Louisiana W.P.

SCOPE OF SERVICES DEVELOPMENT FOR A SHELL DREDGING IMPACTS STUDY

A Report To The
Louisiana Department of Natural Resources
CONTRACT NO. 21910-85-01

Prepared By:
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November 15, 1984

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Louisiana Dept. of Natural Resources
Natural Resources Building
P. O. Box 44396
Baton Rouge, LA 70804

Reference:

DNR Contract No. 21910-85-01
OCR Contract No. N/A 431-5002-A
Amendment No. 2

Dear Mr. deMond,

The attached materials are my final submission under the contracts referenced above, which are entitled, SCOPE OF SERVICES DEVELOPMENT FOR A SHELL DREDGING IMPACT STUDY. All of the required tasks have ben completed, but with modification in some instances. My comments on each task are as follows.

Task 1. Four trips have been made to Louisiana to obtain as much information as possible from all interested groups. The first meeting was held in Baton Rouge and Lafayette to hear of expectations for the scoping study from government agencies, academia, conservation groups, and industry. In the second meeting I made a preliminary presentation on the study, and received back advise that has been incorporated in this final revision. The third visit was solely with industry representatives in New Orleans to obtain information on recent levels of dredging intensity in Lake Maurepas and Lake Pontchartrain. The last visit was made in mid-November to present my final report to you and DNR's other resource analysts. In between the last two trips, I also made a visit to Dr. Stephen A. Bloom in Gainsville, Florida to get his views on my approaches to field work and data analyses.

Task 2. The bibliography here submitted is not an annotated one. Early on, it became evident that time constraints would not permit coverage of all pertinent literature to that degree. Consequently, I have provided the most complete list of references that could be brought together in the time allowed. Most of these have descriptive titles anyway; so as an unilateral decision, the bibliography in its present form was deemed more useful to DNR and the eventual contractor of choice for the shell dredging study. It contains nearly 1700 citations, and about one-third of these have been located and copied for your use and the use of your contractor - on an indefinite loan basis. Since the literature search was an ongoing activity, the main group of entries is followed by a short addendum. Those entries having one or two asterisks are the ones that have been copied, or are otherwise available from TBCo. Citations that we did not obtain may contain some unavoidable errors.

Task 3. This item is covered in the design of the shell dredging study, because I believe the main information gaps and problems exist mainly for Lakes Maurepas and Pontchartrain. If there is consciencious enforcement action, it is my belief that shell dredging practices on the coast can be adequately regulated by current rules. However, as I have mentioned before, I do believe that the coastal area should be set off in a pattern of grids to assist in permitting and management activities. Also, I strongly feel that all unburied reefs should be completely protected regardless of size.

In reference to the two lakes, I feel that the most important management consideration should be rate and nature of recovery after dredging. Here I refer to water quality, sediments, and the qualitative and quantitative aspects of bottom communities. Dredging activities must be keyed to recovery if these lakes are to be managed as multiple use resources. The main purpose of the study I have outlined it to obtain objective information regarding recovery in a variety of habitat types.

Task 4. This task has been encompassed in the scoping study. However, no provisions have been made to initiate the reviews called for on recreation and economics. I believe these two elements should be separated out and addressed in two small contracts that could be well done in the appropriate departments of local universities.

The last item, and one of great concern, I'm sure, is the matter of cost. My final figure may be reduced considerably if WPCD can pick up the bulk of their work on their own budget. Furthermore, the cost of the station comparability work will probably be less than projected, because I anticipate that matches between control and experimental stations can be made after one or two trials, rather than running the selection process out to three or four.

Even so, the cost is still far above budget. And I really don't know what to do about it in light of the requests for coverage and thoroughness voiced by all interested parties. When you consider that Dr. Sikora's two-year study at just two stations cost nearly $200,000, then the costs listed here for 18 stations seem quite reasonable. As I see the problem, you will either have to make some sacrifices in the study, or find additional sources of funding.

Sincerely,

John L. Taylor

John L. Taylor, Ph.D.
Director

Scope of Services Development for a Shell Dredging Impact Study

INTRODUCTION

Industrial shell dredging began in coastal Louisiana during the early 1900s, with the advent of hydraulic equipment to extract deposits of oyster shell in commercial quantities. Some 30 years later, dredges also began operations in several of the State's fresh and brackish water lakes to obtain shell produced by clams of the genus, *Rangia*.

From these beginnings, Louisiana's shell dredging industry has grown and developed into a substantial, multifaceted enterprise. Current production is about equally divided between oyster and clam shells. It is on the order of six to eight million cubic yards annually, and has a wholesale value of roughly 80 million dollars. Of this amount, between one and three percent revert to the State in the form of sales taxes, severance taxes, and royalties. Much of the State's share supports programs of the Department of Wildlife and Fisheries. One of these is the use of shell as cultch to establish, revitalize, and expand reefs that promote Louisiana's renowned and valuable oyster fishery.

In other applications, dredged shell is widely used in road building and general construction. It also serves as a basic material in the manufacture of cement and lime, animal feeds, chemicals, glass, paper goods, and a variety of other products. Because of its reasonable cost, light weight, and laminar shape, shell is uniquely suited for use as a foundation material in the loose and often moist soils found in many coastal areas. Figures furnished by shell producers show that their industry is worth about 450 million dollars each year to the economy of coastal Louisiana. This figure is based on direct and indirect revenues and includes a multiplier factor of five to account for economic, "ripple effects."

On the other side of the ledger accounts must also be made for the environmental destruction and disturbances that are unavoidable results of shell dredging operations. In principal categories, these perturbations affect bathymetry, sediments, water quality, aquatic life, and public participation in a variety of water related activities. Interactions among these, and many more specific factors, have wide-ranging ecological and socio-economic ramifications that are well documented in an extensive literature covering impacts of shell dredging on the southeastern seaboard and all along the Gulf coast. Even so, findings in practically all of these papers show that the individual, synergistic, and cumulative impacts of shell dredging are mostly transitory and inconsequential when adequate regulations are imposed and enforced. However, as a qualification, this body of work also contains studies which show that dredging impacts, and their severity and duration, become greater as operations progress landward from relatively high energy, dynamic coastal ecosystems into mesohaline and oligohaline locations that are more confined and protected.

In Louisiana, it is this geographic relationship between shell dredging and location that has created an especially vexatious management problem in Lake Pontchartrain. Here, increasing evidence on adverse impacts of shell dredging has caused a serious controversy between those opposed to dredging and those who side with the shell producing industry.

Working under legislative guidelines based on the concept of multiple resource utilization, coastal managers have concluded that available information is insufficient to adjudicate the present conflict over shell dredging in Lake Pontchartrain. For this reason, Governor Edwin Edwards issued Executive Order EWE-84-7, directing the Department of Natural Resources to study the economic, environmental, and other effects of shell dredging within the waters of the State. In accordance with that directive, the Louisiana Department of Natural Resources entered into a contract with Taylor Biological Company for the design of two definitive studies that would demonstrate the direct effects and the cumulative effects of shell dredging on the water quality, sediments, and benthos of Lake Pontchartrain.

PURPOSE AND APPROACHES

As part of that contract, this report was prepared to give DNR an analysis of services and costs for the completion of a Direct Effects Study, and a Cumulative Effects Study and shell reserve assessment. The development of plans for both studies was based on previous experience in the area of shell dredging and on information from many other sources. These included a literature review and comments from numerous individuals in conversations and meetings before and after presentation of preliminary study plans in Baton Rouge on October 2nd and 3rd, 1984.

In overview, the Direct Effects Study has been designed as an experimental investigation, while the Cumulative Effects Study and shell reserve assessment has been designed as a survey. The structure of the Direct Effects Study is based on a pattern of selected station pairs located near the North-South centerline of the Lake in the vicinity of the cross-lake Causeway (Figure 1). One station in each pair is to receive no treatment and will therefore serve as a control area. The other station in each pair will be dredged and serve as an experimental area. Both stations in each set are to be sampled before and after dredging. Subsequently, additional post-dredging samples will be taken at each station at intervals of two months for a period of two years. During this sampling period, the immediate and more prolonged environmental impacts of shell dredging will be evaluated by comparing pre- and post-dredging data from all nine sets of control and experimental stations. Since past dredging practices may influence the course of environmental recovery, the station pairs have been sited to include undredged areas and areas where past dredging has been done at several levels of intensity. Certain stations will provide data for a period greater than two years. These are the pair labeled DC (control) and DX (experimental) and stations one and three, which were all sampled in two previous investigations by methods similar to those that will be proposed here (Sikora, Sikora, and Prior, 1981; and Sikora and Sikora, 1982). Station DX will not be redredged in this study because of its historical significance. One very important condition that must be enforced during this study is a complete prohibition against all dredging and shrimping within one mile of any station. This can be most conveniently achieved by extending the present Causeway

Conservation Zone by an additional two miles along both sides.

As a survey, the Cumulative Effects Study was designed to broadly sample environmental conditions over the entire surface of the Lake, and vertically through bottom deposits that may be as much as 30 feet thick. To achieve the coverage needed for this work, 57 sampling stations were selected within a pattern of sampling grids established by Tarver and Dugas (1973). Other considerations for positioning stations included locations of previous studies; undisturbed shoreline and undredged areas in the open Lake; and shorelines variously influenced by tributary flow, floodway discharges, sewage effluent, and non-point drainage from urban and industrial areas (Figure 2). At all of these stations sampling will include seismic profiling, shallow and deep coring, infauna collections, and water quality measurements. Data from this sampling program should provide a chronological record of alterations in the Lake caused by shell dredging, and by other anthropogenic derangements. The deep coring and seismic work will also be used to prepare a two dimensional, quantitative depiction of the Lake's <u>Rangia</u> deposits. As before, data from earlier studies will be used to the greatest possible extent to augment and corroborate findings from this survey.

