

The Preliminary Report of the National Reservoir Inundation Study



THE PRELIMINARY REPORT
OF THE
NATIONAL RESERVOIR INUNDATION STUDY

by

Daniel J. Lenihan, Project Director
Toni L. Carrell
Thomas S. Hopkins
A. Wayne Prokopetz
Sandra L. Rayl
Cathryn S. Tarasovic

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PREFACE

The Reservoir Inundation Studies Project is an extremely complex undertaking, which requires archeologists conducting the research to assimilate a large amount of data in sciences and specialty areas very different from their own and apply it to an archeological context. Coordination with other archeologists and experts in many related disciplines for purposes of review has been an integral part of the study, and it is with some trepidation that I attempt to acknowledge their help, because it is almost certain that some will either be inadvertently left out or given insufficient credit.

With this in mind, the core team would like to extend its appreciation first to the coordinating representatives of the four Federal agencies contributing to the Reservoir Inundation Studies Project: Ward Weakly, Chief Archeologist of the Bureau of Reclamation; Richard Leverty, Environmental Planner for the U.S. Army Corps of Engineers; Jim Warren, Archeologist for the Soil Conservation Service and Doug Scovill, Chief Archeologist of the National Park Service.

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The following individuals helped us on particular problems or specific elements in our research design. On archaeometric questions, we received a great deal of assistance from Jonathan Ericson of the Los Angeles County Museum of Art. Irving Friedman of the United States Geological Survey, Dan Wolfman of the Arkansas Archaeological Survey, and Peter Klein of the Bureau of Reclamation also provided many useful technical insights in this area. Robert DuRois, University of Oklahoma, provided valuable information on archaeomagnetic collection procedures for saturated soils.

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Preservations specialists who reviewed our work or answered a multitude of questions include Curtiss Peterson of the Florida Board of Archives and History, Donny Hamilton of the Balcones Research Center, University of Texas at Austin, and William J. Burke of Arizona State University on the stabilization of pictographs and petroglyphs in inundated environments.

Etta Peterson of Ames Research center, National Aeronautics and Space Administration discussed at length with core-team members the possible impacts of inundation on amino-acid racemization. Tom Lyons and Dwight Draeger of the Southwest Cultural Resources Center explored with us the structuring of remote-sensing questions into the overall inundation study research design.

Some very noteworthy assistance in regards to weighing the various mechanical impacts on site constituents was also rendered by Paul Knodel and E. J. Carlson of the Bureau of Reclamation, Engineering and Research Center, in Denver.

Jane Harvey edited the manuscript in draft form. It was typed by Peggy Humphreys. Darlene Romero, the Reservoir Inundation Studies Project secretary labored through the typing of countless early drafts and revisions of parts of this report, and typed the final version with the assistance of Christina Lopez.

The Director's office of the Southwest Region of the National Park Service and Robert H. Lister, Chief of the Southwest Cultural Resources Center are thanked for their continued support of this study.

A special debt of gratitude is owed to Calvin R. Cummings, Deputy Chief of the Southwest Cultural Resources Center, who has always been one of the prime movers in promoting and developing a National Reservoir Inundation Studies Project. I fully believe this project would have never been realized without his constant, active support over the last several years.

D.J.L.

FOREWORD

This report stems from an initial cooperative effort of the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the U.S. Soil Conservation Service, and the National Park Service to find practical and demonstrable solutions, at the field level, to commonly shared problems faced by field managers in the conservation management of inundated cultural resources.

During the past decade, a great deal of emphasis has been placed at the Federal level on inventorying, evaluating, and salvaging threatened archeological resources. The land managing agencies have come to realize that this is but a part of the larger program of the management of these resources. This multi-agency study seeks to answer the question, "How should we manage the long-term preservation of inundated archeological resources?"

The success of this effort is due, in large measure, to its being conceived, planned, coordinated, and executed by field personnel--the people in closest touch with the "real-world" problems of inundated resources. Through the pooling of funds, specialized personnel, and facilities of the participating agencies, a program more effective than one undertaken by a single agency was developed.

Douglas H. Scovill
Chief Archeologist

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Chapter I

INTRODUCTION

WHY AN INUNDATION STUDY?

As noted in the prospectus for the Reservoir Inundation Studies Project (Lenihan et al., 1975), there has been a growing awareness on the part of various Federal agencies of a serious blind-spot in their meeting legal obligations to protect and conserve cultural resources. A series of Federal antiquities legislation specifies that land-management and construction agencies must assess and mitigate, where necessary, the impact their activities will have on archeological and historical sites. The classic response to these requirements by construction agencies has been to fund "salvage" efforts, which often result in hurried excavations performed outside the framework of a regional cultural-resources-management plan.

Water-impoundment projects, such as dams and reservoirs, comprise a large portion of the land-modification activities of Federal agencies, but the impact of these activities on cultural resources cannot be adequately assessed and mitigated, because the archeological profession admittedly cannot provide systematic data to serve as criteria for intelligent decisionmaking regarding this issue (Jewell, 1961; Prewitt, 1972; Anderson, 1974; Lenihan, 1974; Garrison, 1974; Carrell, 1974; Ruppe and Green, 1975; Prewitt, 1974).

Environmental impact statements initiated by various Federal agencies have advanced models for understanding the effects of inundation on archeological sites, ranging from those based on the assumption that all is preserved and protected for posterity, to those based on the assumption that all sites will turn into masses of unrecognizable gelatinous material, with no remaining data-retrieval potential. The one element

common to all of the assertions being made at this point regarding the overall effects of inundation on cultural resources is that they are highly speculative and scientifically unsupportable.

It should also be noted that, whatever the nature of the impacts of immersion on these sites may be, the zones are indeed highly sensitive archeologically. The areas flooded by water-impoundment projects tend to correspond with ancient watercourses and river valleys, and archeological evidence indicates that such drainage systems were the primary trade and communication routes for prehistoric and historic man in the New World (Williams and Stoltman, 1965; Robertson and Robertson, 1974; Taylor, 1964; and Neill, 1964).

Representatives of the U.S. Army Corps of Engineers, the Bureau of Reclamation, the Tennessee Valley Authority, and the National Park Service expressed deep concern for this problem in a workshop held at the May 1975 meeting of the Society for American Archeology in Dallas. At this time, the represented agencies made tentative commitments to pool their resources into a coordinated research program, which would be directed toward developing a body of systematic data upon which to base decisions relating to the disposition of cultural resources in Federal impact areas in which freshwater inundation was the primary form of impact.

The assembled group agreed that the proposed studies should be a cooperative, coordinated effort on the part of all Federal agencies involved, which would preclude duplication of efforts and the resultant waste of considerable time and money.

The National Park Service (NPS) has been directed by the U.S. Department of the Interior to fulfill the Secretary's function of providing aid and assistance to other Federal agencies in the field of archeology. In addition, the National Park Service's Southwest Regional Office already had a functioning underwater archeological research team, and was in fact actively involved in confronting the research problem in question. Thus, the National Park Service's Southwest Regional Office was designated as coordinating body for the project.

WHY THIS REPORT?

This report is the second formal publication of the National Reservoir Inundation Studies Project. Its format is designed to describe the progress and results of the first phase of the project in a manner that will be understandable to high-level managers in Federal agencies, as well as to other individuals who might not have professional archeological backgrounds but are integral to decisionmaking processes relating to the disposition of cultural resources. Some sections of the report must, by nature, be fairly technical; however, a strong effort has been made to eliminate and to encapsulate the gist of any necessarily technical portions of the report in explanative concluding paragraphs.

The Reservoir Inundation Studies Project is not a standard archeological research project; rather, it is a cultural-resources-management study specifically designed to assess impacts on archeological values from both permanent and periodic immersion by reservoir waters. This report, therefore, does not provide information relating to the archeology of any particular site or region, except insofar as this archeological information is essential to an understanding of the problem of the destruction or enhancement of data-retrieval potential of that site by freshwater flooding.

As mentioned above, this report focuses on the concept of data-retrieval potential, although this is certainly not the only element comprising an archeological value from a cultural-resources-management viewpoint. Some objects of antiquity have intrinsic symbolic significance for the American people, to whom this federally sponsored project is ultimately accountable.

It should be understood that the report deemphasizes the latter--not because such concerns are considered unimportant, but because they are for the most part non-quantifiable, and best left to bodies such as the President's Advisory Council on Historic Preservation and the State Historic Preservation Office, which have been constituted to deal with the question on a site-specific basis.

WHY THE CORE-TEAM CONCEPT?

One of the key concepts in dealing with personnel needs in the Reservoir Inundation Studies Project effort has been the formulation of a strong core-team. The core-team concept is critical to the effective operation of this unique project for two reasons:

First: The aims and objectives of the project are not exclusively anthropological in nature, and research techniques in the field may often have a very different focus from standard archeological approaches. It would be unrealistic to expect contracting salvage archeologists to effectively operationalize the research strategy of the project without some initial coordination with core-team specialists who are thoroughly familiar with the methodology and techniques.

Second: A large portion of the data-retrieval effort will be conducted while a water-column is still present over the site. This is because many of the sites representative of certain geographical and cultural variables lie under water, and because the variable of the drawdown itself must be controlled for. There are very few individuals in the Country capable of conducting serious underwater archeological research efforts, and at the writing of this report, there are very few standing teams capable of carrying out even local aspects of the underwater component of this project. Individuals comprising the core-team were therefore chosen on the basis of criteria requiring that they have background in standard terrestrial archeology, and have worked in a recognized state or Federal underwater-archeology program. Because none of the institutions in the United States responsible for conducting the pre-inundation archeological effort in the project's proposed test-reservoirs have the underwater-archeology research capability required for some phases of the project, members of the core-team carry out the necessary underwater-data-retrieval operation in coordination with these institutions.

The core-team has several important functions:

1. To coordinate with professional archeological institutions in many areas of the Country to ensure that contracted research efforts directed toward fulfilling

the aims of the Reservoir Inundation Studies Project are conducted in a manner that will allow their effective integration into the project.

2. To actually conduct the underwater aspect of the research in presently inundated sites, when possible, in conjunction with archeologists who are the most familiar with the original pre-inundation field-work.

3. To assimilate the data-returns from all aspects of the project, and from this data, develop coherent statements on the effects of inundation on cultural resources.

GENERAL RESEARCH APPROACH

The core-team approaches the problem of determining the effects of inundation by a series of logical steps:

1. Assessing what is already known about the problem at hand.

A comprehensive literature search has been conducted for any printed material dealing directly or indirectly with the question of freshwater immersion of cultural resources.

Because many of the questions about impact on the physico-chemical nature of the resources may have been partially dealt with in a tangential way by scientists in other disciplines, the team has visited Federal research centers specializing in the dam-construction sciences, including the Bureau of Reclamation Engineering and Research Center in Denver, Colorado; the U.S. Army Corps of Engineers' Waterways Experiment Station in Vicksburg, Mississippi; and the U.S. Geological Survey in Menlo Park, California.

2. Conducting preliminary field sessions to assess test sites for possible inclusion in the project, and simultaneously refining the equipment and techniques needed to extend the testing program to underwater site components. Reservoirs in several geographical and ecological areas around the Country have been assessed for viability for inclusion in the project, and

sophisticated systems for underwater mapping and data-retrieval are being developed.

3. Establishing long-range testing programs in various reservoir situations.

Such testing programs have thus far been instituted at Palmetto Bend, in Texas; Tellico, in Tennessee; Folsom Reservoir, in California; Table Rock Lake, in Missouri; and Cochiti and Abiquiu Reservoirs in New Mexico.

The testing program will be instituted in other areas until a reasonable cross section of reservoirs is obtained.

4. Monitoring systematic testing and report results. This final step will be accomplished through the writing and dissemination of scientific reports on a periodic basis through the course of the project. As in this preliminary report, the emphasis will be on conveying useful information in a resources-management framework and not simply reporting technical-data returns.

From its inception, the Reservoir Inundation Studies Project has been a very open project, in that critical review and close scrutiny by the archeological profession has been actively encouraged. Presentations have been made at meetings of the Society for American Archaeology and International Conference on Underwater Archaeology describing the project goals and intended methodology. Response has been gratifying, and many helpful reviews and suggestions have been forwarded to the core-team researchers in Santa Fe. This interest is appreciated, and it is hoped that the archeological community will continue to take an active interest in a project that may have considerable influence in determining the course of cultural-resources-management activities for the next several decades.

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Chapter II

RESEARCH DESIGN

INTRODUCTION

In the last four decades, the incidence of impacts exerted on archeological sites by reservoir-construction activities has achieved immense proportions. The archeologist's recommendations in response to the threat of inundation impacts has generally been to "salvage" as much of the data-base as possible before flooding occurs. This often translates into abortive attempts at total excavation.

Archeological excavation is in itself a destructive process, and is often conducted in a reactive rather than a planned manner, so the profession is devoting more and more of its efforts to improving the quality of research-designs in salvage archeology, and to developing a conservation ethic within the field (Davis, 1972; Longacre and Vivian, 1972; Struever, 1968; Lipe, 1974). Integral to this conservation orientation has been the conviction that much of the archeological data-base should wherever possible be stabilized, and saved for future investigation at such time as more advanced techniques and more refined research-strategies may permit far greater benefit from site excavation. In a reservoir, this concept of a data-bank depends on the preservation of archeological values from any detrimental impacts which may be caused by freshwater flooding. To date, insufficient information exists to enable reliable generalizations about the short- and long-term effects of flooding on these values.

The major focus of this research design for the Reservoir Inundation Studies Project will therefore be on the acquisition of substantive data that can be used to reasonably determine which reservoir variables will be destructive to specific archeological values, and

which procedures may best be used to mitigate the adverse effects where anticipated--that is, either salvage or attempts to protect and preserve the site. It must be emphasized that this project is designed only to provide the technical information needed by managers and archeologists for their decisionmaking and that this information will not comprise an answer to the problem itself. The specific use of the results of the Reservoir Inundation Studies Project research program must in each case be determined within the context of an enlightened regional cultural-resources-management overview.

The chief concerns relevant to the inundation of archeological remains to be assessed within the context of the Reservoir Inundation Studies Project study include: the mechanical and chemical effects of inundation on cultural and environmental data, and the loss of access to the data-base.

GENERAL RESEARCH OBJECTIVES

The general research objectives of the Reservoir Inundation Studies Project are directed toward developing an organized body of data that will enable Federal land managers to realistically predict the impact of different modes of freshwater inundation on different types of cultural resources, and toward providing these managers with an understanding of the relative effectiveness of alternative techniques for mitigating unavoidable adverse impacts.

These objectives are in line with the conservation ethic set forth by the archeology profession (Lipe, 1974; Lipe and Lindsay, 1974), the American Society for Conservation Archeology, and with the intent of the extant sequence of Federal antiquities legislation in the United States (Reservoir Salvage Act of 1960, as amended, popularly known as the "Archeological Conservation Act," and "Moss-Bennet Bill;" the National Historic Sites Preservation Act of 1966; the National Environmental Policy Act of 1969; and Executive Order #11593, "Protection and Enhancement of the Cultural Environment").

SPECIFIC RESEARCH OBJECTIVES

To accomplish the foregoing general objectives, various tests will be conducted to answer the following

specific questions:

1. What direct effects will the mechanical act of freshwater immersion have on the physical integrity of archeological sites?

This question essentially devolves into a question of impact on vertical and horizontal stratigraphy. Erosion, compaction, liquefaction, and differential settling of cultural materials are examples. The construction of a relative impact chart, which in itself serves as a baseline predictive model for mechanical impacts, will begin to address this problem. Due to the almost infinite number of relevant variables that come into play when dealing with the question of mechanical impacts on the full gamut of possible cultural manifestations in a reservoir, this aspect of the problem will be dealt with in this fashion, rather than through the creation of a huge number of specific predictive hypotheses. It is felt that this would be much more useful to both the concerned manager and interested archeologist.

Note: All of the following research questions are based upon the assumption that the mechanical impact on a specific site has not been so great as to make all further concerns academic.

2. Will chemical or other environmental changes that occur as a result of immersion cause differential preservation of those classes of cultural remains that are usually subjected to attribute analyses by archeologists (ceramics, bone, wood, glass, shell, etc)?

3. Will the effects of immersion, permanent or periodic in nature, skew or make less valid the results obtained from specific dating and analytic techniques?

Dating techniques to be considered include carbon-14, thermoluminescence, dendrochronology, amino-acid-racemization, obsidian-hydration, archeomagnetism, fission-track and alpha-recoil dating, and fluorine analysis. Analytical techniques to be considered include palynology, and the full range of environmental soil analyses (such as pH, soil phosphates, nitrates, and macrobotanical analyses).

4. Will inundation adversely impact the potential a drainage area has for preliminary cultural-resources inventory efforts, including standard survey techniques and remote-sensing?

5. Will inundation impact those qualitative elements of archeological sites that are often used as indicators of natural and cultural features, such as soil color and texture?

The preservation of a site and the cultural data it contains are determined by its environmental context (Ascher, 1968). The degree or extent of preservation will depend ultimately upon the materials of which the sites and cultural remains are composed, and upon the conditions to which they have been subjected throughout their post-occupational life. An important consideration in this regard would be any drastic alteration of their environment. When objects are buried for a long time under conditions that are reasonably constant, they tend to achieve a state of equilibrium with their environment (Plenderleith and Werner, 1971).

Certain reservoir-specific variables must therefore always be considered when the data-retrieval potential of submerged archeological sites is evaluated. One of the most important of these variables is the frequency and duration of inundation. Some reservoirs, including many that are built by the Soil Conservation Service, result in short-term inundation of sites in the impoundment. This creates an alternating wet-dry cycle, which can exert severe impacts upon some classes of data-bearing materials. Other reservoir-specific factors include zonation; reservoir use (function of reservoir and method of releasing water); thermoclines; and rates of sedimentation. Each of these variables will be considered in determining both the short- and long-term effects of inundation.

Although water quality is a variable considered in the context of various hypotheses advanced in this research design, it should receive special attention due to its subtle and complex nature. It is known that industrial wastes and runoff from agriculturally developed areas seriously affect the biosphere in aquatic environments. However, virtually nothing is known about the potential impact of this waste and

runoff on cultural resources. At this point it is being assumed (although not with a great degree of confidence) that the potential impact from this water-quality factor will be confined to soil-chemistry returns, and perhaps to the differential preservation of some of the more vulnerable organic remains. Attention will be given to monitoring the effects of water pollution, insofar as this pollution can be isolated as a relevant variable, and to eventually generating testable hypotheses regarding its potential impacts on archeological values.

The reservoirs that have been selected for intensive study contain sites representing a broad and diverse range of cultural expression. However, in order to assess long-term effects, the areal scope of the study will be slightly expanded to include known submerged sites situated in karst contexts (such as sinkholes and submerged caves). Many of these sites are known to contain well-preserved organic and inorganic remains dating to 10,000 B.P., which will serve as control factors in documenting beneficial effects of inundation. A comparison between data retrieved from reservoir and karst contexts will contribute to the understanding of the various factors that operate to preserve archeological remains.

A final specific research objective will be to determine to what degree state-of-the-art underwater-archeology data-retrieval methods can produce information from inundated sites comparable to information produced by land-archeology techniques. From a resources-management viewpoint, the accessibility of the resource and its scientific data-potential are equal in importance to the condition of the resource in considering the nature of a particular impact. In the state-of-the-art now, certain limitations are found in underwater archeology that are not found in land archeology. The majority of these limitations relate to the physiological aspects of diving; others relate to the physical characteristics of the reservoirs, such as site depth and visibility.

RESEARCH STRATEGY

To operationalize the objectives of this research design in a manner that would encompass the full range of suspected variables and considerations, a logical

framework for systematic testing had to be devised. The degree to which the problems posed and their solutions are validated by the testing framework that we have developed will be problematical, as it is in all scientific endeavors. However, the Reservoir Inundation Studies Project study team believes it is imperative that the nature of this systematic-testing framework be made explicit, so that the degree of reliability of the research tool will be as accessible to scrutiny as the result of the research itself.

There are two distinct problems being confronted by the Reservoir Inundation Studies Project. Both require the construction of separate, but related, predictive models.

The first is to conclusively determine just what sort of impacts on archeological sites derive from freshwater flooding due to dam construction.

The second is to test different methods of mitigation to determine which will be effective in helping to check attrition to the Nation's cultural-resources base. In dealing with the second problem, the approach will of course be in large part dependent on the conclusions reached regarding the first problem.

This research design for the Reservoir Inundation Studies Project must therefore include the generation of two interdependent predictive models, the second of which is a permutation of the first.

Model #1 will establish a basis for anticipating impacts on archeological values from the freshwater flooding of archeological sites applicable to a cross-section of cultural contexts and reservoir environments.

Model #2 will establish a basis for developing and testing the practicality of using mitigative measures other than salvage archeology. At this point, in our Nation, there is no well-organized alternative to the reactive technique of "salvage" archeology when cultural resources are threatened.

Model 1

This model is designed to test the correlation between a particular type of reservoir environment and an impact on a specific archeological value.

The reservoir environment is composed of sets of variables that we have isolated and selected. We are assuming that we have recognized enough relevant ones to establish a significant relationship between the reservoir and the "impact" (a degree of attrition or enhancement) to archeological values--again, as we have defined them. This is not an explanative model, in the sense that archeologists sometimes use a similar framework to confirm the existence of an overriding behavioral law that will explain certain patterns of cultural activity. Rather, it is a framework for testing a predicted relationship between a reservoir phenomenon and a specific effect. Parity between explanation and prediction in scientific testing constructs is well established (Morgan, 1973).

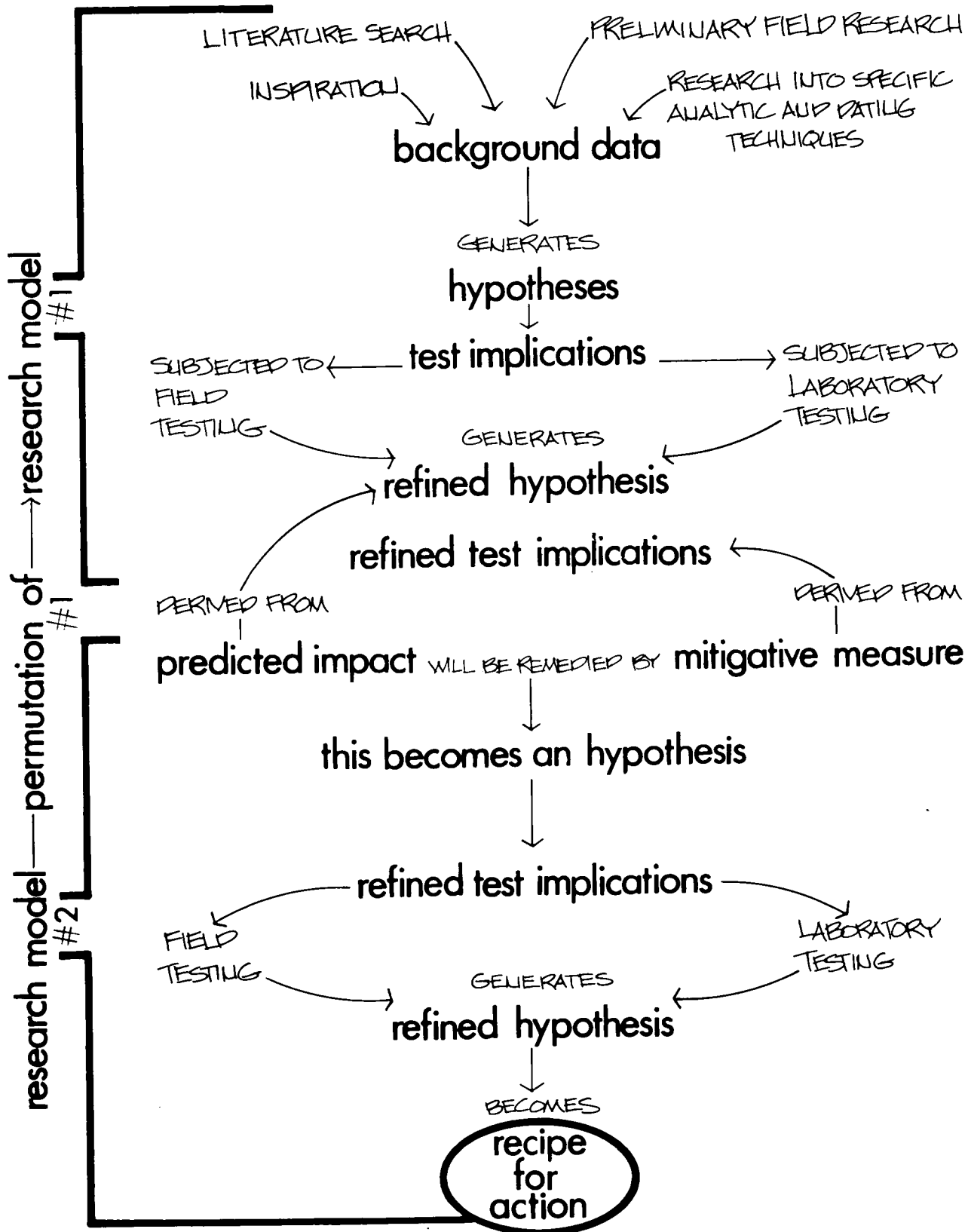
The testing framework is designed to be open-ended and flexible, to allow for the eventual inclusion into the study of variables that had not been originally considered relevant by project researchers.

First, for each data-retrieval category covered by the study, a hypothesis will be made, which predicts whether or not freshwater immersion due to dam construction will negate the effectiveness of the data-retrieval method. For example: "Carbon-14 samples taken from a dry-land site will not yield appreciably different dates from similar samples taken from an inundated or post-inundation site."

This statement would be preceded by an introduction for the non-archeologist and a summary of relevant background material in the form of generating data, which would include any variables that the analysis of available information indicates should be isolated and controlled for in the "test implications."

The test implications, which are the next element in the research design, are a series of "if . . . then" statements, which frame the implications of the hypothetical statement into a series of results that can be logically expected from systematic testing, should the hypothesis prove to be valid. They will be logical developments of the variables noted in the generating data.

If any of the test-implications are proven false by field testing, the original hypothesis must then be



inundation study
research strategy

modified to reflect the new data. In this way, each successive report prepared by the Reservoir Inundation Studies Project team will reflect, in the hypothetical statement on each category of potential data loss or enhancement, the best documented conclusions then available on the specific problem. Also, it will be made explicit just which variables have been considered and exactly what criteria have been used to form conclusions resulting in changes to the original hypothesis. Concurrently with the development and enhancement of these hypothetical statements related to model #1, there will gradually emerge sets of suggested mitigative measures which will be tested and evaluated in model #2.

Model 2

The purpose of this model is to test the correlation between a predicted deleterious impact and the effectiveness of a proposed mitigative measure. As in the case of the first model, in this model we are not designing the question to determine why this correlation exists, but rather to demonstrate with an acceptable degree of reliability that a particular mitigative action is or is not effective. As one high-level Federal manager explained to project personnel, "We need a cookbook to tell us how to best use our money to preserve different cultural resources in different reservoirs." The "cookbook" concept underlines the fact that some of the results of this report are to be used as "recipes for action," so to speak, in the real world.

DEMANDING FROM THE SYSTEM

The research design makes available, on several different levels, the latest information concerning anticipated impacts on a particular archeological value and the best known mitigation measure. On the least technical, and most concise level, the manager or archeologist may look to the introduction and to the latest, most refined hypothesis. If he wishes to further understand the reliability of this hypothesis (which now serves as a propositional statement), he may check the test-implications and the generating-data. In the case of mechanical impacts, the "relative-impact chart" provides an easy visual reference to the same material.

Although the hypothesis and test implications become only moderately more complex as time goes on, the relevant background material (generating data) will increase greatly by the end of the study. As the 4-year monitoring process progresses, Federal managers will be continuously updated and informed about new knowledge concerning the problem of reservoir impacts on cultural resources, and simultaneously provided with the latest in suggested remedial measures, or "recipes for action," that may mitigate the problem. It is anticipated that the resultant data will eventually be put into a computerized format, and that constantly updated information will be instantly available for managers upon demand from a local terminal.

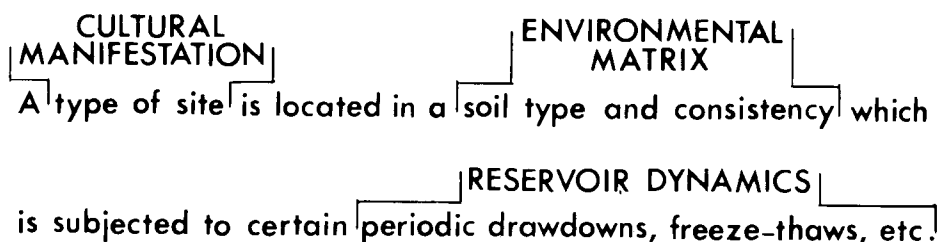
MECHANICAL IMPACTS

Mechanical impacts are impacts that physically upset the context and interrelationships of archeological materials, and, in their most extreme form, completely destroy or displace an entire archeological site. Examples are erosion, freeze-thaw, liquefaction, desiccation alternating with inundation, and siltation. Mechanical impacts on any archeological site are influenced by a host of relevant variables, and the development of a predictive model would have to be reservoir-specific in nature. We have not attempted in this section to map out specific hypotheses for every conceivable reservoir variable that may influence every possible type of archeological site. This would result in literally hundreds of separate hypotheses, and thousands of test implications, all of which would be essentially useless to a manager. Instead a "relative impact chart" has been constructed, which explicitly isolates certain reservoir variables, and predicts in a general way how they will influence preservation or destruction of cultural manifestations.

Although different types of cultural manifestations will have different potentials for resistance to mechanical impacts, only the impacts as they would apply in a relative sense to any given site-type are being considered. This approach is being used for two reasons: First, it is usually the environmental matrix within which the particular cultural manifestation is located that is of critical importance, because if that

matrix is destroyed, the archeological potential of the site is destroyed. Second, not enough inductive generating data exists at this point to enable meaningful predictions on differential impacts on the full range of cultural manifestations due to mechanical effects of flooding. The guidelines for data-collection and site-preparation presented in the next chapter of this report provide a mechanism for collecting this information, and this aspect of the problem may be presented in a hypothetico-deductive framework in later Reservoir Inundation Studies Project reports.

To best conceptualize the problem of mechanical impacts, 3 classes of interrelated variables have been recognized: cultural manifestations; environmental matrices; and reservoir dynamics.



What is known about these 3 variables at this point in the study will be illustrated in a schematic fashion. Two charts follow, the first of which offers predictions as to the relative susceptibility to impacts of certain environmental matrices when exposed to certain reservoir dynamics. The second chart suggests the measure of resistance that different cultural manifestations should generally have against different mechanical impacts. It assigns to various cultural manifestations relative predictive values relating to the susceptibility of the cultural values to mechanical impacts caused by general reservoir conditions. The scale is broad--0 to 3--with 1 indicating lesser susceptibility, and 3 indicating greater susceptibility. In cases in which it is expected that the impact will be negligible, or may even serve to enhance preservation, the value 0 is assigned.

RELATIVE IMPACT CHART

Environmental Matrix (Soil Types)	EROSION FACTORS										OTHER FACTORS	
	Stream Channel and Reservoir Dynamics	Site located on in-side of meander of river	Site located on out-side of meander of river	Water velocity in river over site dependent on such factors as slope and nature of water release	Water with high carrying capacity, e.g. in channel just below dam	Periodic drawdown over site	Subject to wave action, boats, wind etc.	Flood plain inside river channel	Flood plain outside river channel	Zone subject to freeze-thaw	Liquefaction	
Well-graded gravels, gravel-sand mixtures, little or no fines. (GW)	*1	1	1	1	1	1	1	1	1	1	1	
Poorly-graded gravels, gravel-sand mixtures, little or no fines. (GP)	1	2	1	1	1	1	1	1	1	1	1	
Silty gravels, poorly graded gravel-sand-silt mixtures. (GM)	1	2	2	2	1	1	2	1	2	1	1	
Well-graded sands, gravelly sands, little or no fines. (SW)	1	2	2	2	2	2	2	1	1	1	1	
Poorly graded sands, gravelly sands, little or no fines. (SP)	1	2	2	2	2	2	2	1	2	3	3	
Silty sands, poorly-graded sand-silt mixtures. (SM)	2	3	3	3	2	3	3	2	3	3	3	
Clayey sands, poorly-graded sand-clay mixtures. (SC)	1	2	2	2	2	2	2	1	2	3	3	
Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity. (ML)	2	3	3	3	3	3	3	3	3	3	3	
Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (CL)	1	2	1	1	2	1	2	1	2	2	2	
Organic silts and organic silt-clays of low plasticity. (OL)	2	3	3	3	3	3	3	2	3	3	3	
Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts. (MH)	2	3	3	3	3	3	3	2	2	2	2	
Inorganic clays of high plasticity, fat clays. (CH)	1	1	1	1	2	1	2	1	2	2	2	
Organic clays of medium to high plasticity. (OH)	1	1	2	1	3	3	2	1	3	3	3	
Peat and other highly organic soils. (PT)	2	3	3	3	3	3	3	2	3	3	3	

*Numerical weighting predictions in this chart are courtesy of the Bureau of Reclamation Engineering and Research Center. Numeral 1 = minimal impact, numeral 2 = moderate impact, and numeral 3 = maximum impact.

Susceptibility to Mechanical Impact Due To
General Reservoir Conditions

Cultural Manifestations	Susceptibility Value
A. Standing structures of concrete: -Minimal impact may be expected.	1
B. Standing structures of fitted stone; no mortar and/or plaster: -Without such reservoir specifics as high current or undercutting, the structure should be only minimally disturbed.	1
C. Standing structures of stone - mortar and plaster: Should the mortar and plaster deteriorate, which depends on the type of mortar and plaster and reservoir specifics, the stones will collapse.	2
D. Standing structures of fitted stone - rubble-filled: The same situation as in B applies, with additional support gained from the rubble fill.	1
E. Standing structures of plastered adobe: Deterioration of the plaster may take place, with subsequent deterioration of the adobe.	2
F. Standing structures of tabby: Structures of this crushed oyster-shell concrete were generally formed and not bricked. The material will be subject to mechanical deterioration because of the chemical attack on its carbonate bonding.	2
G. Standing structures of adobe - rubble-filled: -Although the rubble fill will give the structure support, the adobe will be subject to deterioration.	2
H. Low-lying rubble of stone: In the absence of such reservoir specifics as high current and/or heavy erosion, the material should be only minimally disturbed.	1
I. Low-lying rubble of adobe bricks: The fact that the adobe is already in a state of rubble indicates a certain weakness. Further deterioration would take place.	2
J. Low-lying rubble of puddled adobe: Puddled adobe does not have the structural strength of brick adobe, and would therefore deteriorate more rapidly.	3
K. Lithic and/or ceramic surface-scatter: Very little impact will occur. If the material is located on a slope, high current may cause redistribution.	1

Cultural Manifestations	Susceptibility Value
L. Standing earthworks, prehistoric mounds, and military structures: These situations will be highly susceptible to the impact of reservoir specifics such as current, erosion, and silting on the soil matrix.	2
M. Subsurface foundations of rock: Negligible impact may be expected.	0
N. Subsurface foundations of wood: If the matrix in which the foundations are located is well-consolidated, the impact will be lessened somewhat.	3
O. Subsurface foundations of adobe: If the matrix in which the foundations are located is well-consolidated, the impact will be lessened somewhat.	2
P. Subsurface foundations of concrete: Negligible impact may be expected.	0
Q. Shell Midden: Minimal impact may be expected, although silting and redistribution due to current and erosion may take place under certain reservoir conditions.	1
R. Soil midden: The material will be more susceptible to erosion than a shell midden.	2
S. Talus-slopes in front of rockshelters: In the absence of reservoir specifics such as high current and/or erosion, the talus-slope should remain relatively intact, though redistribution of any surface material may take place.	1
T. Subterranean rooms: Unless the rooms are filled, it is expected that the walls will collapse and silting will fill the remaining depression.	3
U. Non-backfilled archeological excavations: Trenches, test pits, balks, etc., created as a result of archeological activity, will be heavily impacted, primarily because of slumpage. Backfilling will substantially reduce the severity of the impact.	3

The table offers no reservoir specifics. The values assigned are based upon the mean of the known and assumed effects of inundation upon materials and situations. Because all the values are subject to change, when the effects of the various reservoir specifics are determined, a short explanation of why such values have been assigned to a particular cultural manifestation has been included.

Eventually, the full equation, as represented in the diagram above, will be integrated into one model, and statistical values will be assigned on a graduated basis to the predicted potential impacts. This approach will take into consideration the relative importance of each impact, given a site-type/environment/reservoir-dynamics combination.

It is important to note that even though this research will eventually produce some very useful generalized information on mechanical impacts upon cultural resources in reservoirs, it will always be difficult to apply this knowledge with any great degree of confidence to a given site at a particular point in a specific reservoir. Many environmental variables must be considered when such factors as erosion and sedimentation are dealt with, and reservoir scientists have found the only way to get really reliable data for the forming of predictions for this complex of hydrological problems is to build actual physical replicas, in association with computer models.

Although it would be prohibitively expensive to construct physical models of drainages just for archeological purposes, it would in many cases be quite reasonable to integrate research questions regarding mechanical impacts upon archeological sites into the context of models that are being built for general use by reservoir engineers. This would mean involving cultural-resources-management considerations at an early level in the planning process, which is recommended in the conclusion to this report. It is especially important that mechanical impacts are dealt with in a planned, thoughtful manner, because if this type of impact is traumatic to a particular site, the remaining questions about inundation effects addressed in the research design become academic.

THE DIFFERENTIAL PRESERVATION OF COMMON CULTURAL MATERIALS

This section discusses impacts upon those analytical properties of culturally produced or culturally associated materials that are commonly classified or visually categorized by archeologists; for example, decoration, temper, and color of potsherds. We are concerned here with gross impacts due to mechanical or chemical action that destroy either the structural integrity of the object or its culturally and temporally significant attributes. Other examples are butchering marks on bone, and color in glass artifacts.

We are not concerned in this section with subtle chemical changes, such as those that determine whether or not a bone can be carbon-dated, or subjected to amino-acid-racemization dating or fluorine analysis (these questions are covered in separate sections dealing with the specific techniques)--but rather with the question of whether or not it can still be classified, and its meaning interpreted from a simple visual analysis.

The common cultural materials to be discussed are;

<u>Bone</u>	<u>Animal and Vegetable Fibers</u>
<u>Ceramics</u>	<u>Wood</u>
<u>Stone</u>	<u>Ferrous Metals</u>
<u>Glass</u>	<u>Non-Ferrous Metals</u>
<u>Shell</u>	
<u>Leather</u>	

BONE

Introduction

Osteological remains recovered from archeological sites include human skeletal remains and artifactual

and non-artifactual faunal remains. Materials frequently represented include bone, teeth, ivory, and antler.

Human remains frequently reveal information about burial practices, physical type, genetic traits, nutritional status, mortality, and morbidity. Faunal remains also reveal this information, as well as information about dietary preferences, butchering practices, and various uses of bone materials for tools, weapons, and ornaments.

Generating Data

Whether or not osteological materials will be preserved after disposal depends upon their physical and chemical properties when discarded, and upon the nature of the environment of deposition (characteristics such as temperature, pH, dampness, and the action of natural solvents). Differential preservation of osteological materials depends upon several factors: the type of material, the condition of the material; the age, sex, and health status of the individual or animal at the time of death; and the type or degree of modification, preparation, or treatment.

Bones that have the greatest surface area and porosity (cranial bones and ribs) are more susceptible to destruction than those that are more dense and impervious (such as long bones and teeth). Bone surfaces that have been rubbed from use have a more compressed texture than unworked bone, and are therefore more likely to withstand natural destructive action longer (Semenov, 1973).

The environmental factors that may affect preservation include pH, degree of aeration, movement of water, bacterial action, and the structure and seasonal properties of soil (Chaplin, 1971). Osteological remains are best preserved in an alkaline environment. Bone that has been preserved in acidic soil is usually in a weakened state, because much of the mineral content (calcium phosphate) has been leached out, especially in well-aerated soils. As a result, different degrees of preservation of bone may be noted in areas of a site due to local soil conditions.

Limestone cave deposits are often good preservation environments, due to the alkaline nature of the limestone. Generally, bone that has been deposited in an acidic, sandy soil (pH below 5.6) will not be preserved; however, some bone may be preserved in clay having a pH as low as 3.5 (Dowman, 1970).

In stable soils, crushing is a common cause of damage. Crushing, shearing, and/or distortion of osteological remains may result from the pressure of the overburden, especially if combined with any lateral movement. In a submerged situation, the added weight of a water-column could cause similar disturbances.

Water may have several different effects on osteological materials. Bone is a highly durable, plastic material, which lends itself well to various techniques of treatment and modification. Because bone has anisotropic (directional) properties, it is susceptible to warping when it is exposed to heat and dampness (Semenov, 1973). Wet bone may swell and become deformed; when drying, it may crack. Bone that has been rolled in a stream may be smooth, and exhibit striations and scratches that may be mistaken for traces of use. However, a current of water even containing sand rarely produces striations, because the mechanical pressure of sand is usually not great enough to leave striations (Semenov, 1973).

Bone that has been buried for a long time may be weakened, or disintegrate, if in water for a prolonged period, due to hydrolysis of the ossein, organic component of bone. The result will be a spongelike, waterlogged material, similar to waterlogged wood (Plenderleith and Werner, 1971). One exception is osteological materials that have been mineralized. Such remains are frequently noted in karst contexts, where ideal conditions of alkalinity, constant temperature, and mineralized water have preserved faunal remains for thousands of years (Neill, 1964).

Water not only has an effect on the physical nature of these materials, but it may also affect their dating potential (see section in this chapter on amino-acid-racemization, nitrogen, fluorine, carbon-14). Most dating techniques are dependent upon the rate at which bone collagen degrades. This rate is affected by a number of variables, including pH, hydrology of

matrix, oxygenation, temperatures, micro-organisms, and substances absorbed from ground-water. Changes in all of these variables can occur within a reservoir context, potentially skewing analytic results.

Hypothesis

Osteological remains subjected to reservoir inundation will receive differential preservation, depending upon the condition of the specimens at the time of inundation, and upon the nature of the new environment. Osteological materials that are subjected to such mechanical forces as currents, erosion, and slumpage, or to a pH change toward acidity (pH value below 7.0), will not be as well-preserved following inundation as prior to inundation.

Test Implications

1. In an inundated context, those materials that have the greatest surface area and porosity or those that are poorly preserved will be more susceptible to destruction resulting from pressure and waterlogging than those that are more dense and impervious, and will thus lose potential for identification and analysis following inundation. Bone that has become waterlogged will be more susceptible to crushing, shearing, and distortion due to the weight of water-saturated sediments and the weight of the water-column itself.
2. In an inundated context, dense and impervious materials are less susceptible to crushing and waterlogging, and will therefore be more suitable for identification and analysis even after inundation than less dense and porous materials.
3. In an inundated context, osteological materials that have been mineralized as a result of the absorption of minerals from ground-water will continue to be well-preserved long after inundation.
4. In an inundated context, osteological materials preserved in a fine, poorly-aerated, anaerobic alkaline soil will continue to be preserved.

5. In an inundated context, where chemical changes have altered the pH or introduced bacterial activity, or where mechanical activity has disturbed the soil matrix, loss of osteological materials will result.

6. In an inundated context, osteological materials contained within sites periodically exposed during drawdown will suffer damage or loss during alternating periods of wetness and dryness. Most of the damage will result from warping and cracking.

CERAMICS

Introduction

Pottery is a major source of data for the archeologist. Its abundance in areas with well-developed ceramic traditions gives the investigator a wealth of data. The development and refinement of ceramic typologies permit studies to be conducted from which inferences may be derived concerning such factors as population distribution, technological development, and various aspects of the life-styles of the potters. An example would be determining the social functions of rooms through statistical analyses of sherds from room-floors (Hill, 1966).

The archeologist develops typologies by isolating what he feels are significant attributes of ceramic wares, such as design, texture, color, and decoration. How the ceramic material will withstand inundation and the possible alteration to its attributes is therefore of concern to the study.

Generating Data

The variables that affect the preservation of prehistoric ceramics are numerous and complex, and although standards of manufacture do exist for individual traditions, techniques and materials vary widely. A certain degree of variability exists even within a well-established ceramic tradition, because of the varying qualities of craftsmanship employed by potters. These variables are somewhat reduced in the

case of historic ceramics, due principally to improved firing techniques and materials--but differences in craftsmanship and materials still exist.

To better appreciate the complexity of this problem, the following statement on strength as a primary determinant of longevity for ceramics should be considered. "Strength is not a simple property, for it is influenced by many conditions: texture of the paste, particle size and composition of the clay, method of preparing the paste, technique of building the vessel, rate of drying, temperature and atmosphere of firing, size and shape of the vessel, and alteration after discard" (Shepard, 1968).

