INSTRUCTION REPORT A-77-1

TEST PLAN FOR THE LARGE-SCALE OPERATIONS MANAGEMENT TEST OF THE USE OF THE WHITE AMUR TO CONTROL AQUATIC PLANTS

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The large-scale operations management test is being conducted at Lake Conway near Orlando, Florida, using the white amur or grass carp for aquatic plant control. In-house and contractor groups are collecting data on the project following the rationale set forth in this test plan. The plan includes introductory material, a security plan for preventing escape of the fish when introduced, a "how and where" description of stocking the fish, and a complete description of data collection, management, extrapolation, and analysis.

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PREFACE

The Directorate of Civil Works, Office of the Chief of Engineers, Department of the Army, is sponsoring the test program described in the test plan presented herein. Funds for the program are from two sources, i.e. those directly allocated to the U. S. Army Engineer Waterways Experiment Station (WES) for conduct of the Aquatic Plant Control Research Program, and Department of the Army Appropriation No. 96X3123, "Operations and Maintenance General." The latter was provided to the WES through the U. S. Army Engineer Division, South Atlantic, and the U. S. Army Engineer District, Jacksonville.

Messrs. E. E. Addor and R. F. Theriot of the Aquatic Plant Research Branch (APRB), Environmental Systems Division (ESD), Mobility and Environmental Systems Laboratory (MESL), WES, prepared the test plan under the direct supervision of Mr. J. L. Decell, Chief, APRB, and under the general supervision of Messrs. W. G. Shockley, Chief, MESL, and B. O. Benn, Chief, ESD.

Acknowledgment is made to Messrs. W. N. Rushing and M. M. Culpepper, APRB, for their contributions in the preparation of the sections dealing with the security plan and the control transects.

This document describes the plans for collecting and evaluating data in a Large-Scale Operations Management Test (LSOMT) to be conducted on Lake Conway, Florida, using the white amur fish. Mr. Theriot is project manager for the LSOMT. Other agencies involved with the study are the U. S. Department of Interior Fish and Wildlife Service, Fish Farming Experiment Station, Stuttgart, Arkansas (Agreement No. WES-76-11), who will produce the white amur for the study; the Orange County Pollution Control Department (Contract No. DACW39-76-C-0084), who will monitor water quality during the study; the Florida Department of Natural Resources (Contract No. DACW39-76-C-0083), who will monitor the aquatic vegetation; the University of Florida Department of Environmental Engineering (Contract No. DACW39-76-C-0076), who will monitor the zooplankton, phytoplankton, periphyton, and benthic organisms; the University of Florida Center for Wetlands Research (Contract

No. DACW39-76-C-0019), who is developing a simulation model of the Lake Conway aquatic ecosystem; and the Florida Game and Freshwater Fish Commission (Contract No. DACW-39-76-C-0081), who will monitor the fish, waterfowl, and aquatic mammals during the study.

Directors of WES during the preparation of this test plan were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) AND METRIC (SI) TO U. S. CUSTOMARY UNITS OF MEASUREMENT

Units of measurement used in this report can be converted as follows:

Multiply	By	To Obtain
	U. S. Customary to Metric	
inches	2.54	centimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
acres	4046.856	square metres
acre-feet	1233.482	cubic feet
gallons (U. S. liquid)	0.003785412	cubic metres
pounds (mass)	0.4535924	kilograms
tons (short)	907.1847	kilograms
parts per million	1.0	milligrams per cubic metre
	Metric to U. S. Customary	
metres	3.280839	feet
kilometres	0.6213711	miles (U. S. statute)
square metres	10.76391	square feet
Celsius degrees	1.8	Fahrenheit degrees*

* To obtain Fahrenheit (F) degrees from Celsius readings, use the following formula: $F = 1.8(C) + 32$.

TEST PLAN FOR THE LARGE-SCALE OPERATIONS MANAGEMENT TEST

OF THE USE OF THE WHITE AMUR TO CONTROL AQUATIC WEEDS

1.0 INTRODUCTION

1.1 Background

1.1.1 The U. S. Army Engineer Waterways Experiment Station (WES) is initiating a Large-Scale Operations Management Test (LSOMT) for introducing the white amur (Ctenopharyngodon idella, Cyprinidae) fish into a field-operational environment as a test of its effectiveness for control of hydrilla (Hydrilla verticillata Royle), an obnoxious aquatic plant recently introduced into the southeastern United States.

1.1.2 The white amur is a fish native to eastern Asia but has been introduced into various other parts of the world both as a food fish and for control of aquatic plants. Its alternate common name, "Asian grass carp," alludes to its natural preference for a vegetable diet, and from all available evidence, including experimental pond studies, it is exclusively vegetarian. It is a voracious feeder, and in tests with mixed plant species in closed culture ponds, it has shown a decided preference for hydrilla. Hydrilla is a submerged aquatic plant (grows rooted to the bottom, with the stems remaining under water), which has recently been introduced into the U. S., and is presently the most obnoxious submerged aquatic plant in many of the lakes, ponds, and waterways in Florida, extreme southern Louisiana, and southern Texas (Figure 1.1.2).

1.1.3 Though the white amur is an acceptable food fish, and reportedly can be an exciting game fish, it is, nonetheless, a carp and exhibits some of the undesirable behavioral traits of other carp that have been introduced and naturalized in this country. In particular, it reproduces abundantly and is adaptable to a wide range of habitats. For this reason there has been some concern about its introduction into the open waters of this country for fear of its displacing other currently favored game fish through space limitation and, especially, habitat destruction. Its introduction in most cases has been carefully controlled,

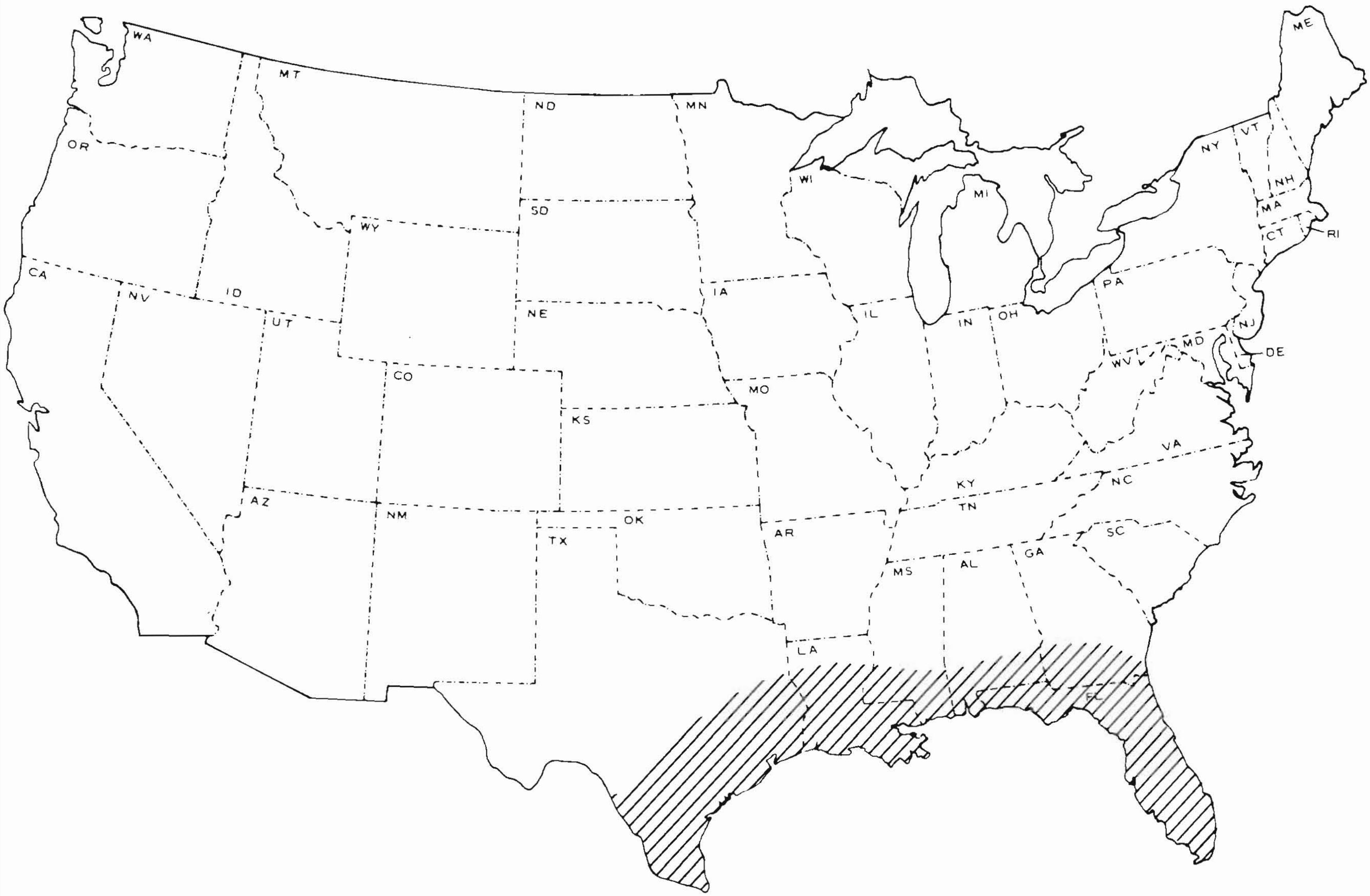

Figure 1.1.2 Range of hydrilla in southern part of United States

and it has been outlawed in several states. Other states allow its introduction under stringent controls for experimental purposes.

1.1.4 Through research sponsored by the U. S. Army Corps of Engineers, under the Aquatic Plant Control Research Program (APCRP), personnel at the U. S. Department of Interior Fish Farming Experiment Station at Stuttgart, Arkansas, have developed a female genotype that produces offspring all of one sex (monosex), so that a nonreproductive population can be introduced into a test area. Hybridization experiments have demonstrated that these monosex genotypes are not able to hybridize with the other naturalized carp species. Thus, the population of the white amur in a test area can be specified and controlled at the time of and subsequent to introduction. It appears, therefore, that the white amur is a potential plant control agent that is ready for an LSOMT for the control of hydrilla.

1.1.5 An LSOMT is defined herein as a field test of a proposed aquatic plant control technique conducted on a selected large area, at a scale and in a manner representative of a full-scale field operations activity. The test is conducted cooperatively by laboratory basic research personnel and field operations personnel, and its purpose is to adapt basic laboratory and small-scale research results to the field and to integrate them into the operations program. Such an LSOMT differs from a pure experiment both in scale and in minimum experimental controls that are imposed on the variables that may affect the outcome of the experiment. It differs from a pure operational project in that the results are carefully monitored over a period of time to determine, first, whether the experimental agent (or procedure) is in fact cost-effective at the scale of field operations, given the test environment; and second, whether significant undesirable changes may occur in the test area ecosystem as a result of the experimental plant control technique. Presence of both laboratory and operations personnel at the test area assures an exchange between these two groups of ideas and problem requirements (theoretical and practical constraints, expectations, and procedural problems).

1.2 Purpose and Scope. The LSOMT is designed to obtain the data necessary to determine the feasibility of using the white amur as an agent for the control and management of the submersed aquatic weed hydrilla. The purpose of this document is to present the various provisions necessary for stocking the fish into the test environment, collecting the required data, and extrapolating the results for management use at the operational level.

1.3 Rationale and Approach

1.3.1 When a proposed technique for aquatic plant control involves the use of biological agents, the responses of the ecosystem (hereafter called, simply, system) to the agents' presence must be determined. Although this is true regardless of the technique, it is especially true for biological agents because of their reproductive potential.

1.3.2 In viewing the white amur as a possible operational tool to control aquatic plants, not enough is known on which to base a design of an operational plan, nor are sufficient data available on which to base an assessment of the effects of the fish on various components of the system. The system responses, along with stated desired long-term effects, predicate such aspects as stocking rates, stocking sizes, optimum time for stocking, and intervals for restocking if necessary. To determine these critical rates and times, it is necessary first to answer several obvious, but basic, questions:

1.3.21 What is the effect of the white amur on hydrilla?

1.3.211 How do we measure the effect?

1.3.212 Does the hydrilla population stabilize?

1.3.213 How do we determine the proper stocking rate of white amur to maintain the desired hydrilla population level?

1.3.214 How do we maintain a sufficient stocking rate for this stabilization?

1.3.22 What is the effect of white amur on the ecology of the lake?

1.3.221 Water quality?

1.3.222 Game fish?

1.3.223 Aquatic macrophytes?

1.3.224 Zoo- and phytoplankton?

1.3.225 Benthos organisms?

1.3.23 What happens to the white amur with time?

1.3.231 Numbers?

1.3.232 Size?

1.3.233 Biomass?

1.3.234 Dietary habits?

1.3.24 What are the operational requirements for using white amur for aquatic plant management?

1.3.241 Spawning and raising white amur?

1.3.242 Constraints on introduction--environmental, political, climatic?

1.3.243 Factor or factors that should be monitored so operators will know what they must do to maintain the system?

1.3.244 Determination of the restocking time interval and numbers for maintaining sufficient stocking rate?

1.3.245 Long-range data collection requirements?

1.3.246 Waters that are amenable to plant control using the white amur?

1.3.3 Following the above rationale, the approach was to design an LSOMT that will provide the necessary data and resultant relations to answer these questions, select a test site that will meet certain desired basic criteria, and conduct the test over a significantly long period of time that will allow system responses to stabilize.

1.3.4 In accordance with the experimental nature of the LSOMT, and on the premise that collateral effects of the control agent may be diverse and subtle, but significant, a set of ecosystem factors were defined, and these factors will be monitored throughout the test period as part of the routine data collection, regardless of whether or not there is prior reason to believe that any given factor of the set will be affected by the selected test agent. In particular, every factor defined in the set will be monitored whether or not it is present in a given place, i.e., zero is a valid value for any defined factor. By definition, any plant control program currently being conducted on the selected site will be considered as an existing factor and will be continued, at least through the baseline data collection phase of the LSOMT; but, thereafter, such a program may be discontinued or modified and treated as an additional experimental variable.