THE DIRECT EFFECTS STUDY

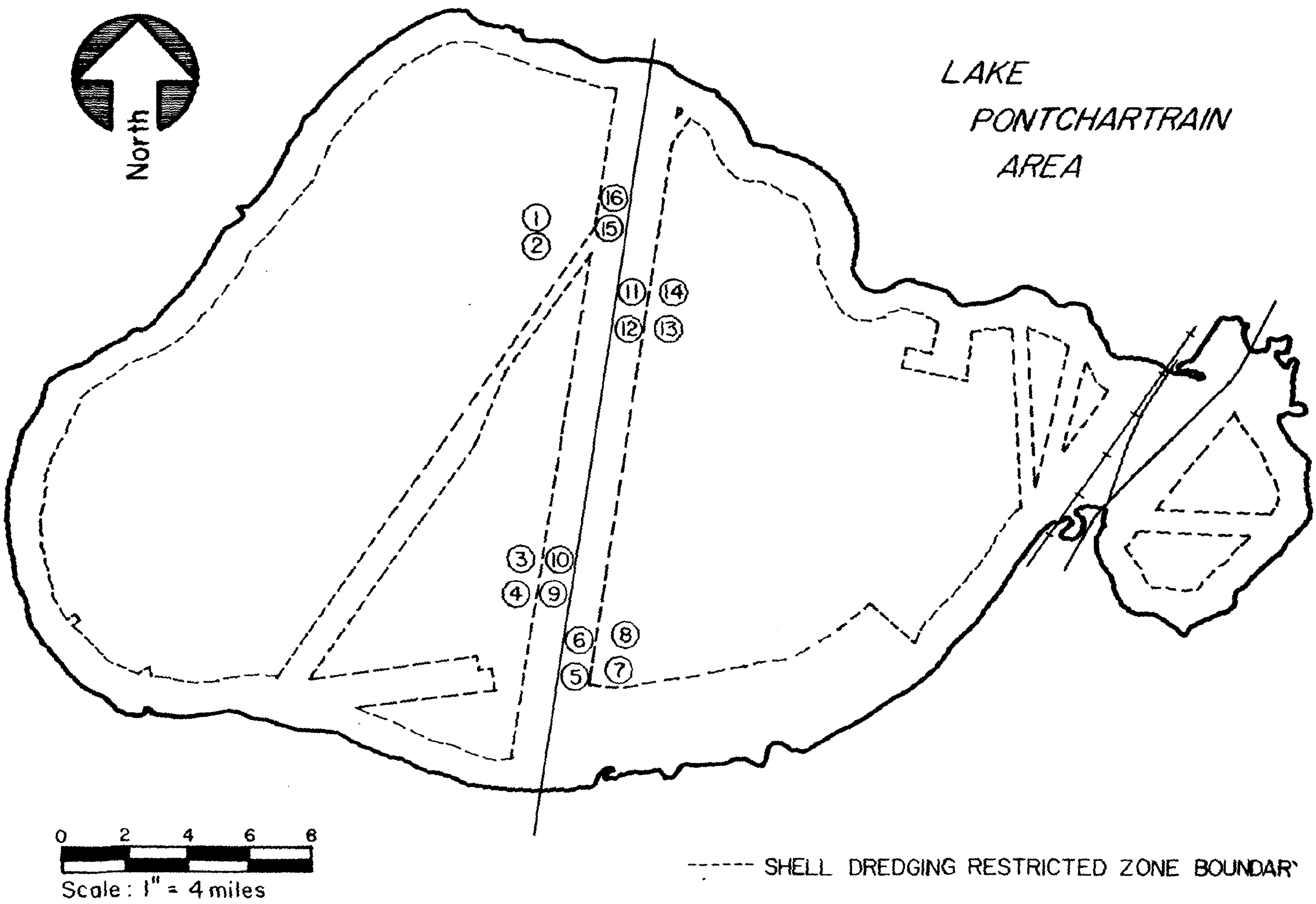
Objectives. This study has been designed to answer four basic questions concerning the management of shell dredging operations in Lake Pontchartrain. First, are there environmental differences between stations in dredged and undredged areas of the Lake? Secondly, what are the immediate impacts of dredging on water quality, sediments, and bottom dwelling organisms? Thirdly, does the Lake recover from these impacts in a reasonable time period? And finally, are the initial impacts and the nature of recovery solely related to past dredging activity, or are other factors involved as well?

Procedures. As a practical matter, station selections were limited to the 18 sites adjacent to the Causeway. Factors bearing on this decision included funding limitations, facilitation of operations for the field study, considerations for shell producers and shrimp trawlers, and simplification of enforcement duties by Wildlife Officers. Nevertheless, in most respects these stations are representative of many dredged and undredged areas in the Lake. Furthermore, the Causeway Conservation Zone has not been directly affected by dredging for nearly 30 years; and differences in many other environmental conditions occur along this corridor from shore to shore and from side to side.

These variables include (1) proximity to coastal development, (2) salinity, (3) water depth, (4) sediment type, (5) dredging intensity, and (6) previous study (Table 1).

1. Pre-study survey. Before systematic sampling can begin for the Direct Effects Study, several field and laboratory determinations must be made to establish the credibility of certain procedures. These tasks include (1) selection and demonstration of an acceptable experimental dredging routine, (2) determination of a safe inter-station distance for respective station pairs, (3) selection of sample replication levels that will provide adequate confidence limits for sediment and infauna data, and (4) the close matching of station pairs in terms of water quality, sediments, and infauna, so that dredging becomes the only significant difference between them.

Addressing these tasks in order, the first is the matter of duplicating a typical dredging pattern for use at the even-numbered experimental stations. A first approximation of such a pattern can probably be made by integrating traces from industry's LORAN C plotter logs of actual dredging operations. Based on a review of a few such logs, the characteristic pattern seems to be oval or circular with a long central axis of one-half mile or less. Industry claims that within this area a dredge normally makes about five loops before moving on to


LAKE
PONTCHARTRAIN
AREA
North
1
2
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6
7
8
9
10
11
12
13
14
15
16
0 2 4 6 8
Scale : 1" = 4 miles
SHELL DREDGING RESTRICTED ZONE BOUNDARY

Table 1. -- Station pairs and site characteristics - Direct Effects Study.

Station Pairs		Geographic Location	Average Salinity (ppt)	Depth (feet)	Sediment Type	Dredging Before 1980	Dredging After 1980	Sampling History
1	Control	N-Central	2.0	13-14	Silty Clay	Light	Moderate	Sikora, 1982
2	Exper.	N-Central	2.0	13-14	Silty Clay	Light	Moderate	-
3	Control	Central	3.0	14-15	Silty Clay	Light	Moderate	Sikora, 1982
4	Exper.	Central	3.0	14-15	Silty Clay	Light	Moderate	-
5	Control	S-Central	3.5	14-15	Clayey Silt	None	None	-
6	Exper.	S-Central	3.5	14-15	Clayey Silt	None	None	-
7	Control	S-Central	3.5	14-15	Clayey Silt	Heavy	Light	-
8	Exper.	S-Central	3.5	14-15	Clayey Silt	Heavy	Light	-
9	Control	Central	3.0	14-15	Silty Clay	None	None	-
10	Exper.	Central	3.0	14-15	Silty Clay	None	None	-
11	Control	Central	3.0	14-15	Sand	None	None	-
12	Exper.	Central	3.0	14-15	Sand	None	None	-
13	Control	Central	3.0	14-15	Sand	Heavy	Heavy	-
14	Exper.	Central	3.0	14-15	Sand	Heavy	Heavy	-
15	Control	N-Central	2.0	13-14	Silty Clay	None	None	-
16	Exper.	N-Central	2.0	13-14	Silty Clay	None	None	-
DC	Control	Central	3.0	14-15	Silty Clay	None	None	Sikora, 1981
DX	Exper.	Central	3.0	14-15	Silty Clay	Heavy	None	-

another location. This preliminary information needs to be verified by further log review, field observations, interviews with vessel operators, and an actual field trial with the plotter in operation and a water quality monitoring team in place.

In regard to the selection of an adequate distance for inter-station separation, presently one-half mile seems to be a satisfactory choice. This distance is based on existing WPCD data which show that changes in water quality around a working dredge are limited to a downcurrent distance of about one-quarter mile. If this distance can be verified during trial dredging, then doubling that figure (one-half mile) would virtually preclude the possibility of contamination at control stations by dredged residuals from experimental stations. Examination of field water quality parameters during dredging should be sufficient for the distance determination. Additionally, while trial dredging is in progress, fathometer and side-scan sonar evaluations should be made by LGS to judge the practicability of these instruments for measuring and recording trenches, ridges, and off-site sedimentation (mud-flows).

Concerning sampling replication, industry has asked for levels that will provide a statistical reliability of 85 to 90 percent for sediment and infauna collections. This would seem to be a reasonable request considering the importance of this study to many interest groups. A trial sampling program will need to be run to establish this degree of sampling confidence. In such a program dredged and undredged station locations should be sampled in the three sediment types to be included in the Direct Effects Study. This approach should cover all likely possibilities for sediment and infauna variability. Suggested locations would be Stations 5 and 7 (clayey silt), 11 and 13 (sand), and 3 and 9 (silty clay). In this trial, 10 replicate cores for sediment and infauna should probably be taken at each of the above six sites. Since the infauna corer has four equal internal divisions, those samples would actually provide 40 collections for the benthos. Based on data from collections at each site, analysis of variance techniques would be used to select levels of sampling for both sediment and infauna which would fall within the prescribed 85 to 90 percent confidence limits for the most demanding station. This task, and the following one, should probably be done in the beginning of March when infauna abundance apparently reaches a peak.