The first factor to be considered in determining the strength of a particular piece of ceramic material is its porosity--that is, the ratio of the volume of the pores to the volume of the mass. Among other factors, porosity strongly affects the density; the permeability (the property that determines the rate of flow of gases and liquids through the ceramic body); the degree of resistance to weathering and abrasion; the extent of discoloration by fluids; and the resistance to thermal shock (Shepard, 1968).

The more limited the porosity, the more limited the permeability, and hence the greater the degree of resistance to water saturation. The porosity of the rough vessel (before application of any slips or glazes) will be determined primarily by two factors: temper, and the nature of the clay.

Temper occurs in two ways: it is nonintentionally included in the clay; or it is added by the potter. Two considerations were prevalent in the selection and addition of tempering material: strength and ease of finishing. Ideally, tempering would result in a stronger vessel, with a surface that was easier to finish. The type and quantity of temper, and the nature of the clay to which it is added are crucial.

Clay will bond better with a coarse material than with a smooth material. Results of tests with sand, sherd, igneous rock, and volcanic ash proved that sherd is the strongest, sand the weakest, and rock and ash intermediate (Shepard, 1968).

Of significance in the nature of the clay are its composition and vitrification range. The vitrification of clay begins during the firing, but requires high temperatures that are often beyond the capability of open-pit kilns. However, the introduction of a tempering agent could bring the temperature level of vitrification down to a range obtainable by prehistoric potters, as is evidenced by the presence of glass in some prehistoric ceramic material. During vitrification, melted matter fills pore spaces, and the porosity is reduced, thereby reducing permeability. Even if vitrification does not take place (as was often the case), porosity is reduced because of the normal melting together of particles (sintering) that takes place during firing.

Sintering is largely a product of the fluxing (bonding) agents present in the clay. Such agents as calcium oxide are common, but their percentage and distribution within the clay are highly variable. However, certain fluxes lower the vitrification point, and too high a percentage of flux will cause vitrification to proceed too rapidly, leading to deformation and instability of the material.

If the ceramic ware is well-made, water saturation should not destroy it. A weakening of the structure will occur because of the inevitable seepage of water into the pores. As the density (less porosity) increases, the weakening effect decreases. The application of slips and glazes will also diminish porosity, thereby strengthening the material.

Ceramic ware has survived intact for several thousand years in marine environments (Bass, 1966; Dirole, 1954; Throckmorton, 1970). Periods of 1,000 years have been recorded for freshwater inundation (Niewiecki, 1973; Andrews, 1959; Marden, 1959). It may be assumed that the surviving material was stable--that is, of high-quality manufacture--and that if a piece of ceramic ware survives in an archeological site, it will survive inundation. However, if the piece is weakened before inundation, water saturation may destroy it.

The second major concern is the preservation of painted designs. The three major techniques of painting occur

before firing; after firing, with secondary heating; and after firing, with no further heatings (Shepard, 1968). The two principal types of pigments are mineral and organic-based.

Variables relating to the durability of painted designs are as numerous and complex as those relating to the manufacture of the ceramic body; indeed, many of the same variables are central to the study of painted designs. For our purposes, however, a few general statements will suffice.

Painted types most resistant to inundation are those painted after firing, which receive secondary heating; and those painted before firing. The two processes involve different pigments, determined through experience to be more suitable to the particular technique.

This factor of differing pigments is of less concern than the bonding quality of the pigment, and protective shields such as glazes.

Ceramic ware that is painted after firing and receives secondary heating produces an extremely stable combination. Ideally, the body will be dense and strong, due to the primary firing. Pigments that could not withstand the high primary temperatures are used to decorate the body. Secondary heating "would have been just sufficient to char and convert [pigments] to carbon" (Shepard, 1968). The carbon actually penetrates the body of the ceramic ware, and will only dissipate with the erosion of the body itself. Further protection is afforded if vitrification takes place--regardless of how slight--which often occurs during the secondary heating.

The process described above also applies to ceramic ware painted before firing, with an important note. The pigment is better suited to the higher firing temperatures however, the potter may not fire the material as high as normal, to avoid any possible loss of pigment through oxidation--and this in turn may result in a weaker body, although this, again, is subject to the many variables discussed above. High-quality work would demonstrate the potter's awareness of the problem, and result in a strong body with well-bonded pigments. If a glaze is applied, it will be

susceptible to severe impact from water saturation. Lead glazes, quite common in American ceramic ware, may become black because the metallic ions combine to form sulphides (Dowman, 1970). They can also become water-soluble.

Ceramic ware that is painted after firing, and receives no secondary heating (known as fugitive ware), will be the most vulnerable to the effects of inundation. In most cases, the pigments will be mineral, applied in a vegetable or animal-fat medium. The combination will be poorly resistant to the elements, and often ground-water and leaching will remove the pigments in relatively dry sites. Water saturation will in most cases act to dissolve the medium, and hence the pigment. Organic pigments will often be susceptible to leaching; however, the pigments will usually penetrate the clay and be protected by any glaze, slip, or incipient vitrification. Deterioration of the clay will result in loss of pigment.

Hypothesis I

The basic ceramic structure of ware from an inundated archeological site will be adversely affected by water saturation, in a ratio directly proportional to its porosity, permeability, and strength.

Test Implications I

1. Ceramic samples of low porosity and permeability, and high strength (that is, stable) taken from an inundated context will be in a state of preservation comparable to ceramic samples of a similar nature taken from a non-inundated context.
2. Ceramic samples of high porosity and permeability, and low strength (that is, unstable) taken from an inundated context will not be in a state of preservation comparable to ceramic samples of a similar nature taken from a non-inundated context.

Assumption

Fugitive pigments have survived on ceramic ware in the non-inundated context prior to inundation.

Hypothesis II

Fugitive painted decoration on stable ceramic ware from an inundated context will be dissolved by water saturation, and will therefore not be in a state of preservation comparable to fugitive painted decoration from a non-inundated context.

Test Implications II

1. Fugitive painted decoration of ceramic samples from an inundated context will not be in a state of preservation comparable to a like number of similar samples from a non-inundated context.
2. Non-fugitive painted decoration of ceramic samples from an inundated context will be in a state of preservation comparable to a like number of similar samples from a non-inundated context.

STONE

Introduction

The stone materials that man has chosen for his tool manufacture vary in terms of the predominant features by which they may be distinguished. Although they differ in "color, luster, fracture-structure, specific gravity, external shape and size, origin, impurities, transparency" (Semenov, 1973), these differences can be subsumed under a few common qualities.

One important quality is overall hardness, which averages 7 on the 10-degree Mohs scale. Another quality is isotropism (glassiness): when struck, rocks exhibit uneven surfaces, characterized by receding concentric waves and sharp cutting edges. The combination of isotropism and hardness in a stone specimen permitted early peoples to further alter the shape of a stone by grinding. Diorite, basalt, granite, and similar stone could be rubbed to remove its irregularities, without causing pieces to break off along granular boundaries, thus permitting stone

to be shaped to fit various needs. Because of the qualities of hardness and isotropism, rocks of very dissimilar natural properties could be chosen for use.

Generating Data

The development of patina is the most characteristic change that flint, chert, quartzite, and similar stone undergo through natural causes. Patination is produced by the interaction of three processes: "(1) oxidation and hydration, (2) dissolution and leaching, and (3) chemical and mechanical disaggregation" (Hurst and Kelly, 1961). As a result of these processes, the stone is dehydrated, and the coloring matter is broken up. The susceptibility of the above-mentioned rock types to patination depends upon their chemical composition and texture. The ratio of silica to other materials, the stability and distribution of impurities, and the granular structure of a specimen all affect the potential for, and rate of, patination. For example, flints that are composed of pure silica or contain chemically stable impurities will not patinate, whatever their grain size or texture (Hurst and Kelly, 1961). Shallow patination does not change the relief of the stone surface, however more advanced patination can cause deterioration of the surface and alter the specific gravity of the specimen, causing it to weigh less than non-patinated stone (Semenov, 1973). An important part of lithic analysis is a consideration of specimen weight. This type of impact upon stone artifacts would hamper full analysis of collected samples.

The formation of a gloss on flints and similar types of stone is related to the quality of the material. Chalk-based flint polishes more readily than limestone flints, quartzites, and cherts. The development of gloss has been associated with water and wind erosion; however, a glossy finish has been found on specimens that were not subjected to these environmental conditions. It is now generally believed that the formation of gloss is due to the chemical interaction between the stone surface and the surrounding soil matrix (Semenov, 1973). An advanced state of gloss-development on a specimen does not destroy the physical integrity of the stone, but will destroy traces of tool use.

Granite, diorite, diabase, sandstone, and similar other stones were often selected for the fashioning of ground-stone implements by early peoples. Because of the granular structure and composition of these stone types, the effects of natural weathering are indicated by exfoliation and crumbling of the surface (Semenov, 1973), with eventual loss of all traces of human modification or use.

The above stone types contain varying amounts of feldspar, which is a major constituent in a great many rocks. Feldspar is subject to weathering, in a ratio based upon the degree of its exposure to wet/dry conditions. The rate of weathering also depends upon the length of time that moisture comes into contact with the feldspar-bearing rock. When a naturally occurring acid, such as carbonic acid, which is found in rainwater, comes in contact with the feldspar, elements in the feldspar go into solution (Press and Siever, 1974). Eventually, the structural integrity of the rock is weakened, and there is a loss of morphology. When a feldspar-bearing rock is buried in saturated or moist acidic soil or submerged in acidic water, the rate of natural deterioration of the rock is further increased.

The carbonate minerals calcite and dolomite are also found in many rocks, and are the major minerals in limestone and some sandstone, as well as in the metamorphic rocks that were formed from limestone and sandstone. When water, which naturally contains carbonic acid, comes in contact with carbonates, the carbonic acid ionizes, and hydrogen and bicarbonate ions form, which go into solution in the water (Press and Siever, 1974). As a result of this series of chemical reactions, the carbonates contained within the rock will be dissolved completely over time. The more prolonged the period that moisture is in direct contact with the carbonate-bearing rock, the greater is the dissolution rate of the carbonate elements. Loss of the structural integrity of the rock specimen is the eventual result. The formation of caves and sinkholes also results from dissolution, which illustrates the potential magnitude of the process.

Various quantities of quartz, feldspar, or carbonate compounds, can be found in virtually all rocks. The degree to which any particular rock will be affected by

weathering will depend upon the stability, distribution and water-solubility of impurities, and the relative amounts of constituent minerals and the previous history of the rock. The dissolution of these elements accelerates when they come in continuous contact with moisture, and is further increased when the moisture is acidic (Press and Siever, 1974). The length of time required for dissolution of these minerals and loss of structural integrity will vary. However, granite ground-stone artifacts which are high in feldspar content, found in a reservoir in California had been severely impacted after 35 years of continuous inundation, and exhibited a great loss of structural integrity evidenced by a tendency of the external surface to crumble on contact (Foster, 1977).

All natural materials tend to achieve a state of equilibrium with their environments (Dowman, 1970). The natural deterioration of these materials proceeds at an even pace only for so long as the environment is not dramatically altered. When an environmental change occurs, deterioration is either increased or slowed. The flooding of a reservoir basin changes not only the immediate reservoir environment, but also the humidity of the immediate area. The introduction of a reservoir does not alter the overall weather pattern, but rather adds a weathering variable. Stone preservation is directly influenced by weather and the amount of available moisture. An increase in moisture, coupled with the freeze-thaw temperature fluctuations found in many parts of the Country, will increase the rate of weathering of stone beyond the rate evidenced prior to introduction of the reservoir, and beyond the weathering rate that occurs in more temperate or less humid zones. As a result, stone from areas of low humidity, or not in direct contact with moisture, weathers at a slower rate than is evidenced when the same stone is subjected to high humidity and constant inundation.

Hypothesis I

Stone artifacts exposed to the changed environmental conditions that accompany inundation will deteriorate at a faster rate than stone artifacts of similar chemical composition and environmental location that have not been subjected to reservoir environment conditions.

Test Implication I

All stone artifacts subjected to inundation will be adversely impacted, and preservation will not be comparable to similar stone not subjected to inundation. The period of time required for severe impacts to become apparent will be differential and depend upon a combination of quality and distribution of water-soluble minerals and the mechanical impacts to which the specimen has been subjected.

Hypothesis II

The differential preservation of inundated stone artifacts will be dependent upon the chemical composition of the artifact in question. Destruction of the artifact will increase with the quantity and distribution of impurities and the relative amounts of feldspar, silica, and carbonates contained within the specimen and the nature of the inundation, i.e., periodic or continuous, to which it is subjected. Preservation and destruction will also depend upon the pH of the water or soil within which the stone is located. Increased amounts of acid in solution will directly affect the rate of mineral dissolution and the loss of structural integrity of the stone specimen.

Test Implications II

1. Stone artifacts which have a high ratio of carbonate minerals and readily water-soluble or unstable impurities to other minerals and are exposed to continuous inundation will deteriorate at a faster rate than artifacts which have a low ratio of carbonate minerals and readily water soluble or unstable impurities to other minerals and are exposed to continuous inundation.

2. Stone artifacts which have a high ratio of carbonate minerals and readily water-soluble or unstable impurities to other minerals and are exposed to periodic inundation will deteriorate at a faster rate than artifacts which have a low ratio of carbonate and readily water-soluble or unstable impurities to other minerals and are exposed to periodic inundation.

3. Stone artifacts which have a high ratio of carbonate minerals and readily water-soluble or unstable impurities to other minerals and are exposed to continuous inundation will deteriorate at a faster rate than artifacts which have a similar composition and are exposed to periodic inundation.

4. Stone artifacts which have a high ratio of feldspar and readily water-soluble or unstable impurities to other minerals and are exposed to continuous inundation will deteriorate at a faster rate than artifacts which have a low ratio of feldspar and readily water-soluble or stable impurities to other minerals and are exposed to continuous inundation.

5. Stone artifacts which have a high ratio of feldspar and readily water-soluble or unstable impurities to other minerals and are exposed to periodic inundation will deteriorate at a faster rate than artifacts which have a lower ratio of feldspar and readily water-soluble or unstable impurities to other minerals and are exposed to periodic inundation.

6. Stone artifacts which have a high ratio of feldspar and readily water-soluble or unstable impurities to other minerals and are exposed to continuous inundation will deteriorate at a faster rate than artifacts which have a similar chemical composition and are exposed to periodic inundation.

7. Stone artifacts which have a high ratio of silica and a low proportion of water soluble or unstable impurities to other minerals and are exposed to periodic inundation will deteriorate at a slower rate than stone artifacts which have a low ratio of silica and a high proportion of water-soluble minerals and unstable impurities and are exposed to continuous inundation.

8. Stone artifacts which have a high ratio of silica and a low proportion of water-soluble or unstable impurities to other minerals and are exposed to periodic inundation will deteriorate at a slower rate than stone artifacts which have a low ratio of silica and a high proportion of water-soluble or unstable impurities to other minerals and are exposed to periodic inundation.

9. Stone artifacts which have a high ratio of silica and a low proportion of water-soluble or unstable impurities to other minerals and are exposed to continuous inundation will deteriorate at a faster rate than artifacts which have a similar chemical composition and are exposed to periodic inundation.

10. Stone artifacts that have been structurally weakened as a result of severe patination or chemical dissolution and are subjected to such mechanical action as tumbling, scouring, direct wave-action, and sub-surface surge will deteriorate at a faster rate than stone artifacts of similar chemical composition and state of preservation that have not been subjected to such direct mechanical action.

11. Stone artifacts that have been structurally weakened as a result of severe patination or chemical dissolution and are subjected to drawdown, freeze-thaw conditions will deteriorate at a faster rate than stone artifacts of similar chemical composition that have not been subjected to these conditions.

GLASS

Introduction

In historical archeology, glass artifacts are one indicator of trade relations, associations between groups of people, and economic change in an area. Their shapes, colors, and decorations provide clues that might otherwise go undetected. The preservation of glass objects and their associated analytical properties is of concern when archeological sites are subjected to the environmental changes that accompany inundation.

Generating Data

The difference in degrees of preservation exhibited by glass objects is due to three main factors: the chemical composition of the glass object; the burial environment; and the length of time of burial.

The chemical composition of glass is the most critical of the factors. Some glasses are extremely unstable, and decompose quickly. Other glasses are chemically stable, and preservation is usually good.

The stability of glass in various environments is determined by the ratio of its silica, alkali metal (sodium or potassium) and calcium oxide content. All glass absorbs moisture from the air, forming a devitrified, crazed surface. However, when unstable glass is exposed to moisture or immersed in water, the sodium and potassium are leached out through hydrolysis and diffusion processes to form porous films of hydrated silica of varying thickness and porosity depending upon the original alkali metal content of the glass and length of exposure to excessive moisture. Once these silica films are formed, they tend to protect the glass from further leaching.

The burial environment does not seem to be as critical a factor in preservation as does the stability of that environment. Glass objects in good condition have been recovered from both saltwater and freshwater contexts, and at varying depths in soil (Brill, 1961).

Time is a factor insofar as the less stable the glass object is initially, the greater the deterioration over time.

The differential preservation of the standard analytical properties of a glass artifact (morphology, color, and decoration) will depend upon the structural integrity of the object, its location within the site, and the specific mechanical actions to which it has been subjected. Most glasses found in the New World are chemically stable, and their structural integrity is good. Direct wave-action, subsurface surge, scour by coarse soils, tumbling of the object, exposure during drawdown, and exposure during erosion and slumping, are all potentially destructive to the analytical properties of basically sound specimens, and could be totally destructive to less sound specimens. The degree to which each of these direct mechanical impacts would be felt depends upon the location of the artifact within the site, and the location of the archeological site within the reservoir. Glass objects that are buried in a site should be better protected than those on the surface of a site. Sites located below the level of the

conservation-pool should be less affected by the direct mechanical impacts mentioned above than those located between the conservation-pool and flood-pool, which experience periodic drawdown, wave action, and erosion.

The exposure and subsequent drying out of a glass object causes crystallization of salts on the surface, and loss of the original color. In some cases, glass objects are found with a network of cracks that permeate the material, and the moist environment acts as a glue to hold the object together. Drying out may cause the artifact to totally disintegrate (Dowman, 1970). Glass artifacts subjected to scour by coarse soils as a result of currents or surge may lose painted decorations, and structurally weak portions may crack or break off entirely. Direct wave-action and tumbling may also cause structural damage to the artifact and the loss of identifying characteristics.

Hypothesis

Glass artifacts found in freshwater-inundated sites that are subjected to the direct mechanical impacts of wave-action, sub-surface surge, scour, tumbling, exposure as a result of drawdown, erosion, or slumping will be adversely impacted; and examination of their analytical properties--that is, morphology, color, and decoration--will not yield data comparable in quality to samples from dry sites, or samples from a freshwater or marine context not subjected to mechanical action.

Test Implications

1. Glass artifacts found on the surface of archeological sites that are permanently inundated by fresh water and not subjected to mechanical action will not be adversely impacted; and examination of their analytical properties will yield data of comparable quality to samples from dry or or marine-inundated sites isolated from surge zones.

2. Glass artifacts found buried in archeological sites that are permanently inundated by fresh water will not be adversely impacted; and examination of their analytical properties will yield data of comparable quality to samples from dry or marine-inundated sites isolated from surge zones.

3. Glass artifacts found on the surface of freshwater-inundated sites that are subjected to periodic drawdown will be adversely impacted; and examination of their analytical properties will not yield data of comparable quality to samples from dry or marine-inundated sites isolated from surge zones.

4. Glass artifacts found buried in freshwater-inundated sites that are subjected to periodic drawdown will be adversely impacted; and examination of their analytical properties will not yield data of comparable quality to samples from dry or marine-inundated sites isolated from surge zones.

5. Glass artifacts from archeological sites inundated by fresh water, which are subjected to scouring by such materials as coarse soils and gravels, will be adversely impacted; and examination of their analytical properties will not yield data of comparable quality to samples from dry or marine-inundated sites isolated from surge zones.

6. Glass artifacts from archeological sites inundated by fresh water, which are subjected to direct wave-action and tumbling, will be adversely impacted; and examination of their analytical properties will not yield data of comparable quality to samples from dry or marine-inundated sites isolated from surge zones.

7. Glass artifacts found exposed as a result of erosion or slumping of freshwater-inundated sites will be adversely impacted; and examination of their analytical properties will not yield data of comparable quality to samples from dry or marine-inundated sites isolated from surge zones.

SHELL

Introduction

Shell is found in archeological sites in two forms: worked ornamentally, or for utilitarian purposes; and as discarded material from food use. Shell has been found in every major cultural region in the United States, and is a valuable indicator of trade between cultural groups. Important data regarding population density and diet may be provided by shell.

Generating Data

Shell, the exoskeleton of a wide variety of marine and freshwater organisms, is composed of either calcite or aragonite, polymorphs of calcium carbonate (CaCO_3). Shell may also contain other minerals, such as phosphates, silicas, and gypsum, but they are quantitatively insignificant when compared to the two calcium carbonate polymorphs.

In the reservoir environment, the major threat to the structural integrity of shell is the conversion of calcium carbonate to soluble calcium bicarbonate ($\text{Ca}(\text{HCO}_3)_2$). This conversion is a basic process induced by the presence of moisture: In a terrestrial site, it would be a relatively slow process, although it would be complicated by the probable action of carbonic acid (H_2CO_3). The total saturation of a reservoir environment would accelerate the conversion of calcium carbonate to calcium bicarbonate. The action of the carbonic acid would continue in a weakened process. Calcium bicarbonate is often reconverted to its original calcium carbonate form in the soil; however, total saturation would present enough water to force it into solution (Dowman, 1970).

The length of time necessary for calcium carbonate to go into solution is not known. Shell has been found after it has been inundated for many hundreds of years although in a state of deterioration (Niewiecki, 1973), and it has not been found where it might be expected, after a period of inundation, indicating loss of material because of deterioration (Schnell, 1974). The rate of deterioration is undoubtedly influenced by such factors as the strength of the material prior to inundation; the location of the material (if located within a compacted matrix, the material may be better protected than if located on the surface or within a porous, loosely consolidated matrix); and the rate of any current that might be present.

Hypothesis

Inundation will accelerate the rate of deterioration of shell, so that samples from an inundated context will not be in a state of preservation comparable to samples from a non-inundated context.

Test Implication

Shell samples taken from an inundated context will consistently be in a poorer state of preservation than samples of a similar age taken from a non-inundated context.

LEATHER

Introduction

Leather has been used by man from earliest prehistoric times for a wide range of purposes, including clothing, shelter material, and containers. However, remains of leather are rare in archeological sites, because it deteriorates quickly, due to bacterial action and a combination of the composition and pH of the soil matrix and the environmental conditions.

Leather is most likely to be found in archeological sites in one of three environments: arid; permanently frozen; or anaerobic waterlogged. (Rare exceptions include such conditions as a heavy salt concentration.)

Generating Data

Leather is defined as processed skin and animal-skin products, including products made from various internal organs. Processing of the skin prevents putrefaction, and allows for long-term use. Being organic material, leather is highly susceptible to attack by microorganisms, and if it were not processed, it would rapidly deteriorate.

Moisture is a prime cause of deterioration. Whether the material is on the surface or buried, moisture above 60% humidity promotes the growth of mildew and bacteria, which attack the cell-structure of the skin (Gulbeck, 1969). Bacterial action requires the presence of oxygen. Organisms thrive "best in aerated, moist and alkaline conditions" (Dowman, 1970). They also exist in acid soils, although not in as great abundance, because bacteria is severely limited in a pH below 5.

Bacterial action will be arrested in both acidic and alkaline soils as a result of inundation, because a virtually anaerobic state soon develops in all but the topmost soil in silt levels in a site. The anaerobic condition would serve to enhance preservation, if other alterations in the material's structure did not take place (Dowman, 1970). Although bacterial action may be stopped in a highly acid soil, chemical attack would cause deterioration of the material. To survive in an archeological site up to the time of inundation, the material would have to have been contained within a soil matrix that would inhibit bacterial and chemical action. Any change in the pH or composition of the soil may have the opposite effect, and act to promote bacterial or chemical action that would attack the material. The bundles of collagen fibers and other protein fibers of water-saturated leather samples will begin converting to a glutinous state and will therefore be in a structurally weakened condition. This will make them highly susceptible to deterioration due to mechanical action, and upon drying they will become very hard and brittle.

Hypothesis

Leather artifacts that undergo mechanical action or extensive pH change (particularly toward a pH below 5) in the surrounding soil matrix as a result of inundation will not be as well-preserved as prior to inundation.

Test Implications

1. Leather samples from an inundated context that have undergone pH changes, particularly towards a pH below 5, will not be in a state of preservation comparable to that prior to inundation.
2. Leather samples from an inundated context that have not undergone pH changes or mechanical impacts will be in a state of preservation comparable to that prior to inundation. (It should be noted, however, that a situation in which there is no pH change due to inundation would be highly unlikely).

3. Leather samples from an inundated context that have not been eroded, and have not undergone mechanical action or pH changes, will be in a state of preservation comparable to that prior to inundation.

ANIMAL AND VEGETABLE FIBERS

Introduction

Animal and vegetable fibers are rarely preserved in archeological contexts, except under special conditions, such as extreme aridity, perennially frozen environment, anaerobic waterlogged environment, and after charring. Because plant and animal fibers are subject to attack by mold and bacteria, especially in contact with decaying animal and vegetal matter, they are seldom preserved outside the above-mentioned contexts.

Animal fibers are composed chiefly of keratin, and include a variety of materials, including fur, hair, feathers, and sinew. When preserved, they may still be attached to the original skin, or may be woven into clothing, blankets, or cordage. Remains of animal hair are sometimes found in coprolites.

Vegetable fibers are composed principally of cellulose, and include a broad range of locally available materials. Fibers are often twisted or woven into cordage for nets, bags, footwear, and fabric, and are used for basketry, mats, and chewing-quids.

Generating Data

Vegetable fibers often decay more rapidly than animal fibers, particularly if they are buried in damp, acidic soils. Animal fibers tend to decay more rapidly than normal in damp, alkaline soils. Dampness causes vegetable fibers to swell and soften, which may lead to rapid deterioration, especially if combined with bacterial activity. In an acidic environment where pH is below 5, bacterial activity is limited (Dowman, 1970). Conditions for the preservation of these fibers

should therefore be favorable. However, extreme acidity may adversely affect the quality of preservation through chemical breakdown.

The effect of water on both animal and vegetable materials should not prove to be detrimental, provided that they are adequately protected within a stable soil-matrix, preferably an anaerobic environment, and that during inundation the chemical constituents and pH of the surrounding soil-matrix is maintained.

Hypothesis

Any major change in temperature, pH, and/or chemical composition resulting from reservoir inundation will result in a change in the rate of deterioration or loss of animal and vegetable fibers.

Test Implications

1. In an inundated context in which all bacterial activity has ceased, such as an anaerobic situation, vegetable and animal fibers will continue to be preserved.
2. In an inundated context in which there is an onset of bacterial activity, vegetable and animal fibers will not be preserved.
3. In an inundated context in which a pH value below 5 occurs, vegetable and animal fibers will be preserved.
4. In an inundated context in which a pH value above 5 occurs, vegetable and animal fibers will not be preserved.
5. In an inundated context in which sites are periodically exposed during drawdown, animal and vegetable fibers will be destroyed due to alternating periods of wetness and dryness. Any mechanical disturbances (such as erosion, slumpage, current action) will accelerate the destruction of these materials.

WOOD

Introduction

The use of wood by man dates from Paleolithic times to the present. It has been used in almost every context, and thus serves not only for artifactual analysis, but also for dating, under certain circumstances. Therefore, its preservation under conditions of inundation is of great importance.

Generating Data

The three main factors that affect the preservation of water-saturated wood are: the breakdown and loss of the cellulosic components of the cell-walls due to bacterial action; the absorption of water into these cavities, causing swelling and distortion; and the deterioration of the object resulting from mechanical action (Barkman and Franzen, 1972; Christensen, 1971).

The loss of cell structure attributable to bacterial action will not in itself destroy an object. The basic form and structural outline of the object will remain in most cases; however, the object will be more susceptible to deterioration due to mechanical action because of its weakened condition. The extent of the damage by bacterial action caused by inundation will be proportional to the length of time the object is immersed and the temperature of the water. Evidence indicates that cold water temperatures act to inhibit bacterial deterioration, thereby helping to preserve wood (Barkman and Franzen, 1972; Throckmorton, 1970; Woolworth and Birk, 1975).

Water has a definite preservative effect on wood, because it limits bacterial organisms found in both acidic and alkaline soils; therefore, if the object has survived in such conditions up to inundation, immersion will probably serve to reduce bacterial action (Dowman, 1970). If the object should be buried in soil matrix or under water-laid deposits, preservation will be further enhanced--assuming, of course, that the pre-inundation soil-matrix was of a nature that prevented the deterioration of the object prior to inundation (Woolworth and Birk, 1975).

Preservation is increased because a mud or soil overlay will present an anaerobic state, which will limit or prevent bacterial action. Wood samples from bogs in Europe are extremely well-preserved due to the anaerobic state within the bog environment (Helbaek, 1970).

Water will occupy the hollow cavities created by any bacterial action, and will prevent a collapse of the internal structure (Plenderleith and Werner, 1971)--which will often cause a swelling and distortion of the wood, because of water absorption (Christensen, 1971). Proper handling and treatment after excavation cannot only preserve the structural integrity of the object, but can also displace the water, and thereby reduce the object to its normal dimensions.

Mechanical impacts such as wave action and surge can quickly destroy a wood object because of the loss of structural strength induced by bacterial action. If the object should be inundated for a period of time, thereby producing some degree of bacterial action, and should then become exposed during a drawdown period, deterioration due to rot and compaction (drying out) may be severe.

The deeper under a water-column an object is located, the less the mechanical actions will affect the materials. The water will also be colder, serving to retard bacterial action. If these conditions are combined with burial of the object, preservation may be excellent.

Assumption

The material is given proper handling and treatment during and after excavation.

Hypothesis

Freshwater inundation will retard the normal rate of deterioration of a wood object in a land context, and such an object will be suitable for analysis following its excavation from an inundated site. Preservation will be superior in sites that are deep in the water-column, covered by soil or silt to a depth of 15 centimeters and not subject to periodic drawdown.

Test Implications

1. Samples taken from an inundated site will be in a better state of preservation for analysis purposes than similar samples taken from a non-inundated site.
2. Samples taken from an inundated site that have been buried under at least 15 centimeters of water-laid sediment or soil-matrix will be in a better state of preservation than similar samples taken from an exposed, inundated site, or a non-inundated site (except for non-inundated sites that are perpetually frozen or are in an area of extreme aridity).
3. Samples taken from an inundated or partially inundated site that is exposed to the mechanical action of waves and/or surge will not be in a state of preservation comparable to similar samples taken from a non-inundated site, or an inundated site at a depth that serves to mitigate such mechanical actions.
4. Samples taken from a site that has undergone periods of inundation and drawdown, and resultant drying, will be in a worse state of preservation than similar samples taken from a non-inundated site or an inundated site that has not undergone periods of drawdown.

FERROUS METALS

Introduction

In the New World, sites representing the historic period yield many artifacts made of iron. Sites of European and later American activity all yield many iron tools. Indian sites of the historic period also yield iron artifacts, and in many situations, iron tools will be found in aboriginal sites during the proto-historic period, after 1492, but before direct European contact with specific Indian cultures. For the Europeans and Americans, iron was a primary component of the culture. The American Indian instantly saw the increased efficiency of iron over stone, and rapidly replaced stone with iron whenever possible (Quimby, 1966). Like other types of cultural

remains, iron artifacts can be used to interpret site-function and intra-site activity-areas. They can also be used to date sites, by virtue of the morphological changes in iron artifacts over time.

Generating Data

When iron comes in contact with air and moisture, the process of corrosion occurs. Corrosion is a chemical and/or electrochemical process depending on the local environment (Hamilton, 1976). Iron objects exposed to air, or in aerobic soils will corrode, and a ferric oxide scale will form. The scale may spall off, or may form a protective layer that inhibits further corrosion. When salts such as sodium chloride are present, the process is accelerated, and spalling can result from mechanical action, such as the expansion of water in the spaces between the ferric scales (Hamilton, 1976).

Anaerobic corrosion can also occur when the sulphate-reducing bacteria that are commonly found in freshwater and waterlogged soils are present (Hamilton, 1976). In an anaerobic situation in which sulphate-reducing bacteria are not present, the corrosion of iron is effectively inhibited.

Assumptions

1. Corrosion of ferrous compounds will occur in dry or wet sites, with few exceptions.
2. Corrosion rates will vary, depending on environmental conditions.
3. The rate of corrosion will be greater in most inundated situations than in dry situations.

Hypothesis

Ferrous-compound (iron) corrosion will accelerate with freshwater-site inundation in most reservoir situations. This acceleration will vary, depending on reservoir conditions (such as depth, water salinity, water currents, bacteria types, and water turnover).

Test Implications

Note: In all test implications, post-inundation samples are compared to pre-inundation samples. Whenever possible, the pre- and post-inundation samples should be the same artifact. (Example: a shovel-blade excavated from a dry site after it is measured, photographed, X-rayed, and so forth, is then replaced in situ).

1. In an aerobic reservoir situation with low salinity, fairly constant temperature, and little current, a ferric-oxide scale will form, and tend to protect the artifact and decrease the rate of further corrosion.
2. In an aerobic reservoir situation with low salinity, varying water temperature, and little current, the ferric-oxide scale formed will spall off, starting another round of ferric-oxide scale-formation and eventual loss of the artifact.
3. In an aerobic reservoir situation with low salinity, fairly constant temperature, medium to high current, and the artifact exposed to this current, the ferric-oxide scale formed will be mechanically spalled off, allowing for the start of another round of ferric-oxide scale-formation and eventual loss of artifact.
4. In an aerobic reservoir situation with a high freshwater salinity due to the nature of the water-drainage system, the electrochemical corrosion process will be accelerated in direct relationship to the percentage of salinity. This change in salinity increases the corrosion rate, resulting in a more rapid loss of the artifact than in a pre-inundation situation.
5. In an anaerobic situation in which inundation introduces sulphate-reducing bacteria into the site environment, corrosion of iron will be accelerated.

NON-FERROUS METALS

Introduction

Non-ferrous metals such as copper, copper alloys (brass and bronze), lead, tin, silver, and gold are found in

varying and unpredictable frequencies at prehistoric and historic sites. Although it is rare, and has a limited spatial distribution, copper is the primary non-ferrous metal in prehistoric sites in North America. Copper is found in the Old Copper culture sites in the Great Lakes Region; and it is found in the form of bells in late Hohokam and Pueblo sites in the Southwest. Mortuary traditions in the Southeast (the Adena, Hopewell, and the Southern Cult are the best known) used copper for a wide range of ceremonial objects; however, these artifacts are rare, and are found primarily in graves of apparently high-status individuals.

Historic Indian sites and historic European and American sites all yield varying amounts of non-ferrous metals: copper, copper alloys, and lead are most common; tin, silver, and gold are rare.

Tin is seldom found in sites dating before the mid-19th century. Because they are precious metals, gold and silver are usually found in ornamental forms. Gold and silver artifacts can be diagnostic; however, their value often makes them heirlooms, and earlier materials may thus be found in later site contexts.

Copper, brass, bronze, and lead artifacts can be used to delineate temporal dimensions, through the analysis of changing artifact attributes over time. Copper artifacts have been chemically analyzed, and the resultant data has helped archeologists define prehistoric copper trade-routes--primarily those between the Great Lakes and Gulf Coastal Plains.

Generating Data

Cupreous metals include all metals consisting of copper or copper alloys (Hamilton, 1976). Cupreous metals, copper, bronze (a mixture of copper and tin), and brass (a mixture of copper, zinc, and often lead), are rarely adversely affected by saltwater immersion, and are probably even less affected by freshwater immersion. Copper is a relatively noble metal, and thus does not readily react with other elements. Bronze and brass will often show pitting and corrosion after immersion; however, this is often due to the differential corrosion properties of tin and zinc.

Copper does combine with elements in all environments, although relatively slowly to form cuprous chloride, cupric chloride, cuprous oxide, cupric carbonates (observable in most land sites), malachite, azurite, and cuprous sulfide.

In salt water, cupreous metals will produce cuprous ions, and the ions combine with chlorides to produce cuprous chloride. Cuprous chloride is the major component of the corrosion layer.

In anaerobic situations, cupreous metals will form cuprous and cupric sulfides. The cuprous sulfide and cupric sulfide leave a black powder on the object, but in most situations very little damage is done.

Lead is a highly stable metal, especially in neutral or alkaline solutions. In anaerobic situations, where sulfate-reducing bacteria are present, sulfide compounds will readily form, and quickly reduce lead artifacts to black sludges or stains.

Tin readily forms compounds with other elements, but seldom survives very long in its original state or shape.

Silver and gold are very noble, and immersion does not adversely affect them, except for the formation of silver sulfides that occur in anaerobic conditions with sulphate-reducing bacteria. In the case of gold artifacts, the silver and copper alloys may be subject to corrosion.

Anaerobic situations will adversely affect all non-ferrous metals. When any rotting organic matter is present - e.g., pre-impoundment vegetation remains - sulfate-reducing bacteria have a very favorable medium to live in; thus, the presence of excess organic material will accelerate non-ferrous-metal destruction.

Studies have shown that there is no change in chlorides due to immersion, unless external chloride sources are introduced as a result of inundation (Wang, 1975). Anaerobic conditions develop in the bottoms of some reservoirs between spring and fall (Wang, 1975), which may affect sites subject to seasonal pool-fluctuations.

Hypothesis

Freshwater inundation in itself will not affect non-ferrous metals differentially from the dry-land situation. When freshwater inundation creates an anaerobic situation, the preservation of non-ferrous metals will be adversely affected. If freshwater inundation creates situations in which the chloride content of the water increases, preservation will also be adversely affected.

Test Implications

1. Cupreous metal samples compared before and after inundation in a situation in which an anaerobic situation is not formed, and the chloride percentage is not increased will show no deterioration other than normal rates.
2. Cupreous metal and lead samples compared before and after inundation in a situation where reservoir impoundment has created anaerobic conditions with sulfate-reducing bacteria will exhibit a marked increase in destruction after immersion.
3. Cupreous metal samples compared before and after inundation in a situation in which inundation has increased the percentage of chlorides in the water will show a marked increase in destruction.
4. Cupreous metal samples compared before and after inundation in sites flooded periodically during the period from spring through fall will show marked destruction.
5. Cupreous metal samples compared before and after inundation from sites flooded periodically during the winter will show no marked destruction above the normal rate.
6. Silver and gold samples compared before and after inundation under all conditions will show no marked increase in destruction.
7. Cupreous metal and lead samples compared before and after inundation in reservoirs with anaerobic conditions, but lacking extensive wood (such as trees and

building-structures), will show less destruction than similar samples from an anaerobic reservoir containing extensive decaying wood.

IMPACTS UPON ANALYTICAL TECHNIQUES

This section deals with the effects of inundation upon certain analytical techniques used by archeologists on primarily non-artifactual elements of a site to determine such factors as site boundaries environmental parameters, and special use. The analytical techniques discussed are:

Soil-Chemistry Analysis

Flotation

Source-Identification Techniques

Microscopic Analysis of Stone Artifacts

Palynology

Standard Survey Techniques and Remote-Sensing Potential

SOIL-CHEMISTRY ANALYSIS

Introduction

Human activity will alter many of the chemical properties of the soil at a site. These chemical modifications result from a wide range of activities. For example, the remains of food leave behind concentrations of chemical residues when they decay, which affect soil pH. In the case of shellfish remains, soil pH will become more alkaline. Hearth and kiln locations will add potassium to the soil as wood/ash is produced. Human excrement will leave high nitrate levels.

Archeologists use chemical analysis to locate human-activity areas, and also to differentiate between and

interpret functional loci within a site (Sjoberg, 1976; Eddy and Dregne, 1964). There is an emphasis in archeology today upon the collection of many types of non-artifactual data (Watson et al., 1971). Within this framework, soil analysis has become a very important technical and methodological tool. Many different chemicals have been tested for use in archeological sites, with varying degrees of success. Some tests are used to clarify highly specific situations (for example, the presence of copper may indicate corn storage in cache pits). For purposes of the Reservoir Inundation Studies Project, several chemical tests have been selected that offer a fairly wide application to archeological interpretation and explanation: test for pH nitrates (NO_3); organic matter; phosphorus (phosphate); and potassium.

Because bone preserves better in a low-acid environment, pH values can be used to detect intrasite areas where bone will be better preserved. In some areas, pH can also be used to detect pit-features and house-locations, where, as a result of resource-procurement activities, chemical residues may be concentrated. Shellfish have shells composed of calcium carbonate (CaCO_3), which will tend to de-acidify soils where they have been discarded, and thereby give higher pH readings.

Nitrate (NO_3) levels are high in refuse containing fecal matter and decomposed animal bodies. Organic-matter testing can indicate whether or not pits were used for food-storage. Phosphorus/phosphates analysis has a very wide range of applications. It is very important because phosphate compounds are highly stable in a stratigraphic location over time. Potassium can be used to indicate wood ash (Eddy and Dregue, 1964).

Generating Data

Soil chemicals are subject to varying degrees of leaching or percolation due to natural precipitation and water drainage. Certain soil types provide more favorable situations for leaching or percolation than others (Downman, 1970). Inundation will alter the natural long-term effects of climate on soil, and should thus affect the chemical nature of the soils.

Periodic inundation will also affect natural soil chemistry. Leaching and percolation (the downward movements of soil chemicals) occurs at rates that vary directly proportionally to the amount of precipitation, with soil-type a relevant variable. Efflorescence due to capillary action occurs at rates that vary directly in proportion to the rate of evaporation, with soil-type the determining variable. The rates of these processes are slowed in tightly consolidated soils, such as silts and clays. The ability of soils to retain soil moisture will also affect the leaching and percolation processes.

pH, organic content, potassium, and phosphates are affected most by leaching. Nitrates are affected primarily by percolation. Ferrophosphate compounds will have a tendency to percolate during dry periods.

pH of Soils

Hypothesis:

At a specific site, absolute pH values will be altered by the effects of inundation, but should still yield relative pH values that are useful for archeological research. In a loosely compacted soil stratum, pH values will approach the reservoir pH value, if this loose stratum does not lie below a compact soil stratum.

Test Implications:

1. A series of soil samples taken from the same soil stratum within a site after inundation will yield different pH values than comparative samples taken prior to inundation.
2. A series of soil samples taken after inundation from features (such as pits, hearths, and post moulds), soils within general areas of site activity, and soils outside general site activity will yield altered pH values from those taken from these areas prior to inundation. The relative intra-site differences

between the pH values of features, general activity areas, and off-site areas after inundation should be sufficient to delineate these site areas.

3. Taken after inundation, pH samples from loosely compacted soil strata will yield absolute values that approximate those of the reservoir water pH values at that location.

Nitrate Concentration in Soils

Hypothesis:

The potential for soil nitrate analysis will be lost in direct proportion to the length of time immersed.

Test Implications:

1. A series of soil samples taken from the surface of a site before inundation will yield nitrate values that are usable for archeological interpretation; comparative samples taken after inundation will yield greatly diminished or undetectable values for nitrates.

2. A series of soil samples taken from all stratigraphic levels within a site before inundation will yield usable nitrate values, but comparative samples after inundation will yield greatly diminished or undetectable values for nitrates.

Phosphate Concentration in Soils

Hypothesis:

Samples taken for soil-phosphate analysis after site inundation will yield lower phosphate values than comparative samples tested before inundation, but relative differences between samples will remain unchanged. Where ferro-phosphate compounds are formed in loose soils, such as sandy loams, phosphates will be lost unless replenished with phosphate from bone apatite, e.g., over a cemetery.

Test Implications:

1. A series of phosphate samples taken after inundation from the same archeological features and the general site location will yield different phosphate values when compared to samples from the same loci prior to inundation, but the interpretation of these values in respect to relative phosphate values should be the same.

2. A series of phosphate samples taken after inundation from iron-rich sandy loams should yield phosphate values that are not usable for phosphate analysis, when compared to phosphate samples taken prior to inundation.

Organic Matter in Soils

Hypothesis:

Inundation will have no effect on the percentage of organic matter in sub-surface soil samples from archeological sites, but will affect the percentage of organic matter in surface soil samples from archeological sites.

Test Implications:

1. A series of soil samples taken from sub-surface features after inundation will contain the same percentage of organic matter as comparative samples taken prior to inundation.

2. A series of soil samples taken from surface features after inundation will contain a different percentage of organic matter than comparative samples taken prior to inundation.

