining fish, followed by their total removal. According to Lopinot (1973), "Fish toxicants represent one of the most effective tools available to the fishery management biologist for the enhancement of fish population and angling quality." The toxicant method was chosen as it is more likely to give sure and relatively fast results in removing the fish from Crystal Lake. The total fish removal will also promote the decrease of nutrients present in the lake by eliminating part of the organic matter present, thus helping to avoid any future eutrophication problems that may occur after restoration is completed.

Restocking the fish population of Crystal Lake

The first decision was to determine a suitable combination of fish species to inhabit the lake. The fish community should maintain a healthy balance among the populations using the resources available from the lake while providing the fishermen with a diverse selection of fish. The following recommendations of the species to be stocked were based upon these parameters:

1. morphological characteristics of Crystal Lake
2. expected water quality in the lake
3. availability of sport fish for recreation
4. availability of food for the fish
5. good fish diversity
6. balanced, self-sustained aquatic community

After considering various fish species as possible components of the restocking program, the following combination was selected:

1. Largemouth bass (*Micropterus salmoides*)
2. Smallmouth bass (*Micropterus dolmieui*)
3. Redear sunfish (*Lepomis microlophus*)
4. Fathead minnow (*Pimephales promelas*)
5. Channel catfish (*Ictalurus punctatus*)

This combination is likely to promote a balanced, self-sustained fish community in Crystal Lake while providing the fishermen with diverse recreational fisheries. This report also makes recommendations on the density and age group of the fishes to be stocked and includes a stocking time chart for the different species. These recommendations are based primarily on information obtained from staff members of the Illinois Department of Conservation, the Illinois Natural History Survey, and several commercial fish hatcheries that were contacted for this purpose. A cost estimate for the restocking program is also included in this section.

Improvement of the fish habitat structure

To achieve the goal of establishing a healthy, self-sustained fish population in Crystal Lake, the availability of habitat structure for the restocked fish must be considered. The term habitat structure refers to the physical characteristics and components of the lake that provide shelter and nesting grounds for aquatic organisms. The quantity of fish habitat is very important as both too little and too much structure may have deleterious effects on the fish population. In the case of too little structure there will not be enough shelter and nesting grounds for the fish. On the other hand, too much structure will make fish unavailable for the predators (Crowder and Cooper, 1979).

The value of habitat structure in fish productivity and angling success in standing waters is well documented in the literature (e.g. Johnson and Stein, eds., 1979). Artificial structures are known to be good fish concentrators because they provide shelter. Specially designed artificial structures are also good at providing spawning habitat required by certain fish species, thus increasing their productivity. More recently, many fishery biologists were successful in showing that artificial structures increase the available habitat for attachment of periphyton, an important food item especially for sunfish. The addition of these structures to standing water bodies may actually improve the food resources for the fish (Prince and Maughan, 1978). Within the above context, periphyton is defined as "the total assemblage of plant and animal communities attached to any firm substrate and also the free-living macro and the micro-organisms found swimming, creeping, or lodged among the attached forms" (American Public Health Association, 1971, in Prince, Strange, and Simmons, Jr., 1976).

The types of environmental structures considered in this report are:

1. those provided by the lake morphology. These include contour shapes, bottom irregularities, type of bottom sediment (i.e. sand, silt, or gravel), and depth;

2. living structures, represented mainly by aquatic macrophytes; and

3. artificial structures, such as submerged reefs, brush, logs, barrels, etc.

The final section includes recommendations on types and amount of artificial structures needed to enhance the fisheries in Crystal Lake, their location and distribution within the lake, and the compatibility of such structures with other planned lake uses (i.e. skating, boating, etc.). Also included are directions for how to build and install some of these artificial structures.

Design of a fisheries management program for Crystal Lake

We agree with George Bennett when he said that "one would be naive to expect any combination of fishes stocked in a man-made lake or pond to be productive of good fishing for an indefinite period of time. Too many of the integrated forces and counterforces that are active for promoting the well-being of a fish population in a primitive environment are absent from a man-made and man-dominated lake" (Bennett, 1962). For this reason, this report also deals with the design of a fisheries management program which basically consists of an annual inventory of the fish population in Crystal Lake, done by recognized professionals in the field. The inventory should produce information such as estimated size and structure of the fish populations, evidence of overharvest, evidence of stunting of any fish population, or the need for additional stocking of fish.

The management program also includes suggestions for fishing regulations such as minimum size of fish that may be kept by the fishermen. Finally, recommendations regarding the use of fish for macrophyte control, if these ever become a problem in Crystal Lake, are also presented.

METHODS

The present situation of the fish populations in Crystal Lake was presented by Gene Sanks, of the Urbana Park District, who conducted a tour of the lake and pointed out the different problems in the area. This provided an opportunity to examine a sample of different fish from the lake, most of which exhibited signs of stunting.

Two methods were used in searching for possible solutions for the fisheries problem in Crystal Lake. First, direct consultation with professionals in the field of fisheries management, mainly from the Illinois Department of Conservation, Illinois Natural History Survey, the Department of Ecology, Ethology, and Evolution of the University of Illinois at Urbana-Champaign, and personnel from several fish hatcheries.

Information from the literature available at the Natural History Survey Library, Biology Library, and the Main Library at the University of Illinois campus at Urbana-Champaign was also used.

The following factors were considered for the final recommendations:

1. expected use of Crystal Lake as a recreational fisheries resource;
2. integrity of the aquatic community;
3. lake aesthetics; and
4. cost of the operation.

The first three factors had a stronger influence on the decision-making process. Cost was not a major constraint as all the options examined had a low cost relative to the overall cost of restoring Crystal Lake.

FINDINGS

The information gathered as a result of this study will be presented next under each of the four following objectives.

Fish Removal

Some of the fish species that were selected to be restocked are already inhabiting Crystal Lake. The bigger individuals of these species could be saved and used later as a part of the restocking program.

For this purpose, Crystal Lake could be shocked, and the bigger desirable fish collected and transported to a temporary holding pond. The Illinois Natural History Survey (INHS) has a pond that could be used to retain the fish until the restoration work in Crystal Lake is completed. Members of the INHS could conduct the shocking of the lake and transport the fish to the holding pond.

After most bigger desirable fish are removed, a fish toxicant can be applied to Crystal Lake to kill all remaining fish. There are a number of toxicants that can be used to kill fish, with Rotenone and Antimycin commonly used. Rotenone is frequently employed by the Illinois Department of Conservation (IDOC) and INHS. Rotenone was selected as the alternative to by more fully investigated.

Rotenone is a plant byproduct. It is degraded by sunlight in a few hours, the actual time depending on the amount and intensity of sunlight during application. If faster detoxification is needed, potassium permanganate can be added to the water (Cumming, 1975).

The fish-killing action of Rotenone is faster in warm water than in colder water. Most of the dead fish will float to the surface and can be removed with the use of nets. The bigger fish can be consumed as food since Rotenone is destroyed during the cooking process. The remaining fish may either be disposed of at the Champaign-Urbana landfill, or used as soil fertilizer.

Rotenone costs about $30-$50 per gallon. The actual amount of toxicant needed in Crystal Lake will depend on the volume of water in the lake at the time of application. It is anticipated that the amount of Rotenone needed will be in the order of 12 to 25 gallons.

The application of Rotenone has to be done by someone licensed for this purpose. Both the IDOC and the INHS have people qualified to perform this job, and will do it if contacted well in advance. The professional in charge of applying the Rotenone will decide on concentration and methods of application. However, Todd Powless (per. comm.) from the INHS gave the following suggestions:

1. Apply Rotenone at a concentration of 4 ppm to insure a total fish kill, including more hardy species such as carp and catfish;

2. Use a hose to send the Rotenone mixture to the deepest parts of the lake. This may not be necessary if the lake is drained to a shallower depth before applying the toxicant;

3. Apply the Rotenone from a motorboat. The propeller action helps mix the toxicant more thoroughly in the lake water.

It is of <u>maximum importance</u> that no water from Crystal Lake be allowed to flow into the Saline Ditch from the time Rotenone is applied until all the toxicant is degraded.

The best time for the application of Rotenone will vary depending on which sediment removal method is to be employed. If complete drainage and sediment excavation is performed, the Rotenone should be applied after the lake has been partially drained. The application of Rotenone at this point is easier because of the reduced volume of water, thus concentrating fish in the deeper parts of the lake. The removal of the dead fish becomes easier because the dry lake margins facilitate the use of nets, and there is also a smaller water surface area to be cleaned.

If a hydraulic method is used to remove the sediment, such as the Mudcat, the Rotenone should be applied before the sediment removal starts. In this manner, any dead fish not removed by the nets can be sucked up along with the sediment.

<u>Fish Restocking</u>

The first requirement for implementing good recreational fisheries in Crystal Lake is the existence of a source of water for the lake which is plentiful, reliable, and of good quality. The various possible water sources, previously discussed in Chapter III, in relation to their suitability for sustaining good fish populations, were examined. It is agreed that groundwater would be the preferred option for maintenance of the aquatic community, provided it is aerated before going into the lake. Aeration by the cascade method, described in the Clark, Dietz report, would be enough to provide the water with enough dissolved oxygen for the fish.

Another factor that affects the quality of the fisheries to be developed in Crystal Lake is the availability of food for all fish in the lake, including the newly hatched ones. The existence of a diverse community of aquatic microorganisms should provide the necessary food for the smaller fish. The aquatic microorgainsms will colonize Crystal Lake by themselves after the lake is refilled. However, in order to speed up the process, the lake could receive plankton samples obtained from other lakes nearby, such as Homer Lake and Clear Lake, the latter at Kickapoo State Park. These samples would provide Crystal Lake with a combination of different algae and microorganisms, thus boosting the development of a diverse aquatic community in the lake. The INHS uses this procedure to improve the aquatic microorganism community in their experimental ponds after they are drained and refilled prior to commencing with a new experiment (Powless, per. comm.). Some of the staff personnel involved in this activity could advise and help the Urbana Park District in conducting this operation in Crystal Lake.

Many different species of fish were considered as possible options for stocking in Crystal Lake. Two of these, black crappie (Pomoxis nigromaculatus) and white crappie (Pomoxis annularis), are commonly stocked as sport fish in lakes throughout Illinois. These species, however, have a high reproductive rate and thus tend to overpopulate a lake, often becoming stunted. Also, when stocked together with largemouth bass, crappie many times outcompete bass, and eventually overpopulate and become stunted (Lopinot, 1972).

Another very common fish in Illinois water bodies is the bluegill, frequently stocked as a forage fish for the bass. This fish presents the same basic problem as the crappie, tending to overpopulate lakes and become stunted.

For the above reasons, none of these three fish species, although commonly used in stocking programs throughout Illinois, were included in our list of fish recommended for stocking in Crystal Lake after restoration work is completed.

The final list of fish to be stocked in Crystal Lake was selected using information from the literature and from direct consultation with staff members from the INHS and IDOC. It was agreed that the lake should be stocked with adult and young fish of each species. The five species considered for stocking, along with a brief description of their life history, are listed below:

- Largemouth bass (Micropterus salmoides), Figure V-1, are abundant throughout the states of Kentucky, Illinois, and Indiana. Warmwater fish found in virtually all types of water, they are intolerant of excessive turbidity and siltation and of low dissolved oxygen conditions. Fingerlings eat primarily zooplankton; as the young get larger they ingest aquatic insects and small fish. Adults are principally piscivorous. In Illinois, the largemouth bass matures usually at two years; spawning

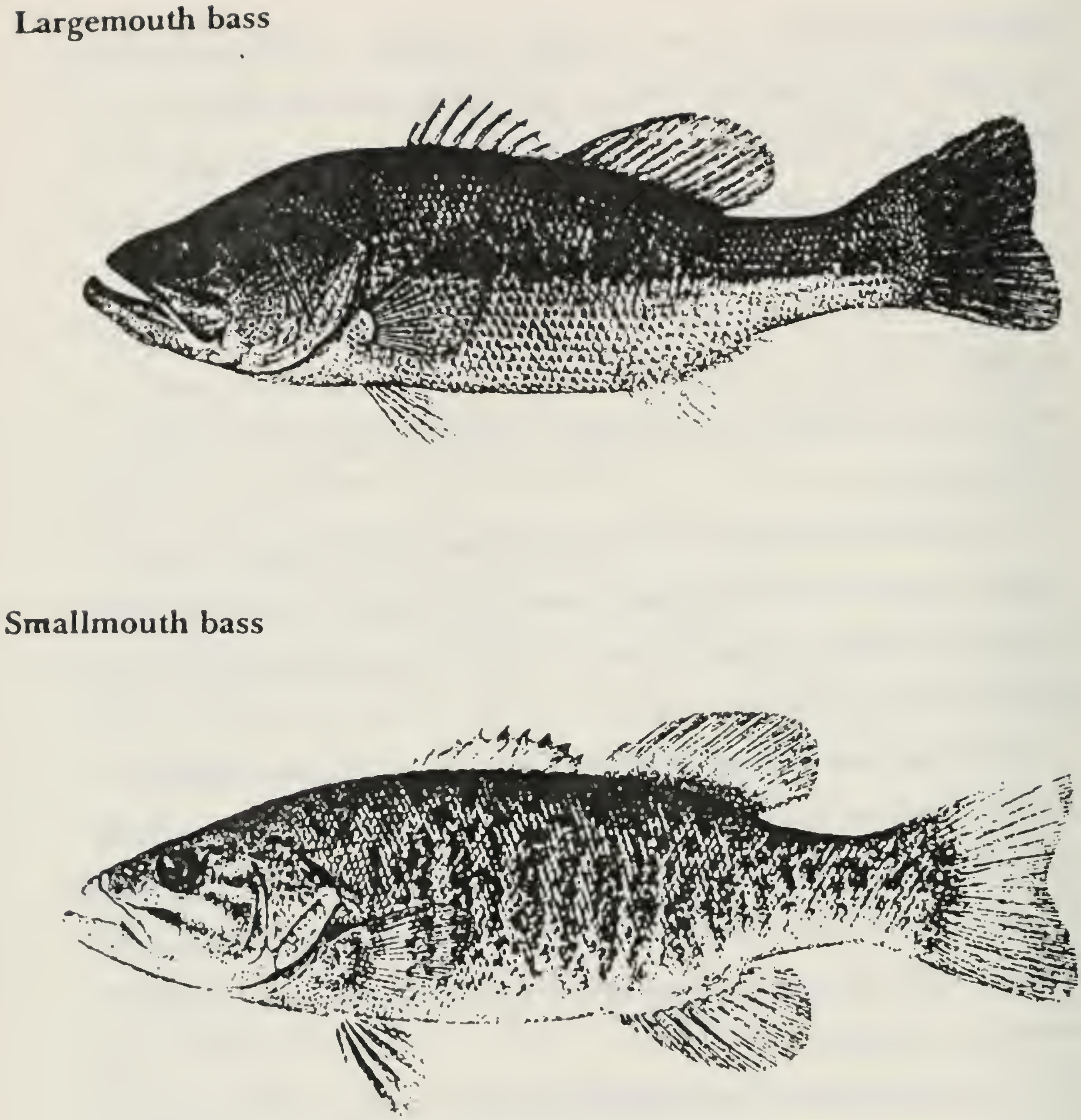


FIGURE V-1. Recommended fish species to be stocked in Crystal Lake (Smith, 1979).

occurs in May and June, with nesting activities beginning when the water temperature reaches 60 F. The male bass prepares the nest on a substrate of sand, gravel, roots, or aquatic vegetation at depths from 12 inches to 7 feet. Habitat or environmental manipulation is considered one of the best tools a resource manager may implement in the management of largemouth bass. These include placement of gravel spawning boxes, installation of brush shelters, and control of excessive weed growth (Mraz, et.al., 1961).