1.4 Definitions. For purposes of this plan, the following definitions will apply.

1.4.1 Baseline conditions. The qualities of the test ecosystem as represented by the baseline data.

1.4.2 Baseline data. Accumulated data (including factor values and narrative descriptive or historical information) relating to the qualities of the test area prior to introduction of the test agent or other experimental activity.

1.4.3 Factor. Any identifiable measurable quality of the experimental ecosystem, for example, dissolved oxygen, water turbidity, plant population density, etc. In statistical analyses of closely controlled experiments, these are called the "variables." By definition, any quality of the system resulting from any established routine plant control practices, including use of chemicals or mechanical removal of plants, or from any other routine cultural treatments of the test area (e.g. sewage disposal) is considered an identifiable factor.

1.4.4 Factor family. Any arbitrary collection of factors that are considered together (i.e. for measurement, description, etc.) because of similarity of monitoring techniques, scientific discipline, or other interests.

1.4.5 Factor value. Any measured or specified quantity of a factor, for example, 5 ppm,* 12 (units)/m^2, 24°C, etc.

1.4.6 Qualities of the ecosystem. A general collective term to refer to both the factors of the system and the intensities (levels) or cyclic variations in factor values.

1.5 The Test Site

1.5.1 In accordance with the field operational orientation of the

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units and metric (SI) units to U. S. customary units is given on page iv.

LSOMT, selection of a test site was constrained by only two qualifying criteria:

1.5.11 First, that the test area be relatively large, so as to be reasonably in scale with the operational requirements of the areas in which the target plant species exists as a general problem; otherwise, it can be of any size, shape, or location consistent with feasible use of the white amur. In particular, any area considered was not either deliberately selected nor rejected because of any prior existing qualities, uses, or values, except for the quality that an overgrowth of aquatic plants currently interferes with at least one preferred use or value, as defined by the public users.

1.5.12 Second, that the test area constitute a definable, relatively closed ecosystem, such that the inflows and outflows can be reasonably established, and, if required by local, state, or Federal regulations, controlled.

1.5.2 The site selected for this LSOMT is a complex of small natural lakes, here collectively referred to as Lake Conway, just south of Orlando, in Orange County, Florida. The complex (Figure 1.5.2) comprises three contiguous or nearly contiguous lakes designated as follows: Lake Gatlin; Little Lake Conway, with two compartments called West Pool and East Pool; and Lake Conway, with two compartments called Middle Pool and South Pool. The complex lies in a simple basin with a single inlet from other upstream basins and a single outlet, both reasonably well defined.

1.5.3 The largest pool, Middle Pool, has an average diameter of about 1.2 miles, and the entire complex is contained within an area of about 1.9 by 2.8 miles. The total water-surface area of the complex at normal elevation (84.8 ft above mean sea level (msl)) is approximately 1820 acres. Seasonal or periodic fluctuation of surface elevation is limited, rarely exceeding 2 or 3 ft.

1.5.4 Information on depth and bottom configuration of the complex is at present limited. From available data, the maximum depth appears to be approximately 35 ft at a point in the north quadrant of Middle Pool. About one fourth of the bottom area of both South Pool and

Figure 1.5.2 Test site, Lake Conway complex

Middle Pool lies below the 20-ft depth contour, and the 10-ft depth contour in both of these pools lies mostly within 600 ft of the shore. No bottom topography data are available for the remaining compartments of the system.

1.5.5 The entire system is intensively used for fishing and water contact sports (skiing, boating, swimming), and hydrilla has become a serious nuisance to these activities, clogging 10 to 20 percent of the surface area. The extent of bottom coverage, however, is not presently known. Local interests currently clear hydrilla from the surface temporarily by frequent spot spraying with a chemical herbicide, which kills the tops of the plants back to a depth of a few feet. Maintenance obviously requires a permament, continuing program.

1.5.6 The Lake Conway area satisfies the criteria for a test site for an LSOMT (paragraph 1.5.1). The proposed test has been coordinated and cleared with all relevant local agencies, and written permission to introduce the monosex white amur into the lake complex has been obtained from the Florida Game and Freshwater Fish Commission (FG&FWFC).

2.0 SECURITY PLAN

2.1 Background

2.1.1 One important aspect of this LSOMT from both scientific and legal standpoints was to ensure that the white amur introduced would be contained within the study lakes for the duration of the experiment. Permission to stock the lake system for the tests was granted with the agreement that an acceptable security system would be established prior to stocking. This portion of the test plan describes the planning and coordination involved in identifying an acceptable system, the location and description of potential escape routes, the design of barriers, a plan for periodically assessing the integrity of the barriers, and a plan for renovating and restocking the lake system in the unlikely event that such drastic measures are warranted.

2.1.2 A meeting was held in Tallahassee, Florida, on 16 December 1975 at the offices of FG&FWFC, attended by representatives from the Fisheries Division of the FG&FWFC, the Florida Orange County Pollution Control Department, and the WES, to discuss the design and implementation of the security plan. The security system would obviously involve the construction of adequate barriers at any locations that would be potential escape routes for the fish. During the discussions, a preliminary or example barrier system design was presented by the FG&FWFC, with the suggestion that the WES proceed with the design of the system. It was emphasized that the examples and suggestions presented by the FG&FWFC at this meeting were to be construed as guidelines and that final design details would depend on such things as size of white amur introduced, analysis of water flows at control structures, and cost. It was agreed that final plans and designs of barriers would be prepared by the WES with approval by FG&FWFC. It was also decided that construction of any necessary barriers should be completed as soon as possible so that any problems arising as a result of their presence could be adequately evaluated and corrected prior to stocking. Subsequent to the 16 December meeting, the WES personnel visited the test site, inspected and documented the characteristics of possible escape routes, and confirmed the locations that would require some type of barrier.

2.2 Physical Features

2.2.1 Location and description of structures requiring barriers. Based on an initial reconnaissance and on information available at that time, it appeared that two pump intakes, two inlet structures, and one outlet structure through which fish could escape might require barriers. After careful on-site inspection of each of these areas, however, it was determined that the two pump intakes already contained adequate barriers that would prevent any fish from escaping. One of the inlet structures proved not to be an inlet at all and thus could not act as an escape route. As a result of this on-site inspection, it was determined that structures that were potential escape routes requiring barriers were the main outlet control structure for the Lake Conway system under Daetwyler Drive and an inlet canal between West Pool of Little Lake Conway and Lake Jessamine. In addition, a barrier placed at the outlet structure of Lake Mare Prairie (also called Lake Warren) would serve as a backup barrier. The locations of the structures are designated as 1, 2, and 3, respectively, in Figure 2.2.1.

2.2.11 Structure 1, the main concern, is an outlet consisting of three concrete culverts under Daetwyler Drive. One culvert is 60 in. in diameter and the other two are 48 in., as shown in Figure 2.2.11, views of the structure from the upstream side. Fish escaping at this location could easily travel to Lake Mare Prairie down Boggy Creek to the Lower Lakes Region and ultimately to Lake Okeechobee. For this reason, structure 3 on Lake Mare Prairie would serve as a secondary barrier along this route.

2.2.12 Structure 2 is a rectangular concrete culvert under the Seaboard Coast Line Railroad near the corner of Orange Avenue and Jamaica Street and measures approximately 4 by 6 ft. This culvert is in a small canal that carries overflow from Lake Jessamine into Little Lake Conway. Figure 2.2.12 shows views of the structure from the upstream side.

2.2.13 Structure 3 is the outlet control structure for Lake Mare Prairie and the secondary barrier to structure 1 (paragraph 2.2.11). Figure 2.2.13 presents views of the structure from the upstream and downstream sides.

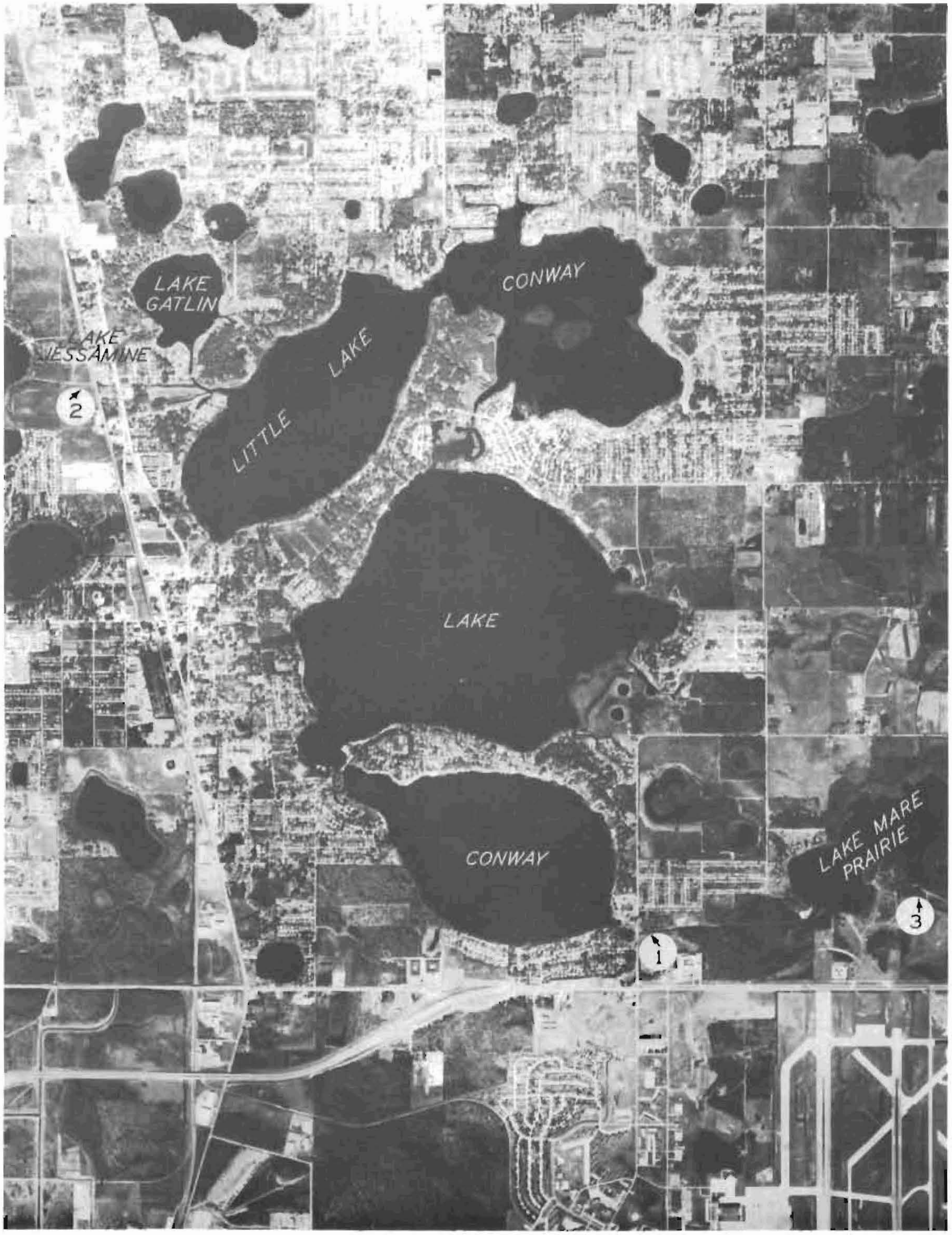
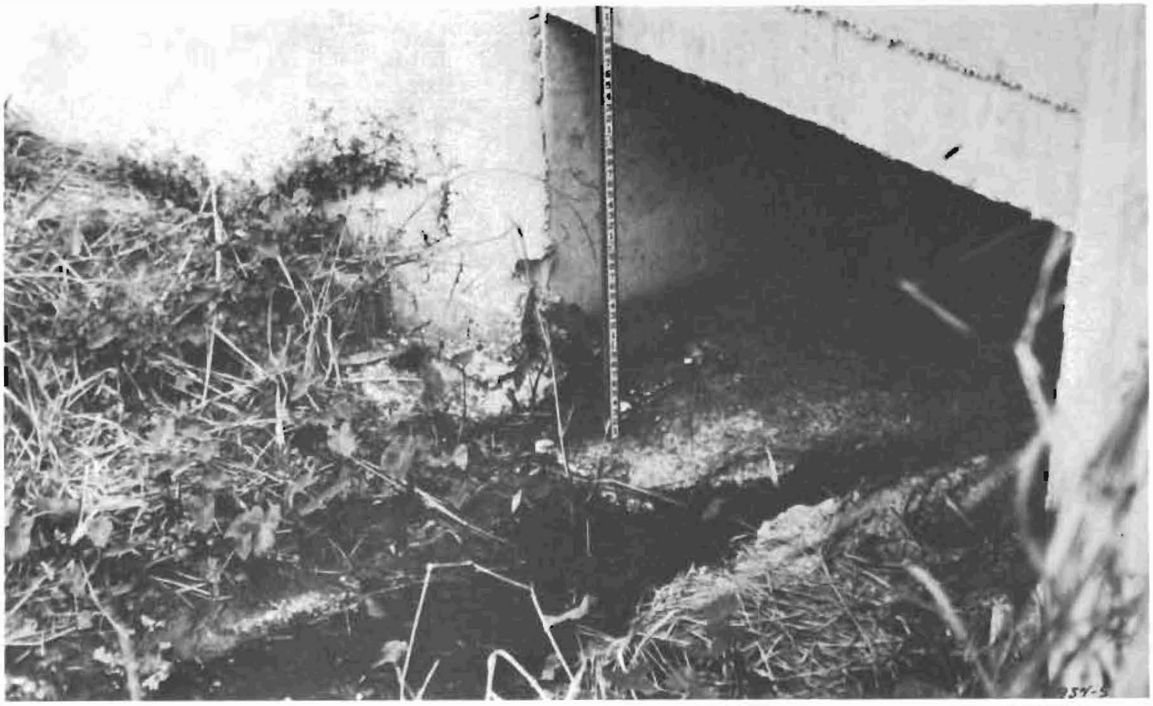