Potassium Concentration in Soils

Hypothesis:

Site inundation will wash out potassium salts from the upper strata of a site, but should not affect the

potential analysis of potassium values below those levels saturated by lake water.

Test Implications:

1. Soil samples of the upper levels of a site taken after inundation should yield different potassium values than samples taken prior to inundation, but will still be usable for relative potassium value interpretation.

2. Soil samples taken from the lower levels of a site after inundation should yield different potassium values than samples taken prior to inundation, but will still be usable for relative potassium value interpretation.

FLOTATION

INTRODUCTION

Flotation is a method that has been used by archeologists to retrieve macrobotanical and small faunal remains. The basic principle of flotation is that substances having different porosities settle out at different rates, resulting in a separation of the light and heavy "fractions" (Struever, 1968). Very simply, flotation involves the subjection of soil samples to a water bath, wherein small, frequently undetected animal and vegetal finer-grain remains are departed out from the surrounding soil-matrix. This procedure works best for loosely consolidated soils, such as sandy soils. Finer-grained soils, such as peat and silt, are more difficult to float, because of their adhesive qualities. Examples of the kinds of remains recoverable through flotation include lithics, bone, fish-scales, seeds, twigs, leaves, bark, fibers, and hair.

Pollen is only visible microscopically. However, the macroscopic returns from flotation are more tangible, and can be fairly quickly analyzed, because the time-consuming chemical processes associated with pollen-analysis are eliminated. The flotation process contributes valuable data leading toward delineating specialized activity areas, utilized and available plant and animal resources, and various methods of food

preparation--all of which may previously have gone undetected. Examples of the kinds of context from which flotation samples are removed include surface; floor-fill; feature-fill such as hearths and storage-pits; food-processing loci; and trash mounds.

Generating Data

Various factors must be considered in evaluating the effect that inundation may have on flotation samples, including the composition of the sample; the soil matrix; and the site context. One of the primary effects that may occur as a result of inundation is that of natural flotation. Surface samples and those situated in coarse-grained soils, such as sand, will most likely be subjected to natural flotation, and resultant redeposition and displacement will present major problems for interpretation. Samples contained within a fine-grained soil-matrix will probably be protected; however, a surface soil cover may be removed during the initial or subsequent inundations, resulting in disturbance of potential flotation samples.

Hypothesis

The results obtained from flotation samples removed prior to and following inundation will vary according to localized soil conditions and mechanical impacts to which the samples is subjected. Flotation samples situated in a loosely consolidated soil-matrix will not yield comparable pre- and post inundation results.

Test Implications

1. In an inundated context, flotation samples situated in loosely consolidated sediments will be subject to natural flotation, and will therefore not yield comparable pre- and post-inundation results.
2. In an inundated context, flotation samples situated in fine-grained soils such as silt or clay are less apt to be disturbed by natural flotation and redistribution, and will therefore yield comparable pre- and post inundation results.
3. In an inundated context, surface flotation samples will be lost or redeposited due to natural flotation, and will therefore not yield comparable pre- and post-inundation results.

SOURCE-IDENTIFICATION TECHNIQUES

Introduction

The essential purpose of the chemical analysis of minerals or artifacts is to discover the components from which they are made, so their origins may be determined. From this source-identification research, inferences can be made about cultural patterns, trade relations, and trade routes.

Neutron-activation analysis, optical emission spectroscopy, X-ray fluorescence spectrometry, and X-ray diffraction analysis are four analytical methods from which identification of the constituent elements of artifacts can be made. These techniques have been applied successfully to metal, glass, obsidian, turquoise, jade, steatite, and pottery (Aitken, 1961; Britton and Richards, 1970; DeBruin, Korthoven, V.d. Steen, Houtman, Duin, 1976; Hall, 1971; Hall, Banks, Stern, 1964; Lambert and McLaughlin, 1976; Perlman and Asaro, 1971; Stevenson, Stross, and Heizer, 1971). Neutron-activation analysis and X-ray fluorescence spectrometry are both non-destructive analytical methods applicable to certain types of archeological specimens. Optical emission spectroscopy and X-ray diffraction analysis require that only a small portion of the artifact be ground for analysis.

Generating Data

In neutron activation analysis, a sample is irradiated by neutrons, which are small, energetic particles without charge. The nuclei of specific isotopes absorb the neutron activating meta-stable radioisotopes. These radioisotopes decay at a particular rate described by their half-lives and produce characteristic spectra.

The high-energy, characteristic gamma radiation of the radionuclides are measured with detectors. Samples with neutron-flux standards of known chemical composition are activated simultaneously with the unknown samples. The intensity of the radionuclide spectra of these standards are compared with those of the unknown samples for quantitative analysis (Ericson, 1977).

Optical emission spectroscopy is based upon the fact that each element of an artifact has a characteristic spectrum of light, which is emitted when a small powdered portion of an artifact is vaporized in an electrode arc. Characteristic spectra are obtained from a spectrograph of the constituent elements, and the resultant graph is then compared with representative spectrographs of known elements to enable determination of the composition of the artifact (Matson, 1970).

Analysis of artifactual materials by means of X-ray fluorescence spectrometry is dependent on the fact that elements within the artifact may be activated with X-rays. Each constituent element of the material produces a characteristic fluorescence from these X-rays, which can be measured spectrometrically to define the chemical, elemental composition of the artifact (Matson, 1970). The procedure developed by Jack and Carmichael (1969) and subsequently used to determine the origin of artifacts by Jack (1976) illustrates the rapidity and accuracy of X-ray fluorescence in the parts-per-million range.

X-ray diffraction is another analytical technique used on archeological materials. As with optical emission spectroscopy, only a small portion of the specimen must be powdered for analysis. X-rays are first passed through the crystals of the powdered sample, and the diffraction patterns produced by the penetration of the X-rays into the micro-crystalline structure of the material are analyzed by means of a diffractometer, to obtain the width, intensity, and position of the structural lines. From this information, an analysis of the mineral structure can be made (Aitken, 1961).

Source-identification techniques are used to analyze various types of artifacts, including lithics, metal, glass, and pottery. These techniques utilize different methods, such as X-rays, gamma rays, and electrodes, to define the elements from which the artifacts are made.

If sufficient physical remnants of the material remain to provide an adequate statistical sample after inundation, neutron-activation analysis, optical emission spectroscopy, X-ray fluorescence spectrometry, and X-ray diffraction analysis will be suitable for use in analyzing the composition of the material.

Hypothesis

Inundation will not affect the analytical characteristics of silicate and some metal artifacts which can be analyzed by neutron-activation analysis, optical emission spectroscopy, X-ray fluorescence spectrometry, and X-ray diffraction analysis; the results obtained from the application of source-identification techniques to artifactual materials will therefore be comparable to results obtained from a non-inundated site.

Test Implication

Samples from an inundated context analyzed by neutron-activation analysis, optical emission spectroscopy, X-ray fluorescence spectrometry, and X-ray diffraction analysis will yield source-identification information about artifacts that is comparable to samples from the same source taken from a non-inundated site.

MICROSCOPIC ANALYSIS OF STONE ARTIFACTS

Introduction

The microscopic examination of stone artifacts for wear and plant and animal residues has become a useful analytical tool for archeologists. Inferences about cultural activities and environmental exploitation have been made on the basis of microscopic analyses (Wilmsen, 1968, 1970; Binford and Binford, 1966).

All stone tools exhibit visible signs of use or manufacture; these signs provide the archeologist with information regarding the possible uses of a tool. The basic traits of manufacture of stone tools fall into four categories: percussion; grinding; sawing and boring; and pecking (Semenov, 1973). Often a combination of techniques was employed in the production of a single tool. All manufacturing activities leave unique marks on the stone.

Signs of wear on stone tools are indicated by a range of alterations to the original shape of the tool; "the

dislocation of comparatively large pieces, discoloration, shatter, creation of scars, dents, notches, and cracks" (Semenov, 1973) is common.

Along with obvious signs of manufacture and wear are less noticeable manifestations, which can only be discerned by microscopic analysis. Such analysis can provide information on not only the "direction of the instrument's movement, but some of the characteristics of its material. Sparkling, crushing of the edge and projections, starring of the surface, micro-retouch, are all traces of manufacture from which the peculiarities of ancient [tool] manufacturing technology can be identified" (Semenov, 1973). Evidence of use also found through microscopic analysis can be observed as differential wear patterns when wear results from friction between the tool and the object of work. The wear patterns resulting from the use of a stone knife in cutting up meat are different from the patterns that remain when a similar knife is used to cut hide or bone (Semenov, 1973).

Microscopic trace elements of animal and vegetal residues have different characteristics, the most common of which are "a dark-reddish, granular substance presenting a scabby appearance . . . [and] dark, thick, viscous and resinous substance[s]" (Briuer, 1976). Residues of plant fibers and carbonized material have also been found. Quite often, these residues exhibit obvious signs of "polishing, smearing, spreading and directionality, usually away from the edge" (Briuer, 1976). From these residue patterns, use can be inferred.

Generating Data

All classes of stone are subject to natural weathering processes. Patination, gloss formation, and exfoliation and crumbling of the surface are the most common types of weathering exhibited by the stone traditionally used to manufacture tools. Shallow patination will not change the relief of the stone surface, but advanced patination can cause deterioration of the surface (Semenov, 1973) and loss of visible and microscopic wear-patterns. The rate of patination or hydration, and the tendency toward this type of weathering depend upon the chemical composition of the

specimen, the stability and the distribution of impurities within the specimen, and exposure to moisture. Constant exposure resulting from inundation may accelerate patination. The development of a patina on fresh stone surfaces can occur in a matter of months. The length of time required for severe patination is different for each rock susceptible to the process.

The development of a gloss on flints, quartzites, cherts, and similar stone does not destroy the physical integrity of the specimen, but will destroy traces of tool use (Semenov, 1973). Gloss formation depends on the chemical composition of the stone and the extant environment. Wind and water erosion have been associated with gloss formation, and the development of gloss on inundated stone specimens may be accelerated.

The chemical composition of the specimen will affect its potential for microscopic wear-analysis after inundation in another way: Specimens that contain a high ratio of carbonates or feldspars to other minerals are subject to dissolution and loss of structural integrity at a faster rate than stones that are not primarily composed of these minerals. Constant inundation will accelerate the deterioration of these rocks; exposure to wave-action, surge, scour by coarse gravels, and other mechanical action will further remove visible and microscopic wear-patterns.

The length of time required for dissolution of carbonate and feldspar minerals and for loss of structural integrity will vary. However, granite ground-stone artifacts found in a reservoir in California had been severely impacted after 35 years of permanent inundation (Foster, personal communication, 1976). The deterioration of these specimens had progressed to such an extent that the artifactual nature of the stone was barely discernible.

Microscopic traces of vegetal and animal residues have been found on unwashed tools from the Southwest (Briuer, 1976). Preservation of these residues may be based in part on the arid nature of the Southwestern environment. Analysis of the specimens has been successful in determining the biological kingdoms to which the residues belong. In less arid environments encountered in other areas of the United States,

chemical and bacterial activity may act to destroy the residues. It is an accepted fact that chemical and bacterial activity increases in warmer or more humid climates; as a result, vegetal and animal remains deteriorate at a faster rate. The inundated environment, with its increase in humidity and potential increase in bacterial activity, may destroy residues. Exposure of the residues to the shallow, warm-water zone of a reservoir will also accelerate their chemical and bacterial breakdown.

Animal and vegetal residues will also suffer under the highly acidic conditions found in some soils of the West and Southeast. However, the anaerobic conditions found in some reservoirs may help to preserve the residues, because of their cold temperatures and lack of bacterial agents.

The washing of stone artifacts removes microscopic residues. The inundated environment, combined with water movement in the form of wave-action, surge, and scour by coarse gravels, may "wash" the specimens to such an extent that microscopic residue analysis is impossible.

Assumption

The stone artifact is in a sufficient state of preservation that microscopic analysis for wear and plant and animal residues is feasible.

Hypothesis

The potential for microscopic analysis for wear and plant and animal residues on stone will be adversely impacted by inundation. The degree of impact will depend upon the state of preservation of the stone; the extant chemical environment; and the direct mechanical action to which the specimen has been subjected. Analysis of inundated specimens will not yield data of quality comparable to that of similar specimens that have not been subjected to inundation. Only the special circumstances of anaerobic conditions or burial in stable soils (that is, soils not subject to erosion, scour, or currents) and very cold temperatures will act to preserve the wear-patterns and residues.

Test Implications

1. Stone artifacts that exhibit patination as a process of weathering will patinate at a faster rate as a result of inundation; examination of inundated specimens for microscopic wear will not yield data of quality comparable to non-inundated stone. The length of time required to destroy traces of tool use will depend on the chemical composition of the specimen.
2. Stone artifacts that exhibit patination as a process of weathering, and are exposed to mechanical abrasion through wave-action, surge, or scour by coarse gravels, will lose traces of tool use. Analysis of mechanically abraded inundated specimens will not yield data of quality comparable to inundated stone not subjected to this action.
3. Stone artifacts that do not patinate, but are subject to mechanical abrasion by wave-action, surge, or scour by coarse gravels, will lose microscopic traces of tool use. Analysis of mechanically abraded inundated specimens will not yield data of quality comparable to stone not subjected to this action.
4. Stone artifacts that exhibit gloss formation as a process of weathering will lose traces of tool use at a faster rate as a result of inundation; microscopic examination of inundated specimens for wear will not yield data of quality comparable to non-inundated specimens. The length of time required to destroy traces of tool use will depend on the chemical composition of the specimen.
5. Stone artifacts that exhibit gloss formation as a process of weathering, and are exposed to mechanical abrasion through wave-action, surge, or scour by coarse gravels, will lose traces of tool use. Analysis of mechanically abraded inundated specimens will not yield data of quality comparable to inundated stone not subjected to this action.
6. Stone artifacts that are primarily composed of feldspar or carbonate minerals will deteriorate at an increased rate when inundated; examination of these structurally weakened specimens will not yield data of quality comparable to similar stone from a non-inundated context.

7. Stone artifacts that are primarily composed of feldspar or carbonate minerals, and are structurally weakened and exposed to mechanical abrasion through wave-action, surge, or scour by coarse gravels, will lose traces of tool use. Analysis of mechanically abraded inundated specimens will not yield data of quality comparable to inundated stone not subjected to this action.

8. Animal and plant residues on stone artifacts will be destroyed if the stone specimen has been subjected to inundation and mechanical abrasion, through wave-action, surge, or scour. Microscopic analysis for residues will not yield data of quality comparable to specimens that have not been inundated and subjected to this mechanical action.

9. Animal and plant residues on stone artifacts will be destroyed if the stone has been inundated in acidic water or buried in saturated acidic soils; analysis for microscopic residues will not yield data of quality comparable to stone that has not been inundated.

10. Animal and plant residues on stone artifacts will be destroyed if the stone is inundated in the shallow, warm-water zone of the reservoir; analysis for microscopic residues will not yield data of quality comparable to specimens that have not been inundated.

11. Animal and plant residues on stone artifacts will be preserved if the stone is inundated in the cold anaerobic water zone of a reservoir, and if the specimen has not been subjected to mechanical abrasion; analysis for microscopic residues will yield data of comparable quality.

PALYNOLOGY

Introduction

Palynology is a major botanical technique in paleoecological work, because it provides information on the development of vegetation and climate. The application of palynology to archeology is extremely

valuable, because it can indicate the relationships between plants, culture, and climate; and it can also provide some dating information.

Generating Data

Pollen is best preserved in sediments in which oxidation is limited or absent--particularly in dense, poorly-aerated sediments, or in acidic environments. Typical soils include organic lacustrine sediments, marls, clays, and dense silt. Although alkaline soils and well-aerated soils such as sand are generally considered unfavorable environments for pollen preservation, they should not be totally disregarded as sources of pollen. Pollen is preserved under such circumstances in many archeological contexts, and an adequate pollen--count may be attained if the sample is large enough.

Pollen analysis is based upon the microscopic identification of pollen from modern plants. For this reason, the investigator must collect data on the natural distribution and habits of modern plants to ensure accuracy on the data-interpretation. Potential sources of error include differential production, differential dispersal, and differential preservation of the pollen grains. Other possible sources of error in data-interpretation include the redeposition of pollen from older sediments and long-distance transport by streams (Faegri and Iverson, 1964).

One of the major problems likely to be encountered in pollen analysis is that of redeposition or redistribution of pollen grains, especially in the littoral zone of a reservoir. Erosion resulting from wave-action produced by fluctuating water levels is likely to be the greatest contributing factor. The effect may range from loss of surficial pollen by flotation to loss of context through sheet erosion and slumpage. (These mechanical impacts are covered in detail in a separate section of this chapter). Redeposited sediments generally contain a mixture of contemporary and older pollen, which can skew the interpretive results. Another possible mechanical effect is that of vertical displacement, in which some of the pollen grains may invade contiguous layers due to a shift or swelling of soil particles. Aside from mechanical

impacts, chemical impacts may also affect pollen preservation. For instance, the introduction of an alkaline body of water may alter the pH balance of an acidic soil in which pollen has been preserved, possibly resulting in the destruction of some of the preserved pollen.

Assumption

The samples have been handled properly in both the field and the laboratory.

Hypothesis I

Some loss of palynological samples will result from inundation, due to flotation, redeposition, and mechanical and chemical disturbances, (such as changes in pH) depending upon the nature of the soil-matrix, and the condition of the preserved pollen.

Test Implication I

1. Samples taken from an inundated context where mechanical and chemical disturbances have occurred will not yield comparable pre- and post-inundation results.

Hypothesis II

Pollen contained within deeply buried dry-land sites will stand a better chance of surviving the impacts of inundation than pollen preserved in shallow sites or in sites containing loosely consolidated sediments.

Test Implications II

1. Samples taken from well-consolidated soils will yield comparable pre- and post-inundation results.

2. Samples taken from loosely consolidated soils or shallow sites will not yield comparable pre- and post-inundation results.

STANDARD SURVEY TECHNIQUES AND REMOTE-SENSING POTENTIAL

Introduction

In an era in which much of the archeology is contract or salvage in nature, it is becoming increasingly expedient to combine standard survey procedures and remote-sensing for site and feature detection; site-location prediction; recognition and differentiation of ecological resources; and photogrammetric and digitalized mapping. Remote-sensing is especially valuable in situations in which a survey or inventory of a large tract of land is required. The survey and remote-sensing capabilities to be considered are: standard survey procedures; aerial remote-sensing proton-magnetometer survey; and resistivity survey.

Standard Survey Techniques

Introduction: An important aspect of archeological research is the site survey. The primary purpose of conducting a survey is to locate and record archeological sites, delineate the site boundaries, and locate specific use and resource areas within a given site area.

Most archeological survey involves walking the entire project area to be impacted or inventoried, and carefully recording all pertinent cultural and environmental data in written, graphic, and photographic form. Wherever possible, existing remote-sensing data, such as aerial photographs, should also be utilized to facilitate survey in areas most likely to contain sites. Frequently, buried sites or features having no obvious surface indications have been detected through various remote-sensing means including aerial photography, magnetometer survey, electrical resistivity, and sub-surface radar (Lyons, 1976; Jorde, 1976; Vickers, Dolphin, and Johnson, 1976; Aitken, 1961, 1970; Arnold and Kegley, 1974; and Clark, 1970).

Survey data can be applied to specific facets of archeological research, such as that undertaken by the Southwestern Anthropological Research Group (SARG) to obtain data on the distribution of prehistoric population aggregates (Gumerman, 1971, 1972. Settlement-pattern studies are receiving increased attention

as archeologists attempt to predict site locations from such variables as resource distribution and landform data.

Generating Data: The question of the impact that freshwater inundation will have on the potential for post-inundation survey will depend in large part upon the nature of the site; its location within the reservoir; and the nature and extent of the various reservoir activities (such as silting and mechanical action) that have taken place. There are documented instances in which additional sites, not recorded during survey, have been exposed along the shorelines of reservoirs (Padgett, 1976). However, in several instances, survey potential has been reduced due to the adverse impacts on the cultural resource of bank erosion, and beach erosion.

The two factors that will pose the greatest limitation in post-inundation survey are siltation and mechanical disturbances (such as currents, sheet erosion, and wave-action). Sites that are buried beneath deep accumulations of silt will be virtually impossible to detect or relocate by the use of standard survey procedures. The problem of mechanical disturbance may also make resurvey difficult, particularly in instances in which the entire site has been washed away or deflated, and artifacts redistributed. In such instances, resurvey will be of the greatest value in evaluating and documenting various impacts to a site and the cultural material contained therein as a result of inundation, rather than in site relocation.

Hypothesis: The capability of standard survey procedures for survey or resurvey of archeological sites following inundation will depend largely upon the nature of the site and the impact of the reservoir variables on the site. Standard archeological survey procedures conducted to relocate archeological sites following inundation will not yield comparable pre- and post-inundation results. This will be most evident in sites that are either buried beneath silt or greatly disturbed by mechanical activity.

Test Implications:

1. Following inundation, archeological sites characterized by surface scatters of cultural materials and/or shallow cultural deposits that are located in areas of low topographic relief and buried beneath deep accumulations of silt will not be detected by standard survey techniques.
2. Following inundation, archeological sites located in topographically distinctive areas and buried beneath deep accumulations of silt will be relocated by standard survey techniques. However, test excavations will be necessary to confirm the actual presence of sites.
3. Following inundation, archeological sites that are not covered with silt, but have been subjected to sheet erosion or other mechanical activity, will not yield comparable survey results in terms of structural integrity and artifact distribution.

Aerial Remote-Sensing

Introduction: Aerial remote-sensing adds an important dimension to the field of archeology in terms of its broad-application to both exploration and intra-site interpretation in archeology. When combined with standard survey procedures, a much greater data base can be obtained, resulting in a more thorough understanding of the interrelationships of the cultural and ecological entities of the site environment. This is brought about in large part as a result of the synopticity that is provided through aerial imagery.

The most frequently utilized techniques of aerial imagery for archeological purposes include panchromatic photography; color-infrared photography; and thermal-infrared scanning imagery. These techniques are fairly inexpensive, and permit a wide range of data-returns in terms of site detection, site distribution, and ecological variables. Of these, panchromatic photography is the technique most widely used for interpreting intersite archeological and paleoecological data, because it offers the advantages of low cost, sharp resolution, and large quantities of

pre-existing imagery. Color-infrared and/or thermal-infrared imagery are recommended for intrasite sampling and stratigraphic-profile mapping, because of the high-contrast properties of the film, and its sensitivity to effects of moisture-content (Jorde, 1976).

Multispectral scanner imagery is another aerial remote-sensing technique that is sometimes used for archeological research. It is more costly than the previously mentioned techniques, but offers the advantage of being able to simultaneously obtain several images of a given area, exposing each image to a different band of the color spectrum (Hampton, 1968). Within the various bands, sensitive changes in vegetation, soil-type, temperature, and moisture can be discerned, which may provide clues to the presence of cultural features. Because of the high costs involved in multispectral scanner imagery, it is suggested that a combination of panchromatic and color-infrared coverage be utilized instead, to achieve a somewhat similar effect. In the final analysis, the efficacy of aerial photography in archeological research depends upon several factors: light conditions; film/filter combinations used; scale; temporal variations; and the ability of the investigator to apply deductive and inductive reasoning in interpretation.

Generating Data: The principal applications of remote-sensing in archeology are oriented toward site and feature detection; site-pattern recognition; local and regional distribution; human-population distribution and size; sampling; volumetrics; mapping; and cultural-resources management (Jorde, 1976). In assessing the impact of freshwater inundation on the cultural-resources inventory, each of these categories of application should be considered throughout each stage of reservoir development and activity--pre-inundation, inundation, and post-inundation. Aerial remote-sensing can be an invaluable tool for monitoring changes within a site environment, as well as for monitoring overall areal geomorphological change resulting from increased erosion and/or siltation. One potentially important use for aerial remote-sensing in reservoir contexts is that of volumetrics. In many instances, it will be possible to calculate the volume of silt contained within or covering a site by pre- and post-inundation

photogrammetric maps of the individual sites. This would be particularly useful for large, complex sites.

Color-infrared and thermal-infrared photography may have application for locating sites and features in recently drawn-down reservoirs, because of the sensitivity of the film and scanner to detect moisture differences. Since soil temperature is largely determined by water content, the differential retention of water by various types of soils may reveal buried or obscure features that are not detectable by panchromatic film coverage (Jorde, 1976).

An additional possibility to be considered is the application of aerial remote-sensing to the locating and mapping of submerged sites. While aerial remote-sensing has been successfully used to locate shipwrecks in clear Caribbean waters, its utility in locating submerged sites in reservoirs is limited to extremely shallow or clear water conditions. A major deterrent to aerial remote-sensing in reservoirs is turbidity. Under turbid conditions the amount of available surface light, upon which the success of aerial photography depends, is severely reduced. However, it may be possible to locate sites using aerial photography by running underwater field checks on phenomena such as clouds of suspended sediment or peculiar current-patterns that may indicate the presence of submerged sites.

Hypothesis I: A comparison of aerial photographs taken before inundation and during drawdown will not yield comparable results. In most cases, post-inundation aerial imagery will yield inferior results as a result of mechanical disturbances not only to the site itself, but also to the surrounding site area. However, aerial photography will provide useful documentation of gross inundation effects on sites and surrounding topography.

Test Implication I:

Sites which have been mechanically disturbed or altered during the inundation period will not yield comparable pre- and post-inundation results.

Hypothesis II: A comparison of aerial photographs taken before and during inundation will not yield comparable results. In most cases, post-inundation aerial imagery will be inferior depending upon the depth and turbidity of the water. The effectiveness of using aerial photography to locate or map sites submerged in deep and/or turbid water will be negligible.

Magnetometer Survey

Introduction: The magnetometer is a useful remote-sensing device for land and underwater site survey; however, the extreme cost of the equipment precludes its widespread application. A magnetometer operates on the principle that buried objects--particularly metallic objects--cause measurable variations in the intensity of the earth's magnetic field. The proton-magnetometer has been successfully used to detect subsurface cultural features, because of the magnetometer's sensitivity in detecting magnetic anomalies caused by ferrous compounds, thermo-remnant magnetism, and different magnetic values of soils within a site (Arnold and Kegley, 1974). These anomalies represent magnetic contrasts between the feature and surrounding matrix (Aitken, 1970).

The efficacy of magnetometer survey in locating prehistoric sites submerged in freshwater reservoirs has not yet been determined. However, it is unlikely that the application of marine and riverine shipwreck survey techniques to prehistoric site-survey would be feasible, due to the reduced strength of the anomalies produced by buried prehistoric cultural features (Arnold, personal communication).

Various attempts have been made to identify the signatures of buried prehistoric features on dry land (Arnold and Kegley, 1974; Weymouth, 1976; and Breiner, 1973). The kinds of archeological features most likely to be detected during a magnetometer survey include kilns; hearths; earth-filled structures such as pits and pithouses, particularly if they have been burned; metallic artifacts; and occasionally sherd concentrations. Some cultural features do not exhibit detectable magnetic contrasts between the feature and surrounding medium (Breiner, 1973). The strength of

the anomaly is determined by such factors as the nature of the feature, its structural composition, its fill composition, the amount of disturbance, the size of the feature, and the depth of the feature.

Kilns and hearths containing large amounts of baked clay are usually easily detected. Hearths containing small quantities of baked clay may be easily detectable if they are not buried too deeply. Sherd concentrations are also detectable, although the magnetic effect is greatly attenuated by the disarrangement of the sherds (Aitken, 1961). Generally, earth-filled features such as pits are detectable. The strength of the anomaly depends largely upon the humus content of the fill material. The effect is magnified if the feature has also been burned. Walls are generally not detectable unless composed of materials that would create a magnetic disturbance, such as brick or volcanic rock, or unless the magnetic susceptibility of the soil adjacent to the wall is high (Aitken, 1961).

One means of identifying problem areas of interpretation is the taking of representative samples of the features and the comparing of the relative magnetization of the surrounding matrix to determine if a measurable contrast exists. Two problems that may be encountered are: the difficulty of discerning magnetic contrast between a feature and the surrounding soil matrix, especially soils having a high mineral content; and the difficulty of instrumentation to perceive prehistoric cultural features buried beneath deep or compacted sediments.

Generating Data: With regard to baked clay features, at this time it is not expected that freshwater inundation will skew the results for pre- and post-inundation comparisons of magnetometer survey, as long as the features remain intact following inundation. However, possible skewing of results from non-baked-earth-filled features could occur if sheet erosion has replaced the original fill with locally occurring soil. This would result in reduced magnetic susceptibility between the feature and surrounding soil-matrix, perhaps precluding detection through magnetometer survey.

Assumption: Mechanical action has not distorted the archeological feature or associated fill.

Hypothesis: Results obtained from magnetometer surveys conducted prior to and following inundation will be comparable.

Test Implication: In an inundated context, where cultural features have remained intact following inundation, a magnetometer survey conducted on a site prior to and following inundation will yield comparable results.

Resistivity Survey

Introduction: Another remote-sensing technique that has been used by archeologists to detect buried archeological features--particularly linear features--is electrical resistivity.

The ability of soil or rock to conduct an electrical current depends upon the quantity of water and dissolved salts and minerals trapped in the interstices. Resistivity operates on the principle that when an electrical voltage is applied between two electrodes, the solution will separate into positive and negative ions through the process of electrolysis, and these ions will migrate to the respective electrode, thereby setting up an electric current. The measurable resistivity is the ratio of the applied voltage to the magnitude of the current. The resistance varies according to the density and dampness of the soil or rock, and upon the solubility and quantity of the salts and acid contained therein (Clark, 1970). Thus, the detectability of archeological features is largely dependent upon local geologic and climatic conditions (Aitken, 1961).

Generating Data: Generally, rock has a very high resistivity compared to soils and clays; however, wide variations can be expected in the latter, depending upon the dampness. Therefore, archeological features such as walls, building foundations, and structures constructed of stone or filled in with stone will

generally produce a high resistance and will be more easily detected. Earth-filled features such as pits and trenches usually produce a low resistance, depending upon the soil-type and the dampness of the soil. Underground caverns have also been detected through resistivity survey, because of the absence of a conducting medium (Aitken, 1961).

The major factors that influence the conductivity of the soil include type, compactness, depth, homogeneity, and dampness. To detect a buried archeological feature, there must be a contrast between the feature and the surrounding soil-matrix. Loamy soils situated atop well-drained subsoils generally produce good resistivity results; sands, clay, and silt may be suitable only if a perceptible moisture contrast exists between the feature and surrounding soil. The effects of differential moisture content on a soil is important for both conductivity and interpretation. Too much moisture can attenuate the resistivity contrast, thereby precluding the detection of buried earth-filled features such as pits and hearths.

The impact of inundation on the potential for resistivity survey of buried cultural features is intimately linked to the factors of soil-type and water content, particularly the latter. Within the fluctuation zone of a reservoir, or during a drawdown in which the water table is apt to be high, features located near the surface may not be detected. One means of alleviating this problem is to conduct the survey during weather cold enough to freeze the water (Aitken, 1961). Conversely, probing a soil that is damp near the surface, rather than at depth, will be less likely to produce evidence of deeply buried cultural features. Soils that are well-compacted usually give more accurate resistivity readings than well-aerated, loosely consolidated soils, because air-pockets trapped in the latter soils give high resistivity readings comparable to stones.

Hypothesis: Comparisons of results obtained from conducting pre- and post-inundation resistivity measurements to detect buried archeological features will vary according to the localized soil and moisture conditions. Buried archeological features that have been filled in with soils of a composition, density,

and moisture-retaining ability differing from the surrounding soil-matrix will yield comparable pre- and post-inundation resistivity results, provided that the water table is not so high as to preclude the detection of those features located near the surface.

Test Implications:

1. In a drawdown situation in which the water table remains high, buried archeological features located near the surface will not be detected by resistivity survey.
2. In an inundated context, earth-filled features that have been backfilled following excavation will not be detected by resistivity survey if the backfill soil-matrix is not appreciably different in composition and moisture content from the surrounding soil matrix.
3. In an inundated context, features such as pithouses, pits, and hearths that have been naturally filled in from local silts and soils will not be detected by resistivity-survey measurements taken during drawdown.
4. Stone walls or stone-outlined features will yield comparable pre- and post-inundation results.

IMPACTS UPON DATING TECHNIQUES

Considered in this section are the effects inundation has on archeological dating techniques. The degree to which freshwater immersion will destroy or enhance the potential for subjecting various elements of an archeological site to dating techniques may be of critical concern to many research designs. However, this report does not address the question of the basic viability or reliability of any particular technique. The Reservoir Inundation Studies Project's research design is geared rather to the problem of whether or not similar results can be expected from samples taken from both inundated sites and non-inundated sites.

The effects of inundation on the following archeological dating techniques will be considered in this section:

Carbon-14 Dating

Dendrochronology

Obsidian-Hydration Dating

Archeomagnetic Dating

Fluorine Dating

Amino-Acid-Racemization Dating

Weathered-Glass Dating

Thermoluminescence Dating

X-Ray Diffraction Dating

Fission-Track and Alpha-Recoil Track Dating

CARBON-14 DATING

Introduction

Carbon-14 dating has for many years been one of the most important absolute dating techniques available to archeologists (Libby, 1955; Berger, 1970). Theoretically, any organic substance should be datable by this technique, because all organic matter is composed of carbon compounds. However, this is not the case; the best material for carbon dating is wood or wood charcoal. During the photosynthesis process in plants, carbon dioxide is absorbed, and some of the carbon dioxide is composed of carbon-14, which is a radioactive isotope. By measuring the ratio of carbon-14 to carbon-12, and knowing the half-life of carbon-14, a date for the death of the wood may be determined. By using carbon-14 analysis on wood, charcoal, or other suitable material from such features as hearths and roof timbers in archeological sites, the material and associated archeological data can be assigned an absolute chronological placement in terms of years (B.P.).

Generating Data

A review of the literature on carbon-14 techniques and theory does not indicate that freshwater immersion will negatively alter the potential of samples for carbon-14 dating, with the possible exception of freshwater bicarbonate exchange in shell. The literature does indicate that some already-existing natural agents that decrease carbon-14 sample-recovery may be magnified. As is the case for all archeological data, the potential problem is the degree of preservation. Although no direct alteration of carbon-14 may occur through mechanical or chemical means, the gross amounts of usable samples may be greatly reduced. The decrease in sample size is the result of the formation of new carbon compounds that occurs in soils every time moisture comes in contact with soil carbons. This process may be intensified under the influence of constant H₂O contact--for example, higher rates of calcium carbonate formation. This carbonate will yield anomalous dates since it is in exchange with the present atmosphere. A portion of the soil carbons used in the carbon compounds comes from carbon-bearing artifacts left by man, such as roof timber, plant fibers, and human and animal bone. Then the problem may be that the necessary sample volume or weight needed will not be obtainable.

Hypothesis I

Carbon-14 samples taken from a feature(s) or geologic or cultural stratum after inundation will yield dates similar to those for comparative carbon-14 samples taken from the same feature(s) or geologic or cultural stratum prior to immersion within the limits of statistical confidence.

Test Implication I

Comparative samples taken prior to and after inundation in all reservoir situations will yield similar dates.

Hypothesis II

In situations prior to inundation, where bulk-sampling techniques are required, or where individual sample

weight or volume are marginal, samples taken after inundation will require larger total soil-matrix units for bulk-sampling of carbon-14; marginal single samples will not be available, requiring the substituting of bulk samples.

Test Implications II

1. Soil samples taken before inundation should yield higher percentages of organic materials per unit size than soil samples of equal water volume taken after inundation.
2. Soil samples taken before inundation should yield higher amounts of charcoal by total weight than soil samples taken after inundation.
3. At sites where marginal carbon-14 samples are taken prior to inundation, adequate samples will not be available after inundation.

DENDROCHRONOLOGY

Introduction

Dendrochronology (tree-ring analysis) when used in archeological dating is dependent on the fact that many trees show an annual formation of growth-rings. The dendrochronologist can count the rings from the exterior to the core in order to obtain a date. By cross-dating specimens that overlap in age, it is possible to build a tree-ring chronology; and by starting with a modern specimen of known date and cross-dating with successively older specimens, it is possible to establish a long-range chronology.

The tree-ring chronology for the Southwestern United States (a highly successful area for this technique) has been established from the present to 59 B.C. (Michels, 1973). With such an established chronology, the archeologist can take his sample, such as a preserved construction-timber, and find its location in the tree-ring sequence. The archeologist then has an absolute reference as to the year the tree died, which

provides him with grounds for inferring a time-frame for possible cultural utilization. This technique also helps to date associated remains in the site.

Generating Data

There are many factors that determine whether or not a sample is suitable for tree-ring analysis: the most important consideration is whether or not the wood is well enough preserved to show the ring structures in analysis, particularly the exterior and bark rings.

The Reservoir Inundation Studies Project is concerned about four major factors that will affect the preservation of water-saturated wood: the breakdown and loss of the cellulosic components of the cell-walls due to bacterial action; the absorption of water into the cavities, causing swelling and distortion the deterioration of the object due to mechanical action; and proper handling following excavation.

The loss of cell-structure due to bacterial action will not in itself damage the acceptability of an object for tree-ring analysis. The basic form and structural outline of the object will remain in most cases; however, the object will be more susceptible to deterioration due to mechanical action because of its weakened condition. The extent of the damage by bacterial action will be proportional to the length of time the object is immersed and the temperature of the water. Evidence indicates that colder water temperatures would act to inhibit bacterial deterioration, thereby helping to preserve the wood (Throckmorton, 1970; Barkman and Franzen, 1972).

Swelling and distortion of wood due to water absorption will not be damaging in itself. The water actually occupies the hollow cavities caused by the bacterial action, and prevents a collapse of the internal structure (Plenderleith and Werner, 1971). The annual growth-rings will still be visible for tree-ring analysis. Proper handling and treatment after excavation can not only preserve the structural integrity of the sample, but can also displace the water, and reduce the sample to its normal dimensions.

If the sample is immersed in shallow water, mechanical deterioration will greatly increase. Wave-action and

surge will act to batter it, and this action, combined with the loss of structural strength due to bacterial action, can destroy it. If the object is immersed for some time, which would induce some degree of bacterial action, and then is exposed during a drawdown period, deterioration due to rot and compaction (drying out) may be severe.

Perhaps the most potentially destructive effect on inundated wooden objects can be perpetuated by improper handling of the object following excavation. If properly excavated and handled, an object that has suffered total deterioration of its cellular structural integrity, and is swollen, may still be acceptable for tree-ring analysis.

No treatment should be attempted in the field. The various techniques of consolidation are long-term and complex, and arrangements should be made with a qualified laboratory. Field handling should consist of providing sufficient support for the object (water absorption has usually made the object too heavy to support itself), and the employment of some method of keeping the object wet until it reaches the laboratory, to prevent collapse due to drying.

Waterlogged wooden objects dating back to Paleolithic times have been successfully excavated, treated, restored, and displayed. The most important factor is proper handling after excavation.

Assumptions

1. The inundated site is far enough below the surface to mitigate the mechanical action (wave-action and surge).
2. The material is given proper handling and treatment following excavation.

Hypothesis

Immersion of a sample will not adversely affect the sample's suitability for tree-ring analysis, although a loss of structural integrity proportional to the length of time and environmental conditions of

inundation will be evident. Mechanical actions associated with drawdown periods adversely affect the sample because of its weakened condition due to immersion.

Test Implications

1. Dendrochronological samples taken from an inundated context will yield dates comparable to those for similar samples taken from a non-inundated context, even after long-term inundation.

2. Samples taken from an inundated context that have been exposed to periodic drawdown will not yield dates comparable to similar samples taken from a non-inundated context.

OBSIDIAN-HYDRATION DATING

Introduction

The use of obsidian by native populations for fashioning various tools has long been acknowledged by archeologists. The dating of these tools was limited to typology and contextual associations until 1960, when the obsidian-hydration dating technique was developed (Friedman and Smith, 1960).

This method depends upon the fact that obsidian absorbs water from the atmosphere to form a hydrated layer, which thickens through time. When a tool is fashioned from obsidian, fresh faces are exposed to the atmosphere, and the process of hydration begins on these faces. The variation of the hydration rates among rhyolitic obsidian (Ericson, 1976) and basaltic glass flows (Norganstein and Riley, 1971) is appreciable, making source-specific determinations necessary.

Researchers measure and can equate the hydration thickness of the new faces to a period of time to date the manufacture of a tool.

Generating Data

There is a direct relationship between the measurable hydration thickness of obsidian and the period of time over which that surface develops: ". . . hydration thickness increasing with the square root of time. . . ." (Friedman and Smith, 1960). However, two relevant variables alter the rate of hydration: the rate is independent of relative humidity, but changes relative to temperature; and the rate is affected by the chemical composition of the obsidian (Friedman and Smith, 1960).

An obsidian sample exposed to atmospheric temperature, either by lying on the surface or being buried in the ground at very shallow depths (1 to 10 centimeters) will exhibit a rate of hydration different from that of similar obsidian buried to depths in excess of 50 centimeters. This is due to the wide diurnal temperature fluctuations found within the first few centimeters under the surface as opposed to comparatively non-existent variations found at greater depths. Additionally, a piece of obsidian exposed to the sun will hydrate much faster than buried obsidian. The difference will be greater at higher elevations, where the direct rays of the sun are less filtered, and where snow cover is minimal (Friedman and Long, 1976).

No direct evidence is available concerning the effects of freezing on the hydration rate of obsidian, but evidence from two obsidian flows that had been covered with ice for most of their history indicates that as long as a vapor pressure of water is present in sufficient amounts to saturate the surface, ". . . the hydration rate will be independent of water pressure. . . ." (Friedman and Long, 1976)--that is, the ambient pressure--but the hydration rate will be affected by the low temperatures present in the reservoir environment.

No evidence yet exists concerning the differential hydration rates that may be expected when the environment in which obsidian is found is dramatically altered, as is the case of total immersion of surface or near-surface samples when flooding occurs in a reservoir situation. Again, the temperature alteration of the environment is the key to the hydration rate.

Although the chemical durability of obsidian is very high (Ericson et al., 1975), the chemical environment of a reservoir may act to alter the measurable surface hydration of a sample. In impoundment areas where the water is highly alkaline, the hydration surface could be eroded, and thereby alter the calculated data (Friedman, personal communication, 1976).

The reliability factor of obsidian hydration should be within ". . . + 10 percent of the true age over periods as short as several years and as long as millions of years. . . ." (Friedman and Long, 1976)-- provided the temperature calculations are accurately determined, and the chemical composition of the particular obsidian is known. By identifying the sources of obsidian artifacts through chemical characterization analysis and using source-specific hydration rates, a significant amount of this variability is controlled for (Ericson, 1976).

Assumptions

1. The mean annual temperature, and therefore the effective hydration temperature, of the soil surface and soil just below the surface will change with the environmental changes caused by inundation.
2. The mean annual temperature, and therefore the effective hydration temperature, of the soil at greater depths will change when subjected to inundation.

Hypothesis

The rate of hydration--a measurable and datable element of cultural remains fashioned from obsidian--will be altered when subjected to the environmental changes that accompany the inundation of archeological sites; and analysis of the hydrated face will yield dates that will not be comparable to samples of similar composition from a non-inundated context.

Test Implications

1. Obsidian that is surficially exposed, or buried at a depth less than 50 centimeters will exhibit a

differential rate of hydration when subjected to inundation; and analysis of the hydrated face will yield a date that is not comparable to an obsidian of similar chemical composition, depth of burial, and length of exposure that has not been inundated.

2. Obsidian buried at a depth in excess of 50 centimeters will exhibit a lesser differential rate of hydration when subjected to inundation; and analysis of the hydrated face will yield a date that is not comparable to obsidian of similar chemical composition, depth of burial, and length of exposure that has not been inundated.

3. A change in the extant chemical environment to a highly alkaline chemical environment, which may accompany inundation, will alter the hydrated face of any obsidian within the altered and saturated zone, and analysis of the hydrated faces will yield dates that are not comparable to obsidians that have not been so exposed.

ARCHEOMAGNETIC DATING

Introduction

Archeomagnetic dating operates on the principle that the intensity and direction of the earth's magnetic field, expressed in terms of angles of dip and declination, changes over time. In London, for example, these variations have been recorded for over 400 years.

As long as the direction of the remnant magnetic field is measurable while the sample lies in situ, the date when the sample's remnant magnetic orientation was dominant can be calculated on variation curves (Hammond, 1974).

It is assumed that the remnant magnetization of a sample represents the orientation of the earth's magnetic field as it existed when the archeological feature was re-heated to the Curie point (675° C), and cooled for the last time. Past angles of dip and declination are recorded in baked clay and clay soils

containing ferromagnetic materials such as magnetite and hematite. In unfired clay, the magnetic fields of the ferromagnetic particles occur at random. When clay is fired to the Curie point, the net magnetization of all the particles is aligned with the earth's magnetic field. On cooling, the alignment of the particle is "frozen," and can be recorded as long as the clay is preserved intact. However, a chronometric date can only be assigned to a sample if a secular variation curve has been established for the region.

