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CONSIDERATIONS FOR ADMINISTERING UNDERWATER CONTRACTS

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Highway & Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways & Transportation and the University of Virginia)

In Cooperation with the U. S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

October 1984
VHTRC 85-R8

BRIDGE RESEARCH ADVISORY COMMITTEE

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ABSTRACT

State highway and transportation agencies are required to inspect all bridges on the public road system using guidelines established by AASHTO. Procedures for inspecting the superstructures are well known and the expertise to perform them is available within highway and transportation agencies. However, the need to inspect bridge structures in water too deep to allow evaluation from the surface presents most agencies with a difficult technical task.

Many states have solved this problem by employing contractors to inspect such substructures. Since procedures for performing these inspections are not standardized, selection of the criteria to be used is left to the contractor.

The objective of this study was to identify issues that should be considered when administering an underwater inspection program to be conducted by contractors. The issues include identifying and prioritizing structures for periodic inspection, establishing inspection procedures to be used, selecting a contractor, formatting the contract, and estimating contract costs.

SUMMARY OF FINDINGS AND CONCLUSIONS

The results established that when using contractors to conduct an underwater inspection program the important issues for consideration include identifying structures that have portions of the substructure underwater, specifying how structures will be placed in a sequence of inspections, specifying inspection procedures, determining criteria for selecting contractors, establishing the contents of a contract, formatting the final report, and estimating contract costs.

Identifying and Prioritizing Structures for Underwater Inspections

Most states have automated data inventory systems that contain the information required to establish an underwater inspection program, including such items as location of the structure, the date of construction, and date of rehabilitation. Identifications of all bridges associated with water would be a routine data output from this inventory; however, it may not be possible to identify all substructures that are actually in water. Further, the average depths of the waters with which these substructures are associated usually are not available. Thus, identifying bridges that require underwater inspections usually requires the availability of additional data items. These items should indicate if a substructure is underwater and the average depth of the water. It would be important to know the seasonal variation in the depth of the water so as to be able to determine if during the year it becomes shallow enough to allow inspection without diving.

The large number of underwater inspections required in most states dictate the use of a prioritizing system. This research has suggested that the system consider basic components of risk assessment, structural data, geographic location, economic considerations, and structure evaluation.

Developing Inspection Procedures

The inspection procedures should be defined to provide consistency in contracts. The definition used in most underwater contracts of levels I, II, and III should be adopted. The inspection should be spelled out as completely as possible to simplify communications between the agency and the contractor.

The most accurate results would be obtained from an inspection of all the piers or piles of a bridge. By performing a level I inspection on all substructures and a level II inspection of a sample based on the results of the level I inspection, reliable data would be insured.

If sampling without level I inspections is unavoidable, the worst case approach is suggested. This approach would be based upon the answer to a question such as, What number of elements in a given structure could be eliminated without the probability of the structure failing? The remaining elements should be inspected.

Selecting a Contractor

To be considered for underwater inspection work, contractors should be prequalified. The advantage to the contracting agency would be a reduction in time required to award a contract by focusing on contractors that have adequate equipment and personnel to perform the tasks required. The contractor can also benefit because his qualifications can be made known to other contractors or agencies who might use his services.

Competitive negotiations appear to be more advantageous than sealed bids for underwater work. Many times the tasks to be performed can be specifically stated; however, the options available for performing these tasks are not always clear to the contracting agency. Through negotiation, the guidance of a potential contractor may increase the quality of the inspection and benefit all parties.

Establishing the Contents of Contracts

By means of the contract, awarding agencies and contractors establish their initial relationships and, to some extent, predetermine the success of their operations. Many times contractors are engaged because the awarding agencies want unique operations performed or do not have the required know-how. In these situations the contract may resemble a gentleman's agreement in which the general object is stated by the agency and the contractor is allowed broad discretion in performing the work.

Failure to specify the work required can result in poor relationships between the agency and contractor. Extended deadlines, requests for increased funding, and incomplete data are a few of the problems that may arise. Because in underwater work the structure and the inspectors are usually "out of sight", detailed contract specifications and task oriented conferences are of major importance.

In addition to administrative details, contracts for underwater work should include a schedule of task oriented conferences, a statement of expected safe diving practices, the detail of inspection desired, and a prescribed format for reporting.