The final pre-survey task involves an evaluation of prospective station pairs to determine their environmental comparability and establish their status as valid control and experimental locations. This will require some additional sampling for water quality, sediments, and infauna. Without benefit of results from the preceding task, the assumption here is that the necessary station evaluations can be made on the basis of field analyses for water quality, and a statistical analysis of data from three sediment cores and five infauna cores (20 subsamples). A recommendation to accomplish this task is as follows. First, water, sediment, and infauna samples would be taken at all control station locations. From around each control station like sampling would be done to find suitable experimental stations. The number of these candidate experimental stations for each control site would be limited to four; and they would be sampled at a distance from it of one-half mile to the North, East, South, and West. In the laboratory, data for the control stations would be worked up first. Then water quality and sediment data would be worked up for all 64 of the possible experimental sites. Tentative station pairings would be made on the basis of the closest water-sediment matches. These choices would then be accepted or rejected on the basis of an analysis and comparison of corresponding infauna data. In some instances the contractor might have to go to the next best fit, and in other cases the best of all four possible options available may have to be accepted. Under similar hydrological conditions sediment type is the principal environmental determinent controlling the development of local bottom communities. That is why hydro and sediment data have been suggested for use as a time-saving guide to the analysis of candidate faunal samples in the search for acceptable pairs of control and experimental stations. In this selection task, the calculation of the degree of similarity between respective control and experimental stations will be done using multivariate analytical methods.

When the station selection process has been completed, all sites should be logged by LORAN C coordinates, and buoyed with heavy ground tackle and a durable surface marker that bears a station number and a conspicuous State property logo.. The coordinates of the protective perimeter zone should be well publicized, especially among the shell producers and commercial and recreational boat operators. Provisions for regular perimeter patrols and enforcement action against violators will be the responsibility of the LDWF.

The contractor for this study should be in a position to do field work for the pre-study survey in the February-March time period of 1986. Collections and other work completed in those two months can probably be evaluated within another four months, so that the Direct Effects Study can start in the fall of 1986 (Table 2).

Table 2. -- Pre-study survey tasks: responsibility, events, and time allocations.

Task-Performance	Days 1	2	3	4	5	6	Months 1	2	3	4
Dredge Pattern -										
Contractor	+	+	+	+	+					
Dredge					+					
Inter-station Distance -										
Contractor					-					
Dredge					-					
WPCD					+ (20)					
Bathymetry -										
Contractor					-					
Dredge					-					
LGS					+					
Sample Reps., Sediments -										
Contractor	- (20)	- (20)	- (20)				+			
Sample Reps., Infauna -										
Contractor	+ (20)	+ (20)	+ (20)				+			
Station Comparability, Water -										
Contractor	-	-	-	-	-	-		+	+	+
Station Comparability, Sediments -										
Contractor	- (20)	- (20)	- (20)	- (20)	- (20)	- (20)		+	+	+
Station Comparability, Infauna -										
Contractor	+ (34)	+ (34)	+ (34)	+ (34)	+ (34)	+ (30)		+	+	+
Station Buoys -										
Contractor	+	+	+							
LDWF	[-	-	-]							

+ = Single task cost item; ( ) = number of operations; - = no additional cost to DNR; [ ] = duration of Direct Effects Study.

2. <u>Field work for the Direct Effects Study</u>. Initially, and at specific intervals thereafter, this study will require close coordination between the Contractor, WPCD, and the dredging companies. As a suggested routine, field work at one station pair would be started every day over a nine day period. On day one, prior to dredging, the Contractor's team would first flag the boundaries of the area to be dredged. The team would then determine bathymetry in the work area by making ~~seismic~~ runs in a crisscross pattern having one leg parallelling the direction of current flow and the other running across it. This team would then take their standard series of samples. These would include field tests for water quality at the surface and bottom, three sediment cores, and five box corer samples for infauna. Next the team would move to the adjacent control station and repeat these procedures.

The WPCD team, having already worked the control site, would then move into the experimental site and make pre-dredging collections at the surface and bottom for their comprehensive list of water quality parameters. Dredging would then commence at the experimental site, and WPCD would sample through the period of dredging as well as for four hours afterward. The WPCD's final set of water samples would be taken at the center of the dredged area, one-quarter mile downcurrent from that point, and near the buoy at the center of the control site. This would complete WPCD's participation for the day. In each of the next eight days WPCD would again work one station pair in the same way. In addition, this team would field test for water quality at the station pair(s) sampled the previous day(s). This system of sampling and resampling would be followed through all eight days of dredging, the sampling at DC and DX on the ninth day, and for nine additional days. In this way each study site would be sampled during dredging operations and afterward for between nine and 17 days. If anomalous values should persist at any station pair beyond the nine-day water sampling period, then sampling would continue at those stations until all field parameters returned to normal.

Returning to the Contractor's field team - while dredging is in progress it could be processing pre-dredging sediment and infauna samples. Upon the completion of dredging, this team will revisit both stations to obtain a post-dredging seismic survey, together with their standard set of samples for water quality tests, sediments, and infauna.

By following this schedule, the initial phase of field work would be completed in nine days for the Contractor and in 18 days for the WPCD. Also, at the discretion of DNR, some aerial monitoring may be requested during experimental dredging. This work would be done to supplement ground data on turbidity plumes, and possible changes in water temperature and chlorophyll a concentrations. As another special provision, DNR may wish to establish several remote sensing arrays on Causeway pilings near one or more station pairs. These instruments would be useful for continuously monitoring surface and bottom water values for salinity, temperature, dissolved oxygen, and perhaps other factors.

After the initial sampling has been done, each station will be restudied at two-month intervals over a two-year period. Following this schedule, on each sampling excursion and at every station the Contractor will make seismic soundings, test surface and bottom water for basic field parameters and collect three sediment cores and five box corer samples for infauna. Coincident with two sampling periods per year (early Spring and late Summer), the WPCD will again take their comprehensive series of water samples at all 18 stations. These seasons have been selected for WPCD's participation because they represent times of maximum contrast for major hydrological factors such as temperature, salinity, turbidity, and dissolved oxygen. At four other times the WPCD should also conduct field tests at all stations after major storm events. These data are needed to make comparisons of gross changes in water quality due to natural disturbances, and observed changes caused by dredging.

Analysis and interpretation of field data from all of this work will probably take about four months. An additional two months would be needed to prepare the final report (Table 3).

3. Equipment, methods, and analyses.

3.1 Vessels. The WPCD already has suitable vessels for routine water quality survey work in the Lake. Presumably, these will be available for use in the Direct Effects Study. Instrumentation should include a ship's compass, VHF and CB radios, LORAN C, and a high resolution fathometer.

The dredge should be one of those having the greatest pumping capacity now permitted by DNR for Lake Pontchartrain. It must have a LORAN C and plotter, and the ship's complement of navigation and communication equipment should be in good working order. The dredge will be accompanied by a barge for loading shell.

The vessel leased by the Contractor needs to be in the

Table 3. -- Direct Effects study tasks: responsibility, events, and time allocations (For key see Table 2).

Task-Performance	Days 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Dredging - Dredge	-	-	-	-	-	-	-	-	-									
Flag Sta. - Cont.	+	+	+	+	+	+	+	+	+									
Bathymetry Field Hydro - Cont.	- (4)	- (4)	- (4)	- (4)	- (40	- (4)	- (4)	- (4)	- (4)									
Sediments Cont.	- (12)	- (12)	- (12)	- (12)	- (12)	- (12)	- (12)	- (12)	- (6)									
Infauna - Cont.	- (20)	- (20)	- (20)	- (20)	- (20)	- (20)	- (20)	- (20)	- (10)									
Comp. Hydro - WPCD	+ (20)	+ (20)	+ (20)	+ (20)	+ (20)	+ (20)	+ (20)	+ (20)	+ (20)									
Field Hydro - WPCD	-	- (2)	- (4)	- (6)	- (8)	- (10)	- (12)	- (14)	- (16)	+ (18)	+ (18)	+ (18)	+ (18)	+ (18)	+ (18)	+ (18)	+ (18)	+ (18)
Aerial Monit. - DNR	?	?	?	?	?	?	?	?										
Remote Monit. - DNR	(??????)																	
Data Anal., Inter. Report - Cont.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Table 3. -- (continued)

Task Performance	Month 2	4	6	8	10	12	14	16	18	20	22	24	28	30
Dredging - Dredge	Done													
Flag Stations - Contractor	Done													
Bathymetry, Field Hydro - Contractor	- (18)	- (18)	- (18)	- (18)	- (18)	- (18)	- (18)	- (18)	- (18)	- (18)	- (18)	- (18)		
Sediments - Contractor (6 days per event)	- (54)	- (54)	- (54)	- (54)	- (54)	- (54)	- (54)	- (54)	- (54)	- (54)	- (54)	- (54)		
Infauna - Contractor (6 days per event)	+ (90)	+ (90)	+ (90)	+ (90)	+ (90)	+ (90)	+ (90)	+ (90)	+ (90)	+ (90)	+ (90)	+ (90)		
Comprehensive Hydro - WPCD	+ (18)			+ (18)			+ (18)			+ (18)				
Field Hydro - WPCD		+ (18)			+ (18)			+ (18)			+ (18)			
Aerial Monitoring - DNR	Done													
Remote Monitoring - DNR	[??????]													
Data Analysis, Interpretation, Report Contractor	+	+	+	+	+	+	+	+	+	+	+	+	+	+

40-foot class or larger. The cabin should be large and spacious, and much open deck space will be needed aft. Speed should be on the order of 12 knots or more. Mechanical rigging will be needed to operate the box corer for sampling infauna. A dive platform or stout ladder will be essential for boarding divers used in sediment coring operations. Provisions should be made to supply running water on deck to facilitate the sieving of infauna samples. Minimum instrumentation would consist of a compass, VHF and CB radios, LORAN C, auto-pilot, and a high resolution fathometer. Electrical service must be available for the operation of side-scan sonar.

