Implementation of Non-Point Source BMPs

In the Fourche Maline Arm of Lake Wister

(C9-996100-05, Task 700)

FINAL REPORT

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November 19, 2002

Foreword

Wister Lake has been a State priority watershed since 1991 when the Oklahoma Legislature appropriated matching funds for a CWA §314 Phase I Diagnostic-Feasibility Study on the lake. The Phase I study documented problems in the relatively broad and shallow reservoir, including low dissolved oxygen, excessive suspended solids and pollution from the watershed. The study recommended methods to reduce the influx of pollutants as well as in-lake measures to mitigate the chronic effects of those pollutants. Additional work was also performed during the Phase I study to gain statewide consensus of the baseline phosphorus load and recommend load reduction goals. Additionally, documentation of point source contributions to the condition of Lake Wister led to eventual phosphorus reductions by Tyson, Inc., in Waldron, Arkansas.

Following the completion of the Phase I report, aerial photo-documentation of a massive algae bloom in the main body of the lake required the Oklahoma Water Resources Board (OWRB) to place Wister Lake's watershed on the Nutrient Limited Watershed (NLW) list. Wister Lake and its watershed are also on the State's 303(d) list. This distinction requires a TMDL by the Oklahoma Department of Environmental Quality (ODEQ), which is ongoing. In addition, the Lake Wister drainage basin has become the focus of an intensive non-point source control program by the Oklahoma Conservation Commission. Successful implementation of drainage basin BMPs and TMDL results will yield reductions of pollutant load to Wister Lake in the future.

The ten years since the initial Clean Lakes award have yielded valuable data on the status of Wister Lake and offered recommendations to improve watershed activities and in-lake dynamics that impact the reservoir. Now it is time, however, to turn our focus to the reservoir and offer solutions to alleviate the very real and immediate symptoms of Wister Lake. The OWRB recently released a draft report to the United States Army Corps of Engineers (USACE), Tulsa District, outlining conceptual designs to control low dissolved oxygen and high suspended solids in Wister Lake (OWRB 2002). This work is designed to enable Feasibility and Implementation work funded through the USACE to alleviate problems exacerbated by in-lake dynamics. The Wister §319 project enabled a demonstration to study the feasibility of establishing aquatic plants in Wister Lake, and propelled OWRB staff to find innovative means to reduce suspended solids.

The Phase I Study recommended creating two different barriers in Wister Lake. One barrier is needed between the lake bottom and the water to prevent sediment from resuspending. Another recommended barrier is one that reduces wave action by breaking up the long fetch over the water. Research cited in the report shows that the most cost effective and long-term solution to creating a barrier between the lakebed and overlying water is to establish native aquatic plants, and this approach is recommended for Wister Lake. The second, fetch-reducing barrier was likewise recommended to assist in the establishment of plants by providing a wave break near the demonstration area. The beneficial effect of vegetation or aquatic macrophytes on water clarity has been long noted and it is for this reason OWRB recommended these methods.

There are several well-documented examples where either aquatic vegetation has colonized or been reduced with commensurate change in water quality. Perhaps the most striking example of aquatic vegetation determining sediment resuspension (and consequently water quality) is the ecological switch incurred at Lake Apopka, Orange

County, Florida. Lake Apopka was characterized as an aquatic plant-dominated lake with relatively high water clarity until a hurricane removed a large swath of aquatic plants from the lake bottom in 1947. Over time this area without aquatic plants expanded to dominate the lake bottom, resulting in a phytoplankton-dominated system. After this ecological switch, Lake Apopka experienced high turbidity and algae growth. As the open water (no vegetation on the lake bottom) area increased, water quality decreased. This stark example displays a directly proportional relationship between aquatic plant coverage in shallow areas and water quality. While the Lake Apopka example relates to submersed plant beds, it is important to note that emergent vegetation has been shown to reduce wind resuspension as well. A study by C.D. Dieter published in the *Journal of Freshwater Ecology* illustrated this concept with the use of sediment traps in areas with and without emergent aquatic vegetation (1990). Areas not protected by emergent vegetation accumulated two to four times the amount of sediment than the protected areas examined in the study.

Although many indirect benefits of establishing native aquatic vegetation, such as the creation of fish and wildlife habitat and the sequestering of nutrients from algae, are expected in Wister Lake, the targeted effect is the reduction of suspended solids in the reservoir. In the pre-319 proposal period, Wister's depauperate aquatic plant community bode ill toward establishing a native plant community. Implementation of a long-term ecological switch in Wister Lake began by determining whether beneficial aquatic plants could be established in the lake. The process, through this 319 grant, was designed to test the conceptual theory behind inducing that switch. Ultimately, the fulfillment of a "switched" ecosystem should result in a reduction of suspended solids. The aquatic vegetation portion of this project bridged the first gap in applying concepts of shallow-water limnology to on-the-ground water quality improvement.

It is important to note that reduction of solids by aquatic plants occurs not by virtue of biological processes but rather the fact that plants reduce kinetic energy in the shallow zones of the lake. In a similar fashion, the reduction of effective fetch is intended to reduce wind drag on the lake surface. Reduced drag on the lake surface reduces wave size and subsequently minimizes sediment scour on the shallow mud flats of Wister Lake. Few tools exist to aid in the design of an implementation plan to reduce fetch in shallow water systems. Modeling has been suggested as having the best potential to define the boundaries of resuspension. To date, theoretical models have been identified relating suspended solids to wind speed, although not in a spatially distributed format. Recent work completed for the USACE on Wister Lake (OWRB 2002) has allowed the OWRB to map the bottom contours of Wister Lake and make the first cut towards spatially defining the resuspension zones. In hindsight both the experimental and control sites in this project seem to be on or adjacent to suspension zones. A portion of the OWRB's work this next fiscal year will attempt to apply the recent spatial information (in GIS format) to theoretical concepts discussed in the literature with the intent of numerically defining the areas of resuspension.

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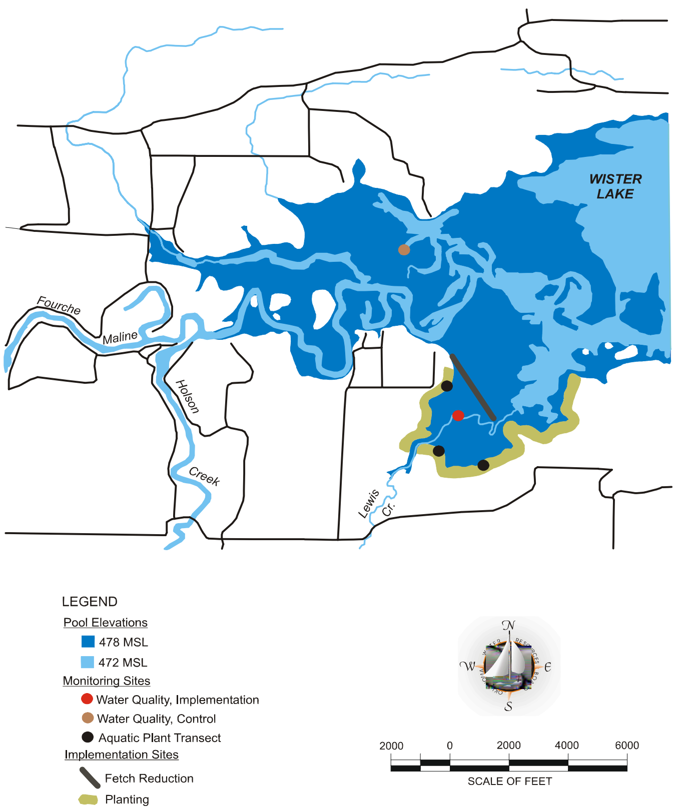
Executive Summary

Overview

Using the results of a Clean Water Act (CWA) Section 314 Phase I Clean Lakes Study, the Oklahoma Water Resources Board (OWRB) received a CWA section 319 grant to demonstrate the feasibility of reducing suspended sediment within the Fourche Maline Arm of Wister Lake in LeFlore County, Oklahoma. Two main goals were the focus of this demonstration: 1) to install a breakwater, or barrier to wave action, to reduce fetch and therefore reduce suspended sediment problems associated with this lake, and 2) to demonstrate whether native aquatic plants could be established in Lake Wister.

To maximize the effectiveness of this project, the OWRB entered into agreements with the U.S. Army Corps of Engineers (USACE) through the Planning Assistance to the States (PAS) program. First, the OWRB and the USACE determined which native aquatic plants could be established in the lake. This decision depended on a variety of factors including plant type, hardiness and availability. A second OWRB/USACE agreement sought to establish the type and placement of materials needed to reduce wave action in the Fourche Maline arm. These joint efforts served to benefit the project as a whole, and specific recommendations from these efforts were translated into the §319-demonstration project through the consensus of local lake stakeholders. Through this process an agreement was made to install a 2100-foot line of round hay bales as a temporary wave barrier in the Lewis Creek arm. Lewis Creek provided an ideal demonstration area for this study. Lewis Creek was also targeted to demonstrate methods for establishing aquatic plants in the reservoir. Monitoring sites for aquatic plants and water quality were also selected. Many local cooperators were key to the completion of this project: the Poteau Valley Improvement Authority (PVIA), Kerr Center for Sustainable Agriculture (KCSC), USACE Wister project, Ouachita Correctional Facility and the Lake Murray State Park.



The accumulation of sediments around plant transplants after the commencement of the study, as well as anecdotal observations by local cooperators, indicate these two suspended sediment control measures hold promise for application in other reservoirs. Options for improving Wister Lake explored with this study have generated optimism among local cooperators.

Fetch Reduction

Installation of the hay bale breakwater was completed through a joint effort by the OWRB, USACE Wister Project, City of Tulsa and the PVIA, all of whom contributed supplies and manpower. The PVIA also furnished equipment and an operator, and the installing contractor developed an innovative anchoring system that minimized impact to the site. By the end of August 1999 a 2100-foot temporary barrier had been installed to reduce fetch and sediment suspension in the Lewis Creek arm of Lake Wister. The barrier lasted approximately 8 months in Lake Wister. Following EPA approval of the Quality Assurance Project Plan in February 2000 the OWRB monitored water quality. Although inadequate overlap of barrier and monitoring did not allow for a quantitative measure of success, it should be noted that local cooperators are now convinced that similar measures will improve the quality of Lake Wister. This was not a common belief at the beginning of the project.

Completed barrier in the Lewis Creek arm.

Aquatic Plants

Several species of plants were documented to grow and reproduce as a result of this project. Six specific species were recommended for long-term efforts to establish a diverse aquatic plant community in Lake Wister. This study has also identified local plant sources and transplant methods for use in future projects, both at Wister and around the state. Herbivore control, such as the wire cages seen at left, is recommended to allow the transplants to establish. Once established, herbivore control would no longer be needed. Plant establishment in Lake Wister has already shown that this remediation device can be successful long-term. The water benefit of established plants is evidenced by the sediment accumulation around the root systems of growing transplants in the lake.

Aquatic plant community transplanted into Lake Wister.

Task 1 – Determine Placement and Method of Fetch Reduction

Planning Assistance to States Study

The OWRB Clean Lakes Phase I Diagnostic Feasibility Study of Lake Wister recommended reduction of sediment suspension by reducing effective fetch in the Fourche Maline arm of the lake (OWRB, 1996). The OWRB entered into an agreement with the U.S. Army Tulsa District Corps of Engineers under the Planning Assistance to States (PAS) program to determine the optimal placement and method of fetch reduction measures for the demonstration project outlined in this report. Structural alternatives were studied and a breakwater, or barrier to wave action, was recommended. The goal of the breakwater in this project was to reduce wave action in a specific region of the lake, the Fourche Maline arm, in order to study the effectiveness of breakwaters in reducing sediment suspension. Four sites were selected for study with input from the OWRB, the USACE and the Oklahoma Department of Wildlife Conservation (ODWC). Final site selection was based on the following criteria: (1) exposure to south-southwest wind, (2) access for construction, (3) limited area for extended study, (4) ability to construct within study budget and (5) potential for fish habitat. Other considerations in site selection were environmental conditions, cultural resources and endangered species (USACE, 1998a).

Several structural breakwaters were found to be suitable for use in this application. The structures considered in detail were rock jetties, floating tire breakwaters, brush bundles and brush piles. See Appendix A for a complete description of these breakwater structures and a map of the sites evaluated. The USACE also considered hay bale breakwaters, but did not evaluate this method to the detail afforded the other listed measures (USACE, 1998a). Each structure was evaluated based on the following criteria: (1) site location, (2) construction cost and (3) potential for fish habitat.

Study Considerations

Cost considerations and site locations were studied in detail for the PAS study. The USACE evaluated a total of 15 structures at the four proposed sites. Several structures and sites were eliminated from consideration because they could not be constructed within the budgetary constraints of this project. Site accessibility for construction was also an important factor, and site 3 was determined to lack the access necessary for such construction. The USACE felt that construction of a 500 foot rock jetty at site 1, costing approximately $63,500, would be most cost effective method (USACE, 1998a).

Environmental considerations were also examined. USACE evaluation concluded that fetch reduction would not adversely impact existing environmental resources. In fact, it was expected that placement of these structures within the Fourche Maline arm of the lake would result in significant improvement in the water quality by decreasing sediment suspension and improving water transparency. This in turn would enhance the establishment of an aquatic macrophyte community along the shoreline and in the shallow limnetic zone, and result in an increase in nutrient metabolism. Another potential effect of reducing sediment suspension would be a reduction in overall turbidity, although it should be noted that construction and installation activities would disturb the lake sediments and as such, a temporary increase in turbidity would be expected (USACE, 1998a).

It was also determined that Section 404 permits would be needed for any construction activities conducted below 478.0 feet NGVD, pursuant to the Clean Water Act. This would need to be obtained from the USACE, Tulsa District, prior to any construction activities. It was recommended that all activities are coordinated not only with the ODWC, but with other state agencies which have jurisdiction over national resource conservation as well. The Environmental Protection Agency (EPA) would act as the Federal Action Agency for National Environmental Protection Act compliance issues (USACE, 1998a).

After careful review of all options, the OWRB decided to implement a hay bale barrier. An inexpensive way to reduce effective fetch and provide shoreline protection, hay bales would also provide over three times the linear coverage a rock jetty would yield. The USACE estimated a cost of $46.24 per linear foot for round hay bales compared to $103.04 per linear foot for brush pile and $126.46 per linear foot for rock jetty. One aspect of using hay bales is that this solution would be temporary, with the hay bales gradually degrading over two seasons. Hay bales have been shown to reduce wave action, and would also help provide an environment that would allow for the establishment of aquatic plants (Anderson, 1996). This application provides an inexpensive means of shoreline protection, and suits the project as a demonstration project.

319 Project Planning

Thorough review of the USACE study, as well as other information available on hay bale breakwaters, was conducted by the OWRB. In 1997 and 1998, a series of meetings was held at the USACE Wister project office to apply the PAS report to the EPA §319 project. The Lewis Creek arm of Wister Lake was determined to be the best site because it is located where the upper end of the lake opens up to large lengths of fetch. Lewis Creek, the main tributary, also runs against the far bank about halfway down the arm, providing a large plateau or mud flat available for barrier installation. Stretching approximately 2100 feet with a maximum depth of 3.5 feet, the plateau in the Lewis Creek arm also comprises a good portion of the ODWC wildlife refuge and thus has reduced boat traffic and activities during portions of the year. All these factors contributed to the selection of site 2 as the target for fetch reduction. Round bales of hay were chosen as the material to construct the breakwater and a method of anchoring the bales to the lakebed was agreed upon. Discussion of methodology, construction and installation of the breakwater occurs in Task 3. It was determined that given the budgetary and time constraints of the project, a temporary breakwater composed of hay bales placed at site 2 would be the most cost-effective means of demonstrating the effectiveness of fetch reduction for the improvement of water quality. Subsequently, it was decided to place a 2100-foot line of hay bales in the Lewis Creek arm (Figure 1.1). Hay bales would be placed round-side down and spaced about 3-5 feet apart. This would allow for 300+ bales to cover a linear distance of approximately 2100 feet at a cost of approximately $70,000.

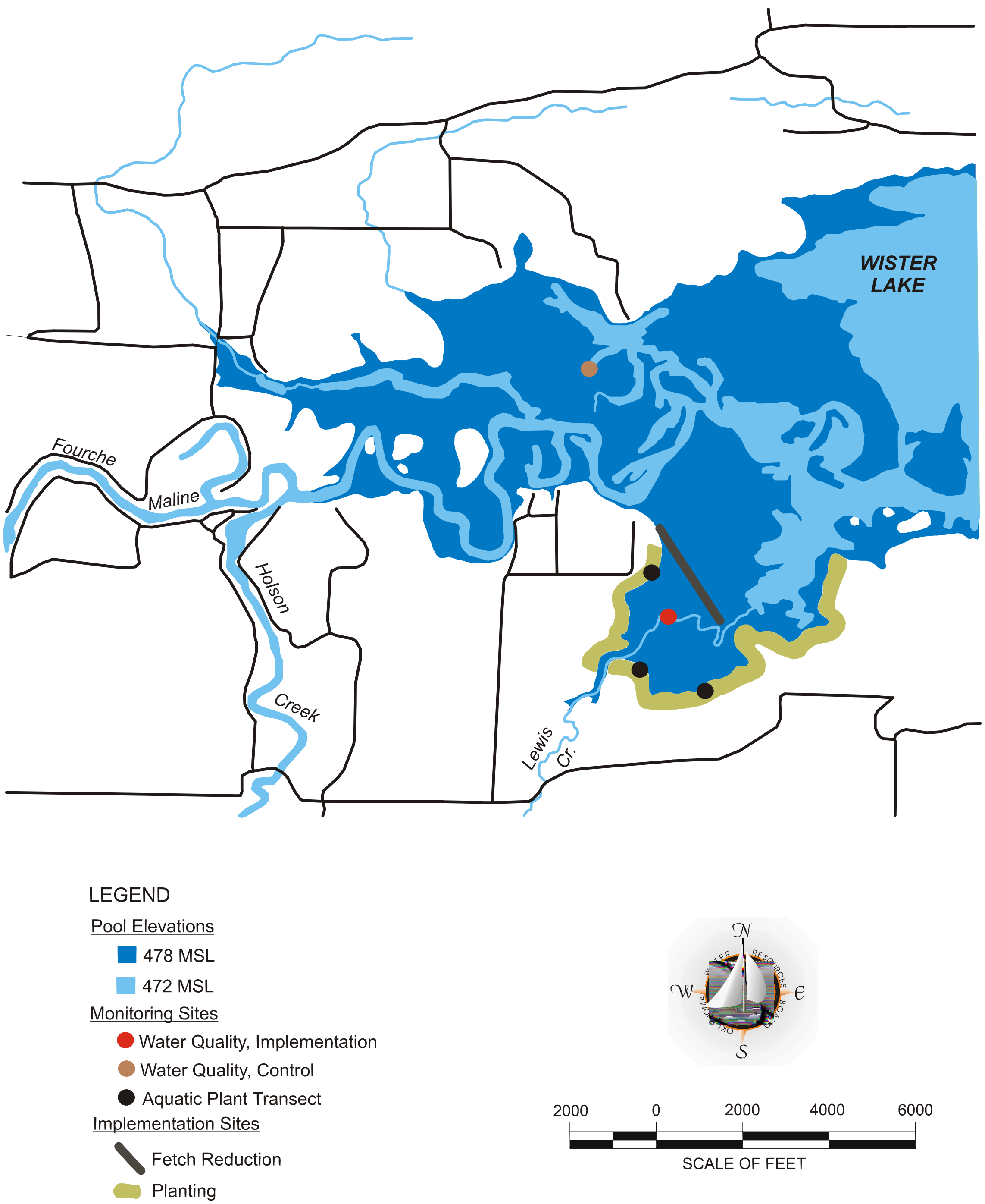


Figure 1.1. Illustration showing the design for hay bale placement in the Lewis Creek Arm of Lake Wister.

Task 2 – Determine Optimal Sites and Methods to Establish Aquatic Plant Community

USACE Planning Assistance to the States Studies

This task was a joint effort between the Tulsa District Corps of Engineers (USACE) and the Lewisville Aquatic Ecosystem Research Facility (LAERF), in cooperation with the Oklahoma Water Resources Board (OWRB). It was conducted under authority of Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251), also known as the Planning Assistance to the States (PAS) program. The aquatic vegetation study was conducted in two phases. The goal of both phases of the study was to determine what types of native aquatic plants could be planted in Lake Wister to improve water quality and aesthetics. Appendix B contains both Phase I and Phase II contracted reports. Phase I focused on identifying potential plants for introduction to Lake Wister while Phase II focused on the monitoring of test plantings as well as recommendations for future efforts. While the PAS Phase II study was concluding project funds were used to complete the planning process for the actual demonstration.

Phase I Study

Phase I focused on plant selection and husbandry and was divided into tasks on plant ecology, environmental conditions, site selection, plant species selection and specific planting methodologies. The LAERF also recommended a monitoring protocol to track the plants. Phase I work occurred from June 1997 through March 1998. This work reviewed the factors of light availability, water chemistry, sediment chemistry and disturbance on aquatic plant ecology. The current environmental conditions of Lake Wister – light availability, water level fluctuations, herbivory and other biotic disturbances – were also reviewed. These two reviews were then cross-referenced to develop a strategy for selecting test plant species. The following describes the process used and its conclusions.

Plants selected for Lake Wister were those tolerant of turbid conditions (Table 2.1). Aquatic plants with emergent leaves or those that have leaves that float at the water surface are more likely than submersed varieties to survive in turbid conditions such as those found in Lake Wister. Selected plantings utilized propagule types with large energy reserves, such as mature containerized transplants and large dormant tubers, because of the poor environmental conditions within the lake. Tubers are dormant "potato-like" structures formed by some species as an overwintering propagule. These structures have rich energy reserves from which the plant re-grows when environmental conditions are favorable.

Planting Methods: The LAERF furnished the initial test plants from their culture ponds in Lewisville, TX. Care was taken to ensure accurate planting depth. Specific planting depth is dependent upon species, with shallower water (0.1- 0.3 meter depth) selected for emergent species, moderate depths (0.3 - 0.5 meter depth) for floating-leafed species, and deeper water (0.3 - 0.6 meter depth) for submersed species. All depths were relative to conservation pool elevation, 478.0 NVGD.

Table 2.1. Recommended plant species and propagule types for test plantings.

Plant Name	Plant Type	Propagule Type
Justicia americana (American waterwillow)	Emergent plant which tolerates water fluctuations	Mature, well-established Transplant
Scirpus validus (bulrush)	Emergent shoreline plant which forms dense colonies	Mature, well-established Transplant
Echinodorus beteroi (burhead)	Emergent shoreline plant	Mature, well-established Transplant
Echinodorus cordifolius (creeping burhead)	Emergent shoreline plant (some already present at Site 1)	Mature, well-established Transplant
Sagittaria graminae (bull-tongue arrowhead)	Emergent plant which tolerates water fluctuations to about 20 cm during growing season	Mature, well-established Transplant
Heteranthera dubia (water-stargrass)	Submersed plant which can develop emergent leaves during low-water periods	Mature, well-established transplant
Potamogeton nodosus (American pondweed)	Floating-leaf plant with high wildlife value and tolerant of water level fluctuations	Mature, well-established transplant or dormant Winterbuds (tubers)
Nymphaea odorata (white waterlily)	Floating-leaf water lily	Mature, well-established Transplant
Nuphar lutea (spatterdock)	Floating-leaf water lily	Mature, well-established Transplant
Potamogeton pectinatus (Sago pondweed)	Submersed plant with high wildlife value reported to be turbidity tolerant	Dormant tuber
Vallisneria americana (wild celery, variety which forms tubers)	Submersed plant with high wildlife value reported to be turbidity tolerant	Dormant tuber or mature, well-established transplant

To plant mature transplants in the field, holes were dug in the sediment that were roughly the size of the root mass of the transplant. The plant and roots were then removed from the pot and placed in the hole. Care was taken not to bury the root mass too deeply in the sediment since this can result in death or delayed growth. Backfilling and pressing the root mass into the sediments ensured anchoring.

To protect from herbivory, a small cage was installed around each transplant (Figure 2.1). Cages constructed from 2-inch by 4-inch, 14-gauge weld wire had proven adequate in protecting plants in other lakes and thus was also employed in Lake Wister. Each cage was anchored with two pieces of rebar to prevent tipping over. Placement of cages minimized grazing by large herbivores and allowed the plants to establish within a protective boundary. Monitoring over several months following initial plantings determined the likely degree of protection required for larger scale efforts. Once plants were established, spreading from the cages usually occurred. For some plants herbivore densities were so high that they prevented spreading outside of the cage

(Table 2.2). In this case additional, large-scale protection would be needed in future studies to allow for spreading outside of the cage.

Monitoring of test plantings was critical to determining the plants and locations that offered maximum potential for larger scale success. This monitoring occurred in late October 1997 when the plants were expected to go dormant and resumed in spring 1998 as soon as lake levels returned to 478.0 elevation. Monitoring was conducted on each individual planting unit (by species). At each site, location maps of each plant propagule allowed easy identification in subsequent visits. Field tags associated with each individual plant were also used confirm the identity of the planting unit. Monitoring consisted of recording the plant species within the cage, the percent cover within the cage, evidence of herbivory, type of herbivory and amount of expansion outside of the cage. Preliminary monitoring showed herbivory outside of the cages to be heavy and diverse. Waterfowl, turtles, hoofed mammals (such as cows and deer), aquatic mammals (such as beaver or muskrat) and fish were noted to eat or disturb various plant species.

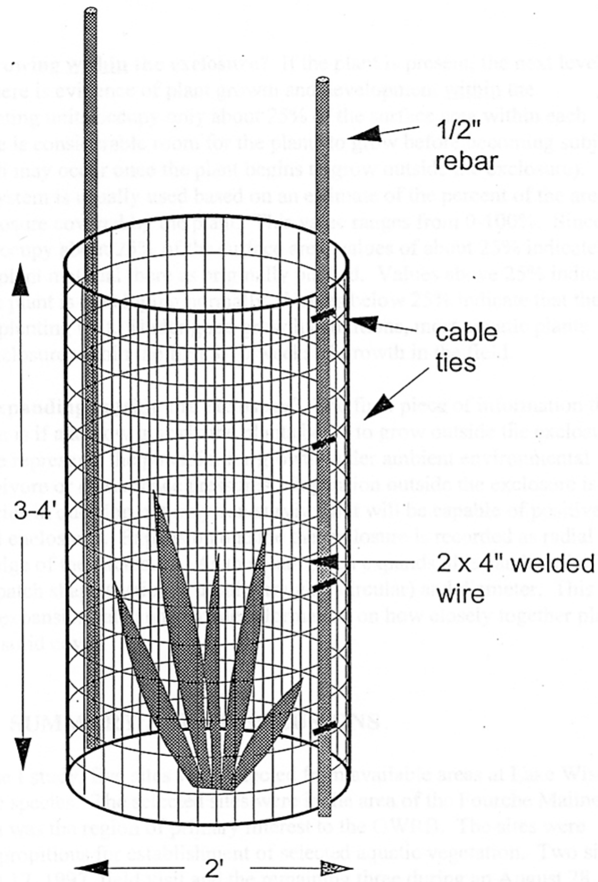


Figure 2.1. Design of "tomato cage" enclosure used to protect plants form disturbance and herbivory.

Phase II Study

Phase II consisted of monitoring the test plantings and making recommendations for future large-scale efforts. Additional plant species were tested during the Phase II effort as monitoring continued and original plant material died out. Monitoring results indicate that species selection, propagule type and degree of protection at the time of planting all strongly influenced the initial establishment and survival of plants in Lake Wister. Additional plant species tested were the flatstem spikerush (*Eleocharis spp*.), rush (*Juncus spp.)* and arrowhead *(Sagittaria spp).* These plants were tested because of their local abundance and potential for mass transplanting.

<u>Monitoring Results:</u> In general, the establishment of containerized emergent or floating-leafed vegetation planted within protective enclosures was excellent (Table 2.2). Submersed species and those plantings with unrooted cuttings or without protective enclosures performed poorly (Table 2.2). All emergent species tested, except burhead *(Echinodorus beteroi),* had excellent survival rates and should be considered for future establishment efforts. Based on the results of plants in other reservoirs around Texas and Oklahoma, it is recommended that special efforts be made to establish American waterwillow, bulrush and bull-tongue arrowhead during future plantings. These species have shown the ability to survive various water level regimes and are capable of rapid expansion along the shoreline. In addition, other emergent species, such as squarestem spikerush *(Eleocharis quadrangulata)* and pickerelweed *(Pontederia cordata),* should be considered for future plantings.

Table 2.2. Summary of plantings made in summer 1997 and spring 1998

Species	Plant Type	*Propagule*	***Protection***	**Potential for Use in Large-Scale Establishment Effort on Lake Wister**
Justicia americana	Emergent	Containerized	Yes	Excellent, all test plantings survived full annual cycle and some were expanding beyond cages.
Justicia americana	Emergent	Unrooted sprigs	No	Not Acceptable. None survived.
Echinodorus beteroi	Emergent	Containerized	Yes	Poor. Only one of seven test plantings survived annual cycle.
Echinodorus cordifolius	Emergent	Containerized	Yes	Excellent. Most plantings survived and some were expanding beyond cage. This plant is already present in small numbers around the lake.
Scirpus validus	Emergent	Containerized	Yes	Excellent, all test plantings survived full annual cycle and some were expanding beyond cages.
Eleocharis sp.	Emergent	Containerized	Yes	Excellent. All plants survived.
Eleocharis sp.	Emergent	Containerized	No	Not Acceptable. None survived.
Juncus sp.	Emergent	Rooted clumps	No	Good. Most survived from April to June 1998.
Sagittaria sp.	Emergent	Containerized	Yes	Excellent. All plants survived.
Sagittaria sp.	Emergent	Containerized	No	Not Acceptable. None survived.
Heteranthera dubia	Submersed	Containerized	Yes	Good. About half of plantings survived annual cycle.
Vallisneria americana (WI)	Submersed	Containerized	Yes	Not Acceptable. Only one plant survived annual cycle and it was barely present.
Vallisneria americana (TX)	Submersed	Containerized	Yes	Not Acceptable. Only two plants survived annual cycle and they were barely present.
Potamogeton pectinatus	Submersed	Containerized	Yes	Not Acceptable. None survived.
Elodea canadensis	Submersed	Containerized	Yes	Not Acceptable. None survived.
Potamogeton nodosus	Floating leaf	Containerized	Yes	Good. Over half of plantings survived annual cycle.
Nymphaea odorata	Floating leaf	Containerized	Yes	Excellent, all test plantings survived full annual cycle and some were expanding Beyond cages.

Both floating-leafed species planted also showed excellent survival results. American pondweed grew quickly after being planted in the summer of 1997. By October 1997, it showed evidence of having expanded farther beyond the cages than other species. A similar species that was not tested in Lake Wister but that has grown well in other reservoirs is Illinois pondweed *(Potamogeton illinoensis).* The white waterlilies planted in 1997 all survived and were vigorously growing during the summer of 1998. In addition to this lily, other lilies, such as yellow waterlilies *(Nuphar lutea)* and American lotus *(Nelumbo lutea)* should be considered.

Most of the submersed species that were tested showed very poor survival rates. Sago pondweed, American elodea, and both ecotypes of wild celery tested showed very poor survival rates. The few plants that survived the test period were observed to be very small and were considered unlikely to survive for long. Better survival was observed for water stargrass, where 11 of 21 plants survived the first annual cycle. However, while survival was considered acceptable, these plants showed very little promise of rapid expansion within the very turbid waters of Lake Wister. Although this species can be used as part of a larger scale plant establishment effort, it is unlikely to grow in larger expanses during the first few years.

Recommendations

As a result of the PAS studies, the LAERF recommended the establishment of "founder populations" of aquatic plant species at various sites around Lake Wister. Founder populations are small colonies of aquatic plants that are established in strategic locations within the reservoir. After these plant colonies become successfully established they serve as a propagule source to fuel continued expansion of plants to unvegetated areas throughout the lake. The colonies expand by production of viable seed and/or vegetative growth. More detailed information on culture and establishment techniques can be found in the recently published handbook “Propagation and Establishment of Aquatic Plants: A Handbook for Ecosystem Restoration Projects” by R. Michael Smart and Gary 0. Dick (WES in press).

Plant Species and Propagule Selection

Initial plant establishment efforts in Lake Wister should focus on emergent and floating-leafed species planted in waters less than 2.5 feet deep. After shallow zone waters ranging in depth from 0 to 2.5 feet are well populated with emergent and floating-leafed species, additional plantings of some turbidity tolerant submersed species can be incorporated. Of the submersed species tested only water stargrass showed potential for survival under present conditions in Lake Wister, although as mentioned above it does have limitations to large-scale usage. Table 2.3 presents a list of good species for use in Lake Wister as well as the type of propagules from which to begin cultures.

Plantings in Lake Wister should utilize mostly containerized transplants. Unrooted cuttings, seed, and other "easier" types of propagules are unlikely to survive the turbid conditions that currently characterize Lake Wister. Although some "clumps" of soft-rush did show some survival, these clumps had very well developed roots that were collected with minimal disturbance. To survive the turbid waters of Lake Wister, plants should have well-developed aboveground stems and leaves as well as good root systems.

Table 2.3. Plant species recommended for large-scale plantings in Lake Wister, Oklahoma.

Name	**Type**	**Propagule Type Needed to Initiate Cultures**
Justicia americana (American water-willow)	Emergent plant which tolerates water fluctuations	Bare-root transplants collected from field or stem cuttings
Scirpus validus (bulrush)	Emergent shoreline plant which forms dense colonies	Bare-root transplants collected from field
Echinodorus cordifolius (creeping burhead)	Emergent shoreline plant (some already present at Site 1)	Bare-root transplants collected from field
Sagittaria sp. (bull-tongue arrowhead)	Emergent plant which tolerates water fluctuations and depths to about 20 cm during growing season	Bare-root transplants collected from field
Eleocharis sp. (Flatstem spikerush)	Prolific shoreline emergent plant which spreads quickly	Bare-root transplants collected from field
Eleocharis quadrangulata (square-stem spikerush)	Tall spikerush which tolerates flooding	Bare-root transplants collected from field
Juncus sp. (Soft rush)	Prolific shoreline emergent plant which spreads quickly	Bare-root transplants collected from field
Potamogeton nodosus (American pondweed)	Floating-leaf plant with high wildlife value and tolerant of water level fluctuations	Stem cuttings
Nymphaea odorata (white waterlily)	Floating-leaf water lily	Bare-root transplants collected from field
Nuphar lutea (yellow waterlily)	Floating-leaf water lily	Bare-root transplants collected from field
Nelumbo lutea (American lotus)	Prolific shallow water plant which expands rapidly	Scarified seed
Heteranthera dubia (water-stargrass)	Submersed plant which can develop emergent leaves in shallow water	Stem cuttings
Potamogeton illinoensis (Illinois pondweed)	Submersed plant which grows quickly and tolerates flooding	Stem cuttings

Propagule Production

Establishment of several dozen founder populations around the lake will require hundreds of planting units of several species of aquatic plants. Commercial nursery pots with drain holes in the bottoms should be used. Quart-size containers (4-inch diameter) are suitable for most emergent and submersed species, while gallon-size (6-inch diameter) are more suitable for most water lilies which often form large rhizomes. These pots are UV stabilized and can be reused several times.

Although aquatic plants can grow in a variety of sediment types ranging from pure sand to highly organic soils, culture is facilitated by use of fine-texture substrate with a moderate organic content (10-20%). If possible, use of sediments collected from ponds or lakes is ideal. However, if such sediments are not available, topsoil can be used. In some cases, fertilization of sediments with nitrogen may accelerate initial growth. Fertilization rates of 1g nitrogen (added as urea or as ammonium salt) per liter of sediment is recommended. If topsoil (rather than pond or lake sediments) is used, the filled pots of soil can be 'cured' underwater for 2 weeks prior to planting.

Pots of cured sediment can be planted with the appropriate type of propagule for each plant species utilized (Table 2.3). These should be kept under controlled, shallow-water conditions for up to 3 months prior to transporting to the field. Best success is seen when plants are cultured long enough to produce "root bound" propagules. The root mass should fill the container and maintain its shape when removed from the pot.

The production of aquatic plant propagules will require adequate shallow-water culture facilities. Shallow-water ponds may offer excellent options if these are available. Lined ponds are preferable to earthen ones because they facilitate keeping cultures of different plants distinct and avoid the growth of endemic vegetation within the pond. Enclosures should be constructed around each species if several species are to be cultured in a single pond. These enclosures can be constructed with t-posts and any type of fine mesh plastic material, such as shade cloth. Enclosures for emergent plants and lilies, which can be cultivated in less than 2 feet of water, can be constructed with black erosion fabric.

Very shallow water tanks constructed of lumber and lined with plastic pond liner offer the greatest benefits for production of emergent plants and lilies. These can be constructed on any level ground that has an adequate supply of fresh water. Tank depth can vary from 10 inches for emergent plants to 16 inches for lilies. A single shallow tank measuring 3 feet by 10 feet can hold well over 100 potted plants and can be constructed from materials costing about $250. Such shallow tanks are easy to manage and can be built with good vehicular access for moving plants around or bringing in sediment or plant propagules.

Herbivore Protection

Protective cages will be needed during the first year or two after plantings to ensure plant survival. Results from plantings in numerous other reservoirs in addition to Lake Wister have clearly demonstrated increased survival and more rapid establishment if the plants are protected. A "two tiered" protection is usually best in reservoir situations. 1) Each individual transplant is protected with a small cage to virtually assure the survival of the transplant. 2) As shown in Figure 2.2, additional protection can be provided by surrounding several individuals with a larger fenced plot using 2-inch by 4-inch welded wire fencing to ensure that a colony of sufficient size is produced as plants grow beyond the individual cage. The size of the fenced plots can be adjusted as needed. In some cases, a "shoreline fence" can be used as shown in Figure 2.3 instead of the larger fenced plot. A shoreline fence is simply a three-sided modification of the fenced plot. These shoreline fences can be irregular in shape. For example, one might extend from the shoreline to the 3-foot depth contour and then along that contour parallel to the shoreline. The fenced plots should have an average plant density from 0.25 and 0.5 plants per square yard.

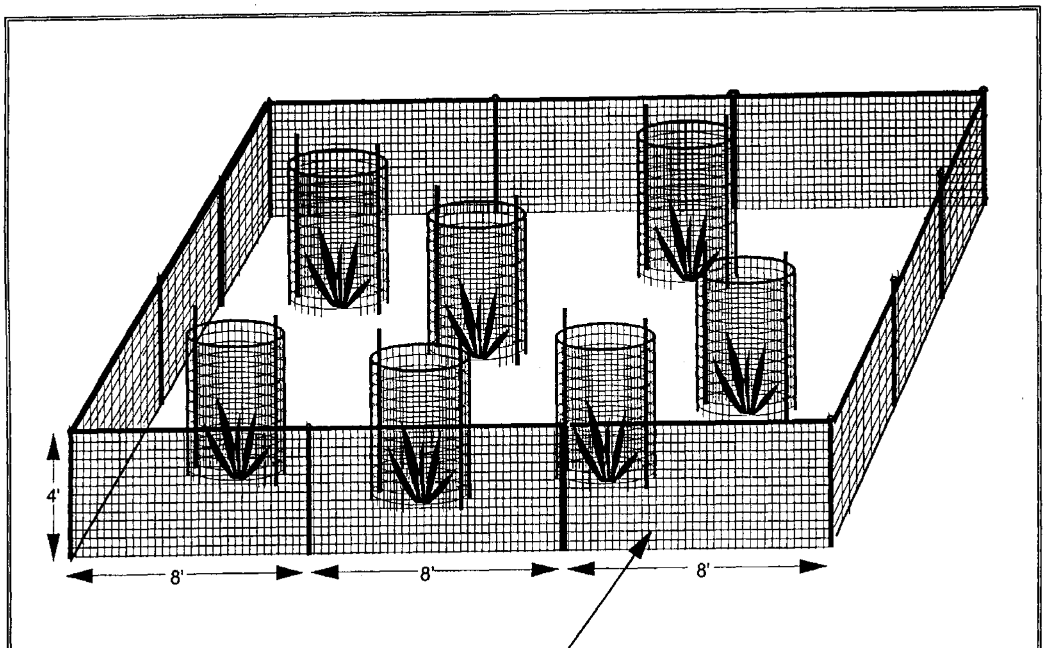


Figure 2.2. Design for fenced plots.

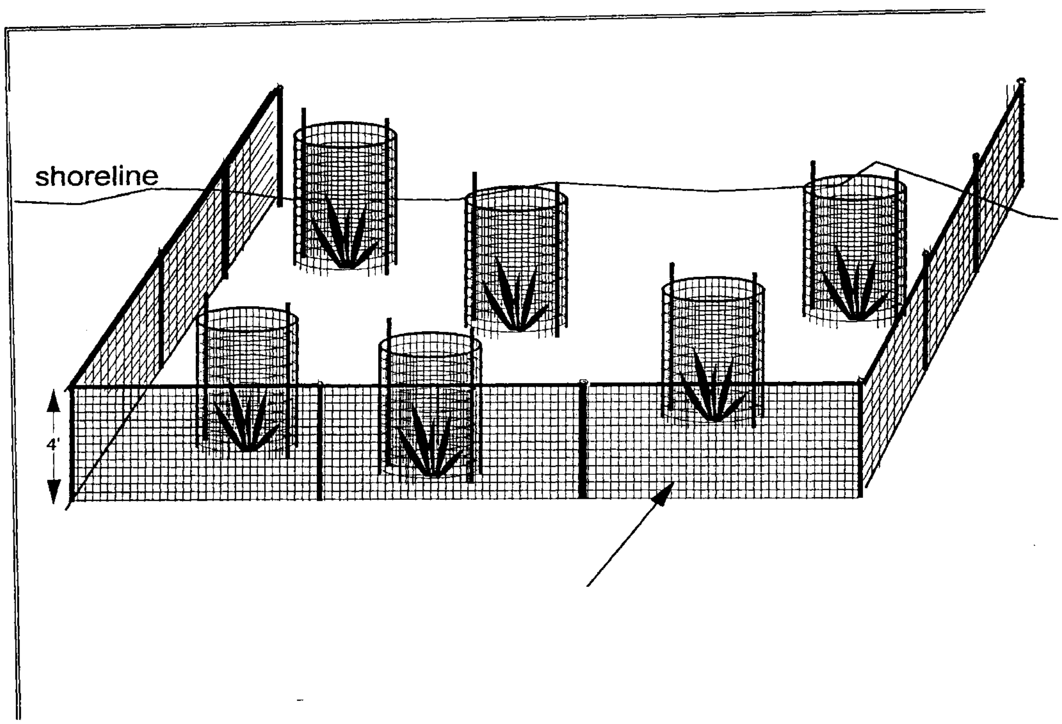


Figure 2.3. Design for shoreline fence protection

Planning for Demonstration

The Lewis Creek arm was again targeted for this demonstration. This area was chosen because of low boat traffic (due to its location in the Wildlife Management Area) and its association with the Fetch Reduction demonstration. As a result of the USACE PAS studies, the OWRB identified target plant species and habitats within Wister Lake to grow native aquatic vegetation. Using these results OWRB staff identified multiple sources for various plant species. Based on the identified sources and USACE-recommended transplanting techniques, OWRB staff developed a planting plan to demonstrate methods of introducing a diverse aquatic plant community to Lake Wister. This plan consisted of coordinating the process of uprooting, transporting, planting and protecting target plant species from each identified transplant area. For this reason the location and abundance of target species was the main focus of our planning process.