Figure 2.2.1 Locations of barrier structures

a. Front view

b. Oblique view

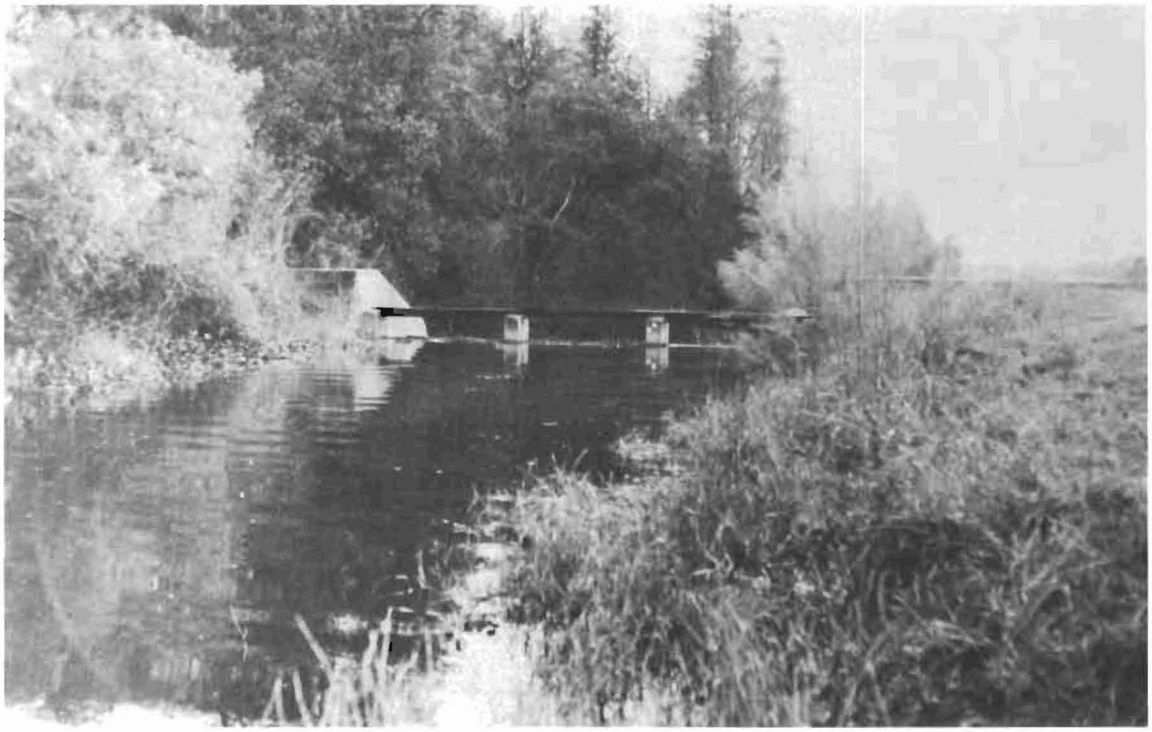
Figure 2.2.11 Culverts (structure 1) under Daetwyler Drive



a. Close-up

b. Front view

Figure 2.2.12 Culvert (structure 2) under Seaboard Coast Line Railroad



a. Viewed from upstream

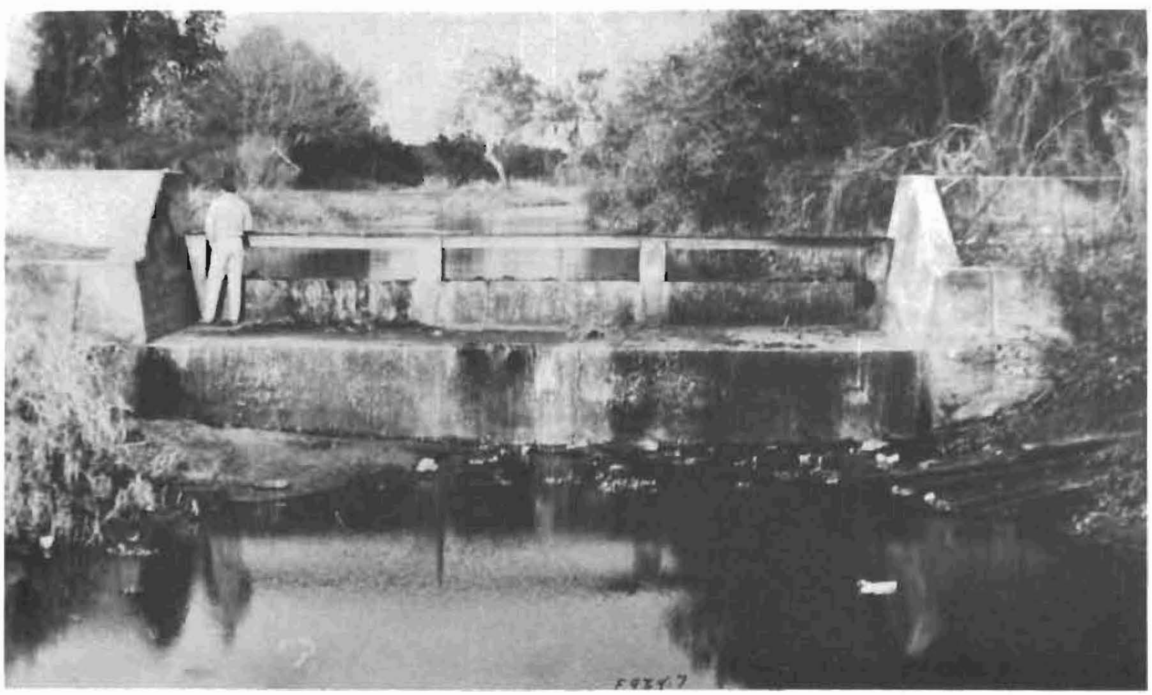


Figure 2.2.13 Outlet control structure (structure 3) for Lake Mare Prairie

2.2.2 Barrier designs. Two critical requirements for the design of the barriers for each of the structures are: (a) they must prevent passage or escape of the smallest white amur introduced, and (b) they must not significantly restrict water flow to the extent that flood control is affected. Based on these criteria and an assumed amur stocking size of not less than 1 lb, the barrier systems to be constructed at structures 1 and 2 will each consist of two fences. At the outlet structure (1), the first fence will serve to deflect and contain debris that would be of a size to damage the second fence or to restrict flow. In addition, this fence will prevent boats from coming into contact with the second fence. The second fence will serve as the barrier to prevent passage of the fish. At the inlet canal between Lake Jessamine and Little Lake Conway (structure 2), the first fence will mainly serve as a barrier to debris and the second fence as a fish barrier. The first fences, then, are intended to prevent or greatly minimize the possibility of damage to the fish barriers, or second fences.

2.2.21 Structure 1. The debris fence at structure 1 will consist of 10-gauge wire-mesh fencing with 2-in. openings attached to 4- by 6-in. treated pilings supported with 4- by 6-in. angle bracing. The pilings will be placed on 10-ft centers (Figure 2.2.21). The fence will extend from an elevation of 91 ft msl to within a few inches of the lake bottom (approximate elevation of 77 ft msl), or an overall height of approximately 14 ft in the center portion of the outlet channel, and will gradually decrease as the fence approaches the banks following the lake bottom contour. In addition to the braced pilings, 2- by 6-in. lateral stringers will be placed between the pilings on 36-in. vertical spacing (detail A of Figure 2.2.21). These stringers will be placed with the 2-in. surface facing upstream to minimize the interruption of the normal flow and will provide additional surface for connecting the wire mesh. The fish barrier (second fence) will be constructed with 4- by 6-in. treated pilings placed on 10-ft centers and 2- by 6-in. lateral stringers. Wire mesh, 10-gauge with 1/2-in. openings, will extend from an elevation of 91 ft msl to an elevation of approximately 84 ft, or an approximate overall height of 7 ft, at

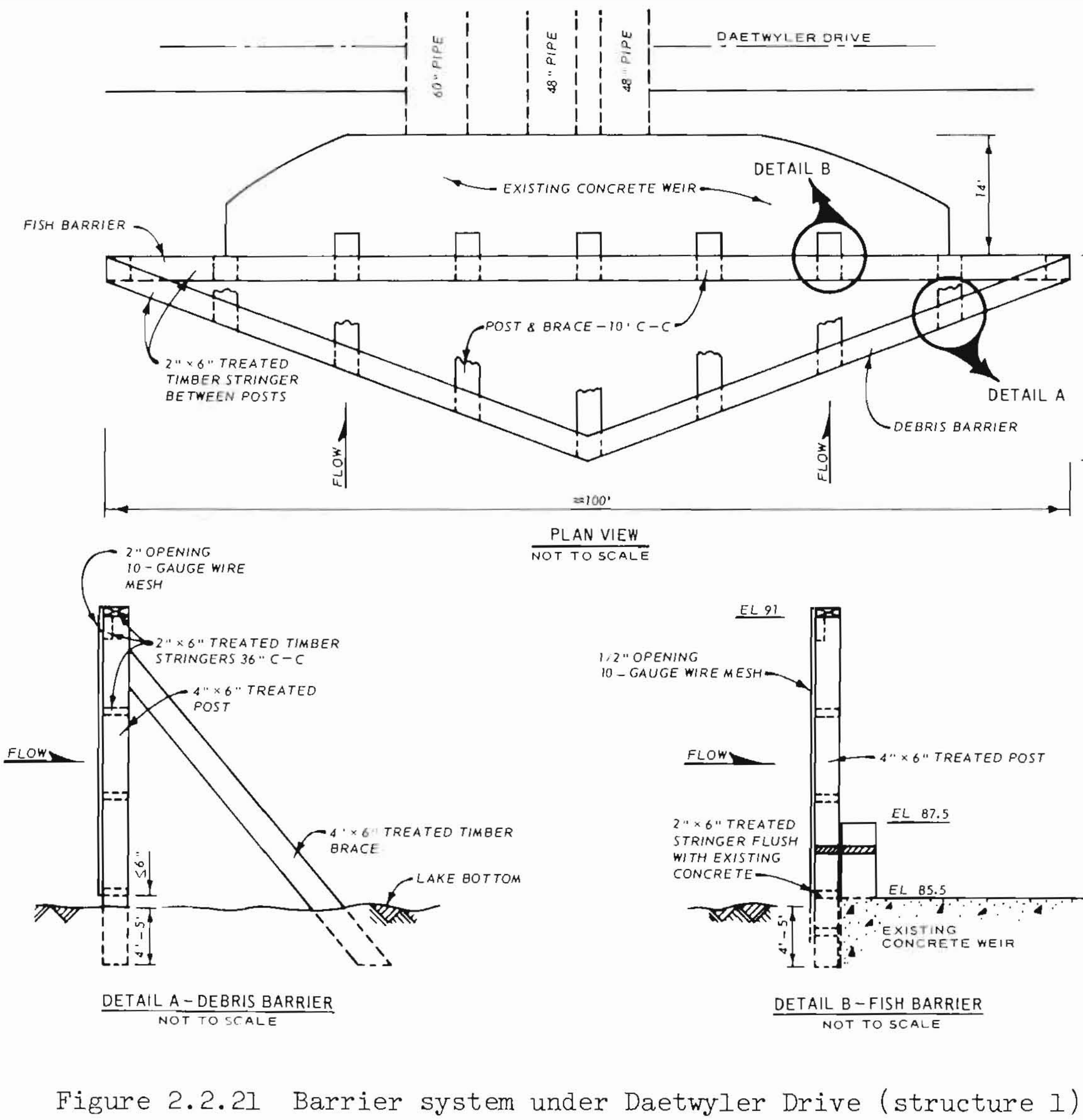


Figure 2.2.21 Barrier system under Daetwyler Drive (structure 1)

the center of the channel. This will place the bottom of the fence approximately 18 in. below the surface of the channel bottom. The barrier will be placed flush against and secured to the existing concrete weir (detail B of Figure 2.2.21).

2.2.22 Structure 2. The barrier system to be constructed at structure 2 will consist of two fences that incorporate the same design as the fences contructed at location No. 1 with one exception: The pilings will be placed on 5-1/2-ft centers (Figure 2.2.22) to ensure a secure installation in the sides of the banks and to alleviate the need for additional bracing. The protective fence will serve to prevent damage from debris only, as there is no boat traffic in this canal.

2.2.23 Structure 3. The barrier to be constructed at structure 3 will consist of a fish barrier only (Figure 2.2.23) and will serve as a backup system to the barrier at structure 1 in the unlikely event that security is breached at that point.

2.2.3 Flow considerations. The possibility that the presence of the barrier system could cause problems related to water flow was investigated. The maximum possible flow through the barrier system was compared with the maximum possible flow through the respective culvert systems at structures 1 and 2. Maximum flow was determined for the barrier systems by considering open-channel flow conditions; for the culverts, flow calculations were based on pipe-flow conditions. For both, the calculations were based on a worst-case condition of hydraulic head. Heads of 6 and 10 ft were used for structures 1 and 2, respectively. The results of these calculations are:

Structure	Hydraulic Head, ft	Maximum Flow Through Existing Culvert 10^5 gpd	Maximum Flow Through Barrier System 10^5 gpd
1	6	6	1200
2	10	870	2060

Based on these calculations and the fact that the worst-case condition has never existed in the Lake Conway system, it was concluded that the presence of the proposed structures will not impede flow into or out of the Lake Conway system such that maintenance of water levels will be affected.