Cost for the lease of such a vessel should be no more than five or 600 dollars per day, including the operating crew. This means that vessel cost for the pre-study program (12) days @ $600 per day) would amount to $7,200; and for the Dredging Effects Study (81 days @ $600 per day) it would be $48,600, or a total for both field programs of $55,800.

3.2 General field observations and supporting data. The Contractor will design a log sheet for each field collection with entry spaces for field observations, specific collecting data, a numerical designation, and the required routing for analysis. This sheet will accompany each collection through its processing and analytical pathway, and a duplicate will be checked-off and filed at each successive handling point.

Field observations will include date, time, tide stage, approximate current velocity and direction, depth, percentage of cloud cover, wind directions and approximate velocity, air temperature, and presence or absence of precipitation. Regional meteorological observations on wind and rainfall can be requested from the U. S. Weather Bureau and other regional recording stations, such as the International Airport. The USGS can provide tributary flow records for the Pontchartrain drainage basin, and WPCD can serve as a data aquisition center for the additional hydro data routinely collected by other agencies having ongoing programs within this watershed (DEQWPCD, 1984).

Industry should provide the Contractor with LORAN C plots of all dredging operations during the course of the Study, and DNR can act as a coordinator to obtain pertinent data from any privately or publicly funded research conducted on the Lake within the duration of the Direct Effects Study.

3.3 Records of mud-flows, trenches, and ridges. If possible, these features would be recorded using a fathometer. If not, trials will be made using a side-scan sonar. However, in the event that the density of dredged material is too low for electronic detection by either device, then another method will have to be used to at least record the depth and extent of offsite sedimentation. One suggestion for this would be the use of fine oyster shell to lay out a broad bottom transect downcurrent and well beyond a dredge site perimeter. After dredging, cores taken along this line could be used to directly measure overburden at various distances from experimental dredging operations. The logistics of this method would have to be worked out during trial dredging work in the pre-study survey. Even if a satisfactory electronic bottom trace can be recorded, the dive team can still be used to obtain bottom cores of any disconformities presumed to be especially unusual.

Regardless of the method and survey pattern selected some provision will need to be made for measuring distances. The LORAN C can be used for this purpose, as can an hand-held range-finder (Rangematic). A somewhat less accurate technique is to calculate distance from point-to-point elapsed time and engine speed, based on a prior timed run made over a premeasured course at the same RPMs (4 min./ 1 mile · 6 min./ x miles).

As for cost, the vessel chartered by the Contractor should already be equipped with a high resolution fathometer. If a side-scan instrument is needed, this can probably be procured through LGS for about $200 per day.

3.4 Field and comprehensive water quality parameters. The field, or basic water quality parameters are water temperature, salinity, secchi disk disappearance depth, turbidity, pH, and dissolved oxygen. These are the only tests for which the Contractor will be responsible, while the WPCD will be responsible for these as well as the following more comprehensive list: nitrate, nitrite, ammonia, inorganic, and Kjeldahl nitrogen; phosphorus and orthophosphate; BOD-5; suspended, dissolved, and total solids; sulfates, chlorides, organic carbon; chlorophyll a; selected trace metals; and selected synthetic organic compounds. The selections for metals and organics will be made on the basis of WPCD's tests throughout the Lake in 1984. As in the field tests, samples for these determinations will be taken one meter below the surface and one-half meter above the bottom. Instruments and methods of analysis will be those currently used by WPCD. Supplementary water quality data may be available from industry, and from continuous recording equipment if it is installed.

Furthermore, DNR and the Contractor may decide to obtain some sediment-water interface samples for analysis of such items as hydrated iron and manganese oxides, suspended solids, DO, nutrients, toxins, and etc. This can be done by hypodermic extraction through the plastic barrel of the sediment coring tube described in the next section (3.5). All hydro data will be presented in appropriate appendices of the final report.

As a rough guide to cost, there is listed below an estimate of the price for each analysis. Field tests are no cost items.

Analysis	Price	Analysis	Price
Nitrate N	$ 10	Dissolved Solids	$ 5
Nitrite N	10	Total Solids	5
Ammonia N	10	Sulphates	5
Inorganic N	10	Chlorides	5
Kjeldahl N	14	Organic Carbon	25
Phosphorus	14	Chlorophyll a	10
Orthophosphate	14	Trace Metals	50 ea.
BOD-5	8	Synthetics	50 ea.
Suspended Solids	5		

3.5 Coring devices for sediment and infauna sampling. The coring tube proposed for sediment sampling is one designed by Dr. Joseph Donoghue of the Department of Geology at Florida State University (please see attached letter and drawings on the following pages). This device is a diver-operated, piston type corer that uses clear three and five-eights O.D. plastic tubing in the barrel. In operation, virtually undisturbed cores as long as six feet have been obtained. On deck, a sediment sample inside the clear plastic tube can be conveniently observed, measured, or photographed. Dr. Donoghue is willing to demonstrate this corer to DNR, and would be pleased to provide equipment and orientation to the Contractor awarded the Direct Effects Study. Cost of a new corer is about $200, and purchase price of the CAB tubing is $7 per foot (AIN Plastics, Inc., 249 E. Sandford Blvd., P.O. Box 151, Mt. Vernon, NY - (914)668-6800).

The corer proposed for the infauna study is a modified Jonassen and Olausson box corer manufactured by Mr. Frank O'Hara of Specialty Services Company in Bryan, Texas (please see the attached photos on the following pages). This was the instrument used by Sikora in his earlier benthic work in Lake Pontchartrain. In a newer model, however, the inside of the corer is divided into equal quarters to provide subsamples. This feature is desirable because it has a number of useful statistical applications. The purchase price of this corer is about $2,500.

3.6 Sediment analyses. In the pre-study survey, 10 cores will be taken at each station for the sampling replication level determinations (60); and three cores per site will be taken to determine sediment comparability between prospective pairs of control and experimental stations (120). In these tests, all samples will be photographed and measured to record layering characteristics, and any other features of apparent importance will be recorded. Next, the upper three inches

The Florida State University
Tallahassee, Florida 32306
Department of Geology

November 2, 1984

Mr. John Taylor
P.O. Drawer 730
Lynn Haven, Florida 32444

Dear Jack,

Enclosed are some of the items you asked about over the phone the other day. I hope they are of some use.

The two shop drawings are for the most recent of the four piston corers I've built. It works the best and collects the largest sample. The cores are collected in 3 5/8" O.D. cellulose acetate butyrate (CAB) plastic tubes.

The sketch will give you an idea of how the corer works. Any size boat can be used, as long as there is some means for clamping the piston cable to the gunwale. A diver or swimmer with extra weights stands on the bottom. He places the corer assembly on the bottom so that the piston is just above the sediment-water interface. When the cable extending up to the boat is taut and firmly clamped in place, he loosens the thumbscrew on the corer head. He then exerts force downward on the handles, pushing the CAB tube down past the piston. When the tube has gone into the sediment as far as it will go, he again tightens the thumbscrew. The corer is then hauled out of the sediment, using muscle or winch power from the boat. The lower end is capped as soon as it is free of the bottom. Using this method we have recovered undisturbed cores up to 2 m long with the 3 5/8" corer and up to 3 m long with smaller diameter corers.

You asked if it is possible to sample directly through the liner. It is, but I have never had the need to do so. Doug Hammond, at the University of Southern California Geology Department, has sampled gas bubbles in marine cores using a hypodermic needle. He mentions it in a publication, but I can't find the reference. I have also seen Edward Callendar, of the USGS, in Reston, collect estuary cores using CAB tubes with small, taped holes down the side. As soon as the cores were on deck, sediment pore water was extracted from selected holes and analyzed for nutrients.

You also asked for some references on interpreting and reporting grain-size data and relating it to source differences or environmental changes. Some of the more commonly referenced papers that I found in my files are as follows:

Folk, R., 1966, A review of grain-size parameters: Sedimentology, v. 6, p. 73.

Friedman, G., 1961, Distinction between dune, beach and river sands from their textural characteristics: Jour. Sed. Petrology, v. 28, p. 151.

__________, 1962, On sorting, sorting coefficients and the lognormality of the grain-size distribution of sediments. Jour. Geology, v. 70, p.737.

__________, 1967, Dynamic processes and statistical parameters compared for size frequency distribution of beach and river sands: Jour. Sed. Petrology v. 37, p. 327.

__________, 1979, Differences in size distributions of particles among sands of various origins: Sedimentology, v. 26, p. 3.

__________, Mason, C., and Folk, R., 1958, Differentiation of beach, dune and aeolian flat environments by size analysis: Jour. Sed. Petrology, v. 28, p. 211.

Passega, R., 1957, Texture as a characteristic of clastic deposition: Bull. Amer. Assoc. Petroleum Geol. v. 41, p. 1952.