Emphasis was placed on the recommendations developed by the USACE LAERF. However, not all recommendations could be followed. For example, abundant local sources of target plant species were identified. The LAERF recommends cage protection of every individual transplanted plant with a larger cage protecting the general area. Cost considerations precluded the protection of every transplanted plant. For this reason three levels of protection were afforded transplanted plants: high, low and no protection. This enabled herbivore protection methods to be assessed and maximized available plants for transplant. Some protective cages were also designed to protect multiple species as opposed to individual plants. Decisions regarding the planting plan included the necessary manpower to harvest and plant target species, the accessibility of target species and the materials needed to effect the demonstration. Working through these decisions served to cement local partnerships while minimizing cost and maximizing efficacy. Appendix C details the planting plan including estimates of cost, time and manpower. The following describes planting plan considerations.

Planting Considerations

Development of the planting plan hinged mostly on the location, abundance and nursery requirements of each plant species and its relative value to the demonstration. Most aquatic plant sources were identified on publicly held property (federal, state, municipal or foundation) close to Lake Wister. The use of manpower to harvest and plant aquatic plants in Lake Wister avoided the issue of needing permits to harvest with earth-moving equipment. The decision to hire locally to fill out the work crew afforded the opportunity for local publicity and helped to disseminate transplanting techniques.

During planning it was anticipated that lake levels might be too high for effective plantings during part of the season. The planting schedule was thus kept fairly loose to allow for a 5-6 week hiatus to afford the lake to drop to conservation pool. The plan called for the option to stage plants on KCSA property in the event of high lake levels.

The cooperation of the Kerr Center for Sustainable Agriculture (KCSA) was a critical component of the planning process. The no cost access to KCSA culture ponds allowed for the establishment of plant nursery ponds to provide large quantities of high quality target plants for introduction into Lake Wister. The plant species identified as having the greatest potential for survival was the softstem bulrush (*Scirpus validus*). Softstem bulrush has the potential for year-round growth and is drought and flood resistant. Bulrush tends to spread laterally during drought or pool drawdown and has extensive vertical growth (as much as 12' tall) to survive rises in pool elevations. Test plantings with the LAERF also showed that the softstem bulrush could survive extended (6-week) inundation during the growing season. All other plant species tested had to re-grow from tubers or seed following this extended inundation. At the time of the project the only easily accessible population of softstem bulrush was in Lake Murray, under the management of the Oklahoma Department of Tourism. A large part of the planning process entailed the logistics of digging up bulrush tubers from Lake Murray, providing road transport 180 miles to Lake Wister and then water transport to the target area in Lake Wister. Table 2.4 summarizes the timetable and individual goals for introducing aquatic plant species to Lake Wister.

Table 2.4. **Proposed planting plan time sequence identifying planting goals, by individual species and workweek.**

Action		February	March	April	5/10 - 5/15	5/17 - 5/21	5/24 - 5/28	5/31 - 6/4	6/7 - 6/11	6/14 - 6/18	6/21 - 6/25	6/28 - 7/2	7/5 - 7/9	7/12 - 7/16	7/19 - 7/23	7/26 - 7/30	8/2 - 8/6	8/9 - 8/12
Manpower/ Contracts																		
Locate Seed Sources																		
Clean out Kerr pond																		
Set up Nursery areas																		
Water Willow (# of propagules)							9118							9118				
Duck Potato (# of propagules)						12158					12158				12158			
Bulrush (# of propagules)								1559		1559								
***Fragrant Water Lily (2500)**					Har				Pot			Plan						
Seeding													N&SW			WM		
Maintenance																		
Enhancement/ Augmentation					SW											H		

*** 2500 as the target number; Har(vesting),Pot(ting),Plan(ting)**

Key **SW = Smartweed** **N = Nelumbo** **WM = Wetland Mix** **H = Heteranthera**

Emphasis was placed on the bulrush plantings because these plants showed the highest probability of successful establishment. The decision was made to plant as many bulrush units as possible using a planting pattern that followed the shoreline of the Lewis Creek arm. Three levels of protection would be used on these transplants: complete caging, ground or root caging, and no caging. As many protective cages would be installed as money allowed, maximizing future benefit from the transplanting. The decision was also made to plant three transects perpendicular to the lake shoreline in the Lewis creek arm. Here plants such as flatstem spikerush, smartweed, arrowhead, softstem bulrush, cow lily and fragrant water lily would be planted in a repeating sequence starting close to the shoreline and continuing to the end of the transect. A discussion of the implementation of this planting plan follows in Task 3:

Partnerships

Completion of this task served to develop strong partnerships with the Poteau Valley Improvement Authority (PVIA), USACE Lake Wister project office, Kerr Center for Sustainable Agriculture (KCSA), Ouachita Correctional Facility, City of Tulsa, and the Lake Murray State Park. These partnerships and contributions are discussed in Task 3.

Cost

Cost of implementing the planting plan was estimated at $41,000 with approximately $28,000 for personnel, $4,500 for per diem and travel, $7,000 for fencing supplies and $2,500 for maintenance and miscellaneous supplies.

Task 3 – Implement Fetch Reduction and Aquatic Plant Establishment in the Fourche Maline Arm of Wister Lake

Fetch Reduction

Implementation of Fetch Reduction involved acquiring a 404 permit from the U.S. Army Corps of Engineers Tulsa District, purchasing round hay bales, soliciting bids for marine installation and purchasing supplies. The USACE approved the 404 permit under the auspices of habitat improvement. The USACE Wister Project, City of Tulsa and PVIA contributed supplies and manpower to assist with the installation effort. The PVIA also furnished equipment and an operator.

Hay bales were purchased through a contract with the Poteau Valley Improvement Authority (PVIA) for a total cost of approximately $15,000. The PVIA subcontracted the baling effort to a local farmer with equipment capable of creating round bales of hay bound by jute rope. The low-grade round bales of hay, baled from selected areas of the Lake Wister Wildlife Management Area (WMA), were purchased through the PVIA in the fall of 1998. Although the grade of hay was considered low for livestock use, these woody bales were ideal for implementation. The relatively high stick and stem content of these bales help to keep the bales together following placement in the lake. These bales were inundated by a rising pool elevation during the winter of 1998-1999 while stored on WMA property. While inundated these bales retained enough moisture and silt to prevent them from being picked up and transported for installation. Unfortunately these hay bales were lost to the effort. An additional set of hay bales was purchased and stored on the north side of the lake above the flood pool elevation until marine installation. The PVIA provided the manpower and equipment (front-end loader) to move the round bales to the loading area and onto the barges for marine installation. This effort included the construction of a "stinger" attachment for loading hay. This work was performed at no cost to the project.

The marine installation was awarded to Recon Marine out of McAlester, OK for a total cost of $18,000. The PVIA provided the manpower and equipment to load the round bales onto Recon's barge (Figure 3.1). Recon then floated the hay to the installation site (Figure 3.2). Recon Marine developed a method of anchoring the bales to the lakebed using a combination of steel t-post, 9-gauge wire and a scrap piece of 2x4. The steel post was driven into the lakebed while the wire was attached to the top of the post. The wire was then threaded through the bale. As the bales flooded with water the wire was wrapped around the 2x4 (Figure 3.3).

Figure 3.1. PVIA loading the hay onto the barge

Figure 3.2. Transport across Lake Wister to the installation site

Figure 3.3. The installation process

When the bale settled onto the lakebed the 2x4 was snug to the top of the bale. This helped keep bales from floating off when the pool elevation rose above conservation pool. The OWRB furnished steel t-posts from a local business at a cost of approximately $650. Figure 3.4 shows the installed barrier in the Lewis Creek arm of Lake Wister.

Figure 3.4. Completed installation

Installation of the barrier was completed by the end of August 1999 and the completed 404 permit mailed to the Tulsa District USACE September 22, 1999. The OWRB also installed three buoys to mark the line of hay bales as a boating hazard. The City of Tulsa, Spavinaw Lake office donated the buoys with the OWRB providing pick up and transportation to the lake. A local concrete company donated cement to use as anchors while the Wister Project office donated cable and fasteners. OWRB staff placed one buoy at each end of the barrier and one in the middle.

Aquatic Plant Establishment

Completion of this task served to develop strong partnerships with the Poteau Valley Improvement Authority (PVIA), USACE Lake Wister project office, Kerr Center for Sustainable Agriculture (KCSA), Ouachita Correctional Facility, City of Tulsa, and the Lake Murray State Park. First the cooperative efforts will be described and then the demonstration efforts will be described.

Partnerships

The PVIA, the entity that treats and distributes Lake Wister water for municipal and industrial use, provided in-kind service of manpower and equipment. For example, the PVIA loaned a flatbed trailer and constructed a barge to load on the flatbed trailer. This provided critical land and water transport to the planting site. The PVIA also provided assistance to other local cooperators such as the KCSA to help ensure a successful demonstration.

Figure 3.5. Don Goforth coordinated PVIA assistance.

The Lake Wister USACE office provided expert knowledge of USACE and surrounding property. Through the knowledgeable guidance of USACE staff, abundant and accessible sources of arrowhead bull's tongue (*Sagittaria graminaea*), fragrant water lily (*Nymphaea odorata*) and smartweed (*Polygonum spp.*) were identified on federal property. The same staff helped to decipher federal regulations concerning the harvest of these target species from federal property. USACE staff also suggested additional local sources, such as the Kerr Center for Sustainable Agriculture (KSCA), to query about additional aquatic plant sources.

The KCSA also provided key assistance by allowing harvesting of target species off of KCSA property without charge as well as providing free and open access to the use of several fish culture ponds on their property. The fish culture ponds were converted to aquatic plant nursery ponds. These ponds were used to nursery plants such as the arrowhead bull's tongue and fragrant water lily. These and other target species were harvested from federal property, potted and nursed to health in the KCSA ponds, and transplanted into Lake Wister. These target species could not have been demonstrated without the use of KCSA nursery ponds. Additional target species were identified on KCSA property and directly transplanted into Lake Wister. Water willow (*Justicia americana*) and cow lily (*Nuphar luteum*) were the primary species used.

Figure 3.6. David Redhage coordinated KCSA help

The Ouachita Correctional Facility provided a work crew of minimum-security level inmates to assist with the harvest and nursery efforts. This crew helped convert the KCSA fishery ponds to plant nursery ponds at a very low cost. Inmate crews also enabled the OWRB to develop mass transplant techniques at a low cost to the project as well.

The City of Tulsa graciously served as a source area for harvesting target species and also provided manpower to assist with the harvesting effort. Local Tulsa City staff aided in the collection of 15 pounds of high quality American lotus (*Nulembo lutea)* seeds from the upper end of Eucha Lake. The knowledgeable assistance enabled this harvest to occur in a six-hour period. City of Tulsa staff also provided equipment (boats) and staff to assist with the harvest of a large amount of water stargrass (*Heteranthera dubia*). City staff transported the volunteer harvest crew (Tulsa University students) to the harvest site and guided the students on harvest and transport methods.

Figure 3.7. Harvesting Water Stargrass from Spavinaw Lake

The Lake Murray State Park also provided valuable assistance. The staff biologist identified an accessible and healthy stand of bulrush for transplant. In addition, the park allowed the use of one half dozen canoes (usually used for rental and Boy Scout activities) to enable efficient transport of the bulrush tubers from the harvest site to the ground transport site. This generous donation turned out to be critical for the acquisition of the bulrush.

Additional groups assisted with the planting effort, including the Boy Scouts of America, Oklahoma 4H, Sooner Lake/Oklahoma Gas & Electric and Carl Albert State College.

Planting Considerations

Four locally available species of aquatic plants – water willow, softstem bulrush, arrowhead and fragrant water lily – were targeted for introduction to Lake Wister as part of the demonstration plan. A total of 22 pounds of American lotus seeds were harvested from Lake Eucha and Oklahoma State University property. Tests over the winter showed an 80-100% rate of germination for the harvested American lotus seeds. Wetland seeds from local commercial sources were purchased to assess the viability of seeding wetland plants. Bare-root tubers were also purchased and potted to assess the viability of this method for Lake Wister. Volunteer students from Tulsa University harvested water stargrass and floating-leafed pondweed from Spavinaw Lake, and OWRB staff provided transport from Spavinaw Lake to Lake Wister. Additional species were also used as time and the situation allowed. For example, an abundant source of flatstem spikerush (*Eleocharis spp*.) was identified relatively close to Lake Wister. Local sources of plants such as lizard's tail (*Saururus cernus*), mud plantain (*Echinodurus cordifolius*) and cow lily (*Nuphar luteum*) were also identified. This local harvesting allowed for the testing of three additional species.

Planting efforts were grouped according to the level of effort necessary to harvest and plant. The lowest level of effort was the scattering of seeds across mud flats. Sprigging was the next level of effort since this required little harvest or planting effort. Direct transplants required a higher level of care because an entire plant needed to be harvested and special care had to be taken to protect the plants during transport. Root-wad transplants were one of the highest levels of effort. Root tubers were harvested from the ground, with every effort made to keep the surrounding soil matrix. Planting effort was also high because a hole had to be dug underwater to complete the transplant. Transportation of heavy (10 pounds) root wads also required high effort. Plants requiring potting and nursery space were also deemed a high effort plant. The additional steps of potting, moving and planting greatly increased the level of effort.

The demonstration effort did not follow the carefully laid out plan as outlined in Task 2. Rainfall was the primary factor modifying the planting plan. Varying water levels eliminated the local source of arrowhead plants while the higher than normal rainfall also kept the lake level above the conservation pool. The high lake levels (well above 478 NVGD) allowed for planting only 4 weeks of the 13-week summer season (Figure 3.8). This required a reevaluation of the prepared planting plan. The hired crew shifted its focus to harvesting and staging plants on KCSA property until they could be transplanted into Lake Wister. The crew also became the primary harvesters of softstem bulrush from Lake Murray. The following summary of planting efforts primarily reflects the last six weeks of the summer of 1999.

Rough records were kept of the number of plants harvested and the number of plants that made it into the lake. Table 3.1 summarizes these results; plantings have been broken up into three categories, direct and root-wad transplants, potted transplants and sprigged transplants. Planting success values above 100% illustrate the "rough" nature of record keeping.

Table 3.1. Summary of planting success segregated by plant type and transplant method. Note: No records kept for Water Willow

Plant	Arrowhead	Bulrush	Spikerush	Water Stargrass	Smartweed	Water Willow
Transplant Method	Direct	Root-wad	Root-wad	Sprig	Sprig	Sprig
# Harvested	400	2740	200	6400	1360	Unknown
#Planted	400	2650	200	1600	1360	Unknown
Planting Success	100	97	100	25	100	Unknown

Plant	Fragrant Water-lily	Mud Plantain	Lizard's Tail	Pickerel Weed	Arrowhead	Yellow Lotus
Transplant Method	Potted	Potted	Potted	Potted	Potted	Potted
# Harvested	1256	320	400	113	830	1600
#Planted	1270	0	0	0	0	1600
Planting Success	101	0	0	0	0	100

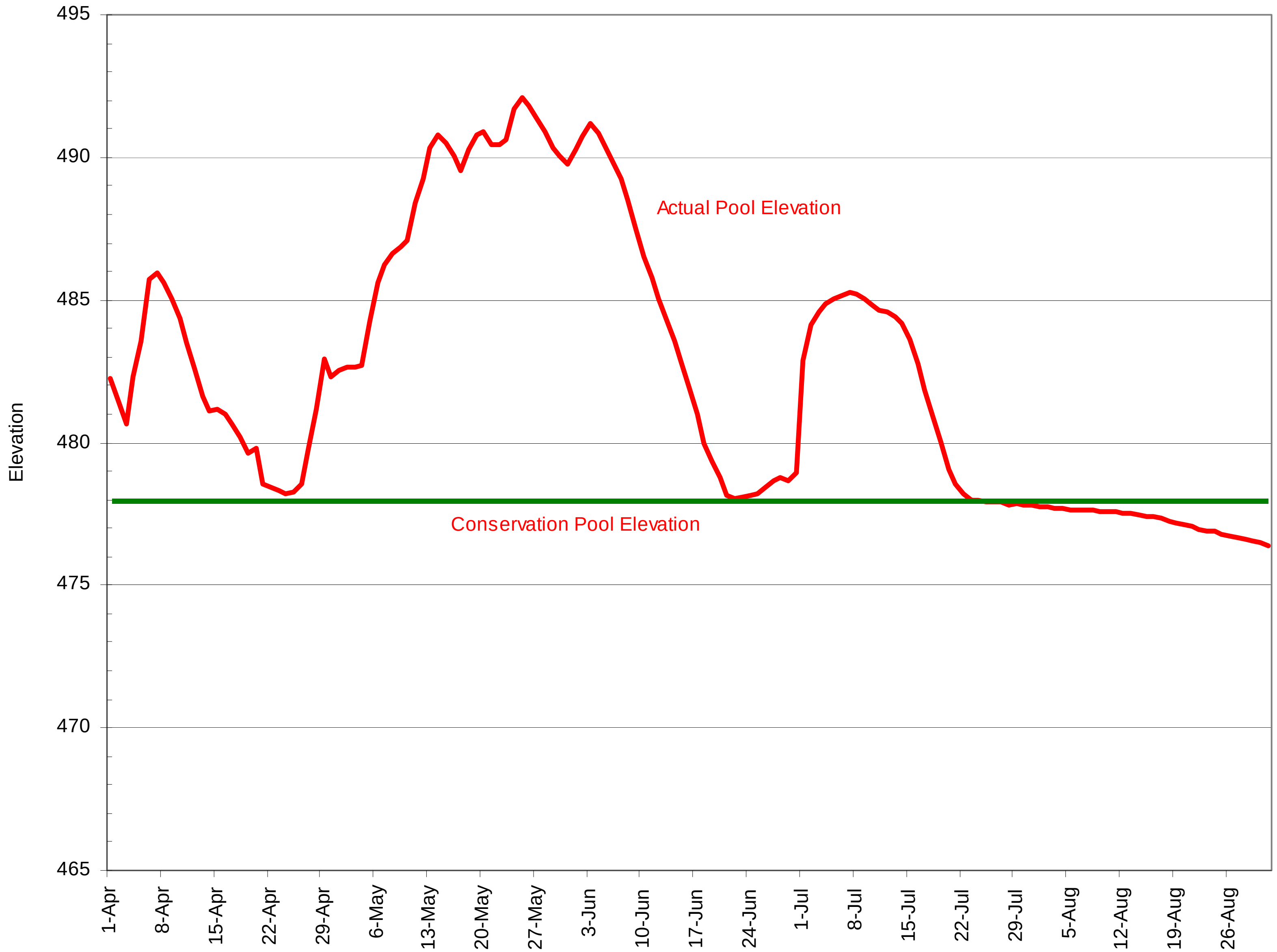


Figure 3.8. Lake Wister Pool elevation April 1999 through August 1999 compared to conservation pool elevation (478).

Discussion

In general, direct and root-wad transplants were the most successful transplant method. Direct transplants worked well when the plant could be harvested and planted within a 24-hour period. It was important to minimize exposure to direct sunlight while the plants were out of the soil. This minimized plant desiccation and overheating. Root wad transplants were successful because the surrounding soil kept root desiccation low. Trimming two-thirds of the above ground biomass minimized transpiration water loss.

Water lilies were the only successful potted transplants. This was primarily based on the different nursery methods used. The lilies were kept in permanent nursery ponds while the other plant species were kept in makeshift ponds constructed of railroad ties and visqueen. The makeshift ponds had a tendency to leak and dry out the pots. When the lake lowered to conservation pool the work crew abandoned the potted plants and focused on the higher quality root wads for transplant. Subsequent observation showed that the arrowhead plants survived the desiccation although the mud plantain and lizard's tail did not. Sprigging turned out to be a successful transplant method for water willow and smartweed but less so for the water stargrass. The lower success for water stargrass turned out to be a function of heat stress. Because of logistics, water stargrass spent some 48 hours in transit and was exposed to significant sunlight. Much of this fragile submersed plant senesced over this short time period. The hardier, emergent smartweed and water willow faired better due to the short transit time from harvest site to lake. Although no records were kept on the water willow, subsequent monitoring showed sprigging to be a successful transplant method. An additional plant that was introduced to Lake Wister but without detailed records was the cow lily (Nuphar luteum). Approximately 100 bare-root transplants were successfully performed.

Efficiencies were realized during the planting effort by covering the more sensitive plants with spriggings for transport to Lake Wister. This allowed for the transport of multiple species and reduced the need for a tarp cover. One drawback of this method was the lack of documentation of sprigs taken and planted in the lake.

One additional efficiency realized was the method of caging the bulrush transplants. Partitioning the planting and caging effort allowed for a greater efficiency of effort if the two were performed in progression as originally prescribed. The original prescription outlined the staking of the plant site with rebar, construction of the cages on site, planting the individual plants and then placing the cages over the plant. The large-scale plantings performed enabled the crew to plant a long line of plants, construct the cages on shore and flatten them for transport to the planting site, expand the cages on site, and stake the cages in place with rebar.

Deficiencies were also realized. One deficiency was the extra time needed to place cages over plants. This led to the setting of ambitious and perhaps unattainable goals. The planting plan also did not account for the staging of plants for more than a six-week period. Staging occurred over a ten-week period. The result was more plants available than time to transplant. This resulted in a loss of harvested plants. An additional deficiency was the lack of any records for the numbers of water willow and cow lilies transplanted. Looking back these plants performed better than many other plant species. For instance water willow showed amazing resiliency from herbivory. Keeping more accurate records would have allowed for more objective evaluation planting success and better tracking of goals.

About 9080 plants were introduced into Lake Wister as a result of the 1999 planting demonstration. This number was short of the original goal of 57,000 plants. This original goal estimated a planting rate of 4,400 plants per week. Unusual rainfall led to the loss of the Arrowhead plant source area and kept the work crew from planting during a majority of the summer (at least three weeks lost). These facts reduced the original goal from 57,000 to 20,500 plants over the 10-week period. Taking this into account yields a revised planting rate of 2,000 plants per week. The actual planting rate was estimated at 900 plants per week, less than half the revised goal. If all of the staged plants had been planted the actual planting number would have increased to approximately 11,750 plants or 1,175 plants per week, still short of the expressed goal.

Upon reflection, the designed planting plan was ambitious and did not accurately account for the time necessary for transportation (loading, driving/boating and unloading) and protection (construction and installation of enclosure devices). Future planting designs should account for these important factors. Although fewer plants were transplanted than planned, a significant number were successfully planted in Lake Wister. The actual number of transplanted plants was higher because of the unaccounted water willow plants. This task successfully demonstrated methods for introducing native aquatic plants from local and remote sources. These methods can be translated into implementation for other projects and lakes across the state.

Task 4 – Monitoring

The progress and growth of aquatic plant transplants and the water quality of Lake Wister were monitored for this project. Figure 4.1 illustrates the location of the water quality monitoring sites and aquatic plant transect sites relative to the demonstrated measures. Additional monitoring was performed for both the aquatic plant and water quality components of the project. The planting demonstration area was included in the aquatic plant monitoring component while additional parameters were added to the water quality monitoring component. This additional monitoring was completed at no cost to the project.

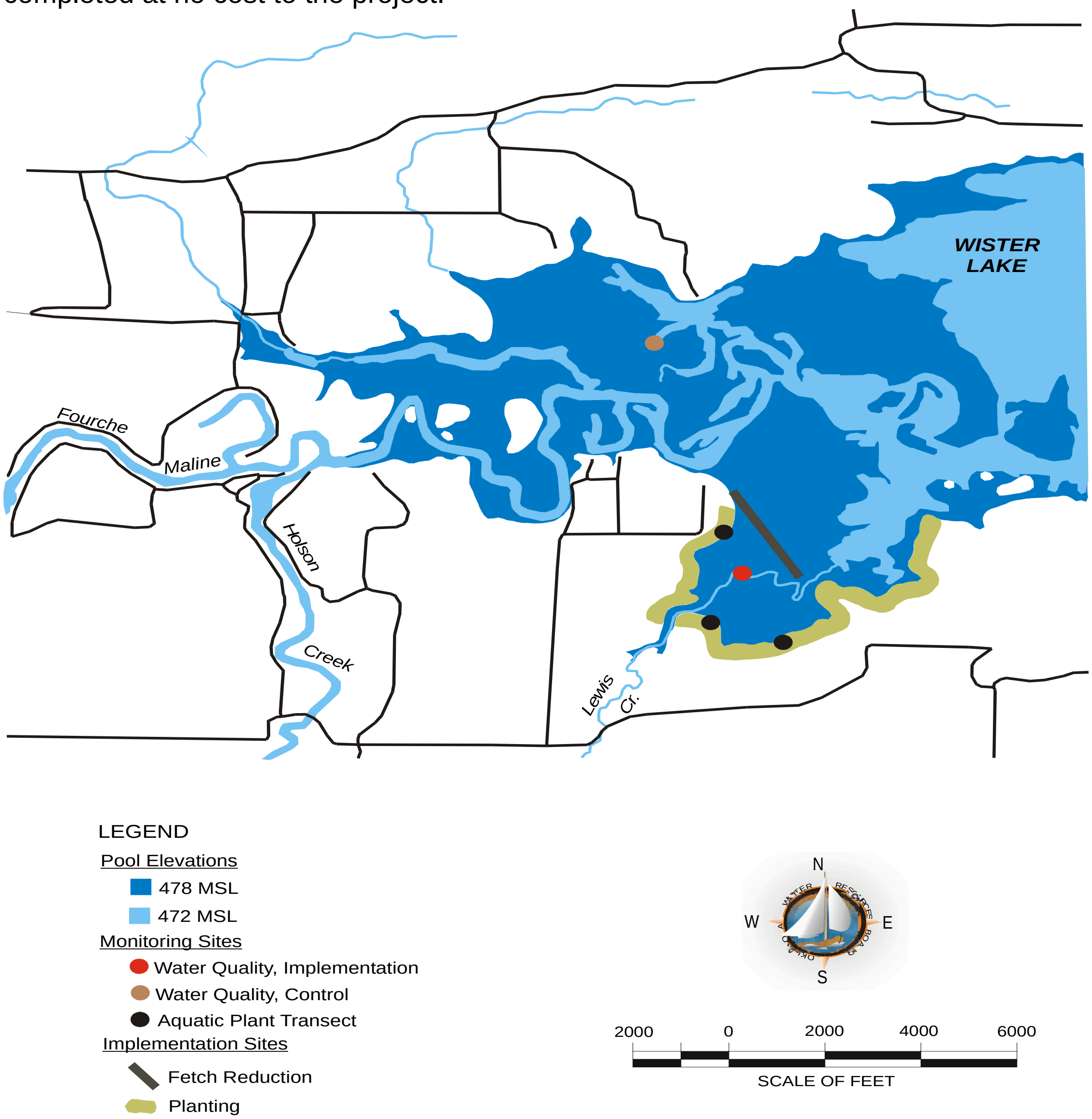


Figure 4.1. Map of Lewis Creek arm of Lake Wister showing water quality and aquatic plant monitoring sites relative to demonstrations.

Water Quality Monitoring

Water quality samples were taken from two sites throughout the monitoring period. A control site was set up in the Pocahontas Slough area to compare against the experimental site in the Lewis Creek arm (Figure 4.1.) The experimental site was set up in the Lewis Creek arm behind the hay bale breakwater barrier, and samples were collected to evaluate the success of the treatment in improving water quality. OWRB personnel and volunteers sampled both sites every other week from March to October. The hay bale barrier broke down after April, allowing for two periods of data to be analyzed; one before and the other following the breakdown of the barrier. Parameters tested in the field included: pH, temperature, dissolved oxygen (DO), DO %saturation, secchi depth, turbidity and specific conductivity. Water samples were collected and taken for laboratory analysis for total suspended solids and chlorophyll-*a.* The City County Health Department of Oklahoma City analyzed samples. Following its closure on July 1, 2000 samples were taken to the DEQ laboratory for analysis. Table 4.1 presents all sample dates for water quality monitoring.

Table 4.1. Summary of water quality monitoring sample dates.

3/23/2000	4/13/2000	4/27/2000	5/09/2000
5/26/2000	6/09/2000	7/08/2000	7/13/2000
7/21/2000	8/04/2000	8/18/2000	9/06/2000
9/27/2000	10/17/2000		

Water quality parameters were examined before and after the collapse of the hay bales forming the breakwater. The first time period, with the breakwater, was from March 3, 2000, through April 27, 2000, included a total of three sample events. The second time period, without the breakwater, began May 9, 2000, continued through the end of October, and included a total of eleven sample events. Because there were only 3 sample events prior to barrier breakdown (compared to 11 after the breakdown of the barrier) statistical differences were not likely to be conclusive. Non-parametric ANOVA statistics were run on the two sets of data comparing experimental to control during each time period, and separate sets of statistical analyses were run to compare one time period to the other to see if any possible statistical significance could be drawn from the data. This statistical comparison did not note any statistical significance. Although test results were inconclusive the results are presented.

Table 4.2 summarizes water quality data collected during the monitoring period. The following narrative describes this data using figures for assistance. Box and whisker plots were generated and data analyzed using Fisher's individual error rate. Box and whisker plots graphically depict the range of a given data set and its distribution. In each box, the statistical median or 50th percentile is indicated by the middle horizontal bar, the mean by a solid red dot, and the 25th and 75th percentile ranges by bars at the top and bottom of the box, respectively. The vertical bars, or whiskers, represent the range of values, and asterisks indicate any outlying values. By comparing the box and whisker plots, in particular the means and medians of each box, the differences between sites is readily apparent. Statistical differences were tested using analysis of variance (ANOVA) with significance assumed at or above the 95% level.

Table 4.2 Tabular Summary of water quality data for Wister Lake

Parameter	Minimum		Maximum		Mean	
	Control	Exp.	Control	Exp.	Control	Exp.
Temperature (°F)	50.0	50.0	90.0	90.0	71.7	71.3
Secchi Depth (cm)	4.0	2.0	30.0	20.0	13.8	11.2
Total Suspended Solids (mg/L)	18.0	29.0	530	832	23.6	60.6
Turbidity NTU	24.5	30.0	106	109	25.8	31.5
Chlorophyll-a (μg/L)	8.0	0.4	34.1	62.6	17.1	18.6
Chlorophyll-a TSI	50.0	21.6	65.2	71.2	58.3	59.1

Water temperature ranged from a high of 90°F on September 6, 2000, to a low of 50°F on April 4, 2000, at both sites. The mean temperature during the sampling period was 71.7°F at the control site and 72.5°F at the experimental site. Figure 4.2 displays the surface lake temperature values recorded at both sites during monitoring activities. Water temperature values were fairly consistent between sites, and there was no significant differences found between the control and experimental sites.

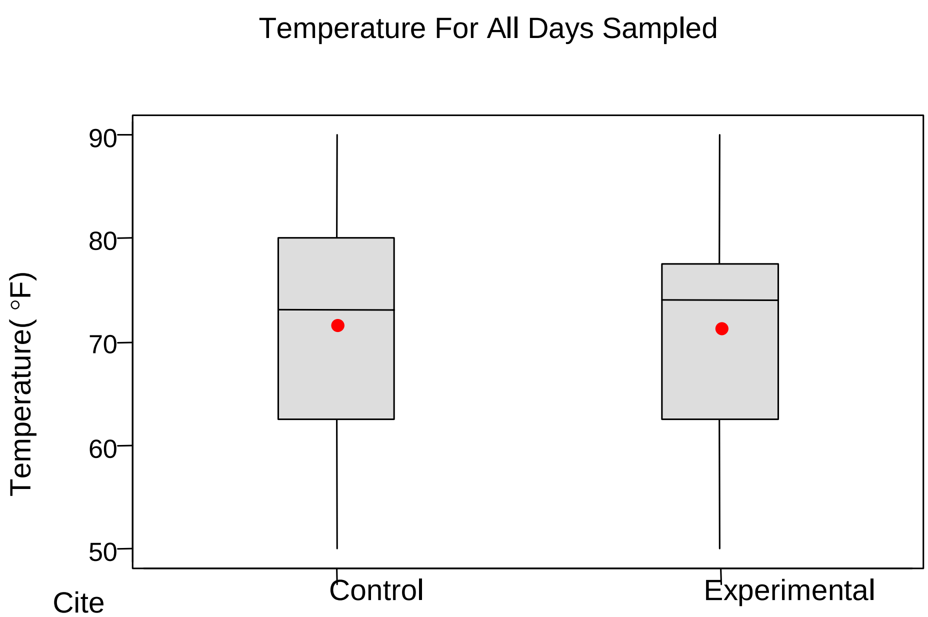


Figure 4.2. Water temperatures at Wister Lake during all days sampled.

Secchi depth ranged from 8.00-20.00 cm at the control site and 6.5-20.00 cm at the experimental site during the breakwater, with a mean between the two sites of 12.50cm. After the breakwater the control site values ranged from 4.00-30.00 and the experimental from 2.00-18.00 cm, with a mean between the sites of 11.19 cm. A decrease in over all secchi depth can be seen between the two time periods, showing that the values before the collapse were slightly better. However, no statistical differences were found between the two sites. Figures 4.3 and 4.4 represent the data from the two time periods.

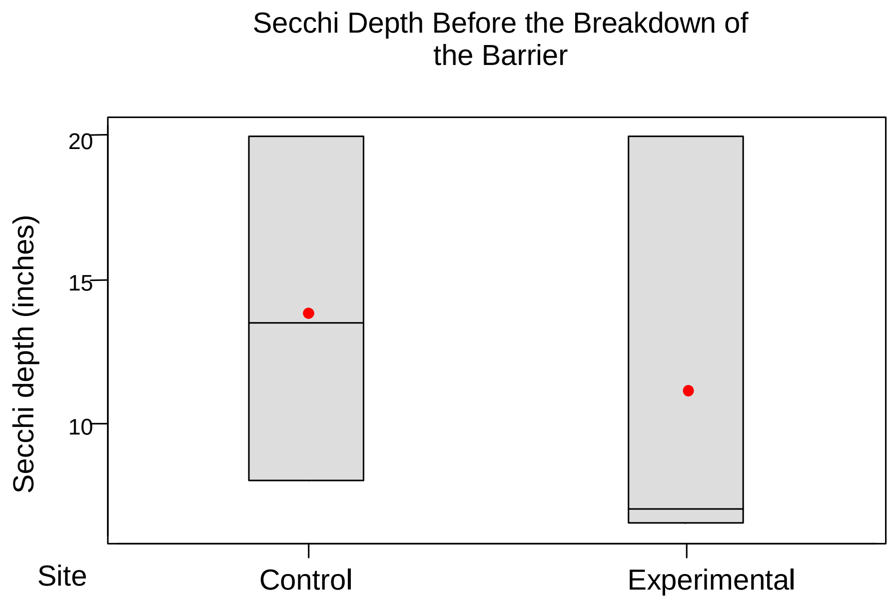


Figure 4.3. Secchi Depth values of Lake Wister before the hay bale barrier broke down.

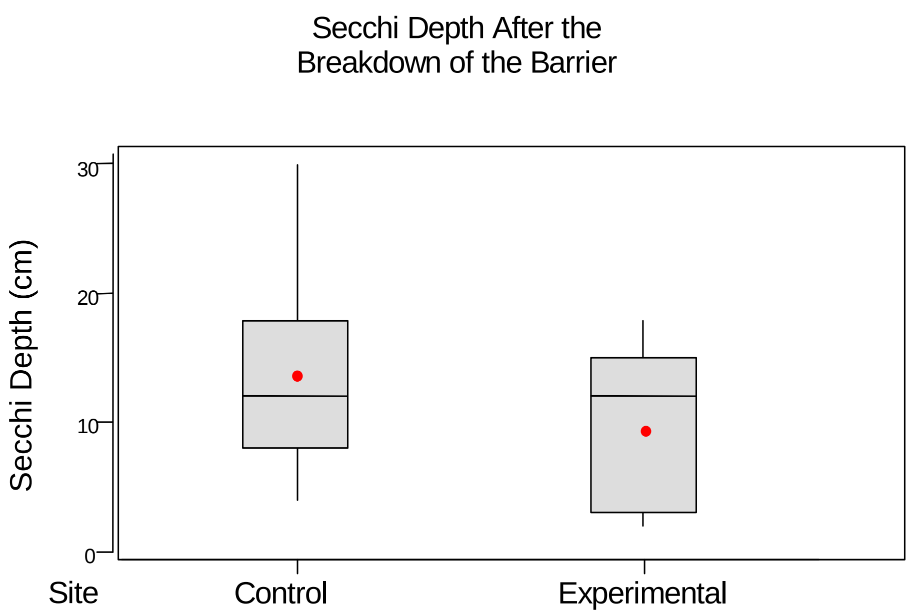


Figure 4.4. Secchi Depth values of Lake Wister after the hay bale barrier broke down

Turbidity ranged from 24.50-27.00 NTU at the control site and 30.00-33.00 NTU at the experimental site before the collapse of the barrier with a mean between the two sites of 29.63 NTU. After the collapse the control site values ranged from 25.5-105.5 NTU and the experimental from 33.00-109.00 NTU, with a mean between the sites of 55.37 NTU. Mean values were lower than after showing that the lake was slightly clearer before than after barrier collapse. However, no statistical differences were found between the two sites. Figures 4.5 and 4.6 represent the data from the two time periods.

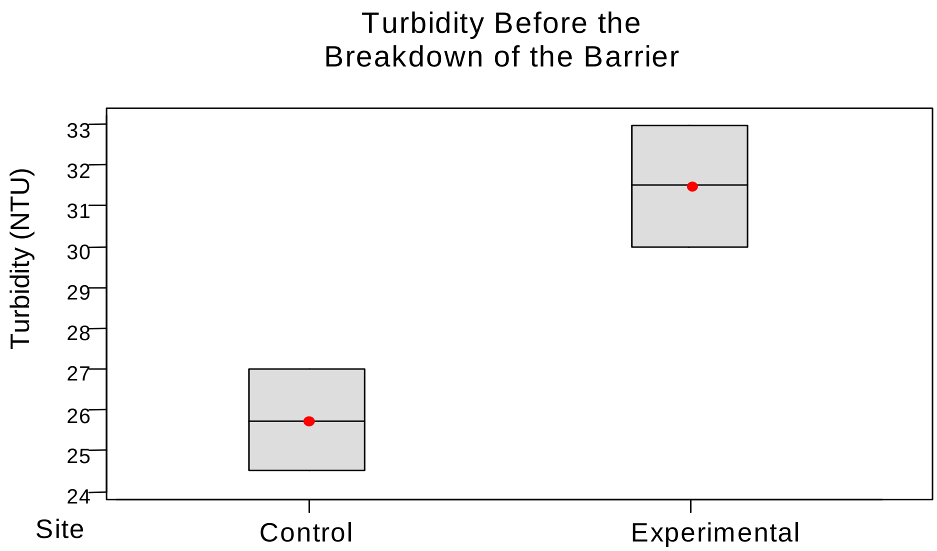


Figure 4.5. Turbidity values of Lake Wister before the hay bale barrier broke down

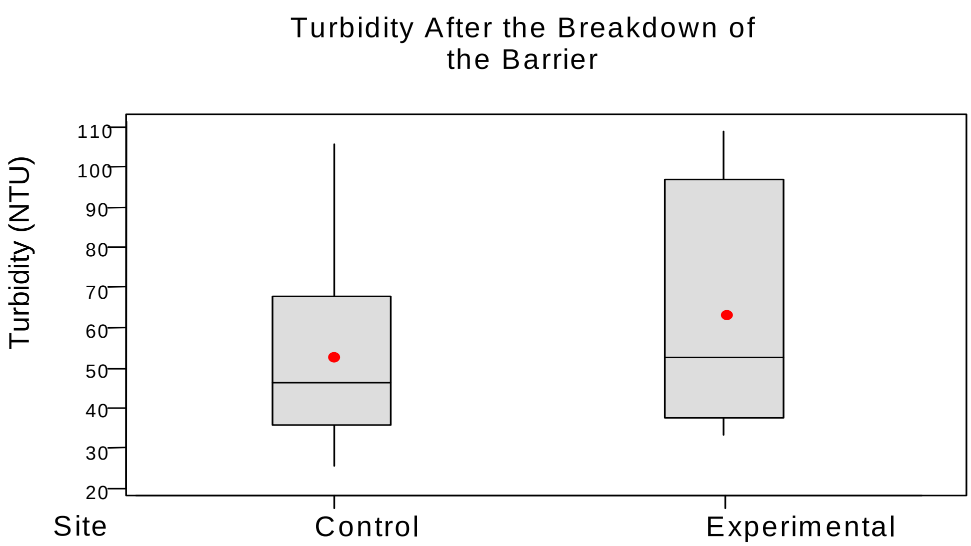


Figure 4.6. Turbidity values of Lake Wister after the hay bale barrier broke down.

Total suspended solids ranged from 19.90-28.50 mg/L at the control site and 39.00-109.00 mg/L at the experimental site before the collapse of the barrier with a mean between the two sites of 42.13 mg/L. After collapse, control site values ranged from 18.00-530.00 mg/L and the experimental from 29.00-832.00 mg/L, with a mean between the sites of 119.53 mg/L. Total suspended solids values from before the barrier collapse are lower than those found afterwards; showing that perhaps the barrier had some effect on the amounts of solids present. However, no statistical differences were found between the two sites. Figures 4.7 and 4.8 represent data from the two time periods.

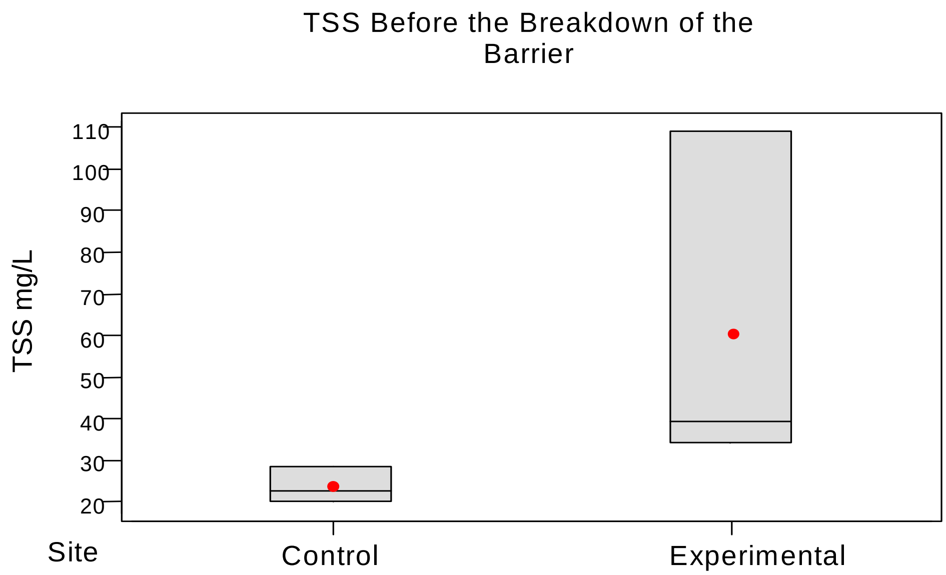


Figure 4.7. Total Suspended Solids values of Lake Wister before the hay bale barrier broke down.

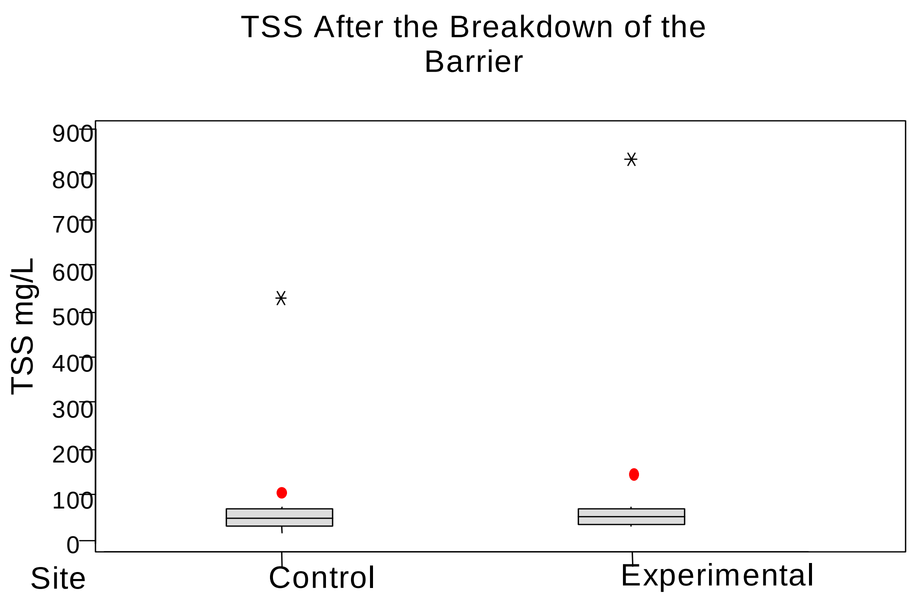


Figure 4.8. Total Suspended Solids values of Lake Wister after the hay bale barrier broke down.