Generating Data

Best results in archeomagnetic dating are obtained from well-fired clay samples, such as fired clay floors and walls, kilns, ovens, and well-built hearths. All samples must be in situ at the time of sampling.

Possible errors can be attributed to natural physical phenomena, field extraction techniques, and instrumentation. Remnant magnetism can be acquired from a sample without reheating, due to time, chemical change, and introduction into strong magnetic fields (Michels, 1973). Fortunately, most of these problems can be detected and corrected in the laboratory.

Inundation may cause some problems in archeomagnetic dating. Certain chemical changes can result from the formation of new minerals that may be susceptible to re-magnetization; however, such chemical changes rarely occur in well-fired clays. Adverse effects may be noted in samples collected from highly acidic or anaerobic contexts. Any mechanical distortion or movement of a sample could disrupt the magnetic orientation. Once a sample is wet, it should not be allowed to dry out, because a change in the volume of the sample and/or flaking could possibly disrupt the magnetic orientation. This could present a problem in sites that will be periodically exposed during reservoir drawdowns; differential expansion and contraction of the baked samples could occur, as could physical loss of all or part of the sample due to erosion and wave-action, especially in exposed, unprotected features.

Assumption

The samples have been handled properly in both the field and the laboratory.

Hypothesis

Archeomagnetic samples removed from reservoir contexts will not exhibit adverse effects from inundation, except when exposed for periodic drawdown conditions.

Test Implications

1. In an inundated context, undisturbed specimens not adversely affected by the mechanical impact of waves, currents, and erosion will yield comparable pre- and post-inundation results.
2. In an inundated context, specimens disturbed by direct or indirect mechanical impacts, or by internal expansion and contraction, such as may occur during periods of drawdown, will not yield reliable results.

FLUORINE DATING

Introduction

The analysis of the fluorine content of buried bones and teeth is a relative dating technique. This technique is based upon the fact that the mineral content of ground-water almost always contains fluorine. When the water percolates through a site, it slowly and irreversibly alters the chemical composition of porous bone materials. Fluorine accumulates in bone with time, and the amount present, when compared to the amounts in similar bones in the same area of the site, can be interpreted as giving a relative date for the time of burial of the bone. Because of variable environmental conditions--that is, the mineral and chemical compositions of the soil and ground-water--the amount of fluorine found in bone specimens will also vary from site to site, and often within a site. Different types of bones will accumulate fluorine at varying rates even

if they are from the same location in a site (Protsch, 1973). Thus, the extrapolation of this data to bone material from other sites is precluded, except when environmental factors are identical. It should also be noted that the process of fluorine analysis involves at least partial destruction of the sample.

Generating Data

Hydroxyl ions within bone are displaced when groundwater, which contains fluorine, percolates through an archeological site, thereby changing hydroxapatite to fluorapatite. Fluorapatite is less soluble than hydroxyapatite. The ground-water percolation effect of fluorine is basically irreversible, which means that when fluorine is fixed into the bone structure, it is not readily removed. Consequently, when bone specimens have been displaced or redeposited in a site for some reason, fluorine analysis can act as an indicator of such contextual impact (Oakley, 1970; Michels, 1973).

When the fluorine contained in bone material from an inundated context is analyzed, environmental factors such as soil composition, temperature, pH, and water circulation, may affect the fluorine uptake, which in turn would affect the bone's datable characteristics. The two situations in which bone material will be found in a reservoir environment are: buried in sediment (that is, in an unexcavated, undisturbed or backfilled site); and exposed on the bottom surface, or protruding out of the sediment.

Bones buried in sediment will be less susceptible to the increased or decreased fluorine concentration found in a reservoir, as will bone continually exposed to the water-column. The buried bone will have a much slower uptake of fluorine, which is more comparable to a terrestrial situation. However, exposed bone will have a much greater chance for excessive fluorine fixation, which would make the bone appear older than it actually is. The possibility also exists that in an acidic environment of below pH 6, fluorine will be dissolved out of the bone with phosphates, which will make the specimen appear younger (Gulbrandsen, 1976). It is difficult to make concrete assumptions about freshwater effects on fluorine analysis, because the possible effects have not yet been tested.

Hypothesis

Changes in the chemical composition of the water or soil, temperature, pH and/or a mechanical impact on the burial environment of an inundated sample of bone material will affect the rate of fluorapatite formation in the sample, resulting in fluorine dates that will not be comparable to those for similar bone samples of the same age taken from the same strata and area of a non-inundated site. If two samples have been subjected to the same reservoir variables over time they will remain suitable for use as subjects for relative dating.

Test Implications

1. Bone samples taken from an inundated site in which the chemical composition of the water or soil and/or the temperature of the surrounding environment have altered the rate of chemical reaction of the fluorapatite formation, will not yield dating results comparable to those of similar bone samples of the same age taken from the same area and strata of a non-inundated portion of the same site.
2. Bone samples taken from an inundated context in which the pH value has dropped from above pH6 will not yield comparable dating results to similar bone samples of the same age from the same area and strata of a portion of a non-inundated site where the PH has remained constant.
3. Bone samples taken from an inundated context in which mechanical impacts have exposed buried bone to chemical change that will alter the rate of the chemical reaction of fluorapatite formation will not yield fluorine dating results comparable to those for similar bone samples of the same age taken from a non-inundated portion of the same site.
4. Bone samples which have been subjected to the same pre- and post-inundation environmental factors will retain their suitability for use as subjects for relative dating.

AMINO-ACID-RACEMIZATION DATING

Introduction

Chemical dating techniques are based upon the testable assumption that after human or animal bones have been buried, sequential chemical reactions result in a continuous accumulation or depletion of some substance within the bone. Dates can be obtained when analysis of the chemical reactions supplies a continuous set of data that can be equated to specific times (Cook and Heizer, 1953).

Amino-acid-racemization dating involves the analysis of the progressive depletion of certain amino-acids contained within bone. If the environment from which the bone has been removed has remained constant since the time of burial, the depletion rate of amino-acids from the bone should also have been constant (Ortner et al., 1972). Analysis of this rate of protein removal provides a frame of reference that will yield a date for the archeological bone specimen.

However, the occurrence of a constant environment is problematical, because variables such as rainfall, temperature, and soil pH will affect the relevant environmental factors of an archeological site (Ortner et al., 1972). These climatic variables can also alter the chemical reactions taking place during bone degradation, so they must be corrected and calibrated for.

Because the chemical reactions upon which this technique depends are so easily influenced by environmental conditions, analysis of bones by this technique does not always yield accurate results. If perfected, amino-acid-racemization analysis could prove to be a valuable archeological dating technique, since only small amounts of a sample are used for analysis.

Generating Data

It has been observed in simulated laboratory situations that environmental variables such as ground-water, temperature, and pH in both soil and water will affect the decay rate of the amino-acids within bone specimens,

and that this in turn will skew dates obtained from the amino-acid-racemization analysis of the bones (Ortner et al., 1972; Hare, 1974a, 1974b).

The amount of water available within the bone or the surrounding environment directly affects the rates of racemization of the amino-acids in bone. Hydrolysis of bone protein to form amino-acids is a function of water content. The intrinsic water contained in the bone is enough to initiate the chemical reactions that control racemization (Hare, 1974b).

Laboratory testing has shown that when fresh bone is heated at low temperature and dried, no racemization of amino-acids is shown. Conversely, when excess water is present in the environment surrounding the bone, leaching, as well as protein hydrolysis and amino-acid-racemization, will occur (Hare, 1974a, 1974b). Bada, Kvenvolden, and Peterson (1973) have observed that concurrent with the leaching of amino-acids out of the bone, diffusion of amino-acid contaminants from the surrounding environment into bone specimens will occur. In order to correct for these climatic variables, and to assess the effects of possible contaminants, a complete reconstruction of the environmental history is needed for analysis.

The effects of climatic variables on the decay rate of amino-acids are interrelated. The diffusion-controlled process of leaching is dependent upon temperature (Hare, 1974a). Laboratory tests indicate that minute fluctuations in temperatures can produce significant variations in absolute dates from bone specimens in archeological sites (Ortner et al., 1972). Therefore, when bones are dated by amino-acid-racemization analysis, the mean annual temperature must be controlled for, and an estimation of temperature fluctuations since the time of burial should be made.

Assumption

A complete record of the sample's environmental history since the time of inundation, including mean annual temperature data, has been maintained, and forwarded with the sample to the laboratory.

Hypothesis

A sample taken from an inundated context will prove suitable for amino-acid-racemization dating, except in reservoirs where it will be exposed to intermittent periods of wetting and drying, and the associated significant temperature fluctuations which attend wet-dry cycles. A sample taken from the constant environment of a karst-spring will prove more reliable for amino-acid-racemization analysis.

Test Implications

1. Inundated samples will yield corrected dates comparable to similar samples from a non-inundated context.
2. Inundated samples taken from a reservoir in which they will be exposed to intermittent periods of wetting and drying, including significant temperature fluctuations, will not yield results comparable to samples from an undisturbed non-inundated context.
3. Samples taken from a karst-spring formation where environmental conditions have remained constant for thousands of years will yield results comparable to or better than like samples taken from a non-inundated context.

WEATHERED-GLASS DATING

Introduction

The formation of weathering crusts on ancient glass has been observed since the mid-18th century (Brewster, 1963), and it has been noted that the crusts were actually hydrated layers that had formed during the course of decomposition (Hausmann, 1856). But it was not until the publication of a letter from Brill and Hood (1961) that the full possibilities of using the weathering crusts to date glass became apparent.

Previously, glass could only be dated through general contextual associations and morphological information

derived from the artifact. The new dating technique was based upon the theory that ". . . the weathering crusts on the archaeological objects of glass may have been formed over extended periods of time and. . . might be a reflection of some periodic or cyclical change . . . for example, seasonal variations in temperature. . . ." (Brill and Hood, 1961).

Weathered-glass dating will not provide the archeologist with a date of manufacture or period of use, but it will provide a relative date based upon the time when the artifact was first buried or submerged. It is thus a more accurate indication of the date when associated artifacts were also buried.

Generating Data

All glasses are composed of three basic raw materials: quartz sand, which provides silica, the basic ingredient of glass; soda, which acts as a flux to aid in the breakdown of the quartz; and lime, which stabilizes the glass, and inhibits the solubility of the silica-soda mix (Brill, 1963). Other materials are found in glass, but the above are basics. The raw materials found in glass--carbonates (soda), sulphates, and silicates containing calcium (lime and quartz)--are considered insoluble salts, but they are actually only insoluble insofar as they do not readily dissolve in water. The deterioration of glass is based upon chemical reactions that begin when the glass is exposed to moisture, and accelerate when the glass is buried or submerged.

Glasses are unstable in both acidic or alkaline-moist environments; however, deterioration will take place more quickly in the latter (Downman, 1970). The alkalis within the glass migrate to the surface, and are leached out and carried away from the object through capillary action. When available moisture is reduced or limited, the remaining silica repolymerizes the results in a surface layer of silica (that is, a silicate exoskeleton) on the glass. The process will continue throughout the period of burial, and, it should be noted, ". . . the layers are thin, physically separated, amorphous siliceous layers, with closely conforming contours. . . ." (Brill, 1969). However, in the case of submerged glasses, the crust appears intact, and the layers appear as discontinuities within that crust.

There seems to be a definite relationship between the layering process and either of two environmental phenomena: the temperature change from winter to summer; or the change from wet to dry season (Brill, 1961). Although in many areas variations in temperature and amount of moisture can be quite dramatic, in more temperate zones the prolonged changes in average temperature appear sufficient to cause layering. Annual variation in the temperature of the ocean due to hypolimnion overturn has also proven adequate to cause lamination. Glass artifacts recovered from Port Royal, Jamaica, where only a 4° C temperature variation has been recorded, exhibited lamination, and yielded dates that closely correspond to a historic earthquake that rocked the island (Brill, 1963).

The relationship between the time of the lamination of the glass and the period of time over which the glass has been buried or submerged seems to be direct.

If one accepts the annual (or nearly annual) rate of formation beginning at about the time of burial in the earth or submersion in water, then a count of the layers in the crust should correspond to the number years elapsed of years since the weathering commenced (Brill, 1969).

The variability found in the thicknesses of the weathering crusts can be attributed to four basic factors: the composition of the glass (some glasses are more, or less, resistant to deterioration); the composition of the attacking solution, specifically the pH; the temperature fluctuations within the extant burial environment; and the length of time involved. The variability in thicknesses of the layers does not present any problems in terms of dating.

Glasses that seem to best lend themselves to use of this technique are those dating from Medieval times through the early 18th century. Others are so fragile or so corrosion-resistant that they are unusable. In all cases, the most important requirement is that the object has not been cleaned or dusted, so that the weathering crust remains intact.

Assumptions

1. The datable samples are properly recovered and handled.
2. There have been no direct mechanical impacts (such as tumbling and scouring) upon selected samples.
3. There are sufficient temperature variations within the inundated environment.

Hypothesis

Analysis of the weathering crust will yield comparable dates for samples taken from dry or marine-inundated sites and samples taken from freshwater-inundated sites.

Test Implications

1. In all temperature ranges and variations, the weathering crust will develop in such a manner as to be datable, and analysis will yield comparable dates for dry or marine samples and freshwater samples.
2. In all environmental conditions (buried and/or submerged), the weathering crust will develop in such a manner as to be datable, and analysis will yield comparable dates for dry or marine samples and freshwater samples.
3. In all locations, vertical and horizontal, within an archeological site, the weathering crust will develop in such a manner as to be datable, and analysis will yield comparable dates for dry or marine samples and freshwater samples.
4. In all sites in all locations within a reservoir that contain glass artifacts, the weathering crust will develop in such a manner as to be datable, and analysis will yield comparable dates for dry or marine samples and freshwater samples.

THERMOLUMINESCENCE DATING

Introduction

The use of thermoluminescence to date archeological materials is a fairly recent development. The technique is used primarily to date ceramic materials, but it can also be used on heat-treated lithics and fire-cracked rock.

One of the conditions of thermoluminescence dating requires that the initial firing of the material would be hot enough to have released the thermoluminescence built up and stored in the raw material since earliest geologic times; therefore, the laboratory analysis would reflect only the thermoluminescence accumulated from the time of the original firing to the time of analysis.

Thermoluminescence operates on the assumption that radioactive elements within the material to be dated will cause ionization, electrons, and other charge-carriers to form. The charge-carriers remain trapped within the material at normal ambient temperatures. Upon laboratory heating to 400° C or higher, the charge-carriers are released; a reaction takes place that restores them to their stable state; and the excess voltage produced by the reaction is emitted in the form of photons of light. The light is measured by a photomultiplier tube or by a predetermined dose of ionizing radioactivity (Cairns, 1976). The data may then be put into a formula, which takes into account certain variables affecting the process, and the age of the material since the time of firing can be determined.

Generating Data

A major source of error in thermoluminescence dating is the shielding effect that ground-water has on the annual rate at which gamma, beta, and alpha decay produce carriers. It is assumed that total immersion of the material will present a maximum saturated condition. Under this condition, the sample and local soil environment can be shielded by an effective absorption of ionizing radiation. Additionally, the

water column over the sample will reduce the cosmic contribution, accounting for approximately 30% of the total dose rate (Ericson, 1977). If the period of immersion should extend over a length of time, 20% of the archeological life of the material, the acceptable limits of error may be exceeded. This factor would affect the least stable materials the most--that is, ceramic material, heat-treated lithics, and fire-cracked rock, in that order.

Hypothesis

Samples that have been inundated for 20% or more of their archeological lives will be adversely affected, and will not yield data comparable to that yielded by samples that have not undergone such long-term immersion.

Test Implications

1. Samples taken from an inundated site will show anomalous results when subjected to thermoluminescence analysis after a period of immersion in excess of 20% of their archeological life as determined by other standard dating techniques, which is not correctable during analysis, and will not be comparable to a given number of similar samples that have not undergone such long-term immersion.

2. A given number of samples taken from an inundated site will not produce anomalous results that are not correctable during analysis if the samples were collected before a period of immersion in excess of 20% of their archeological life as determined by other standard dating techniques, and will be comparable to a given number of similar samples that have not undergone inundation.

X-RAY DIFFRACTION DATING

Introduction

The application of x-ray diffraction analysis to determine the archeological age of bone specimens has

been used as a relative dating method for some time. With this technique, a specimen is X-rayed, and a detailed analysis is made of its crystalline structure by means of a diffractometer (Weymouth and Mandeville, 1975). The lines of the mineral structure of the bone are examined for position, width, and intensity. To obtain a date from this technique, the distance between two specific lines of the bone microstructure must be found. This distance will decrease progressively with age, because of the accumulation of fluorine in the bone from percolating ground-water (Baud, 1960). Because of the numerous variables that can affect accurate determination of the fluorine content, some scientists dispute the accuracy of the X-ray diffraction method of dating bone. For example, McConnell (1962) states "While the geochemical and geological uncertainties have been recognized numerous crystal-chemical concepts concerning the nature of the carbonate-apatite minerals have been almost completely disregarded" (McConnell, 1962).

Generating Data

Because the X-ray diffraction method of dating bone material is essentially the application of radiocrystallographic techniques to the volumetric analysis dating method of bone fluorine (Baud, 1960), the factors affecting the fluorapatite of the bone samples used for fluorine dating should also affect the fluorine uptake of bone samples used for X-ray diffraction dating. (For a detailed discussion of the effects of freshwater inundation on quantitative fluorine dating analysis, see discussion of fluorine dating in this section.) With reference to the associated fluorine material, it can then be assumed that the datable qualities of the bone will be affected by inundation, if the burial environment does not remain constant.

Hypothesis

Inundation will adversely affect the dating characteristics of bone samples used for X-ray diffraction analysis; analysis of bone specimens from an inundated context will not yield dates comparable to samples from a non-inundated context.

Test Implication

Inundated bone samples will not yield X-ray diffraction dating results comparable to bone samples from a non-inundated context.

FISSION-TRACK AND ALPHA-RECOIL-TRACK DATING

Introduction

Fission-track dating and the recent associated development in alpha-recoil dating are some promising new techniques that archeologists are beginning to adapt to their needs. Like many other archeological techniques, they were pioneered by geochronologists, and were originally intended for the dating of much greater periods of time than the New World archeologist usually deals with. The techniques date the time of formation of certain minerals, particularly those with glass-like properties, such as obsidian and mica. In fission-track dating the radioactive decay of the uranium content in these minerals is what is actually being monitored, while in the alpha-recoil-track dating process the alpha decay of uranium, thorium, and samarium-147 are monitored. Although this dating technique would ordinarily involve time periods too great to be of interest to New World archeologists, thermal clearing events such as the firing of prehistoric ceramic vessels that contained obsidian and mica and related minerals in the clay and tempering agents would be measurable from the time of their last critical heating event. Certain man-made glasses have a very high uranium content; consequently, some historic glass artifacts may be datable using this technique.

Generating Data

Fission-track or alpha-recoil dating could be skewed due to the effects of inundation by the dilution of the uranium content in the samples. Although uranium is water-soluble, and some of it may be lost to the water, the loss should be negligible for the time periods we are concerned with in this study.

Hypothesis

Samples taken for fission-track and alpha-recoil dating purposes will not be skewed due to the effects of inundation.

Test Implication

Comparative samples of the same age as determined by established archeological controls taken for fission-track and alpha-recoil dating purposes in all reservoir situations will yield similar results.

OTHER IMPACTS

LOSS OF QUALITATIVE DATA RELATING TO STRATA AND FEATURES

Introduction

Archeological data-recovery is often largely dependent on the ability to subjectively discern certain values in a site that are not removable or quantifiable in a normal sense. Although natural and cultural stratigraphy can often be identified by analyzing the elements that comprise the strata, such as soil-matrix for the former and cultural artifacts in the latter, the most useful indicators for the archeologist are color and texture. When the archeologist is not using arbitrary excavation levels, he will usually be keying his efforts in accordance with distinctions based on visual and tactile criteria that he knows from experience and intuition may have archeological significance.

For example, in the acidic, clayey soils of the Southeast, an archeologist's prime indices of cultural activity will often be centered around stains in the ground. These may be the only remaining indication of the presence of a living area, burial, post mold, etc. He may also gear his excavation levels to perceived distinctions in soil texture and color. In the Southwest, an excavator may determine that he has reached

the bottom of an excavation unit when he hears his trowel clank on a hard occupation surface--another tactile type of indicator.

If inundation results in the loss or muting of such distinctions in color, texture, culturally induced compaction, or other tactile or visual cues that can be perceived by the archeologist, it would indeed comprise a significant impact on the resource.

Generating Data

Decomposing organic matter will alter the surrounding soil-matrix. This decomposing organic matter creates a micropodzol, which may be represented by color contrast (stain); a textural contrast (grain); or both. Soil stains and grain differences are both grouped under the term soil silhouettes (Biek, 1970). House-posts, the contents of food-storage pits, skeletons, wooden tools, or containers, will all alter the soil immediately around them when they decompose. In many situations, soil silhouettes will be the only indication of the past presences of such organic remains.

Soil stains are formed when a decomposing object colors the soil with its own chemicals. Woods leave a dark-gray stain; copper a greenish stain; iron a reddish stain. In most situations, the stain extends vertically and horizontally away from the object. If extensive leaching does not occur, a nearly perfect representation of the decomposed object will remain. With extensive leaching, the color change will be dispersed and become an amorphous stain area.

Textural changes are caused by the actual combination of the organic materials of objects with the soil-matrix. In most situations, the micropodzol is less compact than the surrounding parent soil. In the case of iron, harder crustaceous material will be formed.

The creation of midden soils is an extreme case of soil change due to the introduction of organic matter into a site by human behavior. In most cases, both color and textural changes are involved.

In different soil types, stains will take on different colors and textures. Soil types will also determine the extent and rate of the dispersion of color changes away from the decomposing object. Specific studies of the effects of inundation on soil silhouettes are not available. However, there are situations that lend themselves to inductive conclusions, and can thus help produce testable deductive hypotheses. It has been observed that in compact soils such as clays and clayey loams, soil stains are not affected by periodic flooding. In loose soils such as sands and sandy loams, soil stains maintain integrity if they are constantly wet, but are leached out or dispersed if they are alternately wet and dry. Soil texture differences seem to maintain their integrity under all conditions.

Hypothesis

Soil silhouettes will in certain soil types be affected by inundation. Soil stains will be more affected than soil textures. The depth below the land surface will affect soil silhouettes with relationship to the degree of soil saturation. At sites that are alternately wet and dry, soil stains will be more affected than at sites that are constantly inundated.

Test Implications

In all cases, soil silhouettes are compared in terms of pre- and post-inundation conditions.

1. A soil silhouette consisting of both color and textural qualities in compact soil (clay, silt, silty clays) will maintain interpretive integrity.
2. A soil silhouette consisting of both color and textural qualities in loose soil (Sand, sandy loam) on a constantly inundated site will maintain interpretive integrity.
3. A soil silhouette consisting of both color and textural qualities in loose soils (sand, sandy loam) on a site that is periodically inundated will maintain textural distinctions, but will lose color quality.

4. A soil stain in loose soil (sand, sandy loam) on a site that is periodically inundated will be lost.

5. Soil silhouettes located below the maximum extent of soil saturation will not lose their color or textural integrity.

FAUNAL IMPACTS

Introduction

Faunal impacts on archeological sites have always been of concern to investigators. Material may be shifted within a site due to the burrowing activities of various animals, such as moles and prairie dogs. Impact may also be in the form of surface and slight sub-surface disturbance caused by grazing animals such as cattle and sheep.

Generating Data

Inundated sites will be subject to the same type of faunal impact as terrestrial sites--that is, burrowing and surface disturbance. More severe burrowing impacts will generally be limited to sites located in shallow water or on the edge of the reservoir. Air-breathing vertebrates such as beaver, turtle, and alligator will create the most severe impacts; however, they will generally limit their nest-building to shallow water. The beaver, for example, will build its lodge above the water level, but the entrance will begin below the surface, with a tunnel to the living chamber.

Disturbance of deeper sites will be less severe. Certain freshwater fishes, such as the catfish, do burrow, but their burrows are not extensive. Freshwater pelecypods (clams) burrow to make shallow living chambers; fishes may also create surface disturbances with their activities, but they are of minimal concern.

Sites located on the edge of the reservoir pool may be subjected to impact from animals coming to water. The most severe impact will undoubtedly be caused by cattle

in the areas near the water's edge, which are soft and vulnerable to decomposure. This impact will not be more severe than similar impacts on terrestrial sites. Grazing animals may strip a site of its ground-cover, leaving it vulnerable to erosion in its upper horizons. Movement over a dry site following a rain will produce an impact similar to that described for an inundated site.

Contamination of an inundated site may be caused by naturally deposited faunal remains. An example of inundation-induced natural contamination of a site was reported at Abiquiu Reservoir, where the appearance of an incongruous fish-scale in a flotation sample caused some confusion (Schaafsma, 1976). This problem may occur with any fauna that inhabit a site area, and with terrestrial fauna on sites in shallow water or on the edge of a reservoir pool. The problem also occurs on terrestrial sites; it is of minimal concern, although the investigator should be aware of the possibility.

Hypothesis

Inundated sites will be liable to possible faunal impact, with those sites located in shallower water liable to undergo more severe impacts. However, these impacts will be no more severe than those imposed upon terrestrial sites.

Test Implications

1. Sites located on the edge of the reservoir pool and subjected to disturbance by animals coming to water, particularly herd animals such as cattle, will show more severe faunal impact than those sites not subjected to such disturbance.
2. Comparative examination will demonstrate that the faunal impact undergone by inundated sites will not be more severe than similar faunal impact undergone by terrestrial sites.

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Chapter III

GUIDELINES FOR DATA-COLLECTION AND SITE-PREPARATION

INTRODUCTION

What are the impacts of freshwater flooding on archeological sites? What mitigative measures are best suited to cope with these impacts?

These are the two over-riding questions posed by the Reservoir Inundation Studies Project. The guidelines that follow are directed toward the development of a body of knowledge that will begin to address these questions.

The theoretical orientation expressed in the preceding chapter on research design is reflected in the approach advocated in these guidelines. Specific data-collection elements requested are based upon the hypotheses and test implications presented in the previous chapter, and the data that accrues as a result of guideline implementation will aid in the empirical testing of these hypotheses. As the results of post-inundation comparative testing are accumulated, and to the degree each test implication is nullified, the hypotheses will be re-formulated, and the test implications revised. The data-collection and site-preparation information in the following chapter will continue to be revised to deal with questions that emerge as a result of unexpected test results.

An important point to be understood is that these guidelines are not directed toward solving human-behavior problems at the archeological sites under investigation. Instead, they will be used to determine the relative effects of immersion on the archeological data-potential and physical integrity of a site over time.

Standardization is stressed in the guidelines, to eliminate the variable of data-collection methods on

the results, and also to facilitate computerization. No effort has been made to address the relative value of the procedures presented; rather, the inquiry focus is on the ability to obtain comparable returns from these procedures after inundation.

The specific methods for data-collection presented here may be contradictory to the previous training or experience of the personnel involved; this may be based, in part, on the specific nature of the information needed to isolate the causal relationship between environment and inundation impacts. The methods outlined do not therefore necessarily reflect all of the ways in which a sample could be taken or analyzed. For example, testing for soil pH should optimally be done on both dry and damp samples. The guidelines procedure requests the results from a dry sample only. Analysis of damp soil samples, whether resulting from rain, snowfall or other phenomena, could alter test results because the chemical nature of these "introduced" waters will probably not be the same as that which will eventually flood the site. The Reservoir Inundation Studies Project is concerned with the interaction between the reservoir water and the soil, and the results of pH analysis of samples in their natural, dry state are best suited to meet the research needs of the project. For this reason, all data-collection and site-preparation procedures set forth should be implemented in accordance with Reservoir Inundation Studies Project specifications.

The research approach used by the principal investigator of a particular project may require a different method of sample collection than that outlined in these guidelines. When such a situation occurs, both methods of sample-collection should be employed. If it is noted later that the results of testing differ significantly between the Reservoir Inundation Studies Project sample and the principal investigator's sample, the Inundation Studies Project personnel would appreciate being informed of the discrepancy.

The guidelines are not intended to interfere with the research design planned for use at the site under investigation; rather, they are intended to ensure that the data that accrues from a particular archeological effort will also meet the needs of the Reservoir Inundation Studies Project.

The guidelines are divided into two sections: the first deals with collection; and the second with site preparation.

The data-collection section deals with overall site data-acquisition and organization. The first part of this section addresses the organization of standard data that are normally required to document all sites excavated under contract reservoir archeological programs, and presents a standardized format for this data that will readily lend itself to assimilation into this study. Maps, datum placement and stabilization, excavation-unit information, photography, remote-imagery, provenience control for pre- and post-inundation comparative samples, and artifact distributional analysis are all considered. The second part of this section deals with the various types of dating and analysis techniques that are used by archeologists to glean interpretive data from archeological sites. Specifications for sample collection have been developed in consultation with researchers in each of the various specialty areas. Not all of the dating procedures presented will be applicable to each site under investigation; however, the inclusion of as many of the procedures as possible into the excavations being conducted is urged. The results of the standardized approach to data-collection presented in the first section will provide for inter- and intra- regional information comparisons for the inundation study.

The site-preparation section presents selected methods for monitoring direct mechanical impacts of inundation, such as slumping, erosion, and sedimentation, as well as subtle effects on soil color, stratigraphic compaction, loss of provenience for artifacts, and differential destruction of features or other remains. Information on the placement of site-location devices, such as sonic pingers, markers, and buoys, for use after immersion, are outlined. Also considered are specific preparations for standing structures, machinery, excavated units, pictographs and petroglyphs, and post-inundation temperature determination.

DATA-COLLECTION

This section deals with overall site-data acquisition and organization, and provides a format for the

integration of the information into the Reservoir Inundation Studies Project. It is hoped that the information provided will serve to encourage the addition of interpretive techniques or data-recording procedures not previously considered or widely used. Many of the particulars of site selection and preparation, and the implementation of these guidelines, will depend on the imagination and judgment of the individual conducting the archeological investigation. It is not within the scope of these guidelines to discuss the viability of excavation or data-organization procedures currently employed in New World archeology; they are often dependent upon local conditions and research designs. Each researcher approaches excavation of a site with certain goals and questions, and these guidelines should in no way hinder the development of any particular research orientation.

MINIMUM SITE-DATA REQUIREMENTS

To facilitate the use and computerization of all site data, a baseline approach has been developed, wherein informational elements common to most archeological research programs are standardized. These informational elements are comprised of the minimum data required to adequately document sites excavated through contract-archeology programs in reservoirs, and of data that are considered critical to the development of a nation-wide pre- and post-inundation comparative base for cultural resources that will be impacted through inundation.

Maps

Mapping and mapmaking are important parts of careful documentation of any archeological site. The use of the standard mapping techniques used to obtain information for planimetric and topographic maps is extremely time-consuming, and errors can be made. These problems are amplified in the mapping of large or complex sites.

Photogrammetric procedures have been successfully used at large, complex Pueblo sites in the Southwest (Lyons, Hitchcock, and Ebert, 1976), and greatly facilitated

the analysis of site characteristics and relationships. Photogrammetric procedures can also provide more accurate and detailed maps than can be obtained by traditional methods (Pouls, Lyons, and Ebert, 1976), with savings of both time and money. An ancillary advantage to photogrammetry is its adaptability to digitization of mapping information. The computerization of data relevant to terrain and site can provide the archeologist with not only accurate, clear topographic and planimetric maps, but also with drawings of the site from any perspective desired (Pouls, Lyons, and Ebert, 1976).

Photogrammetry is potentially applicable to many different types of archeological sites, but it is most practicable as a mapping tool when applied to very large sites, of 2 acres or more (Lyons, personal communication, 1977), which are not situated in densely forested areas. It is also applicable to areas that contain numerous small sites, which often occur in reservoir-impoundment areas. The use of photogrammetry should be seriously considered in such areas.

A topographic map, a planimetric map, and a soil profile should be prepared for Reservoir Inundation Studies Project site-information controls. The scale used on the maps should be adequate to clearly depict such aspects as surface-collection or excavation units, features, soil-stratigraphy, structures, and datum points. All measurements should be referenced to the primary datum. The use of the metric system is preferred.

The two maps and the profile should all be prepared to the same scale, when feasible, and a plastic or mylar overlay system devised. These measures will facilitate the use of the materials by the Reservoir Inundation Studies Project team, and aid in computerization for an information-recall system. This system will be made available to contracting archeologists, managers, and planners, to aid in total cultural-resources management in the reservoir. Use of the "three map system" (two maps plus soil profile) for site documentation will allow the study team to readily select informational elements for specific research needs, pinpoint areas where impacts have occurred, and duplicate samples for comparative purposes.

A grid-system should be developed for the site within which excavation or surface-collection units can be clearly defined, and the primary datum-point located. This system should be used to designate the locations of the photographic stations discussed in this section, and to facilitate the gathering of information on the soil profile. Whether a numerical, letter, or alphanumeric grid-system is used, it should be clearly defined.

Topographic Map: A contour map should be prepared, which depicts all significant vegetational and physiographic aspects of the site. Such aspects as site limits, features, structures, trash or dump areas, and primary datum and secondary datums above maximum flood pool should be clearly indicated. The distance between contour intervals will depend upon the terrain, but should be small enough to reflect changes in elevation of not more than 2 meters (6'). Such minimal interval information will aid considerably in planning the post-inundation diving needed for monitoring purposes. The site's geomorphic setting (for example, levee deposit, stream terrace, alluvial fan) should also be noted in some manner on this topographic map.

Planimetric Map: The planimetric map will be more detailed in nature, and should show all excavation units, surface-collection units, datums, photographic stations, structures, features, and so forth, and clearly indicate those units that have been prepared for inundation (as specified in the site-preparation section of these guidelines). The nature of the site-preparation may be coded in some manner in the map legend.

The grid-system devised for the site should also be included on this map, or on an appropriate clear plastic overlay; each unit should be easily identifiable, whether surface collection or excavation was carried out, and unit designations should be clearly indicated.

Soil Profile: Several vertical measurements should be made, to record the depths of the cultural deposits, and the changes in soil stratigraphy. These measurements can be made with a power or hand-operated soil-auger having a 1" or 1-1/2" bit or bore; the auger hole locations should be tied into the overall site

grid-system previously discussed, and holes should be distributed evenly throughout the site. In addition, some off-site areas away from the obvious cultural-activity zone should be augered for comparative purposes.

Soil-deposition processes (such as by water or wind) should be noted on the cross-section. Standard soil terminology should be used to differentiate between soil types (pedalfers, pedocals, and laterite) and soil horizons (A, B, and C). Artifact density, e.g., artifacts per cubic meter, as it relates to the soil stratigraphy within the site, should also be shown.

Datum-Points

A permanent datum-point set in concrete should be established for the site under investigation, and should be accurately tied in to physical features which lie above maximum flood-pool. Whenever possible, this primary datum should be referenced to a USGS bench mark, or similar permanent point. This datum should not be a wooden stake, but rather a length of galvanized steel pipe or white PVC (plastic) pipe, 1 1/2" to 2" minimum diameter. It should be set a minimum of 50 centimeters below the ground surface, with 1 meter protruding above the surface of the site. A post-hole digger or soil auger with a large bore should facilitate this procedure. If galvanized pipe is used for the datum, all identifying information should be clearly marked near the top of the pipe; steel letter stamps are recommended for this purpose. If PVC pipe is used, the requisite information should be engraved into the pipe near the top, and marked over with permanent black marker. Threaded caps for either the PVC or steel pipe may be used to record the most pertinent data, for example, "Datum No. 1," but this information, as well as site number, grid designation, and so forth, should be repeated on the pipe. One or two small holes should be drilled in the cap to allow air to escape when the pipes become inundated.

Two secondary datums, also set in concrete, should be established above maximum flood-pool, and accurately located relative to the primary datum. These secondary datums should be located so that they can be used to triangulate in on the primary datum after the site has been flooded. These datums should be set in concrete,

as specified above, but should not protrude more than 30 centimeters above the ground surface. If possible, a concrete base, built up 15 centimeters above the ground surface surrounding the lower portion of the pipe, should be constructed to help prevent casual vandalism of the datums. In addition to being marked with the datum-designation information, each datum should be clearly marked or labelled: "Federal Property - Do not Remove."

Excavation Data

The particulars of unit-selection for excavation, surface collection, or trenching, and the specific procedures employed for each, will be dependent upon the research strategy of the principal investigator for the site in question. However, all units undergoing examination should be referenced to an overall grid-system, which accurately locates the unit vis a vis the permanent primary datum, and indicates its relationship to other units. Whether a numerical, letter, or alphanumeric grid-system of unit designation is used, the system and unit designations should be clearly defined.

One permanent corner-stake should be left for each excavated unit that will be used for Reservoir Inundation Studies Project control purposes. Each excavation-unit should have a sub-datum, which will facilitate taking measurements within the unit, and all units should have the same sub-datum, i.e., northwest corner, etc. This sub-datum should be used as the permanent corner-stake for the unit. The stakes should be of the same material as specified above for the datums--that is, galvanized steel or PVC pipe--and they should be set in concrete in the same manner as previously outlined. If the excavation-units are juxtaposed with no intervening bulks, sufficient numbers of outside stakes should be left to adequately define the shape of the unit. The stakes should then be permanently set. In the event that this type of excavation unit, or any other areas within the site, is allocated a sub-datum, it too should be permanently set in concrete. Each corner-stake should clearly identify the unit under investigation. Steel letter stamps on galvanized steel pipe and engravings and permanent,

waterproof black marker on plastic pipe are recommended to identify the unit stakes. (For more detailed information on minimum stake size, and the setting up and location of identifying information on the stakes, see the "datum-points" heading earlier in this section.)

Information to be gathered during excavation, and if feasible to be included in or as an appendix to the site report, should include but not be limited to:

1. Unit-excavation-level planimetric maps (show sample-collection areas, features, etc.).
2. Unit-profile maps for finished unit (clearly designate sample-collection areas).
3. Unit datum-point (reference all measurement for samples collected, features, artifacts, etc., within the unit to this sub-datum; all units should have the same sub-datum, i.e., northwest, southwest corner, etc.).
4. Unit-excavation procedures and other general information should include, but not be limited to: An explanation of excavation procedures used (for example, arbitrary 10 centimeters, 20 centimeters, etc., levels; stratigraphic excavation levels; horizontal excavation levels from unit surface; etc.).

Unit-surface preparations (cleared of brush, surface collection of artifacts, etc.).

Rationale for unit selection (sampling, hearth noted on surface, etc.). Screening process used, and size of screens, etc.

Complete record of all excavation activities within the unit, samples collected, features, photos, artifacts, condition of unit as left for inundation, description of preparation methods employed, etc.

Photographic Record

A complete photographic record should be maintained, and should include general photographs of the site prior to excavation, and general photographs of the site and excavation units as they are left for inundation. These photographs will be especially helpful in the assessment

of direct mechanical impacts, and in the accurate determination of specific locations in the site after immersion. Photographs should be taken from established stations, which have been set up within the overall site grid-system. Photographic documentation of the excavations as it progresses and of significant features should also be made from these stations. For complete photographic documentation, both black-and-white and color print or slide film should be used.

In situations in which artifacts, osteological material, features, and so forth, are left in situ for the purpose of comparative analysis after inundation, photographs that show the general condition of the material or features should be taken. Careful attention should be paid to photographing soil discolorations that reflect past human activity, because these stains may be the only visual clue available to the archeologist--and preliminary research indicates that they may be lost when inundated.

The use of black-and-white infrared film to photograph soil-profiles or soil discolorations should be considered. Stratigraphy that is often not clearly discernible on panchromatic photographs becomes visible when infrared film is used. The high-contrast properties of infrared film and its sensitivity to moisture content make it amenable to documentation of stratigraphy, especially if the profile is complex, or difficult to interpret.

If any protective measures are taken for the excavation-unit under investigation, such as lining with plastic, or backfilling with anomalous material, photographs should clearly show what methods were employed.

The following minimal information should be recorded on photographic-record forms:

Name of reservoir

Date

Site number

Type of film used

Film speed

Camera and lens type (if using more than one lens, indicate other lenses used, and code with asterisks or some other indicator; e.g., 35mm SLR Pentax w/55mm Lens[*], w/28mm[**], or w/210mm[***]).

Photographic station (if more than one station is on a sheet, skip one line, and indicate new station).

Camera direction (from photo station).

Subject description (including unit-designations or feature number, etc., and lens code, e.g., "*BRM-2 at rt. ctr., Feat. 33 in ctr. Jones Creek enters at rt. foreground (thick bushes)."

Frame number.

Photograph catalogue number.

Note: If continuation sheets are used, indicate page numbers as 1 of 3, 2 of 3, etc.

Provenience-Control for Samples

The location of all samples collected should be referenced to the excavation-unit sub-datum, and measurements recorded in unit notes and on sample-collection cards. In the case of samples collected for the Reservoir Inundation Studies Project, and in cases in which the wall or sample-collection area will not be further excavated during the course of work at the site, the exact location of the sample should be marked by a galvanized steel spike. The spike should measure 12" by 3/8", and the sample number should be recorded on a strip of brightly colored contact paper, pressed just below the head, forming a flap. Plastic surveyors' tape is also suitable, and may be sewed and tied in place, leaving a loose flap end. The number should be recorded on the flap with a permanent black marker. The spike should be left in place, whether the excavation unit is backfilled or left open; this will enable study-team archeologists to quickly pinpoint sample-collection areas, and will also aid in the collection of duplicate samples after immersion.

Remote-Sensing

Remote-sensing is the most promising method of fast, efficient site location and general site-data-collection and mapping available to the archeological discipline, and it is being more and more widely accepted and used in the field.

Remote-sensing can provide the regional scope needed in archeology, because it presents information in a manner that is readily adaptable to the integration of sites into an overall prehistoric system, as that system functioned within the environment, and as it was expressed through inter-site dynamics. The extent of the role that remote-sensing can play in ". . . archeological discovery, data collection, and constructive inference . . ." (Ebert and Lyons, 1976) has unfortunately been only superficially considered by archeologists. Although remote-sensing is not yet fully-exploited as a tool in archeology, the loss of the potential data which can be accrued by this process is considered important in the Reservoir Inundation Studies Project. Through a comparison of remote-sensing returns prior to, during, and after inundation, the question of what remote-data is lost as a result of flooding can be addressed.

Aerial photographs of the reservoir area are most often taken early in the project-stage by the involved Federal agency, for management and construction purposes. However, remote-sensing programs designed for optimum archeological data-retrieval are not usually included in these flyovers. This may be attributed in part to the still-nascent nature of the archeological applications of remote-sensing. Consultation between reservoir-construction planners, remote-sensing specialists, and contracting archeologists regarding the inclusion of archeologically oriented remote-sensing at the earliest stages of the reservoir planning process would enable dual use of remote-sensing flyovers, for the benefit of both management and archeology.

In those instances where the consulting archeologist was unable to coordinate early with the reservoir planners, and the project status has moved beyond the stage of initial flyovers, copies of existing imagery should be obtained, and known sites or general site

areas pinpointed. The scale, film type, and resolution of the imagery should be noted in the site report, and on the back of each photograph. If additional aerial photography is planned, archeology-oriented programs should be included.

There are also on-the-ground remote-sensing programs that can be implemented after initial flyovers of the reservoir have been completed.

Electrical resistivity, sub-surface radar, and magnetometry, are three such programs that are applicable to many different types of cultural manifestations, and should be considered in planning the remote-sensing programs to be used in the reservoir.

There is an extremely wide range of programs and uses to which remote-sensing can be applied in archeology. The National Park Service has recently published an excellent report on remote-sensing, entitled "Remote-Sensing Experiments in Cultural Resource Studies, Non-destructive Methods of Archeological Exploration, Survey, and Analysis" (Lyons, 1976), which can provide the concerned archeologist with an overview of remote-sensing applications.

Artifact Distribution

As a result of human activity, clusters of artifacts and other materials are non-randomly distributed within archeological sites. Analysis of artifact distribution can be used to discover different activity areas within a site, or to infer use of an artifact through its association with tools of known use. For this reason, distributional analysis is a valuable interpretive tool in archeology.

The impacts on the distribution of surface artifacts caused by initial flooding, or of currents occurring during inundation, and the loss of associational information that could otherwise be obtained, is a concern of the Reservoir Inundation Studies Project. Careful pre-inundation mapping of surface artifactual material will help to address the problems of what artifact associations are lost as a result of inundation.