Formatting the Final Report

The final report documents that inspections have been made and provides data for analyses. It is important that final reports be consistent in format so that information in one can be easily compared to that in others when determining the need for follow-up work and scheduling future inspections. Elements of the final report are title page, foreword, executive summary, table of contents, list of figures, photographs, introduction, activity description, inspection procedures, structures inspected, conclusions and recommendations, and appendices.

Estimating Contract Costs

One of the principal concerns of agencies issuing underwater contracts is what appear to be large disparities between the costs of contracts for similar work as has been noted for work performed by similar agencies in different states. The disparities result from variables such as travel time, equipment rental, and availability of personnel. Nevertheless, a relatively constant base cost figure is $500 a day for a three-man dive team.

RECOMMENDATIONS

Because the purpose of this research was to identify items that should be considered in administering underwater contracts, few recommendations were expected to be offered. However, consideration of the areas listed below could lend improvement to underwater inspection programs.

1. The bridge inventory should be modified to provide locations of bridge substructures that are underwater and estimations of the water depths.

2. The system suggested in this report for prioritizing underwater bridge inspections should be developed and improved upon as necessary.

3. The Department's underwater inspection program should be modified to include the identification of bridge substructures underwater, the scheduling of initial and follow-up inspections, and a computer data bank to store information. The use of a computer program would facilitate the evaluation of data obtained from an inspection and the scheduling of subsequent inspections.

4. Underwater contracts should be awarded through competitive negotiations rather than through sealed bids.

5. A study should be undertaken to identify variables which affect the deterioration of substructures underwater and the extent of that deterioration. This work might include developing methods of predicting the rate at which concrete spalls under given situations or the rate at which scour can be expected to occur. Unless these variables are understood, it will be difficult to establish accurate weightings for use in a prioritizing scheme.

6. A system or formula for sampling to enable the evaluation of structures through inspecting less than the total structure should be tested and developed.

7. An attempt should be made to establish the relationships between data acquired above water and conditions existing underwater, with the objective of evaluating the conditions of substructures underwater without diving. A method for determining the rate of deterioration of materials could be as basic as submerging a block of material in water when a structure is constructed, then retrieving and inspecting it at intervals.

SI CONVERSION FACTORS

To convert from	to	Multiply by
ft	meter	0.304 8
psi	pascal	6.894 757 E + 03

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INTRODUCTION

The national concern for bridge safety in the eighties may hold for state highway and transportation agencies implications similar to those that resulted from the environmental concerns in the seventies. Passage of the National Environmental Protection Act in 1969 established a requirement for documentation and review of the probable impact of new transportation facilities upon the environment and, further, made the availability of federal funds for construction dependent upon an elaborate review and comment process. Now in the eighties, national publicity about the failure of the Mianus River bridge on the Connecticut Turnpike has focused attention on the quality of bridge inspections. The Center for Auto Safety has filed a lawsuit in the U. S. District Court charging the U. S. Department of Transportation with failure to enforce biennial inspections of bridges. The Center's goal is "to get the Federal Highway Administration to apply pressure to local and state governments that are failing to comply with safety requirements. Such pressure could involve holding up funds for a single project until inspection and posting requirements are met." (11HS Status Report, Vol. 19, No. 6, April 14, 1984, p. 7).

Evidence that the federal government is influenced by these and other concerns is shown in the fate of a recent proposal by the Federal Highway Administration (FHWA) to increase the time between inspections for certain types of bridges. The Federal Register of January 20, 1983, recorded that the FHWA was requesting comments on this proposal from concerned parties. One justification for this proposal is that the time and money saved by increasing the interval between inspections for some categories of bridges that would entail only a negligible increase in risk to the public could be used more efficiently to replace or rehabilitate structurally of functionally obsolete bridges, which is the primary objective of the National Bridge Replacement Program. Recently, this proposal, which seemed a logical approach to maximizing resources and was gaining support, was withdrawn. The implication seems to be that the federal government recognizes the extent of the national concern and will attempt to influence the states to strengthen bridge inspection programs.

One of the most problematical aspects of any bridge inspection program is evaluating portions of structures which extend underwater. In fact, many states do not have a program for routinely conducting underwater inspections.(1) The Virginia Department of Highways and Transportation is attempting to strengthen its underwater inspection program through efficient use of contractors.