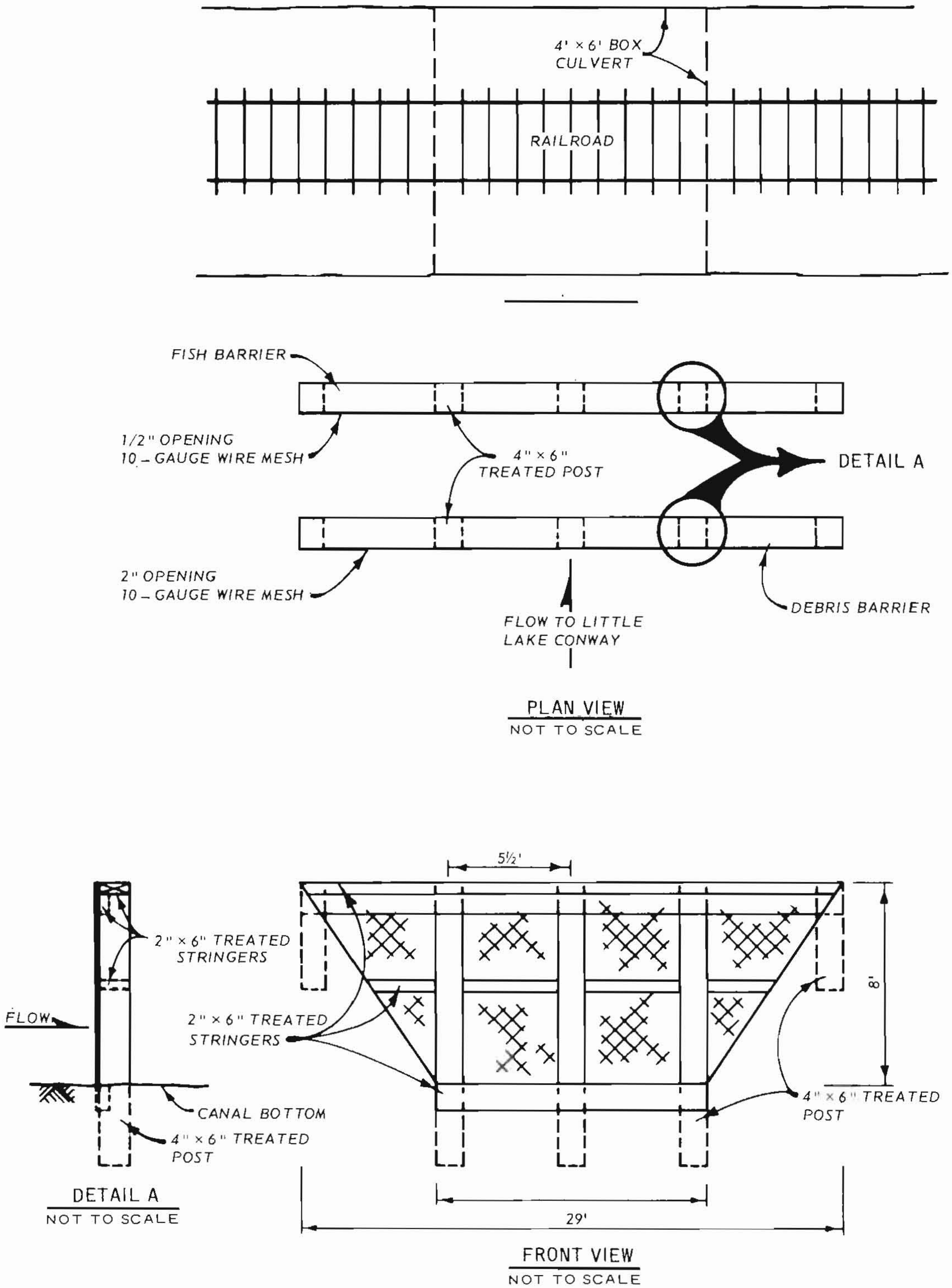


Figure 2.2.22 Barrier system at the inlet canal from Lake Jessamine (structure 2)

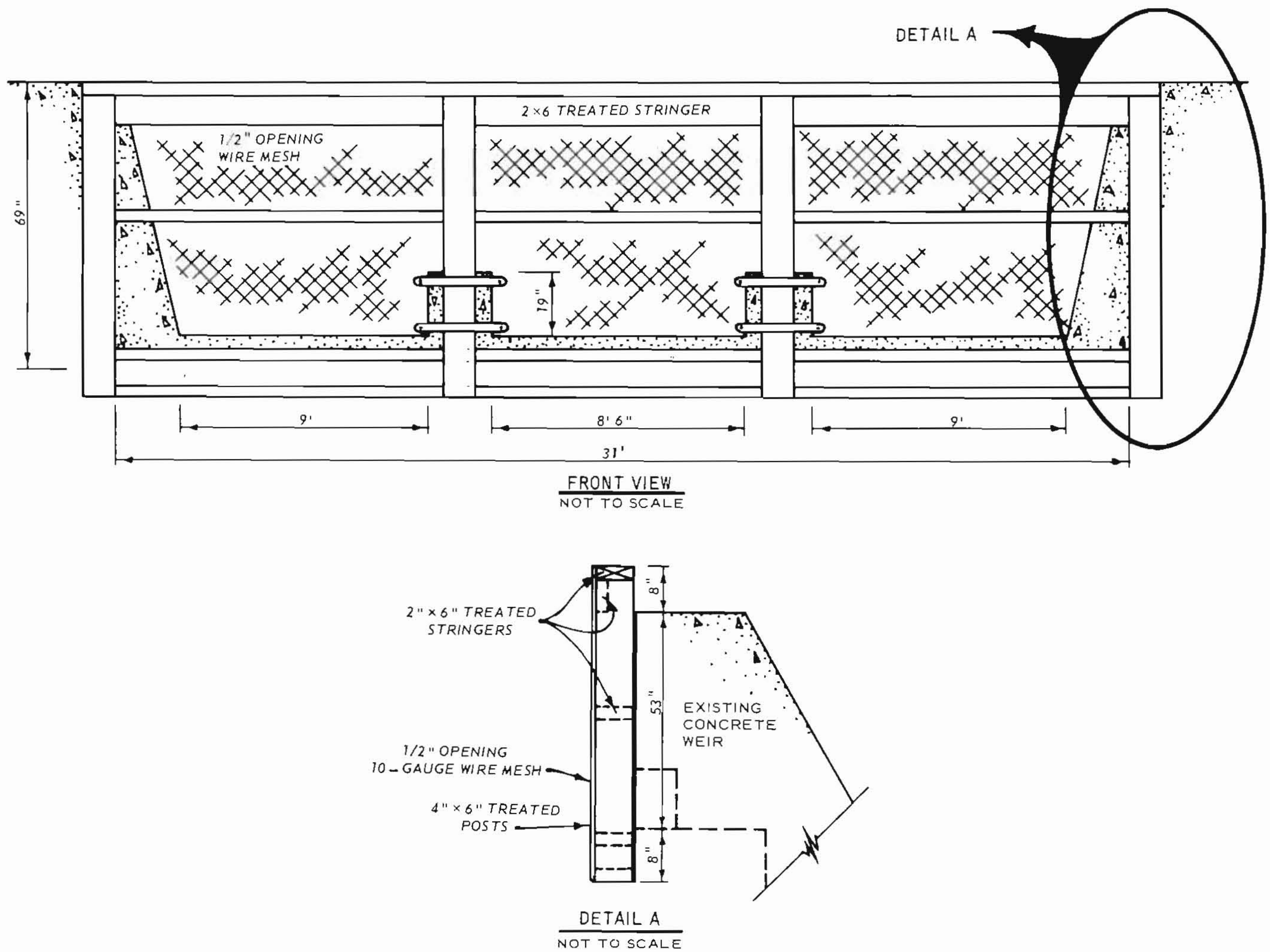


Figure 2.2.23 Barrier system at Lake Mare Prairie (structure 3)

2.3 Monitoring. Each of the barrier systems to be constructed, as well as those already existing, will be inspected periodically to ensure that each system remains intact and to clear away any trash and debris that may have collected since the last inspection. These inspections will take place twice weekly on a regular basis, with additional inspections immediately following heavy rains. Scuba divers will inspect the underwater portion of all fish-barrier fences monthly. In the event of a sustained period of high water lasting more than two days, the scuba divers will inspect the submerged portions of these fences at least once every four days until water levels subside to normal. Adjustments in this schedule may be necessary prior to the introduction of the white amur into the lakes, as a result of any unforeseeable problems that may arise subsequent to barrier construction. Such adjustments will be coordinated with all agencies concerned with the study.

2.4 Coordination of Corrective Action in the Event Security Is Breached. The purpose of the security system is to prevent escape, through natural pathways, of the white amur that will be stocked for this test. Possible escape through unnatural pathways, such as transporting by fishermen, cannot be positively controlled. For example, if a white amur is discovered downstream of the Lake Conway system and no barrier has been breached, it is logical to assume the fish was transported. Also, the fish might just as well have come from another lake previously stocked with amur. Short of permanently identifying each fish stocked for this test, no positive conclusion can be drawn as to the origin of any amur found in an unexpected area unless the security system has been breached. Since corrective action may have to be drastic, specific procedures will be established for rapid assembly of test participants and interested persons if the security system is breached. At such an assembly, alternative corrective actions will be considered by all participants prior to a final decision on necessary actions. The most drastic corrective action would be the complete renovation and restocking of the lake system. For this reason, implementing methods and costs of this action are discussed below.

2.4.1 Renovation. Renovation is here defined as killing every fish of every species of every size in the lakes to positively eliminate every single white amur. To accomplish this, the lakes would have to be treated with 2- to 3-ppm rotenone chemical. This treatment would require approximately 8200 gal of chemical based on 1820 acres of water having an average depth of 6 ft (10,920 acre-ft). At a current price of $15.00/gal, this treatment would cost $123,000. Application would require 12 people and 6 boats equipped with appropriate pumps and appurtenant hardware. The entire Lake Conway system could be treated in 1 day.

2.4.11 It has been estimated that the Lake Conway system contains an average of 450 to 500 lb of fish per acre. Renovation would yield an estimated 819,000 to 910,000 lb of dead fish. Physical removal of this quantity of dead fish is considered to be the major problem in renovation; it would have to be accomplished within 2 days after chemical treatment. This would require removal of 225 tons/day, and the operation could be efficiently carried out only during daylight hours. Leaving the fish in the lakes to decay and sink is not considered to be an acceptable alternative to physical removal, since complete decay and sinking of the fish would not be complete for approximately 12 days.

2.4.2 Restocking. In the event that renovation is necessary, standard procedures presently used by the FG&FWFC could be followed for restocking. This would require the stocking of 150 bass and 500 pan fish fingerlings per acre. Pan fish is an equal mixture of bream and shell crackers. Bass would be stocked in the spring and pan fish in the fall. At present (1976) this process costs approximately $30/acre, or approximately $55,000 for the Lake Conway system.

3.0 STOCKING PLAN

3.1 Background

3.1.1 Since the long-term effects of a viable white amur population on a U. S. aquatic ecosystem have not yet been determined, an all-female population will be introduced into the test area as a precaution against the establishment of a permanent population* that may escape and spread to other water bodies. Since very few of the monosex fish exist, a spawning and rearing program was initiated by the WES to be carried out by the personnel at the facilities of the U. S. Department of Interior (USDI) Fish Farming Experiment Station at Stuttgart, Arkansas. Plans have been made to spawn and rear a monosex population of white amur for the LSOMT on Lake Conway. It is possible that as few as 12,000 fish will be sufficient to obtain the level of control compatible with the major uses of the test area, i.e. boating, skiing, swimming, fishing, and aesthetics. It is emphasized that control does not mean complete eradication of one or more weed species, but only the reduction and maintenance of the plant biomass such that it enhances or at least does not detract from the constructive uses of the water body. Plant biomass equilibrium is a goal that can only be reached within relatively broad limits because of the growth dynamics of both the control agent and the weed population. It is anticipated that control can be effected at Lake Conway in 3 to 5 years without danger of removing so much vegetation that the ecosystem will become unbalanced.

3.1.2 This part of the test plan discusses how the number of fish to be introduced will be determined, the techniques used in spawning and rearing the fish, and how the fish will be transported to the test site and released. The location and characteristics of the release points at the various pools are also discussed. Finally, a short discussion on marking the fish for subsequent monitoring is presented.

3.2 Stocking Rates and Schedule

3.2.1 In addition to considering the lake system as a total water body, each of the five pools that comprise the Lake Conway system will

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* Assuming no reproduction, the life span of the population of the white amur is estimated to be from 12 to 15 years.

be considered separately for stocking purposes. The total submersed vegetation (standing crop) existing in each pool, as well as the time selected (elapsed time from the date of stocking) for achieving control, will determine the individual stocking rates regardless of surface acres of water involved. Standing crop of all plant species sampled will be measured monthly (Work Unit G, paragraph 4.2.8) prior to stocking the test site. These values in association with results obtained from the stocking model (paragraph 6.2.2) will be used to determine the total number and size of fish* needed to stock each of the pools in the test site.

3.2.2 Because spawning and rearing monosex white amur in the numbers desired have never been done before, it is conceivable that sufficient fish to properly stock the entire Lake Conway complex will not be available at the desired stocking time. If the total number of fish required exceeds the total available fish, a decision will be made as to which one of two optional stocking plans will be exercised. The first plan considers the lake complex as a single water body, and the stocking will be achieved by time-spaced increments. The decision to exercise this option would have to consider the short-term future availability of additional fish for the supplemental stockings. The second plan considers each pool as a separate lake, and the available fish will be used to stock selected pools, with the stocking of the other pools to be delayed until sufficient monosex fish are available to stock in accordance with the requirements to achieve the desired control. In this latter case, it may be desirable to erect some type of barrier between the lake pools to ensure control of the stocking rate. Because of the recreational activities in the Lake Conway complex, only a very limited number of types of fish barriers could be used. These are presently being evaluated. The WES personnel will be responsible for determining the stocking rate as well as the date for introduction. The tentative date for the first introduction of the fish is during the period March-April 1977. This date was chosen because it is more advantageous to

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* The 1-lb minimum stocking size was selected to reduce the amount of predation that would occur. It is expected that, at this weight, less than 10 percent of the population will be lost to predation.

transport and handle the fish in cool weather. Also, the target weed (Hydrilla verticillata Royle) is acquiescent in the winter season.