- Smallmouth bass (Micropterus dolomieui), Figure V-1, is widely distributed in Indiana, Kentucky, and the northern two-thirds of Illinois. They prefer deeper and cooler waters than the largemouth bass. Due to intolerance to turbid waters, a clean unsilted bottom is an essential requirement for substantial populations. Feeding habits are similar to those of the largemouth bass. Generally, they are unable to compete with the largemouth bass (Bennett and Childers, 1961). The conditions at Crystal Lake will not be very favorable for the establishment of a substantial population of smallmouth bass. However, the introduction of smallmouth in Crystal Lake should be attempted because of its relatively low cost and of the added benefits in the event the smallmouth succeeds in getting established in the lake.

- Redear sunfish (Lepomis microlophus), Figure V-2, occurs throughout Illinois, Indiana, and Kentucky. The redear thrives best in warm, clear, quiet water with standing aquatic vegetation. Young eat zooplankton and green algae; adults eat plankton, some insects, snails, and a few small fish. Redear usually become sexually mature at 1 year and spawn in May and June; eggs are laid in nests within or near vegetation

Redear sunfish

Channel catfish

Fathead minnow

FIGURE V-2. Recommended fish species to be stocked in Crystal Lake (Smith, 1979).

in waters less than 10 feet deep. Some individuals may spawn several times a year. Redear grows well, reproduces moderately, and is thought to be suitable for stocking with largemouth bass in ponds. The adult redears are sport fish, while the young provide forage for the bass. As a sport fish, the redear grows larger than the bluegill and is considered more difficult to catch because it inhabits deeper water.

- Channel catfish (*Ictalurus punctatus*), Figure V-2, occurs through Illinois, Indiana, and Kentucky. The catfish may be found in muddy water even though it prefers clearer water, and is also tolerant of standing water. Young eat insect larvae, zooplankton, and some algae; adults have been found to eat a tremendous variety of materials. Channel catfish mature between 5 and 8 years of age and 12 to 13 inches in length. They spawn in semi dark, secluded nests under rocks, in log jams, holes, and other protected sites. Spawning occurs from May to July. They will not spawn in transparent ponds unless a dark place is provided, such as submerged barrels or 10 gallon cans. Channel catfish are frequently stocked with bass and sunfush, but will rarely reproduce successfully under these conditions. If spawning occurs, the tiny fry are quickly devoured by the predating bass and sunfish (Lopinot, 1972). Periodic restocking is recommended to keep the populations at sufficient levels.

- Fathead minnow (*Pimephales promelas*), Figure V-2, is one of the common and characteristic minnows of the Prairie regions. It has high tolerance for high temperature, high turbidity, and low levels of dissolved oxygen. Adults are commonly 1.6 to 2.8 inches long. Its food consists mostly of algae and other plant material, but aquatic insects are also eaten. Spawning occurs from the end of May to early August; a female may spawn 12 or more times in a season. A diversity of objects such as boards, rocks, and tree-roots may be utilized for spawning. The fathead minnow is not very tolerant of competition and is seldom abundant in habitats that support a large variety of other fish (Pflieger, 1975).

Crayfish will likely colonize Crystal Lake on their own after the lake is filled. If possible, this process should be expedited by stocking these organisms. Crayfish serve as another food source for the bass and also were shown in some instances to have a beneficial influence in keeping the growth of aquatic macrophytes under control (Saiki and Tash, 1979).

Largemouth bass and smallmouth bass are recommended as the main sport fishes in Crystal Lake. The redear sunfish would be the principal forage fish, also acting as a sport fish. Fathead minnows should be stocked mainly to add diversity to the system, and although they also constitute another potential food source for the bass, it is not likely that they will attain population sizes large enough to provide a principle food source for bass. Although channel catfish will have to be partially restocked in Crystal Lake every year, their introduction is advantageous because they constitute an additional option for the fishermen, while also adding to the diversity of the fish community.

Another important point considered for this study is the stocking schedule for the different fish species. An experiment conducted in Missiouri evaluated two different stocking methods for farm ponds (Dillard and Hamilton, 1969). The first method consisted of stocking largemouth bass in the summer, and bluegills and channel catfish in the fall; the second method recommended is a single stocking time for all fish species in the fall. The results of that experiment showed that the different methods had little influence on sizes attained by the various fish age classes. However, the first method appeared to result in better fish population structures. The first method gives an extra age class of bass which will increase predation pressure on the bluegills, thus providing better growth conditions for both bass and bluegills. The extra age group of bass has the additional advantage as the first cohort enters the creel a year earlier and thus relieves the fishing pressure on the bass stocked sooner.

The stocking of fingerlings (fish up to one year old) in Crystal Lake can be done through the IDOC. The DOC's district biologist should be contacted at least one year prior to the stocking date to assure availability of fish. The district biologist will then determine the quantities needed for each of the fish species requested by the Urbana Park District. The fish are ordered by the IDOC from the Sand Ridge Hatchery in Manito, IL., and are available for a $25.00 stocking fee in addition to the rate of $1.00 per acre. Crystal Lake could be completely stocked with fingerlings at the cost of $33.00.

In relation to the stocking of adult fish, three suggestions about the densities at which each fish species should be introduced in Crystal Lake were obtained.

Table V-1 displays the suggestions made by the IDOC (Lutterby, per. comm.). The IDOC also recommended stocking 200 bluegill/acre. These will not be considered in the calculation of stocking costs because

Fish	Number/Acre
largemouth bass	80
smallmouth bass	40
redear sunfish	200
channel catfish	100

TABLE V-1. IDOC recommendations for type and number of fish/acre.

bluegill were eliminated as an option for Crystal Lake. There was also a recommendation for restocking 50 channel catfish/acre every year.

Table V-2 contains the INHS recommendations (Powless, per. comm.).

Table V-3 shows the recommendations made by Fender's Fish Hatchery (per. comm.). The hatchery recommended buying smaller fish instead of adults. According to this source, the fish size would be initially smaller but would grow to adult size within one year and the operation would be less expensive. Fender's Fish Hatchery also recommended stocking 150 perch/acre (3 to 5 inch size). As with the bluegill, the perch will not be included in the calculation of costs for the stocking of Crystal Lake.

A list of private fisheries is available from the IDOC. Of all the hatcheries contacted by us, only two presently had the requested fish available. These two fish hatcheries were:

A. John B. Fitzpatrick Fishery Management Service. 214 E. North St., Dwight, IL 60420. (815)584-2545. The prices furnished for the fish already include delivery costs, and are displayed in Table V-4.

B. Fender's Fish Hatchery. Route 1, Baltic, OH 43804. (614)622-0681. The prices for the fish <u>do not</u> include delivery costs. They are displayed in Table V-5.

The costs for stocking Crystal Lake with adult fish were estimated using the prices from Fender's Fish Hatchery, as that was the hatchery that could currently supply most of the recommended fish. The cost for stocking minnows was calculated using the price from the John B. Fitzpatrick Fishery. The assumptions made for the cost estimates were:

1. largemouth bass at an average length of 10 inches;

2. smallmouth bass at an average length of 8 inches;

Fish	Number/Acre
largemouth bass	50
smallmouth bass	50
redear sunfish	50
channel catfish	30
fathead minnow	20 lbs.

TABLE V-2. INHS recommendations for type and number of fish/acre.

Fish	Size	Number/acre
largemouth bass	6 to 7 in.	150
smallmouth bass	2 to 4 in.	150
redear sunfish	3 to 5 in.	150
channel catfish	3 to 5 in.	200

TABLE V-3. Fender's Fish Hatchery recommendations for type and number of fish/acre.

Fish	Size	Price $
channel catfish	9 to 13 in.	.80 each
fathead minnow	adult	2.50/lb.

TABLE V-4. Fish prices at the John B. Fitzpatrick Fishery Management Service.

Fish	Size	Price $
largemouth bass	3 to 4 in.	.35 each
	4 to 6 in.	.55 each
	6 to 7 in.	.80 each
	over 8 in.	.25 per in.
smallmouth bass	2 to 4 in.	.35 each
	4 to 7 in.	.15 per in.
	over 7 in.	.20 per in.
redear sunfish	3 to 5 in.	.25 each
	5 to 6 in.	.50 each
channel catfish	3 to 5 in.	.35 each
	5 to 7 in.	.50 each
	7 to 9 in.	.75 each

TABLE V-5. Fish prices at Fender's Fish Hatchery.

3. all prices do not include delivery; and

4. all calculations assume Crystal Lake is eight acres in size.

The cost estimates for each of the three stocking schemes are listed in Tables V-6, V-7, and V-8. It is important to remember that the cost for stocking Crystal Lake will likely be bwer than estimated, depending upon the number of fish saved in the shocking operation.

One probelm that should be avoided in Crystal Lake is the initial overstocking of fish. Overstocking reduces fish growth due to excessive competitive pressure and will cause fish to be too small by the time they reach their harvest time. Once a lake is overstocked, significant reductions of the fish populations is a very difficult task, which frequently can only be achieved by more drastic means, such as the use of fish toxicants. On the other hand, if the lake is understocked, new fish may always be added. This course of action should be preferred over the other extreme of overstocking and all the subsequent problems it may create.

Fish Habitat Development

The fish habitat in Crystal Lake was divided into three different categories to facilitate the development of their study. It is important to remember that in the lake, all three types of habitat structure interact with each other, and the results from improving the characteristics of each of the three variables may be more noticeable than just acheiving optimal conditions in one category and neglecting the others.

The findings of this study concerning the improvement of the fish habitat in Crystal Lake will be presented next under each of the three

Fish	Number/Acre	$/Fish	Total Cost ($)
largemouth bass	80	2.50	1600.00
smallmouth bass	40	1.60	512.00
redear sunfish	200	.50	800.00
channel catfish	100	.75	1600.00
			4512.00 Total

TABLE V-6. Estimated expenditure incurred by IDOC's fish stocking recommendations.

Fish	Number/Acre	$/Fish	Total Cost ($)
largemouth bass	50	2.50	1000.00
smallmouth bass	50	1.60	640.00
redear sunfish	50	.50	200.00
channel catfish	30	.75	180.00
fathead minnow	20lbs.	2.50/lb.	400.00
			2420.00 Total

TABLE V-7. Estimated expenditure incurred by INHS's fish stocking recommendations.

Fish	Number/Acre	$/Fish	Total Cost ($)
largemouth bass	150	.80	960.00
smallmouth bass	150	.35	420.00
redear sunfish	150	.25	300.00
channel catfish	200	.35	560.00
			2240.00 Total

TABLE V-8. Estimated expenditure incurred by Fender's Fish Hatchery fish stocking recommendations.

Fish	Number/Acre	$/Fish	Total ($)
largemouth bass	80	.25/in.	1600.00
smallmouth bass	40	.20/in.	512.00
redear sunfish	200	.50 each	800.00
channel catfish	100	.75 each	1600.00
fathead minnow	20lbs.	2.50/lb.	400.00
			4912.00 Total

TABLE V-9. Recommended stocking densities for adult fish, and respective costs.

different categories of habitat structure.

A. Lake morphology

This category includes the fish habitat provided by the physiographic characteristics of the lake. These include lake contour, shape, bed topography, type of bottom sediment, and depth. The information presented below was obtained mainly from a study on procedures for the development of fisheries production of surface mined lands (Leary, 1980).

Depth is a very important lake characteristic. It can determine the possible recreational uses for the lake and can influence the type of aquatic organisms that will be able to colonize the lake, due to the volume of water in the lake and the amount of sunlight that will reach the bottom. In order to accommodate a diverse fish population, a lake should have a depth greater than 12 feet in at least 25% of the lake surface area. Some places should be as deep as 18 to 20 feet; these offer better habitat for fish like the smallmouth bass and also act as a refuge for the fish during winter, when shallower areas of the lake may freeze.

The lake contour should be irregular to create coves and bays along the shore (Figure V-3). This configuration decreases the visual field of the fish, thus creating more sheltered areas. Many fish species are territorial, especially during spawning season, and will not reproduce well if there are other fish within sight of their nests.

The lake bed topography should be irregular, with holes, peaks, and rocks, to create more fish habitat (Figure V-4). The irregularities also diminish the visual range of the fish, thus creating more sheltered spaces for prey fish and some macroinvertebrates, such as the crayfish.

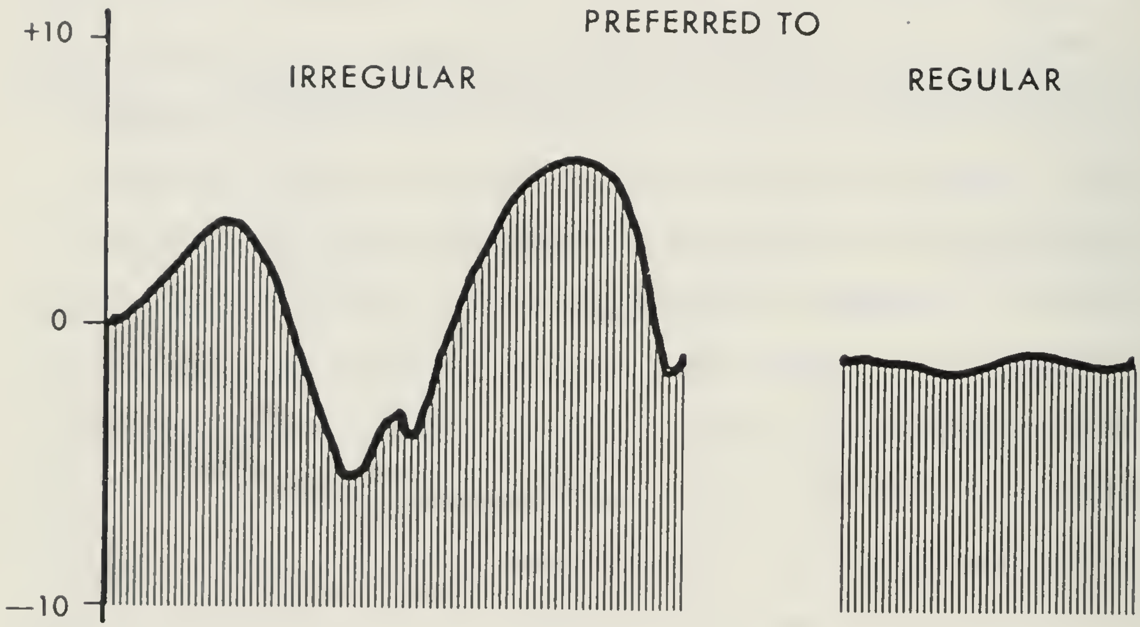


FIGURE V-3. Comparison of irregular contour of lake bottom which increases fish habitat with that of a regular homogenous type lake bottom.