The objective of this report is to identify those aspects of underwater inspections which can be specifically stated in a contract and those which would result in an efficiently administered underwater inspection program.

National bridge inspection standards require that all bridges located on public roads be inspected at least once every two years. The inspections are to be conducted in accordance with the AASHTO standards stated in the "Manual for Maintenance Inspection of Bridges."(2) In general, highway and transportation departments throughout the nation comply with these standards. Many states, however, do not comply with the standards in inspections of the portions of structures below water.(3) There are several reasons why the portions below water are treated differently than the exposed portions, including the following:

1. The AASHTO standards state in section 2.4.2(3), Inspection Items, part (3) piers and abutments:

   > Investigating the footings for evidence of significant scour or undercutting. Making the inspection at the season of lowest water elevation will facilitate this work. Probing and/or diving will be necessary at many piers. This will normally be required at approximately five-year intervals except under unusual conditions.

   This section generally has been interpreted to mean that any portion of a bridge below the water need be inspected no more frequently than every five years, rather than every two years.

2. It seems to be generally accepted that any major damage below water can be detected by abnormalities in the portion above water.

3. For most states inspections below water require the services of a contractor with diving capabilities, and because of the cost of this service such inspections usually are made on only very high priority structures. In some states the relative unavailability of underwater contractors makes this option very expensive.

However, the premise upon which this study was based is that all states would include underwater inspections if the know-how were available.

SCOPE

This research identified the following issues as warranting consideration in administering contracts for underwater work.

- Identifying and prioritizing structures for underwater inspections
- Developing inspection procedures
- Selecting a contractor
- Establishing the contents of contracts
- Formatting final report
- Estimating costs of contracts

METHODOLOGY

To obtain information for this study meetings and interviews were conducted with personnel responsible for bridge inspections within the Virginia Department of Highways and Transportation, in other states, in federal agencies, and with contractors and from manuals they provided. The information developed was reviewed by a study task force and most of the people contacted in the early stages of the study.

EVALUATION

The research is discussed under the headings listed previously in the section titled SCOPE. The issues identified as warranting consideration in administering contracts for underwater inspections are discussed in a general manner, and it is anticipated that they will be modified, specifically by traffic engineers, structural engineers, economists, and persons with experience in bridge inspections.

Identifying and Prioritizing Structures for Underwater Inspections

A basic element of any inspection program is the information needed to determine the number of structures requiring inspection. Although recognized as important, the condition of that portion of bridges underwater has not been a high priority concern in most states, and the information needed to determine the number of bridges requiring underwater inspection is not available. The bridge inventory required by federal regulation shows the bridges associated with water but not whether the structures are in water nor the depth of the water under a bridge.

Based on information available on their maps, many states have responsibility for more bridges with substructures underwater than can reasonably be inspected in a short period of time and thus would need a prioritizing system to upgrade their inspection programs to include structures underwater. The system would not be used to decide what bridges would be inspected, but to determine the order in which all bridges would be inspected during a given time period.

A report by Harness and Sinha defines priority programming as follows: "Priority setting is the method of evaluating each project with respect to each other project within a work category. Programming is the matching of projects with available financial resources for implementation at a specific point in time."(4) Ideally, the elements of a priority system would have numerical values by which bridges in need of immediate attention would be objectively differentiated from those in less critical need, such as new structures.

The objective of this section of the report is to discuss some of the variables that seem essential to a system that would prioritize structures for underwater inspection.

Of the many studies that have been conducted on priority programming, nine deal with prioritizing underwater structures for inspection and these were drawn upon in selecting the variables discussed below. The groupings of variables are not listed in order of importance and are not meant to be all inclusive.

Risk Assessment

The importance of this element stems from the need to provide safety for the users of the structures. Although the safety of all structures is important, those that would entail the greatest risk to the public in the event of failure must be distinguished from those that would present a lesser risk. Traffic volume is used to evaluate the probable risk to the public. Assuming the worst case -- as bridge failure -- the greater injury likely would be sustained by the users of bridges with high volumes of traffic. Therefore, these bridges would be of more concern than those with low volumes, if traffic volumes were the only element to be considered.

Structural Data

Elements in this group are given attention in establishing priorities for inspection; however, little historical information is available for accurately assigning a weighting scale. The elements in this group are construction materials, quality of construction, foundation type, structure age (or remaining life), and moveable vs. stationary spans.