3.3 Spawning and Rearing. The spawning and rearing of the monosex population of white amur is the responsibility of the USDI Fish Farming Experiment Station, Stuttgart, Arkansas (paragraph 3.1.1). A brief discussion of this activity follows.

3.3.1 Spawning. The spawning technique being used to produce the monosex population of white amur for the LSOMT is artificial gynogenesis.* Spawning was conducted in May and June 1976, since that is the time of year the mature females become gravid. The gravid females were induced to ovulate by hormone injections. Approximately 50 hr after the first hormone injection, the eggs were hand-stripped from the females and were fertilized. The fertilized eggs were then treated with a $2^{\circ}C$ cold shock for 10 min. This procedure increases the number of diploid gynogenetic offspring. Following the cold shock, the eggs were placed in hatching jars and hatching occurred from 26 to 32 hr later. The newly hatched fry were then placed in holding tanks and fed a diet of live brine shrimp.

3.3.2 Rearing. Approximately one week after hatching, the fry were placed in 1-acre rearing ponds at a rate not to exceed 35,000 fry per acre. The eight ponds available at the Stuttgart facility provide a rearing capacity for 280,000 fry. For the first month, the fry are fed primarily on the zooplankton and phytoplankton available in the fertile rearing ponds. As the fry mature, they are fed daily on commercial minnow meal. Thirty percent survival of approximately 1/2-lb fish is expected by 1 October 1976. At that time, depending on size and general health of the fish, a decision will be made whether or not to diffuse the population to reach the desired minimum stocking size of 1 lb by March 1977. The general health and growth of the fish are monitored throughout the rearing period.

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* For a detailed account of the process of artificial gynogenesis, the reader is referred to Dr. Jon G. Stanley's report entitled "Production of Monosex White Amur for Aquatic Plant Control," Contract Report A-76-1, November 1976, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

3.4 Transporting and Release

3.4.1 Transporting. A commercial fish farming operator will be contracted to haul the white amur from the rearing ponds in Stuttgart, Arkansas, to the test site at Lake Conway, Florida. Prior to the transport operation, the contractor will be required to submit a detailed operating plan to the WES for coordination and approval. Pertinent aspects of the operation are presented in the following paragraphs.

3.4.11 The vehicle used to transport the fish to Florida will be a compartmented tank truck with a carrying capacity of 15,000 lb of fish. It will be equipped with a mechanical water circulator, cooling, filtration, and aeration system. The tank truck will be loaded with water that is the same temperature as the water in which the fish are stored. Once the fish are loaded, they will be tempered* for shipment, i.e., the temperature will be gradually reduced to about 28°C for shipment. The truck will be loaded in Stuttgart in the afternoon and travel overnight, arriving at a WES-designated release site on Lake Conway the next day (travel time approximately 20 hr). Upon arrival at the release site, load mortality will be estimated. In addition, representative samples of the fish will be taken (in accordance with arrangements made with the FG&FWFC) to the Florida State Fish Hatchery at Rich Loam to be subsequently observed for determination of long-range mortality.

3.4.2 Release. If sufficient fish are available to stock the entire lake system at one time, or with supplemental stockings, the fish will be released at selected locations (section 3.5) in proportions that take into account the weed infestation existing in each respective pool, in an effort to obtain as even a dispersal within each pool as possible. If individual pools are to be successively stocked, the WES will designate the pools and the order in which they will be stocked. If the access ramps to any of the stocking sites are not sufficiently strong to handle the load of the large tank truck, or maneuvering room

* In this case, temper means to change the existing temperature of the water in the fish tank to coincide with the temperature of the water at each of the introduction sites. This is done to prevent death of the fish caused by shock due to a large temperature differential. The usual tempering rate of the white amur is 2°C/hr.

is limited, a short-bed truck fitted with a fish transport tank will be used to bring the fish to the actual release point. In these cases, the fish will be transferred from the large tank truck to the small truck after tempering.

3.5 Release Sites. Several access sites for stocking each pool have undergone preliminary evaluation, and two sites in each pool have been chosen, based on accessibility and loading capacity. Figure 3.5.1 shows the locations of these sites; a brief description of each site is given in the following paragraphs. The odd-numbered sites are considered primary release sites for their respective pools, and the even-numbered sites are secondary release sites.

3.5.1 Lake Gatlin

3.5.11 Site No. 1 (Lake Gatlin Avenue launch). This site has an unsurfaced access ramp and only limited maneuvering area near the water's edge. Therefore, its use will be restricted to small transport trucks.

3.5.12 Site No. 2 (Harbor Island Drive launch). This site has a concrete-surfaced access ramp but is not sufficiently reinforced to withstand the weight of a large tank truck. Having only a limited maneuvering area, its use will also be restricted to small transport trucks.

3.5.2 Little Lake Conway West Pool

3.5.21 Site No. 3 (Randolph Street launch). This site has a reinforced 4-in.-thick concrete ramp strong enough to support the weight of a large tank truck. There is also adequate maneuvering area.

3.5.22 Site No. 4 (Ferncreek Street launch). This site has an asphalt-surfaced ramp in very poor condition, with a very limited area for maneuvering. Its use will be restricted to small transport trucks.

3.5.3 Little Lake Conway East Pool

3.5.31 Site No. 5 (Old Dominion Street launch). The asphalt-surfaced ramp of this site will not withstand the weight of a large tank truck. Although there is adequate room for maneuvering, the use of this site will be restricted to small transport trucks.

3.5.32 Site No. 6 (Cullen Lake Shore Drive launch). The

Figure 3.5.1 Locations of fish release sites

concrete-surfaced ramp at this site is not strong enough to support the weight of a large tank truck. In addition, there is limited area for maneuvering; therefore, this site will be restricted to use by small transport trucks.

3.5.4 Lake Conway Middle Pool

3.5.41 Site No. 7 (Venetian Street launch). This site has a reinforced concrete ramp, which is considered to be strong enough to support the weight of a large tank truck. There is, however, limited room for a large truck to maneuver, so this site will probably be restricted to use by small trucks.

3.5.42 Site No. 8 (Orlando Drive launch). The ramp at this site is surfaced with concrete but is not strong enough to withstand the weight of a large tank truck. Thus, its use will be restricted to small trucks.

3.5.5 Lake Conway South Pool

3.5.51 Site No. 9 (Perkins Street launch). This site has a reinforced concrete ramp of sufficient strength to support the weight of a large tank truck. There is also adequate room for maneuvering.

3.5.52 Site No. 10 (Trentwood Street launch). Although this site has a concrete-surfaced ramp, it is not strong enough to withstand the weight of a large tank truck. There is also limited area for maneuvering; therefore, its use will be restricted to small trucks.

3.6 Marking of Fish

3.6.1 The feasibility of marking the entire white amur population to be stocked into Lake Conway is still being evaluated. There are two major reasons for desiring that identifiable groups of white amur be used in the LSOMT. First, the information derived from the data collected on retrieved marked fish would aid in the determination of feeding behavior, fish density, degree of utilization of specific aquatic plants by the fish, and ideal stocking rates in impoundments. Second, fish captured in waters surrounding the Lake Conway test site could be positively identified as to whether or not they are members of the population stocked for the LSOMT.

3.6.2 The major problem associated with a mass marking program for the Lake Conway LSOMT is the limited time available to develop a reliable marking technique. Various fish-marking techniques are being evaluated for possible preliminary testing. Considerations to be analyzed in the evaluation are permanency of marks, possible effects on behavior and feeding activities, difficulty and cost of application, and possible reduced survival due to handling during the marking process.

3.6.3 If the decision is made to mark each or selected individual fish for the LSOMT, the fish population will be identified by five distinct group markings, one for each pool in the study area. The number of fish in each group receiving their respective marking will be determined by the stocking rate necessary for each pool in the study area.

4.0 DATA COLLECTION PLAN

4.1 Scheduling and Coordination

4.1.1 The scheduling and coordination of the data collection phases of the LSOMT are arranged and maintained by the WES through contracts and conferences with the test participants. Each participant, as a contractor, is required as part of the contract to submit to the WES a schedule of data collection. Upon receipt of these schedules, the WES then meets, when necessary, with the participants to generate an overall data collection schedule. Fieldwork is coordinated to ensure minimal interference with other sampling teams and minimal influence on other factor values. Field data collection is performed according to the coordinated schedule. As a general policy, it is desired that every specified factor (paragraph 4.2.1) be measured simultaneously at every prescribed control data station (paragraph 4.3.3). Obviously, however, such policy cannot be complied with infallibly; therefore, any required or desired deviation from the agreed upon data collection schedule is coordinated with the WES. This coordination is provided to each contractor-participant by the WES to ensure accordance with test requirements and simultaneity for anticipated correlation analyses to be performed in the future.

4.1.2 Field data will be collected on the test area for at least 1 year prior to the introduction of the fish. These data will be used to establish the baseline conditions of the system for comparisons with conditions that prevail after the fish are introduced. Monitoring will then continue for approximately 3 years after introduction of the fish. All data and narrative reports of observations will be submitted to the WES data management group not later than 2 weeks after field collection, on a form or in a format mutually agreed upon by the WES and the cooperating agency (paragraph 5.2).

4.2 Data to be Collected

4.2.1 Designation of factor families. In accordance with the rationale set forth in paragraph 1.3.4, ecosystem factors relevant to any LSOMT have been identified and will be monitored as test variables throughout the test period as part of the routine data collection program. These factors have been grouped into factor families, according to alliance through scientific disciplines. The factor families are tabulated below. (The letters at right in the tabulation identify work units, defined according to similarities of the measurement techniques appropriate to the various factors within each factor family. This assignment of factor families to work units is primarily for administrative purposes.)

Factor Family		
Number	Name	Work Unit
	Physical Qualities	
1	System usage and values	A
2	General system qualities (hydrography)	A
3	General site qualities - (basin)	A
4	Meteorology	B
5	Water quality	C
6	Sediment quality	C
	Biotic Qualities	
7	Zooplankton	D
8	Phytoplankton	D
9	Benthos (include crustaceans, insects, amphibians)	D
10	Periphyton	D
11	Fish	E
12	Mammals (include marsupials, etc.)	F
13	Waterfowl, birds	F
14	Aquatic (vascular) plants	G

Specific factors to be monitored in each work unit are identified in Table 4.2.1 (see paragraph 4.2.9 for a more complete explanation of this table). The purpose, scope, and basic procedural requirements for each factor family assigned to work units are contained in the following paragraphs.

Table 4.2.1

Summary of Data Collection Program for LSOMT - White Amur

1 Work Unit	2 Factor No.	3 Family Name	4 Factor Name	5 Sampling Interval*	6 Data Source, Comments
A	1	System usage and values	Fishing	--	Fish and game agencies
			Hunting	--	Fish and game agencies
			Recreation Swimming Boating Skiing	--	Park and recreation agencies
			Aesthetic	--	Park and recreation agencies, public hearings
			Commerce (transport)	--	Chambers of Commerce, transportation agencies
			Consumption Domestic Manufacturing Irrigation Livestock	--	Chambers of Commerce, public utilities, agricultural sciences
			Beach and shore	--	Chambers of Commerce, parks and recreation agencies
	2	General system qualities (hydrography)	Geographic location	--	Maps
			Perimeter description	--	Maps, on-site inspection
			Bottom topography	--	Maps, on-site inspection, survey
			Beach and shore topography	--	Maps, on-site inspection, survey
			Water elevation (seasonal variation)	--	Maps, on-site, literature, records
	2	General system qualities (hydrography) (continued)	Water inflow and circulation	--	Maps, on-site survey
			Shore vegetation	--	On-site inspection
			History (as deemed relevant)	--	Literature, interviews, records search
A	3	General site qualities (basin)	Backshore topography	--	Maps, on-site survey
			Backshore land use	--	Maps, on-site survey

(Continued)

* For definitions of entries in this column, see paragraph 4.2.94.