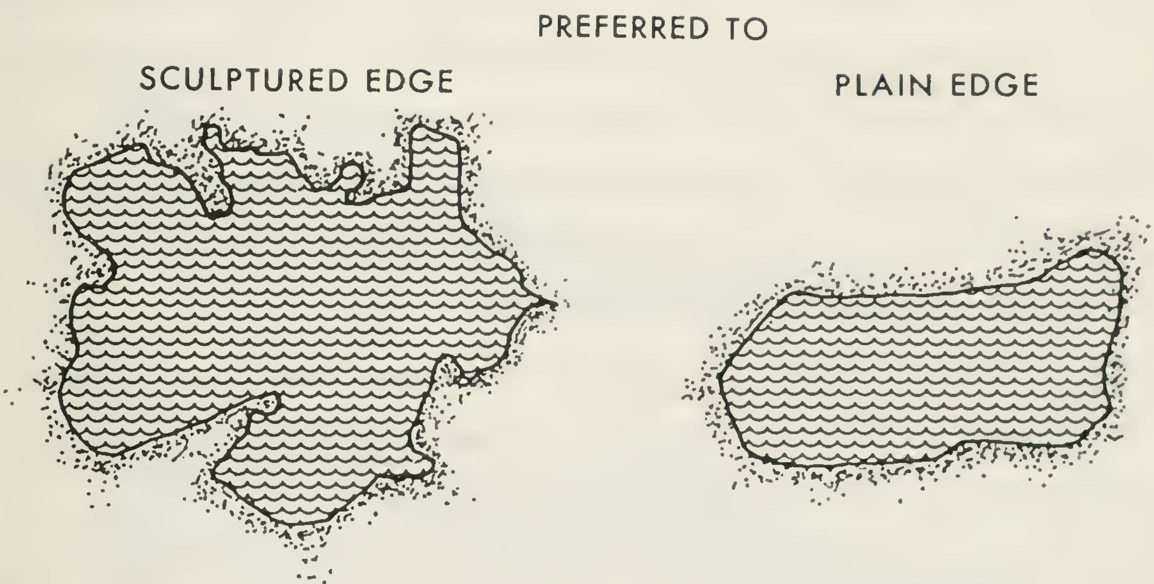


FIGURE V-4. Irregular lake bed topography which provides habitat.

The littoral shelf consists of the shallower areas along the margins; it is there that most of the aquatic plants will grow and most fish will spawn. The littoral areas should amount to approximately 20% of the surface area, and should have depths in the range of 2 to 5 feet. Areas less than 2 feet should be kept to a minimum to limit the growth of aquatic macrophytes in the lake. The width of the littoral shelf can be adapted to the needs of each region of the lake; it could be widened where fish spawning is desired, and narrower in fishing areas, boating areas, or where extensive growth of aquatic macrophytes is not desired (Figure V-5).

The slopes along the lake bottom are also a very important feature of lake morphology, as they determine the rate at which lake depth changes with distance. The slopes should be gentle in the littoral areas, in the range of 1:10 to 1:20, but should increase abruptly to at least a 1:3 ratio beyond that point (Figure V-6). This rapid increase in depth with distance will help confine the growth of aquatic macrophytes to the littoral shelf, by limiting the amount of light that will reach the bottom for photosynthesis.

The addition of large rocks along the margins for bank stabilization will also increase fish and invertebrate habitat in the lake (Figure V-7).

B. Living Structures

Living structures are mainly represented by aquatic macrophytes, which probably will establish themselves in the first years after the lake is filled.

The aquatic macrophytes are very important in providing shelter for the young fish, and also furnish essential habitat for the micro and

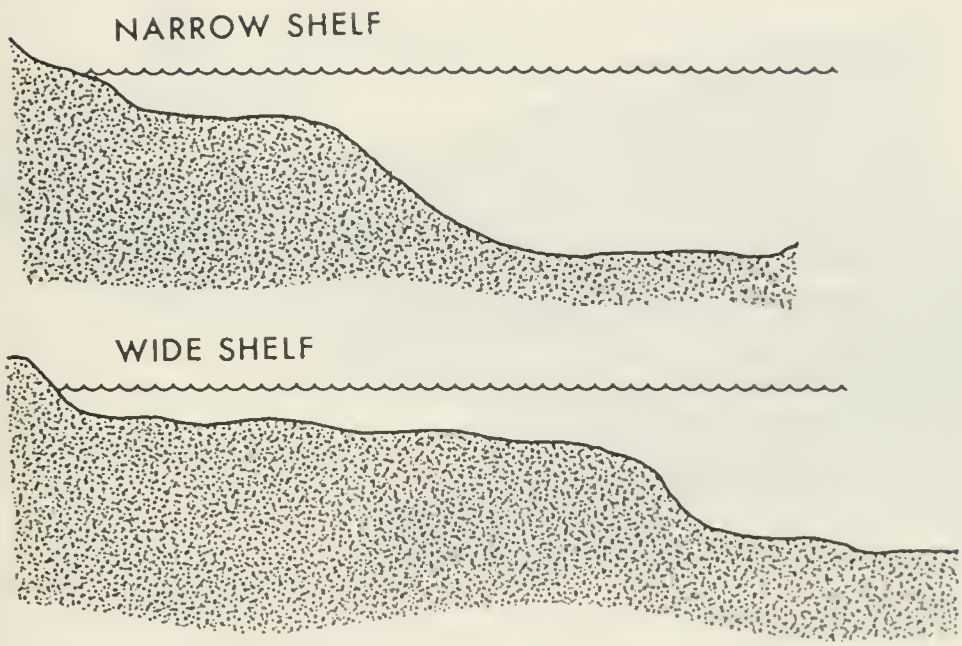


FIGURE V-5. Cross-section of a wide and narrow littoral shelf.

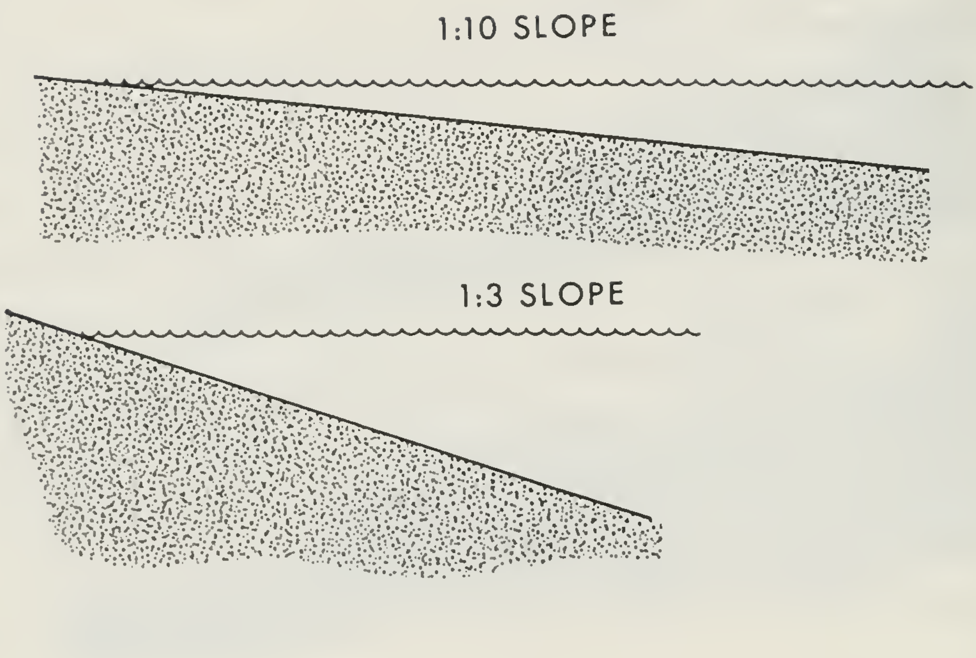


FIGURE V-6. Diagram of a 1:10 and a 1:3 littoral shelf slope.

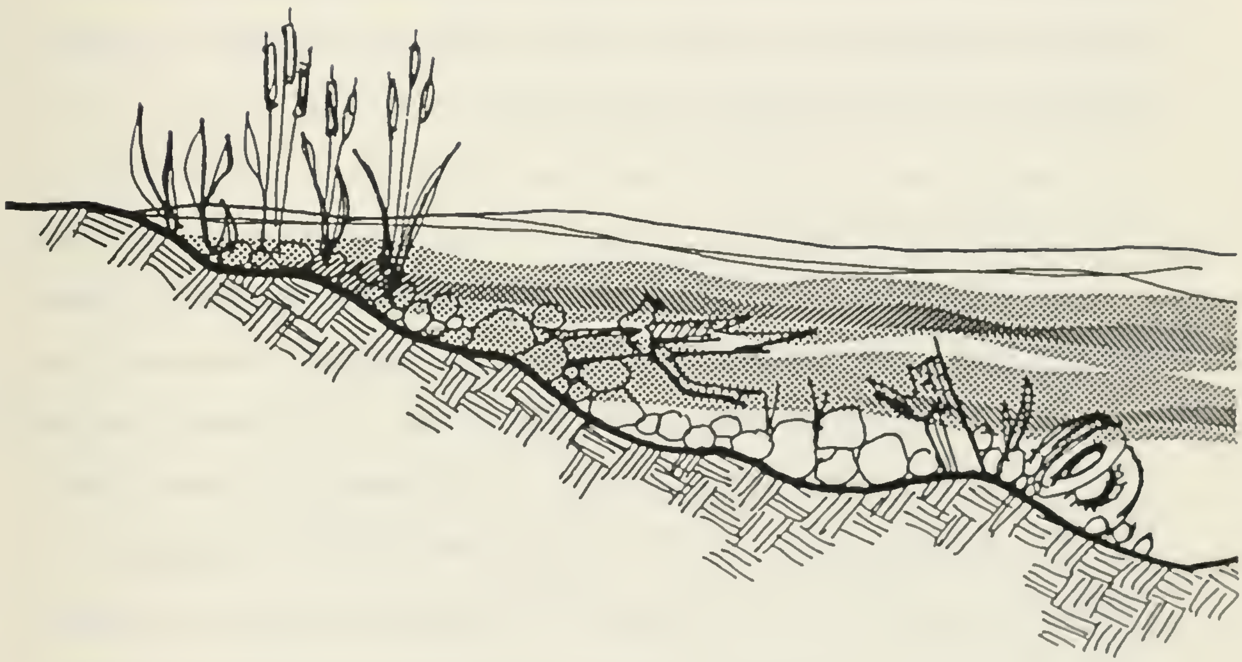


FIGURE V-7. Cross-section of littoral shelf showing placement of large rocks to provide stabilization.

macroinvertebrates in the lake, which are at the base of the food web in an aquatic community. The excessive growth of these plants, however, may pose a serious problem to the fish populations because they will provide excessive cover for the forage fish. One common way to control macrophyte growth in lakes is by mechanical means, in which case it is recommended that the trimming of the plants be done in rectangular strips (Crowder and Cooper, 1979), approximately 2-3 feet wide. This pattern should be followed in order to leave enough patches of macrophyte where the young fish and invertebrates can still thrive. This strip pattern will also provide enough feeding edges for the larger fish.

C. Artificial structures

The artificial structures more closely analyzed in this study were the artificial submerged reefs and the special structures for spawning.

"An artificial reef may be described as any collection of rigid structures placed close together in an aquatic environment to improve fish habitat" (Prince et.al., 1977). "Reef structures should be bulky, possess many cavities, and have several entrances. Reef structures that arise well above the bottom provide more shelter and surface area than do low-profile structures. These, however, may be better for shallow water and can be used to increase spawning area" (Prince et.al., 1977).

The main objective in investigating the use of artificial reefs was to assess their value as shelters for the fish. A study in Smith Mountain Lake, Virginia, showed that largemouth bass are highly structure oriented (Prince and Maughan, 1979). They prefer brush shelter areas, whereas the smallmouth bass do not show the same preference (Vogele and

Rainwater, 1975). Studies comparing the suitability of brush shelters and tire reefs in providing shelter showed that:

1. brush shelters are more efficient to concentrate bass than tire shelters (Wege and Anderson, 1979);

2. largemouth bass are more attracted to high profile tire units, while the sunfish prefer the triangular unit (Prince and Maughan, 1979b);

3. brush shelters were found to concentrate crayfish (Rodeheffer, 1945).

The main purpose in using submerged artificial reefs in Crystal Lake will be to increase the shelter areas available to the fish, especially in the deeper regions where the aquatic macrophytes are not expected to grow significantly. Floating reefs were eliminated from consideration because they would interfere with other uses of the lake, such as boating, while simultaneously impairing the aesthetic quality of the lake.

Both brush shelters and tire reef units were evaluated for installation in Crystal Lake. The costs of artificial reefs can be closely controlled by using cheap and durable construction material, such as scrap automobile tires and old Christmas trees. Their construction is fairly simple and can be done as a community project (Prince and Maughan, 1978). It is recommended that the Urbana Park District build these reefs, possibly offering this activity as a summer job for students.

The following directions for the construction of these habitat structures were obtained from a publication entitled "How to Build a Freshwater Artificial Reef" (Prince et.al., 1977).

The brush shelters may consist of old Christmas trees. A 3/8 inch hole is drilled at the base of the trunk of each tree and a piece of steel bar stock forced into the hole. The butt of the tree is then put into a 5 gallon can filled with concrete to three quarters of its capacity (Figure V-8). These single tree units may be connected with polypropelene line at the time of installation.

Tire reefs consist of assemblages of four types of tire units.