Chlorophyll-a values ranged from 13.95-20.12µg/L at the control site and 14.16-22.22 µg/L at the experimental site before collapse of the barrier with a mean between the two sites of 17.84 µg/L. After the collapse the control site values ranged from 8.00-34.11 µg/L and the experimental from 0.40-62.60 µg/L, with a mean between the sites of 21.07 µg/L. The chlorophyll-a values from before barrier collapse are lower than those found afterwards, showing that perhaps the barrier had some effect on the amount of chlorophyll-a present. However, no statistical differences were found between the two sites. Figures 4.9 and 4.10 represent the data from the two time periods.

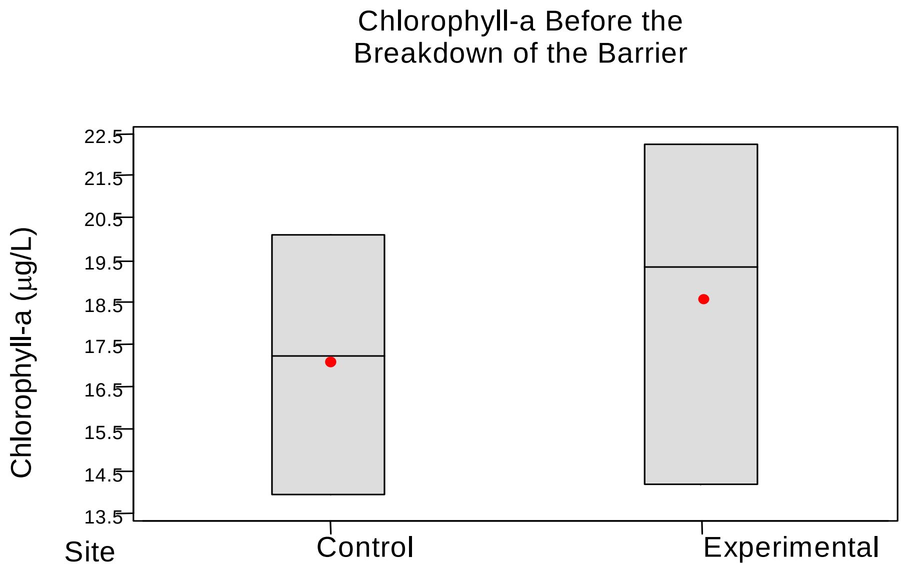


Figure 4.9. Chlorophyll-a values of Lake Wister before the hay bale barrier broke down.

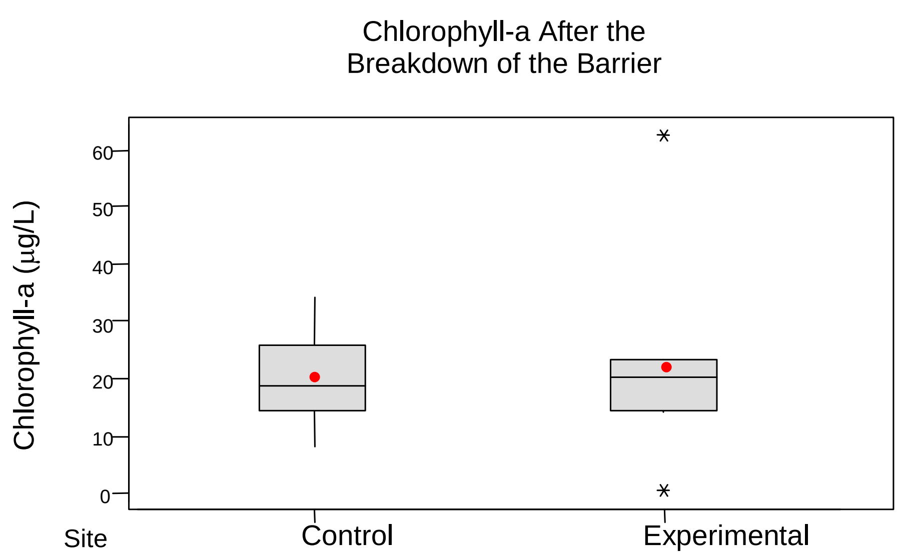


Figure 4.10. Chlorophyll-a values of Lake Wister after the hay bale barrier broke down.

Trophic state indices (TSI) are commonly used to express measured algae productivity in water bodies. Carlson's TSI is used by the OWRB for determining trophic status of Oklahoma water bodies using the ranges of: 0-39 as Oligotrophic, 40-49 as Mesotrophic, 50-59 as Eutrophic, and >60 as Hypereutrophic. TSI values were calculated using chlorophyll-a data collected for the time period sampled at Wister Lake. These values ranged from 56.37-60.05 for the control site and from 56.60-61.00 at the experimental site before the collapse of the barrier. The mean value between the sites was found to be 58.71. The mean value shows Wister Lake to be eutrophic at the time of sampling, before the collapse of the barrier. After barrier collapse the range of values at the experimental site was 50.02-65.22, and 21.61-71.18 at the experimental site. The mean value was determined to be 57.69 between the two sites. Again this indicates a eutrophic status for the lake. Figures 4.11 and 4.12 show the distribution of TSI values throughout the sampling period. No statistical difference was found between the two data sets.

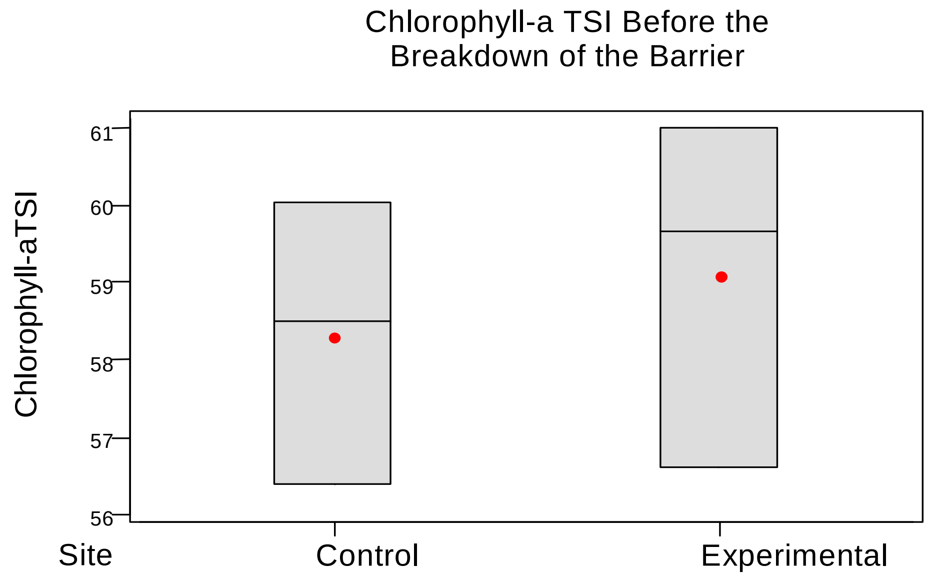


Figure 4.11. Chlorophyll-a TSI values of Lake Wister before the hay bale barrier broke down.

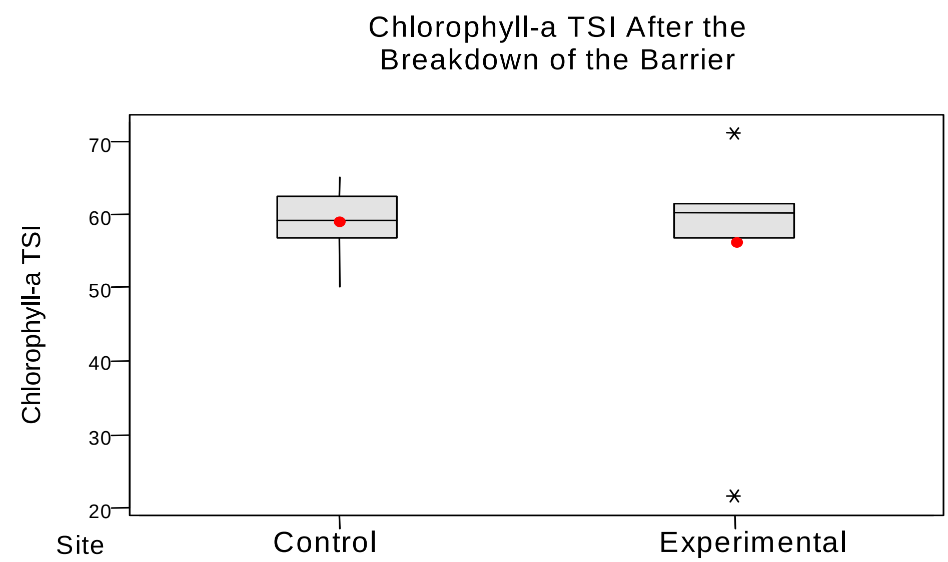


Figure 4.12. Chlorophyll-a TSI values of Lake Wister after the hay bale barrier broke down.

Overall, data collected at the two sites showed no statistical differences between the experimental site and the control site primarily because the low number of samples taken before the barrier broke down decreased statistical confidence. Only three sample events occurred while the breakwater was intact. This number is not enough upon which to base conclusions. Site comparison after the breakwater showed no statistically significant difference between the two. Graphic examination showed a higher range for suspended and settleable solids in the Lewis Creek arm (experimental site) as opposed to Pocahontas Slough (control site). Although not conclusive this does suggest that the Lewis Creek arm of Wister Lake is an area of in-lake sediment suspension.

Aquatic Plants

The most noticeable transplanting success was a line of bulrush root wads that roughly followed the green line seen in Figure 4.1 on page 31. Because of the extensive transplant work and high visibility of the root wads, monitoring of aquatic plants was expanded to include the assessment of bulrush root wad transplants along with the three transects. OWRB staff trained in aquatic plant taxonomy conducted monitoring of plant growth and reproduction. Surveys were conducted on May 26, 2000, June 9, 2000, July 27, 2000, and September 6, 2000 examining both the softstem bulrush transplants along the shoreline and the three transects perpendicular to the shoreline. Pool elevation was at 477.93 NVGD on 5/26/2000, 487.1 NVGD on 6/9/2000, 478.47 NVGD on 7/27/2000 and 477.16 on 9/6/2000. Figure 4.13 shows how lake pool elevation varied by 7-8 feet throughout the monitoring period.

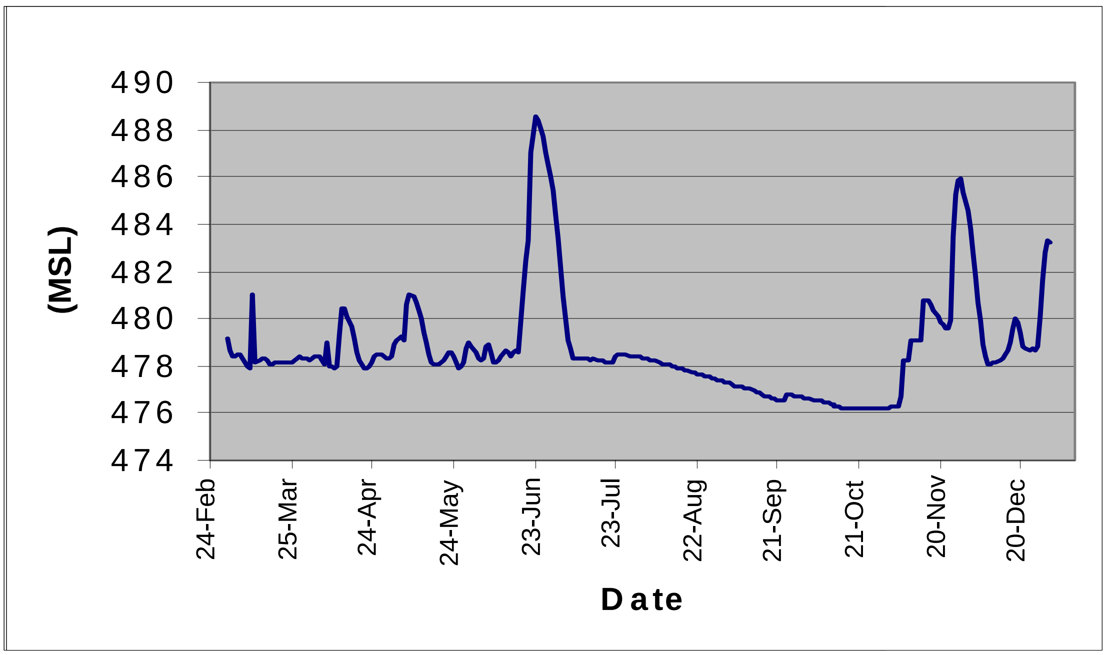


Figure 4.13. Plot of Lake Wister pool elevation (in Mean Sea Level) versus date over the project-monitoring period, February 2000 – October 2000.

Approximately 1.75 miles of shoreline were planted with softstem bulrush transplants. These plants were placed approximately four feet apart with a water depth ranging from 3 to 12 inches below conservation pool. Three levels of protection from herbivory were used -- high, low and none. High protection consisted of placing a "tomato" cage constructed of 2-inch by 4-inch galvanized wire around the transplant (Figure 4.14). To prevent entry from the top as well as the sides, some cages were "bent" over the top to completely enclose the cage. A low level of protection was given by placing 24-inch by 24-inch pieces of 2-inch by 4-inch galvanized wire mesh flat on the ground over the transplant (Figure 4.15). This measure protected the root mass from disturbance but not the above ground growth. Finally, a portion of the transplants was given no cage protection at all. Monitored parameters included number of living shoots, depth of the water at which the plant was growing, height of the tallest shoot, presence or absence of reproductive structures, caged status and type of cage, other species growing with the bulrush, and whether or not herbivory had occurred.

Figure 4.14. High transplant protection.

Figure 4.15. Low transplant protection.

While the demonstration line of bulrush was being transplanted, three transects 100 feet long were established perpendicular to the shoreline in the Lewis Creek arm. Here plants such as flatstem spikerush, smartweed, arrowhead, softstem bulrush, cow lily and fragrant waterlily were planted at 5-foot intervals in a repeating sequence. Starting close to the shoreline at one end of each transect, 3 sets of 20 plants (one every 5 feet for 100 feet) were planted for a total of 60 plants of each species. Planting was completed between July 26, 1999, and July 30, 1999. Transect #1 started just below conservation pool (478.0 NVGD) and ended at approximately 16 inches below conservation pool. Transect #2 started at approximately 2 inches below conservation pool and ended at approximately 6 inches below conservation pool. Transect #3 started at approximately conservation pool and ended at approximately 18 inches below conservation pool. Transect plantings were protected with caging on August 11, 1999. By this time the pool elevation had dropped to 477.55 NVGD. By mid-August no plants were found below the waterline of 477.5 NVGD. Only noticeable plants were protected with caging material on the three transects. Consequently each transect had a different length protected by caging material -- 25 feet for #1, 100 feet for #2 and 50 feet for #3. In all 35 sets of plantings were protected with caging material.

Transects

60 plants of each species were planted along the transects at five-foot intervals – a total of 420 plant units. Before caging material was installed to protect the new plants 25 of the original 60 (42%) had been eliminated by herbivory. This left 175 total plants to monitor for survival and growth during the growing season of 2000. Monitoring occurred on May 26, 2000 for transect #1; June 9, 2000 for transect #2 and #3; July 27, 2000 for all transects; and September 6, 2000 for all transects. Pool elevation was 477.93 NVGD on May 26, 2000, 487.1 NVGD on June 9, 2000, 478.47 NVGD on July 27, 2000, and 477.16 on September 6, 2000. Survival rates were calculated for two time periods for each species of plant. The first time period has been termed “overwinter”. Overwinter survival represents the ability of each species to survive through the dormant (winter) period and produce new growth during the next season. The second time period has been termed “summer”. Summer survival represents the species noted during spring monitoring to have survived through the summer 2000 growing season.

35 plants of each species survived the fall 1999 planting for summer 2000 monitoring. Two species of plants not planted the previous year were occasionally noted (Table 4.3). Early success was noted with the spikerush, smartweed, bulrush and arrowhead plants (Figure 4.16**)**. Growth was seen predominantly in the caged area of the transects, with little to no vegetation remaining outside the cages. By the end of the summer, the transects showed growth and reproduction of bulrush. There was also some smartweed survival, as well as water willow and arrowhead. On Transect 3, cow lily showed some survival, but no growth (Figure 4.17). During the early spring, water willow and arrowhead established reproductive structures, however these species were flooded out when the lake level rose. Both species recovered by fall, but no additional further reproductive structures were noted.

Table 4.3. Species survival rates along monitored transects.

	Overwinter	Summer
Grass	na	0.0
Water Primrose	na	0.0
Spikerush	40.0	71.4
Smartweed	28.6	20.0
Arrowhead	20.0	0.0
Water Willow	57.1	15.0
Bulrush	14.3	60.0
Cow Lily	8.6	0.0
Fragrant Waterlily	2.9	200.0

Overall the spikerush had the highest (overwinter and summer periods) survival rates than any other plant. Water willow showed the highest overwinter survival while fragrant waterlily the highest summer survival. This number is skewed since only one plant was noted to overwinter while two planted were noted in the fall, thus the 200% survival rate. Although this number does not suggest the species is a good candidate for immediate transplants it does highlight the tenacity of the species. When considering both overwinter and summer survival rates spikerush showed the highest, followed by water willow, bulrush and finally smartweed with the lowest significant survival.

Figure 4.16. June 9, 2000 - Transect 1 showing growth of water willow, bulrush, smartweed and arrowhead. Some aquatic grasses also were noted here.

Figure 4.17. June 9, 2000 - Transect 3. There was little survival except for cow lily (***Nuphar luteum***) **in caged area.**

Bulrush Transplants

A large quantity of bulrush was lost to herbivory between transplanting and monitoring. Approximately 2650 transplants were completed in 1999 while the maximum number of transplants noted the following year was 892. Most of the overwinter loss was limited to the unprotected transplants while both levels of protection yielded survival rates greater than 90% (Table 4.4).

Table 4.4. Survival rates of transplanted Bulrush root wads based on the initial amount of transplanted material.

		Survival Rate (percent)	
Level of Protection	Amount Transplanted	Winter	Summer
None	1785	3.2	45.6
Low	268	90.3	109.9
High	597	96.8	96.8

Counting the number of shoots per transplant, the number of transplants with sexual reproductive features and the number of transplants showing vegetative reproduction, our team monitored the health and reproductive potential of each transplant. Transplants with a high level of protection were much healthier than transplants with low or no protection (Table 4.5). The presence of sexual reproductive features displayed a gradient from a low percentage with no protection to a high percentage with high protection (Table 4.6). This gradient reflects the relative health of the transplant – the healthiest (most protected) transplants were able to dedicate more energy toward sexual reproduction than those with low protection measures. Vegetative reproduction, as evidenced by new shoots outside of the protected area, was only noted for transplants receiving a high level of protection late in the growing season. (Table 4.7).

Table 4.5. Transplant health as measured by median number of aboveground shoots segregated by level of protection.

Date	median # of shoots		
	None	Low	High
06/09/2000	3	1	17
07/27/2000	0	1	21
09/05/2000	2	7	36

Table 4.6. Percent of transplants with sexual reproductive structures by level of protection.

Date	% transplants with reproductive structures		
	None	Low	High
06/09/2000	9	39	95
07/27/2000	8	25	86
09/05/2000	4	16	82

Table 4.7. Percent of transplants showing expansion outside of caged area, by level of protection.

Date	% transplants with outside growth		
	None	Low	High
06/09/2000	n/a	0	0
07/27/2000	n/a	0	0
09/05/2000	n/a	7	52

An additional observation was whether aquatic plants other than the bulrush were present. Although not a measure of plant health this does reflect the ability to introduce more than one species with a root wad transplant. Observations of additional species did not seem to follow a clear trend of level of protection although a higher percentage was noted when some protection was afforded the transplant (Table 4.8). The most prevalent additional species observed was water willow, which was extensively sprigged into the Lewis Creek arm. One potential explanation for the higher number of additional species present with no- and low- protection is that the full cages kept the water willow sprigs from washing into the cages. The no- and low- protected transplants then “caught” the drifting sprigs. Other species found with the bulrush included *Sagittaria graminae* (arrowhead), *Sagittaria latifolia* (another species of arrowhead), *Eleocharis montevidensis* (flatstem spikerush), and *Polygonum* sp. (smartweed) (Figure 4.18). During the June survey, *Heteranthera dubia* (water stargrass) and *Potamogeton* sp. (floating-leafed pondweed) were also noted in a few of the standing cages. It is thought that most of these species were present on the soil of the root wad and represent a transported seed bank.

Table 4.8. Percent of transplants with additional species observed by level of protection.

Date	% transplants with other species		
	None	Low	High
06/09/2000	54	87	53
07/27/2000	25	99	88
09/05/2000	73	72	53

Figure 4.18. Water willow and arrowhead plants transplanted with the bulrush.

Analysis of the data revealed that the caged plants had a far better survival rate than those not caged. Those not caged showed considerable loss to herbivory and also some loss by wave action. The plants that were protected in standing cages (high level of protection) showed considerably less herbivory than those afforded a low level of protection (covered with flat cages) (Figure 4.19). Standing cages also revealed a greater percentage of the plants that had other species growing with them. Comparison of the data also revealed that considerably more of the plants protected in the standing cages had reproductive structures (Figure 4.20). These show that the plants with a high level of protection were the most robust transplants and most viable for establishment in Wister Lake.

Figure 4.19. Transplanted bulrush in September 2000. The second plant from the left represents a transplant that received a low level of protection. All other plants in the picture received high level of protection.

Figure 4.20. Sexual reproductive structures on bulrush.

Strong, healthy bulrush transplants also showed an indirect water quality benefit: reduced suspended sediment. This was evident when the lake was below conservation pool. Observation showed that sediment had accumulated in the growing stand of bulrush. This is evident as a mound of mud surrounding the transplant (Figure 4.19). As the project progressed, local cooperators noted the ability of aquatic plants to settle or filter out suspended solids in Lake Wister.

Task 5 – Evaluate Success of Implementation Efforts

Effectiveness of Fetch Reduction

Presentation and a preliminary data evaluation can be found *Task 4 – Monitoring*. Evaluation of the effectiveness of the installed barrier was not possible because only three sample events occurred while the temporary barrier was in place. The project QAPP was submitted to OSE for transmittal to EPA in early June of 1999. The breakwater was completed in late August 1999 and lasted into April 2000, an approximate life of 8 months (the expected two-season life span.) Samples were taken in March and April of 2000 following official EPA approval of the Quality Assurance Project Plan (QAPP). Observation showed that perhaps one-half to one-third of the barrier remained by the end of April 2000. By May no significant remnants of the barrier could be found. Three samples were not enough data to base conclusions about the effectiveness of the installed breakwater. Following interagency comments the QAPP was forwarded to EPA for review and approval in August 1999. EPA approval was garnered February 2000. The extensive state and federal review period overlapped with the completion of the breakwater installation and precluded an adequate data set for evaluation. Although inconclusive, the collection of water quality data was completed in good faith by the OWRB at no cost to the grant award. The intent of constructing a temporary barrier was to demonstrate locally (in the Lewis Creek arm) the use of breakwaters to reduce wave action and suspended sediment concentrations. Using breakwaters for water quality improvement should not be discarded because success was not documented in this project.

It is important to understand that although statistically significant water quality differences were not found this effort did result in changed attitudes about Lake Wister. Following the completion of the effort local cooperators were optimistic that options exist to benefit water quality in Lake Wister. This attitude was not evident at the beginning of the project.

Aquatic Plant Demonstration

Several species of plants were documented to grow and reproduce as a result of this project. Transect monitoring showed spikerush, water willow, bulrush and smartweed as the species with the highest potential for survival and reproduction in Lake Wister. Transplant monitoring showed that a high level of protection would vastly improve the chances of establishing introduced plants. Bulrush transplants receiving a high level of protection from herbivory had a 97% survival rate and showed robust health. Table 5.1 lists the species shown to successfully grow and reproduce in Lake Wister. Plants highlighted in bold print were the species with the best overall survival during this project. One plant, *Echinodurus cordifolius* or mud plantain, has also been included in Table 5.1 even though it was not evaluated through this project (Figure 5.1). This plant was introduced through the earlier PAS study with the USACE and seemed to have established a permanent stand in one small portion of the lake. In order to maximize the potential for this stand of plants to be permanent it was left undisturbed and not included in the project.

Table 5.1. Plant species noted to grow and reproduce in Lake Wister. Highlighted names show the greatest potential for long-term establishment in Wister Lake. Planting considerations are also noted.

Common Name	Genus species	Planting depth (MSL)	Propagule type	Source
Softstem Bulrush	*Scirpus validus*	478-477	Root wad	McAlester Army Ammunition Plant (MAAP)
Water Willow	*Justicia americana*	478-477	Spriggings	Kerr Center for Sustainable Agriculture (KCSA)
Smartweed	*Polygonum* sp	478.5 --477.5	Spriggings	KSCA
Flatstem Spikerush	*Eleocharis montevidensis*	478	Spriggings/ root wads	KSCA
Arrowhead	*Sagittaria graminae*	478 – 477	Bare root	USACE Wister Project
Mud Plantain	*Echinodurus rostratum*	478	Bare root	USACE Wister Project

Figure 5.1. Patch of mud plantain, *Echinodurus rostratum*, in Lake Wister.

Proven planting methods considering factors such as planting depth, transplant type and sources have been given in Task 3. Commercial sources have not been listed since local sources have been identified. It is important to note that the Kerr Center for Sustainable Agriculture (KCSA) has offered the use of its converted fish culture ponds for a long-term planting effort in Wister Lake. In addition the MAAP has approved the transplanting of bulrush from Department of Defense property to KCSA culture ponds. The KCSA has also agreed to allow direct harvest of selected species from its properties for the purpose of establishing a native aquatic plant community in Wister Lake. Arrowhead has been harvested from small ponded areas within the upper flood pool of Lake Wister. Culture of the mud plantain stand, noted above, should be attempted as well as any additional transplants in other areas of the lake. Care must be taken to not denude this relatively small stand of mud plantain.

In order for the plants to establish in the long-term, they must be able to establish substantial growth away from high protection areas. Future planting efforts in Lake Wister must address the issue of adequate herbivore protection. One possibility would be to selectively harvest herbivores such as beavers and muskrats in and near the target area on an annual basis. Protection for transplants would be using “tomato” cages. Herbivore control would **not** be used to eliminate the herbivores but to reduce the population to a level that will allow for plant expansion beyond the protective cages. Herbivore control would be required for 6-10 years until the plants could become established.

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Implementation of Non-Point Source BMPs in the Fourche Maline Arm of Wister Lake

(C9-996100-05, Task 700)

Oklahoma Water Resources Board

Appendix A

FETCH REDUCTION IN FOURCHE MALINE ARM OF
WISTER LAKE
WISTER LAKE, OKLAHOMA

Prepared by the
U.S. Army Corps of Engineers
Southwestern Division
Tulsa District

for the
Oklahoma Water Resources Board

July 1998

FETCH REDUCTION IN FOURCHE MALINE ARM OF WISTER LAKE
WISTER LAKE, OKLAHOMA

INTRODUCTION

This report presents structural alternatives for fetch reduction in the Fourche Maline arm of Wister Lake, Oklahoma, to reduce sediment resuspension and improve water quality. Suitable locations were identified; breakwaters for each location were selected; and an implementation plan, including schematics and cost estimates of typical breakwaters, was developed. A separate study titled "Lake Wister Native Plant Establishment Study"(U.S. Army Corps of Engineers, Tulsa District 1998) considered the planting of appropriate vegetative species as a non-structural alternative.

STUDY AUTHORITY

The U.S. Army Corps of Engineers (USACE), Tulsa District conducted the study for the Oklahoma Water Resources Board (OWRB) under authority of Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251). This authority establishes cooperative assistance to states for preparation of comprehensive water plans.

Section 319 of the Water Resource Development Act of 1990 (Public Law 101-640) provides authority for cost sharing of the Planning Assistance to States Program. The cost-sharing ratio for this study is 50% Federal and 50% non-Federal. The USACE, Tulsa District and the OWRB signed a Letter Agreement on September 25, 1997, for this study. The Letter Agreement is shown in Appendix 1.

STUDY PURPOSE

The purposes of this study were to determine optimal locations for placement of fetch reduction structures in the Fourche Maline arm of Wister Lake and to develop a plan for implementation of these structures. Results of this study will be used by the OWRB as part of a multiphase study through Section 319 of the Clean Water Act to improve the water quality of Wister Lake.

PROJECT LOCATION AND DESCRIPTION

Wister Lake is located in LeFlore County, Oklahoma, as shown in Figure 1, approximately 10 miles southwest of the town of Poteau. The multipurpose lake was placed in operation in 1949.

Project purposes are flood control, water supply, low flow augmentation, water conservation, and sedimentation. The conservation pool elevation has varied since 1949; however, since 1996, it has been kept year-round at 478.0 feet National Geodetic Vertical Datum (NGVD). The top of flood control pool elevation is 502.5 feet NGVD.

PROBLEM STATEMENT

Water quality is steadily declining in Wister Lake, particularly in the Fourche Maline arm. Wister Lake has historically been a shallow lake, with the westernmost reaches consisting of little more than mudflats. Water quality problems linked to high turbidity led to a congressionally mandated increase in conservation pool elevation to 478.0 feet NGVD. This increase in elevation has effectively created additional mudflats in the Fourche Maline arm of the lake where depth at conservation pool is typically 1-2 feet.

Wister Lake provides water for municipal use to the Poteau Valley Improvement Authority and the Heavener Utilities Authority. Recent studies conducted by the USACE (1994) indicate the lake is eutrophic due to nutrient loading and high turbidity. Both nutrient levels and turbidity are highest in the Fourche Maline arm of the lake. Fetches, where the wind blows unobstructed across the lake, in excess of a mile along the Fourche Maline and 2 miles along Lewis Creek worsen the turbidity. Prevailing south-southwest winds from spring through fall, when the lake is typically at its lowest level, resuspend sediments in the Fourche Maline arm of Wister Lake, resulting in an increase in turbidity.

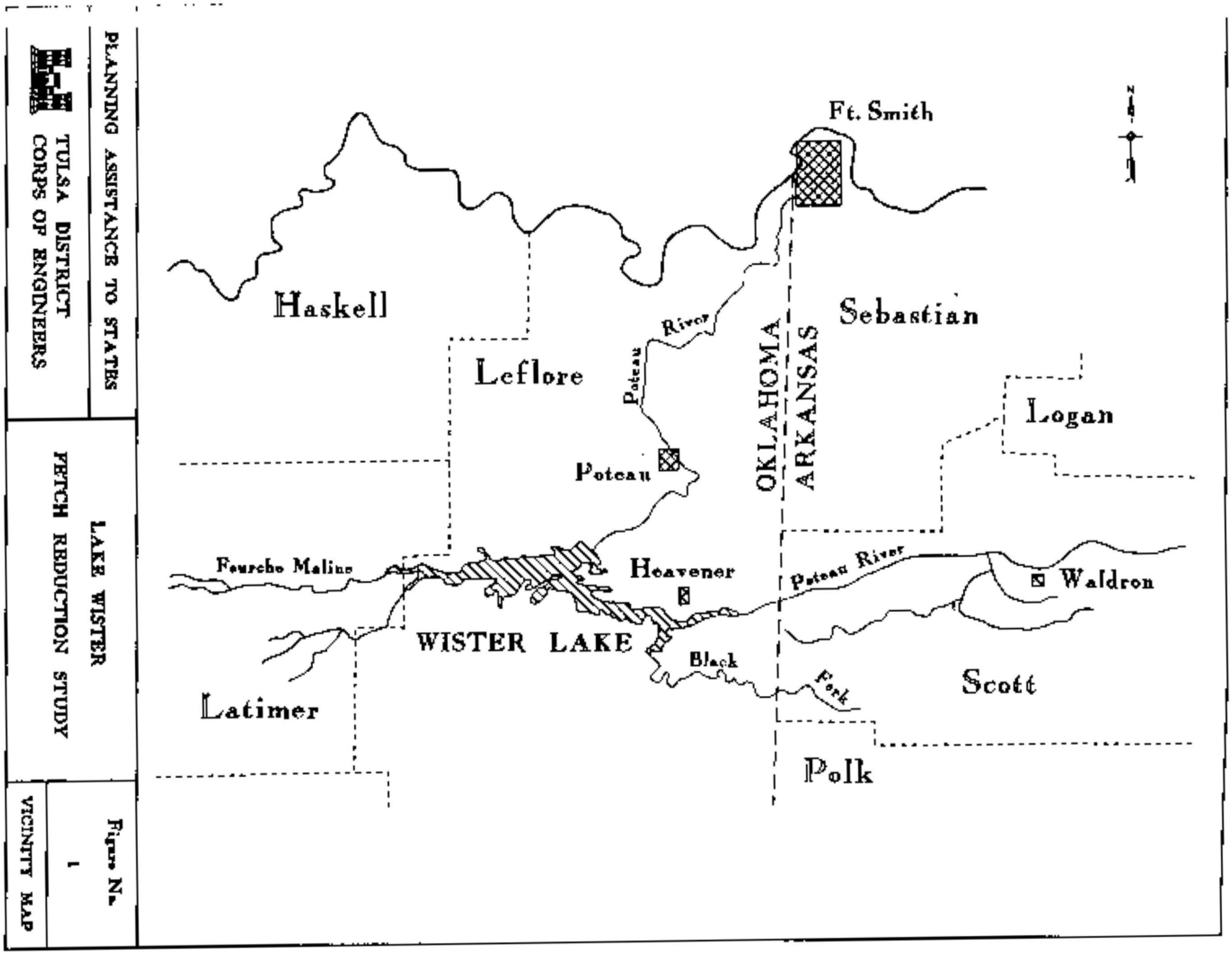
One method for reducing suspended sediment in the lake is the inclusion of breakwaters to reduce the fetch. This study will provide input to the OWRB for their multiphase study to improve the water quality of Wister Lake. Results of this fetch reduction study will be used as a basis for construction of breakwaters at Wister. When construction is completed, the OWRB will collect and evaluate water quality data for a 1-year period as part of their Section 319 grant.

SITE SELECTION

Potential sites were selected with input from USACE, OWRB, and Oklahoma Department of Wildlife Conservation (ODWC) personnel. Figure 2 shows the locations of all sites considered. Two visits to Wister Lake revealed a number of potential sites. The first visit did not afford a chance to get out on the lake; therefore, preliminary sites were determined by looking at U.S. Geological Survey topographic maps and from conversations with USACE, OWRB, and ODWC personnel. The topographic maps do not clearly show the shallow nature of Wister Lake. A second visit to the lake allowed a chance to go out in a boat. OWRB and ODWC personnel were not available for the second visit. Most of the preliminary sites were not accessible, were already sheltered by vegetation on the banks and in the lake, or were too shallow. Final sites were selected based on the following criteria:

- Exposure to south-southwest wind
- Easy access for construction
- Limited area for extended study
- Ability to construct within study budget
- Potential for fish habitat

A description of each site follows.


PLANNING ASSISTANCE TO STATES
TULSA DISTRICT
CORPS OF ENGINEERS
LAKE WISTER
FETCH REDUCTION STUDY
Figure No.
1
VICINITY MAP
Ft. Smith
Haskell
Sebastian
Leflore
Logan
Poteau River
Poteau
OKLAHOMA
ARKANSAS
Fourche Maline
Heavener
Poteau River
Waldron
WISTER LAKE
Black Fork
Scott
Latimer
Polk

SITE 1

Located on the Fourche Maline, Site 1 is northwest of a rock outcropping approximately 0.5 mile west of Lewis Creek and adjacent to an existing unimproved road. The site extends approximately 500 feet from the rock outcropping to the Fourche Maline channel.

SITE 2

Located near Lewis Creek and adjacent to an existing unimproved road approximately 0.5 mile east of Site 1, Site 2 is an old dike approximately 6,500 feet in length. The site extends approximately 500 feet from the shoreline to the remnants of an old dike and could be extended about another 800 feet on the southern edge of the dike. USACE personnel at Wister indicated that this dike might be so heavily eroded now as to be unidentifiable.

SITE 3

Located approximately 1 mile north of Site 1, Site 3 is an old dike approximately 6,400 feet in length. The entirety of this dike remnant could be used for a construction area; however, access for construction is somewhat lacking. The nearest road is at least 0.2 mile from the northern edge of the dike. USACE personnel at Wister indicated that this dike might be so heavily eroded now as to be unidentifiable.

SITE 4

Located approximately 1 mile east of Site 2, Site 4 is an inundated roadbed approximately 1.75 miles in length across the lake.

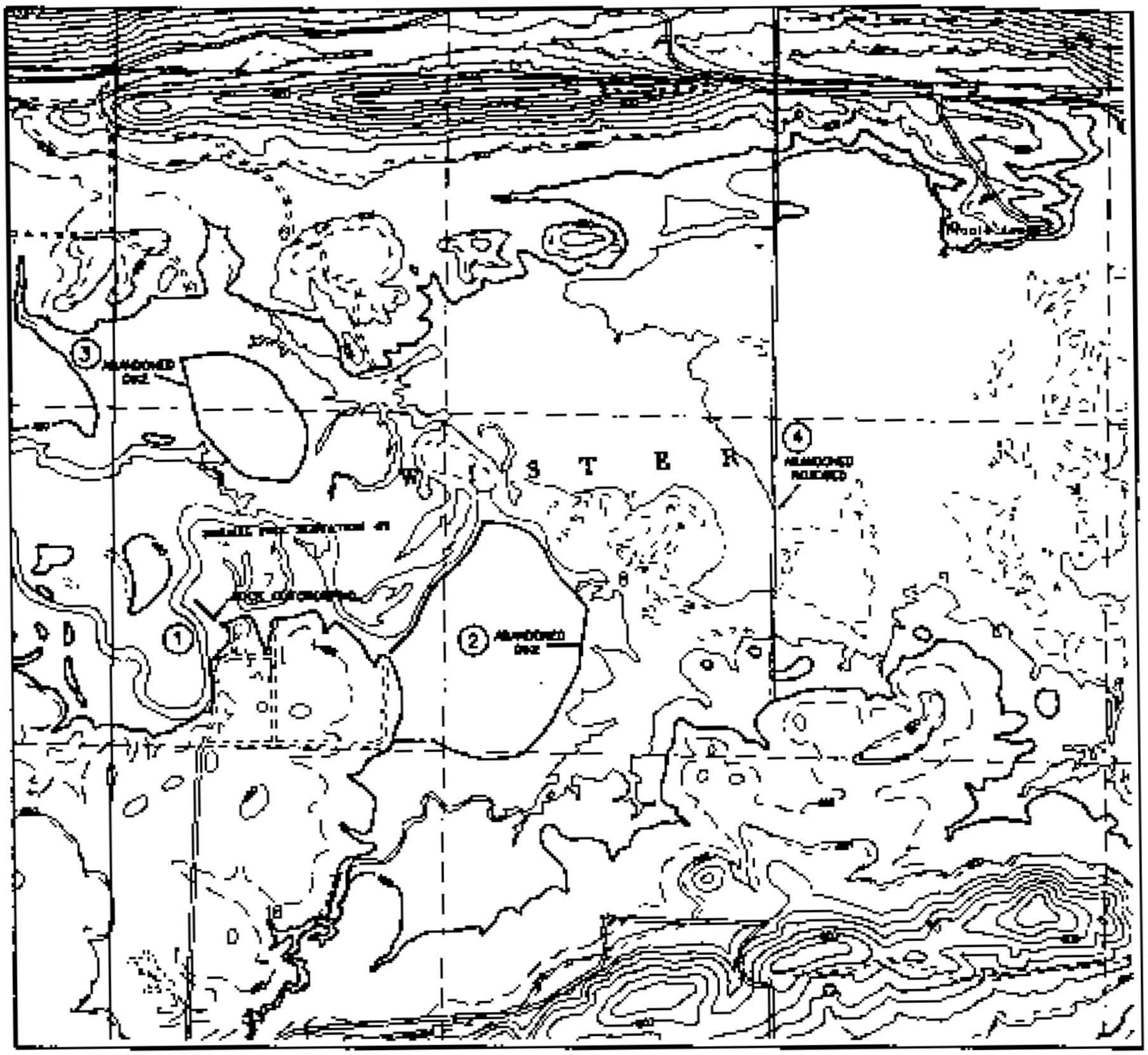
Access for construction, a major factor in determining project cost, is optimal for Sites 1 and 2. An unimproved road in conjunction with lake drawdown could possibly provide access to Site 3.

BREAKWATER SELECTION

Structural breakwaters, such as rock jetties, floating tire breakwaters, brush bundles (a form of branch box or brush box), and brush piles, are suitable for use in this application. Final selection of breakwaters was based on the following criteria:

- Site location
- Construction cost
- Potential for fish habitat

A description of each breakwater follows. Details about each breakwater, including drawings and specifications, are located in Appendix 2.



PLANNING ASSISTANCE TO STATES	LAKE WISTER FETCH REDUCTION STUDY	Figure No. 2
TULSA DISTRICT CORPS OF ENGINEERS		SITE MAP

ROCK JETTY

The most solid structure considered, a rock jetty, consists of 18-inch riprap over a course of crushed stone. Potentially the most costly breakwater, it requires the least maintenance and provides some habitat for fish. The 8- to 10-foot-wide crest would provide a stable location for fishing.

FLOATING TIRE BREAKWATER

This is the only breakwater considered that would continue to function during high lake level conditions. The floating tire breakwater consists of units of 18 tires strapped together by conveyor belt edging material anchored to the bottom of the lake. The breakwater is anchored in a way that allows the breakwater to continue to float even when the lake is above conservation pool.

BRUSH BUNDLE

This is a modified version of a brush box or branch box. It consists of bundles of brush secured between rows of posts driven into the lake bottom. The brush provides excellent fish habitat.

BRUSH PILE

The brush pile is similar to the brush bundle, but omits the posts. It is wider than the brush bundle and is secured by auger-type anchors. The brush pile also provides excellent fish habitat.

Hay barriers were also considered, but were not developed in detail. The hay barrier consists of a row of round hay bales (approximately 1,000 pound dry weight) placed close together (similar to the brush pile structure). This structure would degrade quickly, but could be useful for the stated purpose of this project.

Associated with construction of any of these structures is the planting of a variety of vegetation where the breakwater meets the shore to reduce erosion.

The use of breakwaters for this project is somewhat nonstandard. Typically, these structures are used to protect a shoreline from erosion. In the case of Wister Lake, the goal is to reduce wave action in a region of the lake, specifically a small enough portion of the Fourche Maline arm, to study the effectiveness of breakwaters in reducing sediment resuspension.

ALTERNATIVES

As previously stated, only structural alternatives were considered in this study. For each selected site, a number of alternatives were chosen. The first four alternatives, designated S1 through S4, are for Site 1. This site is the smallest of the four studied and is suitable for any of the structures described above. Based on the location of the channel with respect to the shore, a maximum structure length of 500 feet is possible. Site 2 allows for a structure as little as 500 feet long or as much as 1,300 feet long. Based on amount of exposure to the south-southwest wind,a longer structure would be needed at this site to effectively reduce the fetch. Alternatives for this site are labeled S5 through S8. Site 3 has definite access problems and is best suited for nonstructural alternatives; however, the existing dike could be built upon with a structure ranging from 3,200 feet for one side to 6,400 feet for the entire dike. Plans S9 through S11 cover the alternatives for Site 3. Floating tire breakwaters were not considered for this site due to the entire structure being located away from the shore. Site 4 is considered only to show what could be done if there were no funding constraints. Ideally, a structure would be built on the abandoned roadbed from the north shore of the lake to the south shore, with only a break at the channel. A structure along this roadbed would separate the lake into two parts. Although this would provide a very effective breakwater, the costs associated with construction at this site would prevent implementation under the current grant. Table 1 summarizes the various structural alternatives.