(Sheet 1 of 4)

Table 4.2.1 (Continued)

1 Work Unit	2 Factor No.	3 Family Name	4 Factor Name	5 Sampling Interval	6 Data Source, Comments
A	3	General site qualities (basin) (continued)	Drainage basin General climate General topography General hydrography Geology Soils Land use/management practices Nutrient sources Sediment sources Urban/industrial functions History (as deemed relevant)	--	Maps, on-site inspection, survey, literature and records, interviews
B	4	Meteorology	Wind speed	*	Continuous or periodic recorders, not less than about 12 readings per 24-hr cycle, all factors
			Wind direction	*	
			Air temperature	*	
			Relative humidity	*	
			Solar radiation (reflected radiation)	*	
C	5	Water quality	Turbidity	Mo	Secchi disk on-site and laboratory sample on-site
			Temperature	*	Monthly continuous recording, various depth intervals
			Conductivity	*	Monthly bulk sample or continuous on-site recording
			pH	*	
			Transmissivity	*	
			Dissolved oxygen	*	
			Color	*	
			Total phosphorus	Mo	Laboratory analysis of bulk water sample
			Orthophosphate	Bi	
			Total organic nitrogen	Mo	
			Nitrate-nitrite	Mo	
			Ammonia	Mo	
			Hydrogen sulfide	Bi	

(Continued)

(Sheet 2 of 4)

Table 4.2.1 (Continued)

1 Work Unit	2 Factor No.	3 Family Name	4 Factor Name	5 Sampling Interval	6 Data Source, Comments
C	5	Water quality (continued)	Calcium (Ca Co_2-HCO_3)	Mo	
			Chlorophylls (A)	Mo	
			Phaeopigments	Mo	
			Heavy metals	Bi	
			Pesticide residues	Mo	
			Total suspended solids	Mo	
			COD	Bi	
			BOD	Bi	Laboratory analysis of bulk water sample
			REDOX	Mo	
			Depth	Mo	
			Alkalinity	Bi	
			Acidity	Bi	
			Chlorides	Bi	
			Total solids	Bi	
			Total Kjeldahl nitrogen	Bi	
	6	Sediment quality	Total phosphorus	Mo	Laboratory analysis of bulk sediment sample
			Orthophosphate	Mo	
			Total organic nitrogen	Mo	
			Nitrate-nitrite	Mo	
			Ammonia	Mo	
			Total organic (combustible)	Mo	
			Sediment particle size	Mo	Soil screen
D	7	Zooplankton	Count, by species or life-form	Mo	Bulk samples, net or screen samples
	8	Phytoplankton	Count, by species or life-form	Mo	Bulk samples, net or screen samples
	9	Benthos	Count, by species or life-form	Bi	Bulk samples, net or screen samples, on-site survey for crustaceans, amphibians, etc.

(Continued)

(Sheet 3 of 4)

Table 4.2.1 (Concluded)

1 Work Unit	2 Factor No.	3 Family Name	4 Factor Name	5 Sampling Interval	6 Data Source, Comments
	10	Periphyton	Count, by species or life-form	Mo	Inspection of plants and other fixed underwater surfaces
E	11	Fish	By species:		
			Abundance	Mo	Field observation, capture
			Size distribution	Qt	
			Sex distribution	Qt	
			Spatial/areal distribution	Mo	
			Feeding activity	Mo	
			Food habit	Mo	Observation, stomach analysis
			Reproductive activity	Mo	Observation, examination
F	12	Aquatic mammals (and related types)	By species:		
			Population density	Mo	Observation, trapping, tagging
			Areal/spatial distribution	Mo	
			Age distribution	Mo	
			Sex distribution	Mo	
			Habitat preference	Mo	
			Food preference	Mo	Observation, stomach analysis
			Feeding activity	Mo	Observation
			Reproductive activity	Mo	Observation, examination
	13	Waterfowl, birds	By species (as for mammals):	Mo	(As for mammals)
G	14	Aquatic vascular plants	Height profile	Mo	Profilometer, fathometer, meter stick
			Area coverage	Mo	Compass and tape survey
			Biomass, by species	Mo	Bulk volume at specified depths
			Population density, by species	Mo	Taxonomic survey Voucher specimens
			Phenology Flowering stages Production of vegetative propagules	Mo	Visual observation

(Sheet 4 of 4)

4.2.2 Work Unit A. This work unit covers factor families 1, 2, and 3.

4.2.21 Purposes. The purposes of this work unit are to: (a) describe and document the general characteristics, uses, and values of the Lake Conway aquatic ecosystem; (b) identify present uses and values that may be affected by changes in the system resulting from the presence of the white amur fish; and (c) identify places in the system that may be of particular interest by reason of special uses or outstanding values, or by reason of unique topography, substrate, circulation patterns, or the like. In addition to its use in the LSOMT, the information is required for comparing the Lake Conway area with other areas in which the white amur may be considered for use in operational applications.

4.2.22 Scope of work. The work being done under this work unit consists of collecting general descriptive data, supplemental to specific environmental data, required to evaluate the impact of the white amur on the uses, values, and qualities of the ecosystem. Monitoring system responses approximately 3 years after the introduction of the fish will provide data from which to determine effects of the fish on uses and values and, in particular, evaluate public response to both the presence of the fish and to any changes in the system that result from the fish's activities.

4.2.23 Factors and data sources. The primary sources of information for this work unit are inquiries and interviews with persons affiliated with various public agencies, conservation groups, sports clubs, etc., and by examination of records and data at such agencies and organizations. The minimum usage and basic descriptive information (factors) required and their data sources are listed in Table 4.2.1.

4.2.24 Sampling. Sampling is done as required.

4.2.3 Work Unit B. This work unit covers factor family 4.

4.2.31 Purposes. The purposes of this work unit are to: (a) monitor and document meteorological factors in the LSOMT area; (b) identify conditions that may affect water quality, circulation patterns, exchange rates, etc., prior to and after introduction of the white amur into the system; and (c) provide information that will be useful for this test area and other areas in which white amur may be considered for use in operational applications.

4.2.32 Scope of work. The work being done under this work unit consists of collecting general descriptive meteorological (or micro-meteorological) data, using standard instruments and recording devices. The WES selected one or more data stations that reasonably represent the range of general climatic conditions in the ecosystem. Data are collected at each station according to a schedule that ensures definition of the normal cycles occurring at any given station.

4.2.33 Factors and data sources. The minimum meteorological factors monitored are the following: wind speed, wind direction, air temperature, relative humidity, solar radiation, and perhaps reflected radiation (Table 4.2.1). Any or all of these may be sampled at more than one level, not to exceed four levels, at one or more of the designated sampling stations. Data, particularly rainfall data, will also be collected from all weather stations or other official weather stations, within the ecosystem watershed.

4.2.34 Sampling. Weather factors will be sampled by continuous or periodic recorders, at least at one station. The final schedule is such that readings are made with sufficient frequency to determine daily cycles and trends for each season.

4.2.4 Work Unit C. This work unit covers factor families 5 and 6.

4.2.41 Purposes. The purposes of this work unit are to: (a) monitor and document water quality and quality of bottom sediments in the LSOMT area; (b) establish baseline levels and seasonal cyclic variations in selected quality factors prior to introduction of the white amur; and (c) follow trends after introduction of the fish.

4.2.42 Scope of work. The work being done under this work unit consists of collecting data required to evaluate the impact of the white amur on water quality and quality of bottom sediments in the ecosystem. The WES has selected 11 permanent data control stations (paragraph 4.3.3) that will reasonably represent the range of general conditions in the ecosystem. The location of data collected will be referenced to these control stations according to a schedule and procedures agreed upon by the WES and contracting personnel.

4.2.43 Factors and data sources. The minimum water quality and bottom sediment factors being monitored and their data sources are listed in Table 4.2.1. Samples are obtained at the water surface and at 1-m depth intervals at each sample station. Factors for which incremental depth samples are inappropriate are tested with a column sampler to obtain a composite sample. Samples are analyzed according to procedures outlined in either Standard Methods for the Examination of Water and Wastewater (Thirteenth Edition) or Methods for Chemical Analysis of Water and Wastes (1974), or in accordance with procedures mutually agreed to by the contractor and the WES.

4.2.44 Sampling. Sampling is done at least monthly for all water-quality factors and at least bimonthly for sediment-quality factors at each sampling station. In addition, certain selected factors may be sampled at more frequent intervals (hourly, etc.) by automatic recorders.

4.2.5 Work Unit D. This work unit covers factor families 7, 8, 9, and 10.

4.2.51 Purposes. The purposes of this work unit are to: (a) monitor and document zooplankton, phytoplankton, and benthonic organism populations in the LSOMT area; (b) establish baseline levels and trends prior to introduction of the white amur; and (c) follow trends after introduction of the fish.

4.2.52 Scope of work. The work being done consists of collecting data required to evaluate the impact of the white amur on populations of zooplankton, phytoplankton, and benthonic organisms in the LSOMT ecosystem. The WES, in cooperation with contractor personnel, will select 11 permanent control data reference stations (paragraph 4.3.3) that will reasonably represent the range of general conditions in the ecosystem. Data being collected are keyed to a reference station according to a schedule and procedures agreed upon by the WES and contracting personnel.

4.2.53 Factor and data sources. The factor being sampled relative to periphyton, plankton, and benthonic organisms will be the number of individuals, identified by species or species complexes (or other taxonomic or life form groupings, as may be agreed upon), per unit volume of water or bottom sediment (Table 4.2.1). For plankton, the counts are taken from bulk samples, or other standard samples as may be agreed upon, at not more than three depths at each of the sampling stations. Benthonic organisms are defined to include crustaceans, other arthropods, amphibians, and similar relatively small bottom dwellers, which will be sampled according to established procedures. Periphyton is defined as the organisms collectively that grow adherent to underwater surfaces. It includes both plants (algae) and animals (e.g. rotifers, etc.), as well as planarians, mollusks, and others of that life habit.

4.2.54 Sampling. Plankton are sampled at each station at 1-month intervals; the benthos are sampled bimonthly.

4.2.6 Work Unit E. This work unit covers factor family 11.

4.2.61 Purposes. The purposes of this work unit are to: (a) monitor and document fish population dynamics in the LSOMT area; (b) establish baseline levels and trends in the populations of game fish in the system prior to introduction of the white amur; and (c) observe trends or changes in the populations after introduction of the white amur.

4.2.62 Scope of work. The work being done under this work unit consists of collecting data required to analyze the impact of the white amur on other fish populations in the system. In particular, it is important to evaluate the interaction between the introduced white amur and those other fish in the system whose value for game or aesthetics is already established. It is assumed, however, that various other fish that have no identified special value (minnows or whatever) contribute to the stability or general function of the system and are, therefore, also to be included in the monitoring program. After the white amur are introduced into the system, they will be monitored as an additional component of the total fish community.

4.2.63 Factors and data sources. The minimum factors being monitored in relation to each fish species and their data sources are listed in Table 4.2.1. Population will be estimated and behavior will be observed according to standard accepted procedures, including trapping or hooking, tagging, etc. Food habits, reproductive activity, etc., are determined by examination, according to established procedures or procedures agreed on by the WES and the contractor, including sacrifical procedures when appropriate.

4.2.64 Sampling. Sampling is done at least monthly, using Wegener ring and seining. Gill netting and electrofishing are conducted quarterly, and block net samples are taken semiannually.

4.2.7 Work Unit F. This work unit covers factor families 12 and 13.

4.2.71 Purposes. The purposes of this work unit are to: (a) monitor and document behavior and population dynamics of the higher animals that are ecologically associated with the LSOMT area; (b) establish baseline levels and trends in the populations and their adaptation to, or function in, the ecosystem prior to introduction of the white amur; and (c) follow the trends or changes in the populations after introduction of the white amur.

4.2.72 Scope of work. The work being done under this work unit consists of collecting data required to evaluate the impact of the introduced white amur population on populations of higher animals (mammals, marsupials, and the various birds) associated with the test area system. In particular, the consequences of the introduced white amur population on populations of game animals, game birds, and songbirds, both resident and migratory, must be determined. It is assumed, however, that mammals (hereinafter defined to include marsupials) and birds not otherwise valued by humans may nonetheless contribute to the stability or general function of the ecosystem and are, therefore, to be included in the monitoring program.

4.2.73 Factors and data sources. The minimum factors monitored in relation to each animal and bird species and their data sources are listed in Table 4.2.1. Population will be estimated and behavior will be observed according to standard accepted procedures, including trapping, tagging, telemetry, etc., or procedures agreed upon by the WES and the contractor, including sacrificial examination when necessary.

4.2.74 Sampling. Sampling is done at least monthly.

4.2.8 Work Unit G. This work unit covers factor family 14.

4.2.81 Purposes. The purposes of this work unit are to: (a) monitor and document aquatic vascular plant populations in the LSOMT area; (b) establish baseline levels and trends in the populations prior to introduction of the white amur; and (c) follow trends after the introduction of the fish.

4.2.82 Scope of work. The work being done under this work unit consists of collecting data required to evaluate the impact of the white amur on the aquatic vegetation of the ecosystem. The WES, in cooperation with contractor personnel, will select 11 permanent control data reference stations (paragraph 4.3.3) that will reasonably represent the range of general conditions in the ecosystem. Data are collected at each station according to a schedule and procedures agreed upon by the WES and contracting personnel.

4.2.83 Factors and data sources. The minimum factors monitored are as follows: area coverage, stem frequency (population density) by species, general plant height (height profile), mass by species, and various phenological factors including, in particular, flowering stages and production of vegetative propagules (Table 4.2.1). Since universal standard definitions or measurement techniques for at least some of these factors do not exist (e.g. for population density, plant height, and biomass), specific definition of these factors is subject to negotiation between the WES and the contractor. Voucher specimens will be collected and housed in proper facilities by the contractor or in a herbarium mutually agreed upon by the WES and the cooperating agency. The contractor should anticipate a requirement for visual observations or underwater work requiring the use of scuba equipment and personnel.

4.2.84 Sampling. Sampling is done at least monthly at each sampling station.

4.2.9 Explanation of Table 4.2.1. The following is an explanation of the columns appearing in the table.

4.2.91 Column 1, Work Unit. The "work units" are groups of factors for which sampling procedures are sufficiently similiar as to be considered for sampling under a single contract or by the same field team.

4.2.92 Columns 2 and 3, Factor Family Number and Name. The definition of "factor family" is given in paragraph 1.4.4.

4.2.93 Column 4, Factor Name. The items listed in this column, however, are not all strictly "factors," as that term is defined (paragraph 1.4.3). In some cases, the factors to be monitored are not yet specifically identified, pending a definition of available or feasible sampling methods and other considerations subject to agreement between the WES and the monitoring contractor. In such cases, a general term is listed that is approximately descriptive of the phenomenon for which specific factors will be defined. Names in parentheses in this column are listed as tentative requirements.

4.2.94 Column 5, Sampling Interval. The time interval required for sampling the corresponding factor is tentatively determined. The symbols are as follows:

-- = Less frequently than quarterly, or irregularly as required.

* = See comments in column 6.