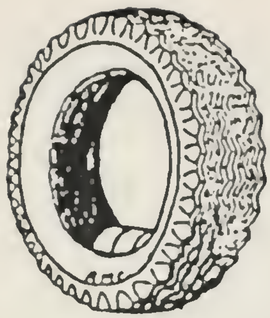
The first type is the single tire unit. For these, a number 10 can filled with concrete is pushed between the sidewalls into the body of the tire as a ballast. Two large air holes are drilled or cut in the tread portion opposite the can to allow trapped air to escape (Figure V-9a).

The next type of tire unit is the triangle unit. For the construction of these, three tires are tightly lashed together to form a triangle of tires whose tread portions are in contact with the ground. One number 10 can filled with concrete is forced between the sidewalls of one of the tires. To assure sinking, large holes are drilled through the tops of all three tires (Figure V-9b).

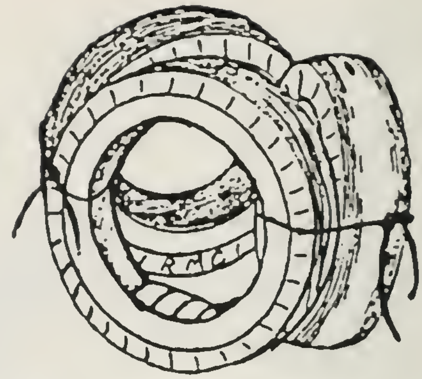
For the pyramid tire unit, three tires are put together to form a cylindrical assembly. Two of these three tire assemblies are then roped together to form a base of 6 tires. A third assembly is lashed on top of the middle of the base to form a pyramid. Six number 10 cans filled with concrete are forced between the side walls of the base tires to anchor the unit. The upper tread portions of all but the middle tire of the top assembly are drilled to allow air to escape. The air trapped in the undrilled tire assures that the unit will sink to an upright position to the bottom (Figure V-9c).

To put together a high-profile tire unit, a large truck tire is placed horizontally on flat ground. Four holes are drilled in the upper sidewall dividing the tire into quarters. The holes are then enlarged

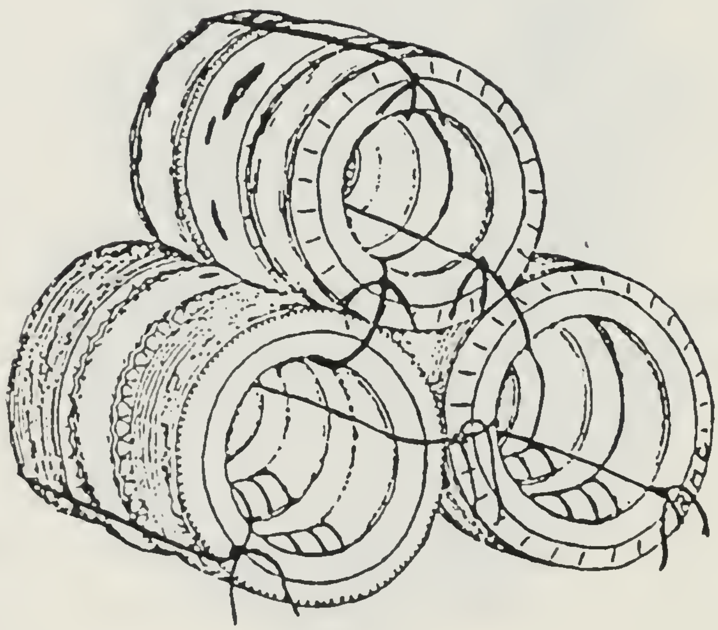
FIGURE V-8. Brush unit for the artificial reefs (Prince, et.al., 1977).



a) Single Tire Unit



b) Triangular Tire Unit



c) Pyramid Tire Unit

FIGURE V-9. Different tire units to be used in the artificial reefs (Prince, et. al., 1977).

by cutting out a wedge toward the center of the tire with a saber saw (use knife blade insert). Four 10-feet pieces of reinforcing bar are each bent perpendicular 2 feet from their ends. These bent ends are then pushed down through the holes, and opposite bars are welded together in the center of the tire. The tire is then filled with concrete. The resulting base tire has four vertical rods rising from it. Two tires are then drilled and slashed further with a saber saw to allow rods to be driven through each. These tires are then threaded down the reinforcing rod parallel to each other above the base tire. Parallel tires are successively forced down the rods to form right angles with the tires below. A horizontal tire threaded over the ends of the rods is used to cap the structure. The tips of the rods are bent to hold the tires in place (Figure V-10). The complete unit weighs several hundred pounds and must be handled with the aid of heavy equipment. It is recommended that they be put in place before the lake is refilled.

The recommended amounts of cover for fish in a lake vary from 0.7% (Wege and Anderson, 1979) to 0.25% of the lake surface area (Prince et.al., 1977).

Another efficient way to improve the amount of shelter for the fish in the lake is to dump any trees and branches that may have to be removed from areas adjacent to the lake into the lake.

This study also analyzed some artificial structures especially developed to improve spawning sites for fish.

Largemouth bass prefer to spawn on gravel rather than on silt or sand as it is easier for the fish to keep their eggs free of dirt when the nest is made on a gravel bed. Artificial spawning areas for the bass can

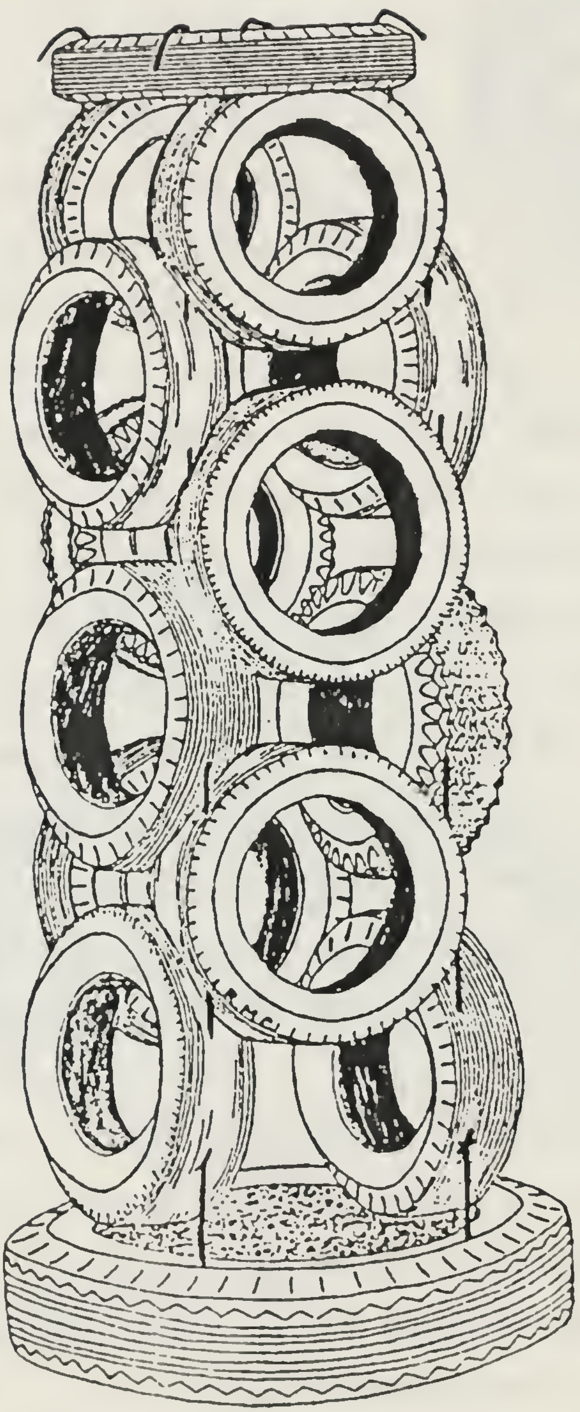


FIGURE V-10. High profile tire unit (Prince, et.al., 1977).

be created with the use of a box-frame, or approximately 1 sq. yd., filled with gravel and placed in water 2 to 4 feet deep (Figure V-11a). These boxes should be installed at a density of 20/acre (Powless, per. comm.); they should not be so close together that the fish could see each other, unless there is something between the boxes, such as submerged brush or log.

Fathead minnows will place their eggs on the underside of leaves, rocks, or inside holes in logs. Concrete blocks, and 6-8 inch diameter pvc pipes cut longitudinally can be used to improve spawning areas for the minnows (Figure V-11b).

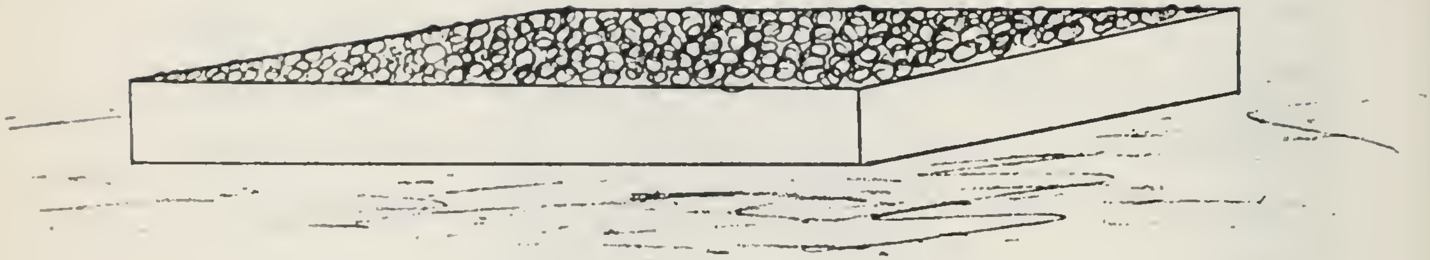
Channel catfish will only reproduce in dark places. For them, 50 gallon drums can be installed on metal rods and put in water 4 feet deep, preferably on a sloping surface, with the entrance hole facing the deeper part of the slope. These structures should be installed at a density of 10/acre.

Fish Management and Monitoring

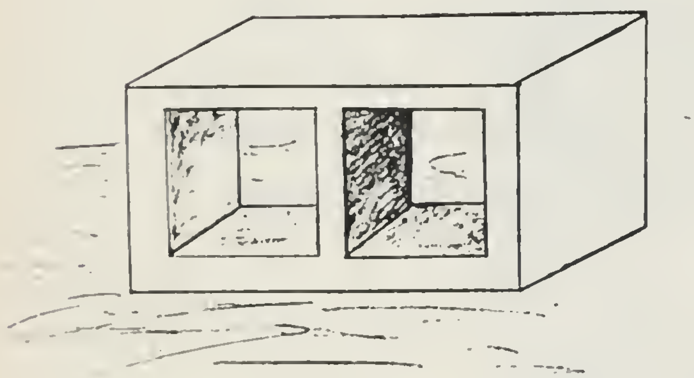
The structure of the fish populations in a lake is a very good indicator of the overall "health" of the system. Lakes stocked with both largemouth bass and bluegill, and which have suitable population structure, will present the following signs (Dillard and Hamilton, 1969):

1. bass fry and/or fingerling present;
2. moderate numbers of all size forage fish;
3. good number of "keeper" size bass and bluegill.

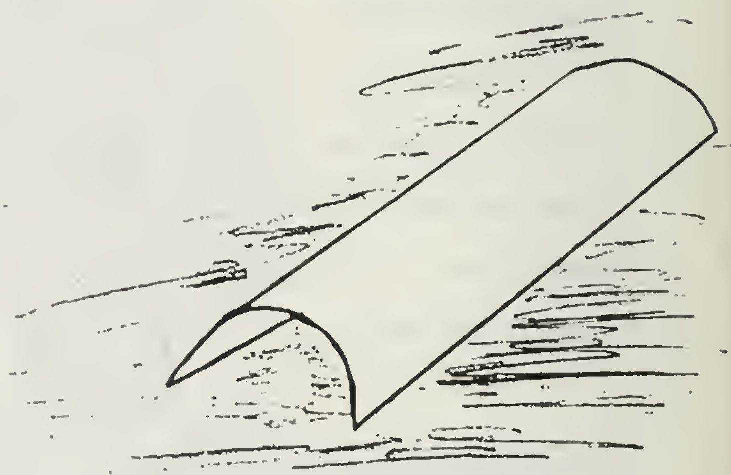
In the case of an unsuitable population structure, the lake will present the following signs:



a) Box frames filled with gravel



b) concrete blocks



c) PVC pipes

FIGURE V-11. Artificial structures for fish spawning.

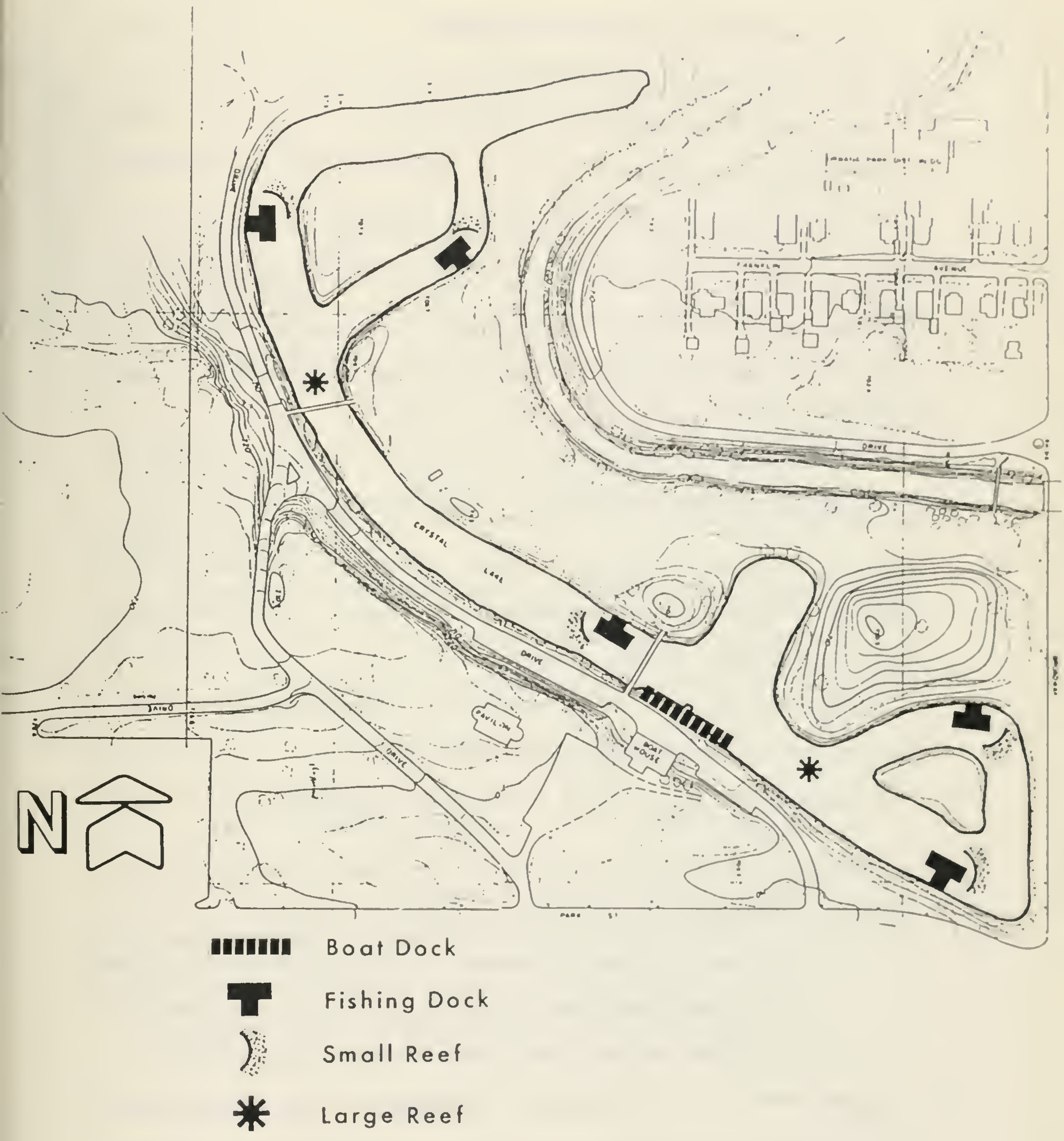


FIGURE V-12. Recommended location of small and large artificial reefs in Crystal Lake.