Table 1. Structural Alternatives

Plan	Site No.	Length (feet)	Structure Type
S1	1	500	Brush Bundle
S2	1	500	Brush Pile
S3	1	500	Floating Tire Breakwater
S4	1	500	Rock Jetty
S5	2	500-1,300	Brush Bundle
S6	2	500-1,300	Brush Pile
S7	2	500-1,300	Floating Tire Breakwater
S8	2	500-1,300	Rock Jetty
S9	3	3,200-6,400	Brush Bundle
S10	3	3,200-6,400	Brush Pile
S11	3	3,200-6,400	Rock Jetty
S12	4	8,250	Brush Bundle
S13	4	8,250	Brush Pile
S14	4	8,250	Floating Tire Breakwater
S15	4	8,250	Rock Jetty

Nonstructural alternatives, such as planting of vegetation, may prove more effective in cost and in achieving the desired goal of reducing the fetch in the Fourche Maline arm of Wister Lake. A previous USACE study identified possible vegetative species for plantings (U.S. Army Corps of Engineers, Tulsa District 1998). Test plantings of these species will reveal which are most suited for survival in the Wister Lake environment. In lieu of pursuing structural alternatives in the vicinity of Sites 1 and 2, these areas could be planted with vegetative species to break up the wave action and hence decrease sediment resuspension.

IMPLEMENTATION

An implementation plan is included at Appendix 2. Included in this plan is a sample set of drawings and specifications detailing the construction of each breakwater selected for study: a brush bundle, a brush pile, a floating tire breakwater, and a rock jetty. These sample plans are not site specific, but the information contained within each is sufficient to construct any of the breakwaters with minimal additional input.

Detailed cost estimates for each structure are included as Appendix 3. Total costs were developed for a 120-foot section of each structure for comparison. It was assumed that each 120-foot section included two safety buoys, one at the middle of the structure and the other at the lake end. A larger spacing between buoys may be acceptable. Coordination with the Wister Lake USACE is advised.

Table 2 summarizes construction cost per lineal foot for each structure type. It is important to note that the cost estimates as developed assume all labor, equipment, and materials will be provided at full cost. If any of these items can be obtained at a lower rate (i.e., donated material, equipment, or labor), one can use the information found on the detail pages of Appendix 3 to determine how the cost per lineal foot would change.

Table 2. Construction Cost Per Lineal Foot

Structure Type	Cost Per Lineal Foot
Brush Bundle	$ 90.09
Brush Pile	$103.04
Floating Tire Breakwater	$111.78
Rock Jetty	$126.46

Although the hay barrier is not included in the implementation plan or the cost estimates, a quick cost per lineal foot can be determined. A typical round bale of hay has a diameter of 5.5 feet and costs approximately $12-$15, Using the equipment and labor costs for a brush pile structure, from Appendix 3, the resulting cost for a 120-foot structure would be approximately $5,549 (or $46.24 per lineal foot).

Table 3 lists construction costs for each structural alternative.

Table 3. Structural Alternative Construction Costs

Plan	Cost
S1	$45,045
S2	$51,520
S3	$55,890
S4	$63,230
S5	$ 45,045 - $117,117
S6	$ 51,520 - $133,952
S7	$ 55,890 - $145,314
S8	$ 63,230 - $164,398
S9	$288,288- $576,576
S10	$329,728- $659,456
S11	$404,672- $809,344
S12	$743,243
S13	$850,080
S14	$922,185
S15	$1,043,295

CULTURAL AND ENVIRONMENTAL CONSIDERATIONS

Each site considered for construction of fetch reduction structures was evaluated for potential impacts to cultural resources, endangered species, or environmental conditions.

ENVIRONMENTAL

Existing environmental conditions included investigations to identify potential environmental problem areas, such as endangered species, cultural resources, wetlands, and water quality. The scope of the investigations did not include a full environmental assessment or an environmental impact statement. Existing environmental conditions are as follows.

Endangered Species

The U.S. Fish and Wildlife Service (USFWS) has identified the American burying beetle, bald eagle, Indiana bat, Interior least tern, Ouachita rockpocketbook mussel, peregrine falcon, leopard darter (w/Critical Habitat), and piping plover as Federally-listed threatened and endangered species which could be found in the project area. According to the USFWS, the bald eagle would be the only species that might be affected by the proposed project (see correspondence in Appendix 4).

Impacts from construction of fetch reduction structures at proposed locations would not likely cause impacts to listed species.

Cultural Resources

A record search was conducted using Tulsa District quadrangle maps modified to indicate the locations of cultural resource sites (see Figure 3).

All actions involving construction of the proposed project will avoid known cultural resource sites. Nevertheless, cultural resource site 34LF166 is near Site 3, and cultural resource sites 34LF199 and 34LF577 are near Site 2. It is recommended that a professional archeologist monitor construction work near these sites.

Following this plan of action, the proposed project should have no effect on historic properties pursuant to Section 106 of the National Register of Historic Places Act of 1966, as amended. Correspondence concurring with this position from the State Historic Preservation Office and the Oklahoma Archeological Survey is included in Appendix 4.

Water Quality

Previous investigations indicate that Wister Lake has been eutrophic for at least 20 years. Mean phosphorus (145 ug/1) and chlorophyll a (16.8 ug/1) levels in the epilimnion of Wister Lake are indicative of eutrophic conditions (U.S. Army Corps of Engineers 1994). It is likely that Wister Lake will attain hypereutrophic status in the near future due to the proliferation of poultry-rearing facilities in the watershed. Unless efforts are taken to minimize runoff from the watershed, nutrient loading from these Confined Animal Feeding Operations will continue to pollute the lake. Water clarity in Wister Lake is extremely turbid, with a mean value of 22 Nephelometric Turbidity Units (NTU) and a recorded maximum of 452 NTU. The water is soft (12-79 mg/l CaC03), poorly buffered (8-70 mg/l CaC03), and contains low levels of sulfate (3-18 mg/1) and high levels of iron (540-26,300 ug/1) and manganese (90-7,560 ug/1). The overall water quality of Wister Lake should be considered poor. Primary concerns regarding Wister Lake water quality are nutrient loading from watershed land use that result in excessive algal production and resuspension of low-density solids (i.e., clay and silt) from sediments.

National Forests and Other Public Use Areas

The proposed project is located less than 5 miles north of the Kiamichi Ranger District of the Ouachita National Forest. Additionally, the Indian Nations National Scenic and Wildlife Area, established by Congressional legislation (Winding Stair Mountain National Recreation and Wilderness Area Act of 1988), is located within the Ouachita National Forest and is authorized for preservation and public use. Wister State Park is managed by the Oklahoma Department of Tourism and Recreation and is composed of Victor Area, Wister Ridge, Quarry Island, and dam site parks along the main body of the lake downstream of the proposed project area. These parks are primarily operated for picnicking and camping and provide a variety of services to patrons. The ODWC manages Potts Creek Park, and the USACE operates Fanny Creek, Conser Crossing, and the overlook parks. Additionally, the Wister Wildlife Management Area (managed by the ODWC) is located on the south shore of the lake and is within the scope of the proposed project area. Sites 1, 2, and 4 are located within lands licensed by the ODWC for the management of waterfowl.

Hazardous, Toxic and Radiologic Waste

There are no known hazardous, toxic, and radiologic waste sites within the scope of the proposed project.

Wetlands

Wetland resources within the scope of the proposed project would be limited to low quality lacustrine habitats.

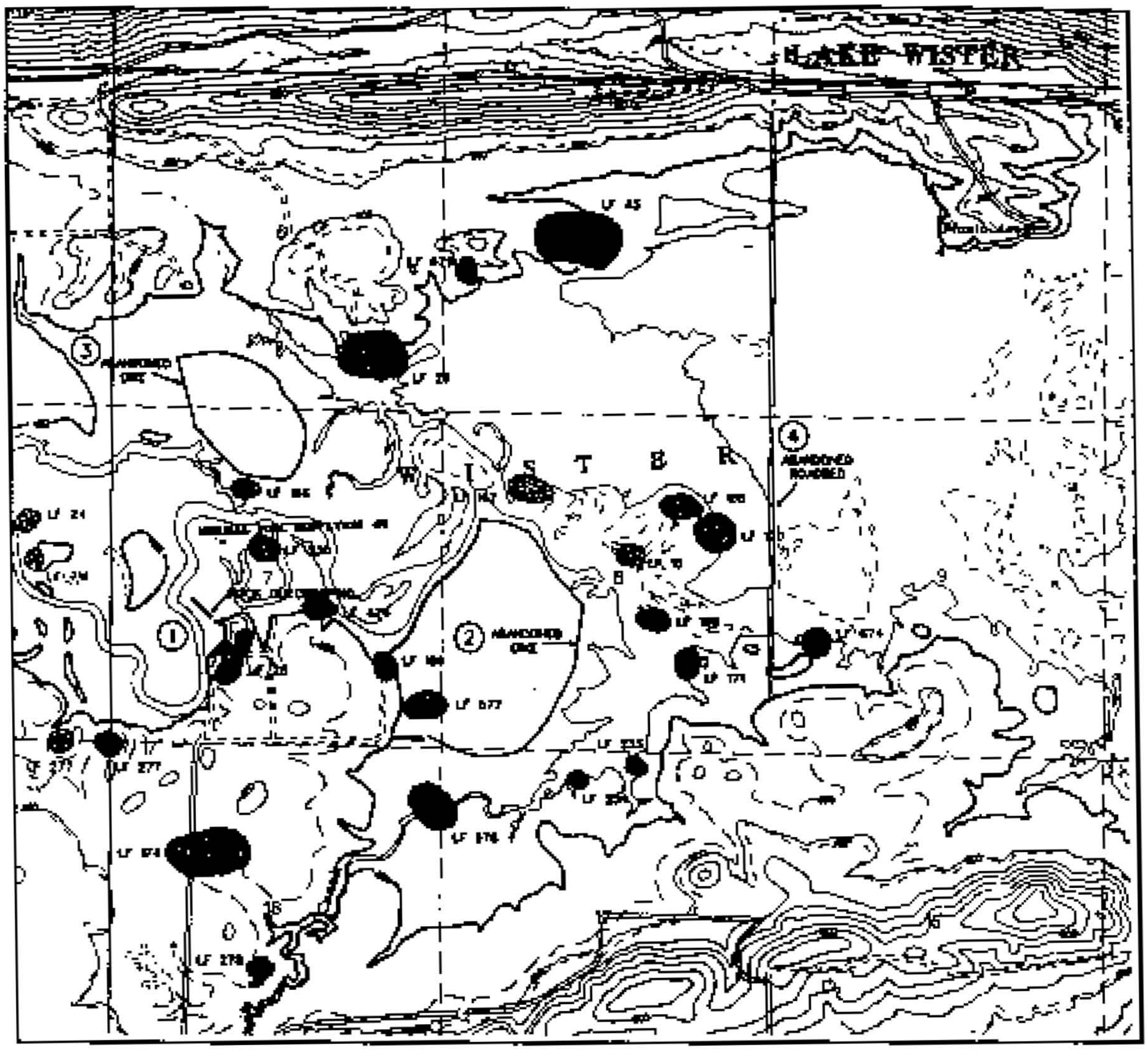
Environmental Considerations

Construction and placement of fetch-reduction structures in Wister Lake, as proposed, should not adversely impact existing environmental resources**.** Ideally, successful fetch-reduction structures would considerably improve the lake's water quality by decreasing the resuspension of low-density solids originating from lake sediments and shoreline. Improved lake transparency could promote macrophytic establishment along shorelines and in shallow limnetic zones of the lake, thereby increasing nutrient metabolism and overall biotic potential. Disturbance to the lake bed during placement of fetch-reduction structures would be realized, causing a temporary increase in turbidity.

Construction activities below elevation 478.0 feet NGVD on Wister Lake would require a Section 404 permit pursuant to the Clean Water Act. Completed construction plans should be submitted for final review to determine the type of permit needed. The proposed project would not likely be within the scope of a nationwide permit. The action would probably require an individual permit that normally takes 60 to 90 days to process.

Prior to construction, a Section 404 (Clean Water Act) determination should be requested from the USACE, Tulsa District (Regulatory Branch) to assure compliance with Federal law.

The project should be fully coordinated with the ODWC and other State agencies with jurisdiction regarding natural resource conservation. The Environmental Protection Agency (the funding agency) would be considered the Federal Action Agency for National Environmental Protection Act compliance issues.



CULTURAL RESOURCE SITES

PLANNING ASSISTANCE TO STATES	LAKE WISTER	Figure No.
TULSA DISTRICT CORPS OF ENGINEERS	FETCH REDUCTION STUDY	3
		CULTURAL RESOURCE SITES

PLAN RECOMMENDATION

A total of 15 structural alternatives were considered in this study. While all are viable projects, many can be excluded from consideration at this time due to constraints of limited construction funds ($50,000 or less) and the need for agreement on the project by all interested parties (i.e., OWRB, ODWC, and USACE). Plans S12 through S15 can be excluded from further consideration due to their high cost. It is also somewhat unlikely that all interested parties would approve of a structure in the lake that extends almost from shore to shore. Plans S9 through S11 can also be dismissed due to high construction cost, although the location could be used for implementation of a nonstructural solution**.** Site 3 lacks access for construction, but plantings could easily be brought in by boat. Plans S5 through S8 could be constructed within the available budget, but only a smaller structure could be built. Given the location of Site 2, this could prove to be ineffective. These plans should be considered the second-best choice. Plans S1 through S4 at Site 1 provide the best alternatives to meet the desired goals of this study. For the size structure required at this site, the cost for each of these plans is within the budgeted amount for construction. The site is optimally located, with roads for access and exposure to the south-southwest wind. Plans S1 and S2, while least expensive and providing the best fish habitat, would require a drawdown of the lake for construction, which may be difficult to coordinate. Plan S3 may not be most desirable by ODWC personnel for fishing purposes or by USACE personnel at the lake for maintenance purposes. Plan S4, while the most costly of the four alternatives at Site 1, would meet the desired goals of the study, has the best access for construction, and provides an excellent platform for fishing while requiring no additional maintenance.

CONCLUSION

This study was undertaken by the OWRB and the USACE to find a solution to the problem of increased turbidity and declining water quality in Wister Lake. The shallow depth of the Fourche Maline arm of the lake combined with wave action caused by wind sweeping over a long fetch in that portion of the lake results in the roiling of bottom sediments and increased turbidity of the lake. This study considered a wide array of structural alternatives for fetch reduction in the Fourche Maline arm of Wister Lake. The alternatives considered ranged from floating tire breakwaters to rock jetties to brush bundles and brush piles. Four sites were selected for construction of different breakwater structures to break up the surge action created by waves moving over the lake.

It is the conclusion of this study that breakwaters would prove effective in reducing suspended sediments in the lake. Of the 15 structural alternatives considered, any of the four at Site 1 should prove effective for continued study. Plan S4, a 500-foot rock jetty, is recommended for construction.

Although a structural alternative has been recommended for construction, it should be noted that nonstructural alternatives, particularly planting vegetative species over large areas of mudflats, may ultimately prove to be more effective at reducing the fetch in the shallow waters of Wister Lake while being less costly than the structural alternatives.

LITERATURE CITED

U.S. Army Corps of Engineers, Tulsa District. 1994. Wister Lake Oklahoma Water Quality Study

U.S. Army Corps of Engineers, Tulsa District. March 1998. Lake Wister Native Plant Establishment Study.

Appendix 1

Letter Agreement

LETTER AGREEMENT
PLANNING ASSISTANCE TO STATES

FETCH REDUCTION IN FOURCHE MALINE ARM OF WISTER LAKE
LAKE WISTER, OKLAHOMA

THIS AGREEMENT, entered into this 25 day of September, 1997, by and between the United States of America (hereinafter called the "Government"), represented by the District Engineer for the Tulsa District, U.S. Army Corps of Engineers, and the Oklahoma Water Resources Board (hereinafter called the "Sponsor"),

WITNESSETH THAT:

WHEREAS, Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251), as amended, authorizes the Secretary of the Army, acting through the Chief of Engineers, to assist the states in preparation of comprehensive plans for the development, utilization and conservation of water and related land resources; and

WHEREAS, Section 319 of the Water Resources Development Act of 1990 (Public Law 101-640) authorizes the Secretary of the Army to collect from non-Federal entities fees for the purpose of recovering 50 percent of the cost of the program established by Section 22; and

WHEREAS, the Sponsor has reviewed the State's comprehensive water plans and identified the need for planning assistance as described in the Scope of Studies incorporated into this agreement; and

WHEREAS, the Sponsor has the authority and capability to furnish the cooperation hereinafter set forth and is willing to participate in the study cost-sharing and financing in accordance with the terms of this Agreement;

NOW THEREFORE, the parties agree to the following:

1. The Government, using funds contributed by the Sponsor and appropriated by the Congress shall expeditiously prosecute and complete the Study, currently estimated to be completed within a twelve (12) month study period (not to exceed 12 months), substantially in compliance with the Scope of Study attached as Appendix A and in conformity with applicable Federal laws and regulations and mutually acceptable standards of engineering practice.

2. The Government shall contribute in cash fifty (50) percent, and the Sponsor shall contribute in cash fifty (50) percent of the total study cost which is currently estimated to be $34,000; provided, that the Government shall not obligate any cash contribution by the Sponsor toward Study costs until such cash contribution has actually been made available to it by the Sponsor. The Sponsor agrees to provide funds in the amount of $17,000, which shall be made payable to the Finance and Accounting Officer, Tulsa District, P.O. Box 61, Tulsa, Oklahoma 74121-0061, within 30 days of receipt of billing by the Government.

3. No Federal funds may be used to meet the local Sponsor's share of study costs under this Agreement unless the expenditure of such funds is expressly authorized by statute as verified by the granting agency.

4. Before any Party to this Agreement may bring suit in any court concerning any issues relating to this Agreement, such Party must first seek in good faith to resolve the issue through negotiation or

other form of nonbinding alternative dispute resolution mutually acceptable to the Parties.

5. This Agreement shall terminate on June 30, 1998, or at the completion of the Study; provided, that, prior to such time and upon thirty days written notice, either party may terminate or suspend this Agreement without penalty.

6. Within ninety days upon termination of this Agreement, the Government shall prepare a final accounting of the Study costs, which shall display (1) cash contributions by the Federal Government, (2) cash contributions by the Sponsor, and (3) disbursements by the Government of all funds. Subject to the availability of funds, within thirty days after the final accounting, the Government shall reimburse the Sponsor for non-Federal cash contributions that exceed the Sponsor's required share of the total study costs. Within thirty days after the final accounting, the Sponsor shall provide the Government any cash contributions required to meet the Sponsor's required share of the total study costs.

7. In the event that any (one or more) of the provisions of this Agreement is found to be invalid, illegal, or unenforceable, by a court of competent jurisdiction, the validity of the remaining provisions shall not in any way be affected or impaired and shall continue in effect until the Agreement is completed.

8. This Agreement shall become effective upon the signatures of both Parties.

FOR THE SPONSOR:

By: J. Ross Kirtley
J. Ross Kirtley,
Chairman
Oklahoma Water Resources Board

Date: 9-9-97

Attest:

Randall K. Thompson
HV Richard Seybolt, Secretary

Date: 9-9-97

(Seal)

FOR THE GOVERNMENT:

By: Timothy L. Sanford
Timothy L. Sanford
Colonel, U.S. Army
District Commander

Date: 25 Sep 97

Appendix 2

Implementaion Plan

This plan includes a sample set of drawings and specifications detailing the construction of each breakwater selected for study: a brush bundle, a brush pile, a floating tire breakwater, and a rock jetty. These sample plans are not site specific, but the information contained within each is sufficient to construct any of the structures with minimal additional input.

BRUSH BUNDLE STRUCTURE

The brush bundle is a modified version of a brush box or branch box, consisting of bundles of brush secured between rows of posts driven into the lake bottom. The brush bundle provides excellent habitat for fish.

General

Brush bundle structures shall consist of 2-foot-diameter by 8- to 10-foot-length bundles of brush secured by cable ties to 6-inch diameter posts as shown on Drawing 1.

Specifications

Posts. Posts shall be 6-inch-diameter treated wood. They shall be placed vertically in the lake substrate in two rows set at 4 feet on centers. The posts shall be placed approximately 6 feet on centers in each row and shall be inserted 6 feet into the substrate. Posts shall extend approximately 3 feet above conservation pool elevation.

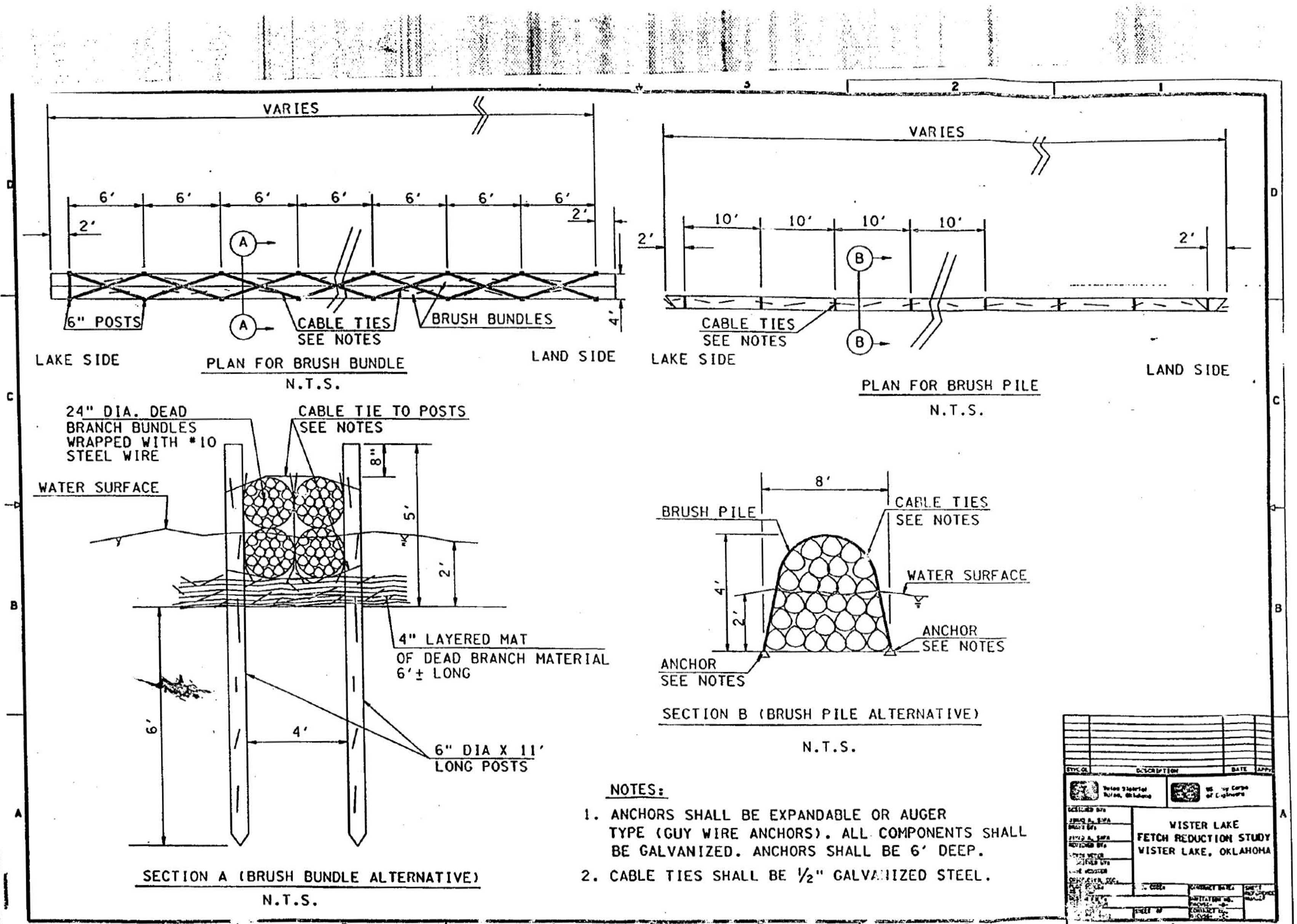
Brush Mat. The brush mat shall be composed of a compacted 4-inch-thick layer of dead branches. The mat shall be placed perpendicular to the length of the brush bundle.

Brush Bundles. Brush bundles shall be composed of a mixture of green and seasoned wood. Tree limbs are acceptable, provided they are compacted. Brush shall be tied in 2-foot-diameter bundles with 410 steel wire. The bundles shall be approximately 8 to 10 feet long and shall extend to within 8 inches of the top of the posts.

Cable Ties. Cable ties shall be 1/2-inch galvanized steel.

Vegetation. Vegetation shall consist of switchgrass and wild rice. Switchgrass shall be planted on shore, perpendicular to the brush bundle structure, and shall extend approximately 30 feet from the center of the brush bundle on either side. Switchgrass shall also be planted in disturbed areas within 50 feet of the shoreline. Wild rice shall be planted in the lake where indicated on drawings in areas where water is less than 2 feet deep or as recommended by the supplier of the wild rice seeds/plants. Planting shall be accomplished in the correct season for the area.

Safety Devices. Safety buoys shall be provided at each end of the brush bundle structure to provide for the safety of the boating public. Each site shall be evaluated to determine specific requirements.



VARIES
6' 6' 6' 6' 6' 6' 6'
2'
2'
4'
6" POSTS
CABLE TIES
SEE NOTES
BRUSH BUNDLES
LAKE SIDE
LAND SIDE
PLAN FOR BRUSH BUNDLE
N.T.S.
VARIES
10' 10' 10' 10'
2'
2'
CABLE TIES
SEE NOTES
LAKE SIDE
LAND SIDE
PLAN FOR BRUSH PILE
N.T.S.
24" DIA. DEAD
BRANCH BUNDLES
WRAPPED WITH #10
STEEL WIRE
CABLE TIE TO POSTS
SEE NOTES
WATER SURFACE
8"
5'
2'
4" LAYERED MAT
OF DEAD BRANCH MATERIAL
6' ± LONG
6'
4'
6" DIA X 11'
LONG POSTS
SECTION A (BRUSH BUNDLE ALTERNATIVE)
N.T.S.
8'
BRUSH PILE
CABLE TIES
SEE NOTES
WATER SURFACE
4'
2'
ANCHOR
SEE NOTES
ANCHOR
SEE NOTES
SECTION B (BRUSH PILE ALTERNATIVE)
N.T.S.
NOTES:
1. ANCHORS SHALL BE EXPANDABLE OR AUGER TYPE (GUY WIRE ANCHORS). ALL COMPONENTS SHALL BE GALVANIZED. ANCHORS SHALL BE 6' DEEP.
2. CABLE TIES SHALL BE ½" GALVANIZED STEEL.
WISTER LAKE
FETCH REDUCTION STUDY
WISTER LAKE, OKLAHOMA

BRUSH PILE STRUCTURE

Similar to the brush bundle structure, but omitting the posts, the brush pile is wider than the brush bundle structure and is secured by auger-type anchors. The brush pile also provides excellent fish habitat.

General

Brush pile structures shall consist of 8-foot-wide by 4-foot-tall piles of brush secured by cable ties to 6-foot auger-type anchors as shown on Drawing 1.

Specifications

Brush. Brush shall be composed of a mixture of green and seasoned wood. Tree limbs are acceptable, provided they are compacted. Brush shall be secured every 10 feet by cable ties connected to anchors.

Cable Ties. Cable ties shall be 1/2-inch galvanized steel.

Anchors. Anchors shall be expandable or auger-type (guy wire anchors). All components shall be galvanized. Anchors shall be a minimum of 6 feet deep.

Vegetation. Vegetation shall consist of switchgrass and wild rice. Switchgrass shall be planted on shore, perpendicular to the brush bundle structure, and shall extend approximately 30 feet from the center of the brush bundle on either side. Switchgrass shall also be planted in disturbed areas within 50 feet of shoreline. Wild rice shall be planted in the lake where indicated on drawings in areas where water is less than 2 feet deep or as recommended by the supplier of the wild rice seeds/plants. Planting shall be accomplished in the correct season for the area.

Safety Devices. Safety buoys shall be provided at each end of the brush pile structure to provide safety for the boating public. Each site shall be evaluated to determine the specific requirements.

FLOATING TIRE BREAKWATER

The floating tire breakwater (FTB) is the only structure considered that would continue to function during high lake level conditions. The FTB consists of units of 18 tires strapped together by conveyor belt edging and anchored to the bottom of the lake in such a way that allows the breakwater to continue to float even when the lake is above conservation pool.

General

A modified Goodyear design will be used. This design consists of modules of 18 tires in a 3-2-3-2-3-2-3 configuration. Individual modules are joined together to produce different width structures. A 2-module-width structure should be adequate for wave conditions experienced on the relatively shallow Fourche Maline arm of Wister Lake.

Quality of construction is critical in this process. Care must be taken to ensure that the FTB's do not come apart during heavy wave action. The construction methods herein should be followed. Questions concerning these details should be directed to Burl Ragland at (918) 669-7231.

FTB Modules

Construction of 18-tire modules consists of: (1) punching holes in the bottom of each tire; (2) filling the top of each tire with urethane foam; (3) stacking tires in the 3-2-3-2-3-2-3 configuration; (4) binding the tire modules with conveyor belt edging material; and (5) fastening the conveyor belts with galvanized bolts, washers, and nuts. A more detailed discussion of each step is provided below.

Step 1. A 1- or 2-inch-diameter hole shall be cut or pneumatically punched in the bottom of each tire. The hole in the tire should be marked to aid in Step 2.

Step 2. Supplemental flotation material shall be inserted in the top of the tire. Approximately 1/2 pound of liquid urethane foam, mixed per manufacturer's recommendations, shall be poured into the top of each tire. Care must be taken to ensure that the hole punched in Step 1 is up when the liquid foam is placed in the tire as shown in Figure 1.

Step 3. Stack the tires in the 3-2-3-2-3-2-3 configuration using an assembly frame as shown in Figure 2. Conveyor belt edging is threaded through the tires during stacking as shown in Figure 3.

Steps 4 and 5. The conveyor belt strap shall be 2- or 3-inches wide and at least 3/8-inch thick. See Figure 4. Holes shall be drilled or punched through the belting for three 1/2-inch bolts, as shown in Figure 5. Strapping shall be pulled tight to hold the tires securely without crushing the tires. There shall be a flat washer used against each belt and a lock washer next to the galvanized nut. The nut is tightened enough to start drawing the washer into the belt. Then the threads on the bolt are battered to prevent the nut from working loose. (Note: Make sure all the top sides of the tire [the side with foam] are in the same outfacing direction before the tires are strapped together.) See Figures 3, 4, 5, and 8 for more detail.

Construction of the FTB From the Modules

The basic 18-tire modules are tied together to develop the desired width and configuration. To tie these modules together, two single tires are required. They should be prepared the same as the tires in bundles (hole-punched in bottom with foam in top) with a strap, three bolts, etc. Therefore, for each module developed (18-tire bundle), two single tires, each with a strap, shall be made. The length of the strap shall be determined by test assembling the bundles as shown in Figure 6 and then making each strap the same length, with bolt holes and hardware as described for the modules. An important difference is that the bolts are hand-tightened only, and the threads are not battered. See Figures 6 and 7 for typical layouts of the modular units.

A bridle chain or bridle line shall be used to connect the modules to the FTB. Figure 9 shows the use of a bridle chain. Figure 10 shows the use of a bridle line.

FTB Specifications

Tires. Tires shall be 14- or 15-inch automotive models.

Conveyor Belt Edging. Conveyor belt edging shall be at least 2-inches wide and 3/8-inch thick for effective performance as FTB binding material.

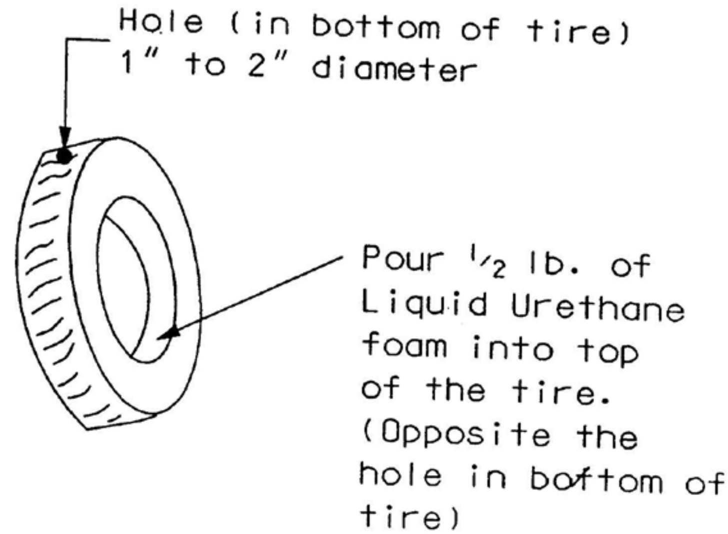


FIGURE NO. 1

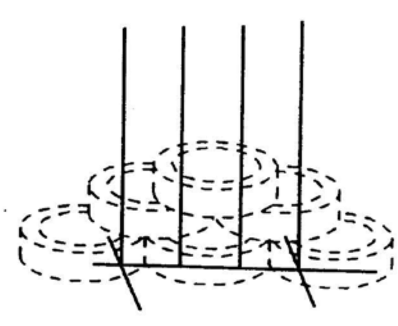


FIGURE NO. 2

ASSEMBLY STAND

Tire bundles are constructed by stacking the tires flat in a 3-2-3-2-3-2 3 configuration. Binding material -- in this case, conveyor belt edging -- is woven through the tires as they are stacked to secure the bundle.

FIGURE NO. 3

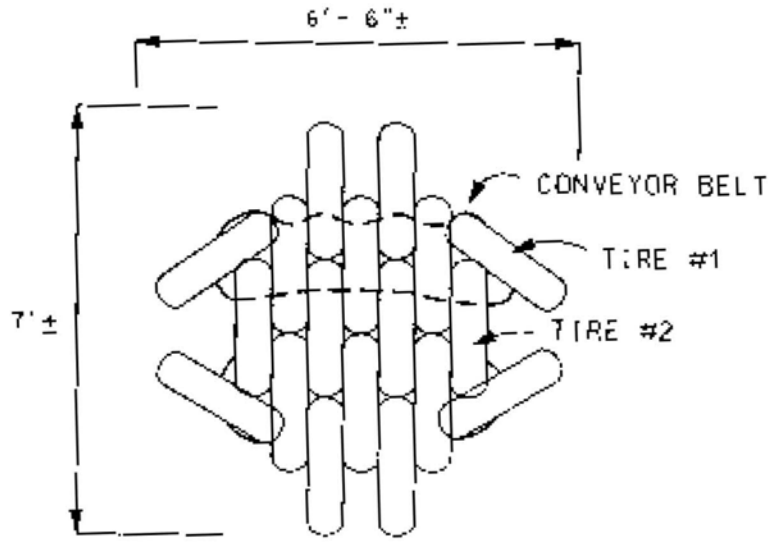


FIGURE NO. 4

TIRE MODULAR UNIT

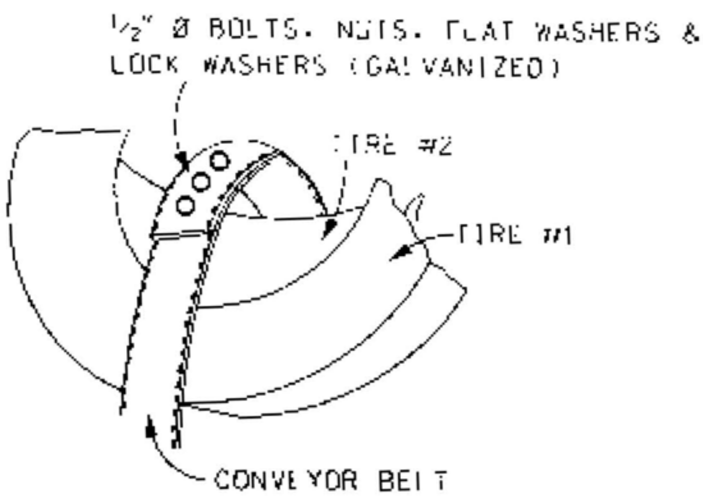


FIGURE NO. 5

BELT ATTACHMENT

2-9

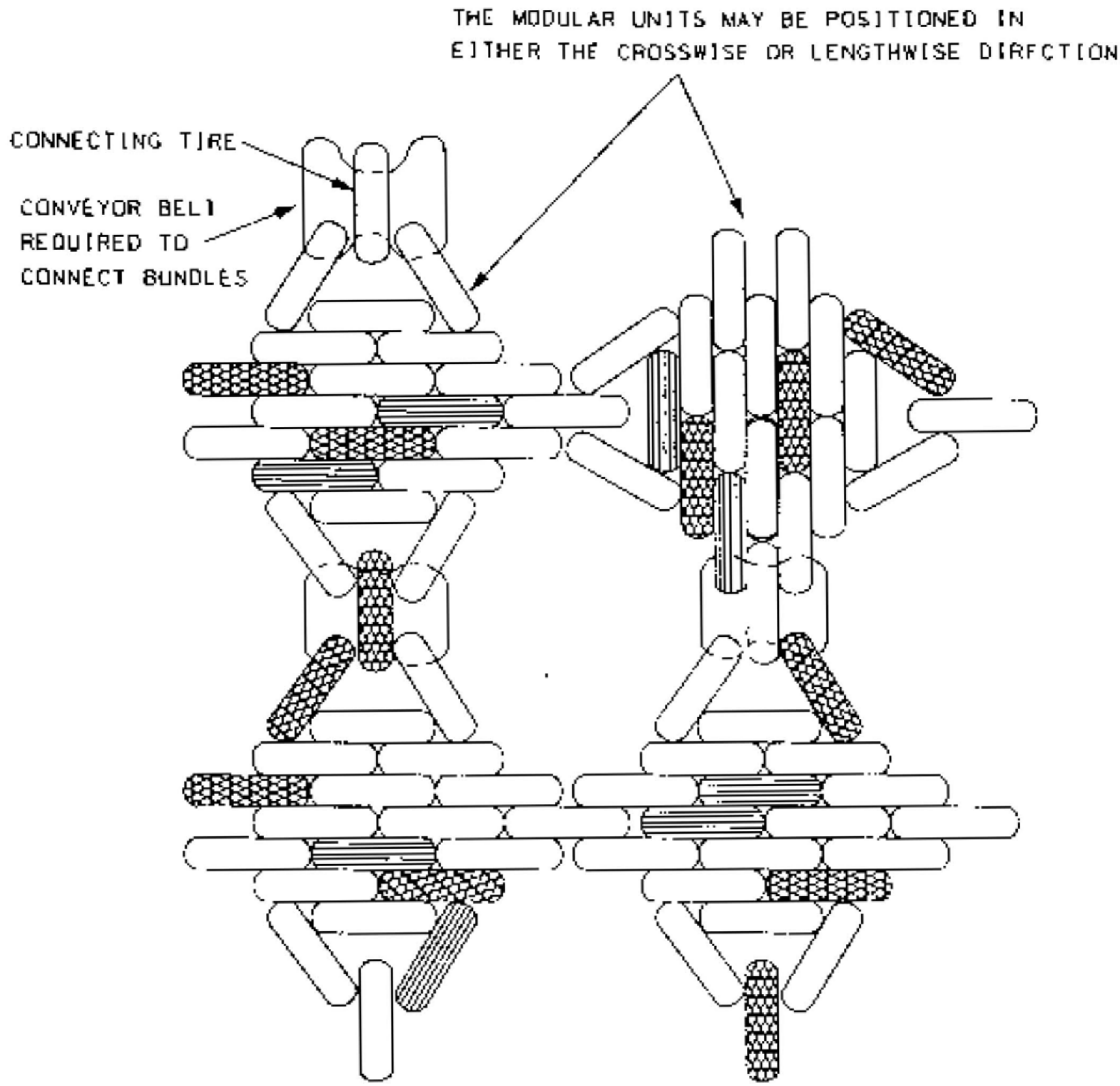


FIGURE NO. 6

MODULAR UNIT – ALT. LAYOUT OPTIONS

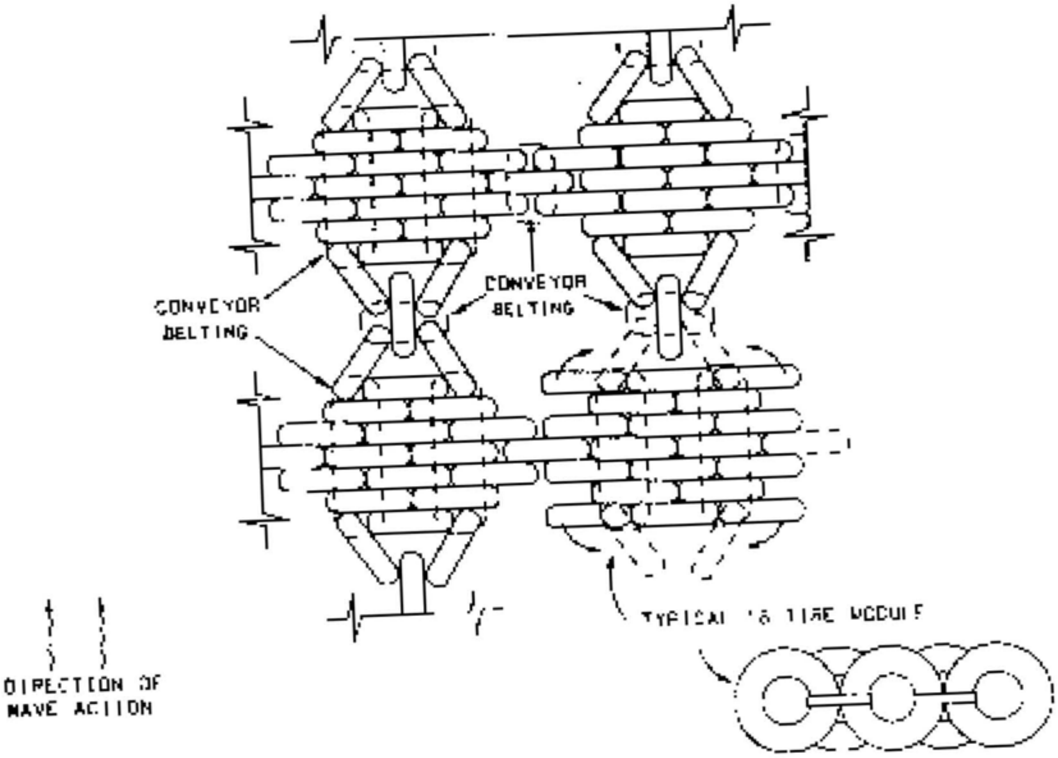


FIGURE NO. 7

PLAN VIEW
PROPOSED FLOATING TIRE BREAKWATER

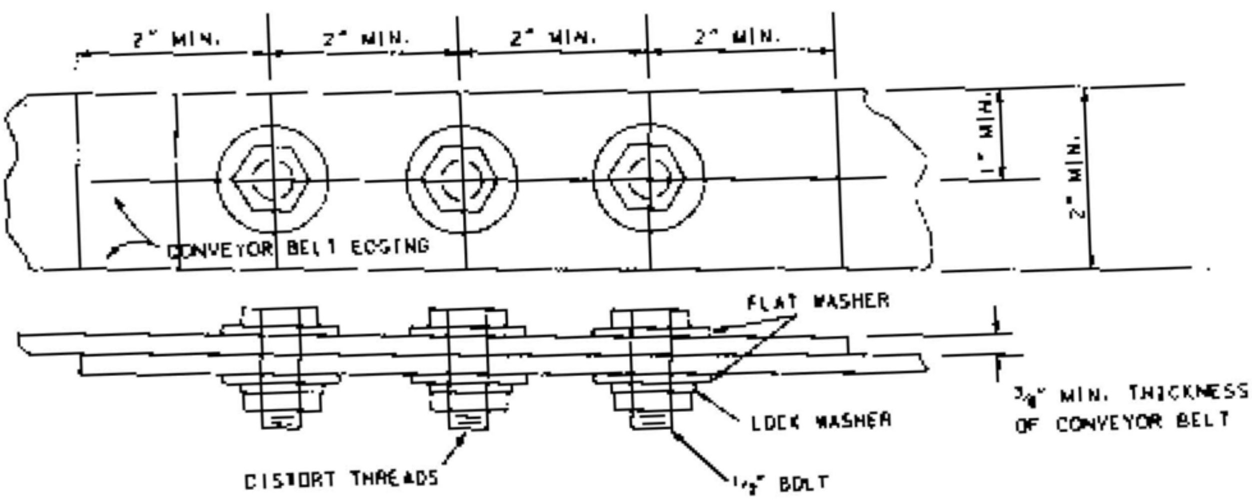


FIGURE NO. 8

TYPICAL BOLT SPACING
(ALL GALVANIZED)