Mo = Monthly

Bi = Bimonthly

Qt = Quarterly

4.2.95 Column 6, Data Source and Comments. The most likely data source or sampling technique, as well as other brief comments, is included.

4.3 Control Transects, End Points, and Data Collection Stations

4.3.1 Transects. The WES has established a system of 14 control transects (Figure 4.3.1) for the test area. These were selected after consideration of the general characteristics of the area as revealed by aerial photographs and on-site inspection. The following selected

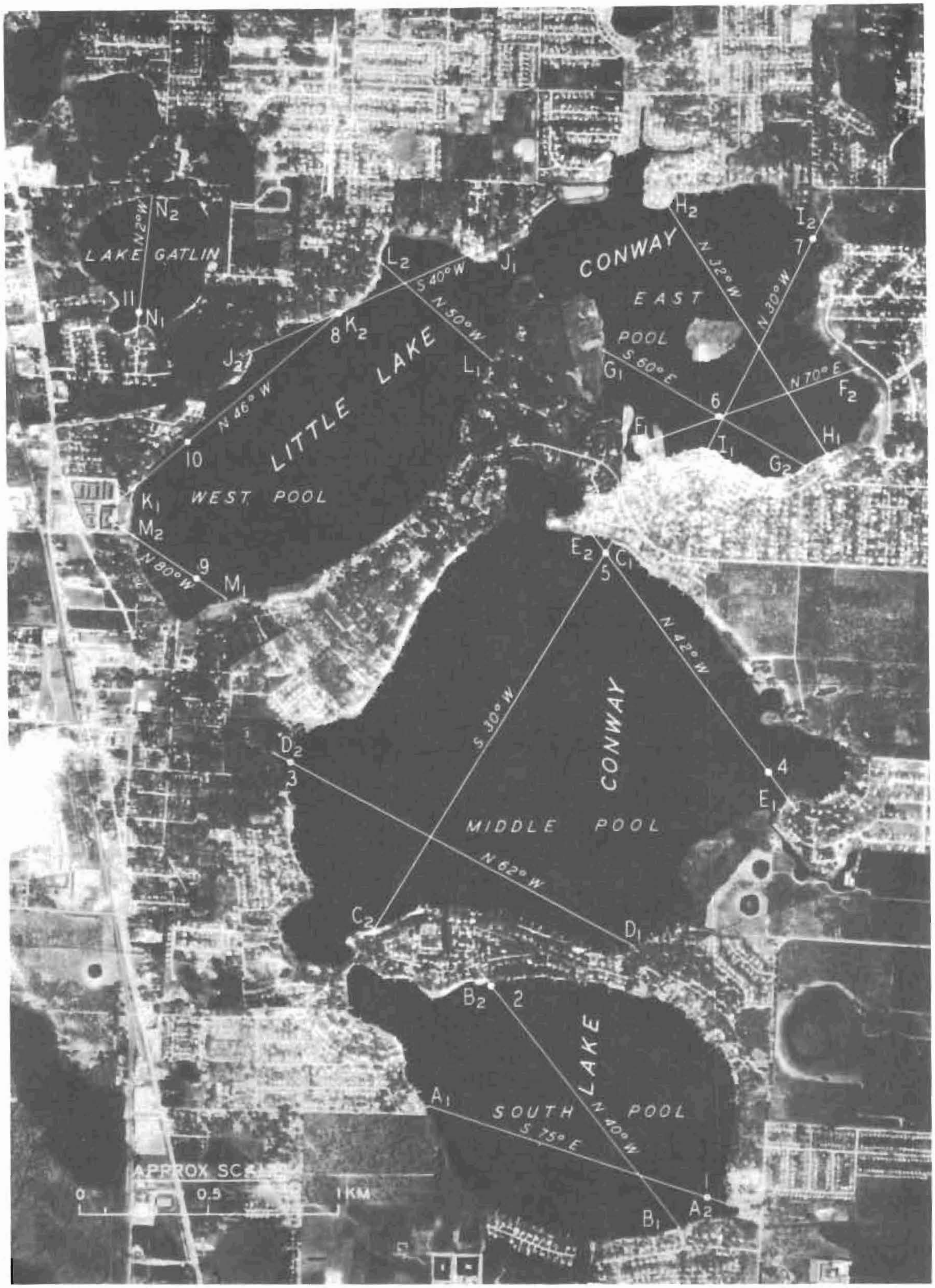

Figure 4.3.1 Control transects and data stations for Lake Conway, Florida, complex

transects are described as to location of endpoints, bearing, and length:

Transect Designation	Bearing	Length	General Location
A_1-A_2	S 75° E	1.3 km	South Pool - Lake Conway
B_1-B_2	N 40° W	1.4 km	South Pool - Lake Conway
C_1-C_2	S 30° W	2.0 km	Middle Pool - Lake Conway
D_1-D_2	N 62° W	1.7 km	Middle Pool - Lake Conway
E_1-E_2	N 42° W	1.6 km	Middle Pool - Lake Conway
F_1-F_2	N 70° E	1.0 km	East Pool - Little Lake Conway
G_1-G_2	S 60° E	1.0 km	East Pool - Little Lake Conway
H_1-H_2	N 32° W	1.2 km	East Pool - Little Lake Conway
I_1-I_2	N 30° W	1.1 km	East Pool - Little Lake Conway
J_1-J_2	S 40° W	1.0 km	West Pool - Little Lake Conway
K_1-K_2	N 46° W	1.3 km	West Pool - Little Lake Conway
L_1-L_2	N 50° W	0.6 km	West Pool - Little Lake Conway
M_1-M_2	N 80° W	0.9 km	West Pool - Little Lake Conway
N_1-N_2	N 2° W	0.6 km	Lake Gatlin

4.3.2 <u>End points</u>. The end points are keyed to physical landmarks or other permanent reference points for easy and consistent field location.

4.3.21 End point A_1. Point A_1 on the western shore of Lake Conway, South Pool, is characterized by a single white boathouse with a flat roof and an attached white boat pier. Onshore is a single-story house with a white roof.

Figure 4.3.21

4.3.22 End Point A_2. Point A_2 on the eastern shore of Lake Conway, South Pool, is identified by a group of trees at the water's edge with several house trailers immediately in the background. To the left* is a yard of palm trees. To the right* of the clump of trees is the back of a white store.

Figure 4.3.22

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* "Left" and "right" in these descriptions refer to the shore as viewed from the lake.

4.3.23 End point B_1. Point B_1 on the southern shore of Lake Conway, South Pool, is characterized by a white boat shed (no walls) with a sloping flat roof and an adjoining white pier. Behind the boat shed is a small gazebo with wood-shingle roof. Onshore is a single-story white house with a white roof. To the left of the boat shed, a 150-ft white beach and a long white pier are located at distances of 20 and 200 ft, respectively.

Figure 4.3.23

4.3.24 End point B_2. Point B_2 on the northwestern shore of Lake Conway, South Pool, can be identified by a single-story white house with black shutters and a red tile roof. In front of the house and behind the white beach is a single, large, 25-ft-tall pine tree with a white basketball backboard attached. To the right of B_2 is a single-story green house with a white roof.

Figure 4.3.24

4.3.25 <u>End point C_1</u>. Point C_1 on the northern shore of Lake Conway, Middle Pool, is identifiable as a double white boathouse with a sundeck roof and a handrail of wooden posts and two pipe rails. A 10-in. letter "N" on the boathouse wall can be seen between the two openings. A small pier is attached to the boathouse, and onshore is a single-story white house with a white roof.

Figure 4.3.25

4.3.26 <u>End point C_2</u>. Point C_2 on the southern shore of Lake Conway, Middle Pool, is characterized by a single, light-green boathouse with a white roof, an aluminum door, and an attached covered pier. The white beach to the left of the boathouse has a retaining wall, and onshore is a single-story green house with a black roof. An unpainted boat house is to the left.

Figure 4.3.26

4.3.27 End point D_1. Point D_1 on the southern shore of Lake Conway, Middle Pool, is identified by a single white boathouse with yellow trim, a flat roof, and an attached covered pier. Two porthole windows are in the right wall of the boathouse.

Figure 4.3.27

4.3.28 End point D_2. Point D_2 on the western shore of Lake Conway, Middle Pool, is distinguished by a single-story brick (lower 1/4) and cypress (upper 3/4) house with a gray roof. A brick chimney stands above the roof line, and a large mimosa tree is in the yard. The yard to the left is full of palm trees.

Figure 4.3.28

4.3.29 End point E_1. Point E_1 on the eastern shore of Lake Conway, Middle Pool, can be identified by a single-story, light-gray to almost-white house with a white roof. A large 50-ft pin oak tree stands in front of the house, and two tall palm trees are at the right corner of the house.

Figure 4.3.29

4.3.2.10 End point E_2. Point E_2 on the northern shore of Lake Conway, Middle Pool, is characterized as a white house with a white roof, a one-story wing, and a two-story wing. A tall pine tree to the right stands out on the shoreline.

Figure 4.3.2.10

4.3.2.11 End point F_1. Point F_1 on the southern shore of Little Lake Conway, East Pool, is distinguished by a large three-story house with a red tile roof and 3 two-story wings.

Figure 4.3.2.11

4.3.2.12 End point F_2. Point F_2 on the southwestern shore of Little Lake Conway, East Pool, is identifiable as a two-story white house with a black roof and a single-story attached garage with a black roof.

Figure 4.3.2.12

4.3.2.13 <u>End point G_1.</u> Point G_1 on the western shore of Little Lake Conway, East Pool, is a lone, tall pine tree standing taller than the forest. A post in the water is in line with the tree.

Figure 4.3.2.13

4.3.2.14 <u>End point G_2.</u> Point G_2 on the southern shore of Little Lake Conway, East Pool, is the tallest pine tree on the skyline. A brown boat shed with a brown roof is just to the right of the tree.

Figure 4.3.2.14

4.3.2.15 End point H_1. Point H_1 on the southeastern shore of Little Lake Conway, East Pool, is identified by a large red boathouse with an aluminum roof.

Figure 4.3.2.15

4.3.2.16 End point H_2. Point H_2 on the northern shore of Little Lake Conway, East Pool, is characterized by a one-story, buff-colored house with a red tile roof and a white beach across the front.

Figure 4.3.2.16

4.3.2.17 <u>End point I_1.</u> Point I_1 on the southern shore of Little Lake Conway, East Pool, is distinguished by a two-story house with a wooden shake roof and a one-story wing. The house has a two-story garage attached with a bell house on the garage roof.

Figure 4.3.2.17

4.3.2.18 <u>End point I_2.</u> Point I_2 on the northeastern shore of Little Lake Conway, East Pool, can be identified by a two-story house with a red tile roof and a one-story wing on each side.

Figure 4.3.2.18

4.3.2.19 <u>End point J_1</u>. Point J_1 on the northern shore of Little Lake Conway, West Pool, can be recognized by a two-story white house with a white roof and a single-story wing. The swimming pool in front of the house has a two-story screen cover that is attached to the house.

Figure 4.3.2.19

4.3.2.20 <u>End point J_2</u>. Point J_2 on the western shore of Little Lake Conway, West Pool, is characterized by a large brick house with the upper one-half being vertical black roofing with a large brick chimney. The house has an attached, screened swimming pool.

Figure 4.3.2.20

4.3.2.21 <u>End point K_1.</u> Point K_1 on the southwestern shore of Little Lake Conway, West Pool, is identified by a gabled end two-story apartment building. The fenced tennis courts are just to the left of the buildings and a concrete boat ramp is on the shore.

Figure 4.3.2.21

4.3.2.22 <u>End point K_2.</u> Point K_2 on the northwestern shore of Little Lake Conway, West Pool, is distinguished by a double, bright-green boathouse beside the public boat-launching ramp.

Figure 4.3.2.22

4.3.2.23 <u>End point L_1.</u> Point L_1 on the northeastern shore of Little Lake Conway, West Pool, can be recognized by a white boathouse with a green roof and an attached covered pier.

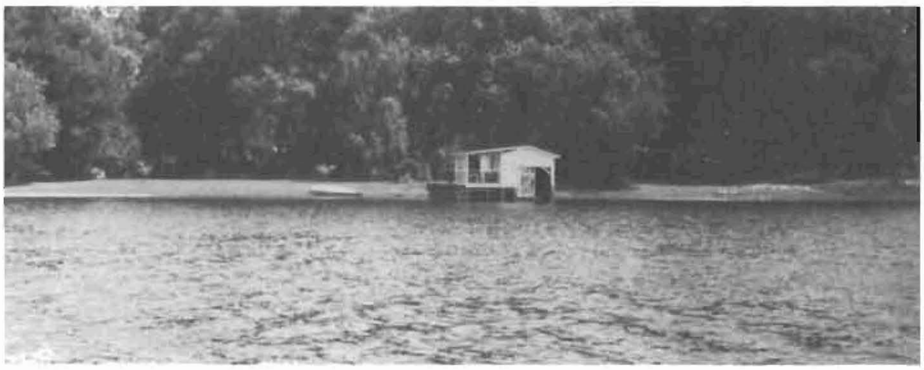

Figure 4.3.2.23

4.3.2.24 <u>End point L_2.</u> Point L_2 on the northwestern shore of Little Lake Conway, West Pool, is identified by a double red boathouse with a flat roof. A white beach is behind the boathouse.

Figure 4.3.2.24

4.3.2.25 End point M_1. Point M_1 on the southeastern shore of Little Lake Conway, West Pool, is characterized by a double boat shed with a tan gravel roof and a dark-red closed storage across the back of the boat shed. A covered pier is attached to the boat shed.

Figure 4.3.2.25

4.3.2.26 End point M_2. Point M_2 on the southwestern shore of Little Lake Conway, West Pool, is identifiable as the gabled end of an apartment building that can be seen just to the right of the fenced tennis courts.