1. no bass fry or fingerling present;

2. complete lack of forage fish;

3. large population of undesirable fish;

4. excessive numbers or lack of particular size groups of forage fish.

The implementation of a fish monitoring program in Crystal Lake would be beneficial because it could uncover any early changes in the fish population structures. These changes, if discovered early in the process, can give information to the park manager as to how the problem could be solved before it becomes too serious.

Fish monitoring is also an important tool in obtaining evidences of overharvest of any fish population, stunting, and/or the need for additional stocking of any fish species. A fisheries monitoring program would be necessary to pinpoint, early in the process, any problems that might be affecting the fish populations.

The monitoring of the fish populations in Crystal Lake could be done by three different groups of people:

1. The IDOC will normally accept this kind of request if contacted well in advance.

2. The INHS also has qualified personnel to perform this job and could be contacted for this purpose.

3. The students from the Fish and Wildlife Management class at the Department of Ecology, Ethology, and Evolution from the University of Illinois, could conduct an evaluation of the fish populations in Crystal Lake as part of their course requirements. Prof. James Karr, responsible for that class, was contacted during the study and considered the idea as a possibility.

One commonly-used fish management tool is the institution of minimum size limits for sport fish, such as bass. For largemouth bass, it is generally recommended that fish smaller than 12 inches should be protected from harvest. More recent studies, however, suggest that different types of size limits should be applied in different situations (Anderson, 1978). In cases when bass populations are depleted and reproductive success is low, the protection of bass in general, and of quality size bass in particular, would be recommended. Minimum lengths of 15 to 18 inches might be applied as long as bass populations are low. If the number of bigger bass is depleted due to natural mortality and/or angling, but the smaller bass are still plentiful, harvest should be aimed at where the surplus is evident - bass less than 12 inches long. According to Anderson (1978), a third approach would be to protect a size range of bass from 12-15 inches, which should include the individuals with the best reproductive capacity.

The implementation of any policy concerning size limits for bass in Crystal Lake should take into account three main factors:

1. the fishing pressure on the bass population after the lake is reopened to the public;

2. the problems of enforcing such a policy;

3. the fact that Crystal Lake is mainly a recreational resource for the Champaign-Urbana area.

If overharvest of bass ever occurs, restocking can always be implemented. On the other hand, if the bass are overprotected, they may end up overpopulating the lake, thus creating more serious problems for the management of the fish populations in Crystal Lake.

Another important problem concerning the fisheries management in Crystal Lake is the introduction of extraneous fish into the system. The development of populations of fish such as bluegill, carp, and crappie may seriously jeopardize the population structures of the more desirable fish. For this, the outfall structure of Crystal Lake should have a system to prevent water from the Saline entering the lake. Accidental introductions of extraneous fish are, however, likely to happen sooner or later, mainly at the hands of children and fishermen. In order to delay and/or decrease this problem, the people using the park should be made aware of the problems that may develop from apparently sporadic and innocuous introductions of fish to Crystal Lake.

RECOMMENDATIONS

The following are recommended in relation to each one of the four main objectives.

Fish Removal

The bigger, desirable fish should be removed from Crystal Lake by shocking and transported to a temporary holding pond, prior to the beginning of any sediment removal activity. It is recommended that the INHS be contacted to perform this job. These bigger fish should be returned to the lake after the restoration work is completed.

The remaining fish should be killed with the use of Rotenone, and removed as much as possible from the lake. It is recommended that the IDOC's district biologist be contacted well in advance to conduct the Rotenone application. In the event that the IDOC is unavailable to perform this job, the INHS should be contacted for the same purpose.

Fish Restocking

Recommendations concerning the restocking of fish in Crystal Lake are:

1. Use of groundwater as a water source for Crystal Lake.

2. Crystal Lake should be inoculated with plankton samples from lakes nearby before the lake is completely filled up, preferably a month or more before the restocking of fish takes place.

3. Stock Crystal Lake with both adult and fingerling fish of the following species: largemouth bass, smallmouth bass, redear sunfish, fathead minnow, and channel catfish.

4. Largemouth bass, smallmouth bass, and fathead minnow should be stocked <u>first</u>, if possible in early spring but no later than early summer. Redear sunfish and channel catfish should be stocked in mid to late fall. The above recommendations concern the adult fish; the fingerlings should be stocked at the time indicated by the IDOC's district biologist.

5. The stocking of fingerlings should be done through the IDOC, at densities recommended by their district biologist.

6. The recommendation concerning the initial stocking densities for adult fish is a combination of the three different suggestions obtained during this study. The recommended stocking densities and costs are presented in Table V-9. It is important to remember that the larger desirable fish that were taken from the lake before the restoration process will then be returned to the lake. This will hopefully make a sizeable contribution to the stocking efforts and will help decrease the costs of purchasing adult fish.

7. The channel catfish should be restocked annually, at a density of 50 fish/acre. This quantity can be adjusted in the future to match smaller or greater fishing pressures on the catfish population.

8. The stocking of crayfish is recommended to help control macrophyte growth in the lake.

9. A reduction in the cost of stocking Crystal Lake can be achieved by acquiring smaller fish. Although this could be done to a limited extent, we do not recommend the indiscriminate use of this procedure. It is important to remember that Crystal Lake is going to be used as a recreational resource, and as such, fish of good sizes should be made available to the public as soon as possible. Also, we should remember that the cost of restocking the lake is relatively small when compared to the total cost of restoring Cyrstal Lake.

Fish Habitat Development

Our recommendations toward the imporvement of the fish habitat in

Crystal Lake are:

A. Lake morphology

1. The depth should be greater than 12 feet in at least 25% of the lake surface. Some places should be as deep as 18-20 feet.

2. The bed topography should be irregular.

3. The littoral areas should represent approximately 20% of the surface area, and should have depths in the range of 2 to 5 feet. Areas less than 2 feet deep should be kept to a minimum.

4. The littoral shelf along the lake margin should not be wider than 6 feet, to limit growth of aquatic macrophytes, with the exception of the ice skating area. The littoral shelf could be wider than that around the islands, to allow for plenty of habitat for the spawning fish.

5. The slopes should be of 1:10 to 1:20 ratio in the littoral area and increase abruptly to 1:3 beyond that point.

6. No alterations are recommended in the lake contour because of the disturbance and bank destabilization that would be created.

B. Living structures

1. If the aquatic macrophytes ever need to be trimmed by mechanical means, the process should leave strips of plants approximately 2-3 feet wide.

C. Artificial structures

1. Submerged artificial reefs should be installed in Crystal Lake. They should amount to 0.25% of the surface area, which for Crystal Lake represents 0.02 acres, or 870 sq. ft. It is recommended that this lower value of reef coverage be used as it is likely that Crystal Lake will present, in a few years, a good amount of cover from aquatic macrophytes.

   The artificial reefs should be composed of both brush and tire units.

   The implementation of two bigger reef areas in the middle of the lake, and five smaller ones near the fishing docks (Figure V-12), is recommended. These smaller reefs will attract fish to the fishing area; their half-moon shape should allow for diversity of fishing sites (reef X non-reef areas) at all docks.

2. The larger reefs should consist of an assemblage of brush shelters and all kinds of tire units. Each larger reef should have at least one high-profile tire unit, which should be put in place before the lake is filled up. The smaller units can be either dropped from a boat or placed on top of the ice at the end of winter, so that they will submerge as soon as the ice cover melts in spring.

3. The five smaller reefs should be comprised of brush shelters and the two smaller tire units, i.e., the single and the triangular units.

4. Any trees cleared during the restoration process should be dumped in Crystal Lake to improve fish habitat.

5. Artificial structures should be installed for the spawning of largemouth bass and fathead minnows. These structures should be placed preferably around the islands and in other secluded areas, to avoid public interference and vandalism.

6. The installation of artificial structures for spawning of catfish is not recommended because even if reproduction is successful, most of the catfish fry are likely to be eaten by the bass and sunfish.

Fish Management and Monitoring

Recommendations concerning the implementation of a fisheries management program in Crystal Lake are:

1. Implementation of a fisheries monitoring program, which would consist of one annual inventory of the fish populations in Crystal Lake. This inventory and the interpretation of its results should be conducted by the IDOC. If the IDOC is unavailable for any reason, the INHS should be contacted for the same purpose, and, as a last resort, the fish inventory could be conducted by the students from the University of Illinois.

2. The information obtained from the monitoring program should be used to pinpoint possible problems affecting the fish populations in Crystal Lake.

3. The initial implementation of any size limit policy for the bass is not recommended. This management tool, however, should be kept in mind in case the fish monitoring program indicates any problem in the structure of the bass population in the future.

4. There should be serious efforts on the part of the Crystal Lake Park administration to try to reduce the possibility of introduction of extraneous fish species into the lake. It is recommended that signs be posted in strategic locations around the lake, such as close to the fishing docks, informing the public of the jeopardizing effect of such introductions on the fish populations in the lake.

FUNDING, PRESENT AND FUTURE LAKE USE

By Mary Martin and Lori Ward

SECTION VI. FUNDING, PRESENT AND FUTURE LAKE USE
by
Mary Martin and Lori Ward

INTRODUCTION

Crystal Lake Park is the largest park in Champaign-Urbana, sited on a 90 acre tract in northwest Urbana adjacent to the County Fairgrounds and Busey Woods. Many past observers have noted the beauty of the Park's 7 acre lake, a beauty intensified by the rarity of area surface waters. However, eutrophication has wrought many changes in the character of the lake since its formation.

Once-common fish have been replaced with less desirable species, and some game fish populations have become stunted (see section V); lake surface has become unsightly and difficult to traverse (see section IV); lake depth has decreased dramatically (see section III). It is likely that such changes have prompted diminished recreational use of Crystal Lake. Implementation of proposed restorational procedures detailed within this report should much improve lake conditions. It was unknown whether such restoration would prompt an increase in lake usership sufficient to warrant increasing the supply of other Park services.

An examination of present recreational use of Crystal Lake and estimation of future lake use following restoration through 1993 was therefore conducted. This study incorporated the following elements:

1. Mail and telephone surveys of Chanpaign-Urbana household's current use of Crystal Lake;

2. Projection of Champaign-Urbana population through 1993.

The use of such methods to estimate present, and expected future, recreational use is well-documented.[1] Various sources were also contacted to assess the potential availability of funding for lake restoration.

Surveys of current and projected lake use should estimate Champaign-Urbana households' valuation of both Crystal Lake, and its restoration. The Park District might include such information in an analysis of the costs and benefits of Crystal Lake restoration. Similarly, the availability of funding will also influence total project value. Such values might be used to rank various lake restoration alternatives, and to rank lake restoration itself among those projects potentially funded by the Park District.

METHODS

An examination of potential lake restoration funding sources, present recreational use of Crystal Lake and estimation of future lake use following restoration through 1993 was conducted using the following methodology:

---

[1]See: International City Management Association, Using Productivity Measurement: A Manager's Guide to More Effective Services, Management Information Service Special Report no. 4 (Washington, D.C.: International City Management Association, 1979); Kenneth Webb and Harry P. Hatry, Obtaining Citizen Feedback: The Application of Citizen Surveys to Local Governments (Washington, D.C.: The Urban Institute, 1973); Hatry and Dunn, Measuring the Effectiveness of Local Government Services; and Hatry et.al., How Effective Are Your Community Services? for a defense of survey research.
See: Seymour M. Gold, "Recreation Space, Services, and Facilities," The Practice of Local Government Planning (Washington, D.C.; International City Management Association, 1979); F. Stuart Chapin, Jr. and Edward J. Kaiser, Urban Land Use Planning (Urbana, Il.: University of Illinois Press, 1979) for a defense of population projections and estimations of future recreational demand.

1. Personal communications with potential sources of funding for lake restoration;

2. Mail and telephone surveys of Champaign-Urbana households;

3. Projection of Champaign-Urbana population through 1993, and of Crystal Lake usership through 1993.

A vareity of sources (References VI) were contacted by telephone to determine the probable availability of lake restoration funding. Their listing is not exhaustive, but illustrative of the major funding sources that might be examined. These sources' responses are examined within the following section (Findings VI).

Mail and telephone surveys of Champaign-Urbana households were used to assess present lake use and usership. Both survey populations were drawn randomly from the 1982 Champaign-Urbana Telephone Directory; page, column, and line numbers were selected from a table of standard statistical formula[1] (Krueckeberg and Silvers, 1974) set for a 90% confidence interval.

Eight hundred mail surveys were mailed to randomly-selected Champaign-Urbana households. Each survey contained a detachable cover letter describing survey purpose and procedures; a sketch of Champaign-Urbana census tracts; and fifteen questions addressing each household member's present lake use, expected post-restoration lake use, and individual characteristics (APPENDIX A). Surveys were double-posted and addressed for return mailing. Their design obviated the need for envelopes.

Heeding Sudman's warnings concerning typical 30% survey response rates (Sudman, 1957), eight hundred surveys were mailed in hopes of garnering the two hundred seventy-one responses needed to accurately analyze results within a 90% confidence interval. However, initial return rate failed to approach the 30% expected response rate. Follow-up was therefore begun upon passage of the deadline for survey return stated in the cover letter. This follow-up consisted of radio, television, and newspaper public affairs messages and classified advertisements as well as limited telephone contact with mail survey non-respondents. These methods were chosen for their ability to reach large numbers of area residents while respecting time and budget constraints.