The surface-artifact-collection criteria used will, of course, be dependent upon the research goals and sampling strategy chosen by the principal investigator at the site under investigation. However, it is strongly urged that a 100% collection of surface materials not be made. Only by leaving a representative sample of the various types of surface artifacts found at the site can a determination be made regarding the differential migration of artifacts as a result of inundation.

The information on artifact distribution gathered from the surface-collection/mapping units, and artifact-provenience information from the excavation units can be plotted in either chart or map form. One simple mapping method is presented in the next paragraph. Whatever exact mapping system is used to gather provenience information on surface materials, it should relate to the overall grid-system for the site in such a manner that surface-collection units and artifactual locations are clearly designated.

The suggested surface-artifact-mapping procedure can take advantage of the overall grid-system set up for the site. Through the use of north-south, east-west baselines, surface-collection/mapping units can be laid out. A portable 1-meter-by-1-meter wooden-frame grid, cross-strung to create 10-centimeter increments, can be laid along these baselines to form 1-meter-by-1-meter surface-collection units. The location of surface material found under the grid can be listed on a sheet of paper (several units fit easily on each sheet). By this means, provenience information relating to collected artifacts is immediately available, and all other materials are permanently referenced for comparison of location after inundation. An example of one entry using this method could be: "Surface Unit - North 1, East 2 - grid square 50N, 30E - utilized chert flake." The locational process is very similar to that in which a point is located on a map by section, township, and range.

DATING AND ANALYSIS PROCEDURES

The number of dating and analysis procedures employed by archeologists to interpret and further understand the material record left by ancient peoples has grown tremendously during the last 30 years.

The testing procedures presented in this section are not all-inclusive; rather a cross-section of techniques has been selected, some of which are widely used and others which have traditionally been area-specific. The fundamental consideration in the selection of the various techniques has been the development of the broadest possible data-base upon which to make determinations of the impact of inundation upon cultural resources.

To facilitate the use of the guidelines, specifications for each of the dating and analysis techniques requested are provided under each subheading. Samples should be taken from areas within the site that an underwater or terrestrial team of archeologists could return to with reasonable ease. Whenever possible, several samples of the same type should be selected from various locations within the site. All samples should be carefully packaged and sealed, so as to prevent the loss or destruction of the material. Double-bagging is advisable. Labels should be taped securely to the outside of the samples. For those samples placed in clear plastic bags for preservation, the label may be taped to the main bag; the second bag may be used to protect the label, and to ensure against the loss of a portion of the sample material, and this second bag should also be taped. Sample identification-labels should be prepared, and marked neatly and legibly with permanent waterproof marker or pen (preferably black). Field-sample data-cards should be typed; if this is not possible, they should be printed neatly in black ink. A clear Xerox or typed copy of the card should accompany each sample sent out for analysis; the original card is retained with other site-excavation information.

Soil Analysis

The study of relationships in soils--such as stratigraphic layering, and content and color--has become an integral part of efforts to reconstruct prior human-activity patterns from archeological investigations. The soil analysis and testing methods to be described include many of the standard procedures currently employed by archeologists, and also a few not previously considered, which are aimed directly at monitoring the mechanical impacts of

inundation. These testing methods should be conducted on all sites where such testing is feasible, and samples should be taken in a manner that will enable them to be subjected to a variety of chemical, mechanical, and visual analyses.

Soil Type and Color: Soil-type identifications should be taken from the most recent county soil-surveys available, which will provide a standard reference for all soil-types. Soil-color identification should be made with the Munsell color charts designed for this purpose, and it should be clearly stated whether the color determinations are being made from wet or dry samples. The standardization of soil terminology and soil color will provide control from area to area and site to site, so that the most accurate cross-referencing of data will be possible.

Soil Composition: The analysis of soil composition is useful in interpreting paleo-environmental conditions. The textural data recovered from such analysis provides information about the nature of soil-particle transport from its source to deposition, and also about the weathering processes to which it has been exposed.

This soil-analysis will be useful in comparisons of the weathering and depositional processes to which inundated archeological sites have been subjected.

Soil Composition
Sample-Collection Instructions

1. Sample(s) should be taken from soil profiles representative of the site, as well as representative of locations outside apparent cultural-activity zones.
2. 2 liters minimum quantity per sample.
3. Sample should be placed in 7" x 12-1/2" plastic or cloth bag. Plastic is preferred.
4. A field-sample data-card should accompany each sample; information should include, but not be limited to:

Name of reservoir

Date

Site number

Type of sample

Sample number

Location relative to permanent datum-points

Provenience

Matrix description

5. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Note: If samples will not be analyzed within 2 weeks of collection, it is highly recommended that they be oven-dried to prevent growth of mold fungus.

Soil Chemistry: Soil chemicals are subject to varying degrees of leaching or percolation due to seasonal variations in temperature and humidity. Inundation, whether permanent or periodic, alters the extant environment, and may concurrently affect the chemical nature of the soil.

The phosphate, nitrate, potassium, and organic contents of anthropic soils are currently being used as indicators of differential human activities (Sjoberg, 1976; Eddy and Dregne, 1964), and the loss of this data through inundation is of concern in the Reservoir Inundation Studies Project. To determine the degree of alteration of these chemicals in the soil and changes in gross organic content, soil

samples to be used specifically for this type of analysis should be taken prior to and after inundation.

Soil-Chemistry
Sample-Collection Instructions

1. Areas selected for samples should be representative of the site, as well as representative of locations outside apparent cultural-activity zones.

2. Minimum quantity:

Phosphate analysis----300 grams
Nitrate analysis-----300 grams
Potassium analysis----300 grams
Organic content-----300 grams

3. Clean sample area from top to bottom.

4. Collect samples from bottom to top.

5. Use clean tools and containers (free of clinging sediment). Use distilled water to clean tools, if possible.

6. Samples should be placed in clean plastic bags and sealed.

7. A field-sample data-card should accompany each sample, and information should include, but not be limited to:

Name of reservoir

Date

Site number

Type of sample

Sample number

Location of sample relative to permanent datum points

Provenience

8. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Note: If samples will not be analyzed within 2 weeks of collection, it is highly recommended that the sample be oven-dried to prevent growth of mold fungus.

pH Analysis of Soil: The analysis of the hydrogen-ion content of soils (pH) to delineate food-preparation or refuse areas has been a standard procedure in archeological investigations for a number of years. Leaching has a direct bearing on the pH content of soils. Inundation dramatically alters this process, and in so doing may affect the potential usefulness of this technique. In order to deal directly with this concern, pH analysis of representative areas of the site under investigation should be conducted prior to and after inundation. In an effort to obtain the most accurate data possible, testing for pH should be done in situ.

pH Analysis of Soil
Sample-Collection Instructions

1. Areas selected for analysis should be representative of the site, as well as of locations outside apparent cultural-activity zones.

2. Analysis should be done in situ with a portable metering device. Any of the chemical meters currently on the market (e.g., Beckman, Chemtrix) are acceptable.

3. A field-sample data-card should include, but not be limited to, the following information:

Name of reservoir

Date

Site number

Type of sample

Sample number

Method used to take sample (include type of meter)

Initial condition of sample (damp, dry, etc.)

Results of test

Location of sample relative to permanent datum point

Provenience

Flotation-Samples: Flotation samples should be taken wherever feasible. If possible and archeologically acceptable, a control column or block should be left intact adjacent to the sample, and marked for later relocation (see section on site-preparation). Careful documentation of the location of visible materials in the sample prior to immersion, as well as a listing of materials floated out, will provide a check on the impacts that reservoir inundation may have on this data-recovery technique.

Flotation
Sample-Collection Instructions

1. Sample(s) should be taken from profiles representative of the site, and of locations immediately outside apparent cultural-activity zones.
2. A field-sample data-card should include, but not be limited to, the following information:

Name of reservoir

Date

Site number

Type of sample

Sample number

Location of sample relative to datum-points

Provenience

Type of materials floated out, e.g., seeds, nuts, leaves; include taxonomic identification, if possible

Initial weight and volume of sample

Erosion and Consolidation Testing: The destruction of archeological sites through slumping, wave-action, and currents within a reservoir is only one of many considerations of the Reservoir Inundation Studies Project. In order to develop predictive models for mitigative purposes, standardized erosion-tests should be made on samples from sites that will be subjected to inundation, either permanent or periodic.

Archeological sites that are inundated are subjected to increased ambient pressure, due to the presence of the water-column that is introduced when a reservoir is flooded. This increased pressure, along with the saturation of the site, may cause the soil-matrix of the site to be weakened, and may also cause differential consolidation of the strata within the site. To account for this phenomenon, and develop predictive models for mitigative purposes, consolidation-tests should be made on samples from sites that will undergo permanent or periodic inundation.

Erosion and Consolidation Testing
Sample-Collection Instructions

1. Sample(s) should be taken from area(s) representative of the site.

2. Sample(s) should be a solid undisturbed block (detailed instructions for taking undisturbed block-samples are included as an appendix to this report).

3. Block-samples should be 20cm x 20cm x depth of cultural deposit to be tested. The sample should contain strata that are representative of the site.

However, it is not necessary to include a sample of the entire cultural deposit if there is little or no change in soil matrix; in this case a 20cm cube is sufficient.

4. A field-sample data-card should accompany each sample, and information should include, but not be limited to:

Name of reservoir

Date

Type of sample

Sample number

Location relative to permanent datum-points

Provenience

5. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Please also mark package with "PROTECT FROM FREEZING OR OVERHEATING"

Stratigraphic Column (Monolith) Testing: The most satisfactory monolith samples for recording and

interpreting the stratigraphy of archeological sites are those that share certain characteristics:

1. The completed sample must be stable in a vertical position.
2. It must be thick enough to preserve sedimentary and pedologic structures.
3. It must show clearly the character of depositional and developmental horizon boundaries.
4. It must be long enough to preserve the entire meaningful profile if a soil is involved, or to permit satisfactory overlap if stratigraphic units are sampled in sections.
5. Its matrix must be sufficiently strong to support the weight of large or heavy rock and bone fragments necessary to adequate representation of the material to be sampled (Fryxell and Daugherty, 1964).

However, monoliths should be taken even if there is no obvious layering within the site. This will provide a comparison that will enable us to begin to understand the effects of immersion on the stratigraphic components of archeological sites. (Specifics on sample preparation, collection, and required materials are appended to this report).

Stratigraphic Column (Monolith) Testing Sample-Collection Instructions

1. Samples should be taken in areas representative of the site.
2. A control area should be left adjacent to sample area, and suitably marked for relocation.
3. A field-sample data-card should accompany each monolith, and information should include, but not be limited to:

Name of reservoir

Date

Sample number

Matrix description

Location relative to permanent datum-points

Provenience

4. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Amino-Acid-Racimization Dating

This dating technique is based upon the measurable depletion of amino acids found in buried bone. Given a stable environment, the rate of depletion is a constant, which can yield an absolute date of burial for the specimen. Environmental fluctuations in temperature, precipitation, and pH of soil and water will all influence the rate of amino-acid depletion within the specimen, and such fluctuations can alter the delicate balance of the chemical reaction upon which the dating technique is based (Ortner et al., 1972; Bada et al., 1973; Hare, 1974a and 1974b).

Minute fluctuations in temperature can produce significant variations in dates resulting from this analysis. Data relating to the mean air temperature of the area--either from weather records or from a station in a nearby and similar temperature regime--should accompany all samples. Records of weekly or bi-monthly ground temperatures are even more valuable, and can often be obtained from an agricultural experiment station or Soil Conservation Service office.

A more technical approach is needed to determine mean temperature in an inundated situation, and the Pallmann method is suggested. (Information on preparation for this procedure may be found in the site-preparation section of this section of the guidelines. Exact specifications are appended to the report.)

The amino-acid-racemization dating process has not yet been perfected in an absolute sense, and its application to various types of freshwater-inundated samples is questionable. However, it is imperative that amino-acid-racemization dating be attempted whenever possible. The process will enable the Reservoir Inundation Studies Project to accurately determine the viability of the dating technique for inundated samples, given the current state-of-the-art.

The following sample-collection procedures have been developed in coordination with specialists in this field, and should be strictly adhered to:

Amino-Acid-Racemization Dating Sample-Collection Instructions

1. 1-gm-minimum sample-size for shell or bone.
2. An accompanying soil-sample should be taken from within a 30cm radius of shell or bone to be dated; 10-20gms minimum quantity.
3. Package soil and shell or bone samples separately, in sterile plastic Ziploc bag, and tape securely. Use corresponding field-sample numbers.
4. Take one soil-sample per shell or bone specimen, except if taking numerous specimens from the same location, when ratio should be 5 specimens to 1 soil-sample.
5. Use clean tools (free of clinging sediment); clean tools with distilled water if possible.
6. Clean tools between samples.
7. A field-sample data-card should accompany each pair (specimen and soil) of samples, and information should include, but not be limited to:

Name of reservoir

Date

Site number

Type of sample

Sample number

Location of sample relative to permanent datum-points

Provenience

Content of sample (burial, hearth, etc.)

Environmental context (riverbed, erosion-gully, etc.)

Annual precipitation

Annual temperature range

Mean annual temperature

If site previously inundated, indicate and give approximate length of time

Soil pH, if known

Associated carbon-14 date, if available

If time-period of associated materials is known, indicate

8. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Archeomagnetic Dating

Samples for archeomagnetic dating should be taken whenever possible. A wide variety of materials are suitable for archeomagnetic dating, and full advantage of this diversity should be taken when selecting samples (Tarling, 1975). If feasible and acceptable to the principal investigator, a portion of the sample area large enough to duplicate the pre-inundation samples should be left undisturbed and suitably marked for relocation with non-magnetic materials such as aluminum or brass rod.

Through the direct mechanical impacts of slumping, wave-action, or differential consolidation of soils adjacent to the feature, inundation may disturb a feature that would otherwise be suitable for this type of dating. Periodic inundation or freezing and thawing, causing a change in the volume as well as a weakening of the internal structure of a sample, may also disrupt the magnetic orientation, and make a precise determination of the past orientation impossible.

The control of sample orientation and collection is critical to the successful application of this dating procedure, and all samples should be taken in a manner consistent with pre-established guidelines. (For reference on the specific technique employed for taking archeomagnetic samples, see appendix to this report.)

Archeomagnetic Dating Sample-Collection Instructions

1. Magnetic orientation and provenience data should be scratched into plaster-covered samples, and repeated on sample-forms.
2. A field-sample data-card should accompany each sample, and information should include, but not be limited to:

Name of reservoir

Date

Site number

Type of sample

Precise orientation of sample

Location of samples relative to each other

Sample number, e.g., 1 of 5

Location of sample relative to permanent datum-points

Provenience

Type of feature

3. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Carbon-14 Dating

Based upon a review of the literature dealing with the theory and techniques of carbon-14 dating, it is strongly indicated that freshwater immersion will not alter the data-results obtainable from the analysis of viable samples. However, those naturally occurring agents that affect the amount of datable carbonized material still recoverable in a dry site may be magnified through inundation, and in those areas where individual samples are marginal in size or availability prior to inundation, the necessary volume or weight needed may not be obtainable after immersion.

To control for this factor in those areas where datable samples are marginal, bulk samples containing at minimum 10 grams of datable carbon material should be taken in addition to individual samples. If the amount of carbon material in the soil is unknown, the field

method, outlined in the following paragraph may be used to estimate the amount of carbon.

Heat the soil sample to boiling (100°C) to evaporate most of the water, then weigh the sample. Reheat the sample over a wood fire (600°C), and weigh the sample again. The weight difference will provide a rough approximation of the carbon (Ericson, personal communication, 1976).

Carbon-14 Dating
Sample-Collection Instructions

1. Minimum quantity for individual samples:
charcoal--10 grams (yields most reliable ages)
wood--15 grams (yields 2nd most reliable ages)
bone--200 grams (charred bone preferred)
peat--25 grams
shell--30 grams
2. Minimum quantity of datable material in bulk charcoal samples--10 grams. For all other samples, the same quantities as stated above.
3. Modern rootlets and root hairs should be picked out of the sample with tweezers.
4. Sample should be placed in plastic bag, sealed, then wrapped with aluminum foil, and securely taped.
5. Standard precautions for contamination should be followed, e.g., clean instruments, no smoking, etc.
6. A field-sample data-card should accompany each sample, and information should include, but not be limited to:

Name of reservoir

Date

Site number

Type of sample

Sample number

Sample composition (charcoal, wood, shell, etc.)

Location relative to permanent datum-points

Provenience

Matrix description

Possible contamination (if any)

Bulk sample: gross weight and size

7. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Dendrochronology

Tree-ring dating (dendrochronology) is at present best developed in the Southwestern United States. Only certain species of trees are acceptable for tree-ring analysis, because of the need for a clear pattern of variable, annual growth-rings. Suitability of species will vary with the environmental sections of the Country, and contact should be made with a tree-ring-analysis laboratory to determine which species are acceptable for the area being investigated.

Although dating may not yet be possible in all sections of the Country, samples should still be taken, for they will prove valuable in the future if a

master chronology is developed, and they may aid current research efforts directed toward developing a master chronology.

If feasible and archeologically acceptable to the principal investigator, some of the material should be left in place, and be suitably marked for relocation. This will provide the Reservoir Inundation Studies Project with a control and a comparative sample.

Dendrochronology Sample-Collection Instructions

1. Datable species are required. Either collect samples from each species represented or contact the laboratory scheduled to do analysis for type of species desired.
2. Solid logs, or sections thereof, are preferable, so that a complete ring-pattern is present.
3. Charcoal is often datable if a complete ring-pattern is present, and should not be overlooked when collecting samples for tree-ring analysis.
4. If sawing of a cross-section is not acceptable or feasible, a bore may be taken.

bore should be 1/4" to 1" in diameter.

the sample must run to or through the core

a hooked wire may be used to break the sample at the core for easy removal

5. Fragile or water-saturated samples are collected in the same manner, but great care must be taken to avoid damage.

The sample may not be strong enough to support itself (particularly true of water-saturated samples), and support must be provided and maintained until delivery to the laboratory.

Water-saturated samples must be kept wet, for drying out will damage the sample; preferably,

sample should be kept immersed until delivery to the laboratory.

6. A field-sample data-card should accompany each sample, and information should include, but not be limited to:

Name of reservoir

Date

Site number

Type of sample

Sample number

Location relative to permanent datum-points

Provenience

7. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Fission-Track and Alpha-Recoil Dating

Although the fission-track and alpha-recoil dating techniques were originally developed to enable determinations of the initial formation of certain minerals, and the process dealt with time-periods beyond the needs of New World archeology, recent developments have permitted the adaptation of these techniques to the archeological dating of more recent materials.

Ceramics that contain micaceous material are most commonly used for the alpha-recoil-dating process. The

presence of mica in sufficient quantities, at least 10 sq mm, in the sherd is the criterion for assessing the suitability of a sample for alpha-recoil dating. As a general rule of thumb for sample collection, it is advisable to choose the largest specimens that contain the most mica discernible to the naked eye.

In Europe, manmade glasses from the 17th and 18th centuries may be suitable for fission-track dating, because of the quantity of uranium found in these specimens. Most New World glasses do not contain uranium in sufficient quantities for this dating process. However, imported glassware manufactured during the last 200 or 300 years may be suitable, and should not be discounted.

Both fission-track and alpha-recoil dating are based upon the depletion of the uranium and thorium content by natural radioactive decay in a sample over a period of time. The successful application of these nascent techniques to freshwater-inundated samples is unknown; however, it is expected that because of the soluble nature of uranium, during inundation the hydration of minerals may in fact result in a reduction of the local radioactive structure, causing anomalous dates.

In an effort to assess the impacts that inundation may have on these dating methods, samples suitable for dating should be collected whenever possible.

Fission-Track and Alpha-Recoil Dating Sample-Collection Instructions

1. Minimum sample size: the largest sherd available that contains clear evidence of micaceous material, and glass samples known to have been manufactured in Europe during the 17th and 18th centuries.
2. Package samples in Ziploc plastic bags, and tape securely.
3. A field-sample data-card should accompany each sample, and information should include, but not be limited to:

Name of reservoir

Date

Site number

Type of sample

Sample number

Location of sample relative to permanent datum-points

Provenience

If site was previously inundated, indicate and give approximate length of time

Associated carbon-14 date (if available)

4. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Fluorine Dating

This dating technique is based upon the effects of ground-water percolation through soil. Trace elements of fluorine in ground-water accumulate in porous bone material at a specific rate (Oakley, 1970). The amount of fixed fluorine in a specimen can be used to infer a relative age of time of burial of the specimen.

Given stable environmental conditions, the rate of fluorine accumulation in bone would provide an absolute date. However, fluctuations in ground-water percolation, temperature, and soil and water hydrogen-ion content (pH) can all act upon the amount of fluorine available for accretion in the specimen.

Data concerning the mean air temperature in the area, from either weather records or a station in a nearby and similar temperature regime should accompany all samples. Weekly or bi-monthly ground temperatures are even more valuable, and can often be obtained from an agricultural experiment station or Soil Conservation Service office. A highly technical approach is needed to determine mean temperature in an inundated situation, and the Pallmann method is recommended. (Information concerning preparation for this procedure may be found in the site-preparation section of the guidelines, and exact specifications are appended to the report.)

The fluorine-dating process has not been perfected in an absolute sense, and its application to freshwater-inundated samples is unknown. However, fluorine dating should be attempted whenever possible. This will enable the study to make an accurate assessment of the viability of this dating technique for use with inundated samples, given the current state of the art.

Fluorine dating of stone is also possible (Taylor, 1975), and samples of this nature should not be overlooked during sample selection.

The following sample-collection procedures have been developed in coordination with specialists in this field, and should be strictly adhered to.

Fluorine Dating Sample-Collection Instructions

1. 1-gm minimum sample size
2. An accompanying soil sample should be taken from within a 30cm radius of bone to be dated--10-20gms minimum quantity.
3. Package soil and bone samples separately in sterile plastic Ziploc bags, and tape securely. Use corresponding field-sample numbers.
4. Take one soil sample per bone specimen, except if taking numerous specimens from the same location, then ratio should be 5 specimens to 1 soil sample.

5. A field-sample data-card should accompany each pair (specimen and soil) of samples, and information should include, but not be limited to:

Name of reservoir

Date

Site number

Type of sample

Sample number

Location of sample relative to permanent datum-points

Provenience

Context of sample (burial, hearth, etc.)

Environmental context (riverbed, erosion gully, etc.)

Mean annual temperature

Soil pH (if known)

Associated carbon-14 date (if available)

If site previously inundated, indicate and give approximate length of time

6. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Obsidian-Hydration Dating

The dating of obsidian fragments should be attempted wherever feasible, even if such dating has no real relevance, or is not high priority in terms of the overall research design. If possible, and acceptable to the principal investigator, some of the material should be left in situ, and suitably marked for relocalational purposes (see site-preparation section). This will provide the study with both a control and a comparative sample for determining differential hydration rates of previously "dry" obsidian and inundated obsidian.

Temperature is a critical factor in the hydration-rate of obsidian (Friedman and Smith, 1960; Friedman and Long, 1976). It is expected that inundation will affect the thermal environment of obsidian samples, which in turn will slow the rate of hydration. Therefore, data on the mean air temperature of the area, from either weather records or a station in a nearby and similar temperature regime, should accompany samples. Records of weekly or bi-monthly ground temperatures are even more valuable, and can often be obtained from an agricultural experiment station or Soil Conservation Service office.

To assess the impact of inundation on hydration-rates, a highly technical approach to obtain the effective hydration temperature is required, and the Pallmann method is suggested (Further information on preparation for this procedure may be found in the site-preparation section of the guidelines, and exact specifications for the process are included as an appendix to the report.)

Obsidian-Hydration Dating Sample-Collection Instructions

1. Minimum quantity: for single component site--10-24 samples
for multi-component site---10-24 samples per component
2. Preferred sample size larger than 5 sq mm.
3. Sample should be placed in plastic or cloth bags.

4. A field-sample data-card should accompany samples, and information should include, but not be limited to:

Name of reservoir

Date

Site number

Type of sample

Sample number

Location relative to permanent datum-points

Provenience

Mean annual temperature

Annual temperature range

Weekly soil-temperature at various depths (if available)

Associated carbon-14 date, if available

Source determination of artifacts, if known

5. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Pollen Analysis

The success or failure of pollen analysis in adding meaningful data to the overall research at any

archeological site depends upon the samples themselves, as well as upon the reason behind taking the samples. Often, special situations in which pollen is likely to be deposited and preserved within sites and in nearby lakes and bogs, are not considered. Pollen is also well-preserved when the soil matrix is in direct association with some metals such as copper (King, Klippel, and Duffield, 1975). Careful consideration of the presence of sedimentary disconformities, erosional surfaces, and traces of fire or peat cuttings is also important. Generally, sandy or alkaline soils are considered unfavorable for pollen-preservation, but may in fact yield adequate pollen-counts if the sample is large enough.

Because of the need to interpret palynological data and integrate it into the research results as more than a pollen record of an archeological site, and because data results can often lead to a redefinition of questions for future or ongoing research at the archeological site, the palynologist should be provided with detailed information concerning the context from which the sample was taken. For example, if the sample was removed from a burial, it should be noted whether it came from the head or thoracic region. If removed from a room or storage-pit, the prevailing wind direction may provide the additional information required to prepare more meaningful data returns.

Pollen grains may be adversely impacted and preservation hindered when the matrix in which they are deposited becomes inundated. A shift in the chemical balance of the soil, redeposition or loss of context as a result of erosion or slumping, and vertical displacement through the swelling or shrinking of soil particles will all impact the pollen.

The fragile nature of pollen, and resultant preservation problems and its potential loss for interpretive purposes are of concern in the Reservoir Inundation Studies Project. The following sample-collection procedures have been developed in coordination with palynologists, and should be carefully followed. This will enable the Reservoir Inundation Studies Project to accurately determine the full impacts that immersion may have on pollen remains and the usefulness of the remains as an interpretive tool after a site has been submerged.

Pollen-Analysis
Sample-Collection Instructions

1. Sample(s) should be taken from strata representative of site.
2. Alluvium--400 gms minimum
Peat--3 cubic centimeters minimum
Sandy soils--30 cubic centimeters minimum
3. Clean sample area from top to bottom.
4. Collect samples from bottom to top.
5. Remove 3-5cms from the profile samples area immediately prior to collection of sample; this will reduce the potential of airborne contamination.
6. Use clean tools and containers (free of clinging sediment); clean tools with distilled water, if possible.
7. Clean tools between samples.
8. Samples should be stored in fresh, unused plastic bags.

Samples should be kept moist, because desiccation wrinkles, grains, and seeds alter surface morphology.
9. Wrap bags with aluminum foil and tape (seal bags from airborne contamination).
10. DO NOT put labels inside bags; tape securely to outside.
11. A field-sample data-card should accompany each sample and information should include, but not be limited to:

Name of reservoir

Date

Site number

Type of sample

Sample number

Condition of sample when taken (damp, dry, etc.)

Location relative to permanent datum-points

Provenience

Matrix description

Context of sample (burial, storage pit, room, etc.)

Environmental context (riverbed, erosion gully, bog, etc.)

Environmental conditions under which sample was taken (windy, hot, snowing, morning, etc.)

12. A sample identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Thermoluminescence Dating

Although thermoluminescence is a controversial and complicated dating process, it should be attempted whenever possible, even if it is not high-priority in terms of the research design. Ceramics are the primary materials dated by this method, but hearths, heat-treated lithics, and fire-cracked rock may also be used (Goksy, et al., 1974; Huxtable et al., 1976). If feasible, some of the material should be left in situ, and suitably marked for relocation.

A major change in the results in this dating technique is expected due to the shielding effects of groundwater. The state-of-the-art in thermoluminescence

dating is such that long-term immersion in the past or periodic immersion may skew the dating sample beyond the correction-capabilities of the process. It is important that data on annual precipitation and periods of past inundation accompany all samples.

Thermoluminescence Dating
Sample-Collection Instructions

1. Ceramic Samples

- a. 1 square cm minimum size per sample
- b. An accompanying soil sample should be taken from within a 30cm radius of ceramic to be dated (2-3 cubic centimeters minimum quantity). Package separately. Be sure to use corresponding field-sample numbers.
- c. Amount: take 1 soil sample per sherd sample, except if taking numerous sherd samples from the same location, in which case ratio should be 5 sherds to 1 soil sample.

2. Hearth Samples

- a. A 2-3 cubic centimeter sample is the minimum quantity of burned soil. The upper 1-cm layer should be removed, and the sample taken in a core, can, or similar container to prevent prolonged exposure to a light source.
- b. An accompanying 2-3 cubic centimeter soil sample from the hearth-fill, taking the same precautions as listed in ceramics discussion above.

3. Heat-treated lithics and fire-cracked rocks

- a. If possible send BOTH heated and unheated samples of same type of material.
- b. An accompanying 2-3 cubic centimeter soil-sample should be taken, taking the same precautions as listed in ceramics discussion.

4. Field-sample data-card should accompany each sample, and information should include, but not be limited to:

Name of reservoir

Date

Site number

Type of sample

Sample number

Location of sample relative to permanent datum-point(s)

Provenience

Annual precipitation

If site was previously inundated, please indicate approximate length of time.

Presumed cause of last heating, i.e., burned structure, roasting pit, hearth, etc., if known.

5. An identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

Weathered-Glass Dating

The dating of glass objects should be attempted even if it is not a priority in terms of the research design. Although there is some controversy concerning the viability of this dating technique (Newton, 1971),

it is still important that weathered-glass samples be taken when available for the purposes of this study. If feasible, and archeologically acceptable to the principal investigator, some of the material should be left in place, and suitably marked for relocation (see site-preparation section of guidelines). These samples will provide the Reservoir Inundation Studies Project with both a control and comparative sample for analysis.

Weathered-Glass Dating
Sample-Collection Instructions

1. Sample(s) should be taken from area(s) representative of the site.
2. Use extreme care to keep weathering crust intact. DO NOT CLEAN OBJECT.
3. If sample is obtained from moist environment, keep moist. DO NOT let it dry out; this could cause flaking and loss of datable weathering crust.
4. Sample should be stored in Ziploc plastic bag, and taped shut.
5. A field-sample data-card should accompany each sample, and information should include, but not be limited to:

Name of reservoir

Date

Site number

Sample number

Location of sample relative to permanent datum-point(s)

Provenience

If time-period of associated materials in site is known, please indicate.

6. An identification label should be taped securely to the outside of the sample, and the following information recorded:

Name of reservoir

Date

Site number

Type of sample

Sample number

SITE-PREPARATION

The preparation of archeological sites for inundation in such a manner as to make them amenable to an external monitoring process and to provide for easy relocation after immersion is a major concern of the Reservoir Inundation Studies Project. Without adequate site preparation, the capability of the research team to replicate samples, assess impacts, and plan mitigation would be seriously impaired. Procedures presented in this section address the preparation of historic structures and features (such as standing structures and machinery), excavated units, pictographs and petroglyphs, and placement of post-inundation temperature-determination ampules, and relocation devices after immersion. As data becomes available on the viability of mitigating impacts through selected preservation techniques such as foams, resin or polymer impregnation, and sandbagging, it will be incorporated into these guidelines.

PREPARATION OF STANDING STRUCTURES AND ASSOCIATED FEATURES

Archeological sites may contain standing structures, machinery (such as flumes), associated cultural features (such as railroad beds), or culturally associated botanical remains (such as orchards or vineyards), which pose a different set of problems from sites not containing these features in terms of both preservation and mitigation. Structures are often raised, and machinery removed, because they may present navigational or other safety hazards.

Sites containing the cultural manifestations mentioned above are important to the understanding of the

total picture of human occupation of an area, and guidelines relating to preparation of the site for inundation will be developed in a later phase of the Reservoir Inundation Studies Project, when more substantive data is available on their preservation and/or destruction in an untreated state. In all cases, these sites should be carefully recorded on site-forms and maps, and be photographically documented.

The condition of the materials from which a structure or machine is constructed should be noted. Samples of the structural material--such as adobe or other brick composition, wooden siding, masonry, or metal--should be collected and referenced with standard provenience data if these remains will not be completely removed or destroyed during reservoir construction. This will provide the study with a sample for post-inundation comparison.

Excavation units associated with these sites should be treated in the same manner as outlined under the subsection on minimum site data, and where applicable, should include preparation as presented under the following subsection on inundation preparation for excavated units.

PREPARATION OF EXCAVATED UNITS

Adequate preparation of excavated units will aid in assessing mechanical impacts, and begin to address questions ranging from the most basic--whether or not to backfill units slated for inundation--to the technical--whether or not to employ sophisticated protective coverings or treatment for selected features or structures.

A representative sample of the excavated units should be selected for testing--some to be left open, unbackfilled, and unprotected--and others to be partially or completely backfilled. Outlined below are procedures that will begin to provide information on inundation effects while preparing the site for post-inundation monitoring. Individual unit selection is up to the discretion of the principal investigator; however, excavation units containing sample-collection areas for dating or other analysis should be included.

Completely Backfilled Unit:

The selected unit(s) should be completely lined with plastic sheeting--either PVC or polyethylene--and be backfilled. If possible, the unit should be filled with material anomalous to the site. If not possible or feasible, plastic sheeting should be orange, yellow, or white. This will provide a visual clue to the Reservoir Inundation Studies Project archeologists when they re-excavate after immersion.

Half-Filled Unit:

A vertical portion of the selected unit(s) should be lined with brightly colored plastic sheeting, and be backfilled, with the adjacent portion of the unit(s) left completely open.

Profile Unit:

Plexiglas sheet(s) should be securely placed directly against a profile or wall that exhibits any of the following:

stratigraphic layering (soil)

features, either cultural or environmental

artifacts

data remains (such as osteological material)

This information should be engraved directly on the Plexiglas showing the location of these items, and marked over with permanent waterproof black marker. University of Tennessee Archeologist Gerald F. Schroedl, found that a router with 1/8-inch veining bit set to engrave 1/8-inch deep was an effective tool for engraving the plexiglass (Schroedl, 1977). This sheet should be covered with plastic and buried.

Information concerning the location and protective treatment of these units should be clearly delineated in overall site maps. Unit maps and written records should also reflect procedures employed.

PREPARATION OF PICTOGRAPHS AND PETROGLYPHS

Specially manufactured pictographs on a sandstone matrix were subjected to simulated lake-environment conditions in a laboratory test of various chemical-preservative coatings (Turner and Burke, 1976).

Poly methyl methacrylate was successful in protecting the treated portion of the rock-art sample, but the untreated portion showed severe deterioration at the conclusion of the 8-month test. This chemical has been tested on a series of representative Southwest sandstones, and shows promise for protecting rock art from the potentially harmful effects of inundation. Poly methyl methacrylate is also suitable for use on rock types other than sandstones, including basalt, granite, tuff, and diorite.

Material sources, chemical preparation, and application method instructions are available upon request to interested individuals from the Reservoir Inundation Studies Project office, or from William J. Burke, Department of Chemistry, Arizona State University.

It should be noted that the chemical-application process is still in the experimental stage, and chemical penetration of the rock matrix will be variable. As more data on chemical preparation or application becomes available, it will be forwarded to interested individuals. More detailed information on the experimental procedures upon which the chemical preservation method is based can be found in Preservation of Pictographs and Petroglyphs, by Christy G. Turner, II, and William J. Burke (1976). Questions on this document should be addressed to Burke.

Whenever possible, chemical protection of inundation-threatened rock art should be attempted. If possible, a small portion of the rock-art panel should be left untreated, to facilitate a determination of the efficacy of each method.

SITE-PREPARATION FOR POST-INUNDATION TEMPERATURE-DETERMINATION

Accurate temperature information is critical for dating by obsidian-hydration, amino-acid-racemization, fluorine dating, and thermoluminescence. Data on the mean temperature, either from weather records or from a station in a nearby and similar temperature regime, should accompany samples for use in these dating methods. Weekly or bi-monthly ground-temperatures are even more valuable, and can often be obtained from an agricultural-experiment station or the Soil Conservation Service.

In order to assess the impacts of inundation on the above dating techniques, a highly technical approach to temperature determination is required. The Pallmann method for mass sampling of soil, water, or air temperatures is suggested. It is based upon the breakdown of cane sugar into simpler sugars, and is accomplished through implanting vials containing a specially prepared solution of cane sugar in the soil. Specific information on this temperature method is appended to this report.

Consultation with, and/or the employment of, trained personnel in solution preparation, sample placement, and interpretation of the data is strongly recommended. The local USGS may be able to provide this expertise, or to provide information on individuals who can provide this service.

The locations of cane-sugar vials should be noted on site maps.

SITE-RELOCATION DEVICES FOR POST-INUNDATION USE

Determining the precise location of an archeological site after it has been flooded is one of the most difficult problems faced by the Reservoir Inundation Studies Project. Turbid water, a lack of easily recognizable landmarks, vegetational changes, and so forth, all contribute to this problem. Although triangulation from secondary datums set above flood pool (discussed in the first section of these guidelines) will aid in general relocation of a site,

to locate the exact position of the site's primary datum--a critical need in order to work at the site--additional methods must be employed.

The first method presented in these guidelines involves the placement of an acoustic pinger, and is preferred because of the high degree of accuracy available. The pinger instrument is quite small, and does not present navigational or other safety hazards.

The second method employs 55-gallon drums, weighted with concrete, and used in conjunction with a fathometer for site relocation. The use of the second method will be contingent upon prior approval and clearance by the Federal agency charged with navigational jurisdiction and safety in the reservoir, because the drums could create a boating hazard in some situations. Permission may also be required from the construction agency, even if that body does not hold navigational and safety authority.

Acoustic Pingers

A wide range of acoustic pingers is available through commercial diving suppliers and manufacturers, and any brand may be used. However, the selected pinger must conform to the following specifications:

1/4 watt

3-year battery-life (minimum)

27 kHz

1-mile range

200' operating-depth (minimum)

The pinger should be attached securely to the upper third of the primary datum pipe by means of radiator clamps, in such a manner as to prevent loss due to initial flooding or strong currents after flooding. To prevent loss of the pinger due to vandalism, the instrument should not be attached to the datum until just before the site is flooded.

Fifty-Five-Gallon-Drums

Three 55-gallon steel drums, stacked one on top of the other, and spotwelded together, should be placed in a location near the primary datum. Numerous large holes should be punched in all of the drums, and the bottom drum weighted with concrete. Any easy-mix, quick-setting concrete is suitable, and two 90-pound bags should produce enough concrete to sufficiently weight the drums to prevent their loss.

A point on the drums, level with the top of the primary datum pipe, should be selected, and information on the distance and compass-bearing to the primary datum permanently marked on the drum. Steel letter stamps are suggested for this purpose. The drum point may be also indicated in this manner; however, a ring or loop welded at the selected point is preferred. The distance and compass-bearing of the primary datum from the drums, as well as the location of the drums relative to the secondary datum triangulation-points, should be recorded on site maps.

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Chapter IV

MITIGATION

INTRODUCTION

The data accumulated by the Reservoir Inundation Studies Project will provide a body of knowledge explaining the effects of inundation on cultural resources. This data, in conjunction with a well-developed regional archeology-overview covering both prehistoric and historic periods, will provide reservoir managers with the information they need to plan and carry out a maximally efficient and appropriate cultural-resources-management program. An integral and primary component of this cultural-resources program will be the initial decision of whether or not to mitigate impacts on archeological sites scheduled to be inundated due to reservoir construction.

The mitigation of impacts upon sites can be accomplished by means of the traditional method of excavation, or by means of attempts to protect sites from the effects of immersion. The Reservoir Inundation Studies Project does not take a position that states that either of these two methods is inherently more efficient or acceptable than the other. The specific mitigation method to be used is the decision of the construction agency acting in conjunction with the appropriate archeological advisory bodies.

The Reservoir Inundation Studies Project will provide available data on protective mitigation procedures to enable these bodies to explore the possible alternatives to excavation, in instances when mitigation is deemed necessary.

Although fully half of the study problem is directed toward the development and testing of mitigation

methods, this aspect of the investigation will receive limited attention in this preliminary report. The reason for this is fairly obvious: we must first develop a reasonable understanding of the nature of the impact before we can develop methods to mitigate it. In the final report, there will be an increased emphasis on findings related to model 2, i.e., those focused on the question of mitigation. Although the requisite data for framing meaningful sets of hypotheses on the question of mitigation does not yet exist, a presentation will be made in the following section of what is known and what may be reasonably attempted at this early stage to help mitigate impacts on sites due to the effects of inundation.

PROTECTIVE COVERS AND SEALANTS

As mentioned in the chapter on research results, the use of protective coverings for sites has been investigated by Reservoir Inundation Studies Project core-team archeologists. Such protective coverings would be used in addition to backfilling, which is recommended in all inundation situations by the team. Several references by Bureau of Reclamation research scientists discussed the utility of various techniques to control water seepage in irrigation canals, and presented the results of comparative tests on various protective agents (Hickey, 1969, 1971a; Morrison, 1971; U.S. Department of the Interior, 1963). These techniques can probably also be applied to protect archeological sites from certain impacts of immersion. Based upon the Bureau of Reclamation findings, and upon various conversations with Bureau of Reclamation scientists, it would appear that several of the products they tested may have application to specific archeological problems, particularly those relating to possible detrimental mechanical effects resulting from inundation.

We have selected the following materials that we feel are best suited to our needs on the basis of successful Bureau of Reclamation test results, cost factors, and accessibility.

Various lining materials to be considered include PVC and polyethylene plastic films, and butyl and EPDM synthetic rubber-lining materials.

The PVC and polyethylene plastic films will probably be suitable for use as a buried lining, because tests have shown that when they are used as an exposed lining, sunlight has a deteriorating effect upon them.

The butyl and EPDM synthetic rubber linings are comparable in performance to the plastic linings, but are more durable when used as exposed linings.

In addition, various chemical soil-stabilizers will be tested. The two that seem to offer the most potential are a vinyl polymer and an acrylic copolymer.

Flocculating agents will also be utilized, but tests on actual water and sediment samples will have to be made to determine which would be more effective.

Things to Note Concerning the Application of Various Chemicals and Linings

1. PVC--what is resistance-potential to bacterial deterioration?

Sunlight has deteriorating effect on both PVC and polyethylene when used as exposed linings.

2. Synthetic rubber linings

a. Butyl and EPDM--comparable in performance to plastic linings, but more expensive, more difficult to obtain watertight field installation, and more prone to shrink.

b. Excellent weatherability, even when exposed, but subject to damage by livestock and falling rocks.

3. Chemical soil-stabilizers

a. Vinyl polymer--good resistance to wind and water erosion and weathering; excellent for stabilizing sandy soils.

b. Acrylic copolymer--comparable to vinyl polymer.

Chemical Stabilization of Soils

1. Vinyl polymer formulation
 - a. Excellent properties for stabilizing sandy soils.
 - b. Good wind and water erosion resistance and weathering resistance.
 - c. Apply at 1 gal. per sq. yd. (1 part polymer - 9 parts water).

2. Acrylic Copolymer

- a. Similar in performance to vinyl polymer.

3. Vinyl polymer vs. plastic film

Advantages:

- a. liquid applied
 - b. elimination of field seams
 - c. lower cost per unit thickness
 - d. cured film more easily repaired

Disadvantages:

- a. lower tear and tensile strength
 - b. greater temperature susceptibility
 - c. requires application over smoother subgrade

4. Liquid Asphalt

- a. some seepage control
 - b. good penetration in silty sand

Disadvantage of Liquid Asphalt:

In % of over 9-12% salts in soil, asphalt won't work

Synthetic Rubber Canal Lining

1. Butyl
 - a. highly resistant to bacterial deterioration
 - b. 1/16" resists puncture in excess of 57.5 psi hydrostatic head
 - c. excellent weatherability
 - d. more expensive than plastics
 - e. some difficulty in obtaining watertight field seams.
 - f. previous unsatisfactory field experience with shrinkage.
2. EPDM
 - a. highly resistant to bacterial deterioration
 - b. puncture resistance comparable to butyl
 - c. excellent weatherability
 - d. more expensive than plastics
 - e. field seams and sheet shrinkage may be a problem.
3. Field Investigations
 - a. butyl rubber lining could be treated somewhat more roughly than plastic films.
 - b. although durable when exposed, subject to damage by falling rocks, etc.; more difficult to bond and anchor than plastics

Plastic Films for Canal Linings

Lab Findings

1. PVC
 - a. more resistant to puncture

- b. more readily available in larger fabricated pieces
- c. easier to repair
- d. 10 mil and better--can provide 4-7 years service under exposed conditions
- e. more susceptible to cold impact than polyethylene
- f. bonds to itself under pressure, precluding the use of adhesive

2. Polyethylene

- a. cheaper (40' x 100' roll 1/2 cost of PVC)
- b. highly resistant to bacterial deterioration
- c. slightly better resistance to outdoor exposure than PVC; 4-7 years' service on 10 mil and better
- d. highly resistant to cold temperatures
- e. must be bonded with special cement and pressure-sensitive tape, or by folding ends together and burying in a trench

3. Field Investigations

- a. where PVC and polyethylene installed as exposed lining, failures occurred after 3 years due to deteriorating effects of sunlight
- b. no root punctures observed in 8 mil PVC after 7 years of service
- c. PVC more puncture-resistant -- withstood scraping of shovels (10-mil thickness)
- d. PVC is not particularly esthetic to look at, and this may be a factor to be considered where periodic exposure to the public is likely, e.g., drawdown period in a national recreation area.