I hope the above is helpful. Give me a call if you have any further questions.

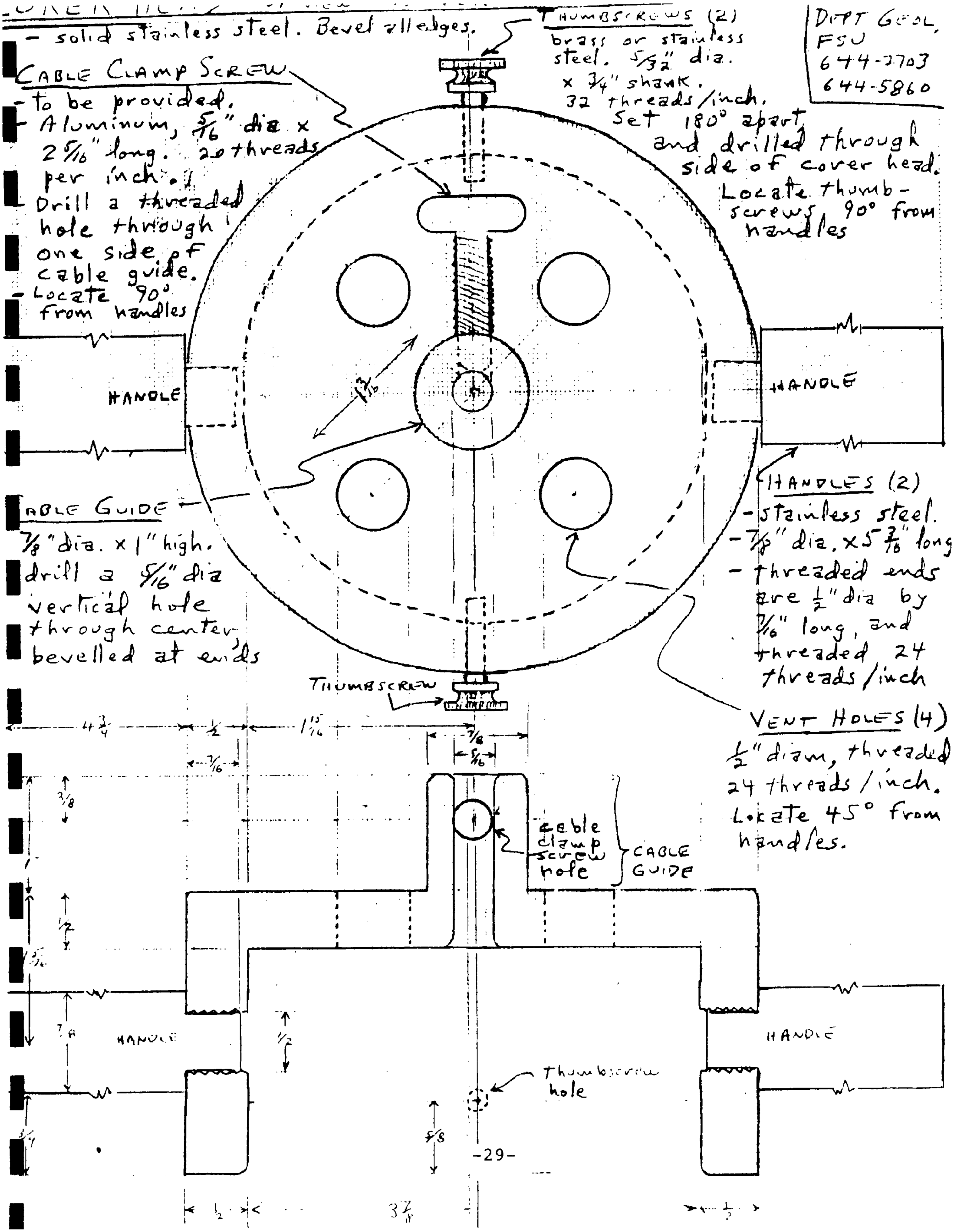
Sincerely yours,

Joe Donoghue

Joseph F. Donoghue

JFD/pr

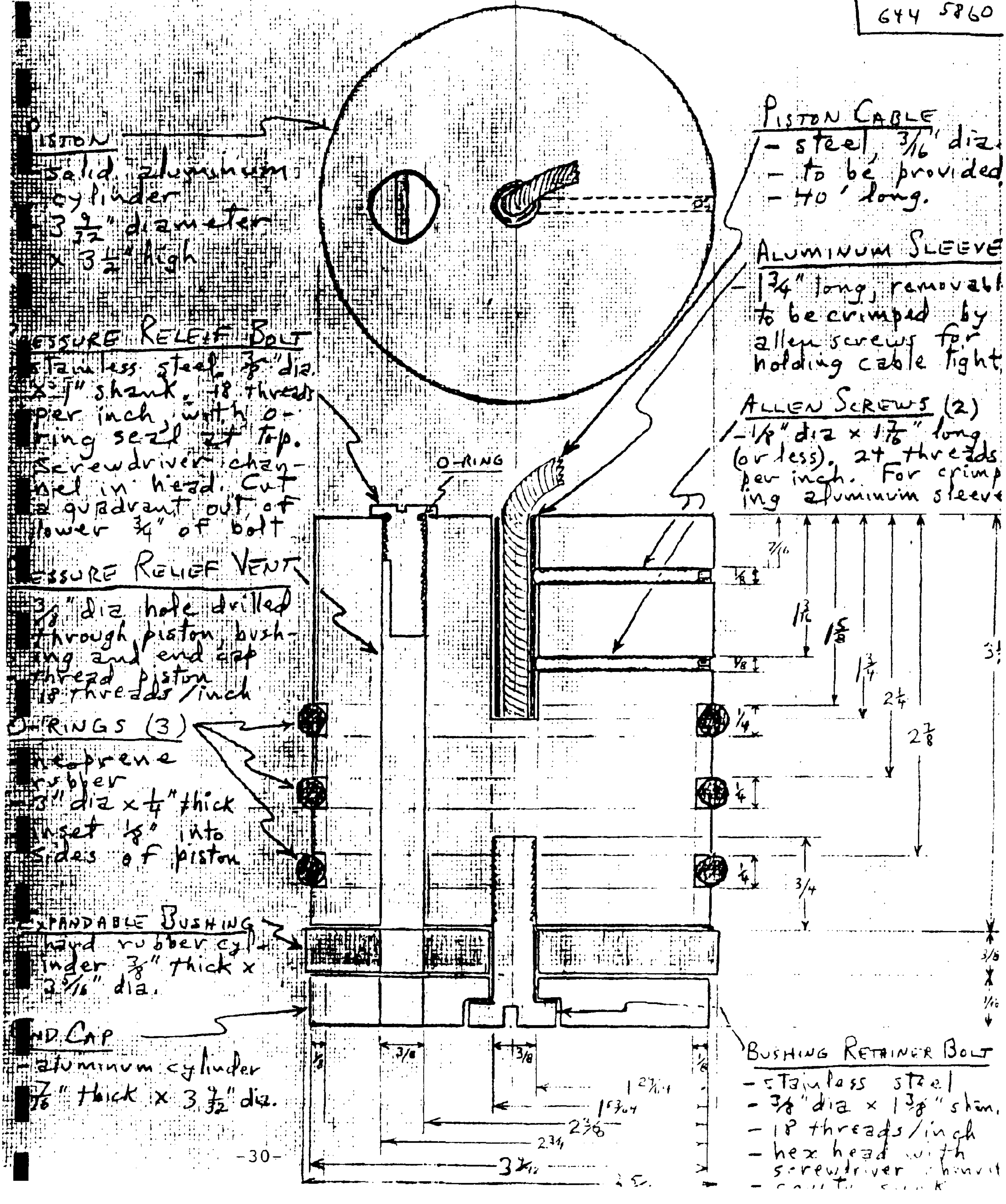
Enclosures

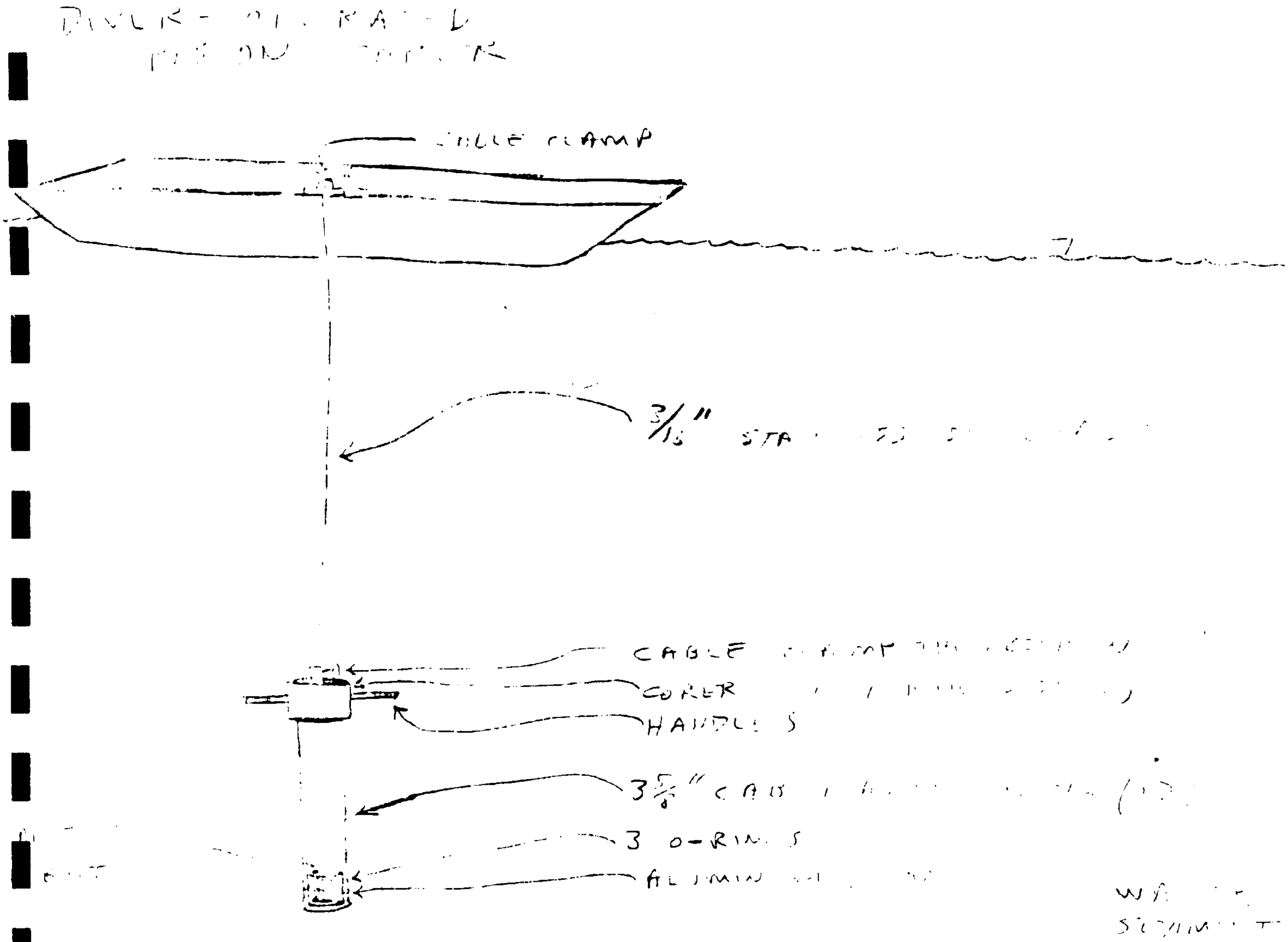

- solid stainless steel. Bevel all edges.
THUMBSCREWS (2)
brass or stainless steel. 5/32" dia. x 3/4" shank. 32 threads/inch. Set 180° apart and drilled through side of cover head. Locate thumb-screws 90° from handles
DEPT GEOL, FSU
644-2703
644-5860
CABLE CLAMP SCREW
- to be provided.
- Aluminum, 5/16" dia x 2 5/16" long. 20 threads per inch.
- Drill a threaded hole through one side of cable guide.
- Locate 90° from handles
HANDLE
HANDLE
CABLE GUIDE
7/8" dia. x 1" high. drill a 5/16" dia vertical hole through center, bevelled at ends
HANDLES (2)