Telephone surveys differed from mail surveys in extent and delivery. Two female questionors delivered 271 telephone surveys between 9:00a.m. and 10:00p.m. on both weekdays and weekends. Each survey consisted of a brief explanation of survey purpose, and eight of the fifteen questions appearing within the mail survey. Unlike mail surveys, in which each household member was requested to respond, telephone questionors surveyed only that individual answering the telephone. Non-respondents consisted largely of individuals who could not be reached, in addition to a small number who refused to participate in the survey.

Mail and telephone surveys were initially analyzed separately. The overwhelming majority of mail survey respondents failed to rank question alternatives as instructed, but rather ranked all affirmatives equally. However, because those surveyed by telephone were also not requested to rank listed alternatives, incorrect mail survey completion facilitated comparison of telephone and mail survey responses. Numbers were assigned each possible question response, then talleyed. Cross-tabulations and frequency distributions were then performed.

Telephone survey responses were analyzed similarly. Identical mail and telephone survey question responses were numbered identically to ease intersurvey comparison.

Cross-tabulations were performed to determine the strength of associations between such telephone survey items as: awareness of Park location with Park visitation (in total, and by sex); Park visitation by respondents sex, location, and length of residence; number of activities performed in conjunction with other activities by frequency; and by sex and location of respondent. Potential lake improvements prompting increased lake usership were tabulated by location, age, and activities performed at Crystal Lake Park in 1982. Respondents were characterized by sex, age, household size, location, and length of residence.

Cross-tabulation made among mail survey items include the following: awareness of Park location with Park visitation; Park visitation by respondents' sex, location, and length of residence; activity performed at Crystal Lake with activities engaged in elsewhere; activities performed by frequency; and by age and sex of respondent. Potential lake improvements prompting increased lake use were again correlated with respondents' age and location, as well as with activities performed elsewhere, and with explanation of activity performance elsewhere. Respondents were grouped according to age, sex, location, conveyance, marital status, household size, frequency of lake use, and length of residence.

Estimation of Crystal Lake usership through 1993 was developed as a function of both projected Champaign-Urbana population through 1993, and of present lake usership. As already noted, mail and telephone survey content was used to estimate present lake usership. Comparison of telephone and combined survey findings was done to conjecture the appearance of mail survey results had they been received in more significant number.

FINDINGS

Through use of the previously described methodology, determinations of the potential availability of lake restoration funding, present and expected post-restoration lake use were generated.

A variety of primarily public sources were contacted concerning restoration funding (References VI). Of these sources, four might provide monies for Crystal Lake restoration. These include:

1. Federal Clean Lakes Act Funding.
2. Illinois Department of Conservation Land and Water Conservation funding.
3. Joyce Foundation grant.
4. United States Department of Housing and Urban Development Community Development Block Grant.

The Federal Clean Lakes Act authorizes state disbursement of three-stage funding for long-term lake rehabilitation. Each state "ranks" its waterbodies on the basis of criteria outlined within the Clean Lakes Program Guidance Manual (U.S. E.P.A., 1980). Classification criteria include lake recreational value, public ownership and access, area population size, integration with other environmental programs, and expected duration of restoration improvements gained (U.S. E.P.A., 1980).

Lakes are ineligible for restoration funding until assigned a rank within the state. Although the Urbana Park District is now assembling data needed for such classification, Crystal Lake has not yet been ranked and is therefore not currently eligible to receive funding. No new applications for Clean Lakes funding are now being processed. Although new project funding may resume in 1985, this is uncertain. Additionally, if lake restoration begins as proposed in Spring 1984, Crystal Lake may become ineligible to receive Clean Lakes funding in 1985. Because the Clean Lakes Act emphasizes long-term restoration, it could be concerned with storm sewer redirection rather than dredging. Availability of Clean Lakes funding, then, is problematic. (U.S. E.P.A., 1983).

Illinois Department of Conservation Land and Water Conservation grants are made available "to acquire or develop land for outdoor recreation." The Park District has applied for such funding and should learn of the grant decision in January, 1984 (Ebetsch, 1983).

The Joyce Foundation, a private organization based in Chicago, may also supply grant monies for lake rehabilitation. The Foundation is described within a pamphlet available through the Foundation. Such funding can be sought through application to the Foundation Program Director. A letter outlining restoration costs and objectives is first requested (Carey, 1983).

The Park District may jointly apply for a United States Department of Housing and Urban Development Community Development Block Grant (C.D.B.G.) with the city of Urbana. It is unknown whether or not Crystal Lake restoration is an eligible use of such funding. Typically, C.D.B.G. funding of lake restoration is awarded where the waterbody serves as a public water supply. The Park District can apply for such funding through the City of Urbana Department of Community Development (Grants Department United States Department of Housing and Urban Development, 1983).

Present lake use findings were developed through the application of frequency distribution analysis and cross-tabulation of mail and telephone survey responses.

Cross-tabulations were performed on telephone survey responses to discover possible correlations between awareness of Park location; Park visitation with respondent sex and location; number of activities performed by respondent sex, location, and age; and respondent attributes including sex, age, location, and household size.

Sixty-nine percent of the two-hundred seventy-one individuals contacted had visited Crystal Lake Park. Of those who had never visited the Park, 54% were unaware of Park location.

Table VI-I reveals a strong correlation between Park awareness and visitation among both males and females (refer to Table VI-I). Seventy-six percent of all females had visited the Park, while 60% of those not visiting were also aware of Park location. Although a smaller percentage of all males were likely to be aware of Park location, aware males had a greater tendency to visit Crystal Lake. Only 38% of male nonvisitants expressed awareness of Park location. Fifty-four percent of all non-visitants were male, and the remaining 46% female.

Associations were then sought between activities performed, sex, age, and household size. The most common number of activities performed by men was four, with 29% of the males in all age cohorts performing four acts. Women most commonly performed three acts at the Park, with 31% of the women questioned choosing this response. Among those Park visitants, 85% of the males questioned performed from one to five of the activities noted in Telephone Survey Question 3 during 1982. Another 13% performed no named activities, but did visit the Park. Similarly, 78% of all female park visitants performed between one and five survey-named

Park Awareness		Phone Survey: Yes	No	Total
Yes	Male	93	20	113
	Female	95	18	113
No	Male	0	33	33
	Female	0	12	12
	Total	188	83	271

TABLE VI-1. Compiled telephone survey results of Crystal Lake Park awareness (ie. location) and Park visitation in relation to the sex of the respondent. Values within matrix represent number of respondents within each category.

Number of Activities Performed	Male A	Male B	Male C	Male D	Male E	Male F	Female A	Female B	Female C	Female D	Female E	Female F
1	0	0	0	3	4	0	0	0	4	5	0	0
2	0	0	2	6	3	2	0	0	7	5	3	0
3	2	1	3	8	6	0	0	1	11	8	6	3
4	2	1	6	9	5	3	0	2	7	4	2	0
5	3	0	1	3	4	0	0	2	6	2	0	0
6	0	0	1	0	0	0	0	0	0	0	0	0
7	0	0	1	7	2	2	0	0	2	3	3	7

TABLE VI-2. Compiled telephone survey results of the number of activities performed by age (see Appendix B, Question 12 for codes) and sex of Park visitors.

activities in 1982. An additional 15% performed non-named Park activities (see Table VI-2). However, breakdown by respondent sex and number of activities performed by age cohort is more interesting. One hundred percent of the number of activities performed between the ages of 0-9 were male. Seventy-one percent of gross totaled activities performed by those aged 10-14 were done by women, however, and 73% of acts done by those aged 15-24 were performed by women. Men performed 57%, 63%, and 59% of acts done by persons aged 25-44, 45-64, and 65 and over, respectively.

Males surveyed performed 268, and females 234, named activities at Crystal Lake Park in 1982. Males composed 73% of those who boated, 86% of those who fished, and 55% of those who described themselves as sitting or walking by the lake. Men also made up 37% of those who ice skated, 45% of those playing at the playground, 47% of nature observer, and 42% of individuals attending children. Males most heavily fished, sat/walked by the lake, observed nature, and attended children (see Table VI-3).

Correlations were further sought between activities performed by location. Table VI-5 distinguishes respondents by sex, location, and surveyed activities performed. The majority of activities were performed by respondents located within census tracts 3, 13, 12.02, 57, and 5, respectively. Interestingly, although several immediately neighboring census tracts did reflect higher than average number of Park activities performed, higher numbers were generated from the area southwest of Crystal Lake (including southwest Champaign). Of those located in non-adjacent census tracts, males frequently responded that they fished, boated, or observed nature, and sat/walked by the lake. Females most

		Activities Performed						
		A	B	C	D	E	F	G
Sex	Male	27	43	13	70	23	65	27
	Female	10	7	22	57	28	73	37
	Total	37	50	35	127	51	138	64

TABLE VI-3. Compiled telephone survey results of the type of activities (see Appendix B, Question 7 for activity codes) performed by Crystal Lake visitors in relation to their sex.

		Age						Household Size							
		A	B	C	D	E	F	1	2	3	4	5	6	7	8
Sex	Male	0	10	33	43	35	25	30	35	15	25	5	0	0	2
	Female	0	0	34	50	27	14	42	53	25	35	5	0	3	0
	Total	0	10	67	93	62	39	72	88	40	60	10	0	3	2

TABLE VI-4. Compiled telephone survey results of the sex, age (see Appendix B, Question 12 for age group codes) and household size of Crystal Lake Park users.

often observed nature or sat/walked by the lake (see Table VI-5).

Mail survey cross-tabulations were performed to gleam possible associations among such items as: Park awareness and visitation; activities done by age and sex of respondent; user attributes including sex, age, household size, marital status, and length of residence. Correlations were also drawn between location and frequency of visitation of respondent. Location was also correlated with sex and length of residence.

Eighty-seven percent of respondents had visited Crystal Lake. A slightly higher percentage of males visited the lake than did females, although this was offset by a slightly larger total of female, over male, visitants. Of those nonvisitants, only 33% of the males were aware of Park location, in comparison with a 62% awareness of nonvisiting women. Such results are similar to those received in the telephone survey (see Table VI-6).

Activities performed are again correlated by respondent age and sex. Males between the ages of 25-44 most frequently performed activities among males, followed closely by those aged 45-64. Among females, those aged 25-44 were also most likely to perform cited activities. Both males and females were almost equally likely to most frequently sit/walk by the lake, seconded by observing nature (see Table VI-7).

Location was originally assumed to be correlated with activity performance. However, analysis of telephone survey response has revealed uneven results. Such analysis has seemed to apply fairly strong correlations between number of activities performed and both adjacent census tract locations and quite distant locations. Analysis of mail survey correlation between location and frequency of visitation (see Table VI-8)

Sex and Activities

Census Tract	Male A	Male B	Male C	Male D	Male E	Male F	Male G	Female A	Female B	Female C	Female D	Female E	Female F	Female G	Total
1	0	0	0	0	0	0	0	0	0	0	2	0	2	2	6
2	0	0	0	0	0	0	0	0	0	0	2	0	2	2	6
3	5	10	5	13	7	10	3	2	0	0	2	0	2	0	59
4	3	2	0	2	0	3	2	0	0	0	2	2	2	2	20
5	3	5	0	5	0	5	0	0	0	2	5	2	5	0	32
6	0	0	0	2	0	2	0	2	2	2	2	5	5	2	24
7	2	2	0	3	0	3	2	0	0	0	0	0	0	0	12
8	2	5	0	5	2	2	2	0	0	2	0	0	2	2	24
9	0	0	0	0	0	0	0	0	0	3	2	2	3	0	10
10	0	0	0	0	0	0	0	0	0	2	0	2	2	0	6
11	0	0	0	0	0	0	0	0	0	0	0	0	2	2	4
12.01	2	2	0	2	0	2	2	0	2	3	5	0	5	3	28
12.02	2	7	0	8	2	7	3	0	0	2	2	0	3	2	38
13	3	5	2	8	2	7	2	0	2	3	2	2	3	0	41
14	2	0	0	2	0	2	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	2	0	2	0	4
52	0	0	2	2	0	0	2	0	0	0	2	0	2	0	10
53	0	0	0	0	0	0	0	0	0	5	7	5	5	3	25
54	2	2	2	5	2	5	3	0	0	2	2	0	2	0	27
55	0	2	2	3	2	3	2	0	0	0	0	0	0	0	14
56	2	2	0	2	0	0	2	0	0	0	0	0	0	0	8
57	2	2	0	3	3	5	2	0	0	0	3	3	7	5	35
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	2	0	2	0	4
60	0	0	0	2	0	0	0	0	0	0	2	0	2	2	8
106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	30	46	13	67	20	56	27	4	6	26	46	23	60	27	451

TABLE VI-5. Compiled telephone survey results of the type of activities (see Appendix B, Question 7 for activity codes) performed at Crystal Lake and the census tract location (see Appendix A map) of Park visitors.

Park Awareness		Park Visitation: Yes	No	Total
Yes	Male	46	2	48
	Female	49	5	54
No	Male	0	4	4
	Female	0	3	3
	Total	95	14	

TABLE VI-6. Compiled mail survey results of Crystal Lake Park awareness (ie. location) and Park visitation in relation to the sex of the respondents.

Activities Performed	Male A	Male B	Male C	Male D	Male E	Male F	Female A	Female B	Female C	Female D	Female E	Female F
A	0	1	0	0	0	0	0	1	0	0	0	0
B	0	1	0	1	0	0	0	1	0	0	1	0
C	0	0	1	2	0	0	0	2	0	1	0	0
D	3	2	6	9	12	1	0	3	9	10	8	1
E	3	2	3	5	1	0	2	3	4	5	0	0
F	2	2	4	9	6	2	0	3	8	11	6	1
G	1	0	0	4	4	0	0	1	0	4	1	0
None	0	0	2	1	3	1	0	1	0	4	2	2

TABLE VI-7. Compiled mail survey results of the type of activities (see Appendix B, Question 7 for codes) in relation to the sex and age (see Appendix B, Question 12 for age group codes) of survey respondents

How Often Visited

Census Tract Residence	Daily	Weekly	Monthly	At least 4 times	At least once	Never	Total
1	0	0	0	0	1	0	1
2	0	0	0	0	0	0	0
3	0	0	1	2	2	3	8
4	0	1	0	0	2	1	4
5	0	0	0	0	5	4	9
6	0	0	0	1	0	0	1
7	0	0	0	2	0	0	2
8	0	0	0	0	2	0	2
9	0	0	0	0	0	0	0
10	0	2	0	1	0	1	4
11	0	0	0	0	2	0	2
12.01	0	0	0	6	3	1	10
12.02	0	0	0	0	1	2	3
13	0	0	0	0	6	2	8
14	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0
52	0	0	2	0	1	0	3
53	0	0	0	0	1	0	1
54	3	2	2	4	0	0	11
55	0	0	0	2	1	4	7
56	0	2	0	2	2	0	6
57	0	0	2	8	2	0	12
58	0	0	0	3	2	0	5
59	0	0	0	0	1	1	2
60	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0
Total	3	7	7	31	34	19	101

TABLE VI-8. Compiled mail survey results of the rate of Crystal Lake Park use in relation to the census tract residence (see Appendix A map for codes) of respondents.

reveals that frequency may be much more strongly correlated with location than is number of activities performed. Those performing a large number of Park activities while living in relatively distant tracts may then visit the Park much more infrequently than would individuals closer to Crystal Lake. These two types of users will place different demands upon Crystal Lake services. Visitation and location were further correlated by sex and length of residence (see Table VI-9). Expected future lake use was addressed through analysis of survey results on expected post-restoration lake usership and projections of Champaign-Urbana population through 1993.