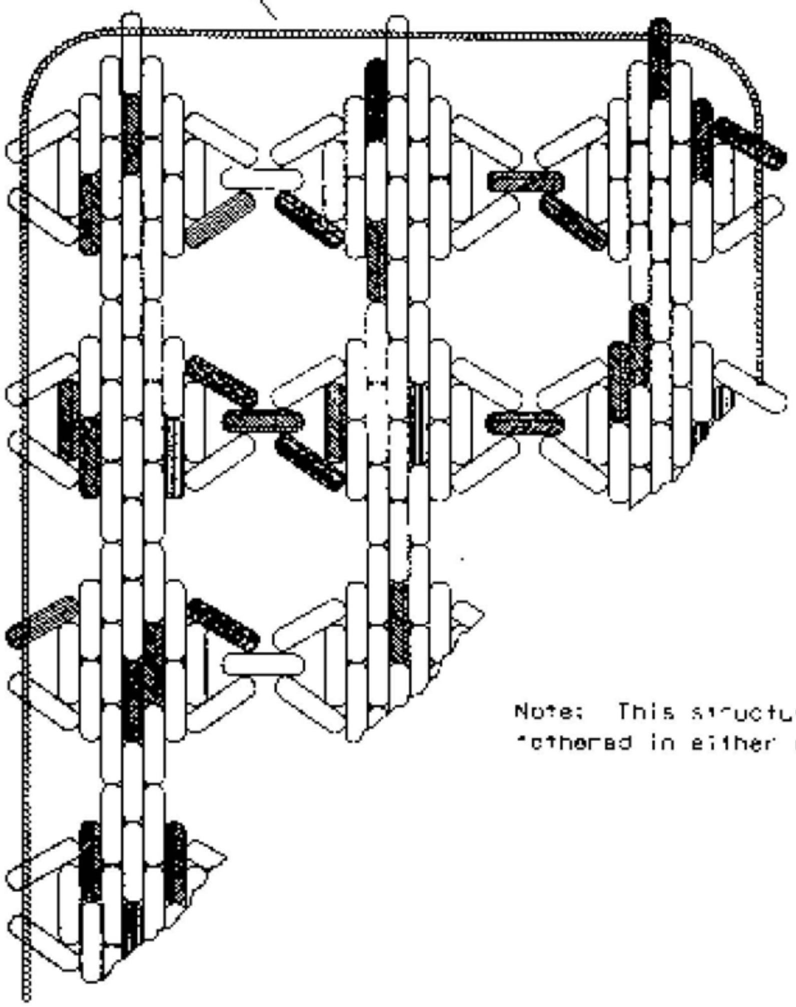
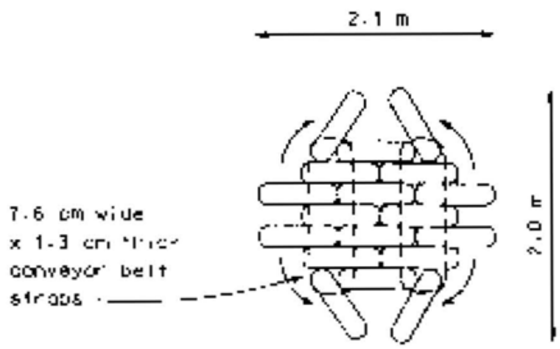


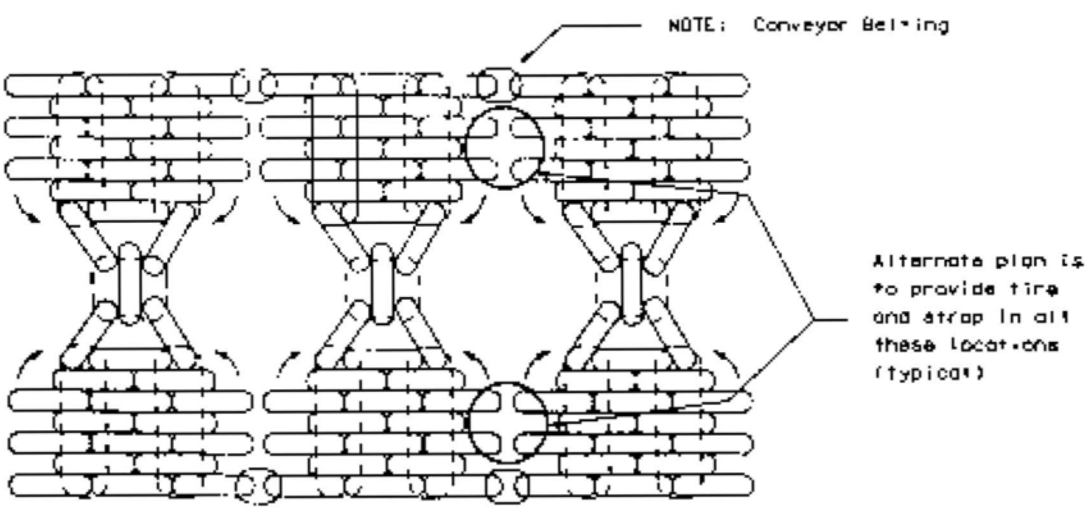
FIGURE NO. 9

2-12

PROFILE SCHEMATIC OF ONE FTB MODULE



PLAN SCHEMATIC OF ONE FTB MODULE



PLAN SCHEMATIC OF SEVERAL FTB MODULES

FIGURE NO. 10

2-13

Urethane Foam. Urethane foam shall be suitable for marine use.

Bridle Chain. Bridle chain shall be either 3/16-inch, welded, galvanized steel with 3/16-inch galvanized steel shackles for connections, or 1/2-inch, open-link, non-galvanized steel with spreadable links developed by Campbell Chain Company.

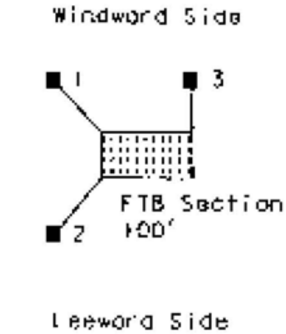
Bridle Line. Bridle line shall be 1/2-inch or larger polypropylene or Poly-D line, with an ultraviolet (sunlight) radiation screen.

Conveyor Belt Fasteners. Fasteners consist of three 1/2-inch galvanized bolts with two galvanized flat washers, one galvanized lock washer, and a galvanized nut as shown in Figure 8. The bolts shall be long enough to permit braiding threads when the nut is torqued. Bolt holes (centerline) shall be no closer than 1 inch from the edge of the belt and a minimum of 2 inches from the end of the strap and spaced a minimum of 2 inches apart.

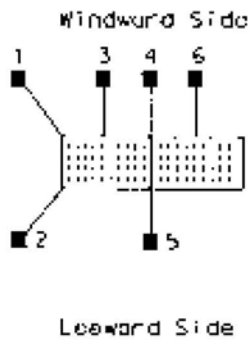
FTB Anchoring

General. After the modules are assembled into towable units, usually about 100 feet in length, they will be towed into place, tied together (as appropriate), and anchored into place. Details on how these FTB are anchored and the materials required are described in this section. An overall sketch showing how the sections are tied together and anchored is provided in Figure 11. Figure 12 illustrates some of the terms used in this section.

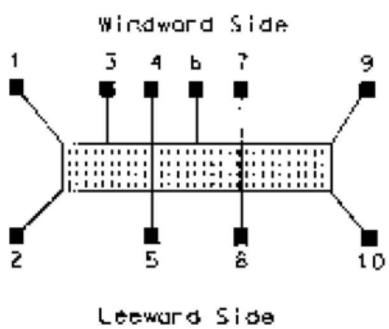
Anchor Cable Attachment. Figures 13 and 14 provide detail on how the anchor cable (mooring line) attaches to the FTB. These cable attachments shall be provided together with all materials and shall be attached to appropriate modules to provide for anchors every 50 feet on the windward side, every 100 feet on the leeward (downwind) side, and at each corner of the FTB. Therefore, 20% of the total bundles should have the anchor straps attached. The conveyor belt edging shall be a minimum of 3 inches wide and 1/2 inch thick, as shown in Detail A.



ANCHORING FOR FIRST SECTION
TOWED INTO PLACE



ANCHORING WHEN SECOND SECTION
HAS BEEN TIED TO FIRST SECTION
(NEED RELATIVELY WINDLESS DAY)



TYPICAL ANCHORING WHEN ALL
SECTIONS HAVE BEEN JOINED

FIGURE NO. 11

2-15

H Incident Wave Height

H_T Transmitted Wave Height

L Wavelength

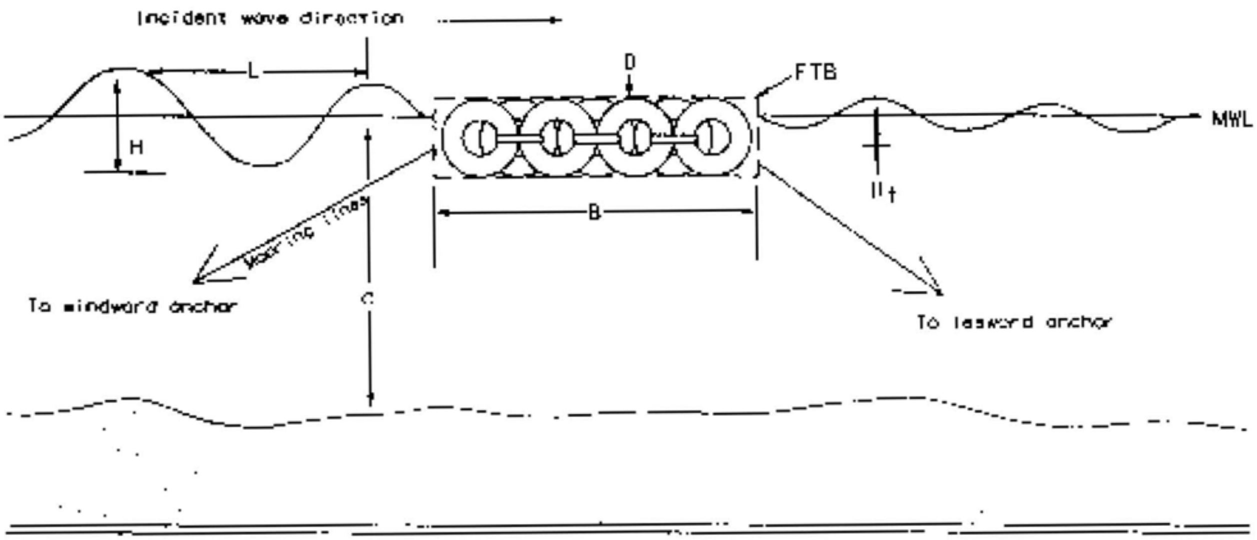
d Water Depth

MWL Mean Water Level

D Tire Diameter

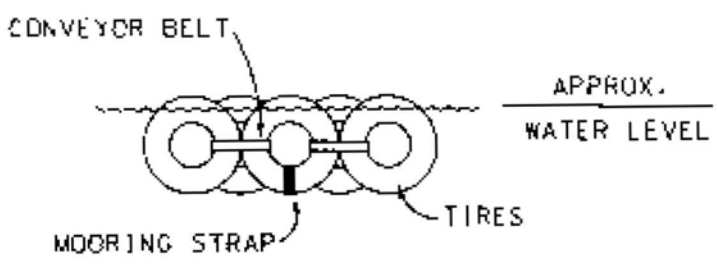
B Beam Size of FTB

H_t/H Ratio of Transmitted to Incident wave height (C_t)



Terms used in describing a FTB.

FIGURE NO. 12



MODULAR SECTION

FIGURE NO. 13

MOORING STRAP DETAIL

2-16

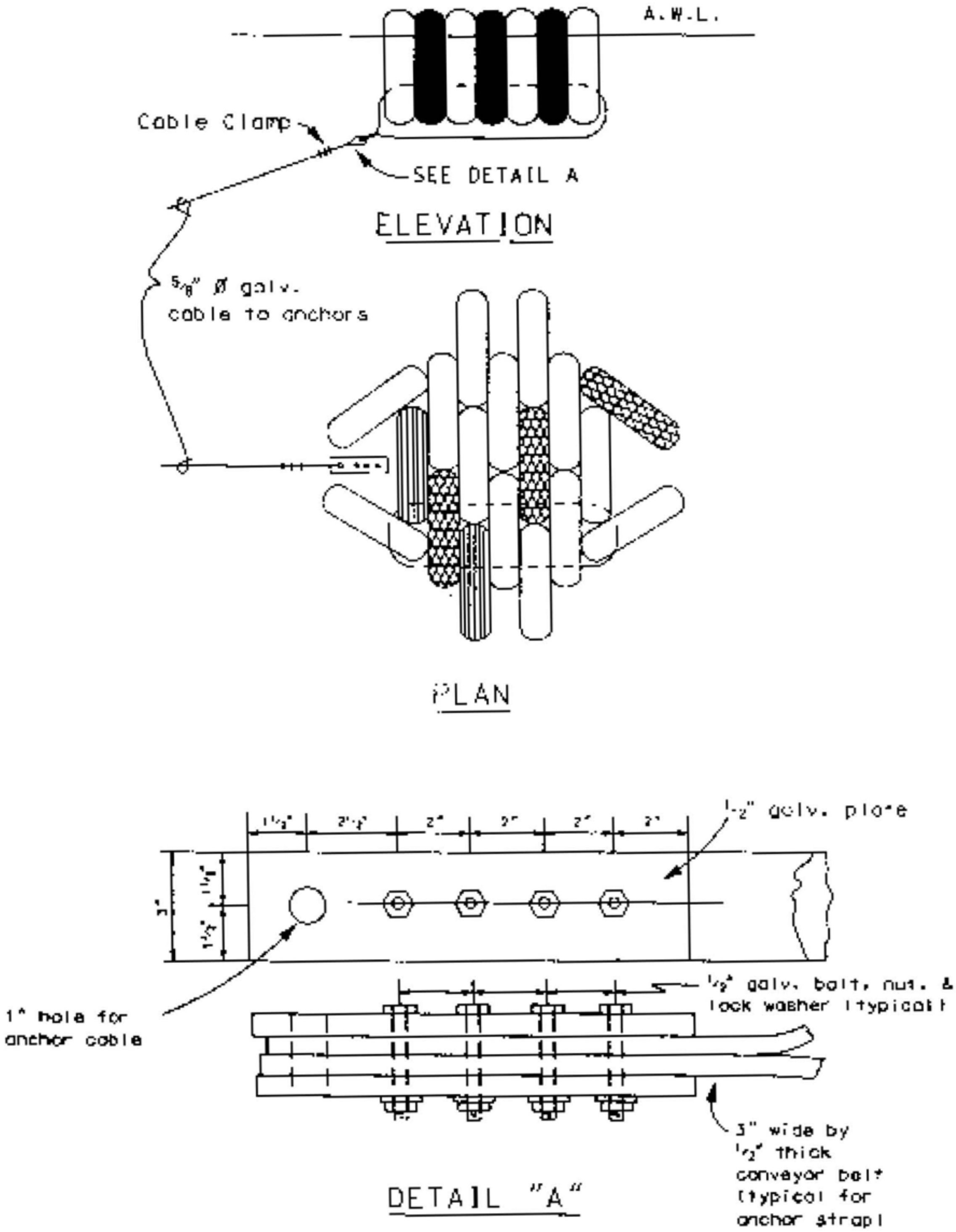

A.W.L.
Cable Clamp
SEE DETAIL A
ELEVATION
5/8" Ø galv.
cable to anchors
PLAN
1/2" galv. plate
1" hole for
anchor cable
1/2" galv. bolt, nut, &
lock washer (typical)
3" wide by
1/2" thick
conveyor belt
(typical for
anchor strap)
DETAIL "A"

FIGURE NO. 14

Anchor System. Two types of anchors shall be used with the Goodyear design: mushroom anchors-and concrete block weights. A mushroom anchor system, as shown in Figure 15, consisting of two 42-inch-diameter concrete cups with a 10-foot-long, 3-inch pipe stem and 5/8-inch galvanized cable is required for each 15 modular units produced. Concrete block anchors, as shown in Figure 16, will be used to keep tension in the anchor cables during fluctuations of the lake surface. One concrete block weight is required for each two mushroom anchors. Cables to connect the anchor to the FTB shall be seven times the depth of water where the FTB will be used. Figure 17 shows a typical layout, and Figure 18 shows anchor details.

Safety Devices. Safety buoys shall be provided at each end of the FTB as necessary to provide for the safety of the boating public. Each site shall be evaluated to determine specific requirements.

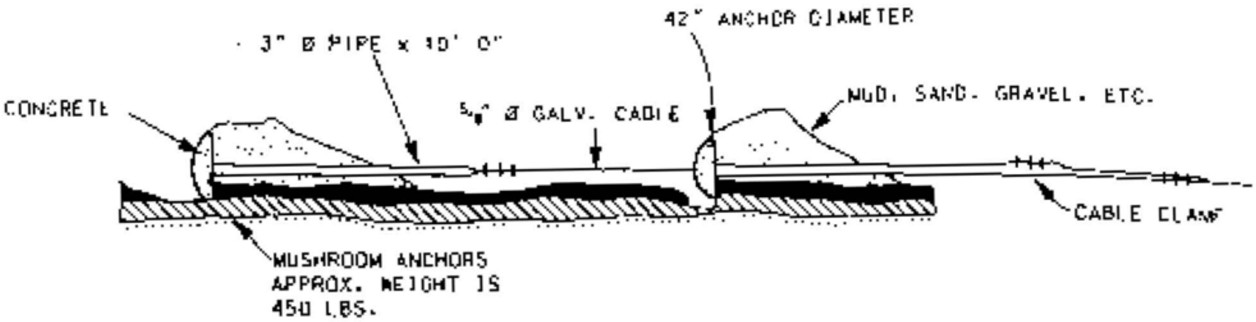


FIGURE NO. 15

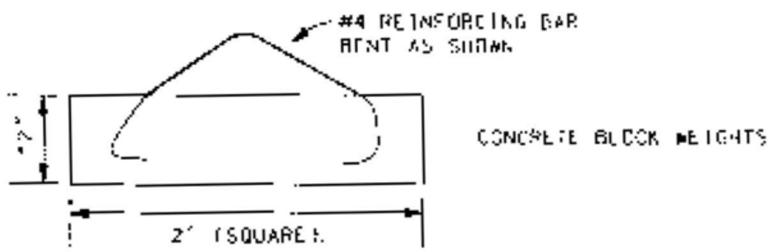


FIGURE NO. 16

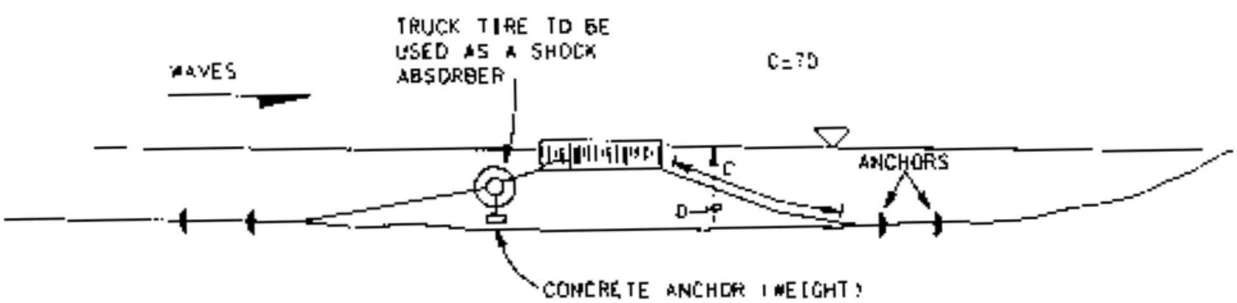
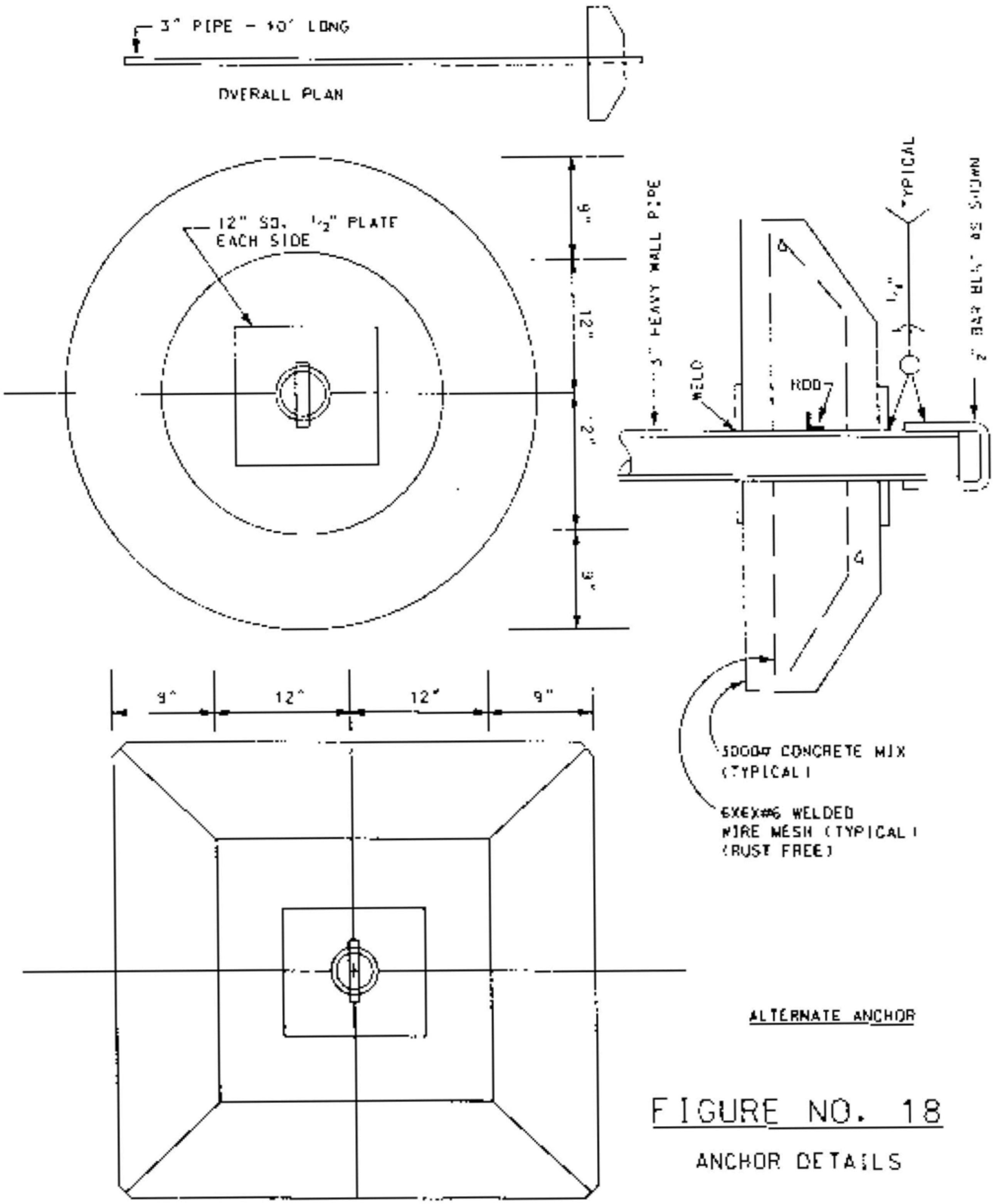


FIGURE NO. 17

2-19

VARIOUS ANCHORS

MUSHROOM ANCHORS



ALTERNATE ANCHOR

FIGURE NO. 18

ANCHOR DETAILS

2-20

ROCK JETTY

The most solid structure considered consists of 18-inch riprap over a course of crushed stone. Potentially the most costly, the rock jetty requires the least maintenance and provides some habitat for fish. The 8- to 10-foot-wide crest would provide a stable location for fishing.

General

Rock jetties shall consist of 18-inch riprap over a 6-inch bedding layer. Riprap shall placed with an 8- to 10–foot wide crest, with the end and sides having a slope that approximates the natural angle of repose (1 vertical on 1.5 horizontal [lV:1.5H). The shoreline end of the jetty shall extend an additional 40 feet to prevent erosion. The rock jetty shall extend approximately 2 feet in height above the conservation pool elevation of 478.0 feet.

Specifications

Bedding Material. Bedding material shall consist of sand, gravel, or crushed stone well graded between the prescribed limits specified below:

Sieve Designation Percent by Weight Passing

U.S. Standard Square Mesh	9-inch and 6-inch Bedding
6"	100
411	85-100
2"	60-80
1"	35-60
3/8"	10-35
No. 4	0-15

The material shall be composed of tough, durable particles; reasonably free from thin, flat and elongated pieces; and contain no organic matter or soft, friable particles in quantities more than 5% of the total sample.

Riprap. Stone for riprap shall be durable and of a suitable quality to ensure permanence in the structure and in the climate in which it is to be used. It shall be free from cracks, seams, and other defects that would tend to unduly increase its deterioration from natural causes. The inclusion of dirt, sand, clay, and rock fines shall not exceed 5% by weight.

Riprap shall be reasonably well graded from the minimum size stone permitted to the maximum size stone permitted. Neither the breadth nor the thickness of any piece of riprap shall be less than one-third its length. Riprap grading shall be as follows:

Riprap Thickness (Inches)	Maximum Size[1] (Pounds)	90% Size[2] (Pounds)	Average Size[3] (Pounds)	8% Size[4] (Pounds)
18	290	170-265	65-90	9

[1]Gradation is for stone having a specific gravity of 2.65.

[2]Defined as that size such that 90% of the stone, by weight, is smaller and 10% is larger.

[3]Defined as that size such that 50% of the total riprap stone, by weight, is larger and 50% is smaller.

[4]Not more than 8% of the riprap, by weight, shall consist of pieces weighing less than the weights shown for the applicable riprap thickness.

Foundation Preparation. Areas above water where bedding material is to be placed shall be trimmed and dressed to conform to existing grades. Low spots shall be brought to grade by filling with random fill or bedding material. Areas below water will require no foundation preparation.

Bedding Layer Placement. Bedding material shall be spread uniformly on the prepared base. Placing of material by methods that will tend to segregate particle sizes within the bedding will not be permitted. Any damage to the surface of the bedding base during placement of the bedding shall be repaired before proceeding with the work. Compaction of the bedding layers will not be required but they shall be finished to present a reasonably even surface free from mounds or windrows.

Riprap Placement. Stone for riprap shall be placed on the bedding layers in a manner to produce a reasonably well graded mass of rock with the minimum practicable percentage of voids and shall be constructed to the grades previously indicated (lV:1.5H)**.** Riprap shall be placed to its full course thickness in one operation and in such a manner as to avoid displacing the bedding material. The larger stones shall be well distributed, and the entire mass of stones in their final position shall be roughly graded to conform to the gradation specified in paragraph "Riprap" above. The finished riprap shall be free from objectionable pockets of small stones and clusters of larger stones. Placing riprap in layers will not be permitted. Placing riprap by dumping into chutes or by similar methods likely to cause segregation of the various sizes will not be permitted. The desired distribution of the various sizes of stones throughout the mass shall be obtained by selective loading of the material at the quarry or other source, by controlled dumping of successive loads during final placing, or by other methods of placement which will produce the specified results. Rearranging of individual stones by mechanical equipment or by hand will be required to the extent necessary to obtain a reasonably well graded distribution of stone sizes as specified above.

Underwater Placement. For underwater placement, riprap and bedding shall be placed with a skip bucket or other approved equipment capable of discharging the material underwater with minimum freefall to reduce segregation. Stone shall be placed systematically beginning at the base of slopes. Low spots in stone shall be located by probing, and all low spots shall be thickened as a minimum, to thickness and grade.

Safety Devices. Safety buoys shall be provided at each end of the rock jetty to provide for the safety of the boating public. Each site shall be evaluated to determine the specific requirements.

Appendix 3

Cost Estimates

4 PLANS TO REDUCE FETCH @ WISTER
PRELIMINARY ESTIMATE FOR COST
COMPARISON PURPOSES-UPDATED
6/23/98 TO INCLUDE BOUYS

Designed By: IN HOUSE
Estimated By: IN HOUSE

Prepared By: TED MCCLEARY

Preparation Date: 03/17/98
Effective Date of Pricing: 03/17/98

Sales Tax: 0.00%

M C A C E S G O L D E D I T I O N
Composer GOLD Software Copyright (c) 1985-1994
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Release 5.30A

THIS ESTIMATE IS BASED ON BEING ABLE TO LOWER THE POOL SO THE WORK CAN BE DONE IN THE DRY. TWO FEET OF WATER IS NOT ENOUGH TO USE MARINE EQUIPMENT AND IS JUST ENOUGH TO MAKE A LAND BASED OPERATION RISKY AND EXPENSIVE. POSSIBLE ALTERNATIVES WOULD BE TO BUILD DIKES FROM WHICH TO WORK; BUT EARTHEN DIKES PRESENT REGULATORY PROBLEMS (AND WOULD BE EXPENSIVE SINCE THE BORROW AREA WOULD BE SOME DISTANCE AWAY) , AND ROCK DIKES WOULD SERVE THE PURPOSE OF THE PROPOSED PROJECT.

THE ESTIMATED COSTS ARE FOR A 120 FOOT SPAN OF EACH PROPOSED DESIGN. THE 120 FOOT SPAN WAS CHOSEN AS A COMMON DENOMINATOR FOR THE PURPOSE OF ESTIMATING COMPARABLE LINEAL FOOT UNIT COSTS.

ESTIMATED COST FOR THE FTB ASSUMES THAT USED TIRES CAN BE FOUND WITHIN AN HOURS DRIVE AND WILL BE FREE FOR THE TAKING.

THE UNIT COSTS SHOWN ON SUMMARY PAGE 1 INCLUDE 25% CONTINGENCIES WHILE THOSE SHOWN ON SUMMARY PAGE 3 INCLUDE ONLY OVERHEAD PROFIT AND BOND. SUMMARY PAGE 5 SHOWS DIRECT COST UNIT PRICES. THE OTHER SUMMARY SHEETS ENABLE YOU TO SEE HOW MUCH LABOR COSTS COULD BE SAVED BY USING OUR OWN FORCES.

PLAN NO. 4 (RIPRAP) WAS ADDED ON 15 APRIL. IT IS BASED ON THE USE OF ROCK FROM THE SPIRO QUARRY. A QUOTE FOR $4.80 PER TON AT THE QUARRY WAS GIVEN IN EARLY APRIL. SINCE THAT TIME, I HAVE TRIED TO REACH THE QUARRY AGAIN TO FIND OUT HOW FAR IT IS FROM THE SITE AND HAVE BEEN UNABLE TO GET THROUGH. THE ESTIMATED COST IS BASED ON A HAUL DISTANCE OF 35 MILES AT A COST OF $.15 PER TON-MILE AND ASSUMES THE USE OF A D6 DOZER TO PUSH THE ROCK AT A RATE OF 100 CY/HR. THIS IS STRICTLY GUESS WORK AS I DO NOT KNOW THE SITE LOCATION, QUARRY LOCATION, OR ANYTHING ABOUT THE LOCAL LABOR POOL.

SUMMARY REPORTS SUMMARY PAGE

DETAILED ESTIMATE DETAIL PAGE

No Backup Reports...

* * * END TABLE OF CONTENTS * * *

	QUANTITY UOM	CONTRACT	CONTINGN	TOTAL CST	UNIT COST	MOT
BB BRUSH BUNDLES	120.00 LF	8,649	2,162	10,811	90.09	
BP BRUSH PILES	120.00 LF	9,891	2,473	12,364	103.04	
FT FLOATING TIRES	120.00 LF	10,731	2,683	13,414	111.78	
RR RIP RAP	120.00 LF	12,140	3,035	15,175	126.46	
TOTAL 4 PLANS TO REDUCE FETCH @ WISTER	1.00 EA	41,411	10,353	51,764	51764.25	

	QUANTIT
JNDLES	
	1.0
MENT	1.0
	1.0
TAL	1.0
BUNDLES	120.0
I.ES	
	1.0
IENT	1.0
	1.0
IAL	1.0
PILES	120.0
J TIRES	
	1.0
MENT	1.0
	1.0
.AL	1.0
NG TIRES	120.0
	1.0
IENT	1.0
	1.0
AL	1.0
IP	120.0
IS TO REDUCE FETCH @ WESTER	1.0

** PROJECT INDIRECT SUMMARY - Level 1 **

	QUANTITY UOM	DIRECT	FOOH	HOOH	BOND	PROFIT	TOTAL CST	UNIT COS
BB BRUSH BUNDLES	120.00 LF	6,871	687	189	116	786	8,649	72.0
BP BRUSH PILES	120.00 LF	7,858	786	216	133	899	9,891	82.4
FT FLOATING TIRES	120.00 LF	8,524	852	234	144	976	10,731	89.4
RR RIP RAP	120.00 LF	9,644	964	265	163	1,104	12,140	101.1
TOTAL 4 PLANS TO REDUCE FETCH & WISTER	1.00 EA	32,896	3,290	905	556	3,765	41,411	41411.3
CONTINGENCIES							10,353	
TOTAL INCL OWNER COSTS							51,764	

	QUANTITY UOM	DIRECT	FOOH	HOOH	BOND	PROFIT	TOTAL CST	UNIT C
BB BRUSH BUNDLES								
BB B BUOYS	1.00 EA	300	30	8	5	34	378	377.
BB E EQUIPMENT	1.00 EA	1,635	164	45	28	187	2,059	2058.
BB L LABOR	1.00 EA	2,139	214	59	36	245	2,692	2692.
BB M MATERIAL	1.00 EA	2,797	280	77	47	320	3,521	3520.
TOTAL BRUSH BUNDLES	120.00 LF	6,871	687	189	116	786	8,649	72.
BP BRUSH PILES								
BP B BUOYS	1.00 EA	300	30	8	5	34	378	377.
BP E EQUIPMENT	1.00 EA	3,000	301	83	51	343	3,777	3776.
BP L LABOR	1.00 EA	2,928	293	81	50	335	3,686	3685.
BP M MATERIAL	1.00 EA	1,630	163	45	28	186	2,051	2051.
TOTAL BRUSH PILES	120.00 LF	7,858	786	216	133	899	9,891	82.
FT FLOATING TIRES								
FT B BUOYS	1.00 EA	300	30	8	5	34	378	377.
FT E EQUIPMENT	1.00 EA	1,053	105	29	18	121	1,326	1326.
FT L LABOR	1.00 EA	3,845	385	106	65	440	4,840	4840.
FT M MATERIAL	1.00 EA	3,326	333	91	56	381	4,187	4186.
TOTAL FLOATING TIRES	120.00 LF	8,524	852	234	144	976	10,731	89.
RR RIP RAP								
RR B BUOYS	1.00 EA	300	30	8	5	34	378	377.
RR E EQUIPMENT	1.00 EA	197	20	5	3	23	248	247.
RR L LABOR	1.00 EA	64	6	2	1	7	81	80.
RR M MATERIAL	1.00 EA	9,083	908	250	154	1,039	11,434	11433.
TOTAL RIP RAP	120.00 LF	9,644	964	265	163	1,104	12,140	101.
TOTAL 4 PLANS TO REDUCE FETCH @ WESTER	1.00 EA	32,896	3,290	905	556	3,765	43,411	43411.
CONTINGENCIES							10,353	
TOTAL INCL OWNER COSTS							51,764	

** PROJECT DIRECT SUMMARY - Level 1 **

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMN	MATERIA	HAUL	TOTAL CST	UNIT COST
BB BRUSH BUNDLES	120.00	LF	245	2,702	1,685	2,483	0	6,871	57.25
BP BRUSH PILES	120.00	LF	341	3,609	3,082	1,167	0	7,858	65.48
FT FLOATING TIRES	120.00	LF	429	4,559	1,078	2,888	0	8,526	71.04
RR RIP RAP	120.00	LF	5	206	197	4,461	4,782	9,646	80.38
TOTAL 4 PLANS TO REDUCE FETCH @ WISTER	1.00	EA	1,019	11,076	6,041	10,999	4,782	32,896	32896.10
OVERHEAD								3,290	
SUBTOTAL								36,186	
HOME OFF								905	
SUBTOTAL								37,090	
BOND								556	
SUBTOTAL								37,647	
PROFIT								3,765	
TOTAL INCL INDIRECTS								41,411	
CONTINGENCIES								10,353	
TOTAL INCL OWNER COSTS								51,764	

** PROJECT DIRECT SUMMARY - Level 1 **

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	HAUL	TOTAL CST	UNIT COST
BB BRUSH BUNDLES	120.00	LF	245	2,702	1,685	2,483	0	6,871	57.25
BP BRUSH PILES	120.00	LF	341	3,609	3,082	1,167	0	7,858	65.48
FT FLOATING TIRES	120.00	LF	429	4,559	1,078	2,888	0	8,526	71.04
RR RIP RAP	120.00	LF	5	206	197	4,461	4,782	9,644	80.36
TOTAL 4 PLANS TO REDUCE FETCH @ WISTER	1.00	EA	1,019	11,074	6,041	10,999	4,782	32,896	32896.10

OVERHEAD	3,290
SUBTOTAL	36,186
HOME OFF	905
SUBTOTAL	37,090
BOND	556
SUBTOTAL	37,647
PROFIT	3,765
TOTAL INCL INDIRECTS	41,411
CONTINGENCIES	10,353
TOTAL INCL OWNER COSTS	51,764

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	HAUL	TOTAL CST	UNIT COST
BB BRUSH BUNDLES									
BB B BUOYS	1.00	EA	0	140	0	160	0	300	300.00
BB E EQUIPMENT	1.00	EA	0	0	1,635	0	0	1,635	1635.24
BB L LABOR	1.00	EA	224	2,139	0	0	0	2,139	2138.57
BB M MATERIAL	1.00	EA	21	424	50	2,323	0	2,797	2796.74
TOTAL BRUSH BUNDLES	120.00	LF	245	2,702	1,685	2,483	0	6,871	57.25
BP BRUSH PILES									
BP B BUOYS	1.00	EA	0	140	0	160	0	300	300.00
BP E EQUIPMENT	1.00	EA	0	0	3,000	0	0	3,000	3000.72
BP L LABOR	1.00	EA	320	2,928	0	0	0	2,928	2927.71
BP M MATERIAL	1.00	EA	21	541	82	1,007	0	1,630	1629.61
TOTAL BRUSH PILES	120.00	LF	341	3,609	3,082	1,167	0	7,858	65.48
FT FLOATING TIRES									
FT B BUOYS	1.00	EA	0	140	0	160	0	300	300.00
FT E EQUIPMENT	1.00	EA	0	0	1,053	0	0	1,053	1053.43
FT L LABOR	1.00	EA	404	3,845	0	0	0	3,845	3845.15
FT M MATERIAL	1.00	EA	25	573	24	2,728	0	3,326	3325.89
TOTAL FLOATING TIRES	120.00	LF	429	4,559	1,078	2,888	0	8,524	71.04
RR RIP RAP									
RR B BUOYS	1.00	EA	0	140	0	160	0	300	300.00
RR E EQUIPMENT	1.00	EA	0	0	197	0	0	197	196.77
RR L LABOR	1.00	EA	5	64	0	0	0	64	64.07
RR M MATERIAL	1.00	EA	0	0	0	4,301	4,782	9,083	9082.70
TOTAL RIP RAP	120.00	LF	5	204	197	4,461	4,782	9,644	80.36
TOTAL 4 PLANS TO REDUCE FETCH & WISTER	1.00	EA	1,019	11,874	6,043	10,999	4,782	32,896	32896.10
OVERHEAD								3,290	
SUBTOTAL								36,186	
HOME OFF								905	
SUBTOTAL								37,090	
BOND								556	
SUBTOTAL								37,647	

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMN	MATERIA	HAUL	TOTAL CST	UNIT COST
PROFIT								3,765	
TOTAL INCL INDIRECTS								41,411	
CONTINGENCIES								10,353	
TOTAL INCL OWNER COSTS								51,764	

08 B. BUOYS	QUANTY UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMN	MATERIA	HAUL	TOTAL CST	UNIT COST
WB. BRUSH BUNDLES										
TOTAL BUOYS	1.00 EA			0	140	0	160	0	300	300.00

BB. BRUSH BUNDLES

BB E. EQUIPMENT	QUANTY	UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMN	MATERIA	HAUL	TOTAL CST	UNIT C
BB E. EQUIPMENT											
MIL AA HYD HAMMER, 2501T#					0.00	0.00	2.69	0.00	0.00	2.69	
	12.00	HR	H10LB001	1.00	0	0	32	0	0	32	2.
MIL AA HYD EXCAV,TRK MTD,0.95CY BKT,4X4					0.00	0.00	37.97	0.00	0.00	37.97	
	12.00	HR	H30AK001	1.00	0	0	456	0	0	456	37.
MIL AA CHAINSAW, 31" LONG BAR					0.00	0.00	1.66	0.00	0.00	1.66	
	100.00	HR	C05H0001	1.00	0	0	166	0	0	166	1.
MIL AA TRK,HWY, 7,200GVW,4X4, 3/4 T-PKUP					0.00	0.00	8.24	0.00	0.00	8.24	
	100.00	HR	T50GA007	1.00	0	0	824	0	0	824	8.
UPB AA SMALL TOOLS					0.00	0.03	1.57	0.00	0.00	1.57	
	100.00	HR	XMIXX020	1.00	0	3	157	0	0	157	1.
BB L. LABOR											
MIL AA Outside Equip. Op. Medium					1.00	11.89	0.00	0.00	0.00	11.89	
	12.00	HR	X-EQOPRMED	1.00	12	143	0	0	0	143	11.
MIL AA Outside Laborer (Semi-Skilled)					1.00	8.85	0.00	0.00	0.00	8.85	
	112.00	HR	X-LABORER	1.00	112	991	0	0	0	991	8.
MIL AA Outside Truck Dr. Light					1.00	10.05	0.00	0.00	0.00	10.05	
	100.00	HR	X-TRKDVRLT	1.00	100	1,005	0	0	0	1,005	10.
BB M. MATERIAL											
M MIL AA 6" Wood Piles					0.00	0.00	0.00	2.50	0.00	2.50	
	440.00	LF	N/A	0.00	0	0	0	1,100	0	1,100	2.
CIV AA 1/2"Φ 6x7 Class Bright Wire Rope					0.01	0.19	0.00	0.80	0.00	1.00	
	600.00	LF	SIWSB	331.25	5	116	0	482	0	598	1.
CIV AA 1/2"x6" Jaw & Jaw Turnbuckles					0.17	4.31	0.00	18.58	0.00	22.89	
	33.00	EA	SIWSB	14.88	6	142	0	613	0	755	22.
L MIL AA 10 Gauge Wire					0.01	0.14	0.05	0.10	0.00	0.29	
	1000.00	LF	ULABL	300.00	10	145	50	100	0	295	0
CIV AA 1/2" Dia Wire Rope Clips					0.10	2.56	0.00	3.54	0.00	6.10	
	8.00	EA	SIWSB	25.00	1	21	0	28	0	49	6
TOTAL BRUSH BUNDLES	120.00	LF			245	2,702	1,685	2,483	0	6,871	57

BP E. EQUIPMENT	QUANTY	UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMN	MATERIA	HAUL	TOTAL CST	UNIT C
BP E. EQUIPMENT											
MIL AA CHAINSAW, 31" LONG BAR					0.00	0.00	1.66	0.00	0.00	1.66	
	160.00	HR	C05HD001	1.00	0	0	266	0	0	266	1.
UPB AA SMALL TOOLS					0.00	0.00	1.57	0.00	0.00	1.57	
	80.00	HR	XMIXX020	1.00	0	0	126	0	0	126	1,
USR AA TRK,HWY, 46,000 GVW, 6X4, 3 AXLE					0.00	0.00	30.91	0.00	0.00	30.91	
	80.00	HR	T50GH015	1.00	0	0	2,473	0	0	2,473	30.
MIL AA FLATBED, 8'x 12.0'					0.00	0.00	0.59	0.00	0.00	0.59	
	80.00	HR	T40XX314	1.00	0	0	47	0	0	47	0.
MIL AA DRILL,MOBILE MNG, SELF-CONTAINED					0.00	0.00	7.34	0.00	0.00	7.34	
	12.00	HR	D30IE3C2	1.00	0	0	88	0	0	88	7.
BP L. LABOR											
MIL AA Outside Laborer (Semi-Skilled)					1.00	8.85	0.00	0.00	0.00	8.85	
	240.00	HR	X-LABORER	1.00	240	2,124	0	0	0	2,124	8.
MIL AA Outside Truck Dr. Light					1.00	10.05	0.00	0.00	0.00	10.05	
	80.00	HR	X-TRKDVRLT	1.00	80	804	0	0	0	804	10.
BP M. MATERIAL											
CIV AA 1/2"0 6x7 Class Bright Wire Rope					0.01	0.19	0.00	0.80	0.00	1.00	
	240.00	LF	SIWSB	331.25	2	46	0	193	0	239	1.
CIV AA 1/2" Dia Wire Rope Clips					0.10	2.56	0.00	3.54	0.00	6.10	
	48.00	EA	SIWSB	25.00	5	123	0	170	0	293	6.
B MIL AA Down Guy Anchor					0.50	12.93	3.40	25.00	0.00	41.33	
	24.00	EA	EELEJ	10.00	12	310	82	600	0	992	41.
CIV AA 1/2"Hvy Duty Wire Rope Thimbles					0.10	2.56	0.00	1.84	0.00	4.40	
	24.00	EA	SIWSB	25.00	2	62	0	44	0	106	4.
TOTAL BRUSH PILES	120.00	LF			341	3,609	3,082	1,167	0	7,858	65.