Figure 4.3.2.26

4.3.2.27 <u>End point N_1</u>. Point N_1 on the southern shore of Lake Gatlin, is distinguished by a single-story, white concrete block house with a black roof. A 25-ft-high flagpole is in the center of the yard.

Figure 4.3.2.27

4.3.2.28 <u>End point N_2</u>. Point N_2 on the northern shore of Lake Gatlin, can be recognized by a white storage shed with a white gable roof on the water's edge.

Figure 4.3.2.28

4.3.3 Data collection stations. Eleven permanent stations have been established at selected points along the transects (Figure 4.3.1) and are identified as follows:

Control Data Station No.	Transect Line	Approximate Distance From Designated End Point
1	A_1-A_2	100 m from A_2
2	B_1-B_2	100 m from B_2
3	D_1-D_2	100 m from D_2
4	E_1-E_2	200 m from E_1
5	C_1-C_2, E_1-E_2	170 m from C_1, 300 m from E_2
6	F_1-F_2, G_1-G_2	380 m from F_1, 360 m from G_2
7	I_1-I_2	100 m from I_2
8	J_1-J_2, K_1-K_2	330 m from J_2, 40 m from K_2
9	M_1-M_2	200 m from M_1
10	K_1-K_2	400 m from K_1
11	N_1-N_2	100 m from N_1

These are designated as control data stations and will provide reference points for locating sampling points used throughout the period of the LSOMT. In addition, supplementary data stations may be established either temporarily or permanently for collecting special data, such as water-quality data at the mouth of feeder streams. All sampling points used at every sampling interval will be referenced on a blank map (Figure 4.3.3) provided by the WES, to be submitted with the data to the WES. The addition of necessary data stations to the original basic net will be accomplished by the participant. The location of these additional data stations will also be marked on the blank map and forwarded to the WES as part of the required periodic data report (paragraph 4.1.2).

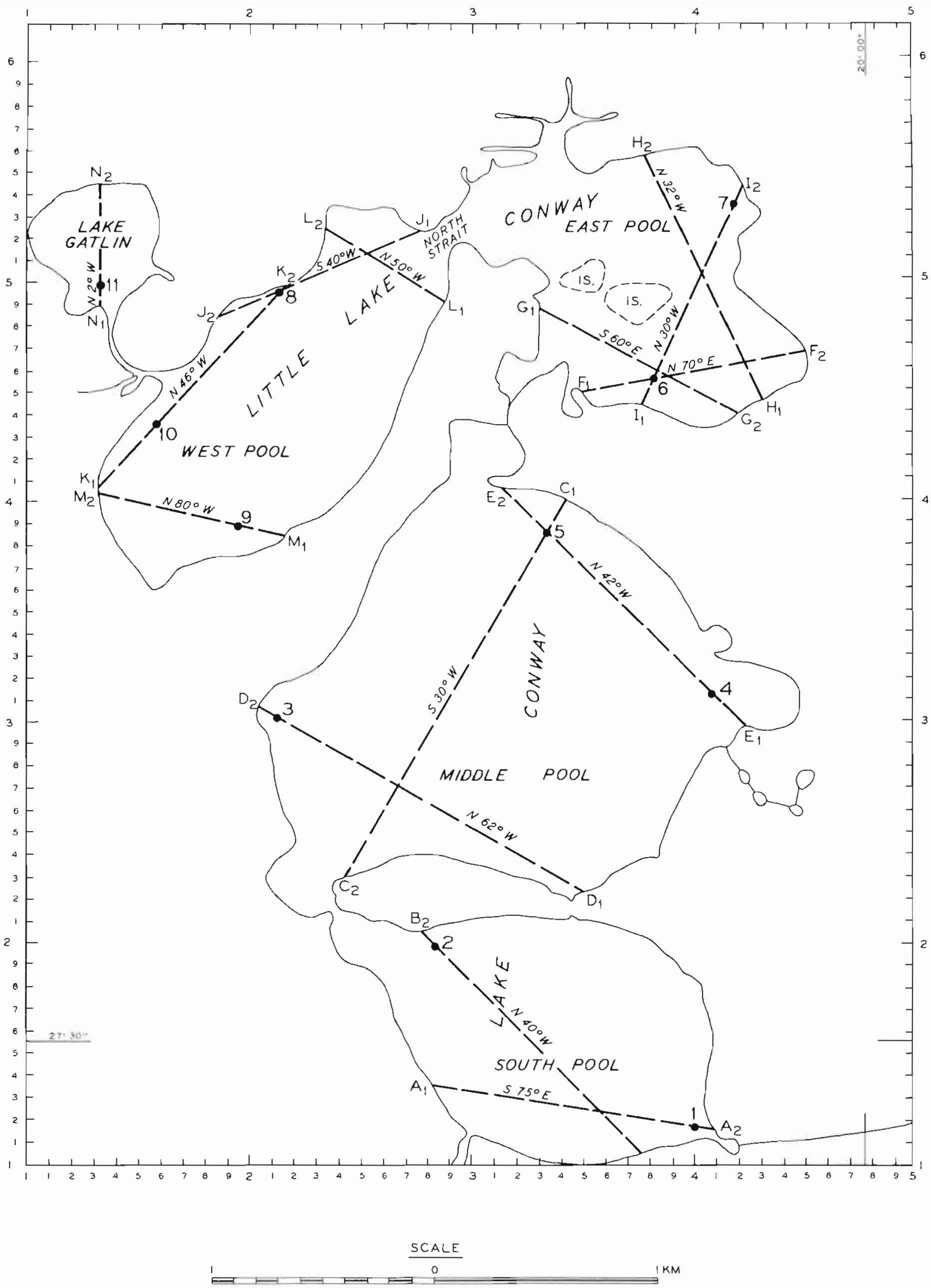

Figure 4.3.3 Blank map for indicating sampling locations in Lake Conway, Florida, complex

5.0 DATA MANAGEMENT

5.1 General. As a central clearing house for all data, the WES will receive all collected data and maintain a data storage and processing system. This system will be computerized and will include manipulative and analytical capabilities.

5.2 Data Formats. To ensure that all data generated in the program are compatible with the storage and processing system, each contractor is required to submit to the WES an example of the data collection forms he proposes to use. Upon receipt of these forms, the WES will review and accept or modify them as required for system compatibility. Any required revisions will be coordinated with the contractor.

5.3 Centralization and Dissemination. Each contractor is required to periodically submit to the WES copies of the collected data in the proper format for dissemination to other participants. Data presentation formats are decided upon by the contractors and the WES personnel. Computer programs will be developed by the WES for providing tabulations, plots, maps, or other summaries of the data to any participating scientist, as appropriate. Data analysis, i.e. correlation and trend analyses, etc., will be performed by the respective contractors, including the WES scientists. In some instances, analyses may be performed on the WES computer by the WES data management personnel, but at the request of the participating scientist.

6.0 EXTRAPOLATION AND MANAGEMENT IMPLICATIONS OF TEST RESULTS

6.1 Empirical Extrapolations

6.1.1 The data collected during this test program will be used to establish the responses of various parts of the aquatic ecosystem in which the test will be conducted. The majority of these relations will depict the time-dependent responses of the measured parameters (section 4.0). In addition, subsequent analysis will be directed toward the determination of the interactions of the system components.

6.1.2 After a sufficient amount of data has been collected to establish the various system responses, the results can be extrapolated to other aquatic ecosystems. To accomplish this in any meaningful way, the similarity of the test site to the site where the test results are to be extrapolated must be established. The sites must be characterized in terms of the pertinent environmental parameters that are sensitive to change. The design of the data collection program for this LSOMT incorporates this type of data. However, it is anticipated that, after analysis of the baseline data, additional parameters will be identified that will have to be incorporated into the data collection program. Hopefully, these requirements for additional data will be minimal.

6.1.3 The extrapolations based on the empirical data will not be applicable to all aquatic ecosystems having problems with submersed plants, even within the State of Florida. After the necessary pertinent parameters have been compared, the range of variation of many of these may well be judged to be too great to place another ecosystem in the class of Lake Conway. It is believed that prediction models will provide an analytical framework that will enable scientists to extend the test results to other ecosystems having widely variant conditions from those characterized at Lake Conway.

6.2 Model Extrapolations. In addition to being used for *post facto* analyses, the collected data will be used to develop and validate ecosystem models. Such models are an essential aspect of the LSOMT concept. They will serve two purposes. First, they will provide the necessary means for predicting when the test treatment has been optimized. This is accomplished by extrapolating the correlation and trend analyses to predict whether or not the population of white amur should be sustained, increased, or decreased, and whether other supplemental data collection should be introduced, or whether existing data should be discontinued or the frequency of collection modified. Second, they will have the necessary capability for extrapolating identified cause-effect relations from the specific test area to other ecosystems where similarities and dissimilarities with the test area are known and in which plant growth control problems are similar to those in the test area.

6.2.1 Ecosystem model

6.2.11 One of the models being developed simulates the relations among the various components of the aquatic ecosystem. Although the model is intended to eventually be of a general nature, the present development is directed specifically to Lake Conway, Florida. To date, the formulation of this model is based on information existing in the literature as well as some previously collected data on Lake Conway. As the LSOMT data collection program progresses, these data will be used in the development and final formulation of the model. The model considers the following components present and their response to the presence of the white amur:

6.2.111 Hydrilla
6.2.112 Periphyton
6.2.113 Native submersed plants
6.2.114 Native fish
6.2.115 Total dissolved phosphorus
6.2.116 Detritus

6.2.12 As more data become available through the data collection program and the model is refined, simulations for Lake Conway will be conducted periodically to study the system's responses to the presence of various proposed stocking levels of white amur. These simulations along with the baseline data collected and results from the stocking model will be used to determine the stocking size and number of white amur to be placed in the Lake Conway system.

6.2.2 Stocking model

6.2.21 In the design of the overall experiment, it was apparent that one basic question had to be answered as soon as possible. That is: "How many white amur of what individual size must be stocked in Lake Conway to effect some level of control?" This leads to the more basic question of "How does one determine the proper stocking size and numbers?" Following the general rationale that the end objective in stocking the fish is to achieve an acceptable level of long-term weed control in some near future time frame, a model has been developed. This model requires as input the following ecosystem parameters: water temperature, species of weed(s) present, total surface acres of water, percent infestation of weeds, average depth of infested area, weight per unit volume of plant material, initial individual weight of the fish, number of fish to be stocked, and maximum time interval within which a level of weed control is desired. At present, the model contains relations that consider:

6.2.211 The particular plant species growth with time in terms of biomass.

6.2.212 The conversion of plant biomass to fish flesh as a function of fish size.

6.2.213 Weight gain per fish for a selected time interval as a function of fish size.

6.2.214 Loss rate of fish due to predation as a function of fish size.

6.2.215 Loss rate of fish due to natural causes as a function of fish size.

6.2.216 The efficiency of the fish as affected by the necessity to cruise for food as a function of amount of plant biomass remaining.

6.2.22 Generally, the model performs the necessary calculations over an increment of 0.1 year, cycling alternately between the plant growth relations and the fish growth and activity relations. The outputs provided as a result of making the calculations over a specified length of time include:

6.2.221 Plant biomass as a function of time.

6.2.222 Weight of an individual fish as a function of time.

6.2.223 Number of fish as a function of time.

6.2.224 Total weight of the fish population as a function of time.

6.2.23 At present, the shape and magnitude of the relations used in the model are based on data available in the literature and previous studies conducted by other agencies. In addition, a sensitivity analysis is being conducted to determine how each relation influences the characteristics and response of the outputs. Although newfound data are continually being used to substantiate the relations in the model, the data requirements for confirming the relations will be much better identified after the sensitivity analysis is completed. Obviously, present data gaps are already distinguished, but until a ranking of sensitivity is established, no priority can be established for the initiation of laboratory or small-scale studies needed to generate the needed data.

6.3 Management Implications

6.3.1 The overall objective of the LSOMT is to determine if the white amur is an operationally feasible weed control tool. Feasibility in the context of the LSOMT is meant to imply that the use of the fish is practical, economically acceptable, and environmentally compatible. The modeling results, as well as the empirical relations established from the results of the data collection program, will have a direct bearing on the eventual operational aspects of the program. From an operational standpoint, there eventually must be a management program for continual, operational maintenance of the white amur to ensure continued weed control wherever it is established. This research is intended to provide operations management with the information necessary to determine:

6.3.11 Lakes and streams that are amenable to plant control using the white amur.

6.3.12 Restocking requirements, if any, that are necessary to maintain any particular system at a desired level.

6.3.13 The type and number of facilities required to maintain a sufficient supply of fish to support a state-wide weed control program.

6.3.14 The manpower, equipment requirements, and logistic problems of sustaining such a weed control program.

6.3.15 Permit regulation requirements for proper compliance with governing state agencies.

6.3.16 Requirements for periodic monitoring of established systems.

6.3.2 Once the models have been validated, the test results from Lake Conway can be extrapolated to other conditions. These extrapolations will be used in the development of an engineering manual for the operative use of the white amur as a method of weed control. In addition, the models will be available to the operations management personnel. These models will enable them to rapidly decide on the stocking rate based on expected long-term effects on the ecosystem.

6.3.3 The requirement for environmental impact assessments (EIA's) and statements (EIS's) are well known, and should the white amur be used in a comprehensive state-wide operational weed control program, an EIS will probably have to be prepared. The validated models will enable the user to extend the Lake Conway test results to include a majority of the aquatic environments and, therefore, provide a sound basis for rapidly preparing the required EIS.

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Addor, Eugene E

Test plan for the large-scale operations management test of the use of the white amur to control aquatic plants, by Eugene E. Addor [and] Russell F. Theriot. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1977.

1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Instruction report A-77-1)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C.

1. Aquatic plant control. 2. Fishes. 3. White amur. I. Theriot, Russell F., joint author. II. U. S. Army. Corps of Engineers. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Instruction report A-77-1)

TA7.W34i no.A-77-1