Tables VI-10 and VI-11 are compilations of information obtained from surveys which would likely increase Park use if specific facility improvements were made. Of those surveyed by telephone, 18% stated an intention to visit Crystal Lake more often if lake surface were cleaner; 15% would increase visitation if more pleasant odors were achieved; 14% related increased use to bank revegetation; and 9% to the presence of more fish within the lake (see Table VI-10 for details). Respondents to the mail survey also supported the above improvements although the importance attached to each specific improvement were somewhat different. Mail survey responses suggest 19.5% increase in usership if lake odor and surface cleanliness were improved, while 14% linked increase use to bank revegetation and 8% to more fish (Table VI-11).

Census tract residence of telephone respondents was not related to survey response but was important in the mail survey. This is likely attributable to interest by near-Park households, prompting higher responses from residence in the immediate vicinity of the Park. Individuals within

	Length of Residence																
	Male								Female								
	Visited				Not Visited				Visited				Not Visited				
Census Tract Residence	less one	1-4	5-9	10+	less one	1-4	5-9	10+	less one	1-4	5-9	10+	less one	1-4	5-9	1
1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3	0	0	0	0	0	0	0	0	0	5	0	1	0	2	0	
4	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	
5	0	1	0	4	2	0	0	0	0	1	0	1	2	0	0	
6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	
7	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	
8	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
10	0	1	0	1	0	0	0	0	0	1	1	0	0	0	0	
11	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	
12.01	0	0	1	5	0	0	0	0	0	0	0	4	0	0	0	
12.02	0	1	0	2	0	0	0	0	0	0	0	1	0	0	0	
13	0	0	0	2	0	0	0	1	0	0	0	4	0	0	0	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
52	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	
53	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
54	0	3	0	2	0	0	0	0	0	5	0	0	0	0	0	
55	0	1	0	2	0	0	0	0	1	1	0	2	0	0	0	
56	0	2	0	1	0	0	0	0	0	2	0	1	0	0	0	
57	0	0	0	6	0	0	0	0	0	0	0	6	0	0	0	
58	0	0	1	2	0	0	0	0	0	0	1	1	0	0	0	
59	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total	1	12	3	28	2	1	0	1	2	22	3	23	2	2	0	

TABLE VI-9. Compiled mail survey results of Park visitation in relation to the sex, census tract residence (see Appendix A map for codes) and length of residence at present location for respondents.

Items Which Would Increase Lake Usership

Census Tract Location	A	B	C	D	E	F	G	H	I	J	K	Total
1	0	0	0	0	0	0	0	0	0	0	0	0
2	2	2	0	0	0	0	0	2	0	0	2	8
3	2	0	2	3	3	3	2	5	2	2	0	24
4	2	0	0	2	5	3	2	5	2	3	0	24
5	5	2	2	5	10	10	7	9	3	3	2	58
6	0	0	0	0	5	3	0	5	2	2	5	22
7	2	2	2	0	2	0	2	0	0	2	0	12
8	0	0	0	2	2	2	0	0	0	3	2	11
9	0	0	0	0	2	2	0	0	0	2	0	6
10	2	2	2	2	2	2	2	2	0	0	2	18
11	0	0	0	0	0	0	0	0	0	0	0	0
12.01	5	2	2	3	5	5	2	7	5	3	3	42
12.02	2	0	0	0	3	2	3	0	0	2	2	14
13	3	3	0	3	7	5	2	7	2	2	0	34
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
51	2	2	0	2	2	2	2	2	0	2	0	16
52	0	0	0	0	2	3	0	3	0	0	0	8
53	3	3	3	2	3	2	2	2	2	2	2	26
54	0	0	0	2	3	2	0	2	0	2	0	11
55	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	2	2	2	3	3	2	0	2	2	18
57	5	0	3	2	12	5	5	7	2	0	5	46
58	0	0	0	0	0	0	0	0	2	0	0	0
59	0	0	0	0	2	2	0	2	0	0	0	6
60	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0	0	0	0	0
Total	35	18	18	30	72	56	34	62	22	32	27	406

TABLE VI-10. Compiled telephone survey results of Park improvements which if implemented (see Appendix B, Question 10 for facility codes) would increase Park visitation rates in relation to the census tract location of respondents (see Appendix A for map).

Items Which Would Increase Lake Usership

	A	B	C	D	E	F	G	H	I	J	K	Total
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	0	1	3	2	0	3	1	0	1	12
4	2	2	0	2	4	2	2	1	0	2	0	17
5	0	0	0	0	4	3	0	3	0	0	0	10
6	0	0	0	0	1	1	0	1	0	0	0	3
7	0	0	0	0	0	0	0	1	0	0	0	1
8	0	0	0	0	2	2	0	2	2	2	2	12
9	0	0	0	0	0	0	0	0	0	0	0	0
10	3	0	0	0	1	2	1	2	1	0	0	10
11	0	0	0	0	0	0	0	0	0	0	0	0
12.01	2	1	1	4	2	2	1	4	1	0	1	19
12.02	0	0	0	0	1	0	0	1	0	0	0	2
13	1	1	1	1	3	0	1	2	1	0	0	11
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	2	2	0	2	0	0	0	6
53	0	0	0	0	0	0	0	0	0	0	0	0
54	7	6	6	2	9	5	5	10	3	6	5	64
55	1	1	1	1	1	0	1	1	0	0	0	7
56	1	1	1	1	6	5	1	6	2	2	0	26
57	3	3	3	3	7	6	1	7	5	0	0	38
58	1	1	1	2	2	2	0	3	1	0	0	13
59	0	0	0	0	3	3	0	2	2	1	0	11
60	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0	0	0	0	0
Total	21	17	14	17	51	37	13	51	19	13	9	262

TABLE VI-11. Compiled mail survey results of Park improvements which if implemented (see Appendix B, Question 10 for facility codes) would increase Park use in relation to the census tract location of the respondents (see Appendix A map).

four non-adjacent Park census tracts (ie. 5, 12.01, 57, and 13; Appendix A map) generated 43% of the items which would increase individual usership in the telephone surveys. In the mail survey, 24% of the items generating increased usership were produced by census tract 54 (just east of the Park), 14.5% was produced by tract 57 (south east Urbana), and 10% produced by tract 56 (Urbana north of Florida and south of Washington street.

It is expected that reasons for using recreational facilities other than Crystal Lake Park would be of value in future Park management. These data are presented in Table VI-12.

Projection of Champaign-Urbana area population was also performed to acquire information for predicting future demands upon local resources. Although the cohort-survival method, which was employed in our analysis, does not incorporate such influences as migration, changing economic base, etc. on the final estimate, it does utilize birth and survival rates and local population figures. The projected population estimates obatined using the above methodology are presented in Table VI-14. The Illinois Bureau of the Budget has recently completed population projections for Champaign County. The Champaign County Regional Planning Commission, however, has not yet developed such projections for Champaign and Urbana, although they anticipate the availability of the figures in the near future. Thus, the projections in Table VI-14 are based upon the limited amount of information available.

Activity	Number of Responses
Boating	11
Fishing	12
Ice Skating	12
Sitting or Walking by lake	37
Playing at Playground	22
Observing Nature	53
Attending Children	13

TABLE VI-12. Compilation of mail survey results on recreational activities of respondents performed in the area at locations other than Crystal Lake Park.

Reason	Number of Respondents
Deeper Lake	7
Better Boating	8
Better Lake Odor	11
Better Skating	10
Able to Swim in Lake	10
More Fish Stocked in Lake	13
Better Quality of Fish Stocked	13
Greater Variety of Activities in Area	15
Better Provisions for Handicapped	5
Better Transportation	0
Closer to Home	19

TABLE VI-13. Compilation of reasons given in mail survey responses for performing recreational activities at locations other than Crystal Lake Park.

	Year				
	1980	1985	1990	1993	1995
Population	109,278	119,854	130,472	130,621	134,657

	Male		Female		
	White	Non-white	White	Non-white	Total
1980	46,679	8,591	45,402	8,606	109,278
1985	51,223	9,346	49,854	9,432	119,854
1990	55,822	10,076	54,325	10,249	130,472
1993	55,864	10,106	54,367	10,285	130,621
1995	57,444	10,512	55,912	10,789	134,657

TABLE VI-14. Projected Champaign-Urbana Area population through 1993 using the cohort-survival method.

RECOMMENDATIONS

The availability of funding for lake restoration, the importance residents attach to Crystal Lake, and the potential impact of population increase and restoration upon demand for park services can all affect the type and timing of restoration undertaken by the Park District.

An examination of the probability of obtaining funding for lake restoration, present lake use, and post-restoration lake use through 1993 has revealed information relevant to such concerns, permitting the formulation of the following recommendations.

It is recommended that the Park District continue to seek funding from private as well as public sources, including the Joyce Foundation, and HUD Community Development Block Grant (CDBG) funding. Although Federal Clean Lakes funding is highly problematic, Illinois EPA has recommended that the Park District continue lake testing should such funding become available. Because future availability of such is uncertain, however, it cannot be recommended that the Park District indefinitely delay restoration.

Surveyed expected post-restoration lake use and population forecasts through 1993 suggest the increased future demand for Crystal Lake as a natural and recreational resource. Analysis of present lake use implies that individuals are willing to travel to Crystal Lake from southwestern Champaign, for both fishing and non-fishing purposes. Crystal Lake might then be assessed as a valuable area resource. It is recommended that this value be included in an analysis of potential costs and benefits associated with the restoration of Crystal Lake.

APPENDIX A

Mail questionaire sent to local residents and the accompaning cover letter. Numbers on city map represent census tract codes used in survey for the twin cities of Urbana-Champaign.

Urbana Park District

General Office
901 N Broadway • Urbana, Illinois 61801 • 367-1536

11 October 1983

Dear Crystal Lake Park Area Household:

The Urbana Park District is looking at ways to improve the condition of Crystal Lake. It is considering deepening the lake, removing surface algae, restocking the lake with fish, and making other improvements.

Before lake improvement is begun, the Park District wishes to discover which changes community members might most prefer. Students from the University of Illinois are working with the Park District to conduct this survey. It asks how each member of your household uses Crystal Lake now, and how household members might use the lake in the future if certain changes were made.

Please read and answer as many questions as possible.

Survey results will be tabulated and made available through the Urbana Park District. The actual survey form you return will not be kept. Your name, address, telephone number, and any information that might identify you also will not be kept.

Your participation in this survey is voluntary. Survey results will help to determine what kinds of changes are made at Crystal Lake. If you have any questions or comments about the survey, please contact me.

To Return This Survey:

1) Fold the survey so that our preprinted address is shown. No envelope is needed.
2) Staple or tape shut the folded survey form.
3) Mail the survey to the address shown by November 1, 1983. The survey has already been stamped.

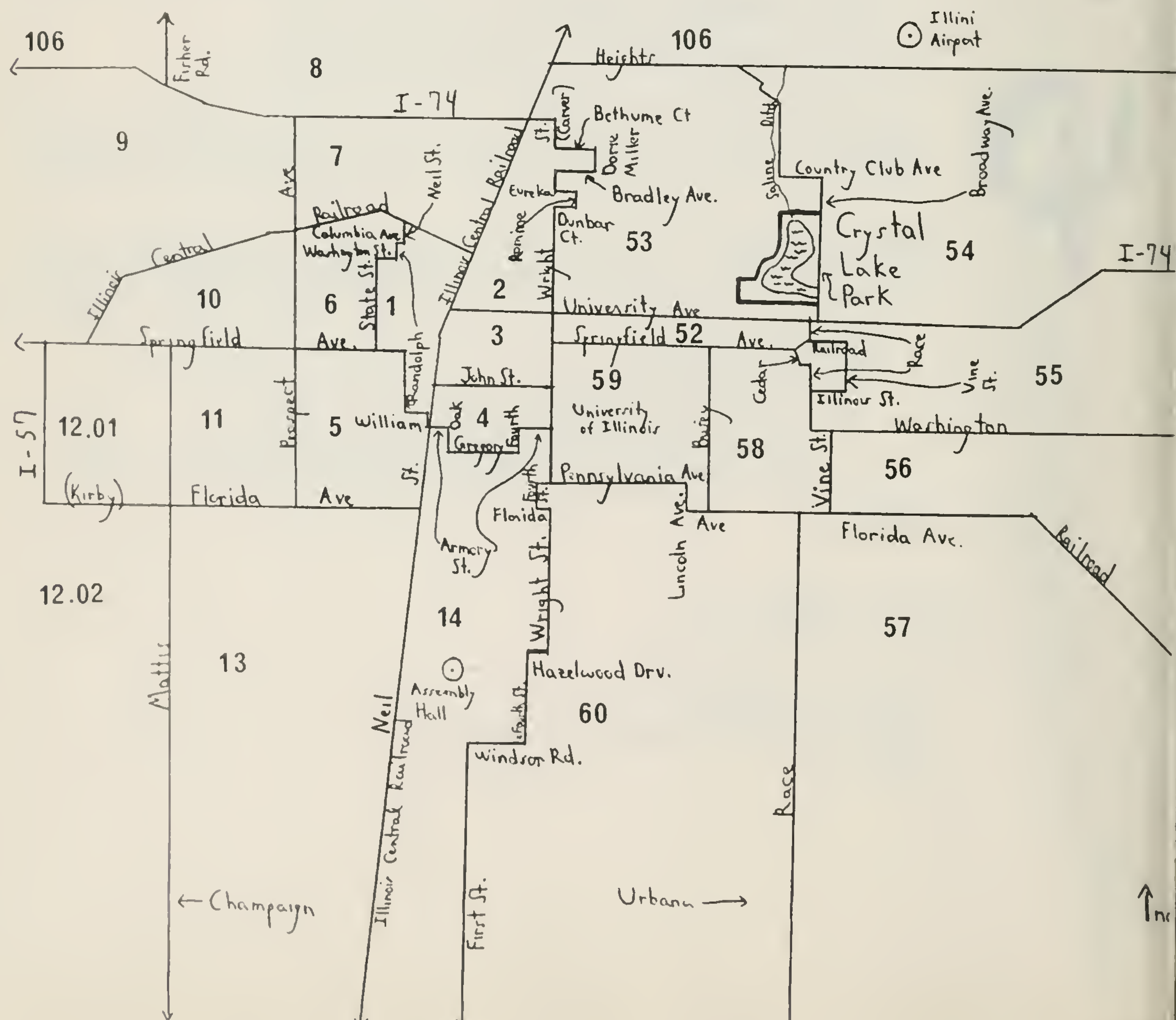
Thank you.