4. Uses

- a. linings
- b. cutoff curtains in vertical trenches

TACSS

Tanaka Aqua--Reactive Chemical Soil Stabilization Systems Evaluation of TACSS compared with other soil stabilizers--result of various tests.

1. TACSS

- a. volumetric ratio of solidification--high
- b. one liquid chemical grout (hydrophobic nonhydrated gel)

2. Ubrex Formaldehyde Type

- a. volumetric ratio of solidification--very low

3. Acrylic Amide Type

- a. volumetric ratio of solidification--low

4. Water Glass Type

- a. volumetric ratio of solidification--low

5. Chrome Lignin Type

- a. volumetric ratio of solidification--very low

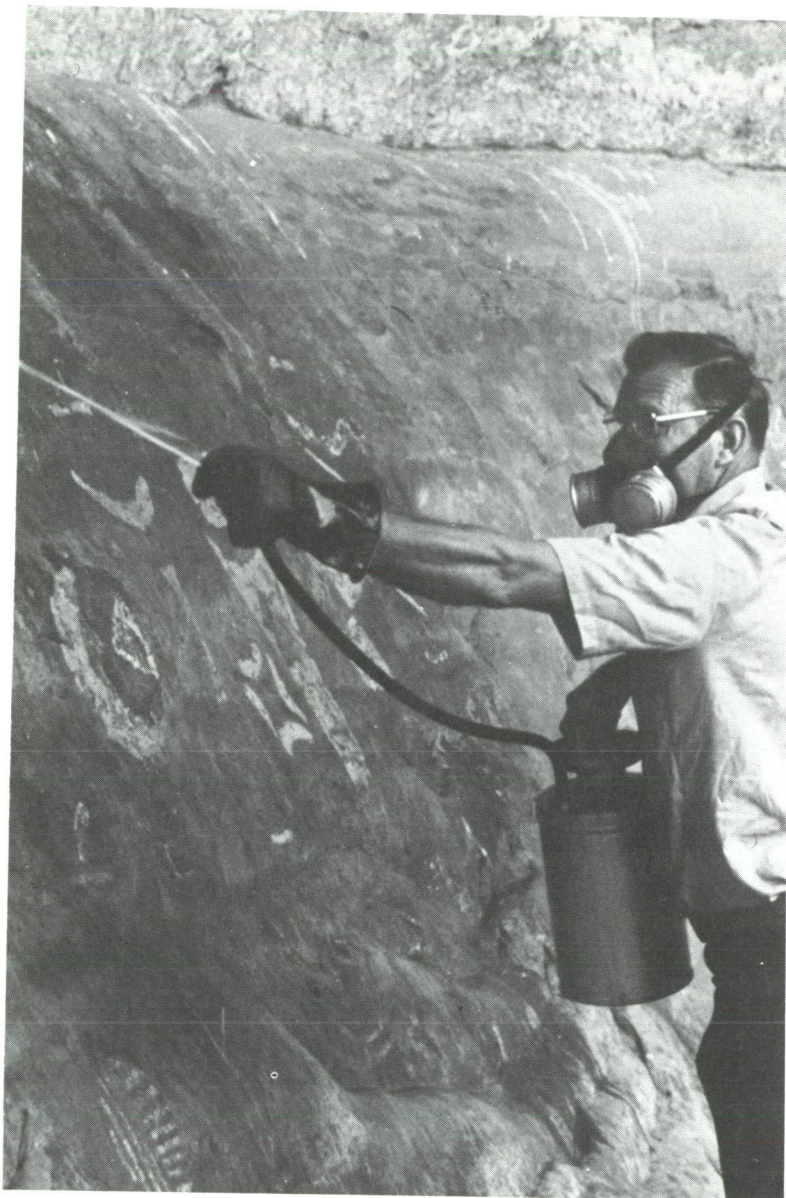
EROSION AND SEDIMENT DEFLECTORS

Considered in conjunction with, or alternative to, these direct protective measures is the application of mitigative techniques that would alter destructive reservoir forces. Techniques that have potential for

altering destructive reservoir forces may include the use of checkdams situated up current from the site, bank revetments, and cofferdams. The use of natural or introduced vegetation may also help prevent erosion during the initial inundation period. To allay erosion to the old river-channel before the rising waters have actually jumped the banks, revetments such as "jacks" should be considered. Channel stability studies, are often general in nature--that is, mean configurations and mean water velocity are figured for whole reaches of the reservoir, but hydraulic engineers can use much of this information to apply to specific points in a channel.

Combinations of procedures may be used in situations where a soil stabilizer in association with a checkdam may be called for to minimize mechanical impacts and ensure effective site preservation. With the use of any mechanical protective measure, there will be the possibility that water may undermine the site. This situation may necessitate the use of peripheral protective devices to minimize water penetration on the boundaries of the site. Also, it must be ensured that potential data-returns are not affected by introduced chemicals, or by the degeneration of petrochemical material intended for protective purposes.

Modeling facilities of the dam-construction agencies are unfortunately oriented toward a reservoir-specific, rather than general, approach to developing generalized predictive models for a specific problem such as erosion. The Reservoir Inundation Studies Project core team believes that in cases where models are built to simulate the dynamics of a particular reservoir, erosion of cultural sites within the impact zone should be worked into the model or into associated mathematical models. This is of special importance when the sites downstream from the dam are considered. It should also be noted that the varying magnitudes of water released into the existing channel downstream (which is a function of the nature of reservoir operation) are only one aspect of the erosional problem. Another is the fact that the water, before moving through the dam, will have in most cases lost a great amount of its sediment load, and will therefore have a higher carrying capacity.



Larry Sanderson of the Bureau of Reclamation applies a chemical preservative to a pictograph panel before inundation at the Davis Pool site in Glen Canyon National Recreation Area. The Inundation Studies team is monitoring such efforts at preservation because of the possible application of these techniques as mitigative measures before flooding.

This means that the same amount of water downstream will cause greater erosional problems than water that has not released its sediment.

OTHER CONSIDERATIONS

One potential impact of inundation of concern to the Reservoir Inundation Studies Project team is the loss of the ability to use remote-sensing as a survey tool. To help mitigate adverse impacts in this area, a preventive approach can be utilized. Where standard flyovers of a drainage are conducted during the planning phases of reservoir construction, it would be of great benefit to first coordinate with archeological remote-sensing experts to ensure that the film types, resolution, scale, and so forth, are also adequate for cultural-resources-management purposes. Sometimes only the addition of minor specifications, at minimum cost, would be needed to enable cross-utilization of this imagery by archeologists.

Photographic techniques may also be the key to mitigating certain impacts on archeological features. For instance, if soil-stain and other information on color and texture should be lost through inundation, it is possible that it may be retrieved by the application of color-infrared photography.

CONCLUSIONS

If the appropriate resources-management bodies opt for preservation efforts rather than salvage in a particular situation, many variables will influence the choice of the type of protective system that will be most effective. The protective methods employed--such as concrete, asphalt, plastic sheeting, chemical stabilizers--will depend on the individual reservoir environment and the categories of data on which preservation efforts are to be focused. As the Reservoir Inundation Studies Project progresses, the refinement of our knowledge of the nature of the effects of inundation will allow the development of more sophisticated protective measures.

A final overall consideration: Those sites that have been inundated in years past, and are slated to remain indefinitely in conservation pools, still lie on Federal land, whether or not there is a body of water lying on top of them, and they should therefore be reevaluated in cultural-resources-management schemes. In fact, it may be determined that regional cultural-behavioral questions may be better answered in certain cases by the examination of submerged sites than exposed terrestrial sites. In other words, underwater archeology should be seen as a viable resources-management tool, and not as an exotic luxury to be indulged in when all available land sites have been investigated.

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Chapter V

UNDERWATER DATA-RETRIEVAL TECHNIQUES AND DIVING SPECIFICATIONS

UNDERWATER DATA-RETRIEVAL TECHNIQUES

When we work under water, we alter the traditional methods of data-retrieval, even though in most cases the same information must be collected as on a terrestrial site (in addition to various data that are of unique interest to this study). The following section will explore the various methods and tools employed by the Reservoir Inundation Studies Project in underwater data-retrieval, and separately examine three major areas:

Mapping

Sampling

Data-Recording

MAPPING

A site is investigated under water in much the same way it is on land. The Reservoir Inundation Studies Project is not concerned with carrying out actual excavations for the purpose of its investigations; however, mapping and sampling must be carried out under the same referencing-controls as on land. The completion of a detailed map of a site after inundation enables team archeologists to compare the site under both pre-inundation and post-inundation conditions, and much can be learned about the effects of slumping, compression, and other potential threats to the physical integrity of an inundated site.

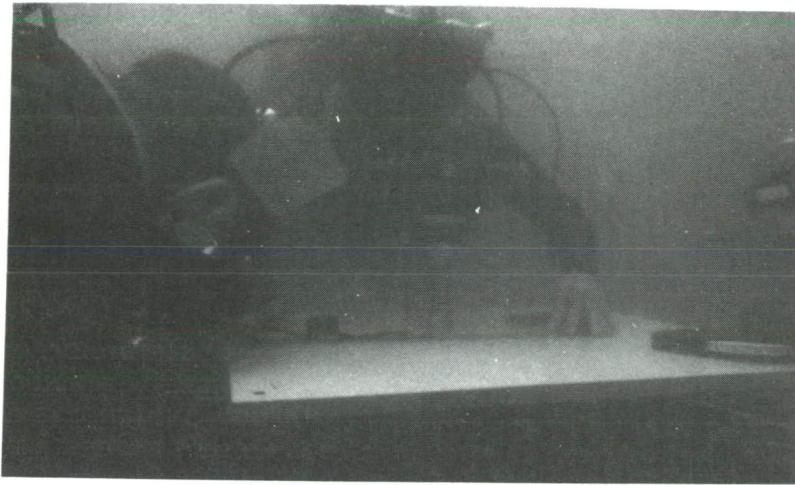
To obtain the most accurate site-maps possible, we have specially designed an underwater-survey system.

The equipment was designed and built according to Reservoir Inundation Studies Project specifications by Barry Kerley, a contract diving-equipment specialist. This system consists of the use of a plane-table, alidade, and stadia-rod with a self-contained lighting system, in conjunction with a wireless diver-to-diver communication system.

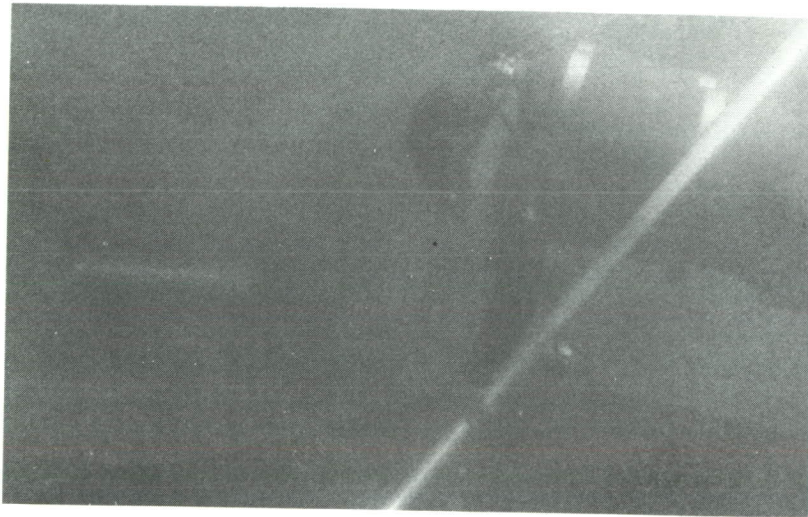
The plane-table base is made of stainless steel, in a square table configuration with four folding adjustable legs. The table base may be grossly leveled by use of the adjustable legs, and set firmly in silt before the table-top is leveled. The table-top consists of a square sheet of Plexiglas, on top of which is a sheet of sanded acrylic mounted by four corner screws. The table-top is mounted on the base by means of a centered leveling head assembly, which was adapted from a conventional transit. This allows for the fine leveling of the table-top, which is determined by spirit levels clamped on the edges at right angles.

The alidade used with the plane-table is custom-made from a terrestrial line level transit. Because the optics are useless under water, they have been removed, and cross-hairs installed. The transit is mounted on a brass pedestal, which is mounted in turn on a beveled-edge stainless-steel blade. When the alidade is constructed in this manner, it may be used as a traditional alidade. The transit capabilities of the horizontal circle and vernier may also be used to turn angles. (See below for this application in conjunction with a fathometer.)

By using the plane-table and alidade, a map may be drawn under water. At the end of the day, the acrylic sheet can be removed from the table and brought up, to enable transference of data and study of the material. This method offers the considerable advantage of same-day mapping results. The acrylic sheet may also be covered with a large sheet of paper especially designed for underwater use, which would eliminate the need for transferring data until the final maps are drafted. The table may be left submerged in place overnight, should additional mapping from the same datum-points be needed, thereby saving the setting-up time.



Underwater plane-table and alidade especially constructed for the Reservoir Inundation Studies Project by Barry Kerley, diving-equipment consultant, are used by core-team members in a site-mapping exercise.



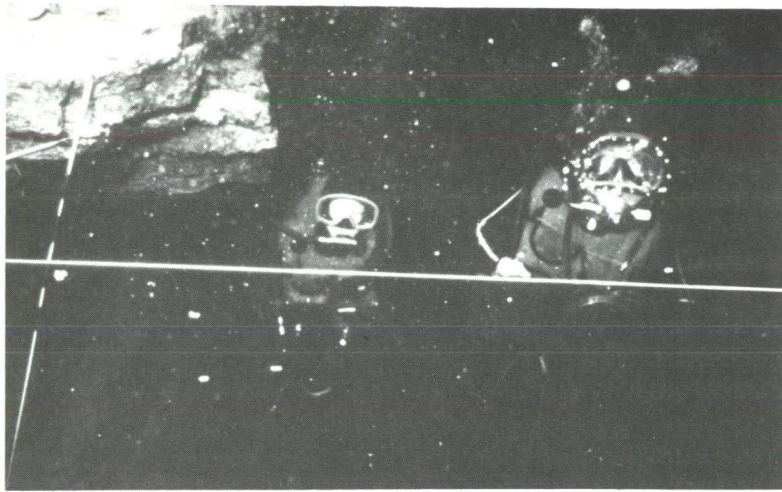
A specially designed lighted stadia-rod for use in low-visibility water is employed during a mapping operation. The white object in the left background is the plane-table. Note that from this distance the divers at the table are not visible.

The stadia-rod, which is used for shooting points and taking elevation, is a metrically graduated Plexiglas rod, 2.4 meters long. The rod is buoyant, but a weight attached to its bottom allows it to stand straight on the bottom without support. A self-contained lighting system, powered by rechargeable nickel-cadmium batteries, permits easy sighting in low-visibility situations.

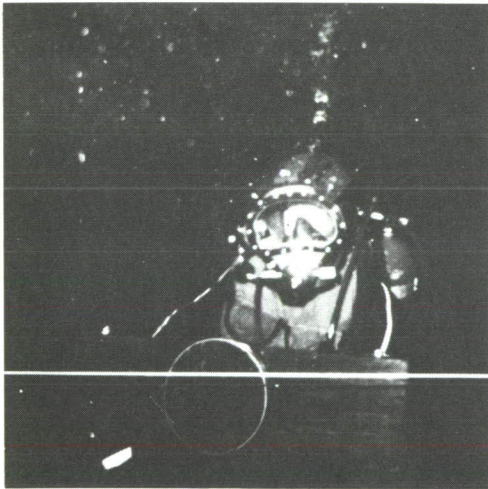
The surveyor and rod-man may establish instant verbal contact through the use of wireless underwater communications. This system also enables contact between the diver and the surface, so that the work may be monitored by support personnel. The advantages of a wireless communication system are readily apparent: Much time is saved when either member of the survey-crew must deviate from the mapping plan, as can often occur; problems encountered during mapping may be quickly solved without necessitating a break in the work for hand-signals or written communications; and in low-visibility situations, the rod-man can pinpoint the elevation-reading and convey it to the surveyor.

A fathometer (depth recorder) may be used to measure and record horizontal sightings during mapping and survey, either in conjunction with the plane-table and alidade, or independently. The model being used is a portable, precision, survey-type fathometer, designed to provide detailed permanent recordings of underwater topography. The unit includes calibration controls, to correct readings from one environment to another, and thereby enabling the most accurate readings possible to be obtained. The recorder, which operates off a common 12-volt car battery, is manned on the surface. The transducer, which is connected by cable to the recorder, is diver-operated. The diver is equipped with surface communications to enable coordination with the recorder operator.

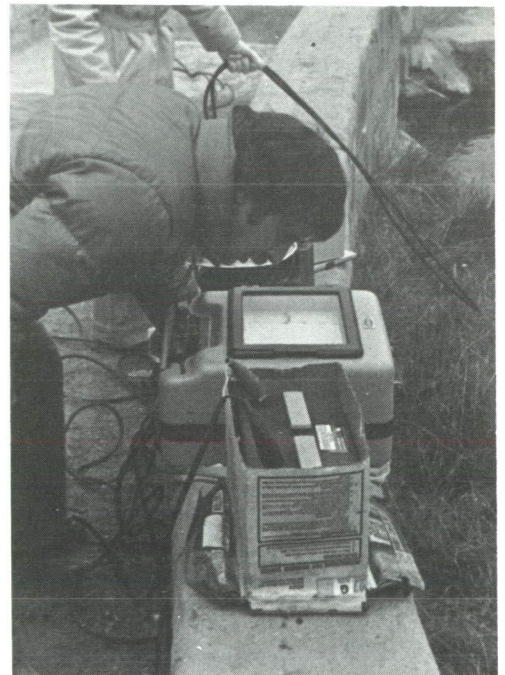
The fathometer can be used most effectively in conjunction with the plane-table and alidade. The transducer may be mounted on the alidade sighting-tube; in this instance, the alidade would be used as a transit (see above for construction of the alidade/transit) and the appropriate angle turned.



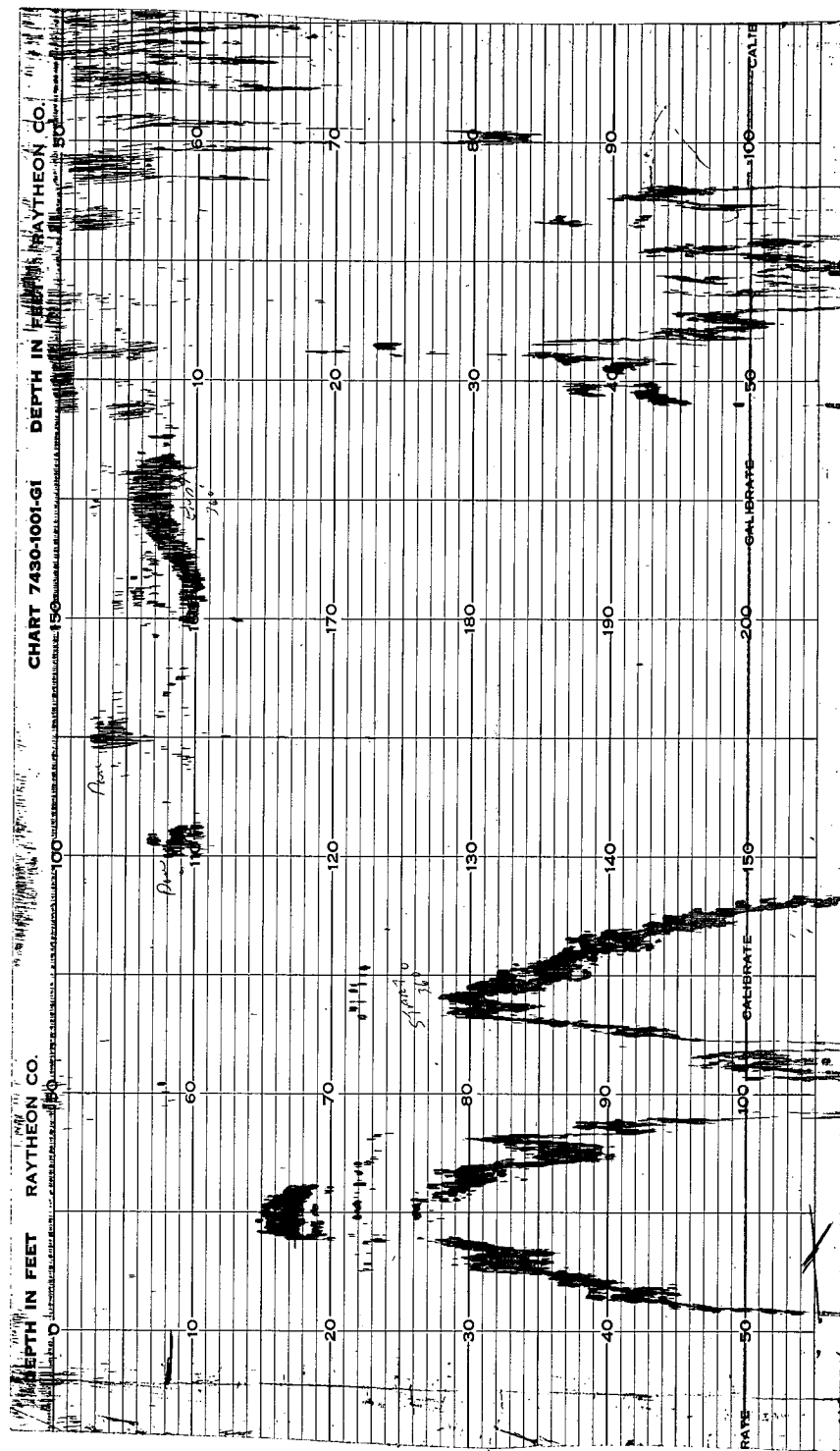
Core Team archeologists approach baseline with handheld fathometer unit used for mapping. Diver on left is tending the fathometer cable and communications wire which have been united into a single "umbilical" to the surface.



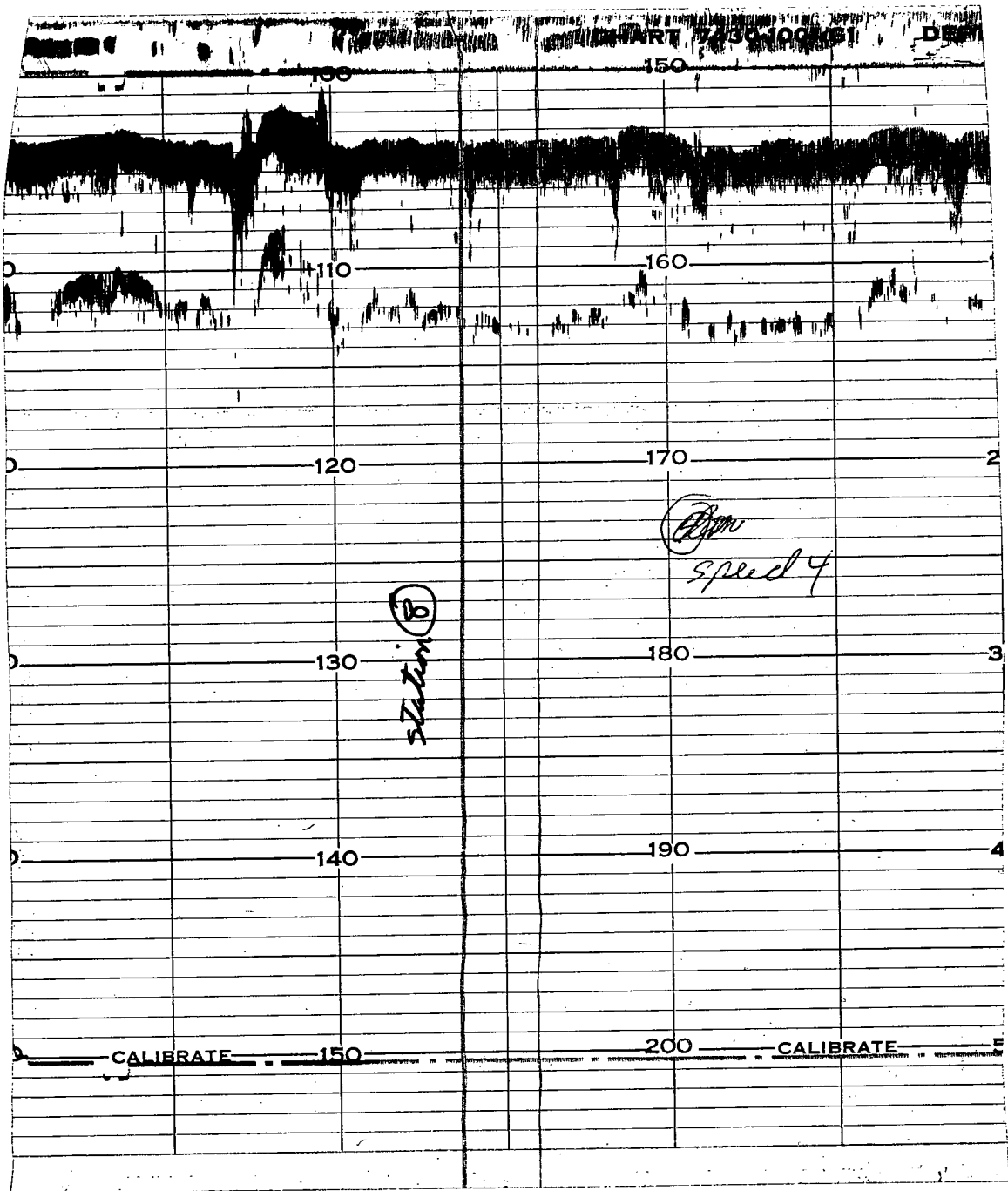
Instrument is leveled on the baseline.



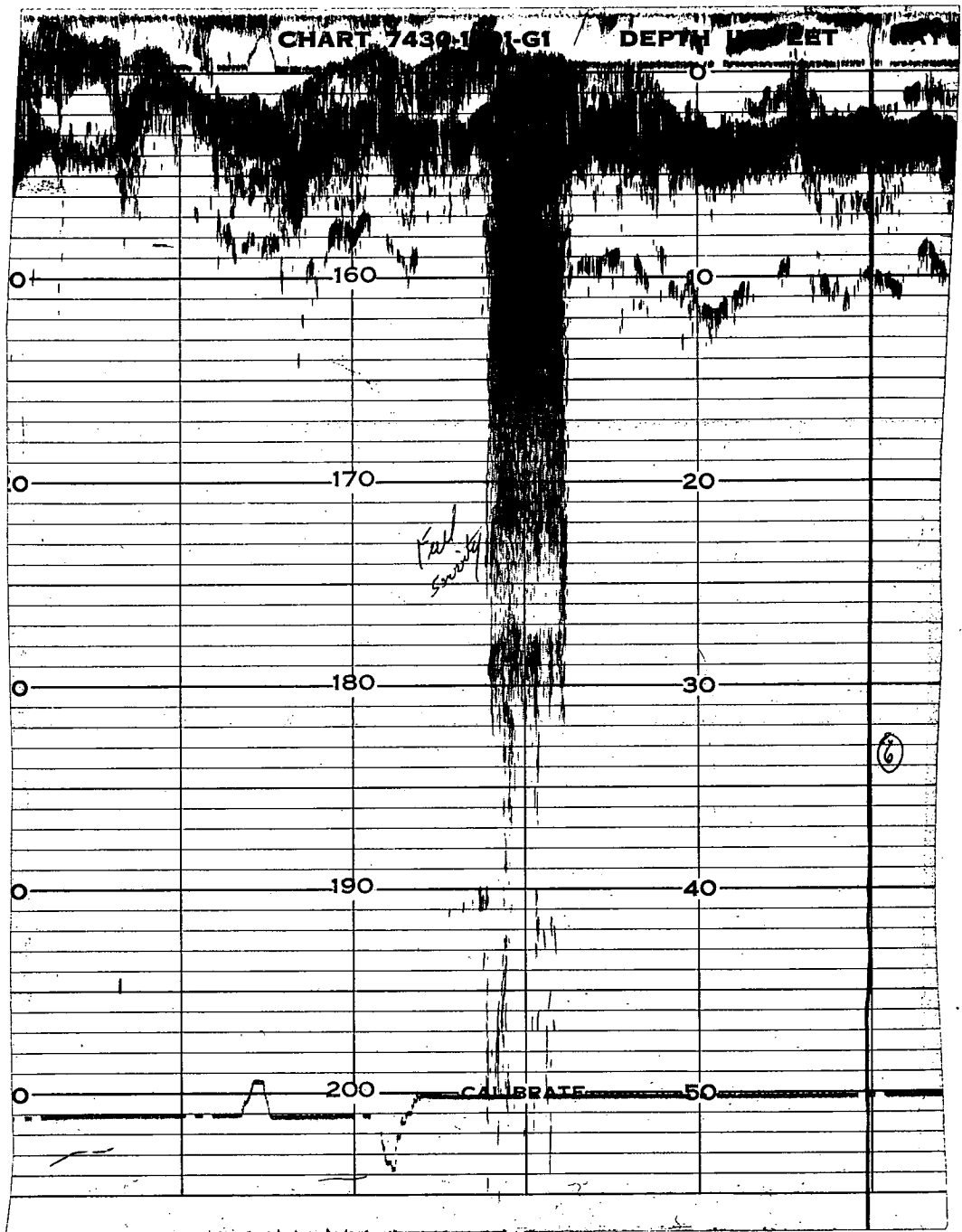
Archeologist monitors surface readout of the fathometer mapping results. He can use voice communication to the divers below to provide instant feedback on mapping results.



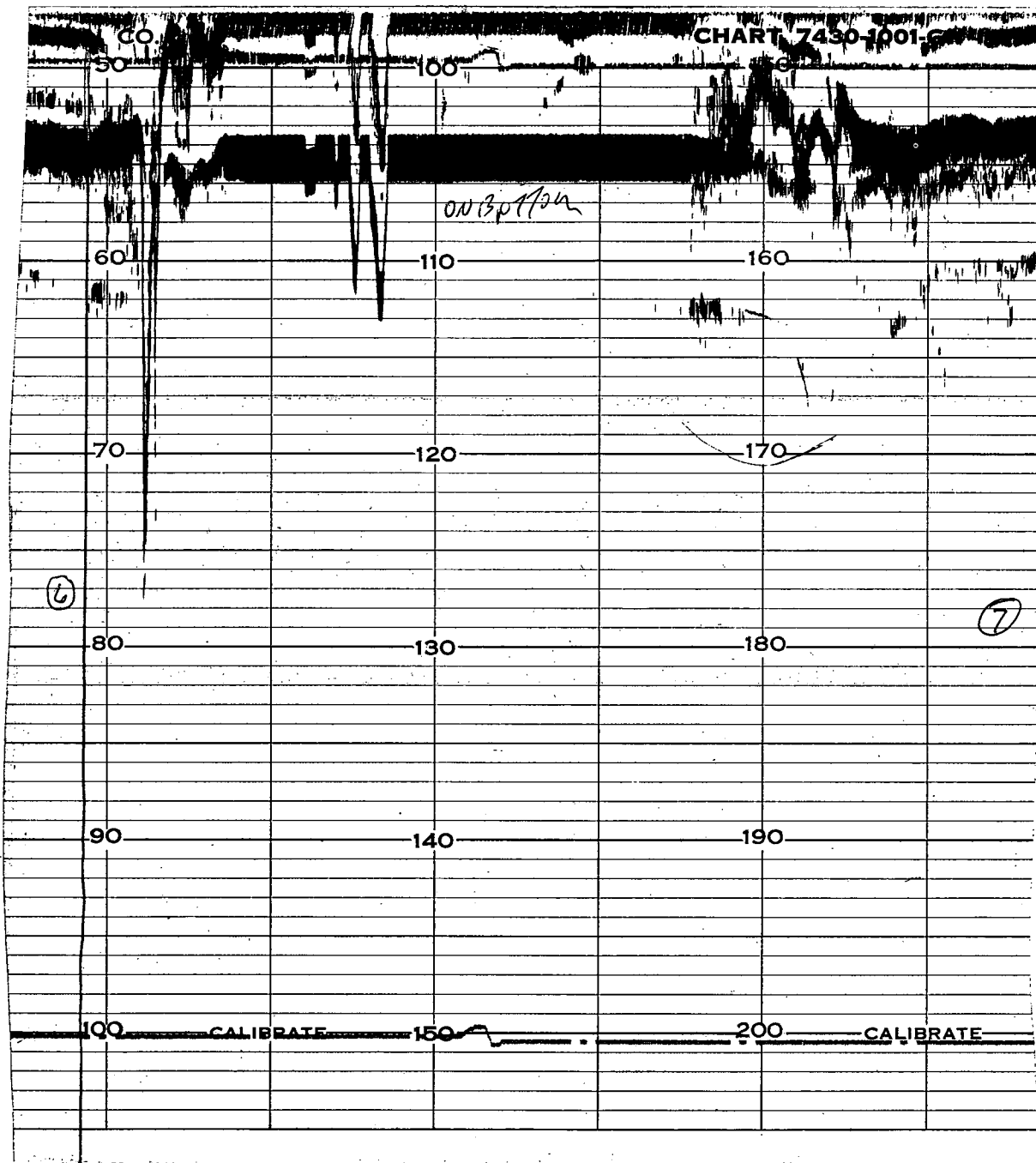
This chart demonstrates the ability of the fathometer to record relatively small objects in open water. The two readings labelled "Dan" represent a diver passing in front of the transducer at a distance of 11 feet and 5 feet, respectively. The fathometer was calibrated for this test not to record any reading over 55 feet. This can be seen by the disappearance of the wall between the readings labelled "start 360" and "end 360".



This chart section demonstrates the full sensitivity of the unit. The heavy, wide vertical reading represents suspended particulate matter in the water. Calibration is necessary at each site to determine the correct sensitivity.



The heavy vertical line is an event-mark. When the diver signals that he is stabilized and ready to take a reading, a switch on the console is thrown, which marks this optimum reading for a particular station. The surface operator also writes the station-number next to the event-mark, for easy reference.



This reading was taken while the transducer was stabilized on the bottom. It illustrates the type of precision reading that could be obtained with a tripod. The backwall of the shelter is represented by the heavy horizontal line labelled "on bottom". The thin line on the 100 calibrate immediately above the heavy line represents the transducer. This reading shows a distance of 3.5 feet from the transducer to the wall.

Once on the proper sighting, the surveyor informs the recorder-operator on the surface to "mark" the recorder chart. The operator then activates an event-mark, which permanently designates the exact spot on the chart from which the reading was taken. The surveyor tells the operator the angle from north of the reading, plus any pertinent feature-information, which the operator then records on the chart. The next angle is turned and the process repeated.

From time to time, situations may arise in which the use of the plane-table and alidade is precluded--such as in environments of extremely low visibility, approaching blackout, or in areas on very steep slopes. The fathometer may then be used independently.

The site is prepared by setting horizontal and vertical controls. Heavy construction-rods may be set down, and metal wire tightly strung between them. The wire is marked in increments determined appropriate for the site, and the transducer is either hung from the wire and moved down the line, or physically moved from point to point by a diver. At each point, the diver stabilizes the transducer by means of attached spirit-levels, and advises the recorder-operator to "mark" the chart, while also informing him of the point-number. This system has proved quite satisfactory in situations in which visibility is extremely poor. The recorder-chart is removed at the end of each day, and the map plotted. The chart serves as a permanent survey-record, which may be referred to at any time in the future.

SAMPLING

To monitor, analyze, and interpret the effects of inundation, it is necessary to take periodic, controlled samples. As on a terrestrial site, provenience and laboratory specifications must be carefully adhered to in order to obtain an acceptable sample. Because of the nature of a submerged environment, and the alterations it introduces to the site and materials located therein, the sampling procedures will in many cases have to be modified to accommodate these specialized conditions.

Field-work during Phase I of the Reservoir Inundation Studies Project has been largely devoted to the gathering of general assessment data and the refining of mapping and recording procedures--but some preliminary sampling efforts are also being made. Field-work during Phase II will be oriented toward the development of sampling strategies and collection procedures, and then to their systematic operationalization. It is during Phase II, therefore, that sampling procedures will be formalized. Currently, the Reservoir Inundation Studies Project is contacting specialists in various fields to obtain information that would be useful in determining the optimum method of collecting and stabilizing the full range of archeological samples from an underwater context and requisitioning any equipment that may be needed.

The Reservoir Inundation Studies Project core-team is also beginning to practice tentative sampling procedures on mock sites. All training will be carried out on such mock sites, in keeping with the project philosophy that data-recovery techniques that involve disturbing a site should not be refined or practiced on the actual resource. Initial sampling procedures will be formalized by the beginning of the 1977 field season, but modifications will continue throughout Phase II, as new problems are encountered and site-specific demands become evident.

DATA-RECORDING

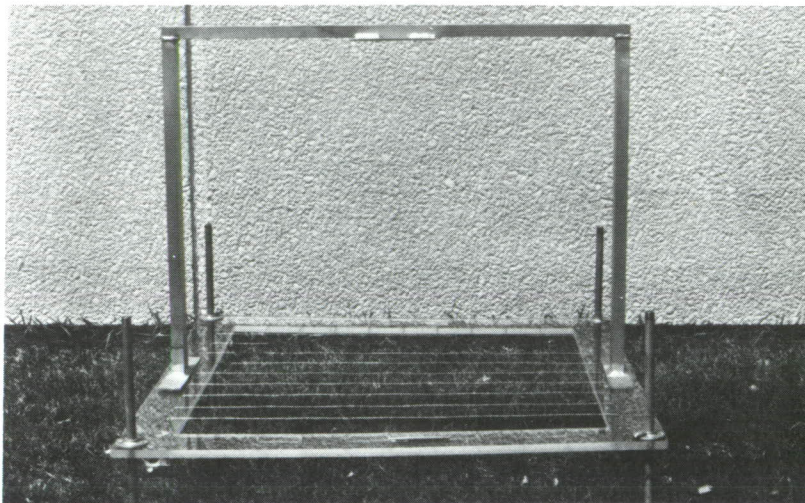
The recording of all pertinent underwater data by various photographic, videographic, and manual techniques is a concept basic to the acquisition of data, and as such plays a significant role in the Reservoir Inundation Studies Project. The record is used in all aspects of the study: documentation, mapping, analysis, interpretation, cataloging, and dissemination of results.

Photography

The principal camera used for the underwater work is a completely self-contained amphibious 35mm viewfinder camera. It accomodates several lenses of varying



Cold temperatures are a major problem in research diving. A Core-team member prepares to dive in a constant volume dry-type suit. She is being assisted by another team archeologist who is wearing a standard wet-suit.



A specially designed photographic tower centered on a plexiglas and wire grid can be used for photogrammetric mapping. The legs are adjustable for adaptation to an uneven bottom.

focal-lengths, although a 21mm distortion-corrected, wide-angle lens has been found most suitable for most of our purposes. The 92° field-of-vision allows the photographer to move in close (to 2.5 feet) to the subject (which is often necessary in poor-visibility water), and still capture all or most of the image on a single frame. For the low-light situations that characterize most underwater work, the project has two 100/150-watt-second strobes, which are compatible with the 35mm camera. Both strobes supply a light-field wide enough to accommodate both the 21mm wide-angle lens and the conventional 35mm lens.

To obtain the best possible photographs of excavation-units or isolated features, the project had an underwater grid with a photo-tower specially designed and built. The grid consists of a 1.2 meter-square piece of Plexiglas, from the center of which has been cut a 1 meter-square section. This opening has been cross-strung at 10-centimeter intervals with stainless steel wire, producing a 1-meter-square, 10-centimeter-interval grid. Using adjustable legs, the grid may be put over a unit and leveled. The photo-tower, made of aluminum, is mounted over the grid. The camera is centered on the top of the tower, so that photographs may be taken vertically through the grid. When using the 21mm lens, the entire grid area may be photographed with a single exposure. This photograph is a permanent record of the exposed unit. The process may be repeated on each exposed stratigraphic or arbitrary level in the unit.

By keying the grid into a system of surveyed datum-points, the map may be incorporated into an overall site-map. If desired, a number of exposed units may be mapped in this manner, producing a site-map drawn from a photographic mosaic of the site.

Videography

The Reservoir Inundation Studies Project is currently in the process of obtaining an underwater video-system. Such a unit will make a tremendous contribution to the efficiency of the project. The system will include a hand-held camera with light connected by cable to a topside video recorder and

onitor. The diver is equipped with communication to the surface, which is recorded directly onto the video-tape. This allows for the recording not only of the visual aspects of the work, but also of the diving-archeologist's first-hand comments and observations.

The monitor permits topside viewing by non-diving scientists, who may communicate with the investigator, and actually direct the work when necessary, and these comments are also recorded on the video tape. The free flow of instantaneous audio and visual information between the archeologist and the surface maximizes the efficiency of the dive, as well as creating a permanent audio and visual record of the investigation for future reference and analysis. The effectiveness of a video system as an archeological tool in an underwater context was well demonstrated at the Warm Mineral Springs archeological project in Florida directed by W. A. Cockrell.

Of particular interest to the Reservoir Inundation Studies Project is the video-camera's ability to "see" better than the archeologist in murky water. Direction from the surface or post-dive examination of the tape can often reveal detail that is not readily apparent to the human eye in poor visibility situations under water. This factor can prove to be a great advantage in certain field situations.

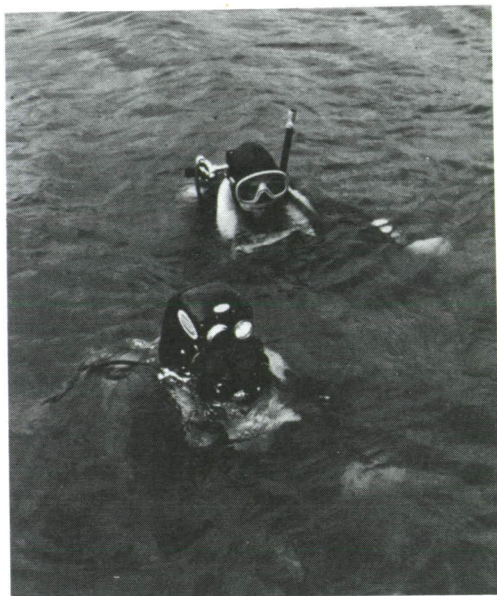
The video-system might also be useful in creating a "video-grammetric" plan of a site. The site would first be properly referenced, by means of a grid or other suitable reference techniques. By running a constant course, both horizontal and vertical, a video-record could be made. Surface monitoring could quickly tell if the result was satisfactory, and relay adjustments to the operator, if necessary. From this video-record, a site map could be drawn.

Photographic and videographic techniques are both used to record all aspects of underwater work, but at times one method may be considered preferable. Ideally, the Reservoir Inundation Studies Project prefers to record all information on both video-tape and film. Using black-and-white film gives the added benefit of providing top-quality slides for projection and study, and also top-quality prints for publication.



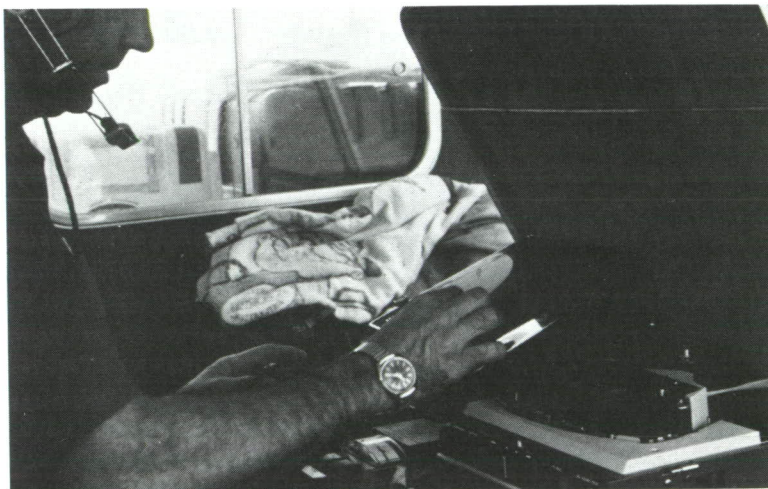
Project director (in helmet) is checked out by Byron LeBlanc of General Aquadyne Corporation before descending to evaluate the potential of this head mounted video-tape system for the project's recording needs. Dramatic video returns from the low visibility water in Arenosa Rock Shelter in Amistad Reservoir indicated that this technique could have great value to the study.