- stainless steel.
- 7/8" dia. x 5 7/8" long
- threaded ends are 1/2" dia by 7/16" long, and threaded 24 threads/inch
VENT HOLES (4)
1/2" diam, threaded 24 threads/inch. Locate 45° from handles.
THUMBSCREW
1 3/16
4 3/4
1/2
1 15/16
7/8
5/16
7/16
3/8
1
1/2
1 3/4
7/8
1/2
3/4
5/8
cable clamp screw hole
CABLE GUIDE
HANDLE
HANDLE
Thumbscrew hole
1/2
3 7/8
1/2

PISTON - TOP VIEW AND VERTICAL CROSS-SE...

- solid aluminum. Bevel all edges.

DONOGHUE
DEPT GEOL.
FSU
644-2703
644 5860




CLAMP
CABLE
CORER
3

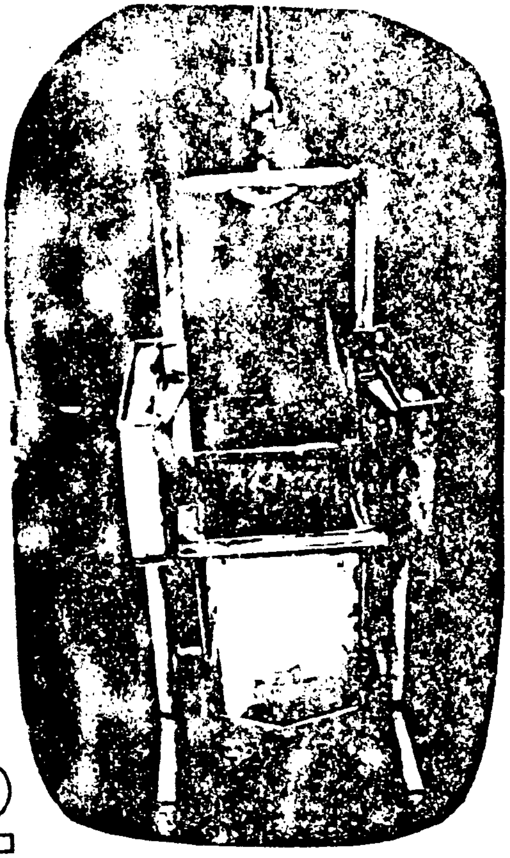
NEW UN

SPECIALTY SERVICES COMPANY
P. O. Box 3762
Bryan, Texas 77801

(409) 845-4025

AD IN BOXES

1



2

UNIT COCKE WITH LEAD B UP

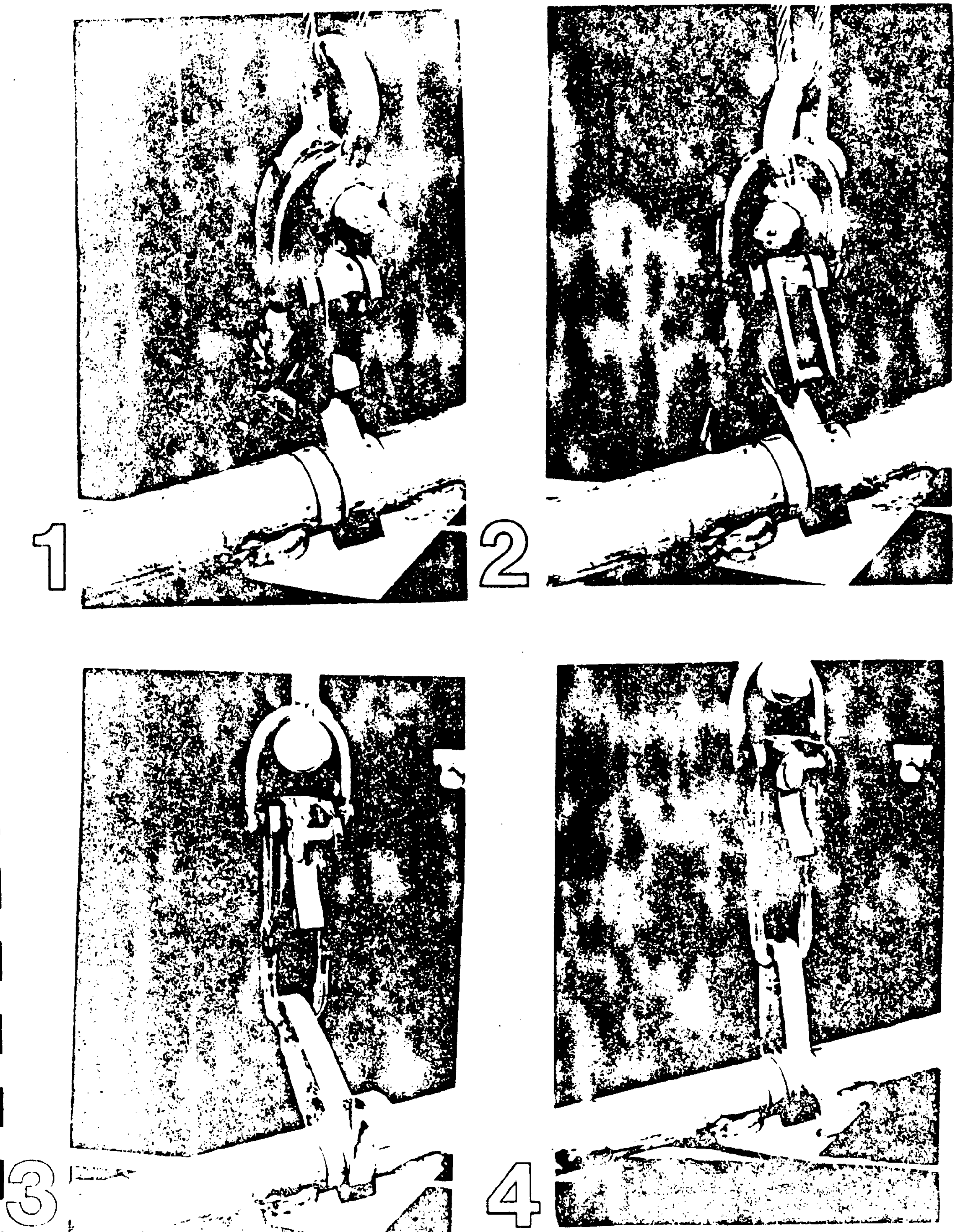
3

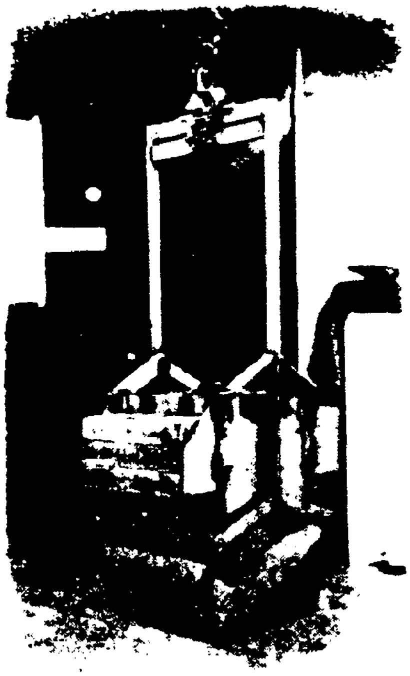
UNIT Closed WITH LEAD BOXES down

WEIGH of LEAD BOX CLOSES JAWS (spades)