LABOR ID: [illegible] EQUIP ID: [illegible]

FT B. BUOYS	QUANTY	UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMN	MATERIA	HAUL	TOTAL COST	UNIT COST
FT. FLOATING TIRES											
TOTAL BUOYS	1.00	EA			8	140	0	160	0	300	300.00

FT E. EQUIPMENT	QUANTY	UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMN	MATERIA	[illegible]	TOTAL CST	UNIT COST
FT E. EQUIPMENT											
UPB AA SMALL TOOLS					0.00	0.00	1.57	0.00	0.00	1.57	
	370.00	HR	XMIXX020	1.00	0	0	581	0	0	581	1.57
USR AA TRK,HWY, 46,000 GVW, 6X4, 3 AXLE					0.00	0.00	30.91	0.00	0.00	30.91	
	15.00	HR	T50GM015	1.00	0	0	464	0	0	464	30.91
MIL AA FLATBED, 8'x 12.0'					0.00	0.00	0.59	0.00	0.00	0.59	
	15.00	HR	T40XX014	1.00	0	0	9	0	0	9	0.59
FT L. LABOR											
MIL AA Outside Laborer (Semi-Skilled)					1.00	8.85	0.00	0.00	0.00	8.85	
	370.00	HR	X-LABORER	1.00	370	3,275	0	0	0	3,275	8.85
MIL AA Outside Truck Dr. Light					1.00	10.05	0.00	0.00	0.00	10.05	
	15.00	HR	X-TRKDVRLT	1.00	15	151	0	0	0	151	10.05
# MIL AA Used Tires-no material cost					0.03	0.57	0.00	0.00	0.00	0.57	
	740.00	EA	ACARA	50.00	19	420	0	0	0	420	0.57
FT M. MATERIAL											
CIV AA 5/8"D 6x7 Class Bright Wire Rope					0.01	0.30	0.00	1.07	0.00	1.37	
	350.00	LF	SIWRB	217.50	4	106	0	375	0	480	1.37
CIV AA 1/2" Dia Wire Rope Clips					0.10	2.56	0.00	3.54	0.00	6.10	
	30.00	EA	SIWSB	25.00	3	77	0	106	0	183	6.10
CIV AA 1/2"Hvy Duty Wire Rope Thimbles					0.10	2.56	0.00	1.84	0.00	4.40	
	10.00	EA	SIWSB	25.00	1	26	0	18	0	44	4.40
L 5 AA Gr 50 Restmat,Ftgs & Slabs,#3-#6					1.00	22.17	0.00	498.23	0.00	520.40	
	0.01	TON	SIWRC	4.00	0	0	0	5	0	5	520.40
MIL AA Weld Wire Fab in Slabs, 6x6W6					0.01	0.15	0.00	0.11	0.00	0.26	
	40.00	SF	SIWRB	362.50	0	6	0	4	0	10	0.26
MIL AA Pour Slab on Gr,< 6",Crane & Bkt					0.65	11.04	5.44	54.00	0.00	70.48	
	1.50	CY	ALABG	13.75	1	17	8	81	0	106	70.48
MIL AA Misc Castings,Heavy Sect,> 150 #					0.01	0.19	0.01	3.39	0.00	3.59	
	300.00	LB	SIWSC	525.00	2	56	4	1,017	0	1,077	3.59

FT A. MATERIAL	QUANTY UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMNT	MATERIA	HAUL	TOTAL CST	UNIT C
L MIL AA 3" (80mm) Galv Steel Pipe				0.01	0.09	0.00	4.77	0.00	4.86	
	30.00 LF	MPLUE	500.00	0	3	0	143	0	146	4.
L CIV AA 1/2" Dia x 1-1/2"Long Hex Bolts				0.04	1.07	0.00	0.25	0.00	1.32	
	160.00 EA	SIWSA	30.00	7	171	0	40	0	211	1.
L MIL AA 1"Foam Spray,R?.7 Urethane Insul				0.00	0.05	0.01	0.31	0.00	0.37	
	1480.00 SF	APLAE	1000.00	4	72	12	459	0	543	0.
B AF AA Conveyor belting, 3/8" Thick				0.00	0.09	0.00	1.00	0.00	1.09	
	480.00 SF	ACARG	500.00	2	41	0	480	0	521	1.
TOTAL FLOATING TIRES	120.00 LF			429	4,559	1,078	2,888	0	8,524	7?.

RR B. BUOYS	QUANTY UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMN	MATERIA	HAUL	TOTAL CST	UNIT COS
RR. RIP RAP										
TOTAL BUOYS	1.00 EA			0	140	0	160	0	300	300.0

RR E. EQUIPMENT	QUANTY	UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMNT	MATERIA	HAUL	TOTAL CST	UNIT COST
RR E. EQUIPMENT											
UPB AA BLADE, STRAIGHT, HYDR, D-6					0.00	0.00	3.90	0.00	0.00	3.90	
	5.00	HR	T10GA009	1.00	0	0	20	0	0	20	3.90
MIL AA DOZER,CWLR, D-6D,PS					0.00	0.00	35.45	0.00	0.00	35.45	
	5.00	HR	T15CA008	1.00	0	0	177	0	0	177	35.45
RR L. LABOR											
MIL AA Outside Equip. Op. Heavy					1.00	12.81	0.00	0.00	0.00	12.81	
	5.00	HR	X-EQOPRHVY	1.00	5	64	0	0	0	64	12.81
RR M. MATERIAL											
M USR AA Rip Rap, 3/8 CY to 1/4 CY					0.00	0.00	0.00	8.50	9.45	17.95	
Pcs	506.00	CY	CODE K	0.00	0	0	0	4,301	4,782	9,083	17.95
TOTAL RIP RAP	120.00	LF			5	294	197	4,461	4,782	9,644	80.36
TOTAL 4 PLANS TO REDUCE FETCH @	1.00	EA			1,019	11,074	6,041	10,999	4,782	32,896	32896.10

APPENDIX 4

ENVIRONMENTAL CORRESPONDENCE

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
222 S. Houston, Suite A
Tulsa, Oklahoma 74127

March 18, 1998

#2-14-98-I-328

Mr. David Combs
Chief, Environmental Analysis and Compliance Branch
Tulsa District, U.S. Army Corps of Engineers
P.O. Box 61
Tulsa, Oklahoma 74121-0061

Dear Mr. Combs:

This responds to your letter dated March 17, 1998, requesting a list of endangered and threatened species in the Fourche Maline arm of Lake Wister in LeFlore County. The Corps is assisting the Oklahoma Water Resources Board in studying the feasibility of placing breakwater devices (brush boxes) at potential sites to improve water quality in the Fourche Maline arm.

Based on the information submitted, the only listed or proposed threatened or endangered species that may be affected by the breakwater devices is the threatened bald eagle.

If you need further information, please contact Ken Frazier at 918/581-7458, extension 234.

Sincerely,

for Charles M. Scott

Jerry J. Brabander
Field Supervisor

KDF:ag:FA/WISTRSEC22.COE

Oklahoma Historical Society *Founded May 27, 1893*

State Historic Preservation Office • 2704 Villa Prom • Shepherd Mall • Oklahoma City, OK 73107-2441
Telephone 405/521-6249 • Fax 405/947-2918

June 2, 1998

Mr. David Combs, Chief
Environmental Analysis & Support
Tulsa District Corps of Engineers
P.O. Box 61 (CESWT-PL)
Tulsa, OK 74121-0061

RE: File #1334-98; Wister Lake Fetch Reduction Project

Dear Mr. Combs:

We have received and reviewed the documentation submitted concerning the referenced project in LeFlore County.

Examination of historic resource files in this office finds no properties documented within the project area that meet the criteria for listing on the National Register of Historic Places. Our research indicates that there is little likelihood such historic properties will occur.

In addition to review by this office, a review focusing on prehistoric resources by the Oklahoma Archeological Survey is required for determining the presence of National Register quality prehistoric sites. Documentation on any historic archaeological site discovered in the course of archaeological surveys should be submitted to the State Historic Preservation Office for review. This is an integral part of the Section 106 process.

Should the Oklahoma Archeological Survey conclude that there are no prehistoric archaeological sites of National Register quality, and should no historic site have been discovered in the process of survey, the State Historic Preservation Office finds no properties eligible for the National Register of Historic Places within the referenced project boundaries.

Should further correspondence pertaining to this project be necessary, the above underlined file number must be referenced. If you have any questions, please contact Mr. Marshall Gettys, Historical Archaeologist, at 405/521-6381. Thank you.

Sincerely,

Melvena Heisch

Melvena Heisch
Deputy State Historic
Preservation Officer

MH:pm

OKLAHOMA

FRANK KEATING, GOVERNOR
GREG D. DUFFY, DIRECTOR

DEPARTMENT OF WILDLIFE CONSERVATION

1801 N. Lincoln   P.O. Box 53465   Oklahoma City, OK 73152   PH. 521-3

May 11, 1998

Jim Boggs
Tulsa District Corps of Engineers
P.O. Box 61
Tulsa, OK 74121-0061

Subject: Endangered Species Review of Proposed Breakwater Devices to Reduce Suspended Particulates in Lake Wister

Dear Mr. Boggs,

This responds to your request for an endangered and sensitive species impact review with regards to a proposal to install breakwater devices within the Fourche Maline Arm of Wister Reservoir for the purpose of reducing suspended particulates.

We have reviewed the maps and written information provided with regard to this project and compared these with our current records of threatened and endangered species. Based upon this review, it does not appear that this project will result in any negative impact to endangered species or local wildlife populations. A copy of your letter was mailed to David Robertson, the area biologist for the Wister Wildlife Management Area, for his review and comments. If he has any special site-specific concerns, you will receive a separate comment letter from him.

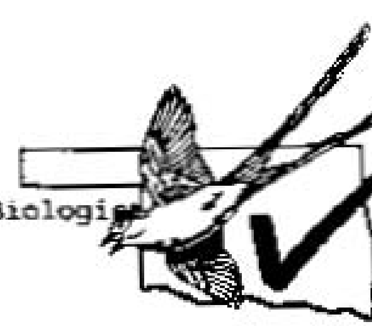
We appreciate the proposed use of brush boxes and brush piles as breakwater devices in this project. In other studies, these structures have demonstrated benefits to fisheries resources through the enhancement of cover/shelter. We therefore support their use in this project.

We appreciate the opportunity to review and provide comments on this study. If you have any questions or need additional information, please contact me at (405) 521-4619.

Sincerely,

Mark D. Howery

Mark D. Howery
Natural Resources Biologist



Implementation of Non-Point Source BMPs in the Fourche Maline Arm of Wister Lake

(C9-996100-05, Task 700)

Oklahoma Water Resources Board

Appendix B

PLANNING ASSISTANCE TO STATES

LAKE WISTER NATIVE PLANT ESTABLISHMENT STUDY

PHASE I REPORT

Prepared for
Oklahoma Water Resources Board
By
U.S. Army Corps of Engineers, Tulsa District

MARCH 1998

LAKE WISTER NATIVE PLANT ESTABLISHMENT STUDY

PHASE I REPORT

INTRODUCTION

Phase I of the Lake Wister Native Plant Establishment Study resulted from a common desire between the U.S. Army Corps of Engineers (USACE) and the Oklahoma Water Resources Board (OWRB) to determine what types of native plants could be planted at Lake Wister to improve water quality and make lake resources more attractive to recreationists and other interests. Lake Wister is located about 2 miles south of the town of Wister in LeFlore County. Oklahoma (see Figure 1). and was completed in May 1949. Project purposes are flood control, water supply, low flow augmentation, water conservation, and sedimentation.

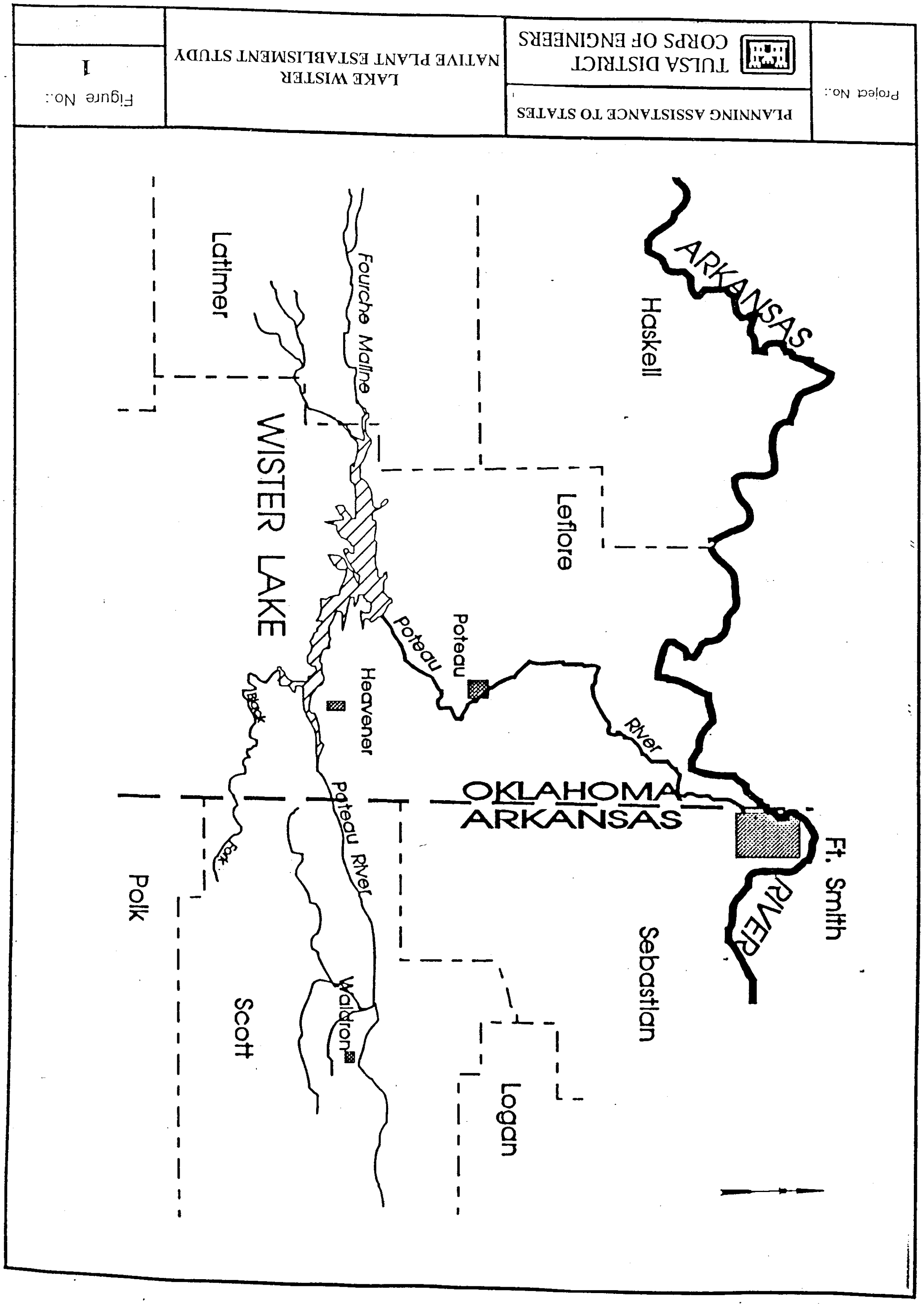
Phase I was conducted by the Tulsa District and the Lewisville Aquatic Ecosystem Research Facility (LAERF), U.S. Army Corps of Engineers, in cooperation with the OWRB. For more information, contact Dr. Robert Doyle or Dr. Gary Dick, U.S. Army Corps of Engineers, Waterways Experiment Station, Lewisville Aquatic Ecosystem Research Facility, RR#3, Box 446, Lewisville, TX 75056, Phone: (972) 436-2215, Email: **rddoyleodgte.net**

AUTHORITY

This study was conducted under authority of Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251), as amended, which authorizes the Secretary of the Army, acting through the Chief of Engineers, to assist states in preparation of comprehensive plans for development, utilization, and conservation of water and related land resources, also known as the Planning Assistance to States program.

Cost sharing for the study was conducted under authority of Section 319 of the Water Resources Development Act of 1990 (Public Law 101 -640), which authorizes the Secretary of the Army to collect fees from non-Federal entities to recover 50% of the cost of a Planning Assistance to States project.

FIGURE I
LAKE WISTER LOCATION MAP



STUDY PARTICIPANTS AND COORDINATION

The Lake Wister Native Plant Establishment Study was conducted by Tulsa District, USACE personnel, assisted by aquatic plant experts from the LAERF, a field research station of the Waterways Experiment Station. The OWRB is a participant in the study and is the non-Federal cost-sharing sponsor for the study.

STUDY OUTLINE AND SCOPE

The Lake Wister Native Plant Establishment study will be conducted in two phases. Phase I consists of the following: Analysis of available water quality and water level data for Lake Wister; site visits by USACE and OWRB personnel to identify specific sites for initial test plantings; and determination of specific native macrophytes to be planted, as well as specification of planting techniques and monitoring protocol.

The Phase I Report is divided into the following four parts: 1) A review of aquatic plant ecology that will describe the three types of aquatic plants commonly found in Oklahoma and Texas and the environmental conditions that most often influence growth and development of aquatic plant communities; 2) A review of the environmental conditions currently present in Lake Wister and how such conditions might help or hinder efforts to establish aquatic plants; 3) A report of site visits made by USACE, LAERF and OWRB personnel to select sites for test plantings; and 4) A description of specific methods to be used by OWRB personnel in implementing test plantings within Lake Wister. This will include plant species selection, specific planting methodologies to be employed, and a description of the monitoring protocol to be used to track the success of the test plantings. The implementation phase will be made by OWRB personnel.

The OWRB will implement the test plantings and the monitoring phase to determine the specific plants most likely to establish within the lake based on the results of Phase I. Phase II will be completed after implementation of test plantings. After monitoring has been completed in July 1998, the USACE and the LAERF will work with OWRB personnel to analyze the results of the test plantings. The USACE and the LAERF will prepare the Phase II Report based on data and information obtained from the monitoring activities.

PROBLEM STATEMENT

Lake Wister is a hyper-eutrophic reservoir with highly elevated levels of suspended solids and nutrients. A U.S. Environmental Protection Agency (EPA) Clean Lakes Phase I Diagnostic/ Feasibility Study conducted by the OWRB from October 1991 through September 1994 has provided evidence of some major problems that need to be addressed to improve water quality in the reservoir. Both watershed and within-lake processes appear to be adversely affecting the water quality of the reservoir.

Control efforts are currently being implemented within the Wister watershed to minimize the impacts of the watershed on the lake's water quality. For example, the Oklahoma Corporation Commission has taken measures to ensure environmental compliance of oil and gas exploration within the lake's watershed. In addition, Best Management Practices (BMP's) that could reduce the impact of the extensive poultry industry within the lake watershed on the lake's water quality are being discussed.

In addition to watershed influences, the Clean Lakes Phase I study also suggested that within-lake sediment resuspension is also a contributing factor to poor water quality. The most heavily-impacted portion of the reservoir with respect to sediment resuspension appears to be the Fourche Maline Arm, where suspended sediments and nutrients are highest. Turbidity within this portion of the reservoir is highly elevated. In fact, the middle 50% distribution of turbidity ranged from 32-61 Nephelometer Turbidity Units (NTU's), and over 75% of the readings exceeded the State's water quality standard of 25 NTU's.

The Clean Lakes Phase I study recommended that efforts be made to reduce sediment resuspension in the lake, especially within the Fourche Maline Arm. Turbidity reduction efforts will obviously improve the water clarity of the lake. In addition, since most of the phosphorus measured within the lake is in a particulate form, it is believed that efforts to reduce turbidity will have the added benefit of nutrient reduction in the water column.

One method recommended for suspended sediment reduction was establishment of a native aquatic plant community within the Fourche Maline Ann. This Section 22 (Planning Assistance to States) study will assist the State in determining optimal sites and methods to establish a diverse aquatic plant community within the Fourche Maline Arm of Lake Wister.

AQUATIC PLANT ECOLOGY

Aquatic plants are those species with special adaptations to survive under water or in shallow flooded soils. Aquatic plants can be classified for many purposes according to their primary zone along a depth gradient from the shoreline to deep water. Emergent aquatic plants are those species commonly found at the edge of the water. These are rooted plants that have stems extending above the water surface and all, or most, of their leaves above the water surface. These plants commonly live in the depth range of 0-30 centimeters (cm) of water. Floating leaved aquatic plants are species that are rooted in water, but have leaves that float at the water surface. Water lilies and several species of pondweed exhibit this type of growth form. These plants commonly live in water depths ranging from 15-100 cm. Finally, submersed aquatic plants are those species that live completely under water. The depth range of these plants is limited by light availability. In very clear systems, they may grow to depths of 10 meters or more, while in very turbid systems they may be entirely absent.

As shown in Table 1, several factors have been identified that limit aquatic plant growth. Although a hierarchy of which factors are most significant is difficult to establish, light is typically considered the most significant single factor limiting both distribution and abundance of submersed plants. However, all factors interact in a complex manner to determine where a given plant community is found and the abundance of the community.

TABLE 1
FACTORS POTENTIALLY LIMITING THE ABUNDANCE AND DISTRIBUTION OF AQUATIC PLANTS

Factor	Specific Concern	Specific Effect
Light	Total quantity of light	Water clarity is the primary variable affecting submersed plant distribution. Emergent and floating-leaved plants are much more tolerant of turbid conditions.
Water Chemistry	Inorganic carbon	Submersed plants get all inorganic carbon from the water; emergent and floating-leaved plants get inorganic carbon from the air.
	Plant macro- and micronutrients (N&P + trace elements)	Will stimulate growth of attached algae (periphyton) and is usually detrimental to submersed plants.
Sediment Chemistry	Plant macro- and micronutrients (N&P + trace elements)	Most rooted aquatic macrophytes appear to obtain nutrients primarily from the sediment in which they are rooted.
Disturbance	Abiotic (wave action and water level fluctuations)	Abiotic disturbances like wave action and water level fluctuations have a negative impact on aquatic plant communities unless such disturbances take place during periods when the plants are dormant.
	Biotic (Herbivory)	Aquatic plants are heavily grazed by numerous organisms (insects, some fish, mammals, etc.), and the impact is negative.

LIGHT AVAILABILITY

Light is the single most significant factor limiting submersed aquatic plant distribution and abundance. The amount of light available to submersed aquatic plants is typically dependent on the transparency of the water. In highly turbid systems, such as Lake Wister, submersed plants may be unable to grow or may be limited to water depths of less than 0.5 meter (m) during the actively growing period.

Light limitation is expressed both in the maximum depth to which plants may grow, as well as the different species that may colonize and thrive under differing regimes of light. Turbid conditions will limit the depth to which plants can grow and favor those that put most of their leaves in an underwater canopy near the water surface.

Light penetration is typically measured with a Secchi disk, though more accurate measurements can be made with an underwater irradiometer (from which light attenuation USACEfficient estimates are generally made). The more turbid the water, the less light transmitted. Low transparency may be the result of suspended inorganic solids (e.g., silt or clay particles), phytoplankton growth, and dissolved organic material.

WATER CHEMISTRY

The two most significant components to water chemistry for plant growth are inorganic carbon (dissolved carbon dioxide, carbonate, and other forms) and dissolved plant macro- or micronutrients. Of these, inorganic carbon is the most significant. Because substances diffuse 10^{-4} more slowly in water than air, concentrations of dissolved carbon dioxide are substantially lower in water than air; therefore, carbon for photosynthesis can be limiting to submersed plants. Some submersed plants overcome this limitation by utilizing bicarbonate as a carbon source. Emergent and floating-leaved plants obtain their carbon dioxide from the atmosphere and are generally unaffected by the inorganic carbon content of the water.

Some plant macronutrients, such as potassium, are taken up by submersed plants predominately from the water. However, most of these nutrients are readily available in surface waters. It is rare that a rooted submersed aquatic plant is limited by the supply of a nutrient (other than carbon dioxide) available only from the water. Most commonly, rooted plants are limited by nitrogen availability and, more rarely, by phosphorus, both of which are more typically taken up from the sediment.

SEDIMENT CHEMISTRY

Like their terrestrial counterparts, most rooted submersed plants can be limited by nitrogen or phosphorus from the sediment. Because nitrogen is lost via denitrification under low oxygen conditions (which is common in flooded soils), nitrogen is typically the nutrient most limiting to submersed plant growth. Water column phosphorus or nitrogen are generally not limiting to the growth of rooted submersed plants other than what might settle to the sediment. However, in some cases excess nutrients in the water column might stimulate the exuberant growth of attached algae (periphyton) which can shade the leaves of submersed plants.

DISTURBANCE

Several mechanisms are responsible for disturbances within a lake environment. Such disturbances can be either abiotic or biotic in origin. Abiotic disturbances in lakes commonly include wave action and water level fluctuations. The level of such disturbances are particularly critical during the active growth period of the macrophytes which occurs from May through October. While well-established populations of aquatic plants are quite resilient to short-term disturbances such as severe storms or high and low water, initial efforts to establish aquatic plants are often complicated by unusual abiotic disturbances. In addition to human activity, biotic disturbances can include herbivory or agitation of the bottom for feeding (e.g., common carp) or nesting (e.g., sunfish). Efforts to establish aquatic plants in other unvegetated reservoirs such as Lake Wister have often been hampered by herbivory from mammals (beaver, nutria, muskrat, etc.) and turtles (especially red-eared sliders) and disturbance by common carp feeding or spawning in shallow water,

ENVIRONMENTAL CONDITIONS IN LAKE WISTER

Initial plant establishment efforts in Lake Wister will need to contend with two primary environmental factors: poor light penetration due to very turbid water and significant water level fluctuations. Also, herbivory may later hinder expansion of established colonies of aquatic plants in the lake. Available data on these factors are reviewed below.

LIGHT AVAILABILITY

Light penetration is often measured as <u>Secchi</u> depth, a factor that is controlled by the amount of <u>turbidity</u> in the water and is commonly reported in NTU's . Turbidity is a measure of the total amount of material in the water column which prevents light penetration. In Lake Wister, turbidity is largely due to suspended clays and silts, although relatively high algal populations also contribute to poor light penetration. As expected, during periods when turbidity in the lake is high, corresponding light penetration is low (see Figure 2).

Lake Wister is a turbid lake (see Figure 3). Turbidity during the EPA Clean Lake Phase I study averaged 52 and 33 NTU's in the Fourche Maline Arm and the Poteau Arm, respectively, Fortunately, seasonal maximum turbidity values occur during the winter and early spring (January-March) when turbidity values can exceed 100 NTU's. This is a period when most aquatic plants are dormant. During most of the growing season, turbidities in the Fourche Maline and Poteau Arms were much lower and ranged between 20-45 NTU's. Water transparency, as measured by Secchi depth, increases during the early summer (see Figure 4). In both 1993 and 1994, there was a significant increase in Secchi depth during May and June when Secchi depths ranged from 40-80 cm. While still turbid, these values are much more in line with values commonly seen in other reservoirs where some aquatic plant communities survive. This early season clearing may facilitate plant growth. Even so, the turbidity in Lake Wister is quite high for submersed aquatic plants.

FIGURE-2
Relationship of Secchi depth to turbidity in Lake Wister, OK.

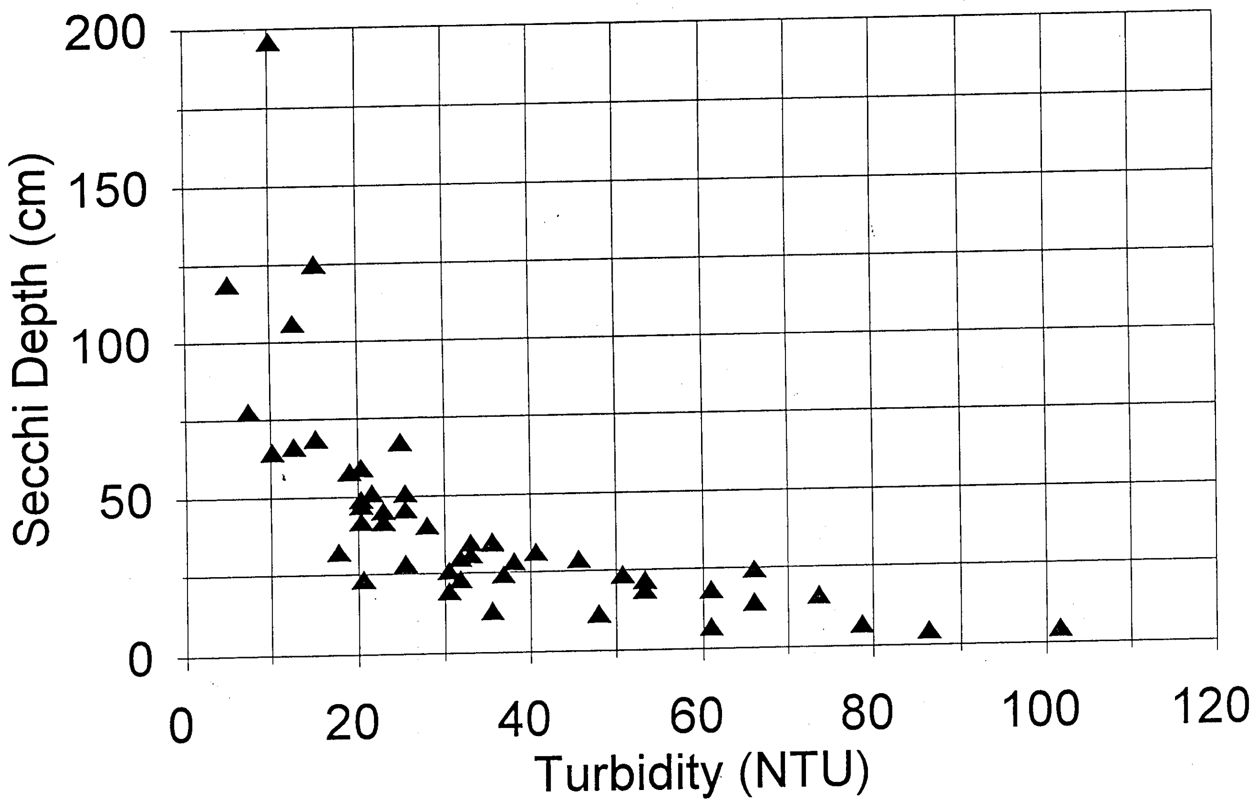


FIGURE-3
Turbidity in the two major arms of Lake Wister
(where most plant restoration efforts are being considered.)

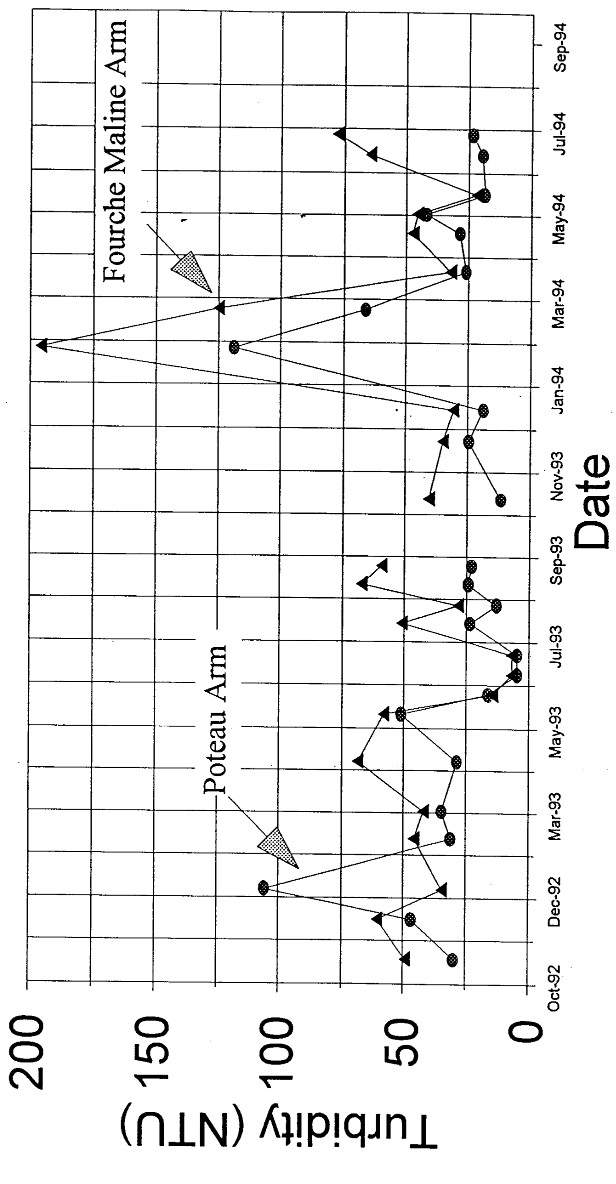
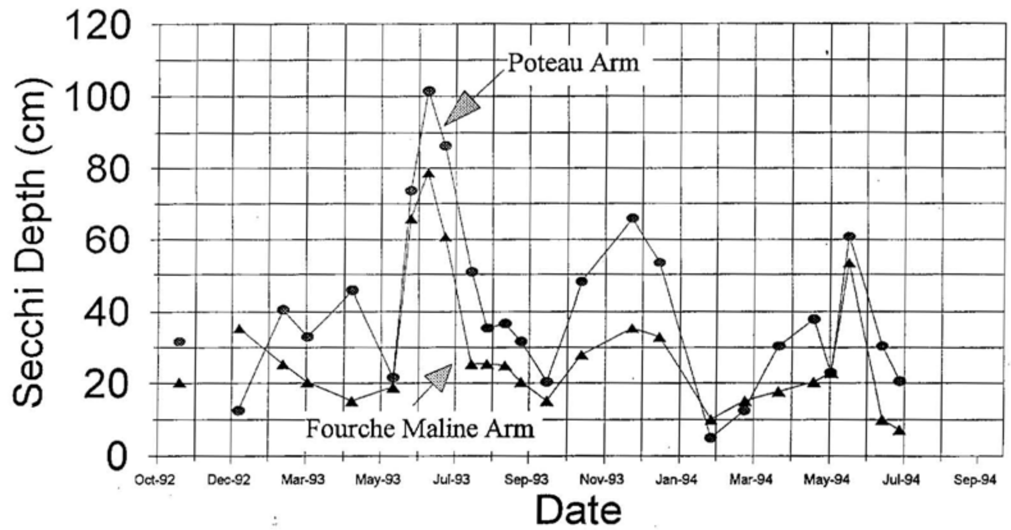


FIGURE-4
Secchi depth in the two major arms of Lake Wister.
(Where most plant restoration efforts are being considered.)



WATER LEVEL FLUCTUATIONS

Lake Wister shows considerable water level fluctuations over the course of the year (see Figure 5). During the winter and early spring (December-April), lake levels usually increase by 14-16 feet and may increase as much as 20 feet. Again, it is fortunate for plant establishment efforts that these spikes in water elevation occur during a period of the year when most aquatic plants are dormant. During most of the growing period (May-September), water levels show considerably less fluctuation (see Figure 6). In fact, significant water level declines during the summer period have been extremely rare over the past 10 years. While aquatic plants can likely survive short-term flooding during the growing season, drawdowns during this period significantly impact the community.

Lake Wister has recently undergone a change in water level management strategy. Over the past several years, the lake's conservation pool has been gradually raised from its original level of 471.6. Recently, the conservation pool has been permanently increased to 478.0. Although water level increases are likely to continue during the winter and early spring due to rains, there may be a flatter pool during the remainder of the year. If so, this water level management will significantly enhance efforts to establish aquatic plants in the lake.

HERBIVORY AND BIOTIC DISTURBANCES

There are no quantitative data on the levels of potential herbivores or other animals that might disturb plant establishment efforts on Lake Wister; however, from a qualitative point of view, it is known that many mammals, birds, reptiles, and fish that can graze or disturb aquatic plants are found within the lake region. These include, but are not limited to: beaver, migratory waterfowl, turtles, and rough fish (common carp, etc.). Because biotic herbivory and disturbance have been significant factors in other plant establishment efforts, initial screening tests should include provisions for protecting transplants during the establishment phase. Ultimately, as plant populations expand, it is expected that biotic disturbances will be less of a factor than during the initial establishment phase.

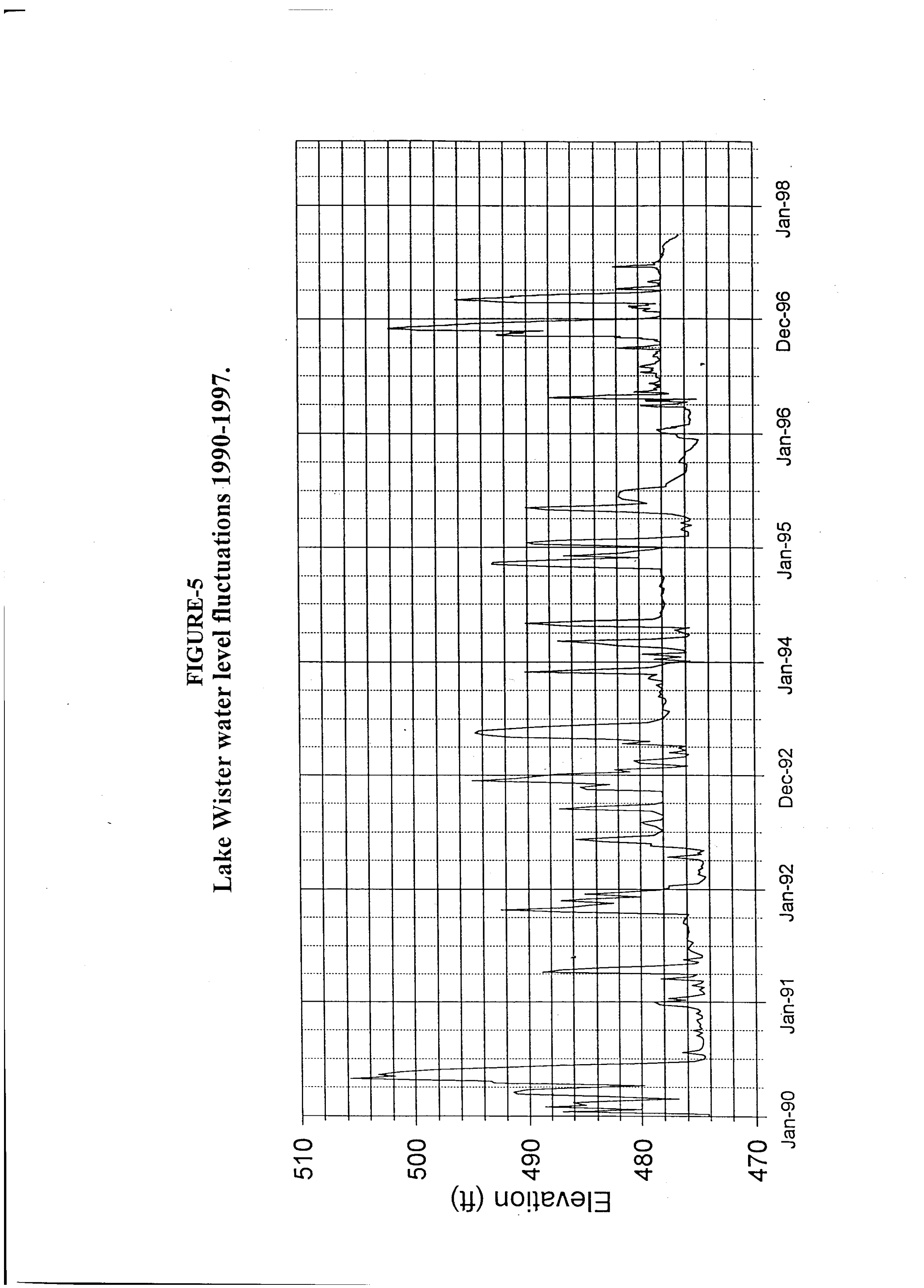


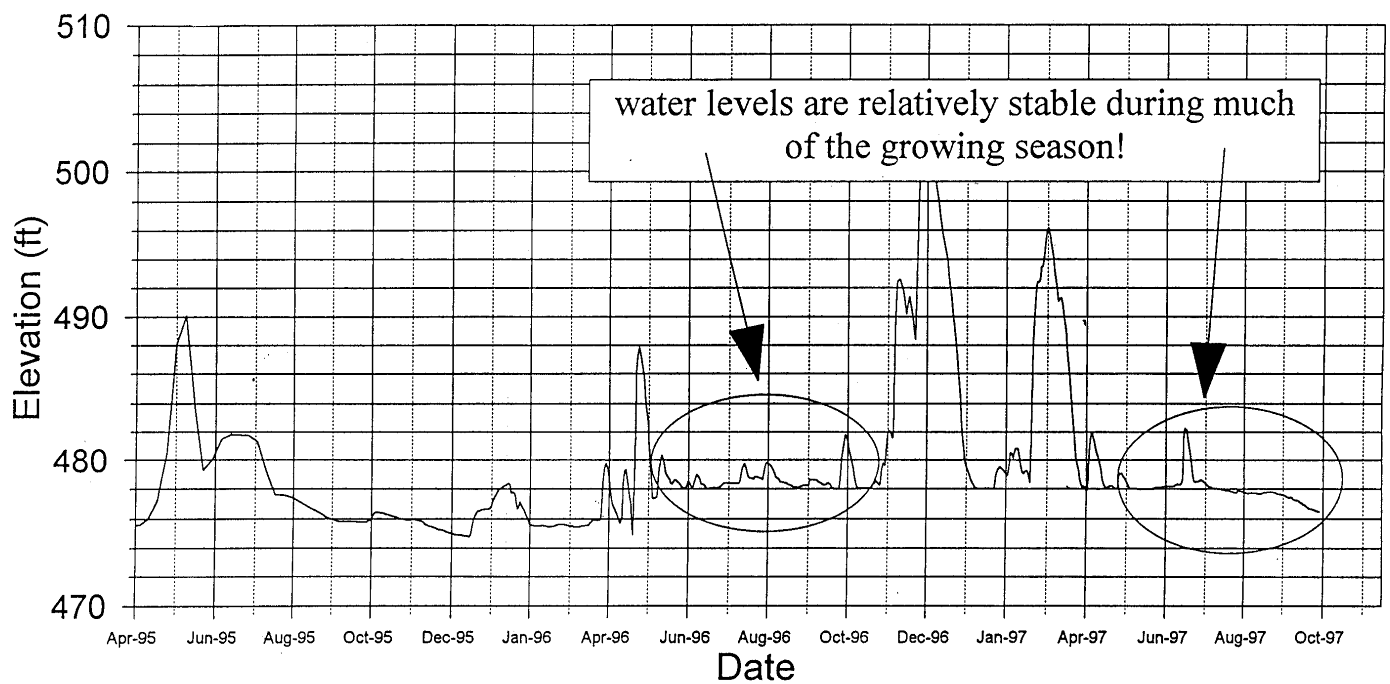
FIGURE-5
Lake Wister water level fluctuations 1990-1997.
Elevation (ft)
510
500
490
480
470
Jan-90
Jan-91
Jan-92
Dec-92
Jan-94
Jan-95
Jan-96
Dec-96
Jan-98

Figure 0.1

FIGURE-6

Lake Wister water levels for 1995-1997

(Note relatively flat pool levels during the summer growing period.)