(Photo--David Dibble)



Team member in the video helmet is accompanied by an in-water tender as they prepare to conduct video-taping operations in Arenosa Rock Shelter.

(Photo--David Dibble)



Byron LeBlanc tends surface console of the video-tape reporting to the cameraman on the returns from the surface monitor. Such instant feedback on data returns is invaluable.

(Photo--David Dibble)

The video-system may also be used to obtain still-photos. The tape may be stopped at any specific point, and the monitor photographed. Due to the nature of helical scanning, the principle behind videography, the resolution will not be as sharp when the image is frozen as when the tape is playing. This, coupled with the fact that to properly photograph a monitor picture, a special shutter must be used (non-focal-plane, as in 2 1/4" cameras), the use of a still camera for still photos is preferred. The video-system also poses inherent logistical problems, due to the amount of equipment and surface support needed, making it unfeasible for work in many areas where a still camera could be easily utilized. However, the advantage of being able to take stills from the monitor should not be overlooked. Analysis of the tape may reveal information not noticed before, and it would be possible to isolate pertinent sections for still-photography after the crew has left the area, producing a still for study that might have been otherwise lost.

It should also be noted that the use of a still-camera in the recording of a sampling procedure may produce gaps in data returns. The videographic method, on the other hand, produces a flowing, continuous record, which includes the entire activity--and hence, all the information.

Because of its instantaneous feedback, the video-system allows the crew to know exactly what has been recorded, which is a distinct advantage over still photography. One does not know until after processing if the camera has malfunctioned, thereby possibly producing a blank roll of film, or inferior-quality photographs. Processing itself is a risk, as project archeologists learned when four rolls of valuable underwater photographs were destroyed in a processing mishap. With the video-system, the contents of the tape are known before the crew leaves the field.

Manual Techniques

The photographic and videographic techniques of data-recording are both used in conjunction with individual records, manually recorded by one of the investigators on each dive. These records are made on either underwater paper or sanded acrylic slates. Sketch maps, survey information, and any other pertinent data

are recorded to provide an independent record of the investigation, which not only stands on its own, but may be used to supplement and interpret the photographic and videographic records.

Diving situations occasionally occur that preclude the effective use of both camera and video equipment, such as near blackout water. Then only handwritten records of the investigator are possible with a separate record of the dive being made by the surface support crew through the use of diver-to-surface communication. The Reservoir Inundation Studies Project has two such surface-communication systems--one wireless, and one cable-connected. The surface record serves as a check on data-recording, and as an independent record, if the original underwater record is lost during a dive.

Obtaining and manually recording data under water in poor-visibility conditions is often slow, tedious work. One advantage of the core-team concept is a long period of association in which team members can develop and practice techniques for dealing with such problems. The project is equipped with powerful self-contained underwater lights, which can often make the difference between being able to work or not. Under the worst conditions, the lights will usually give the diver 6" of cloudy visibility. If the slate is placed over the light, the writing area is illuminated from underneath, due to the translucent quality of the slates, producing a light-box effect, and thereby providing enough illumination for writing.

In an attempt to overcome the problem of poor visibility and its restrictions, project personnel are in the process of designing a work-chamber, into which clear water can be pumped, thereby displacing murky water. The chamber would be dome-shaped, 2.4 meters high, have a base diameter of 3 meters, and be made of light-weight, non-absorbent sailcloth. It would be supported by inflatable tubing, and be secured to the bottom by weights or pins. The top would be vented, to allow for the escape of air-bubbles and the displacement of murky water. The clear water would be pumped from the surface to the chamber, entering at the base. The surface water is warmer than the cooler water at depth, and would therefore displace the murky water through the top. Entry would be gained through a zippered opening on the side. It is hoped that this

system would permit clearing to an extent that would allow for acceptable photographic, videographic, and testing conditions.

The primary purpose of data-recording is the acquisition of a systematic body of knowledge for analysis and interpretation. Several other purposes are also served: The data stands as an archival record of the research, which is always available for future reference; and this record is used to communicate the research to interested parties in scientific and lay communities. Because data-recording plays such a significant role in archeological research, the Reservoir Inundation Studies Project will continue to expand and improve its data-recording techniques.

DIVING SPECIFICATIONS

The Occupational Safety and Health Administration guidelines and the National Park Service Diving Policy are strictly adhered to as minimum standards for the Reservoir Inundation Studies Project. The research diving needs of the project are such, however, that advanced training is required, and specialized procedures must be developed.

TRAINING

All project core-team personnel receive advanced training in: surface and sub-surface diver rescue; deep-diving; decompression-diving; altitude-diving; advanced first-aid; surface-supplied diving; lift operations; underwater photography; the use of reels and underwater rigging; the use of full-face mask (including DM-5 and KMB-10); wired and wireless underwater communication; and underwater mapping and recording. A heavy emphasis is also placed upon silt-control techniques and other procedures that reduce bottom disturbance.

EQUIPMENT

Tanks

Core-team personnel are uniformly equipped with double-

tank units, having air capacities ranging from 71.2 cubic feet to 100 cubic feet per tank.

Manifold

A "dual" manifold is used by all personnel, except in those rare instances in which single tanks are called for. A dual-type manifold permits the use of two separate regulators that each have access to the complete air supply of both cylinders. This results in total redundancy in breathing equipment, and is far superior to an octopus rig, because the latter device does not provide backup in the event of a first-stage-regulator failure.

Buoyancy Control

Large-capacity buoyancy-compensators, utilizing low-pressure automatic inflation from the breathing supply with two CO₂ cartridges as backup are the standard vests used by project personnel.

Exposure Suits

Wet-suits and constant-volume, inflatable dry-suits are both used by team members, depending on the situation.

Decompression Equipment

All personnel are equipped with a watch; an oil-filled depth-gauge (for work at depth); a capillary depth-gauge (for work in shallow water and under decompression conditions); and submersible U.S. Navy standard air-decompression tables.

Lighting Systems

On all night dives, in dark water, or in caves, team members carry two lights:

Primary lighting system--A series of wet nickel-cadmium cells in a Plexiglas pack strapped to waist. This power-pack amounts to 7.2 volts, which operate a hand-

held 55-watt quartz-iodide 6-volt lamp. These lights are extremely bright, and can be recharged from a car battery in 20 minutes.

Secondary lighting system--A commercial rechargeable underwater flashlight. This unit utilizes dry nickel-cadmium cells, which must recharge over a much longer period of time (approximately 12 hours) after each use. For this reason, it is usually used only as a backup or emergency light.

DECOMPRESSION PROCEDURES

The depth and length of time involved in the Reservoir Inundation Studies Project research dives often create a need for staged decompression stops. Special precautions have been taken to ensure the safety of project personnel, especially because a recompression chamber is seldom readily available at project work-sites.

1. All team personnel are thoroughly trained in decompression diving, and take part in simulated situations before making actual dives.
2. Surface-supplied oxygen is substituted for air at the 20' and 10' stops (although U.S. Navy standard air-tables are followed), which provides an enormous safety factor.
3. A marked line is used to gauge the depths of dives at altitude, and a special set of altitude-conversions for decompression are strictly adhered to.
4. Divers must completely rest for one full minute before ascent to a decompression stage, or to the surface.
5. Before leaving the water after a stage decompression dive, divers take a 5-minute rest period, chest-deep in water. Heavy exertion immediately after a decompression dive is prohibited.

RESERVOIR INUNDATION STUDIES PROJECT DIVING CERTIFICATION
and PERSONNEL PRE-FIELD DIVING REQUIREMENTS

Core-Team Divers

Swimming (no equipment):

1. Swim underwater 75' on one breath with no dive or push-off.
2. Swim underwater 150' on 4 breaths with no dive or push-off.
3. Swim 400 yards, nonstop, in less than 10 minutes.
4. Swim 25 yards, nonstop, at the end of the 400-yard swim using 2 resting strokes.
5. Demonstrate survival swimming for 20 minutes (treading, bobbing, floating, drownproofing, etc.).
6. Tread water, legs only (hands out of water), for 2 minutes.
7. Tow another person of equal size 50 yards; the first 5 yards the victim should be struggling; demonstrate CPR.
8. Recover 10-lb. weight from a depth of at least 8'.

Skin-Diving:

(Note: All skin and scuba-diving skills are to be performed wearing a wet-suit jacket, a weight-belt adjusted for proper buoyancy, and an inflatable vest).

1. Demonstrate swimming with snorkel and fins with and without a mask.
2. Skin dive to a depth of 15' and recover an object.

3. Swim 880 yards, nonstop, in less than 18 minutes (with skin-diving equipment, using no hands).
4. Remove mask, fins, and snorkel under water and surface. After resting, dive and recover mask, fins, and snorkel on 1 breath. All equipment is to be in place, with mask and snorkel clear of water upon surfacing.
5. Complete rescue of another skin-diver. Execute a proper entry; swim 50 yards to another diver; pick up diver on the bottom in a minimum of 8' of water; bring diver to the surface; administer mouth-to-mouth resuscitation in deep water for 1 minute; tow diver 50 yards while administering resuscitation.

Scuba-Diving:

1. Demonstrate a well-controlled scuba ditch and recovery: descend to the bottom in a minimum of 8' of water and remove mask, snorkel, scuba, and weight-belt (retain fins); shut off air, swim 25' horizontally and surface; rest, dive, swim 25' horizontally and recover equipment. The total exercise is to be completed with all equipment in place within 5 minutes.
2. Demonstrate scuba bailout: enter the water carrying mask, fins, snorkel, weight-belt, and tank with regulator attached (air shutoff and regulator purged); settle to the bottom, assume a stationary location and don equipment. During exercise, control and possession of all equipment must be maintained. Upon completion of donning equipment, surface and tread water for 5 minutes without the use of vest, snorkel, or regulator. Exercise must be performed in a minimum of 8' of water.
3. Transport another scuba diver 100 yards in less than 4 minutes. Person being transported may not assist. Both divers are to wear scuba, weight-belts retained; breathing from regulator is not permitted.
4. Buddy-breathe with another diver while swimming horizontally underwater for 10 minutes--5 minutes as recipient, 5 minutes as donor. Divers are not to surface during the entire exercise; masks are not to be worn.

Other:

1. All divers on the core-team must be National Park Service certified, with a current medical examination form on file with the project diving officer.

2. All divers must fill out a project diving questionnaire, and present a log of at least 50 open-water dives. Although a log is preferable, a signed statement of participation in at least 50 dives, along with names and addresses of individuals who can verify (dive buddies or dive supervisors) this participation, would be acceptable.

3. A comprehensive written examination covering all areas of general diving expertise must be passed by all core-team members.

Note: The above water-skills standards represent a combination of National Park Service diving requirements and the National Association of Underwater Instructors (NAUI) assistant instructor skills test, with some additions and variations. National Park Service standards are met or exceeded in all cases.

Visiting Divers

Individuals wishing to participate in official project diving activities on a limited basis for a period not to exceed 2 weeks must meet the following requirements:

1. Must be fully certified by a nationally recognized diver-certification agency.

2. Must have a current medical examination form on file with the project diving officer.

3. Must be diving under the auspices of a recognized state or Federal agency or institution.

4. Must be willing to observe all project rules and regulations.

5. Must be in the company of a core-team diver, who in all cases will be the dive leader.

6. Must have gone through one complete project orientation dive with the project dive officer or his designate. This dive would include training in standardized project signals, self-rescue, and buddy-rescue techniques and accident management procedures.

Note: The above requirements may be modified in special circumstances at the discretion of the project dive officer.

Chapter VI

CONCLUSION

PROJECTIONS

Phase I of the Reservoir Inundation Studies Project terminates with the completion of this preliminary report. As indicated in the prospectus, the first phase was devoted to conducting background research on the problem of inundation; engaging in preliminary field-research; constructing guidelines for the integration of data from ongoing salvage efforts into the study; developing a viable capacity for underwater investigations; selecting test areas, and developing a systematic research design to be utilized in subsequent phases of the project.

Future phases of the study will focus upon the operationalization of the research design in field and laboratory situations and upon integrating data from outside contractors into an interim and final report. There will also be some aspects of the research approach that will receive more emphasis in future phases of the project than they received in Phase I.

LABORATORY TESTING

The project director has been convinced since the inception of the Reservoir Inundation Studies Project that a portion of the work could best be conducted in a laboratory environment, but that the project should for the most part be a field endeavor. In the real world, after all, cultural remains exist in reservoirs, not in laboratory environments. Where possible, it is felt that the one-to-one correlation that exists should be assessed without forcing a leap of faith to a laboratory-controlled simulation of reservoir variables. One would have to assume that the laboratory

situation has replicated all the relevant variables in its test-model; and also that the acceleration process necessary to simulate the temporal factors in the study has not had a skewing effect. There are, however, some aspects of the study that can be much better controlled in a laboratory situation, and some aspects that are too logistically difficult to test in the field. Consequently, arrangements are being made to conduct systematic testing of certain possible inundation effects in closed environmental units.

Specific aspects of the study that are amenable to the use of laboratory model are: the evaluation of certain mechanical effects, such as erosion and compression; and the possible impact of water-movement on microscopic wear-analysis.

COMPUTER PROGRAMMING

During Phase II of the Reservoir Inundation Studies Project, elements of the research design that lend themselves to computerization will be programmed. The criteria for choosing the reservoir areas to be programmed will be based upon whether the data in question is suitable in quantity and nature for computerized format, and whether it fits readily into one of the two models in the research design.

CONCLUSION

This preliminary report of the Reservoir Inundation Studies Project has focused upon outlining the parameters of a very complex problem, and an approach to dealing with it. Background studies and preliminary field-assessments have been conducted to enable the devising of predictive models for determining the impact of inundation on cultural values. Each section of the report has been constructed so that it can stand independently, but several general concluding remarks need to be made.

First it should be emphasized that neither this report nor any future reports that develop out of the Reservoir Inundation Studies Project is intended to be

used as the final word regarding cultural-resources-management decisions. The project has begun by providing a general data-base for decision-making on a reservoir-specific and site-specific basis. The selection of certain sites for salvage or preservation efforts should not depend merely on a prognosis of which sites will be the worst impacted or the easiest preserved. The question of significance, the determination of which derives from an understanding of the total archeological picture, becomes paramount at this point. In other words, an enlightened regional cultural-resources overview is necessary for the meaningful use of this data-base.

For some time, many archeologists have been expressing concern about the lack of a regional-overview base for the selection of sites to be mitigated in reservoir salvage situations (by either salvage sampling, or excavations or attempts at conservation) (Binford, 1964; Struever, 1968; Lipe, 1974). There is also concern that the organizational limitations of archeology today do not allow sufficient input from related disciplines to adequately assess the bio-physical environment in which cultural remains occur (Struever, 1968).

The Reservoir Inundation Studies project core-team members have been intensely involved in confronting the issue of reservoir impacts on cultural resources during this first 9-month phase of the project, and they have become increasingly convinced that these abovementioned concerns are valid.

Often, the funding mechanisms behind the conducting of mitigative actions only allow for work to be done in areas which will be actually physically touched by the rising waters of a reservoir. Such a condition might be an explicit stipulation of the funding agency involved, or else a de facto condition caused by limited time and/or monies. In either case, the result is the same, if the region in which the reservoir has been built does not already have a reasonable cultural-resources inventory. That is, decisions will be made to mitigate selectively, according to whims and educated guesses about which sites are really the most anthropologically significant. The Reservoir Inundation Studies Project team warns that the results of the study will be of little value when used in such a fragmented resources-management milieu.

We strongly recommend that increased efforts be made toward funding on region-specific, not reservoir-specific, bases, when initial survey and inventory efforts are being made. Money could possibly be made available from planning funds for proposed projects on a district basis. This would be particularly appropriate in the case of the U.S. Army Corps of Engineers, which defines its district boundaries along the lines of major drainage-systems, because these drainage-systems also frequently comprise the confines of a particular form of cultural expression.

It is understood that efforts are already being made in some areas to deal with this problem, and that, in fact, many of the solutions being endorsed here have also been entertained by others. The fact remains that, for whatever reasons (and some of them are probably very good ones), the situation remains critical, and until it is resolved, optimal use of the results of this Reservoir Inundation Studies Project will be impossible.

SCHEDULING AND FUNDING UPDATE

PHASE I: January 1, 1976 to January 30, 1977
(1976 FY and Transition Quarter)

Funding was not made available as anticipated in the draft Reservoir Inundation Studies Project prospectus of January 1976; thus, several target-dates projected in phase I were not met until 3 months after the original target-date.

Elements

1. Literature search completed May 30, 1976; published version available January 1977
2. Reservoirs visited during drawdown period:
 - a. Painted Rocks Reservoir, Gila Bend, Arizona
 - b. Roosevelt Lake, Arizona

3. Reservoirs visited that have sites that have been continually immersed since initial flooding:

- a. Amistad Reservoir, Texas
- b. Lake Mead, Arizona
- c. Lake Havasu, Arizona
- d. Lake Walter F. George, Georgia
- e. Table Rock Reservoir, Missouri
- f. Lower Monumental Lake, Washington

4. Specific sites visited that have been continually immersed, or have immersed sections due to natural conditions:

- a. Montezuma Well, Arizona
- b. Silver Springs, Florida

5. Work was conducted at Arenosa Rockshelter, Lake Amistad, Texas, to document the effects of inundation.

6. Tentative guidelines completed June 30, 1976; guidelines completed January 30, 1977. Preliminary report completed January 30, 1977.

7. Preliminary report completed January 30, 1977.

8. Reservoirs selected or being considered for selection for comparative analysis within the scope of the research design:

- a. Table Rock Lake, Missouri
- b. Palmetto Bend Reservoir, Texas
- c. Saylorville Reservoir, Iowa
- d. Tellico Reservoir, Tennessee
- e. Walter F. George, Georgia
- f. Abiquiu Reservoir, New Mexico

- g. Cochiti Reservoir, New Mexico
- h. Navajo Lake, New Mexico
- i. Conchas Lake, New Mexico
- j. Folsom Reservoir, California
- k. Chesbro Reservoir, California
- l. New Melones Reservoir, California

Budget

Total = \$130,000

Actually Spent = \$130,000

PHASE II: October 1, 1976, to September 30, 1977
(FY 1977)

Elements

1. Guidelines and research design will be operationalized in as many reservoirs as possible. Emphasis will be on the selection of reservoirs in California, the Pacific Northwest, and the Northeast. In phase I, reservoirs in the Southwest, Southeast, and Midwest were selected for research within the scope of the Reservoir Inundation Studies Project research design.

2. In areas where guidelines and research design were operationalized in phase I, monitoring will continue. Decisions will be made on the length of time needed to produce reliable data-results in previously established test-areas.

3. Data-collection will be begun in established test-areas by core team members, or be contracted out and monitored by team members.

4. In-house experiments with protective techniques will be initiated, to develop additional data on protective coverings for archeological sites.

5. The core-team will pursue development and refinement of underwater techniques for archeological data-retrieval and underwater excavation.

6. There will be consideration of remote-sensing capability and reliability for data returns before and during inundation and after drawdown in reservoirs.

Specific projects planned are:

a. A magnetometer survey at Palmetto Bend Reservoir, Texas

b. A comparison of aerial photographs taken prior to inundation and during a drawdown at three as-yet-unselected reservoirs.

7. Reservoir Inundation Studies Project study-controls will be established at a site to be inundated in Cochiti Reservoir.

Budget

Project staff salaries	\$80,000
Equipment acquisition, maintenance, and repair	15,000
Transportation and per diem for core-team	20,000
Contracts for data acquisition and analysis	37,000
Consultant services	<u>5,000</u>
Total =	\$157,000

PHASE II (cont'd): October 1, 1977, to September 30,
1978 (FY 1978)

Elements

1. Continuation of data-collection in reservoirs where tests have been established.
2. Establishment of on-site tests for protective coverings, using data obtained from FY 1977 experiments.
3. Test projects will be conducted at reservoirs in California, the Pacific Northwest, the Northeast, and Southeast.

Budget

Staff	\$90,000
Equipment acquisition, maintenance, and repair; and transportation of personnel	35,000
Data-analysis	20,000
Consultant services	10,000
Contract services	<u>30,000</u>
Total =	\$185,000

PHASE II (cont'd): October 1, 1978,79 to September 30,
1979 (FY 1979)

Elements

1. Continuation of data-collection for interpretation of the effects of inundation.

2. Collection of data on sites selected for on-site protective coverings.

3. Comprehensive, long-term pre-inundation tests will be established in each major geographic area of the Nation. These tests will provide for the long-term monitoring of site-inundation by reservoir activities.

Budget

Staff	\$90,000
Equipment acquisition, maintenance, repair; and transportation of personnel	40,000
Data-analysis	20,000
Consultant services	10,000
Contract services	<u>25,000</u>
Total =	\$185,000

PHASE III: October 1, 1979, to September 30, 1980

Elements

1. Final collection of data to be used in final research report:

- a. Data on effects of inundation
- b. Data on effectiveness of protective covers

2. Final report on the effects of inundation on archeological resources and possible protective mitigative measures. Target date, September 30, 1980.

Budget

Staff	\$95,000
Equipment acquisition, maintenance, repair; and transportation of personnel	30,000
Data-analysis	25,000
Consultant fees	15,000
Contract services	<u>20,000</u>
Total =	\$185,000

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APPENDIX A: RESULTS OF PRELIMINARY RESEARCH

GENERAL DISCUSSION

One of the major goals of the project is to compile a data-bank containing information that can form a base for developing predictive models, so that land managers and archeologists may know what types of impacts to expect, and can assess which mitigative alternatives to consider in the interest of cultural-resources management.

In order to assess what impacts can be expected from inundation, a variety of sites located in several reservoirs throughout the Country have been selected for testing, on the basis of geographical, geological, and cultural diversity. In selecting for diversity in cultural and geomorphological settings, a wide range of variables will be included in the final assessments.

The field sessions conducted during Phase I of the Reservoir Inundation Studies Project have for the most part been reservoir-assessment trips. When these reservoirs are analyzed for the more intensive testing phase of the project, four variables are assessed:

Prior documentation

Accessibility of site/site relocation

Reservoir environment

Logistical support

Before any actual reconnaissance of a site is attempted, prior documentation is researched. Prime consideration is given to sites that have adequate pre-inundation documentation, because a major portion of the project will involve a comparison between pre- and post-inundation data-retrieval and analysis potential.

Optimal prior documentation would include the complete mapping, sampling, and recording techniques described in the section of this report dealing with guidelines for data-collection and site-preparation. Because of the rapid development and perfection of archeological techniques within the past 35 years, some of the

older reservoirs that have been or will be examined by the study team do not always conform to these guidelines. However, these reservoirs will still be considered for more intensive investigation, because length of inundation supplies a variable not available in current salvage projects.

It should be mentioned here that testing will not be confined to the well-documented, previously excavated sites. In some instances, naturally impounded areas, such as freshwater springs, sinks, and karst formations, will be assessed, because temporal controls can be developed through on-site testing of these long-term inundated sites.

With a grasp of the location and cultural content from the pre-inundation documentation, on-site investigation begins. Once the site is reached, depth of the sites is a major consideration. Generally, sites deeper than 120' are not regarded as feasible for intensive investigations due to physiological limitations of the divers. At such depths, working time is restricted to the point that intensive testing is made inefficient; however, some limited investigations will be conducted of sites deeper than 120', because the possibility that water depth is a destructive factor to archeological sites must be considered and tested. A deep site may be specially chosen for the more intensive testing phase of the project to test this specific "depth" variable.

Relocation of sites can be a major problem. In most cases, sites investigated by the team have not been observed prior to inundation. The location information on site-cards was recorded when the site was dry, and many or all of the major reference points may have been inundated with the site.

When possible, contact is made with the archeologist who originally surveyed or excavated the site, who may then either pinpoint the site on a topographic or reservoir map, or meet the team in the field to aid in relocation. Reference to major landmarks in the general area may help to pinpoint the site.

A survey dive is then made, using various survey-techniques, including compass transects; arc surveys

using a line off of a set point; and remote-sensing. Relocation sometimes occurs relatively quickly, if the site-card information is correct, and physical remains of the site are in evidence. (During the initial assessments, problems have been encountered in using this process due to poor site recording).

During the course of the assessment, the site is referenced, by shooting the location with a transit or compass; and photographic references are made. Although a site may be marked under water by means of a permanent datum-point, it is never flagged on the surface in a manner that would invite possible disruption by sport divers or pot hunters. With proper referencing, Reservoir Inundation Studies Project team archeologists can return at various times to monitor the site and continue investigations.

While the general area is surveyed for physical remnants of the archeological site, various reservoir environmental factors are monitored. Water visibility and temperature readings are taken from the surface to the bottom or deepest areas of the site. Visibility is a major factor in the relocation and eventual assessment of the site. Although a site may be mapped and tested in less than 2'-visibility water (as was accomplished by the core team at Arenosa Rockshelter in Amistad Reservoir), increased visibility makes any work under water more efficient. Reservoir temperature is recorded to provide a better understanding of the diving environment, and also because there is the possibility of differential effects of temperature on preservation of cultural remains in an archeological site.

The bottom configuration of the general site area is also noted during assessment. While it may act in some respects to preserve a site, the accumulation of silt or mud can hamper site relocation. In certain situations, the only visible remnants of a site may be covered with silt ranging from a scant covering 2' to 10' deep.

Bottom configuration also includes the extent to which the site is covered by vegetation. Heavy tree or shrub accumulations make surveying the site more difficult. For example, at Lake Mead in Nevada (see later section in this chapter), mesquite cover was so thick, and visibility so limited, that surveying for the submerged

historic Mormon Town of St. Thomas was made more difficult. However, pre-inundation and site-location information was sufficient to enable the team to relocate the town.

ASSESSMENTS

PAINTED ROCKS RESERVOIR, ARIZONA

The feasibility of conducting inundation studies within the Painted Rocks Reservoir was evaluated through onsite reconnaissance of previously reported sites, from June 17-19, 1976. Before they visited the reservoir, members of the Reservoir Inundation Studies Project team spent time researching background data at the University of Arizona's Arizona State Museum, and at the National Park Service's Western Archeological Center--both located in Tucson.

At the Arizona State Museum, site file-cards and archeological base maps of the reservoir were consulted and copied. At the Western Archeological Center, several preliminary reports and the final report of the reservoir's archeological inventory survey were studied. Literature dealing with the cultural resources of this reservoir area is limited, and William W. Wasley's and Alfred E. Johnson's "Salvage Archaeology in Painted Rocks Reservoir, Western Arizona" is the "best and most complete document.

An on-ground assessment of sites that would be appropriate for study within the scope of the present research strategy for the Reservoir Inundation Studies Project revealed that no previously excavated sites that were subsequently inundated are now accessible. Several excavated sites were never inundated, and the remaining excavated sites are located in a thick mesquite and saltcedar marsh on the north side of the reservoir. Access to the latter sites is primarily cross-country, and involves a walk of approximately 4 miles, before the marsh is entered. A site visited on the south side of the reservoir (T13:5) was 5/8 mile from a road, and heavily overgrown with saltcedar. Although recorded and inundated, this site was never excavated.

Relocation of sites within the actual maximum flood-pool area is hindered by a dense and extensive growth of saltcedar. This saltcedar accurately delineates the maximum reservoir pool limits. The availability of a helicopter would greatly assist the team in locating some sites that are marked by trash-mounds or platform-mounds.

An important indirect impact on inundated sites--at least in Painted Rocks Reservoir--is the noticeable change in vegetation in the inundated area. This vegetational change is characterized not only by an increase in population density, but also by a total change in speciation. Saltcedar has become the dominant plant in the floodpool area. The dense stands of saltcedar exclude indigenous trees and shrub species. Saltcedar root disturbances may exert a highly destructive force upon archeological sites. Although the natural plant community is comprised of large shrubs and trees, such as paloverde and mesquite, it is very openly spaced under natural hydrological and climatic conditions. The effects of root disturbance by the original plant community seem to be much less destructive than that in present introduced saltcedar situations.

A study of the effects of saltcedar introduction would seem important. Such a study would first have to assess the actual root-disturbance potential of saltcedar. If the hypothesized disturbance is high, an archeological test situation would then have to be generated. Because no previously excavated sites in the saltcedar-dominated flood area are accessible, the control situation needed to implement this research is unavailable. Testing of the effects of introduction of saltcedar into reservoir environments may not be ideally conducted at this particular location. However, the possible impacts upon sites, by not only saltcedar, but also by other vegetational changes caused by inundation, should be thoroughly evaluated.

LAKE HAVASU, ARIZONA

The Reservoir Inundation Studies team met with members of the Bureau of Reclamation's Lower Colorado Region Dive Team at Lake Havasu, Arizona, on June 22 and 23, 1976.

Because limited pre-inundation archeological excavation was conducted in the reservoir area, there is scanty background data relating to submerged sites. However, it had come to our attention from a Bureau of Land Management memo to the chief of the National Park Service's interagency archeological services office in San Francisco, that a local diving club planned to undertake excavations of Aubrey Landing, a drowned 19th-century steamboat-landing townsite in the Lake Havasu reservoir area.

On the basis of this knowledge, and consideration of the possibility that this submerged historical archeological site may be useful for data comparison in our research, it was decided the Project should conduct dives and evaluate the underwater archeological potential of the reservoir.

The Bureau of Reclamation's Lower Colorado Region office provided the Study team with 2 boats and the assistance of 4 members of their dive team: Max Groom, Dive Safety Officer; Hollis Pope; Wayne Deason; Dave Branstetter; and Mack McCormick, boat-tender.

Using information from local residents and newspaper articles, the National Park Service and Bureau of Reclamation crews dived in the general area of the confluence of the Bill Williams and Colorado Rivers--the pre-inundation location of Aubrey Landing. This area is easily accessible and workable by boat.

The water conditions in the reservoir do not appear to hinder underwater investigation. Visibility ranges from 6" to 5'--comparable to most of the reservoirs we will be testing. The bottom varies from sand, rock, and shallow silt, to 1 1/2' or more of silt close to shore and several feet of silt near the river channel. The Bureau of Reclamation divers maintain that visibility improves in winter to a maximum of 20'.

One of the main determinants of site and reservoir suitability is pre-inundation excavation, so that comparisons can be drawn, and assessments made of the effects of immersion on specific sites. Because little archeological work has been previously performed at Lake Havasu, this reservoir will be assigned a low priority for extended testing by the Reservoir Inundation Studies Project team.

However, if overall water and diving conditions are acceptable, and site location and continued logistical support are available, the reservoir might be considered an acceptable area in which to test mapping, sampling, and remote-sensing techniques.

LAKE THEODORE ROOSEVELT, ARIZONA

The Reservoir Inundation Studies Project team worked at Theodore Roosevelt Lake, Arizona, from June 26-30, 1976. The team was met by Martin McAllister, a Southwest Region Forest Service (U.S. Department of Agriculture) archeologist; and by Ray Ruppe of Arizona State University.

In June, the lake is in a drawdown period. Most of the site-assessment work was conducted at 30' and shallower. Visibility ranged from poor to fair. Silt was not a problem, because it usually ranged from only 1" or 2" to 6", which is not a problem to divers. The only investigated area that had deep silt was one in which we checked for a submerged Pueblo site across from Roosevelt 9:5 noted on aerial photographs.

The lake is cold, and a full wet-suit with hood is required. A dry-suit would merit strong consideration for any prolonged work deeper than 45'. During June, the lake layers are very clearly stratified, as can be seen from these readings:

30' - 74°F	8' - 10' visibility without light
45' - 65°	(no visibility-reading taken)
60' - 58°	(no visibility-reading taken)
75' - 54°	3' visibility with faralight

Background research was conducted at the National Park Service's Western Archeological Center in Tucson. Initially, Roosevelt 9:6 appeared to be the most promising. Roosevelt 9:6 is a Hohokam Colonial Period pithouse village, excavated by E. W. Hauray in the early 1930's; a report was privately published in 1932.

After a bottom search and a search of the shore for an adjacent Pueblo site proved unsuccessful, it was

decided that the reported location could be incorrect. Arizona State Museum maps placed Roosevelt 9:6 off School House Point, but the site card-file placed it closer to Pacter Spring, the next drainage downstream.

After inspection of a large Pueblo site across from Windy Point (possibly Roosevelt 9:7), it was determined that Roosevelt 9:6 and similar sites would be extremely difficult to relocate by direct search and survey, due to the lack of structural remains, silting, and poor visibility. Remote-sensing--that is, side-scan sonar, or fathometer--may possibly prove effective here.

The archeological resources of Lake Roosevelt are considerable, and have a fair amount of prior documentation, but there are inconsistencies in reported site locations. Lake Roosevelt has been assessed as viable for possible future research by the Reservoir Inundation Studies Project; however, at this time, there are no active plans for research in the reservoir.

MONTEZUMA WELL, ARIZONA

Members of the study team visited Montezuma Castle National Monument on July 2 and 3, 1976. With the consent of Superintendent Glenn Henderson, the group made one dive to evaluate the well's potential for inclusion in the intensive testing phase of the Reservoir Inundation Studies Project.

As discussed in a previous National Park Service archeological report by George Fischer, the talus slope around the rim of the well is littered with an abundance of cultural debris, including ceramics and ground-stone implements, which had probably fallen into the well from the habitation sites above.

It was determined that Montezuma Well presents some potential, in a very limited sense, for our study. There is a large amount of submerged cultural material evident in the talus slopes around the perimeter at the sink, the study of which would be of unquestionable archeological value. For the most part, however, this material is not suitable for use in the Reservoir Inundation Studies Project, because there is not

sufficient prior archeological data with which to compile an adequate baseline control on effects of immersion. The one exception would have been the presence of fairly intact ceramics, lithics, or building material in a well-stratified context. After close observation, the study team has concluded that, although it is possible that such a situation may exist beneath the talus overburden, an absolute determination will require a controlled full-scale testing excavation. Such an excavation would present some logistic problems to the archeologist, and a possible management problem to the area superintendent, and would result in data that may possibly be skewed due to the high carbon-dioxide content of the water.

Diving conditions at Montezuma Well were workable, but by no means ideal. To get to the deeper part of the well, one has to wade through the perimeter, which consists of 2'-3'-deep mud and pond weeds. Visibility was 7' at the surface, and 6'4" from 10' deep to the bottom. There was no vertical stratification of water temperature: the water-column registered a constant 75°. Full wetsuits would not be required, except for working dives.

The bottom of the well has a strange consistency, resembling a white lava flow moving on top of a suspended bottom that has a silica-gel consistency. Further investigation of the area would be required to explain this "moving bottom" phenomenon. It should also be noted that there is apparently a 7-minute interval between the time that the water exits from the well and the time when it reaches the outfall outside the well's wall.

If further testing is to be conducted, a more efficient means of transporting equipment will have to be developed. During our initial testing phase, double tanks had to be packed in for the long trek up to the rim and then back down to the well's edge. A dive staging area would have to be set up at the water's edge, with a compressor to fill tanks and storage-areas for gear.

Future testing could be carried on in the well, although some major logistical problems would have to be worked out prior to a more intensive investigation. It has been determined that further research at the well is low in priority for the project.

LAKE MEAD AND LAKE MOJAVE, ARIZONA/NEVADA

The Reservoir Inundation Studies Project team investigated Lake Mead and Lake Mojave from July 5-9, 1976.

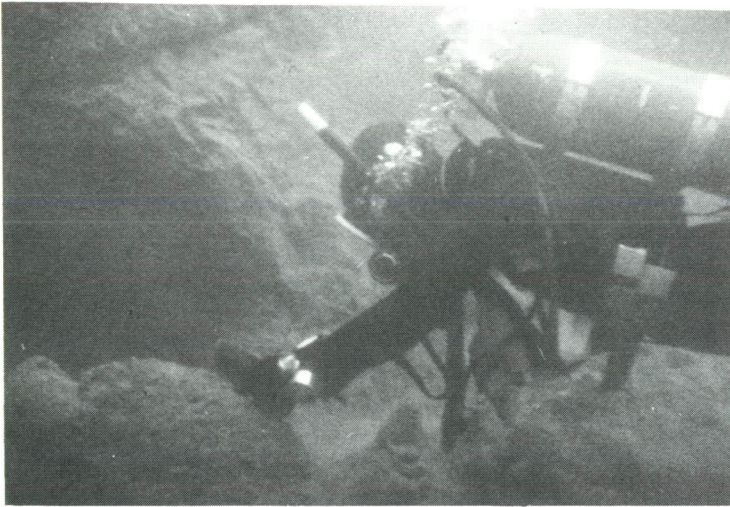
Copies of area maps with plotted sites were obtained from the National Park Service's Western Archeological Center in Tucson.

Assistant Chief Ranger David J. McLean of Lake Mead National Recreation Area provided support, and personally accompanied the team on its investigations. He arranged for the Lake Mead archeological site file to be available for use in preliminary background research.

A search of the site card-files produced an abundance of prehistoric sites, several of which had been excavated. Descriptions of over 100 sites that appear to satisfy research requirements were obtained from the file.

The first site investigated was the submerged Mormon town of St. Thomas, dating from around 1890, and situated in the upper reaches of Overton Arm of Lake Mead. The remains of a walled structure were located in 28' of water. Visibility at a depth of 10' measured at 7'4", and at a depth of 20' measured 5'10". The silt overburden varied between 6" and 1'. The bottom was quite cluttered with mesquite and brush, and although such an environment would limit work to poor-visibility techniques, a full investigation could be carried out. (See diagram, for dimensions of wall structure).

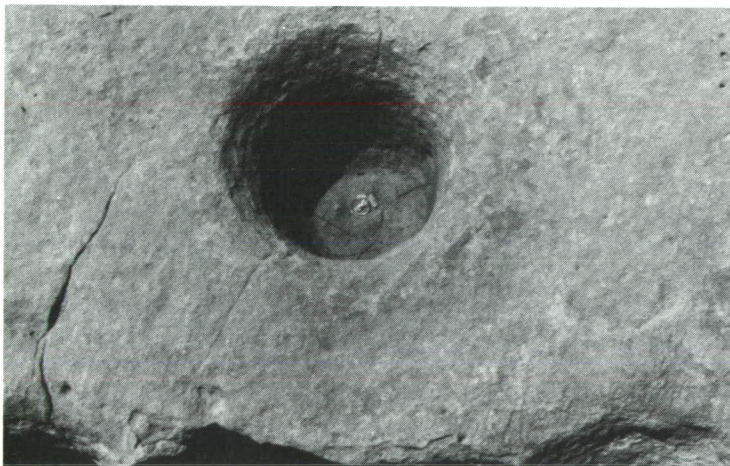
Across from and north of St. Thomas is the "Lost City," which consists of a cluster of Pueblo and Paiute sites. A bottom survey did not produce any evidence of the sites. The bottom was heavily covered with mesquite and brush, with visibility from 1' to 5', and silt layers from 6" to 1-5' thick. Team members put ashore at the Lost City site area relocated an extensive Pueblo complex. Although all of the sites were situated on relatively high ground, the area appeared to have been inundated at some time in the past. These sites serve as a key to the submerged portion of the complex, and a future survey should relocate the submerged sites for use in comparative studies.



A project archeologist investigates a submerged rockshelter in Lake Mohave.



In front of the rockshelter, a pestle is found still in place in a bedrock mortar.



A similar feature in a dry context several miles upstream.

Lake Mead offers very good working conditions. Water temperature at the surface varied in different areas from 75° to 83°, with only a gradual temperature reduction down to 80', where the temperature is 60°. Visibility ranges from adequate in shallow water (4' to 6'), to good in many places in deep water (24' of measured visibility at a depth of 50'), with appreciable surface light at 130', although lights would be required for work deeper than 80'. Divers observed that visibility increased at depth--to perhaps 30' at a depth of 130'.

Almost the entire length of narrow Lake Mojave is shown on early archeological base-maps as being dotted with submerged prehistoric sites. The team concentrated its investigations upon two areas south of Willow Beach, Monkey Hole, and "the Caves". Several rockshelters were relocated and identified on the basis of ground-stone and bedrock mortars. The area would appear to contain a wealth of still-fairly-intact sites located in depths from 35' to 80'.

Lake Mojave, located below Hoover Dam, and formed by Davis Dam, has excellent visibility. Visibility of between 20' and 30' was the norm, and little silt was encountered, except in the bed and wash areas of the Old Colorado River. A mild current of about 1/2 knot is present. A current such as this would be beneficial, serving to keep the site "clean" of suspended silt during testing. The water is comparatively cold (55°) and dry-suits should be used for prolonged work in this area.

Lake Mead and Lake Mojave both offer sites and conditions that are suitable for extensive investigations by the Reservoir Inundation Studies Project team. Support facilities, including boating and diving support equipment are available.

MARMES ROCKSHELTER, WASHINGTON

Two members of the Reservoir Inundation Studies Project team visited the Marmes Rockshelter site in southeastern Washington from July 19-22, 1976, to investigate its potential for use in the project. The study-team members were met at Washington State University, Pullman, by Ann Monseth Irwin, Operations



Reservoir Inundation Studies Project core-team members conduct assessments and underwater investigations from this mobile unit. The trailer carries an air compressor, wet-suits, mapping table, and other wet or dirty items that should be separated from the fragile electronic gear carried in the van.



Inundation Study archeologist takes temperature readings at Marmes Rockshelter. The tape in his left hand is for measuring visibility conditions. Such information is a standard part of the data collected for assessment purposes.

Manager of the Laboratory of Anthropology. Complete access to all pertinent excavation reports, maps, and materials was made available to the team. In addition, the team members were able to meet and discuss the site in detail with project zoologist Carl E. Gustafson; Paul Gleeson, who participated in all phases of the excavations, and excavated one of the few deep test pits; and Al Marshall, who was most helpful with the geology of the site and area. Conversations with the above, and the meeting with Ann Irwin, combined to give the team excellent background information relevant to the archeology of the Marmes Rockshelter.

The Marmes Rockshelter site contained human skeletal and cultural remains dated to 10,000 to 11,000 years old. The site was excavated between June 1962 and 1968 by Washington State University, under the direction of Richard D. Daugherty, and through the sponsorship of the National Park Service. Because of the exceptional nature of the finds, the Marmes Rockshelter site was designated a National Historic Landmark site in 1964.

The site was to be inundated by the Lower Monumental Reservoir of the Snake River, and plans were implemented for construction of a levee by the U.S. Army Corps of Engineers to prevent flooding. When it became obvious that the levee would not prevent inundation, the already-excavated areas of the site were lined with plastic film, backfilled with sand, and in some areas capped with gravel. The site was completely flooded by February 26, 1969.

It should be pointed out that the water did not come over or through the levee; rather, it percolated into the impounded area through a gravel bar on the western edge of the site. The water did not percolate through any excavated area of the site, but it percolated into the impoundment around the periphery, so that flooding was gradual. The team focused its attention primarily on the floodplain section of the site. The interior of the rockshelter was backfilled to within 1.5' of the water surface, and it was feared that large breakdowns in the interior of the shelter would prevent effective sampling.

The floodplain component of the excavations offers excellent background-data and accessibility, and also contains a deep trench test-area that went below the

Harrison Horizon, which served as the limit of excavation for the rest of the site. This deep test-trench is located at the southwestern corner of the intersection of the two primary trenches cut by bulldozers to clear off overburden, and was excavated in 5' x 5' squares. The east-west trench was 35' wide and 150' long. The north-south trench was approximately 20' wide and 200' long. Two secondary north-south trenches were cut on either side of the primary north-south trench at the extreme east and west ends of the cross-trench. These secondary trenches measured 25' by 35' on the east, and 25' by 70' on the west. All trenches were lined and backfilled prior to inundation.

Diving conditions on the floodplain proved quite satisfactory. The bottom was covered with dense vegetation, except for the trenches, which had not been severely encroached upon by aquatic weeds because of the plastic liner and sand backfill. All the trenches were relocated, and it is felt that any particular point along the trenches could be found without great effort. Visibility was very good, measured at 7.4 meters at 25'. The temperature of the impounded area was quite stratified, measuring 71°F at surface, 65°F at 24', 62°F at 28', and 59.5°F at 30'. Dry-suits would be required for prolonged work below 25'. The greatest depth noted by the team on this dive was 31'. The team confined its investigations to the northern area of the floodplain, but slightly more depth may be attained out toward the levee wall.

Excavation data indicated that the depth of the trenches ranged from 8' to 14' in the deep test area. The depth of the water-column, from 20' to 30', is sufficient at this point to allow use of an airlift for removal of the backfill so that the necessary testing procedures may be carried out.

The site is accessible by road, so boat support is not necessary. Small towns lying within 15 miles of the site offer food and lodging, and a state park 5 miles away offers ideal camping facilities.

The Marmes Rockshelter site offers good site conditions and good background data, and merits strong consideration as a choice for the intensive field phase of the Reservoir Inundation Studies Project.