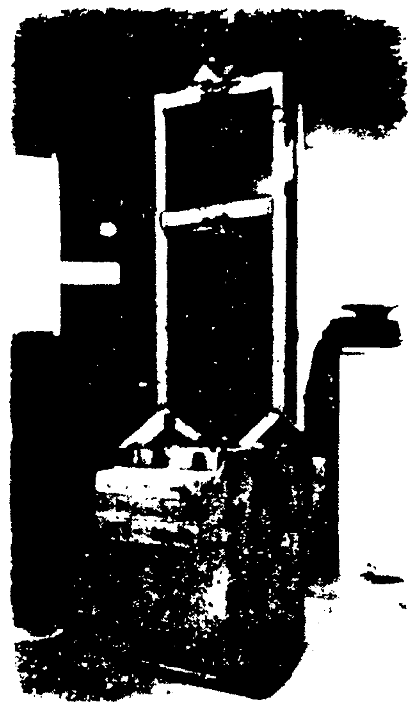
4

New



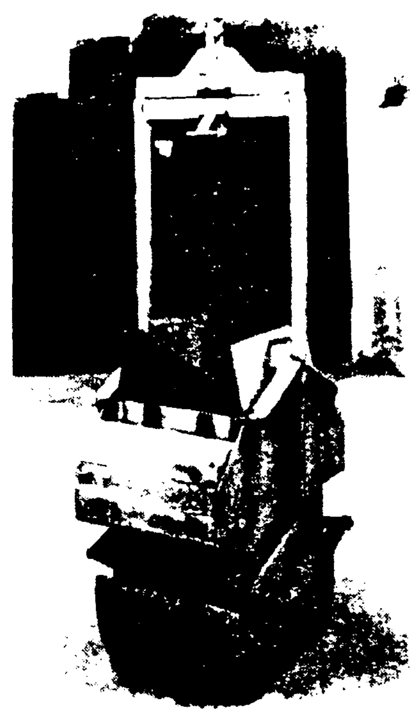


The corer cocked and ready to go over the side.



Box corer after the sample has been retrieved (simulated) and back over the deck. Note the trigger is now tripped. The safety pin that precludes the opening of the jaws allows the corer to be decked while subsamples are being taken.

To dump the sample, the safety pin has been removed and the corer is let down on the deck. Tilt corer so that it is resting on one jaw, nudge with knee and it will start opening. After the jaws have opened about 4 or 5 inches, it can be set back level.



The wire has been slacked completely and the corer is ready to be dumped by engaging the trigger and lifting with the winch wire. The cycle has been completed and the rig is ready to go over the side again.

of each core (biotic zone) will be carefully extruded, homogenized, and apportioned for the following tests: (1) organic, inorganic, and total carbon - LECO system; and (2) total texture in one-half phi intervals, together with statistical calculations for mean grain size, sorting, skewness, and kurtosis - Folk, 1974. Information needed on similarity between intra- and inter-station samples will be generated by multivariate analytical procedures.

In the Direct Effects Study, three cores will be taken at each station immediately before and after dredging (102), and then at two-month intervals for the two-year duration of sampling (648). These collections will be handled in the manner described above, but other fractions will be apportioned for additional physical and chemical analyses. The additional physical analysis will be for bulk density (Sikora, Sikora, and Prior, 1981). The additional chemical analyses will include tests for (1) nitrate, nitrite, ammonia, inorganic, and Kjeldahl nitrogen; (2) phosphorus and orthophosphate; (3) sulphates; and (4) scans for trace metals and synthetic organic compounds -emission spectrometer and gas chromatographic mass spectrometer. These scans would only be done immediately before and after dredging to determine which elements and compounds should be included in subsequent testing over the duration of the Study. This work would be directed by the Contractor with consultation, and perhaps assistance from WPCD. Results from these tests will be treated individually and collectively for graphic and cluster diagram representations. All sediment data will be reported in appropriate appendices in the final report.

On a per sample basis, the group of carbon analyses costs about $50, and together, the textural and statistical analyses run about $60. Bulk density tests are here estimated at $10 each; while other sample costs would be $50 for the nitrogen series, $25 for the phosphorus series, $10 for sulphate, and about $800 for each of the scans. However, after the scans have been done on the first pre- and post-dredging samples, charges for a single metal or synthetic compound would be $50 each.

Using these prices, a cost breakdown for the pre-survey and the Direct Effects Study has been estimated as follows: pre-survey - $6,600 (replication level work), and $13,200 (comparability work), or a subtotal of $19,800; and $184,110 (first pre- and post-dredging samples), and $327,240 (subsequent samples), or a subtotal of $511,350, and a grand total of $531,150 for all of the sediment work. For this calculation, the cost of analyzing three metals ($150) and three synthetic compounds ($150) was included for the 12 sampling events after dredging.

3.7 Infauna analyses. In the pre-study survey, 10 box corer samples will be taken at each station for the sampling replication level determinations (60). An estimated five corer samples per site will be taken to determine the comparability of infauna at prospective pairs of control and experimental stations (200). And in the Direct Effects Study, five corer samples will be taken at each station immediately before and after dredging (170), and then again at two-month intervals for the two-year duration of sampling (1080).

Specimens from each quarter of every box corer sample in all sampling events will be processed and recorded as a discrete group. This procedure will begin by individually sieving each subsample (0.5mm screen) and preserving the residue in properly labeled, plastic, screw-cap containers filled with a solution of 10 percent, buffered formalin containing rose bengal dye. Plywood sample carriers should be constructed

(20 compartments) and used for shipboard sample storage and offloading.

In the laboratory, the contents of each jar will be resieved. Following this screening specimens will be picked out under dissecting scope magnification and sorted by major groups into screw-cap vials containing 70 percent ethanol or isopropanol. These vials will then be transferred to the appropriate taxonomists for species identifications and enumeration. Identifications should be made to the lowest practical level, and a reference collection must be maintained by the Contractor. Taxonomic specialists should be available for the following invertebrate groups - Mollusca, Oligochaeta, Polychaeta, Rhynchocoela, Crustacea, and larval aquatic insects.

The diversity and abundance data for subsamples at each station will be presented in a sequence of tables appended to the final report. These tables should contain a phylogenetic and alphabetical list of species, together with the numbers collected and their frequency of occurrence. Summarized data at the end of each table should include the total number of species, total number of individuals, number of individuals per square meter of bottom, Shannon-Weaver Index of Diversity, and Evenness-J.

In the pre-study survey these data will be used in making the multivariate analyses used to determine the needed level of sampling replication; and to objectively select locations for eight of the nine experimental stations. In the Study itself, these data will be used in multivariate analyses to show the magnitude of dredging impacts and the rate and extent of environmental recovery for respective sampling sites over the two-year study period.

The cost for collecting and processing each corer sample is about $200. At this rate, the identification of infauna in the pre-study survey would amount to about $52,000. In subsequent sampling the figure would be $250,000, making a grand total of $342,000 for both phases of the Direct Effects Study.

3.8 Data reductions and presentations. Czekanowski's coefficient, in its similarity form, is suggested for use in the pre-study survey to determine the amount of sampling replication that will be required to satisfy the 85 to 90 percent confidence limits requested for infauna data. This coefficient contains both diversity and abundance factors, and is probably as well suited for this study as any of the generally used measures of faunal similarity (Boesch, 1977; and Bloom, pers. comm.). In the selection of appropriate pairs of control and experimental sites, this coefficient will also be used to determine inter-station infauna resemblances. Likewise, a multivariate similarity coefficient can be developed to determine the level of replication required in sediment sampling; and to assess the degree of similarity between sediments at control stations and possible experimental locations (Bloom, pers. comm.; and Donoghue, pers. comm.).

In the main Study, the multivariate approach, and extensions of that approach, can be used to develop cluster diagrams from classification analyses; and to develop graphic representations from recovery-stability analyses (Bloom, 1980; and Saloman, Naughton, and Taylor, 1982). These are powerful data reduction techniques. For example, cluster diagrams based on station similarities for sediment and infauna facilitate comparisons between station pairs as well as between any two stations in the entire control-experimental matrix.

As an extension of the multivariate approach, the multivariate quantification of community recovery is a statistical data transformation technique that should be particularly useful in this Study. In this analysis community properties at a station before dredging are represented statistically as a three dimensional entity that can be plotted as a position on a graph. Then following dredging, community properties in each succesive sample can be statistically evaluated by the same procedure and compared for likeness to the mathematical form of the original community. On the graph, the undisturbed community is symbolized as a line from the y-axis that extends from a zero point and runs above and parallel to the x-axis. When points for post-dredging samples are plotted from the x-axis, the line connecting them indicates the degree of community recovery as it approaches or departs from the zero-line. If the recovery-line touches the zero-line over the time course of sampling, then recovery may be considered to have occurred. Figures in the last two references illustrate this concept, and these publications have been attached for DNR's use.