SELECTING PLANT SITES

Site visits to Lake Wister were conducted on two occasions to select sites for initial test plantings. Site visits on July 17, 1997, and August 28, 1997, were conducted by Dr. Gary Dick (LAERF) and Mr. Paul Koenig (OWRB). Water levels on the reservoir at these times were approximately at conservation pool. These site visits focused on the Fourche Maline Arm of the reservoir since this is the region of primary interest by OWRB. Results of these site visits were very encouraging. The recent increase in pool level for Lake Wister to 478.0 has resulted in extensive shallow water environments within the Fourche Maline Arm that appear suitable for test plantings. Two sites were selected on July 17 and three additional sites were identified on August 28 (see Figure 7). It should be noted that accurate maps of the lake showing the actual shoreline at the new pool level of 478.0 do not exist yet. Available maps, from which Figure 7 was digitized, show the original pool level of 471.6 and the original maximum flood pool of 502.2. The actual shoreline at this time is intermediate between those two levels.

As shown in Figure 7, the following sites were selected for aquatic plantings:

Site 1. Site 1 is a shallow (mean depth <1 m), protected cove, approximately ½ hectare in size located just off the main channel of the Fourche Maline channel. Several desirable shoreline species, such as buttonbush *(Cephalanthus occidentalis)* and creeping burhead *(Echinodorus cordifolius),* were found along the shoreline. Bottom elevations at Site 1 ranged from 478.0 – 475.5

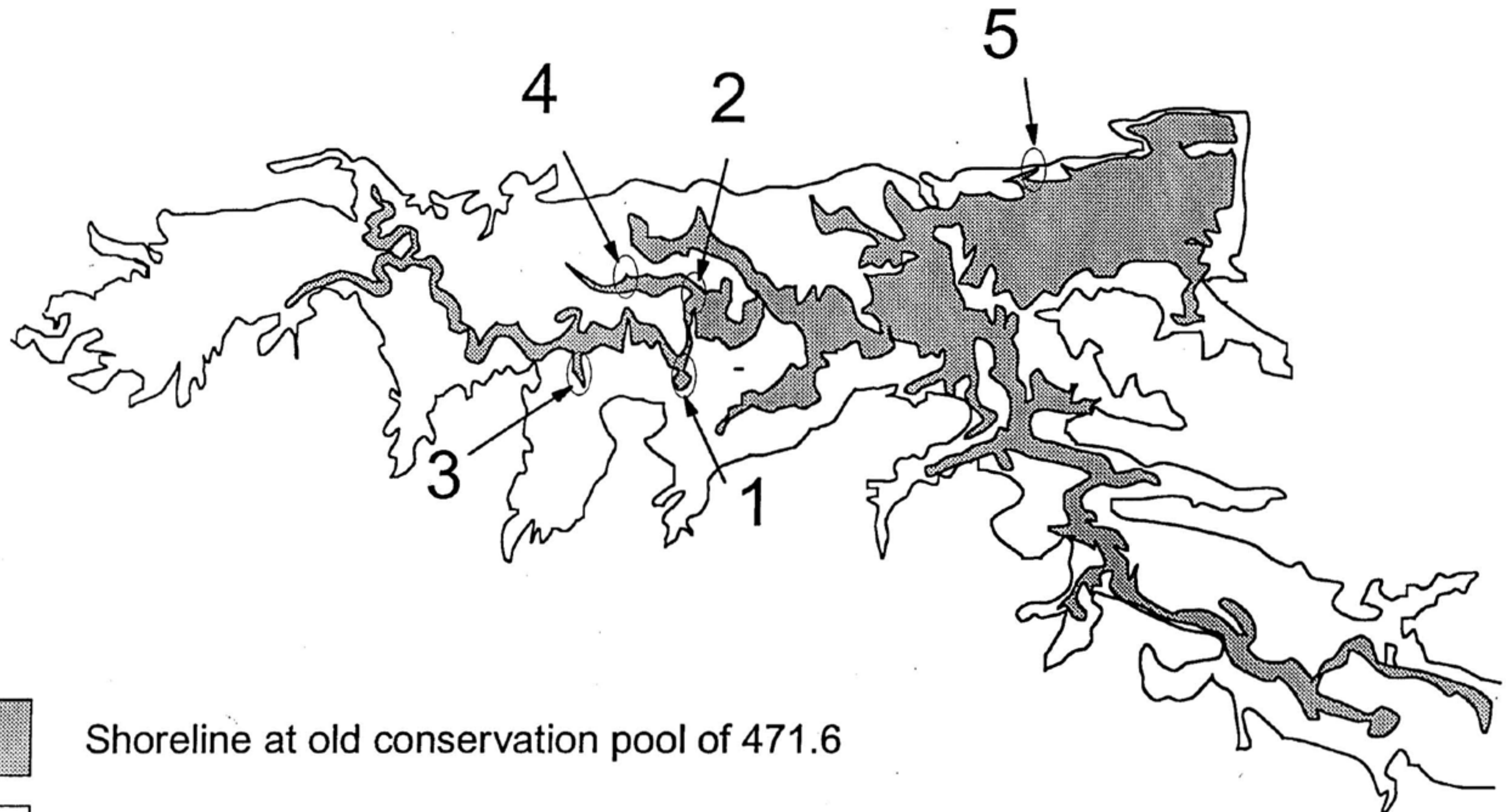
Site 2. Site 2 is a more exposed site with an extensive shallow flat (< I m depth) adjacent to a deeper channel. Buttonbush stands were present along the perimeter of the channel. Bottom elevation at the site selected for planting was about 476.5.

Site 3. Site 3 is another small protected cove off the main Fourche Maline channel. Bottom elevations for the cove again ranged from 478.0-475.5.

Site 4. Site 4 is located upstream from Site 2 along one of the minor inflows to the lake. This is a shallow area with extensive growth of buttonbush. This site is shallower than the others and may be subject to exposure in the event of minor water level drops. Bottom elevations were estimated at 477.5.

Site 5. Site 5 is located in a small cove just off the main body of the reservoir.

FIGURE-7
Lake Wister, Oklahoma
Recommended Aquatic Plant Test Sites



Shoreline at old conservation pool of 471.6

Shoreline at old flood pool of 502.2

RECOMMENDATIONS FOR TEST PLANTINGS

SPECIES AND PROPAGULE TYPE SELECTION

Based on environmental conditions currently present on Lake Wister, test plantings should focus primarily on turbidity-tolerant plant species which show a herbaceous-perennial life history.

The high water periods during the winter and early spring on Lake Wister dictate utilizing plants with an herbaceous-perennial life history. Herbaceous-perennial plants are those that survive for many years (as opposed to annual species which survive only one year), but that are dormant through the winter period (as opposed to evergreen-perennial species which are metabolically active throughout the year). Herbaceous-perennial plant species can overwinter as tubers within the sediments or as dormant root crowns. Focusing efforts on plants with this life history will maximize the probability of long-term success because the plant communities will be able to build up mass from year to year (due to the fact that they survive for multiple years). In addition, the dormant winter stage will be important because of the extensive water level increases common during the winter and early spring. Evergreen perennial species would be unlikely to survive these periods of deep flooding, since they would be metabolically active at that time. Herbaceous-perennial species will be dormant at times of floods and should survive those periods.

Because of very high levels of turbidity, the plants selected should also be tolerant of turbid conditions. Aquatic plants with emergent leaves or those which have leaves that float at the water surface would be most likely to survive the turbid conditions of Lake Wister. However, because of the excellent wildlife value and ability to colonize deeper water, some submersed species can also be planted during the test planting phase, although the potential for success with these species is considered low.

Finally, because of the poor environmental conditions present within the take, plantings should utilize propagule type with large energy reserves, such as mature, well established transplants or large dormant tubers. Tubers are dormant "potato-like" structures formed by some species as an overwintering propagule. These structures have rich energy reserves from which the plant re-grows when environmental conditions are favorable. Previous research at the LAERF has clearly demonstrated that plant establishment efforts utilizing less vigorous types of propagules (e.g., seed or poorly-established plant fragments) have very low levels of success even under good conditions. Table 2 provides a list of plant species that meet these criteria.

TABLE 2
RECOMMENDED PLANT SPECIES AND PROPAGULE TYPES FOR TEST PLANTINGS

Plant Name	Plant Type	Propagule Type
Justicia americana (American waterwillow)	Emergent plant which. tolerates water fluctuations	Mature, well-established shed transplant
Scirpus validus (bulrush)	Emergent shoreline plant which forms dense colonies	Mature, well-established transplant
Echinodorus beteroi (burhead)	Emergent shoreline plant	Mature, well-established transplant
Echinodorus cordifolius (creeping burhead)	Emergent shoreline plant (some already present at Site 1)	Mature, well-established transplant
Sagittaria graminae (bull-tongue arrowhead)	Emergent plant which tolerates water fluctuations and depths to about 20 cm during growing season	Mature, well- establ1 shed transplant
Heteranthera dubia (water-star grass)	Submersed plant which can develop emergent leaves during low-water periods	Mature, well-established transplant
Potamogeton nodosus (American pondweed)	Floating-leaf plant with high wildlife value and tolerant of water level fluctuations	Mature, well-established transplant or dormant winterbuds (tubers)
Nymphaea odorata (white waterlily)	Floating-leaf water lily	Mature, well-established transplant
Nuphar lutea (spatterdock)	Floating-leaf water lily	Mature, well-established transplant
Potamogeton pectinatus (Sago pondweed)	Submersed plant with high wildlife value reported to be turbidity tolerant	Dormant tuber
Vallisneria americana (wild celery, variety which forms tubers)	Submersed plant with high wildlife value reported to be turbidity tolerant	Dormant tuber or mature, well-established transplant

PLANTING METHOD

For difficult environments such as Lake Wister, planting only plants with larger energy reserves such as mature transplants or dormant tubers is strongly recommended**.** Mature transplants are "potted" plants, aquatic species grown **to** root-bound conditions in half-gallon to one-gallon pots. The energy stored in the root systems of these transplants is enough to withstand planting shock and most environmental stresses that may occur following planting. The LAERF has well-established stocks of all of the plants listed in Table 2.

Extreme care should be taken to ensure accurate planting depth. Specific planting depth is dependent upon species, with shallower water (0. 1-0.3 m) selected for emergent species, moderate depths (0.3-0.5 m) for floating-leaved species, and deeper water (0.3-0.6 m) for submersed species. All depths reported are relative to mean water level during the growing season (478.0 for Lake Wister).

To plant mature transplants in the field, holes should be dug in the sediment that are roughly the size of the root mass of the transplant. The plant and roots should be removed from the pot and placed in the hole. Care must be taken not to bury the root mass too deeply in the sediment since this can result in death or delayed growth. Backfilling and pressing the root mass into the sediments will ensure anchoring.

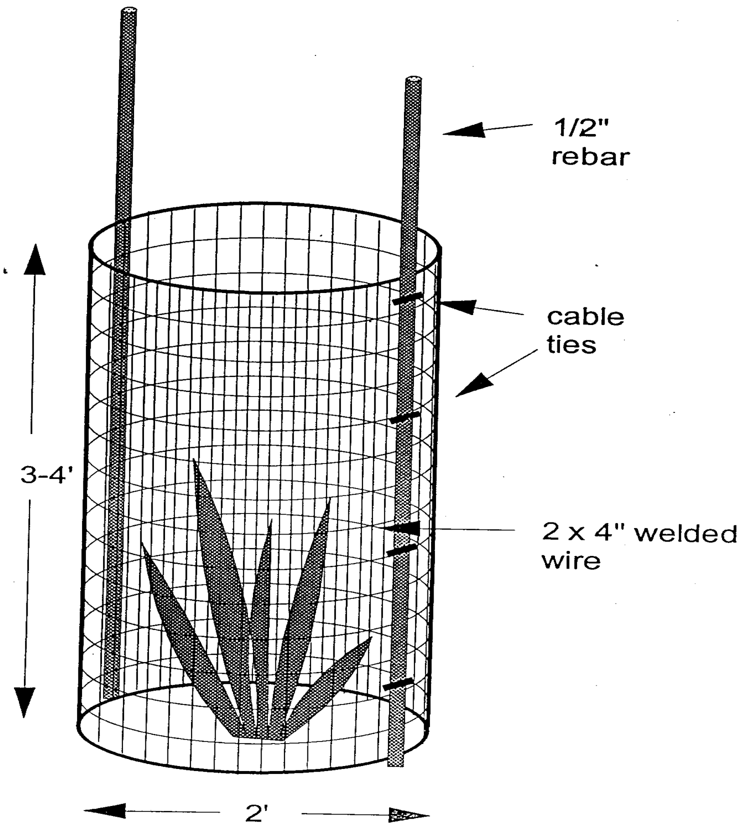
To protect from herbivory, a small cage should be installed around each transplant (see Figure 8). Cages constructed from 2 inch by 4 inch, 14-gauge weld wire have proven adequate in protecting plants in other lakes. Each cage should be anchored with two pieces of rebar to prevent tipping over. Placement of cages will minimize grazing by large herbivores and allow the transplants to establish within a protective boundary. Once plants are established, spread from the cages should occur. If herbivore densities are so high that they prevent this spread, additional, large-scale protection may be required. Monitoring over several months following initial establishment in the field is generally enough to determine the likely degree of protection required for larger scale efforts.

MONITORING METHOD

Monitoring of test plantings will be essential to determining species and sites that will offer maximum potential for larger scale success. This monitoring will be conducted by OWRB personnel and should be conducted approximately monthly during and after plantings are made until late October, when the plants can be expected to go dormant. Monitoring should resume in the spring of 1998 as soon as lake levels return to the 478.0 level.

Monitoring should be conducted on each planting unit individually. At each site, location maps of each plant propagule planted should be made so that these can be easily identified in subsequent visits. In addition, each planting site should have a field tag associated with the planting to confirm the identity of the planting unit when monitoring is done.

FIGURE-8
Design of "tomato cage" exclosure.



Monitoring should be conducted to document the survival, establishment and growth of' the plants as follows:

a. **Is the plant still surviving?** This is basically a presence/absence record. Each exclosure (tomato cage) must be visited individually and the presence or absence of the plant verified. In some cases, because of the turbid water, the plants may not be visible from the surface and it may be necessary to reach down into the exclosure and "feel" for the plant in the exclosure.

b. **Is the plant growing within the exclosure?** If the plant is present, the next level of information is whether there is evidence of plant growth and development within the exclosure. Because the planting units occupy only about 25% of the surface area within each tomato cage exclosure, there is considerable room for the plants to grow before becoming subject to herbivore pressure (which may occur once the plant begins to grow outside the exclosure). A semi-quantitative ranking system is usually used based on an estimate of the percent of the area within the tomato cage exclosure covered by the plant. This value ranges from 0-100%. Since the original planting units occupy about 25% of the surface area, values of about 125% indicate that there is about as much plant material there as originally planted. Values above 25% indicate positive growth and that the plant is developing normally. Values below 25% indicate that there may be problems with that planting unit. Under good growth conditions, most aquatic plants rapidly expand to fill the exclosure within the first 8-10 weeks of growth in the field.

c. **Is the plant expanding outside the exclosure?** The final piece of information that the test planting can provide is if and how quickly the plants begin to grow outside the exclosure. Growth inside the exclosure represents the potential for growth under ambient environmental conditions but without herbivore or disturbance pressures. Expansion outside the exclosure is evidence that the plant species in question not only can survive, but will be capable of positive growth outside of protected enclosures. Expansion outside the exclosure is recorded as radial distance from the outside edge of the exclosure. As the plant patch expands, this can later be recorded as an estimate of patch shape (which is usually roughly circular) and diameter. This will allow estimates of the expansion rate and provide information on how closely together plants must be planted to achieve solid cover.

SUMMARY AND CONCLUSIONS

As part of this Phase I study, five sites were selected from available areas at Lake Wister for test plantings of aquatic species. The selected sites were in the area of the Fourche Maline Arm of the reservoir which was the region of primary interest to the OWRB The sites were determined to be the most propitious for establishment of selected aquatic vegetation. Two sites were selected during a July 17, 1997, field visit and the remaining three during an August 28, 1997, field visit. The results of plant monitoring will be incorporated in a Phase II report.

It is the recommendation of this study that the aquatic vegetation selected by the LAERF be planted at the designated sites. It is further recommended that a program of monitoring of the plants' progress be conducted by the OWRB.

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PLANNING ASSISTANCE TO STATES

LAKE WISTER NATIVE PLANT ESTABLISHMENT STUDY

PHASE II REPORT

Prepared for
Oklahoma Water Resources Board
By
U.S. Army Corps of Engineers, Tulsa District

December 1998

LAKE WISTER NATIVE PLANT ESTABLISHMENT STUDY

PHASE II REPORT

INTRODUCTION

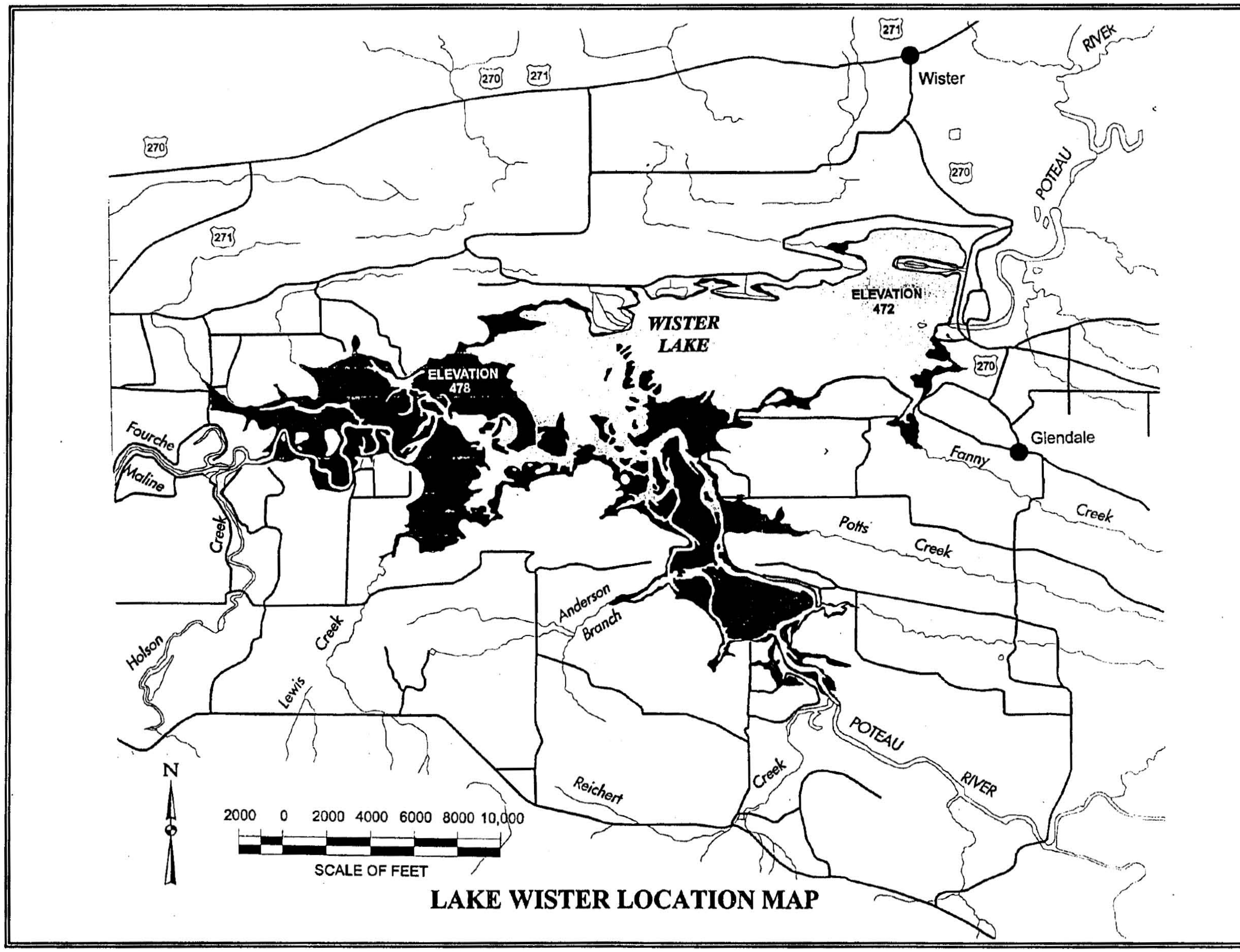
The Lake Wister Native Plant Establishment Study resulted from a common desire between the U.S. Army Corps of Engineers (USACE) and the Oklahoma Water Resources Board (OWRB) to determine what types of native plants could be planted at Lake Wister to improve water quality and make lake resources more attractive to recreationists and other interests. Lake Wister is located about 2 miles south of the town of Wister in LeFlore County, Oklahoma (see Figure 1), and was completed in May 1949. Project purposes are flood control, water supply, low flow augmentation, water conservation, and sedimentation.

This study was conducted by the U.S. Army Corps of Engineers, Tulsa District and the Lewisville Aquatic Ecosystem Research Facility (LAERF) in cooperation with the OWRB For more information, contact Dr. Robert Doyle or Dr. Gary Dick, U.S. Army Corps of Engineers, Waterways Experiment Station, Lewisville Aquatic Ecosystem Research Facility, RR#3, Box 446, Lewisville, TX 75056, Phone: (972) 436-2215, Email: rddoyle@gte.net

AUTHORITY

This study was conducted under authority of Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251) which is also known as the Planning Assistance to States program. Section 22 authorizes the Corps of Engineers to assist states in the preparation of comprehensive plans for development, utilization, and conservation of water and related land resources.

Cost sharing for the study was conducted under authority of Section 319 of the Water Resources Development Act of 1990 (Public Law 101-640), which authorizes the Secretary of the Army to collect fees from non-Federal entities to recover 50% of the cost of a Planning Assistance to States study.



Wister
Glendale
WISTER LAKE
ELEVATION 472
ELEVATION 478
270
271
POTEAU RIVER
Fanny Creek
Potts Creek
Anderson Branch
Reichert Creek
Lewis Creek
Holson Creek
Fourche Maline
N
2000 0 2000 4000 6000 8000 10,000
SCALE OF FEET
LAKE WISTER LOCATION MAP

FIGURE 1

STUDY PARTICIPANTS AND COORDINATION

The Lake Wister Native Plant Establishment Study was conducted by Tulsa District, USACE personnel, assisted by aquatic plant experts from the LAERF, a field research station of the Waterways Experiment Station. The OWRB is a participant in the study and is the non-Federal cost-sharing sponsor for the study.

STUDY OUTLINE AND SCOPE

The Lake Wister Native Plant Establishment Study was conducted in two phases. Phase I determined specific plants most likely to establish within the lake and consisted of the following 1) an overview of aquatic plant ecology; 2) an evaluation of current ecological conditions within Lake Wister to support aquatic plants; 3) results of site visits conducted by LAERF, USACE, and OWRB personnel to select test planting sites; and 4) a description of specific methods to be used by OWRB personnel in implementing test plantings within Lake Wister. The OWRB conducted the test plantings and the monitoring phase based on the results of Phase I.

Phase II consisted of monitoring the test aquatic plantings. The actual test plantings were not part of the Phase I or Phase II studies, but were funded separately. Phase II monitoring was conducted by LAERF and OWRB personnel after the test aquatic species were planted. The monitoring activities were completed in June 1998. The observations and data collected from the aquatic plant monitoring activities are included in this Phase II report.

PROBLEM STATEMENT

Lake Wister is a hyper-eutrophic reservoir with highly elevated levels of suspended solids and nutrients. A U.S. Environmental Protection Agency Clean Lakes Phase I Diagnostic/ Feasibility Study conducted by the OWRB from October 1991 through September 1994 provided evidence of some major problems that need to be addressed to improve water quality in the reservoir. Both watershed and within-lake processes appear to be adversely affecting the water quality of the reservoir.

Control efforts are currently being implemented within the Wister watershed to minimize the impacts of the watershed on the lake's water quality. For example, the Oklahoma Corporation Commission has taken measures to ensure environmental compliance of oil and gas exploration within the lake's watershed. In addition, Best Management Practices (BMP's) that could reduce the impact of the extensive poultry industry within the lake watershed on the lake's water quality are being discussed.

In addition to watershed influences, the Clean Lakes Phase I study suggested that within lake sediment resuspension is a contributing factor to poor water quality. The most heavily impacted portion of the reservoir with respect to sediment resuspension appears to be the Fourche Maline Arm, where suspended sediments and nutrients are highest. Turbidity within this portion of the reservoir is highly elevated. In fact, the middle 50% distribution of turbidity ranged from 32-61 Nephelometer Turbidity Units (NTU's), and over 75% of the readings exceeded the State's water quality standard of 25 NTU's.

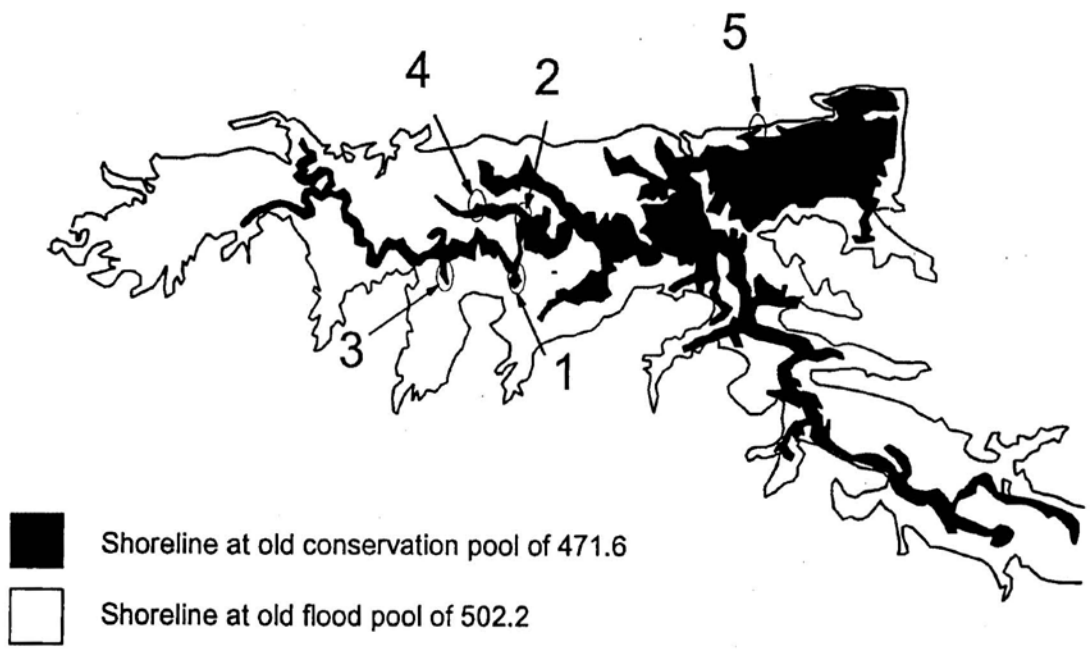
The Clean Lakes Phase I study recommended that efforts be made to reduce sediment resuspension in the lake, especially within the Fourche Maline Arm. Turbidity reduction efforts will obviously improve the lake's water clarity. In addition, since most of the phosphorus measured within the lake is in a particulate form it is believed that efforts to reduce turbidity will have the added benefit of nutrient reduction in the water column. One method recommended for suspended sediment reduction was establishment of a native aquatic plant community within the Fourche Maline Arm.

Efforts are currently underway to determine the feasibility of establishing native aquatic macrophytes in Lake Wister. The primary objective of these establishment efforts is to improve water quality by lowering turbidity and nutrient concentrations within the water column.

OWRB personnel conducted the suggested test plantings and subsequent monitoring based on the Phase I report and verbal recommendations from LAERF. Following is an evaluation of the test planting data.

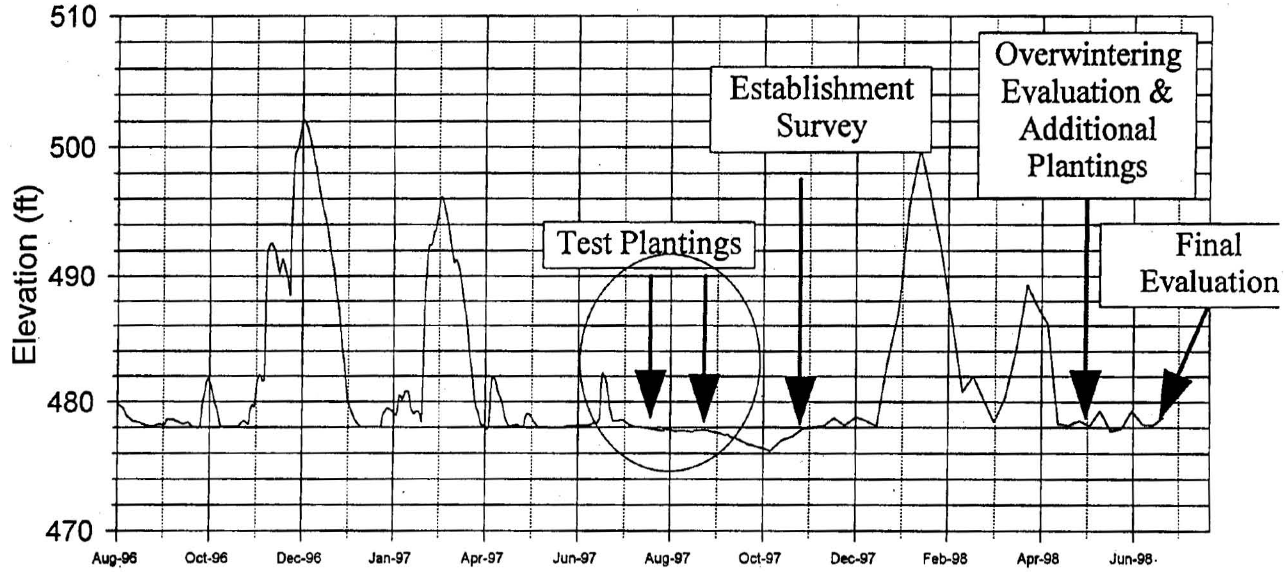
BACKGROUND

Lake Wister site visits were made on July 17 and August 28, 1997, by Dr. Gary Dick (LAERF) and Mr. Paul Koenig (OWRB) to select initial test planting sites and conduct test plantings. The five sites selected for test plantings are shown in Figure 2. Sites I and 2 were selected on the July 17 site visit, and sites 3, 4, and 5 were selected on the August 28, 1997, site visit. Site selection focused on the Fourche Maline Arm of the reservoir because that is the most turbid region of the lake and of primary interest to OWRB The recent increase in the top of the Lake Wister conservation pool level to 478.0 has created extensive shallow water environments within the Fourche Maline Arm which appear suitable for test plantings. Reservoir water levels during those site visits were at approximately elevation 478.0 (see Figure 3). A brief description of the five selected planting sites follows:



PLANTING SITE LOCATIONS

FIGURE 2



WATER LEVELS ON LAKE WISTER
DURING TEST PLANTING PERIOD

FIGURE 3

Site 1 is a shallow protected cove with a mean depth of less than 1 meter. It covers approximately 50 acres and is located just off the main channel of the Fourche Maline channel as shown in Figure 2. Several desirable shoreline species, such as buttonbush *(Cephalanthus occidentalis)* and creeping burhead *(Echinodorus cordifolius)*, were found along the shoreline near the site. Bottom elevations at Site 1 ranged from 478.0 to 475.5 feet mean sea level.

Site 2 is more exposed than Site 1 and has extensive shallow mud flats with a water depth of less than one meter. It is adjacent to a deeper channel. Buttonbush stands were present along the perimeter of the channel. Bottom elevation at the site selected for planting was about 476.5.

Site 3 is another small protected cove off the main Fourche Maline channel. Bottom elevations for the cove again ranged from 478.0-475.5.

Site 4 is located upstream from Site 2 along one of the minor inflows to the lake. This is a shallow area with extensive growth of buttonbush. This site is shallower than the others and may be subject to exposure in the event of minor water level drops. Bottom elevations were estimated to be 477.5.

Site 5 is located in a small cove just off the main body of the reservoir.

Selection of Species and Propagule Types. The plant species selected are turbidity tolerant and herbaceous-perennial and are suitable for current environmental conditions at Lake Wister. The high water periods during the winter and early spring on Lake Wister require plants with a herbaceous-perennial life history. Herbaceous-perennial plants are those that survive for many years (as opposed to annual species which survive only one year), but are dormant through the winter period (as opposed to evergreen-perennial species which are metabolically active throughout the year). Herbaceous-perennial plant species can overwinter as tubers within the sediments or as dormant root crowns. Focusing efforts on plants with this life history will maximize the probability of long-term success because the plant communities will be able to build up mass from year to year (due to the fact that they survive for multiple years). In addition, the dormant winter stage will be important because of the extensive water level increases common during the winter and early spring (See Figure 1). Evergreen perennial species would be unlikely to survive these periods of deep flooding, since they would be metabolically active at that time. Herbaceous-perennial species will be dormant during periods of floods and should survive those periods.

The selected plants were those tolerant of turbid conditions because of the very high levels of turbidity within Lake Wister. Aquatic plants with emergent leaves or those that have leaves that float at the water surface are most likely to survive the turbid conditions of Lake Wister. However, although the potential for success with submersed species was considered low, some submersed species were also planted during the test planting phase because of their excellent wildlife value and ability to colonize deeper water.

Finally, the selected plantings utilized propagule types with large energy reserves, such as mature containerized transplants and large dormant tubers, because of the poor environmental conditions within the lake. Tubers are dormant "potato-like" structures formed by some species as an overwintering propagule. These structures are dormant and have rich energy reserves from which the plant re-grows when environmental conditions are favorable. Previous research at LAERF has clearly demonstrated that plant establishment efforts utilizing less-vigorous types of propagules (e.g., seed or poorly-established plant cuttings) have very low levels of success even under good conditions. Table I provides a list of plant species and propagule types that were used for the test plantings in Lake Wister.

TABLE 1
TEST PLANTING SPECIES AND PROPAGULE TYPES

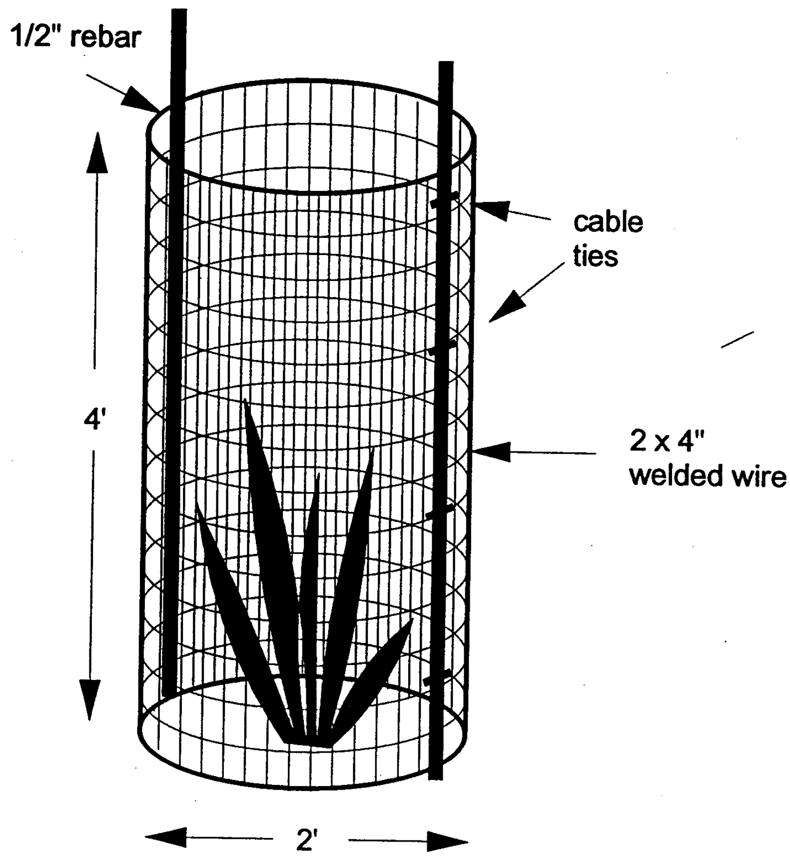
Plant Name	**Plant Type**	**Propagule Type Used**
Justicia americana (American waterwillow)	Emergent plant which tolerates water fluctuations	Containerized transplants, Summer 97, Stem cuttings, Spring 98
Scirpus validus (bulrush)	Emergent shoreline plant (forms dense colonies)	Containerized transplants, Summer 97
Echinodorus beteroi (burhead)	Emergent shoreline plant	Containerized transplants, Summer 97
Echinodorus cordifolius (creeping burhead)	Emergent shoreline plant (some already present at Site 1)	Containerized transplants, Summer 97
Sagittaria sp. (bull-tongue arrowhead)	Emergent plant which tolerates water fluctuations and depths to about 20 cm during growing season	Containerized transplants, Summer 98 & Spring 98
Eleocharis sp. (Flatstem spikerush)	Prolific shoreline emergent plant which spreads quickly	Containerized transplants, Spring 98
Juncus sp. (Soft rush)	Prolific shoreline emergent plant which spreads quickly	Bare-root clumps, Spring 98
Potamogeton nodosus (American pondweed)	Floating-leaf plant with high wildlife value and tolerant of water level fluctuations	Containerized transplants, Summer 97

TABLE 1 (Continued) TEST **PLANTINGS SPECIES AND PROPAGULE TYPES**		
Plant Name	**Plant Type**	**Propagule Type Used**
Nymphaea odorata (white waterlily)	Floating-leaf water lily	Containerized transplants, Summer 97 & Spring 98
Heteranthera dubia (water-star grass)	Submersed plant which can develop emergent leaves in shallow water	Containerized transplants, Summer 97
Potamogeton pectinatus (Sago pondweed)	Submersed plant with high wildlife value reported to be turbidity tolerant	Dormant tuber, Summer 97
Vallisneria americana (wild celery)	Submersed plant with high wildlife value reported to be turbidity tolerant	Containerized transplants, Summer 97
Elodea canadensis (American elodea)	Submersed plant	Containerized transplants, Spring 98

Planting Methods. The specific planting depth varied with plant species, but care was taken in all cases to ensure accurate planting depths. Shallow water depths ranging from 0. 1 to 0.3 meters were selected for emergent species; moderate depths of 0.3 to 0.5 meters were selected for floating leaved species. Deeper water depths ranging from 0.3 to 0.6 meters were selected for submersed species. All depths are relative to the mean growing season water level which is 478.0 for Lake Wister.

Holes that were roughly the size of the root mass of the transplant were dug in the bottom sediments. The plant and roots were removed from the pot and placed in the sediment hole. Care was taken not to bury the root mass of the plant too deeply in the sediments because that could result in delayed growth or death. The root mass of each plant was pressed into the sediments, and the sediment hole around the plant was backfilled to ensure adequate anchoring,

A small cage similar to the device shown in Figure 4 was installed around each vegetative unit that was planted during the summer of 1997 to protect the plant from herbivory damage. The cages were constructed from 2 inch by 4 inch 14-gauge weld wire and were anchored with two pieces of rebar to prevent the cage from tipping over.



TYPICAL PLANTING CAGE DESIGN

FIGURE 4

Additional plantings were made during April 1998. Some initial plants that were established during the previous summer and placed in the exclosures failed to survive, so the dead plants were replaced with new containerized transplants. Some aquatic species were also planted in April 1998 without herbivore protection. Several dozen cuttings of Justicia *americana* were planted at various sites because of the availability of cuttings during this survey

AQUATIC PLANT MONITORING

Monitoring Method. Monitoring was conducted for each planting unit. Maps were drawn to show the location of each plant propagule at each site to ensure easy plant identification during the monitoring phase. When monitoring was completed, a field tag was left at each planting site to confirm the identity of the planting unit. The monitoring was conducted to document the survival, establishment, and growth of the plants.

Monitoring of the test plantings was conducted by OWRB and LAERF personnel three times following the initial planting efforts in July and August 1997 (Figure 1). The first monitoring effort was made in late October before the plants went dormant to document the effectiveness of short-term establishment (Establishment Survey). Monitoring resumed in April 1998 as soon as lake levels returned to the 478.0 level (Overwintering Evaluation). A final evaluation was conducted in June 1998. Several questions were asked during the monitoring phase:

a) Is the plant surviving? This was basically a record to determine if the plant survived. Each planting location was individually surveyed, and the presence or absence of the plant was verified. In some cases, the plants were not visible from the surface because of the turbid water and it was necessary to reach down into the exclosure and "feel" for the plant.

b) Is the plant growing within the exclosure? If the plant was present, the next level of information was whether there was evidence of plant growth and development within the exclosure. The planting units occupied only about 25% of the surface area within each tomato cage exclosure at the time of initial planting; consequently, considerable room existed for the plants to grow before becoming subject to herbivore pressure which could occur once the plant began to grow outside the exclosure. The approximate percentage of the tomato cage covered by plants was recorded for each planting unit. Since the original planting units occupied about 25% of the surface area, values of about 25% indicate that there was only as much plant material as was originally planted. Values above 25% indicate growth, and those below 25% indicate a loss of plant material.

c) Is the plant expanding outside the exclosure? The final data the test planting provided was if and how quickly the plants grew outside the exclosure. Expansion outside the exclosure was recorded as radial distance from the outside edge of the exclosure.

Results. The monitoring results indicate that species selection, propagule type, and degree of protection at the time of planting all strongly influenced the initial establishment and survival of plants in Lake Wister. The survival results were consistent at all sites for the test plantings made in the Summer of 1997 as shown in Tables 2 and 3. Table 4 shows additional test plantings made in Spring 1998. All plantings shown in Table 2 utilized containerized, mature transplants planted within protective cages.