COCHITI RESERVOIR, NEW MEXICO

During the 1974 field season, the University of New Mexico's Office of Contract Archeology excavated a number of sites along the middle Rio Grande River, between Bandelier National Monument and Cochiti Dam. All sites were situated within the 100-year flood-pool level of the proposed Cochiti Reservoir.

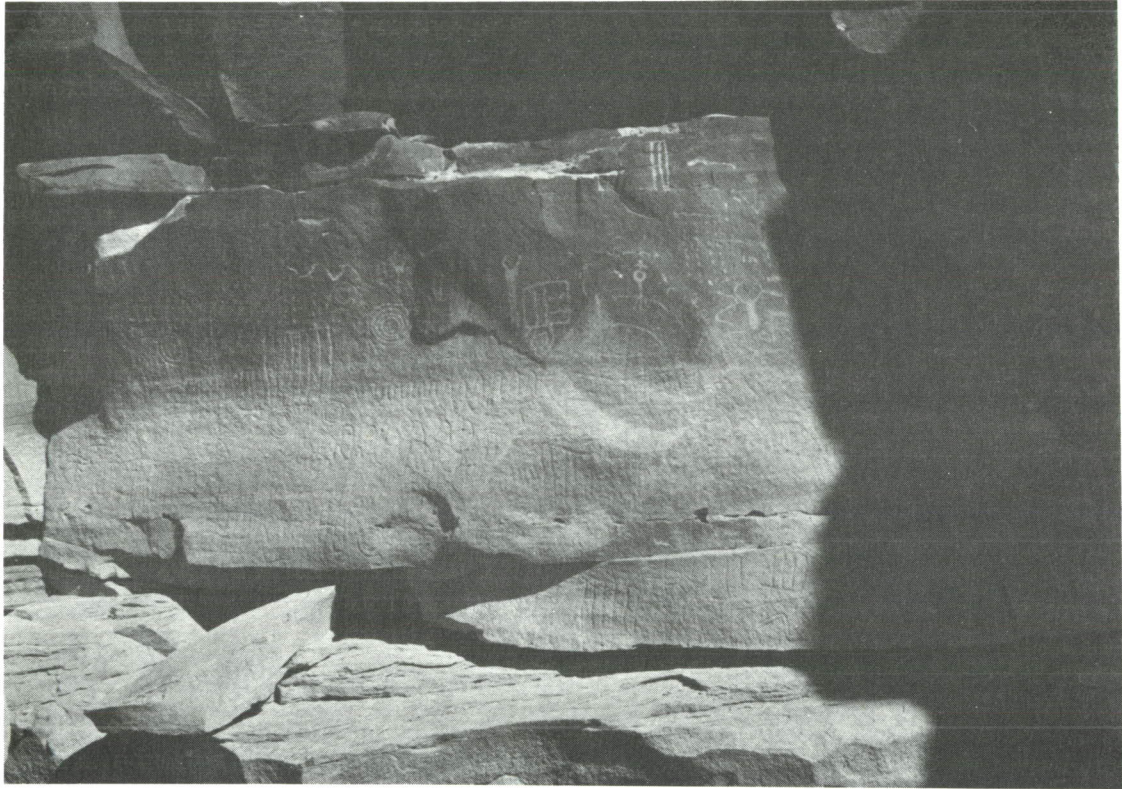
One of these sites, LA5014, a partially excavated Coalition Period Pueblo site, was selected for assessment by the Inundation Study team. During December 1975 and January 1976, the rising waters of Cochiti Reservoir briefly inundated the site. A series of photographs taken of the site before inundation in 1975, and after inundation in April and June 1976, records the site damage that has occurred as a result of flooding.

The site consists of two separate blocks of contiguous rooms. The outline of the rooms is delineated by basalt clasts, which had originally been set in trenches. Time and nature have washed away all remains of the adobe walls that were built atop these foundations. In most cases, the only evidence of floors are floor features such as hearths and pits.

A subterranean kiva is associated with each room-block. One kiva was completely excavated, and left unback-filled; the other was partially excavated, and later backfilled. The completely excavated kiva showed serious slumping. Adobe plaster that previously covered the slab walls has sloughed off. Standing water and vegetation were noted in the bottom of the kiva.

The surface room-blocks have not been seriously affected by the inundation. The basalt clasts and internal room features (such as hearths) remain intact. However, it is not known at this point whether or not any subtle disturbances such as flaking and expansion may have occurred within the hearths, which might skew archeomagnetic dating.

At the northeastern edge of the site are several petroglyphs pecked into large basalt boulders. These will be periodically examined to see what effects, if any, erosion and the chemical properties of the water may have on these resources.



This rock art panel, located at Conchas Lake, New Mexico, has been impacted by the fluctuating water levels of the reservoir.

(Photo--Courtesy of School of American Research)

This site and other sites not now slated for inundation will be prepared for comparative testing for inclusion in the Reservoir Inundation Studies Project.

WALTER F. GEORGE RESERVOIR, ALABAMA/GEORGIA

From October 21-22, 1976, study-team archeologists visited Walter F. George Reservoir, located on the Alabama/Georgia border. Frank Schnell, archeologist with the Columbus Museum of Arts and Crafts in Columbus, Georgia, who has worked on an assessment of archeological resources remaining in Walter F. George Lake, met the team in Eufaula, Alabama, and accompanied them during their assessment of the reservoir. Mr. Schnell has had a personal interest in the effects of inundation on archeological sites, and is well-informed about the types of problems with which the study team is concerned.

When the reservoir was formed in 1962, 400 archeological sites located by the River Basin Surveys of the Smithsonian Institution were inundated. Seventy-two of these had been tested by the Smithsonian Institution; the University of Georgia Laboratory of Archeology; and the Department of Anthropology of the University of Alabama.

The U.S. Army Corps of Engineers, managing agency for the reservoir, supplied the study team with a boat and pilot for their work at the lake. Three sites were examined during the initial assessment.

The Rood Mounds Site, an early Mississippian Mound, was investigated first. This site has never been inundated, but because of its proximity to Rood Creek, it has become a peninsula extending into the lake. Thus, various mechanical impacts have begun to affect the structural integrity of areas of the site lying adjacent to the reservoir edge. Slumpage, horizontal undercutting, (measured to a depth of 6') have been observed by Mr. Schnell at this site. A 2'-3' moat surrounding the site prior to inundation has since been enlarged to 5'.

The next area examined by the study team contained the remnants of the Reeves Mound Site, a Cartersville-Crooked River site, which had been partially excavated

by the University of Alabama. Except for a 10'-by-12' area that was projecting out of the water about 3' when the team was there, this mound remains in an almost continually inundated state (although during low water periods a larger portion of the site is exposed). The mound's location in a large floodplain exposes the site to various mechanical impacts: natural waves and prop action resulting from boat traffic appear to be damaging the exposed areas of the mound; the vegetative covering is being reduced by erosion.

An attempt was then made to relocate the permanently inundated Mandeville Site, in the southern end of the reservoir; however, because of the repositioning of channel buoys in the area, the team was unable to find the site. With more time, and correct locational information, a resurvey and possible testing of the site may be considered in the future. A short dive was made in the area to check reservoir conditions. Water temperature was estimated to be about 65°, with no appreciable change to a depth of 30', which is the bottom in this area. Water visibility was at least 2', and surface light penetrated to the bottom.

Several archeological sites with prehistoric earthworks are situated in the Walter F. George Reservoir. Knowledge of the effects of reservoir inundation on earthworks is critically needed--particularly in the Southeastern United States, where there are many sites with earthworks. Because the sites in Walter F. George Reservoir are well-documented in regard to their pre-inundation conditions, they will be considered as test situations for further work within the scope of the Reservoir Inundation Studies Project research design.

SILVER SPRINGS, FLORIDA

Project archeologists conducted an assessment of the underwater-archeology potential of the head spring at Silver Springs, Florida, on October 26-27, 1976. Prior work in the main spring had been conducted at the Cavern Site (Neill, 1964), an underwater site located in the large limestone cavern through which the spring-water emerges. Divers brought cultural material and faunal remains of mammoth and mastodon to the surface. Unfortunately, much of the faunal material remaining in the cave is largely disturbed; over the years, divers

entering the cave have placed it in neat piles atop large limestone spalls that have sloughed off the cave walls and ceilings.

Although there is an abundance of historic material, such as bottles, coins, and glass, no prehistoric cultural materials were observed in either the cave or the sink area outside the cave. It is possible that sub-surface testing with a coring device might yield ceramic, lithic, and bone artifacts. The numerous archeological sites and isolated artifacts located in and around springs and spring-runs attest to the prehistoric and historic popularity of spring areas.

The potential for research in the head spring lies in obtaining results from coring sediments from the cave and spring area. Equally important is the abundance of well-preserved faunal remains, many of which represent extinct faunal forms, which have been submerged for thousands of years. Detailed analyses of the faunal material and deposition environment could yield information on the various factors contributing to the preservation of these materials.

PRELIMINARY MAPPING AND SAMPLING AT AMISTAD RESERVOIR, TEXAS

The initial assessment completed in April 1976 by the Reservoir Inundation Studies team at Amistad Reservoir near Del Rio, Texas, indicated that complete background data was available; sites were accessible and readily located; diving conditions were acceptable; and logistical support was quite adequate. Because reservoir conditions fulfilled the criteria used to choose areas for more intensive testing, it was decided that the team would return to Amistad in late August and early September to continue research in the reservoir.

Three phases of site-inundation research were conducted. A major portion of the field-work was devoted to assessing freshwater effects on Arenosa Rockshelter, an Archaic site located on the Pecos River, 3/4 mile from the confluence of the Pecos and Rio Grande Rivers. Dave Dibble of the Texas Archeological Survey directed excavations at the rockshelter during portions of three field seasons

between 1964 and 1967. The Arenosa rockshelter is an extremely deep site, with well-defined stratigraphic profiles extending to 40' in depth, due to periodic flooding of the two rivers, and subsequent deposition of alluvium on human-activity areas.

Project archeologists were able to relocate Arenosa when the initial assessment of Amistad was made in April 1976. One of the primary research aims of the second investigation was to re-map the new-inundated shelter so that a comparison could be made between the map completed by the team and the site maps and photos taken during salvage excavations. From this comparison, an analysis could be made of the mechanical effects of freshwater immersion on the site. Dibble was present when the reservoir was filling to its conservation pool, and observed the standing profiles at Arenosa slump as the water rose. Re-mapping was carried out to graphically represent his observations.

Because the water visibility in this specific area of the reservoir was poor (usually less than 2'), re-mapping of the shelter proved to be a complex undertaking. Three different methods were attempted.

The first considered was use of the underwater plane-table, and alidade (for a complete description of these instruments refer to the chapter of this report devoted to underwater data-retrieval techniques). The poor water visibility at this site precluded use of this method, because optimal use of the alidade even with lighted stadia-rod, requires considerably better visibility. Also, the shallow, low configuration of the rockshelter did not lend itself to mapping with the stadia-rod.

The second method considered was the use of an azimuth ring drafted onto the plexiglas top of the underwater plane and the use of fiberglass tape for distance measurements. This method would have been applicable if the talus in front of the shelter had not been so steep. Because of this steepness, the plane-table was not high enough to enable measurements to be taken at the rear of the shelter. In addition, the prevalence of extremely fine, deep sediment in the area caused the plane-table to sink into this material.

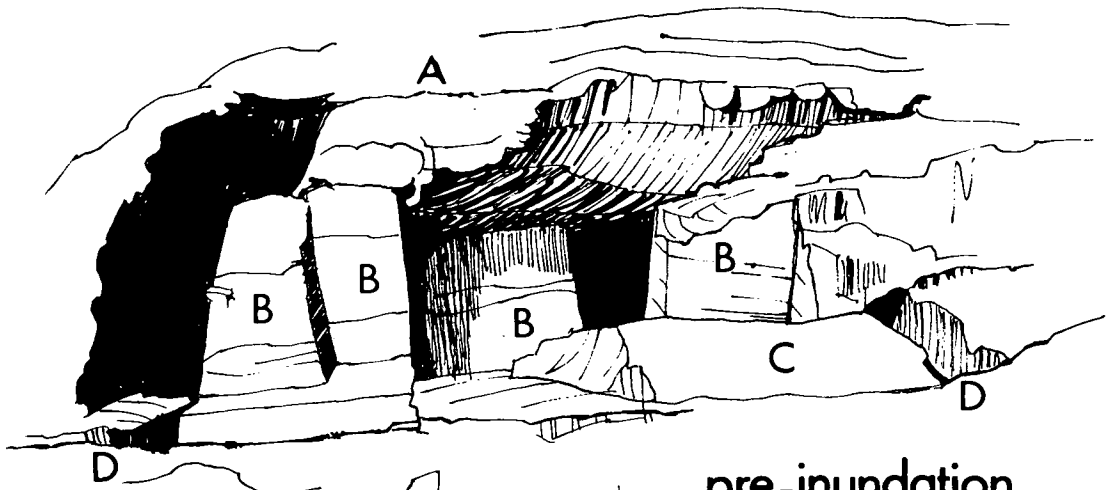
The third method involved use of two horizontal parallel baselines laid across the opening of the rockshelter.

One diver remained at the baselines to guide the diver with the end of the tape to the rear of the shelter, and by using a series of predetermined line signals, the first diver made certain that the tape remained perpendicular to the baseline. The second diver, at the back of the shelter, then leveled the tape so that a third diver could swim along the perpendicular tape at 1-meter intervals and take distance measurements to the ceiling of the shelter and to the top of the sediments on the bottom of the shelter.

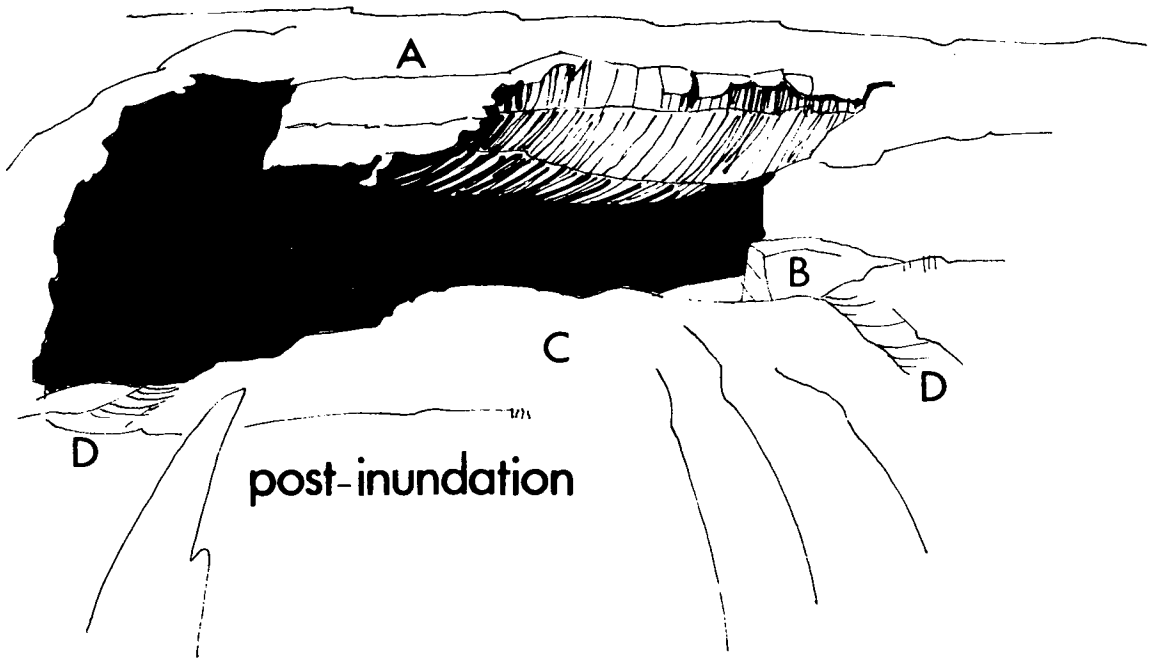
After the map was completed by this baseline technique, the archeologists tested the use of a fathometer for mapping in this situation (use of this instrument detailed more completely in the chapter in this report devoted to underwater data-retrieval techniques). The transducer-head was moved along the baseline, facing horizontally into the rockshelter, to obtain horizontal distance readings to the bedrock wall. The team was only able to work with the fathometer for a limited time at the shelter, but was able to ascertain that the system would work, and would probably achieve acceptable results in low-visibility situations, with more efficiency than a manual system, such as the baseline technique described above.

Another task undertaken by the team at Amistad was the removal of an adobe brick from an historic ranch-house site that had been submerged when the reservoir was formed in 1968. One of the project goals is to develop techniques for preserving sites that will eventually be inundated. The brick was removed from a low wall adjacent to the house. The weakened condition of the wall brick required that extreme care be taken in its removal. It was placed on a piece of cement block, and was transported wet, in a plastic bag, back to shore. It was then placed in a Styrofoam container filled with water from the reservoir, and transported back to Santa Fe for eventual analysis by National Park Service stabilization experts.

It is anticipated that a determination of the chemical effects of fresh water on certain types of adobe can



pre-inundation



post-inundation

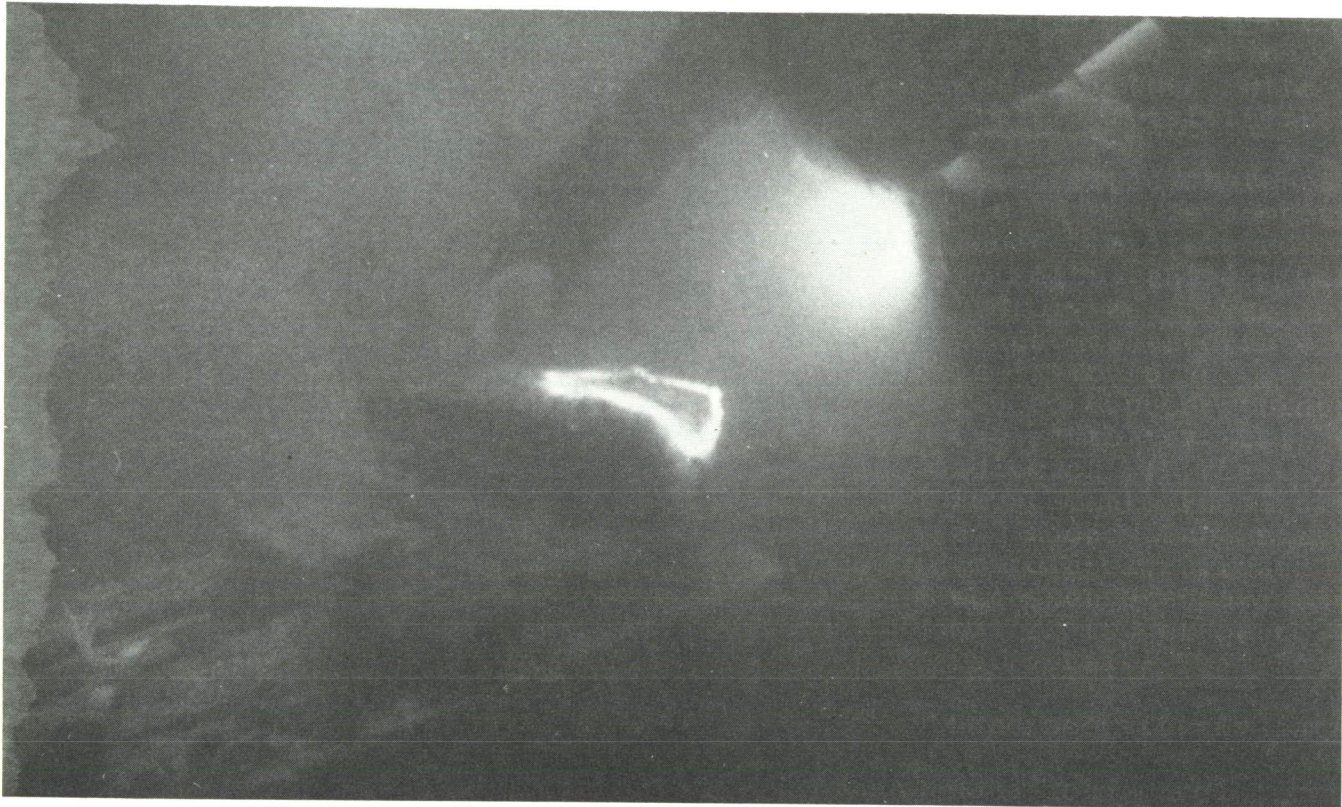
arenosa rockshelter

PICTURE CAPTIONS

The pre-inundation figure is a schematic representation taken from site photos.

The post-inundation figure is a schematic representation taken from Inundation Study mapping results.

- A The lip of the overhang is composed of rock, and the configuration remained unchanged from the inundation to process.
- B The high standing profiles which were extensive prior to inundation had slumped and were not in evidence following inundation except for a small section left standing at the far right bottom of the site.
- C A large limestone spall which dominated the site prior to inundation had been completely covered with a silt layer. This is a result of the slumping of the profiles and silt deposition after flooding. Talus slopes in front of the shelter had raised as a result of this deposition.
- D Two backhoe cuts on either side of the site were relocated, but had slumped and filled following inundation and were only slight depressions.



A 20th-century adobe brick that has been submerged in Amistad Reservoir for 8 years has been moved to the top of a nearby cinder-block wall to be photographed before being taken to the surface.

be made from this analysis. One possible benefit of the analysis could be the development of a preservation technique that could be applied to the adobe prior to inundation, to protect the structure during immersion.

The last aspect of field-work carried out during the Amistad trip was the continued investigation of sites in the reservoir that could be suitable for inundation research.

Dr. Dave Dibble met the core team in Del Rio for 3 days during the field session, and while mapping was in progress at Arenosa, he and the rest of the team proceeded with site relocation.

Examined first was a dry cave located on the Devil's Arm of Amistad Reservoir, where a burial was uncovered by national-recreation-area visitors. The water-level of the reservoir was 8' higher just before the team's August visit because of unusually high-rainfall during July and early August, and the cave could therefore have possibly been inundated. Other bones were located during investigations of the cave, and further study is contemplated by Dr. Dibble.

Another inundated rockshelter, situated toward the mouth of the Devil's River, was relocated with Dr. Dibble's assistance. Underwater assessment of the site was not undertaken at that time, but with this new locational information, the Reservoir Inundation Studies Project core-team will be able to return later to examine the site. Dr. Dibble also pinpointed on reservoir topographic maps other inundated sites that could be appropriate to the project's research.

In addition to the preliminary assessments conducted by core team archeologists, contracts have been initiated with Federal and state agencies and universities for the implementation of field procedures aimed at empirically testing the hypotheses outlined in the research design chapter of this report. Each reservoir selected for study will incorporate as many variables as possible for the analysis, dating or preservation situations outlined in the research design. The following areas have been selected for study to date:

Tellico Reservoir, Tennessee - The Toqua Site: The application of the Inundation Study guidelines for

archeological data-collection at Toqua was limited because of the advanced stage of the field-work when the Inundation Study became involved. Since the Toqua site will be continuously immersed, only the effects of constant immersion will be testable. Wherever possible, arrangements have been made to take the pre- and post-inundation samples from the same location. The University of Tennessee performed the work under this contract.

Palmetto Bend, Texas: Six sites in this reservoir have been selected for study. Located in several different areas of the reservoir they will be subjected to different periods of inundation. Some sites will be continuously under, others will be periodically inundated, and others will only be affected by extreme high pool conditions and/or boat wakes.

The guidelines for archeological testing, presented in chapter three, are being implemented in full insofar as the field situation permits. A continuing monitoring program has been established with the Bureau of Reclamation for silt deposition and erosion studies at these sites. In addition, tests have been set up to compare the results of a magnetometer survey of one site before and after inundation. The Texas Archeological Survey performed the work under this contract.

Glen Canyon, Arizona:

One of the goals of the Reservoir Inundation Study is to test the efficacy of preservation techniques for the long term protection of sites. A pictograph panel in Glen Canyon was treated with applications of poly methyl methacrylate or plexiglas in an effort to protect the rock art from any potentially adverse effects from flooding. A principal concern at this site was the potential for discoloration of the art and the spalling off of sections of the panel. The rock art panel will be monitored for an extended period of time to document its condition. The Bureau of Reclamation and Arizona State University jointly organized this test and the Inundation Study was invited to observe the process.

Table Rock, Missouri: The research emphasis at Table Rock is on the mechanical effects of inundation,



Silting in Abiquiu Reservoir, New Mexico, has resulted in partial burial of this jacal structure. Only the tops of the window and door frames are now visible.

(Photo--Courtesy of School of American Research)

alteration of culturally-associated chemical values, and effects on lithic and ceramic artifacts. Four sites which had been partially excavated prior to filling of the reservoir have been selected for study. The University of Missouri, Columbia, performed the work under this contract.

Abiquiu Reservoir, New Mexico: All of the sites selected for study have been seasonally inundated since their initial flooding in 1960 (Schaafsma 1977). Accurate records of water levels within the reservoir and the period of inundation for each site can be determined. The range of dating and analysis procedures selected for testing within the scope of the research design include: carbon-14 dating, source identification analysis of ceramics and lithics, obsidian hydration dating, alpha-recoil track dating, thermoluminescence dating, archeomagnetic dating, pollen analysis, flotation analysis, soil chemistry analysis and artifact distribution analysis. Non-inundated sites will serve as the control for comparison of effects. The School of American Research performed the work under this contract.

Saylorville Lake, Iowa: One site was selected for study at Saylorville. Sample collection and site preparation procedures as outlined in the guidelines chapter have been implemented, and a range of samples collected for post-inundation comparison. Iowa State University performed the work under this contract.

Folsom Lake, California: The research emphasis at Folsom is on the mechanical effects of inundation and morphological alteration of artifacts resulting from 20 years of inundation. A range of analysis and dating samples collected from the Pedersen site according to Inundation Study specifications, will be analysed in a later phase of the research and results correlated with the inundation history of the site. The California State Department of Parks and Recreation performed the work under this contract.

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APPENDIX B: SUPPLEMENTS TO GUIDELINES FOR DATA-COLLECTION
AND SITE-PREPARATION

Undisturbed block or cube samples.¹ The surface of the soil to be sampled is trimmed smooth and about level. For large cube samples, a square column of soil 1 in. *[3 cm] smaller on each side than the inside dimensions of the box. [The cube may be wrapped with cheesecloth prior to placing the box over sample]. The box is centered over the sample and is seated on the soil surrounding the bottom of the sample. Loose soil may be lightly tamped around the outside bottom of the box to affect a good seal. A 50/50 mixture of paraffin (crystalline wax) and microcrystalline wax that has been allowed to cool almost to the congealing point is poured around the sample to the top of the box. After the wax mixture has cooled, the box cover is attached. The sample is then cut loose with a spade and turned over. The bottom of the sample is trimmed out to 1/2 in. [2 cm] below the bottom of the box, and this space is filled with the wax mixture. Care must be taken to ensure a good bond between this wax and the wax previously poured so that the sample is completely encased in the wax. As the soil at the bottom of the sample is trimmed out, the exposed surface of the wax mixture should be scraped clean of all foreign material, and a small amount of very hot wax mixture first applied in order to partially melt the exposed wax to ensure a good bond between the two pours. After the wax mixture has cooled, the bottom of the box is attached.

¹U.S. Army Corps of Engineers Manual, Engineering and Design, Soil Sampling, June 30, 1969, p. 70.

*The material in brackets has been added during a review process by Inundation Study personnel.

Soil Monolith Preparation

1. Locate a representative site. Avoid roadcuts or other disturbed areas.
2. Prepare a nearly vertical plane surface on one wall of the pit.
3. Mark out the section to be sampled. Lateral variation of horizons determines a suitable width. Most of our monoliths are 6 inches wide.
4. Apply as much vinylite resin solution as will soak into the soil. A plastic bag or an ice cream carton is a suitable container. Punch a small hole near the bottom of the container when you are ready to apply the solution. If the soil is not structurally stable wait 24 hours. Otherwise go ahead as soon as the resin surface is dry (15 to 30 minutes).
5. Apply one uniform coating of cellulose acetate solution, by pouring it from a carton or can. Some guiding or brushing may be necessary.
6. Wait until the surface is dry (15 to 30 minutes). Excavate the soil on either side of the treated section. Be cautious as you cut close to the edge of the treated section, using a sharp knife.
7. Place a smooth board against the treated section. Cut behind the soil column, starting at the top. Secure cloth ties around the soil column and board. If the soil is not structurally stable, put the ties very close together. If necessary, slide a sheet of cloth or plastic behind the soil column as you cut behind it, and then secure the ties. Cut clear to the bottom of the section. You will need pruning shears and a pruning saw to cut roots.
8. Cut through any remaining soil; make sure that the bottom of the column is severed, and then pull the board and its soil column to a horizontal position.

9. Remove the cloth ties. Put a clean mounting board beside the soil column. It should be wider and longer than the column. Leave about 1 inch of board at the top and about 6 inches of board at the bottom.
10. Apply a strip of cellulose acetate solution to the mounting board.
11. Lift the removal board and the soil column over the mounting board, and slide the removal board out from under the soil column. Avoid scraping the cellulose acetate glue off the mounting board. Have some assistants help in this step the first time you attempt it.
12. Position the soil column carefully, and push any loose soil pieces back into place. Scrape off any excess cellulose acetate.
13. Wrap the soil monolith securely before transporting it.
14. Unwrap the soil monolith. When it dries to a moisture content in the upper field capacity range the structure will be most apparent. Work out a natural looking surface. Avoid leaving knife marks. If the soil is too dry when collected, or becomes dry before you are ready to remove excess soil, rewet the profile and let it dry to a suitable water content. Do not try to work out a completely dry profile except in the case of very sandy or gravelly soils. Do not try to work out massive horizons when they are dry. Use a knife with care. Use air from a hose or suction from an industrial-type vacuum cleaner as you remove excess material.
15. Let the soil dry completely. Keep it in a safe place, where it will not be moved or jarred since it is not stable.
16. Apply enough vinylite resin solution to soak the soil completely to the board. A can or cardboard carton with a hole punched near the base works well. Soak a small section of the profile (about 6" x 6") at one time. Avoid going back over a wetted section, to prevent forming a shiny resin skin on the surface.

17. Let the profile dry 24 hours. Test structural pieces with the fingers to see if any are loose. If many are loose repeat step 16. This is rarely necessary but may be required if a soil has a high content of swelling clay and strong blocky or prismatic structure.
18. Let the profile dry 24 hours if it has been re-treated.
19. Check again for loose pieces. Use cellulose acetate dispensed from a simple oil can (enlarge the tip) to glue any loose pieces. Use care.
20. Apply a bead of cellulose acetate around the edge of the profile. This will have to be done with the board and monolith tipped, and may have to be repeated. Wait until the bead on one edge is completely dry before you tip the board at a different angle. If there are large voids between the board and monolith surface, fill with tissue and moisten with cellulose acetate. Compress the tissue to a smooth surface. Apply extra coats of cellulose acetate to the tissue surface until it is entirely smooth along the bead.
21. Wait 24 hours. Paint the exposed board and attach a mounting wire.
22. Attach pictures or other information - items below the monolith.
23. Handle with care. At five to ten year intervals reglue any loose pieces. If an ENTIRE section becomes loose use vinylite resin again. The board will then need to be sanded and repainted.
24. Materials
 - (a) Mount on plywood 1/2 inch thick.
 - (b) Acetone -- any chemical supply house and some paint stores. Store away from any flame. Avoid breathing fumes. Source example:

Van Waters and Rogers
N. 809 Washington Street
Spokane, Washington

About \$1.00 per gallon.

- (c) Methyl isobutyl ketone -- many chemical supply houses. See precautions under acetone.
Source example:

Great Western Chemical Company
West 1133 College Avenue
Spokane, Washington

About \$1.20 per gallon.

- (d) Cellulose acetate -- very few chemical supply houses. Source example:

Cellulose acetate E-398-3, from
Eastman Chemical Products
Kingsport, Tennessee

\$30.00 per 50-pound bag (minimum).

- (e) Vinylite resin -- very few sources. Source example:

VYHH grade, from
Union Carbide Corporation
Plastics Division
22 Battery Street
San Francisco, California

\$50.00 per 100-pound bag (minimum).

- (f) Cellulose acetate solution:
2,250. grams cellulose acetate in 5 gallons of acetone. Store in an all-metal container. Make up at least one week before it is needed. Shake or stir frequently to speed solution. Put some acetone in the bottom of the container before you add the cellulose acetate to ensure solution. Keeps indefinitely. Shake before using. Avoid getting glue on the threads of the plug.

- (g) VYHH vinylite resin solution:
1,200. grams VYHH resin in 5 gallons of a mixture of acetone (about 2/3) and methyl isobutyl ketone (about 1/3). See item (f) for precautions. Keeps indefinitely.

25. This procedure is based on the original work of Voight, in Germany, and of Berger and Muckenhirn, in Wisconsin, U.S.A. Modifications have been proposed

by many persons. For some references see Smith and Moodie (Soil Sci. 64:61-69, 1947) and Smith, McCreery, and Moodie (Soil Sci. 73:243-248, 1952).

Henry W. Smith
Professor of Soils
Washington State University
Pullman, Washington 99163

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Pallmann Method for Mass Sampling of Soil, Water, or Air Temperatures¹

Abstract

Mass sampling of temperature is required in many types of earth science problems. An accurate, precise, and economical technique for mean temperature determination in soil, water or air is afforded by the Pallmann solution method, which relies on the irreversible breakdown of sucrose sugar into the simpler forms, d glucose and d(-) fructose. These sugars are optically active, thus changes in their concentration results in measurable changes in the optical properties of the solution. Since optical rotation ratios are proportional to chemical concentration ratios, one may determine the reaction velocity coefficient, which in turn depends on temperature according to the van't Hoff-Arrhenius Law...

Theory

...This irreversible breakdown of cane sugar into simpler sugars is accompanied by changes in the optical properties of the solution, which can be measured by means of an optical polarimeter...

Accuracy and Precision

*[The temperature determined by this method is not the arithmetic mean temperature. Since sucrose hydrolysis responds exponentially to temperature changes, the

¹Philip J. O'Brien, Geological Society of America Bulletin, October, 1971, 82:2927-2932.

*The material in brackets has been added during a review process by the Inundation Study personnel, and Dr. Irving Friedman, geochemist with U.S. Geological Survey in Denver, Colorado.

Selection of the appropriate pH may be guided by reference to graphs published by Schmitz and Volkert (1959, p.6). To use these charts three quantities must be estimated. First, an estimate of the mean temperature to which the solution will be exposed must be made; further, the approximate number of exposure days must be determined and finally, the amount of rotation which the experimenter wishes the solution to undergo is selected. The usual range of Rtime is $10^\circ < Rtime < 30^\circ$ using a mercury light source. With these three values, the pH needed to achieve the desired optical rotation is ascertained.

Two sample batches are taken from the mixed chemicals. The first is composed of two sub-samples whose rotation angles are immediately read to establish the initial rotation angle (Rinit) of the solution prior to any hydrolysis. The other batch of ten 20 ml samples are placed in an oven at low heat. Every 15 min. one sample is removed and its rotation angle read. This procedure is continued through the end point of the reaction in order to establish the final rotation value of the solution (Rinfi). The remainder of the sample batch is poured into 20 ml glass ampoules and sealed quickly with a high intensity flame. The ampoules are then immediately frozen since sucrose inversion stops when the sensors are frozen. Ampoules must be kept frozen prior to exposure at the field site and refrozen upon retrieval. This is easily accomplished with dry ice.

Laboratory Analysis and Computation

Rotation angle readings are made on a precision polarimeter such as the Rudolph Model 70 used by the writer. The device consists of a mercury vapor light source, a polarizer unit, a tube trough, a sample tube and an analyzer head.

Ampoules are removed from the laboratory freezer at 5-min intervals and placed in a water bath at room temperature. After 15 min each ampoule is removed, dried, and shaken vigorously for a few seconds to disperse liquid crystals which form after thawing. The crystals have a threaded texture and polarimetric determinations are impossible in their presence.

At this point, the ampoule is broken open at the neck and about 4 ml of the solution is poured into the sample tube, washed about and poured out. The sample tube is

then filled, making sure that trapped air bubbles are released. The tube is placed in the tube trough and readings are made through the reading port on the analyzer head after adjusting the image through the telescope. Immediately after reading the rotation angle, a mercury bulb thermometer is inserted in the sample tube and a measurement made so that correction to standard temperature conditions can be made if necessary. At this point, all values needed for calculation of the exponential mean temperature according to equation (7) are available. [A commented FORTRAN IV computer program for calculation of T ($^{\circ}\text{F}$) from equation (7), with a standard temperature correction subroutine is available from the author].

Field Use Example

The writer studied the soil temperature regime in an area of the Mohawk River Valley flood plain west of Schenectady, New York, during 1968-1969. A series of 58, 6 ft deep, 1/2 in. diameter auger holes were constructed for this purpose. Temperatures were measured at each station of this network on eight different occasions during the two-year experiment period using an electronic thermistor probe system. During the winter period (1968-1969), when the ground was frozen and snow covered, mean soil temperatures 6 ft below ground surface were determined by the sucrose hydrolysis method.

Field installation of the ampoules was accomplished as follows. About four frozen ampoules at a time were transferred from a picnic cooler containing dry ice to a small, hand-carried cold case also provided with dry ice. At each auger hole site the 1-ft long, wooden marking stake [for Inundation Study purposes - minimum marker stake length should be 1.5m, set for 60cm below the surface to aid stability] was removed and a 6-ft strand of no. 20 copper wire was fastened to the tip of the stake. An ampoule was then removed from the cold case and the free end of the copper wire attached to it. The ampoule was lowered to the bottom of the auger hole, thus coming to rest in the temperature environment of the surrounding soil. The marking stake was then replaced and the soil was firmly tamped about it...the 6-ft soil temperature range, in the subject area, was 5.6°C about a mean of 7.5°C . Thus, departure of the exponential mean from the arithmetic mean was slight, as is commonly the case in soils.

"Pallmann Temperature" will be an integrated exponential temperature. However, the change of rate of hydration of obsidian with temperature is also an exponential function, and the Pallmann temperature is a closer approximation to the effective hydration temperature than is the arithmetic mean annual temperature. The precision of the Pallmann method depends upon proper calibration of the Pallmann solutions]...The absolute accuracy of the Pallmann method is "...influenced by a series of minor laboratory and field measurement problems...but overshadowing all other sources of inaccuracy is that sucrose hydrolysis responds exponentially to temperature changes..." (Lee 1969, p.425). The cumulative error from field and laboratory sources is considered small.

Solution Preparation

The Pallmann solution is an acidified, buffered sucrose solution composed of two solutions mixed in volume 1:1. In one there are 1,500 gm of sucrose in 1,000 ml of water, and in the other 404 ml of 0.2 m sodium citrate (buffer) plus 596 ml of 0.2 n hydrochloric acid. In order to inhibit the growth of microorganisms, a small amount of formaldehyde is added. Each sensor costs about \$0.15 to prepare.

The Pallmann solution freezes at -4.7°C . This results in cessation of the sucrose hydrolysis reaction; moreover, the reaction will not continue until complete thawing of the solution has occurred. Addition of 150 gm liter⁻¹ of reagent grade sodium chloride depresses the freezing [point from -4.7°C to about -20°C . If salt is added to the solution, the constants a and b of equation (7) becomes 5656.3 and 19.5797 respectively, as determined by Lee (1969, p.429). [EQ. 7]:

$$T(^{\circ}\text{K}) =$$

-a

$$\text{pH} - b - \log + \log \left[\frac{\log R_{\text{init}} - R_{\text{inf}}}{\log(R_{\text{time}} - R_{\text{inf}})} \right].$$

Since the sucrose hydrolysis reaction is catalyzed by hydrochloric acid, setting of solution pH must be carefully controlled to at least two decimal places.

A comparison of the mapped temperature data for each of the eight different observations series revealed significant spatio-temporal consistency of the 6-ft soil temperatures. The elongate, north-south temperature axis persisted as a maximum and several subsidiary temperature convolutions maintained themselves.

The quasi steady state soil temperature regimen, suggested above, allowed a simple test of sucrose method reliability. One would expect the chemically determined soil temperature pattern to be closely similar to the pattern occurring before and after the period of ampoule exposure.

Conclusions

The sucrose hydrolysis method is an accurate, precise, and economical method for mass sampling of mean temperature. The technique should therefore find increasing application in ecological and environmental studies. This paper, together with those referred to, provides an adequate basis for effective utilization of Pallmann solution methodology.

References Cited

- Lee, R.
1969 Chemical temperature integration: Jour. Appl. Meteorology, V. 8, p.423-430.
- Schmitz, W.; Volkert, E.
1959 The measurement on a reaction velocity basis with the polarimeter and its use in climatology and ecology, especially in hydrology and forestry: U.S. Department of Commerce-Foreign Area Section-Translation WB/T-110, 1966, 30 p. [trans. from German by Brumbach, J.J., and Lee, R.].

Field Collecting Procedures and Measurement Preparation¹

The primary consideration in selecting suitable burnt features for magnetic dating is whether any movement has occurred in the sample since baking. Disturbed features will introduce unknown amounts of error in the results. Second, there is the practical question of whether the samples can be extracted without breaking. Third, they should be well baked and free from impregnation of organic matter. Finally, since local magnetic fields can introduce error, it is desirable to obtain at least 5 samples from any single locality, and preferably as many as 20.

The archeological Research Laboratory in England, one of the principal institutions conducting research and development in this technique, has published a rating of the quality of various kinds of features with respect to archaeomagnetic dating:

Category I (good): Structures containing a substantial floor of well-baked clay.

Category II (average): Kilns and ovens having an intact circumference of solid wall, not less than a foot in height; well-built clay hearths.

Category III (poor): Unsubstantial hearths, kilns with incomplete walls, patches of burning, iron-smelting sites.

Category IV (very poor): Stone structures, poorly-fired tile, and brick ovens.

Once the best sampling area of the feature to be dated has been selected, the next step is to isolate a series of close-spaced, tiny pillars of burnt clay which can fit into the 2 by 2-inch brass frame of the extraction jig. This is a time-consuming process, since such pillars have to be excavated out from the surrounding material. The task must proceed cautiously so as not to dislodge or break off the stumplike projections that

¹Joseph W. Michels, Dating Methods in Archaeology, Seminar Press, New York, 1973, pp.134-136.

are being isolated. Dental picks, awls, knives, chisels, and other small hand tools are employed for this purpose. The burnt clay matrix is often very hard and makes the job especially difficult.

The extraction jig then is mounted, in turn, over each isolated sample. The brass frame is slipped carefully over the pillar, and with the aid of modeling clay it is carefully leveled (by reference to built-in bubbles for leveling), and oriented to present-day magnetic north. The orientation is carried out with a Brunton compass that fits over the top of the jig. Dental plaster then is poured into the frame, surrounding and covering the pillar of clay. The plaster is smoothed flush with the top of the brass frame while still wet. After the plaster has dried (a matter of a few minutes), a cutting instrument is carefully inserted beneath the frame, and the base of the tiny pillar is cut off flush with the frame. The sample now can be moved. It is turned upside down and additional plaster is poured over the bottom and smoothed flush with the frame. Once dry, the frame is removed and a perfect 2 by 2-inch cube of white plaster is revealed. Notations are inscribed on the surfaces of the cube indicating orientation and provenience. When the cubes are received at the dating laboratory, they are routinely washed clean of any viscous remanent, chemical, or isothermal magnetization by means of thermal demagnetization from a temperature of 60°C to standard room temperature.

Guidelines Sample Summary

Name of Reservoir:

Excavated By:

Site No.:

Date:

Recorder:

Please indicate if samples were taken and the number:

1. Amino Acid Racemization sample..... _____
2. Archeomagnetic sample..... _____
3. Carbon-14 sample..... _____
4. Consolidation test sample..... _____
5. Dendrochronology sample..... _____
6. Erosion test sample..... _____
7. Fission track or Alpha Recoil sample..... _____
8. Flotation sample..... _____
9. Fluorine sample..... _____
10. Obsidian Hydration sample..... _____
11. pH sample..... _____
12. Pollen sample..... _____
13. Soil Chemical and Organic Content sample..... _____
14. Soil Composition sample..... _____
15. Stratigraphic column (Monolith) sample..... _____
16. Thermoluminescent sample..... _____
17. Weathered Glass sample..... _____

Guidelines Site Preparation-Procedures Implemented

Name of Reservoir:

Excavated by:

Site No.:

Date:

Recorder:

Please indicate measures implemented:

1. Plexiglass sheeting against profile..... _____
2. Plastic-lined trenches..... _____
3. Trenches or features backfilled..... _____
4. Artifacts left in situ or replaced..... _____
5. Marking of site for relocation purposes..... _____
6. Standing profiles..... _____
7. Pallmann temperature implant..... _____
8. Others..... _____