4. Report Format. Upon the completion of field work, data compilation and analyses will probably take about four months and report preparation can be expected to take an additional two months. This means that about three years will be required to complete all tasks from the beginning of the pre-study survey to the end of the Direct Effects Study.

The Contractor's report to DNR should be organized in standard format to contain an Introduction, Purpose, Area Description, Review of Previous Studies, Methods, Results, Discussion and Conclusions, Recommendations, Executive Summary, and Bibliography. There will also be rather extensive Appendices to show all raw data and any oversize materials such as maps and cluster diagram print-outs.

The Introduction should provide an historical review and current status of shell dredging nationally, with particular emphasis on practices and regulations in Louisiana. Tables along the lines of those used by Templet (1974) would be a good way to summarize this information and provide easy reference to it.

The Purpose of the Contractor's report will be to clearly describe and document the direct effects of shell dredging on water quality, sediments, and infauna; and to record any observed post-dredging environmental recovery over the 24-month field study period. Additional objectives will be to reevaluate two previous studies pertaining to infauna and shell dredging on the basis of the present study (Sikora, Sikora, and Prior, 1981; and Sikora and Sikora, 1982). Then, from these results and evaluations, the primary goal of the Direct Effects

Study will be to make warranted management recommendations on shell dredging to DNR.

The Area Description will be confined to the Pontchartrain Basin with emphasis on anthropogenic influences on the Lake's natural features. Important reference publications for this section include Gulf South Research Institute, 1974; Stern and Stern, 1969; Stone, 1980; and more recent reports by the Louisiana Department of Wildlife and Fisheries, in press; and Coastal Environments, Inc., 1984.

In the Review of Previous Studies, findings from dredging research in coastal areas can be highlighted and summarized. Emphasis here should be placed on studies done in sheltered estuarine situations like Lake Pontchartrain and of course in Lake Pontchartrain itself (Bouma, 1976; and Sikora, Sikora, and Prior, 1981). Furthermore, other literature for the Lake should be researched to develop an historical setting to which data from this study can be compared. Here, care must be taken to evaluate past sampling and analytical procedures so that comparative findings can be properly validated or qualified.

Methods, and other procedural matters, must be clearly and concisely presented. Figures and Tables should be liberally used in both this section and the one below. Preparation of a glossary is recommended. This should include terms and words unfamiliar to the public, and explanations of equations and any other technical items that would otherwise be confusing to the general reader.

The Results section should be organized to first present findings at respective station pairs regarding pre-dredging environmental conditions, impacts associated with dredging operations, and post-dredging changes over time. Following this, comments should be directed toward findings between station pairs and between other station combinations.

In the Discussion and Conclusions section results from this Study will be summarized and critically reviewed within the context of other relevant research in Louisiana and elsewhere. This appraisal will then provide a basis for the formulation of the Contractor's conclusions on the specific aspects of shell dredging in Lake Pontchartrain that can be supported by objective research data. Speculation should be avoided. Areas of special concern to DNR include particulars of the initial impacts of dredging, and the relationship of recovery to past dredging intensity, sediment type, and time.

The Recommendations section will be largely based on the Contractor's conclusions, and should emphasize the development of regulatory criteria that may be useful in the implementation of existing guidelines and the State's overall management plans for Lake Pontchartrain. Coming from this study, any such criteria could relate to water quality, sediment, infauna, community recovery, or some combination of these factors. In proposing any criterion, the rationale for its selection must be evident, and complete monitoring procedures should be described.

If after two years the results of this Study prove to be inconclusive, the Contractor may wish to recommend a time extension along the lines of present research, or justified areas of new research.

This section will be followed by a Bibliography and all appended material. A synopsis of the Direct Effects Study will be prepared as an Executive Summary for the front of the Contractor's report.

<u>COST SUMMARY</u>

Vessel		
Pre-study Survey		
Sample Replicates, Sediment and Infauna		
3 days @ 600 per day	$	1,800
Station Comparability, Sediments and Infauna		
6 days @ 600 per day		3,600
Station Buoys		
3 days @ 600 per day		1,800
Direct Effects Study		
Initial		
Flag stations, bathymetry, hydro, sediment, and infauna		
9 days @ 600 per day		5,400
Subsequent		
Bathymetry, hydro, sediment and infauna		
72 days @ 600 per day		43,200
Total Vessel		55,800
Water Quality		
Pre-study Survey		
Inter-station distance, all parameters plus 3 trace metals and 3 synthetics		
20 samples @ 450 (x2)		18,000
Direct Effects Study		
Initial		
All parameters plus 3 trace metals and 3 synthetics		
180 samples @ 450 (x2)		162,000
Subsequent		
All parameters plus 3 trace metals and 3 synthetics		
72 samples @ 450 (x2)		64,800
Total Water Quality		244,800
Sediment Analyses		
Pre-study Survey		
Sample Replicates, carbon chem., texture and statistics		
60 samples @ 110		6,600
Station Comparability, carbon chem., texture and statistics		
120 samples @ 110		13,200

Sediment Analyses (cont.)	
Direct Effects Study	
Initial	
Carbon chem., texture and statistics, bulk density, nitrogens, phosphorus, sulphates, and 2 scans	
102 samples @ 1805	$ 184,110
Subsequent	
Carbon chem., texture and statistics, bulk density, nitrogens, phosphorus, sulphates, 3 metals, and 3 synthetics	
648 samples @ 505	327,240
Total Sediment	531,150
Infauna Analyses	
Pre-study Survey	
Sample Replicates, taxonomy and statistics	
60 samples @ 200	12,000
Station Comparability, taxonomy and statistics	
200 samples @ 200	40,000
Direct Effects Study	
Initial	
Taxonomy and statistics	
170 samples @ 200	34,000
Subsequent	
Taxonomy and statistics	
1080 samples @ 200	216,000
Total Infauna	302,000
Total Preliminary Analysis	1,133,750*
Data Processing And Final Statistical Analyses @ 10% of preliminary analysis	113,375*
Field Crew Of 6	
Pre-Study Survey	
12 days @ 600	7,200*
Direct Effects Study	
Initial	
9 days @ 600	5,400*
Subsequent	
72 days @ 600	55,000*

Laboratory Staff	
Project Director	
735 days @ 100	73,500*
First Assistant, Field Operations	
735 days @ 50	36,750*
Second Assistant, Laboratory Operations	
735 days @ 50	36,750*
Subtotal*	2,923,450**
Overhead, Contingencies, and Profit @ 30%	877,035**
Grand Total**	$3,800,485**

LITERATURE CITED

Bloom, Stephen A.
1980. Multivariate quantification of community recovery, p. 141-151 In John Cairns, Jr. [ed.] The Recovery Process in Damaged Ecosystems. Ann Arbor Sci. Publ., Inc. , Ann Arbor, MI

Boesch, Donald F.
1977. Application of numerical classification in ecological investigations of water pollution. EPA, Ecol. Res. Ser. EPA-600/3-77-033. Corvallis, OR. 113 p.

Bouma, Arnold H.
1976a [ed.] Shell dredging and its Influence on Gulf Coast Environments. Gulf Pub. Co., Book Div., Houston, TX. x + 454 p.

Coastal Environments, Inc.
1984. Workshop Packet, Lake Pontchartrain Task Force, Proposed Pontchartrain-Maurepas Special Areas. 1260 Main St., Baton Rouge, LA 70802

Folk, R. L.
1981. Petrology of Sedimentary Rocks. Hemphill Pub. Co., Austin, TX. 182 p.

Gulf South Research Institute.
1974. Environmental impact of shell dredging in Lake Pontchartrain. Prepared for Louisiana Shell Producers. Association. GSRI Proj. Rept. No. 414-665-41. 98 p. + appendices.

Louisiana Dept. of Environmental Quality, WPCD.
1984. Louisiana Ambient Water Quality Monitoring System. P. O. Box 44066, Baton Rouge, LA 70804.

Saloman, Carl H., Steven P. Naughton, and John L. Taylor.
1982. Benthic community response to dredging borrow pits, Panama City Beach, Florida. U. S. Arym COE, Coastal Engineering Research Center, Misc. Rep. No. 82-3, Ft. Belvoir, VA. 138 p.

Sikora, Walter B. and Jean P. Sikora.
1982. Ecological characterization of the benthic community of Lake Pontchartrain, Louisiana. Coastal Ecology Lab, Ctr. Wetland Resources, LSU, Baton Rouge, LA. LSU-CEL-82-05. 214 p.

Sikora, Walter B., Jean P. Sikora, and Anny M. Prior.
1981. Environmental effects of hydraulic dredging for clam shells in Lake Pontchartrain, Louisiana. Pub. No. LSU-CEL-81-18. Ctr. Wetland Resources, LSU, Baton Rouge, LA. ix + 140 p.

Stern, Daniel H. and Michele S. Stern.
1969. Physical, chemical, bacterial, and plankton dynamics of Lake Pontchartrain, Louisiana. Louisiana Water Resources Res. Inst. Tech. Rep. No. 4. vi + 60 p.

Stone, James H.
1980 [ed.] Environmental analysis of Lake Pontchartrain, Louisiana, its surrounding wetlands, and selected land uses. Vols. 1 & 2. Ctr. Wetland Resources, LSU, Baton Rouge, LA. LSU-CEL-80-08. Prepared for the U. S. Army COE, Contract No. DACW29-77-C-0253. 1219 p.

Templet, Paul H.
1984. Lake Pontchartrain: A test case for special area planning. Institute for Environmental Studies, LSU, Baton Rouge, LA. 21 p.