TABLE 2
RESULTS OF MONITORING EFFORTS FOR SUMMER 1997 PLANTINGS

Species	Planted	August 28, 1997		October 20, 1997		April 29, 1998		June 16, 1998	
		Surviving	Expanding	Surviving	Expanding	Surviving	Expanding	Surviving	Expanding
Site I									
Justicia americana	4	4	0	4	0	4	1	4	1
Echinodorus beteroi	4	3	0	2	0	1	0	1	0
Echinodorus cordifolius	4	3	0	3	0	3	0	3	0
Heteranthera dubia	4	Planted 8/28/98		*4*	*0*	*3*	*0*	*0*	*0*
Vallisneria americana (WI)	4	4	0	1	0	1	0	0	0
Vallisneria americana (TX)	4	4	0	0	0	0	0	0	0
Potamogeton pectinatus	4	0	0	0	0	0	0	0	0
Potamogeton nodosus	4	4	4	4	4		0	2	0
Site 2									
Justicia americana	4	4	0	4	0	4	0	4	2
Echinodorus beteroi	3	3	0	0	0	0	0	0	0
Echinodorus cordifolius	4	4	0	3	0	2	0	2	0
Heteranthera dubia	2	Planted 8/28/98		4	0	4	0	2	0
Vallisneria americana (WI)	4	4	0	1	0	1	0	0	0
Vallisneria americana (TX)	4	3	0	3	0	0	0	2	0
Potamogeton pectinatus	4	2	0	0	0	0	0	0	0
Site 3									
Justicia americana	3	Planted 8/28/98		3	1	3	0	3	0
Scirpus validus	3	Planted 8/28/98		3	0	3	0	3	1
Nymphaea odorata	3	Planted 8/28/98		3	0	3	0	3	1

Species	Planted	August 28, 1997		October 20, 1997		April 29,1998		June 16, 1998	
		Surviving	Expanding	Surviving	Expanding	Surviving	Expanding	Surviving	Expanding
Site 4									
Heteranthera dubia	9	Planted 8/28/98		8	0	8	1	8	0
Vallisneria americana (WI)	6	Planted 8/28/98		6	0	0	0	0	0
Potamogeton nodosus	11	Planted 8/28/98		10	7	9	4	9	0
Site 5									
Justicia americana	2	Planted 8/28/98		2	0	2	0	2	0
Scirpus validus	2	Planted 8/28/98		2	0	2	1	2	1
Heteranthera dubia	6	Planted 8/28/98		6	0	3	0	2	0
Potamogeton nodosus	6	Planted 8/28/98		6	6	4	0	4	0

TABLE 3 SUMMARY OF ALL SUMMER 1997 PLANTINGS						
Species	**Type**	**No. planted** (7/ & **8/** 1997)	No. **Established (Present on** 10/20/97)	No. **Over-wintering (Present on 4/29/98)**	No. **Surviving Annual Cycle (Present on 6/16/98)**	**Condition of Plants Summer 1998**
Justicia americana	Emergent	13	13	13	13	Excellent, lots of new shoots and growth and many plants expanding beyond cage
Echinodorus beteroi	Emergent	7	2	1	1	Poor
Echinodorus cordifolius	Emergent	8	5	5	5	Excellent, potential for rapid expansion after establishment
Scirpus validus	Emergent	5	5	5	5	Excellent, lots of new shoots and growth and some plants expanding beyond cage
Sagittaria sp.	Emergent	1	1	1	1	Inadvertent introduction along with other shoreline plants. However, this species showed excellent expansion during the Fall of 1997 and survived the winter period
Heteranthera dubia	Submersed	21	20	15	11	Good, many plants growing well
Vallisneria americana (WI)	Submersed	14	1	1	1	Extremely poor, not suitable for use in Wister
Vallisneria americana (TX)	Submersed	8	3	2	2	Extremely poor, not suitable for use in Wister
Potamogeton pectinatus	Submersed	8	0	0	0	None survived, not suitable for use in Wister
Potamogeton nodosus	Floating leaf	25	24	16	15	Good, some plants showed good growth and many expanded outside cage
Nymphaea odorata	Floating leaf	3	3	3	3	Excellent, lots of new leaves, an some expansion outside cages.

TABLE 4 ADDITIONAL SPECIES PLANTED IN APRIL 1998 AND EVALUATED JUNE 16,1998		
Site No.	**Protected (Caged) Plantings**	**Unprotected (Not Caged) Plantings**
1	Eleocharis sp -- good growth by 6/16/98 Juncus sp -- good growth by 6/16/98 Elodea canadensis not found 6/16/98	None
2	Nymphaea odorata still surviving 6/16/98 Eleocharis sp -- good growth by 6/16/98 Sagittaria sp -- good growth by 6/16/98	Juncus sp. clumps -- still surviving 6/16/98 Justicia americana sprigs -- none found 6/16/98
3	None	Eleocharis sp -- none found 6/16/98 Sagittaria sp -- none found 6/16/98 Justicia americana sprigs -- none found 6/16/98
4	Sagittaria sp -- good growth by 6/16/98 Eleocharis sp -- good growth by 6/16/98 Justicia americana -- good growth by 6/16/98	Juncus sp. clumps -- still surviving 6/16/98 Justicia americana sprigs -- none found 6/16/98
5	None	Juncus sp. clumps -- none found 6/16/98 Justicia americana sprigs -- none found 6/16/98

In general, the establishment of containerized emergent or floating-leaved vegetation planted within protective exclosures was excellent (Table 5). Submersed species and those plantings with unrooted cuttings or without protective exclosures performed poorly (Table 5).

All the emergent species tested, except burhead *(Echinodorus beteroi),* had excellent survival rates and should be considered for future establishment efforts. Based on the results of plants in other reservoirs around Texas and Oklahoma, it is recommended that special efforts be made to establish American waterwillow, bulrush, and bull-tongue arrowhead during future plantings. These species have shown the ability to survive various water level regimes and are capable of rapid expansion along the shoreline. In addition, other emergent species, such as squarestem spikerush *(Eleocharis quadrangulata)* and pickerelweed *(Pontederia cordata),* should be considered for future plantings.

Both floating-leaved species planted also showed excellent survival results. American pondweed grew quickly after being planted in the summer of 1997. By October 1997, it showed evidence of having expanded more beyond the cages than other species. A similar species which was not tested in Lake Wister but which has grown well in other reservoirs is Illinois pondweed *(Potamogeton illinoensis).* The white waterlilies planted in 1997 all survived and were vigorously growing during the summer of 1998. In addition to this lily, other lilies, such as yellow waterlilies *(Nuphar lutea)* and American lotus *(Nelumbo lutea),* should be considered.

Most of the submersed species that were tested showed very poor survival rates. Sago pondweed, American elodea, and both ecotypes of wild celery tested showed very poor survival rates. The few plants that survived the test period were observed to be very small and were considered unlikely to survive for long. Better survival was observed for water-star grass, where 11 of 21 plants survived the first annual cycle. However, while survival was considered acceptable, these plants showed very little promise of rapid expansion within the very turbid waters of Lake Wister. Although this species can be used as part of a larger scale plant establishment effort, it is unlikely to grow in larger expanses during the first few years.

RECOMMENDATIONS FOR LARGER-SCALE PLANTINGS

The following general recommendations are for establishing "founder populations" of aquatic plant species at various sites around Lake Wister. Founder populations are small colonies of aquatic plants that are established in strategic locations within the reservoir. After these plant colonies become successfully established, they serve as a propagule source to fuel continued expansion of plants to unvegetated areas throughout the lake. The colonies expand by production of viable seed and/or vegetative growth. More detailed information on culture and establishment techniques can be found in the recently published handbook "Propagation and establishment of aquatic plants: a handbook for ecosystem restoration projects" by R. Michael Smart and Gary 0. Dick (WES in press).

TABLE5
SUMMARY OF PLANTINGS MADE IN SUMMER 1997 AND SPRING 1998

Species	Plant Type	Propagule	Protection	Potential for Use in Large-Scale I Establishment Effort on Lake Wister
Justicia americana	Emergent	Containerized	Yes	Excellent, all test plantings survived full annual cycle and some were expanding beyond cages.
		Unrooted sprigs	No	Not Acceptable. None survived.
Echinodorus beteroi	Emergent	Containerized	Yes	Poor. Only one of seven test plantings survived annual cycle.
Echinodorus cordifolius	Emergent	Containerized	Yes	Excellent. Most plantings survived and some were expanding beyond cage. In addition, this plant is already present in small numbers around the lake.
Scirpus validus	Emergent	Containerized	Yes	Excellent, all test plantings survived full annual cycle and some were expanding beyond cages.
Eleocharis sp.	Emergent	Containerized Containerized	Yes No	Excellent. All plants survived. Not Acceptable. None survived.
Juncus sp.	Emergent	Rooted clumps	No	Good. Most survived from April to June 1998.
Sagittaria sp.	Emergent	Containerized Containerized	Yes No	Excellent. All plants survived. Not Acceptable. None survived.
Heteranthera dubia	Submersed	Containerized	Yes	Good. About half of plantings survived annual cycle.
Vallisneria americana (WI)	Submersed	Containerized	Yes	Not Acceptable. Only one plant survived annual cycle and it was barely present.
Vallisneria americana (TX)	Submersed	Containerized	Yes	Not Acceptable. Only two plants survived annual cycle and they were barely present.
Potamogeton pectinatus	Submersed	Containerized	Yes	Not Acceptable. None survived.
Elodea canadensis	Submersed	Containerized	Yes	Not Acceptable. None survived.
Potamogeton nodosus	Floating leaf	Containerized	Yes	Good. Over half of plantings survived annual cycle.
Nymphaea odorata	Floating leaf	Containerized	Yes	Excellent, all test plantings survived full annual cycle and some were expanding beyond cages.

Plant Species and Propagule Selection. Initial plant establishment efforts in Lake Wister should focus on emergent and floating-leaved species planted in waters less than 2.5 feet deep. After shallow zone waters ranging in depth from 0 to 2.5 feet are well populated with emergent and floating-leaved species, additional plantings of some turbidity tolerant submersed species can be incorporated.

Of the submersed species tested, only water star-grass showed good potential for survival under present conditions in Lake Wister. Table 6 presents a list of good species for use in Lake Wister as well as the type of propagules from which to begin cultures.

TABLE6
PLANT SPECIES RECOMMENDED
FOR LARGE-SCALE PLANTINGS IN LAKE WISTER, OKLAHOMA

Name	**Type**	**Propagule Type Needed to Initiate Cultures**
Justicia americana (American water-willow)	Emergent plant which tolerates water fluctuations	Bare-root transplants collected from field or stem cuttings
Scirpus validus (bulrush)	Emergent shoreline plant which forms dense colonies	Bare-root transplants collected from field
Echinodorus cordifolius (creeping burhead)	Emergent shoreline plant (some already present at Site 1)	Bare-root transplants collected from field
Sagittaria sp. (bull-tongue arrowhead)	Emergent plant which tolerates water fluctuations and depths to about 20 cm during growing season	Bare-root transplants collected from field
Eleocharis sp. (Flatstem spikerush)	Prolific shoreline emergent plant which spreads quickly	Bare-root transplants collected from field
Eleocharis quadrangulata (square-stem spikerush)	Tall spikerush which tolerates flooding	Bare-root transplants collected from field
Juncus sp. (Soft rush)	Profilic shoreline emergent plant which spreads quickly	Bare-root transplants collected from field
Potamogeton nodosus (American pondweed)	Floating-leaf plant with high wildlife value and tolerant of water level fluctuations	Stem cuttings

TABLE 6 (Continued)
PLANT SPECIES RECOMMENDED
FOR LARGE-SCALE PLANTINGS IN LAKE WISTER, OK

Name	**Type**	**Propagule Type Needed to Initiate Cultures**
Nymphaea odorata (white waterlily)	Floating-leaf water lily	Bare-root transplants collected from field
Nuphar lutea (yellow waterlily)	Floating-leaf water lily	Bare-root transplants collected from field
Nelumbo lutea (American lotus)	Prolific shallow water plant which expands rapidly	Scarified seed
Heteranthera dubia (water-star grass)	Submersed plant which can develop emergent leaves in shallow water	Stem cuttings
Potamogeton illinoensis (Illinois pondweed)	Submersed plant which grows quicklv and tolerates flooding	Stem cuttings

Plantings in Lake Wister should utilize mostly containerized transplants. Unrooted cuttings, seed, and other "easier" types of propagules are unlikely to survive the turbid conditions which currently characterize Lake Wister. Although some "clumps" of soft-rush did show some survival, these clumps had very well developed roots which were collected with minimal disturbance. To survive the turbid waters of Lake Wister, plants should have well developed aboveground stems and leaves as well as good root systems.

Propagule Production. Establishment of several dozen founder populations around the lake will require hundreds of planting units of several species of aquatic plants. Commercial nursery pots with drain holes in the bottoms should be used. Quart-size containers (4-inch diameter) are suitable for most emergent and submersed species, while gallon-size (6-inch diameter) are more suitable for most water lilies which often form large rhizomes. These pots are UV stabilized and can be reused several times.

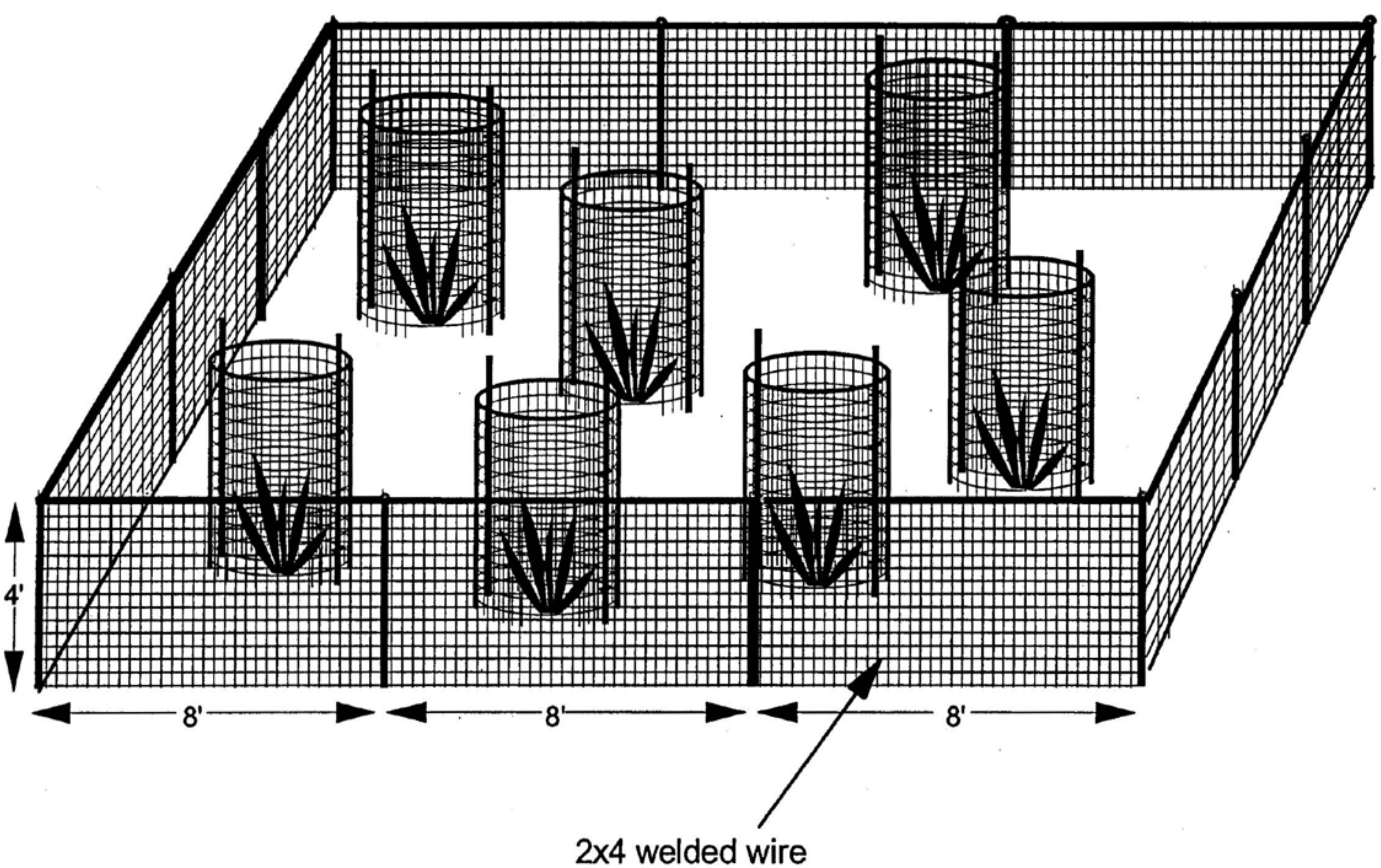
Although aquatic plants can grow in a variety of sediment types ranging from pure sand to highly organic soils, culture is facilitated by use of fine-texture substrate with a moderate organic content (10-20%). If possible, use of sediments collected from ponds or lakes is ideal. However, if such sediments are not available, topsoil can be used. In some cases, fertilization of sediments with nitrogen may accelerate initial growth. Fertilization rates of 1 g nitrogen (added as urea or as ammonium salt) per liter of sediment is recommended. If top soil (rather than pond or lake sediments) is used, the filled pots of soil can be 'cured' underwater for 2 weeks prior to planting.

Pots of cured sediment can be planted with the appropriate type of propagule for each plant species utilized (Table 6). These should be kept under controlled, shallow-water conditions for up to 3 months prior to transporting to the field. Best success is seen when plants are cultured long enough to produce "root bound" propagules. The root mass should fill the container and maintain its shape when removed from the pot.

The production of aquatic plant propagules will require adequate shallow-water culture facilities. Shallow water ponds may offer excellent options if these are available. Lined ponds are preferable to earthen ones because they facilitate keeping cultures of different plants distinct and avoid the growth of endemic vegetation within the pond. Enclosures should be constructed around each species if several species are to be cultured in a single pond. These enclosures can be constructed with t-post and any type of fine mesh plastic material, such as shade cloth. Enclosures for emergent plants and lilies, which can be cultivated in less than 2 feet of water, can be constructed with black erosion fabric.

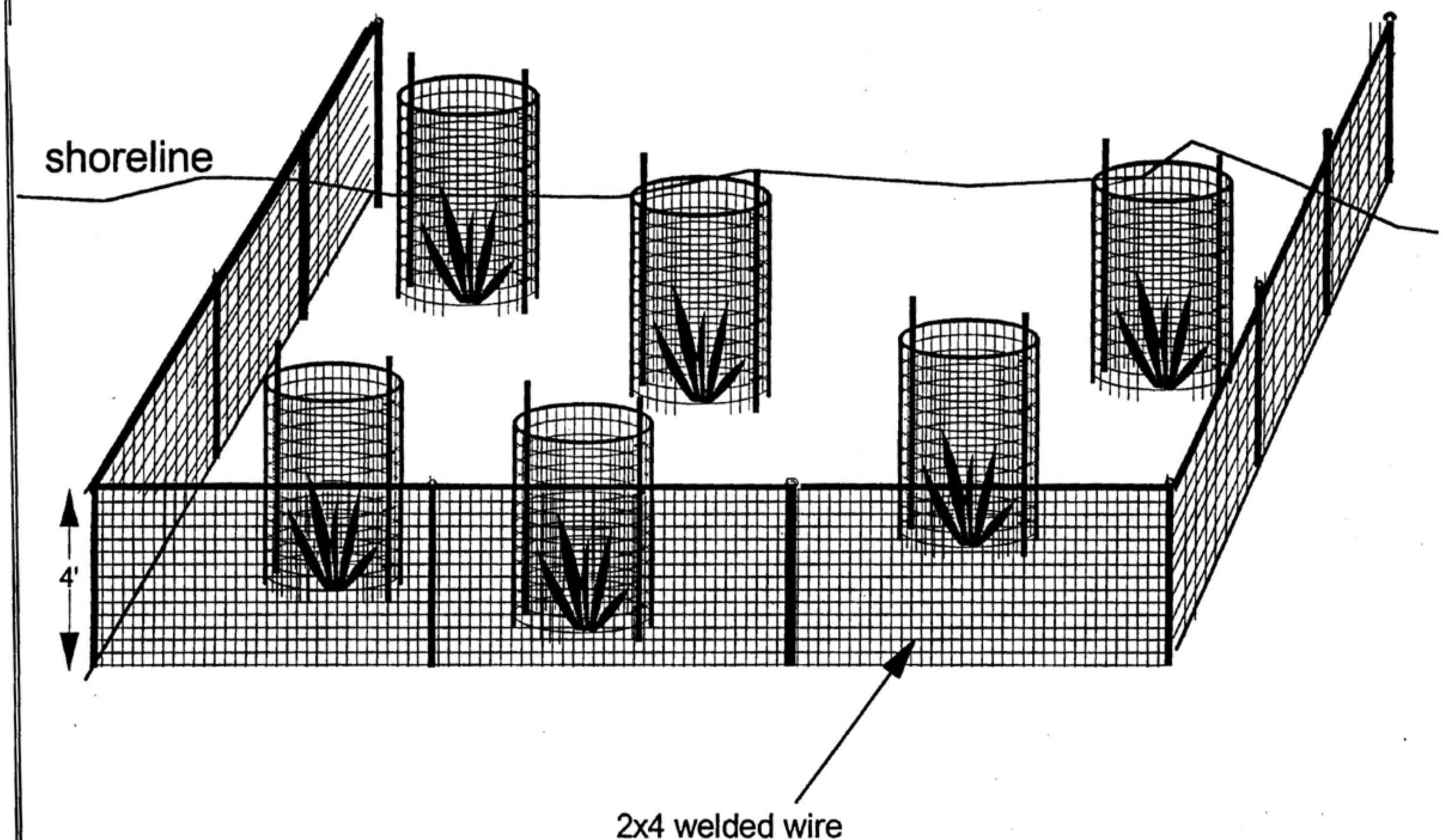
Very shallow water tanks constructed of lumber and lined with plastic pond liner offer the greatest benefits for production of emergent plants and lilies. These can be constructed on any level ground which has an adequate supply of fresh water. Tank depth can vary from 10 inches for emergent plants to 16 inches for lilies. A single shallow tank measuring 3 feet by 10 feet can hold well over 100 potted plants and can be constructed from materials costing about $250. Such shallow tanks are easy to manage and can be built with good vehicular access for moving plants around or bringing in sediment or plant propagules.

Herbivore Protection. Protective cages will be needed during the first year or two after plantings to ensure plant survival. Results from plantings in numerous other reservoirs in addition to Lake Wister have clearly demonstrated increased survival and more rapid establishment if the plants are protected. A "two tiered" protection is usually best in reservoir situations: 1) Each individual transplant is protected with a small cage like the ones used in the test plantings to virtually assure the survival of the transplant; and 2) as shown in Figure 5, additional protection can be provided by surrounding several individuals with a larger fenced plot using 2- by 4-inch welded wire fencing to ensure that a colony of sufficient size is produced as plants grow beyond the individual cage. The size of the fenced plots can be adjusted as needed. In some cases, a "shoreline fence" can be used as shown in Figure 6 instead of the larger fenced plot. A shoreline fence is simply a three-sided modification of the fenced plot. These shoreline fences can be irregular in shape. For example, one might extend from the shoreline to the 3-foot depth contour and then along that contour parallel to the shoreline. The fenced plots should have an average plant density from 0.25 and 0.5 plants per square yard.



DESIGN FOR FENCED PLOTS

FIGURE 5



DESIGN FOR SHORELINE FENCE PROTECTION

FIGURE 6

SUMMARY AND CONCLUSIONS

Plants selected for Lake Wister were those tolerant of turbid conditions because of the very high levels of turbidity within Lake Wister. Aquatic plants with emergent leaves or those that have leaves that float at the water surface are most likely to survive the turbid conditions of Lake Wister.

Selected plantings utilized propagule types with large energy reserves, such as mature containerized transplants and large dormant tubers because of the poor environmental conditions within the lake. Tubers are dormant "potato-like" structures formed by some species as an overwintering propagule. These structures are dormant and have rich energy reserves from which the plant re-grows when environmental conditions are favorable.

Continued monitoring of plantings should be continued for at least 2 years following planting. This will allow additional plant units to be planted as needed. It will also present an opportunity to expand the plantings of those species showing the best survival. All the culture facilities and plant species recommended in this report are currently being utilized at LAERF. If needed, a one-day training program can be conducted at LAERF to teach the techniques mentioned in this report.

Implementation of Non-Point Source BMPs in the Fourche Maline Arm of Wister Lake

(C9-996100-05, Task 700)

Oklahoma Water Resources Board

Appendix C

Proposed Plan To Demonstrate Methods For Successful Introduction Of Aquatic Plan Species To Lake Wister

Subject: Task 700 Implementation of NPS BMPs in the Fourche Maline Arm of Lake Wister - Revegetation efforts.
Objective: To establish a diverse native aquatic plant community in the Lewis Creek arm (2.3 linear miles) of Lake Wister from 10 May 99 to 12 Aug 99. This must be done with effectiveness and efficiency.
Present Situation: Over the last year WQPD staff translated USACE contracted technology to the level of broad based implementation. Manpower followed by equipment was identified as bottleneck factors. The following proposal seeks to maximize impact to the target area. All requested actions can be funded through the Wister 319 project.
Proposal: 1. Hire local (lake area) temporary employees locally through the OWRB and one temp employee out of OKC to monitor and direct work efforts on site.
2. Rent needed trucks through the motor pool.
3. Utilize prison crews for jobs that do not require lake access (minimize security issues).
4. Minimize cooperator equipment use to specialty tasks that may require an operator.
Advantages: 1. Hiring a crew locally minimizes per diem ($2,100/person), ensures a reliable work force (8hr/day) and eliminates use of an employment agency. A capable site manager (Wick Warden) has been identified to lead the three month long field effort.
2. Truck rental ensures availability and reduces reliance on cooperator generosity.
3. Experience from last year show that work in the lake is not effective. In addition five to six hour work days were common. This strategy utilizes the resource but does not obligate us to them for objective completion.
4. Reduces reliance on cooperator generosity.
Disadvantages: 1. Additional effort will be required to identify and hire temps remotely. This will increase reliance on personal contacts within the area.
2. The OWRB will still be reliant on cooperator generosity. Coordination by the on site manager with the cooperators will be crucial.
Action: Post hiring notices at Carl Albert State College to recruit 5-6 reliable students during the summer period. A draft of these notices are provided. Set up rental agreement with State Motor Pool for 3/4 ton truck. Coordinate planting plan with all cooperators to identify areas of specialized need. Planting Plan, Itemized Projected Expenditures and Assignment of Duties attached.

Planting Plan Time Sequence

Action		February	March	April	5/10 - 5/15	5/17 - 5/21	5/24 - 5/28	5/31 - 6/4	6/7 - 6/11	6/14 - 6/18	6/21 - 6/25	6/28 - 7/2	7/5 - 7/9	7/12 - 7/16	7/19 - 7/23	7/26 - 7/30	8/2 - 8/6	8/9 - 8/12
Manpower/ Contracts																		
Locate Seed Sources																		
Clean out Kerr pond																		
Set up Nursery areas																		
Water Willow (# of propagules)							9118							9118				
Duck Potato (# of propagules)						12158					12158				12158			
Bulrush (# of propagules)								1559		1559								
***Fragrant Water Lily (2500)**					Har				Pot			Plant						
Seeding													N&SW			WM		
Maintenance																		
Enhancement/ Augmentation					SW											H		

*** 2500 as the target number; Har(vesting),Pot(ting),Plant(ing)**

Key SW = Smartweed N = Nelumbo WM = Wetland Mix H = Heteranthera

Planting Plan Layout

Each column is a 1' increment parallel to the shore. Horizontal spacing from shore is dependent upon depth (as measured by body parts).

								Depth
DP	DP	DP	DP	DP	DP	DP	DP	**Ankle**
	WW		WW		WW		WW	**Calf**
		SB				SB		**Calf**
		WW				WW		**Knee**

KEY DP= Duck Potato WW = Water Willow SB = Softstem Bulrush

Assignment of Duties

Paul Koenig (Environmental Specialist Supervisor)
- Project oversight; contracts, hiring, off sight coordination.

Robin Randolph (Carl Albert Executive Fellow)
- Assist with project oversight

Wick Warden (Student Temporary Employee)
- On Site Manager, direct work crew, coordinate with local cooperators.

Temporary Employees
- Provide manual labor to get the job done!

Itemized Project Expenditures

Duration of needs = 14 weeks beginning May 10th. 5 days a week. 8 hours a day.

Need	Quantity	Cost/Unit	Itemized Cost	Comments
On Site Manager	1 @$8.50/hr	$340/wk	$4,760	
work crew	6 @$7.00/hr	$280/temp/wk	$23,520	
Cabin at Wister	1	5 days/week 14 weeks	$2,800	
Boats	Pred, Jon + DEQ Jon**	On hand	maintenance only	OWRB
1/2 ton truck	2 (1 from Motor Pool)	$520/month for 4 months	$2,080	OWRB, Note: fuelman service station in Talhina, Griffiths Service Station at 101 Dallas and Railroad St, 918-567-3050 Mechanic (Roy Rainwater) can work on trailers (he can install sealed bearings and maintain trailers!)
flat bed trailer	1	barrow/rent		PVIA
propagule raft	1 built to fit trailer	materials (floats, angle iron, 2x6s)	floats $745 other $150	PVIA provide labor
backhoe	1	borrow/rent		PVIA
dump truck	1	borrow/rent		PVIA
Digging tools	15	$8/ea	$120	
Plant bags	1000	$40	$40	
baby pools	20			
Fencing Material	6,000'	50'rolls@$30/roll	$3,600	
Rebar	8000'	$.30/ft	$2,400	
cell phones	1			
USCG life jackets	6	$15/ea	$90	
Misc Supplies			$500	
TOTAL ESTIMATE			**40655**	

** Currently stored by OWRB

LOCAL (OKLAHOMA) PROPOGULE SOURCE ASSESSMENT

Justicia americana (American Waterwillow) abundant

enough for 2-3 acres of colonization(3400 ft of shoreline, 80 % coverage accessible, 6 ft out)

Scirpus validus (bulrush)= abundant

Eleocharis sp. (Flatstem spikerush)=

Eleocharis quadrangulata (square-stem spikerush)=

Juncus sp. (soft rush)= abundant

Potamogeton nodosus (American pondweed)= abundant

Nymphhaea odorata (white waterlily)= abundant

Nuphar luteum (yellow waterlily)= abundant

Nelumbo lutea (American lotus)= abundant

Heteranthera dubia (water-star grass)= abundant

Potmogeton illinoiensis (Illinois pondweed)=

Potamogeton nodosus (floating leafed pondweed)=

Echinodorus sp. (mud plantain)

Echinodorus beteroi (burhead)=

Echinodorus cordifolius (creeping burhead)=

TRANSPLANT METHODOLOGY

Alisma sp. (water plantain)

Sources (LAERF?)

Contacts (information and permission)

Transplant Technique and considerations

Seed and transplant?

Justicia americana (American waterwillow)

Sources Beaver Lake at the Kerr Center for Sustainable Agriculture, Poteau, OK.

Contacts (Information and or permisson) David Redhage-- (918) 647-9123

Transplant Technique and considerations Individual stems should not be separated. Should be moved in the largest community possible. Fibrous root mass holds stems together. Plant will direct transplant without showing any stress. Load bunches of stems in truck, throw them out in the boat, and put them in water where the communities can be anchored. Rooting in soil not necessary, but have lowest root in contact with soil.

Scirpus validus (soft stem bulrush)

Sources: Murray State Park, Ardmore,OK
~~Latimer County, OK~~

Contacts: Mark Teders, Murray State Park Naturalist—(580) 223-2109
~~Dr. Bob Nairn, Professor of Environmental Science, OU, (405) 325-3354~~

Transplant Technique and considerations Trim all but 1 foot of stems. Dig up plant leaving a 9 inch diameter root ball. Direct transplant to site. Replant by digging hole big enough to put entire root ball into. Fill in empty space with extracted substrate. Be sure that half of the stems height will be out of the water as it recovers from transplant. Also, if planting on dry land be sure that the the root ball is in the ground near or in the water table.

Sagittaria sp. (bulls-tongue/duck potato)

Sources Hwy 271 southbound Just North of Hodgen, OK
Upper fishery Pond, Kerr Center for Sustainable Agriculture, Poteau, OK
Bar ditch below Spavinaw Dam

Contacts David Redhage-- (918) 647-9123 (if using Kerr Center Source)
Harry Chichester —(918) 253-4344 (for Spavinaw source)
Jerry Rainwater —(918) 253-4344 (for Spavinaw source)
Charles Schrodt (US Army Corp of Engineers, Wister Project Office)—(918) 655-7206

Transplant Technique and considerations Smaller plants transplant the best. Larger plants are more likely to be damaged by handling. Reach hand into mud below the root mass and pull. Place in bags or other carrier. Be careful to prevent as much damage to stems as possible, but they will survive a lot of abuse to the stems, but not to the roots. Dessication will KILL the exposed plant. Keep them as cool as possible during transplant, and transplant as quickly as possible. To replant, stick in the mud leaf side up. Be certain that at least 75% of the stem will be out of the water for about 4 weeks after transplant. Initially, the stems may "die off" due to stress, but it **will** soon sent up a new stem if it survives (Which is likely)

Eleocharis sp. (Flatstem spikerush)

Sources: Bar ditch below Spavinaw dam.
1st exit north of Krebs on east side of US 69

Contacts Harry Chichester —(918) 253-4344 (for Spavinaw source)
Jerry Youngblood —(918) 589-4563(for Spavinaw source
McAlester ODOT

Transplant Technique and considerations: Treat like sod, digging up a section with a few inches of soil with the plants (You get a seed bank this way). Plant chunk of spikerush level with mud just close to the "normal" waterline. When soil is taken with the plant, desiccation is less of an issue.

Eleocharis quadrangulata (square-stem spikerush)

Sources LAEF

Contacts Robert Doyle, Gary Dick

Transplant Technique and considerations

Potted plants, Plant level with substrate in water 0.5' - 1.5' deep (to normal pool elevation).

Juncus sp.

Sources Kerr Center Ponds, local bar ditches.

Contacts David Redhage-- (918) 647-9123 (if using Kerr Center Source)

Transplant Technique and considerations Dig up a root mass (backhoe works well) break up into manageable chunks. Plant level with the mud in about 0.5' - 1.0' water depth

Potamogeton nodosus (American pondweed)

Sources Spavinaw Lake

Contacts Harry Chichester —(918) 253-4344 (for Spavinaw source)
Jerry Youngblood —(918) 589-4563 (for Spavinaw source)

Transplant Technique and considerations Be sure that the roots come up with the plant. Place in Plastic Bags after harvesting. Keep cool during transplant (ice or cool water), it is very sensitive to heat. Replant as soon as possible. In Wister, plant where the majority of the leaves can float near surface so it can get adequate light. May grow in super saturated substrate (mud flats). May also sprig as a propagation technique (not the best method)

Nymphhaea odorata (white waterlily)

Sources Hwy 270 near Summerfield
Hwy 59 near Hodgens

Contacts:

Transplant Technique and considerations: Lake transplantation is a three step process; harvesting, potting and lake introduction. Lake bound propogules condition is a potted, root bound plant with floating leaves. Because of this a nursery area is needed to allow the harvested propogules to recover energy and biomass and protect from herbivores. A plant is considered to be a tuber with three characteristics; 1- white rhizomes (roots), 2-floating leaves and 3- a region of the tuber (meristematic) where new leaves are continually generated. New propogule leaf growth is in submersed form. Thus the need for a clear water nursery area. Floating leaves will follow a few sets of submersed leaves.

Steps in Transplant Procedure: Based on your experiences, note and implement protocol enhancements. 1) **Harvesting** - Pull, break off tubers sections being careful to have a meristematic region. Some floating leaves intact is preferable. Take care not to damage the new meristematic growth. NOTE: the bigger the tuber in cross section the better.

2) Collect harvested propogules in a container where they will stay wet and not overheat.

3) Optional Step - Dump harvested propagules into a caged area in the nursery area and let float for a week or so until new roots and leaves sprout. (cage keeps propagules in one spot and protects from herbivores).

4) **Potting** - Submerse a baby pool in the fenced off area. Baby pools seem to hold about 70 pots. Pools hold pots and plants upright while the pool itself is relatively mobile (underwater).

5) Fill 6" diameter pots with fairly consolidated(or firm) mud.

6) Propogule will be planted on top of the mud so that the tuber will not float (thus the need for firm mud) and the meristem faces towards the light (little easier for new leaves).
7) Fill/pack submersed baby pool with potted plants. Close up the caged area and let propogules grow/recovery for a few weeks (until each pot is root bound and has a set of floating leaves and/or flowers).
8) **Lake Introduction -** Be sure to cover potted plants while transporting to minimize desiccation.
9) Plant level to lake bottom for best results
10) Cage plants in-lake when possible for maximum protection and growth.

Nuphar luteum (yellow waterlily)

Sources Kerr Center for Sustainable Agriculture
Contacts David Redhage-- (918) 647-9123

Transplant Technique and considerations Break off the growing end of the plant from the rest of the tuber. Be sure to get some tuber material with it, Not a lot, but some. Direct transplants work well. Avoid desiccation. These tubers **VERY** buoyant. Be creative on planting and keeping these suckers in the mud. Cut hole with boot firming around tuber worked 75% of the time. Hooked rebar may do the trick to anchor the propogules.

Nelumbo lutea (American lotus)

Sources Perkins, OK , Oklahoma State University Agriculture Research Station,
Upper end of Spavinaw and Eucha Lakes
Kerr Center for Sustainable Agriculture, Poteau, OK
Contacts Rick Matheson—(405) 547-2385 OSU AgricultureResearch Station
Harry Chichester —(918) 253-4344 (for Spavinaw and Eucha source)
Jerry Rainwater —(918) 253-4344 (for Spavinaw and Eucha source)
David Redhage-- (918) 647-9123 (if using Kerr Center Source)

Transplant Technique and considerations Harvest seeds, scarify seeds and distribute or culture in nursery area prior to transplant.

Heteranthera dubia (water-star grass)

Sources Spavinaw Lake
Contacts Harry Chichester —(918) 253-4344 (for Spavinaw and Eucha source)
Jerry Rainwater —(918) 253-4344 (for Spavinaw and Eucha source)

Transplant Technique and considerations Harvest plants with root systems with maximum above ground biomass. Keep plants wet and do not let them get very warm. Press root system into mud. Can also sprig the mud with shoots. (Note: Planting with roots referred to sprigging)

Potomogeton sp. (Floating leaved pondweed)

Sources Spavinaw Lake
Contacts Harry Chichester —(918) 253-4344 (for Spavinaw and Eucha source)
Jerry Rainwater —(918) 253-4344 (for Spavinaw and Eucha source)

Transplant Technique and considerations Harvest plants with root systems with maximum above ground biomass. Keep plants wet and do not let them get very warm. Press root system into mud. Can also sprig these plants like Heteranthera.

ESTIMATOR FOR PLANTING PLAN

Planting Estimations based on a perimeter of the Lewis Creek arm of Lake Wister as 12158 ft. These assumptions are harvest and planting time only. Time estimates are harvest and planting time only. No travel to and from the harvest or planting sites, delays to human or mechanical failure, inclement weather or lake level have been considered. One work week is 40 hours per person.

Scirpus validus (bulrush)

Assumptions:

Entire shoreline of the Lewis Creek Arm can be planted with a 4 ft. band of plants at a density of 1 plant per 2 square feet.
Harvesting rate is 20 plants per hour per person (best possible rate)
Planting rate is 20 plants per hour per person.
Working crew is 10 persons (double per person hours for 5 person crews)
Bulrush (Scirpus validus) is the plant all rates and densities are based on.
Transplant method is to move the plant with trimmed stalks (to 1 foot) and a 9 inch root ball.

planting area 12158 ft. of shoreline * 4 ft planting region width = 48632 ft^2 of planting area

number of plants required @ 1 plant/ 16 ft^2

1 plant/4 ft^2*48632 ft^2 of planting area = 12158 plants needed

time required to harvest

12158 plants/20 plants per person per hour=607.9 hours required to harvest
607.9 hours/ 10 people = 60.7 hours per person
Therefore, just the harvest time required to plant the Lewis Creek Arm of Wister Lake is 60.7 hours for a 10 person crew. (about 1.5 weeks of hard work by a skilled, efficient crew)

time required to plant

12158 plants to be planted/ (20 plants per hour) = 607.9 hours
607.9 hours/ 10 persons = 60.79 hours per person
Therefore, just the planting time required to plant the Lewis Creek Arm shoreline of Wister Lake 60.79 hours for a 10 person crew (about 1.5 weeks of work by a skilled, efficient crew)
Planting and harvesting can occur simultaneously meaning the entire job could take about 3-4days and if the harvest crew, once finished harvesting, could be used to plant, conceivably the entire job could take as short a time as 3 days (harvesting and planting finished.

Sagittaria sp. (Duck potato)

Assumptions:

Entire shoreline of the Lewis Creek Arm can be planted with a 4 ft. band of plants at a density of 1 plant per square foot.
Harvesting rate is 600 plants per hour per person (best possible rate)
Planting rate is 2 plants per minute per person.
Working crew is 10 persons (double per person hours for 5 person crews)

Planting area 12158 ft. of shoreline * 4 ft planting region width = 48632 ft^2 of planting area

Number of plants required @ 1 plant/ ft^2

1 plant/ft^2*48632 ft^2 of planting area = 48632 plants needed

Time required to harvest

48632 plants/600 plants per person per hour=81 hours required to harvest
81 hours/ 10 people = 8.1 hours per person
Therefore, just the harvest time that is required to plant the Lewis Creek Arm of Wister Lake is 8.1 hours for a 10-person crew. (About 1 day of hard work by a skilled, efficient crew)

Time required to plant

48632 plants to be planted/ (2 plants per minute * 60 minutes per hour) = 405 hours
405 hours/ 10 persons = 40.5 hours per person
Therefore, just the planting time required to plant the Lewis Creek Arm shoreline of Wister Lake 40.5 for a 10 person crew (about 1 week of work by a skilled, efficient crew)

Planting and harvesting can occur simultaneously meaning the entire job could take about 8 days and if the harvest crew, once finished harvesting, could be used to plant, conceivably the entire job could take as short a time as 5 days (harvesting and planting finished).

Justicia americana (Water Willow)

Assumptions:

Entire shoreline of the Lewis Creek Arm can be planted with a 4-ft. band of plants at a density of 1 plant per 2 square feet.
Harvesting rate is 300 plants per hour per person (best possible rate)
Planting rate is 2 plants per minute per person.
Working crew is 10 persons (double per person hours for 5 person crews)
Water Willow (Justicia americana) is the plant all rates and densities are based on.
Transplant method is to move the water willow as conglomerate mats (as little tearing apart of the root mat as possible)

planting area 12158 ft. of shoreline * 4 ft planting region width = 48632 ft^2 of planting area

number of plants required @ 1 plant/ 2 ft^2

1 plant/2 ft^2*48632 ft^2 of planting area = 24316 plants needed

time required to harvest

24316 plants/300 plants per person per hour=81 hours required to harvest
81 hours/ 10 people = 8.1 hours per person
Therefore, just the harvest time required to plant the Lewis Creek Arm of Wister Lake is 8.1 hours for a 10 person crew. (about 1 day of hard work by a skilled, efficient crew)

time required to plant

24316 plants to be planted/ (2 plants per minute * 60 minutes per hour) = 202 hours
202 hours/ 10 persons = 20.2 hours per person

Therefore, just the planting time required to plant the Lewis Creek Arm shoreline of Wister Lake 20.2 hours for a 10 person crew (about 1/2 week of work by a skilled, efficient crew)

Planting and harvesting can occur simultaneously meaning the entire job could take about 3-4days and if the harvest crew, once finished harvesting, could be used to plant, concievibly the entire job could take as short a time as 3 days (harvesting and planting finished.