Lewis L. Osborne, Ph.D.
Assistant Professor
Dept. of Urban and Regional Planning
333-7127

Please have each member of your household complete this survey.
In Questions (4) through (9) and (11), please mark as many answers as you feel apply, and number these from most frequent use to least frequent use. For example, in Question (4), if you most often walk to Crystal Lake, drive there less often, and never reach the lake any other way, mark 'WALK'- 1, 'CAR'- 2, and leave the other answers blank.

		Person A	Person B	Person C	Person D	Person E	Pe
(1) Before receiving this survey, were you aware of the location of Crystal Lake Park?	YES_						
	NO						
(2) Have you ever visited Crystal Lake Park?	YES_						
	NO						

(3) Place an 'X' in the box where your dwelling is located in the drawing below.



(Turn

		Person A	Person B	Person C	Person D	Person E	Person F
(4) How do you usually get to Crystal Lake?	WALK						
	BICYCLE						
	MOTORCYCLE						
	CAR						
	BUS						
	TAXI						
(5) Approximately how often did you visit Crystal Lake during 1982?	DAILY						
	WEEKLY						
	MONTHLY						
	AT LEAST 4 TIMES						
	AT LEAST 1 TIME						
	NOT AT ALL						
(6) During which season did you visit Crystal Lake most often during 1982?	SPRING						
	SUMMER						
	FALL						
	WINTER						
(7) In which activities did you engage while at Crystal Lake during 1982?	BOATING						
	FISHING						
	ICE SKATING						
	SITTING OR WALKING BY THE LAKE						
	PLAYING AT THE PLAYGROUND						
	OBSERVING NATURE						
	ATTENDING CHILDREN						
(8) In which of these activities did you engage at places other than Crystal Lake during 1982, within the Champaign-Urbana area?	BOATING						
	FISHING						
	ICE SKATING						
	SITTING OR WALKING BY THE LAKE						
	PLAYING AT THE PLAYGROUND						
	OBSERVING NATURE						
	ATTENDING CHILDREN						

Question		Person A	Person B	Person C	Person D	Person E
(9) Why did you perform those activities marked in Question (8) at places other than Crystal Lake Park?	DEEPER LAKE					
	BETTER BOATING					
	BETTER LAKE ODOR					
	BETTER SKATING					
	ABLE SWIM IN LAKE					
	MORE FISH STOCKED IN LAKE					
	BETTER QUALITY FISH STOCKED IN LAKE					
	GREATER VARIETY ACTIVITIES IN AREA					
	BETTER PROVISIONS FOR HANDICAPPED					
	BETTER TRANSPORTATION					
	CLOSER TO HOME					
(10) Would you probably use Crystal Lake: More often (mark +), Less often (mark -), or an equal Amount (mark =), if the following changes were made?	MORE FISH					
	LARGER FISH					
	GREATER VARIETY FISH					
	LAKE DEEPENED					
	LAKE SURFACE CLEANER					
	LAKE BANKS REVEGETATED					
	FLOATING FISHING PLATFORMS					
	MORE PLEASANT LAKE ODOR					
	BETTER ICE SKATING					
	STORMWATER DIVERTED FROM LAKE					
	BETTER PROVISIONS FOR HANDICAPPED					
(11) What is your sex?	MALE					
	FEMALE					
(12) In which range does your age fall?	0-9 YEARS					
	9-14 YEARS					
	15-24 YEARS					
	25-44 YEARS					
	45-64 YEARS					
	65 AND OVER					
(13) What is your marital status?	SINGLE					
	MARRIED					
	WIDOWED/DIVORCED/SEPARATED					
(14) Including yourself, how many members are there in your household?						
(15) How many years has your household lived at its current address, or in the immediate area?						

APPENDIX B. Codes used in Tables for presentation in Section VI of mail survey responses.

Questionaire Number	Code - Answer
1	A = Yes; B = No
2	A = Yes; B = No
4	A = Walk; B = Bicycle; C = Motorcycle; D = Car; E = Bus; F = Taxi
5	A = Daily; B = Weekly; C = Monthly; D = At least four times; E = At least one time; F = Not at all
6	A = Spring; B = Summer; C = Fall; D = Winter
7 and 8	A = Boating; B = Fishing; C = Ice Skating; D = Sitting or walking by lake; E = Playing at playground; F = Observing nature; G = Attending children
9	A = Deeper lake; B = Better boating; C = Better lake odor; D = Better skating; E = Able to swim in lake; F = More fish stocked in lake; G = Better quality fish stocked in lake; H = Greater variety activites in area; I = Better provisions for handicapped; J = Better transportation; K = Closer to home
10	A = More fish; B = Larger fish; C = Greater variety fish; D = Lake deepened; E = Lake surface cleaner; F = Lake banks revegetated; G = Floating fishing platforms; H = More pleasant lake odor; I = Better ice skating; J = Stormwater diverted from lake; K = Better provisions for handicapped
11	A = Male; B = Female
12	A = 0-9 yrs; B = 10-14 yrs; C = 15-24 yrs; D = 25-44 yrs; E = 45-64 yrs; F = 65 and over
13	A - Single; B = Married; C = Widowed/divorced/ separated

SECTION VII. REFERENCES

Anderson, R. 1976. Management of small warm water impoundments. Fisheries 1(6):5-7, 26-28.

Anderson, R. 1978. New approaches to recreational fishery management. New Approaches to Management of Small Impoundments. Gary Novinger and Joe Dillard, eds. North Central Div. Amer. Fish. Soc., sp. publ. 5.

Bass, T., F. Westerdahl, R. Perrine, eds. Non-Point Source Water Quality Monitoring. INYO National Forest. 1975. Davis: California Water Resources Center; Los Angeles: Environmental Science and Engineering, Contribution No. 156.

Bates, R., and J. Hentges. 1976. Aquatic weeds - eradicate or cultivate? Economic Botany. pp. 39-50.

Bennett, G., and W. Childers. 1957. The smallmouth bass. Micropterus dolomieui, in warm-water ponds. Jour. Wildl. Management. (21):414-424.

Bennett, G. Management of Artificial Lakes and Ponds. New York: Reinhold, Publ. Co., 1962.

Benz, D. State Soil Conservation Service. Champaign, IL.

Bringham, A. Illinois Natural History Survey. (per. comm.).

Cairns, J., and K. Dickson, eds. Biological Methods for the Assessment of Water Quality. Philadelphia: American Society for Testing and Materials, 1973.

Carey, T. Joyce Foundation. (per. comm.)

Clark, Dietz. Consulting Engineers. 211 N. Race, Urbana, IL. (per. comm.)

Crowder, L., and W. Cooper. 1979. Structural complexity and fish-prey interactions in ponds: a point of view. Response of Fish to Habitat Structure in Standing Water. D. Johnson and R. Stein, Eds. North Central Div. Amer. Fish. Soc., sp. publ. 6.

Cummins, K. 1975. History of fish toxicants in the United States. Rehabilitation of Fish Populations with Toxicants: A Symposium. North Central Div. Amer. Fish. Soc., sp. publ. 4.

Department of Housing and Urban Development. Chicago. (per. comm.)

Dillard, J., and M. Hamilton. 1969. Evaluation of two stocking methods for Missouri farm ponds. Missouri Dept. Conserv., D-J series 7.

Dufford, D. Department of Conservation. Fisheries Division. (per. comm.)

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

Ebetsch, S. Land and Water Conservation Grant. (per. comm.)

Evans, R. Illinois State Water Survey. (per. comm.)

Federal Housing Authority. (per. comm.)

Fender's Fish Hatchery. Route 1. Baltic, OH 43804. (per. comm.)

Fitzpatrick Fishery Mgt. Service. 214 E. North St., Dwight, IL 60420. (per. comm.)

Fowley, C. City of Urbana. Community Development and Block Grant Division. (per. comm.)

Hach Co. 1982. Products for Analysis. Ames, Iowa.

Hahlberg, . Champaign Dept. of Conservation. (per. comm.)

Hiltibran, R. Illinois Natural History Survey. (per. comm.)

Hubbel, M. Illinois Dept. of Agriculture. Division of Natural Resources. (per. comm.)

Illinois Dept. of Conservation. 1983. Aquatic weeds: their identification and methods of control. Fishery Bulletin No. 4. Springfield: Division of Fish and Wildlife Resources.

Jansen, S. Champaign County Soil Conservation Service. Field Office. (per. comm.)

Johnson, D., and R. Stein. Response of Fish to Habitat Structure in Standing Water. North Central Division Amer. Fish. Soc., sp. publ. 6.

Kempton, J. Illinois State Geological Survey. Hydrogeology Dept. (per. comm.)

Kessler, K. Champaign County Fairgrounds. (per. comm.)

Kothandaraman, V., and R. Evans. 1983. Diagnostic-Feasibility Study of Johnson Sauk Trail Lake. Illinois State Water Survey Contract Report 312.

Krenkel, P., and V. Novothy. Water Quality Management. New York: Academic Press Inc., 1980.

Krueckeberg, S. 1974. Urbana Planning Analysis: Methods and Models.

Leary, M. 1980. Procedures for the Development of Fisheries Production on Surface Mined Lands. Dept. of Civil Eng., University of Illinois. Unpublished Manuscript.

Lopinot, A. 1972. Pond Fish and Fishing. Illinois Fish. Bull. 5, Illinois Department of Conservation.

" " . 1973. Foreword in Rehabilitation of Fish Populations with Toxicants: A Symposium. North Central Div. Amer. Fish. Soc., sp. publ. 4.

Lueschow, L. 1972. Biology and Control of Selected Aquatic Nuisances in Recreational Water. Technical Bulletin No. 57. Wisconsin Dept. of Natural Resources.

Mick, J. Department of Conservation. Fisheries Section. Springfield, IL. (per. comm.)

Mraz, D., S. Kimotek, and L. Frankenberger. 1961. The Largemouth Bass: its life history, ecology, and management. Wisc. Conservation Department publ. 232.

Muenscher, W. Aquatic Plants of the United States. New York: Comstock Publishing Co., Inc., 1944.

OECD, 1982. Eutrophication of Waters: Monitoring, Assessment, and Control. Organization for Economic Co-operation and Development. Paris Cedex.

Osborne, L. Department of Urban and Regional Planning. University of Illinois. (per. comm.)

Osborne, L. 1981. The Effects of Chlorine on the Benthic Communities of Sheep River, Alberta. Ph.D. Dissertation. University of Calgary, Calgary, Alberta. 517 pp.

Pinnock, . Champaign County Forest Preserve District. Executive Director. (per. comm.)

Plieger, W. 1975. The Fishes of Missouri. Missouri Dept. of Conservation.

Powless, T. Illinois Natural History Survey. Fisheries Section. (per. comm.)

Prince, E., J. Strange, and G. Simmon. 1976. Preliminary Observations on the Productivity of Periphyton Attached to a Freshwater Artificial Tire Reef. Proc. Ann. Conf. Southeast Association Fish Wildl. Agencies. 30:207-215.

Prince, E., O. Maughan, and P. Brouha. 1977. How to Build a Freshwater Reef. Sea Grant Publication 77-02. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Prince, E., and O. Maughan, 1978. Freshwater Artificial Reefs: Biology and Economics. Fisheries 3(1):5-9.

Prince, E., and O. Maughan. 1979a. Telemetric Observations of Largemouth Bass Near Underwater Structures in Smith Mountain Lake, Virginia. Response of Fish to Habitat Structure in Standing Water. North Central Div. Amer. Fish. Soc., sp. publ. 6.

Prince, E., and O. Maughan. 1979b. Attraction of Fishes to Artificial Tire Reefs in Smith Mountain Lake, Virginia. Response of Fish to Habitat Structure in Standing Water. North Central Div. Amer. Fish. Soc., sp. publ. 6.

Rodeheffer, I. 1945. Fish Populations In and Around Brush Shelters of Different Sizes Placed at Varying Depths and Distances Apart in Douglas Lake, Mich. Pap. Mich. Acad. Sci. Arts. Lett. 30(1944): 321-345.

Saiki, M., and J. Jash. 1979. Use of Cover and Dispersal by Crayfish to Reduce Predation by Largemouth Bass. D. Johnson and O. Maughan, eds.

Sanks, G. Urbana Park District. (per. comm.)

Sefton, D. Illinois EPA. Lakes Program Coordinator, Division of Water Pollution Control. (per. comm.)

Sefton, D., and J. Little. Volunteer Lake Monitoring, 1981. Springfield, Illinois EPA. 1982.

Sheets, R. Western Lion Ltd. 136 Main, Urbana, IL. (per. comm.)

Sing, C. Illinois State Water Survey. (per. comm.)

Smith, P. 1979. The Fisheries of Illinois. University of Illinois Press, Urbana, IL.

Stout, G. Water Resource Center. Director. (per. comm.)

Sudman, S. 1957. Applied Sampling.

Tazik, D. Illinois Natural History Survey. Aquatic Biology Section. (per. comm.)

U.S. EPA. 1980. Clean Lakes Program. Guidance Manual. Washington, D.C. EPA-940/5-81-003.

U.S. Fish and Wildlife Service, Dept. of the Interior.

U.S. Geological Survey. (per. comm.)

Vogele, L., and W. Rainwater. 1975. Use of Brush Shelters as Cover by Spawning Black Basses (*Micropterus*) in Bull Shoals Reservoir. Trans. Amer. Fish. Soc. 104(2):264-269.

Wege, G., and R. Anderson. 1979. Influence of Artificial Structures on Largemouth Bass and Bluegills in Small Ponds. *Response of Fish to Habitat Structure in Standing Water.* North Central Div. Amer. Fish. Soc., sp. publ. 6.

Wetzel, R. Limnology. Philadelphia: W. B. Saunders Company, 1975.