Construction Materials

Depending upon the type of water in which the substructure rests, the priority of inspection would be affected by the type of materials involved -- concrete, wood, or steel. For example, wooden structures in salt water would be vulnerable to borer attack, concrete would be susceptible to leaching of chemicals in the soil at the mud line (such as high sulfur), and steel would be subject to oxidation.

Quality of Construction

Engineering judgement would be essential in rating the quality of construction. If this could not be determined from data recorded when the structure was built, information from inspections of the superstructure could be used.

Foundation Type

Pilings constructed on rock foundations are not as adversely affected by scour as are friction piles. Friction piles would be weighted higher in the priority ranking than bearing piles, especially when scour is likely.

Structure Age

A life expectancy of 50 years has been arbitrarily assigned to bridge structures; thus, older structures should receive a higher priority.

Moveable Vs. Stationary Spans

The added risk of damage by boat and ship traffic under moveable spans would indicate a need to assign them a higher priority than stationary spans. An added risk is the turbulence from propellers of large vessels, which may cause "necking," a form of deterioration in sections of a pier.

Geographic Location

The area of the state in which a bridge is located would affect the demand for inspection. Weather, velocity of water flow, and water chemistry are variables that should be considered.

Weather

Over a period of time cycles of freezing and thawing temperatures could result in significant damage to a substructure. Bridges in areas of the state where water commonly freezes in the winter should be assigned a higher priority than those in areas where temperatures rarely drop below freezing.

Velocity of Water Flow

A substructure can be expected to be more adversely affected by a rapidly moving stream than by calm water. Problems would also be more likely in areas of frequent flooding. The substructure would be vulnerable to undercutting by high velocity flows, cracking from large debris moving rapidly in flood waters, and scour.

Water Chemistry

Substructures would be more adversely affected by salt water than by fresh water. Because the probability of spalling, corrosion from electrolysis, etc., is greater in the salt water, the structures there should be assigned a higher priority.

Economic Considerations

In addition to the safety of the traveling public, the protection of capital investments is a high priority. The inspection of bridge substructures enables preventative maintenance to be undertaken and relatively inexpensive rehabilitation procedures to be initiated to avoid costly reconstruction. These considerations include cost of replacing the structure, cost of repair, and detour length. Economic considerations include any losses incurred by the public resulting from a structure being out of service.

Replacement Cost

When deferring maintenance might necessitate replacement, structures having a high replacement cost obviously would be assigned a higher priority for inspections than structures having a lower replacement cost, other considerations aside.

Cost of Repair

This element is slightly different from replacement cost. Considering only underwater operations, the resources needed to repair or reconstruct a structure having a moderate replacement value could be higher than those needed to repair a structure with a higher replacement value. An example would be a two-lane stationary span over extremely deep water where repairs would be extremely expensive because of the requirements for highly trained personnel and special equipment. In contrast, where the substructure of a bridge carrying a multilane highway is partly in shallow water, repairs may be less costly. Consequently, the former situation would justify more frequent inspections to detect minor distress before major problems develop.

Detour Length

Assuming a case in which a bridge would be out of service, the length of the detour required would be important. If the bridge provides the only reasonable route of travel to a given location, then it would be weighted higher than if it were one of several in the area.

Structural Evaluation

The service and maintenance history of a structure is important in assessing the importance of immediate inspection. In many cases there are no documented underwater inspection files for the structures but information obtained in inspections of the superstructures will be available and can be used in determining priorities.

In Table 1 several bridges are rated to see if the assigned weights would coincide with those expected from use of a prioritizing scheme based upon the variables discussed above. General units (such as, high, medium, and low) were intentionally used for weightings with the expectation of future modification.

Table 1

Bridge Prioritization Using Trial Weighting Assignments

Variables	Bridges A	B	C
Risk Assessment			
Traffic Volume: Low 1, Moderate 2, High 3	3	2	2
Structural Data			
Construction Material: Concrete 1, Steel 2, Wood 3	1	1	1
Quality of Construction: Good 1, Fair 2, Poor 3	1	3	1
Foundation Type: Bearing 1, Friction 2	1	2	1
Structure Age: New 1, Medium 2, Old 3	2	3	2
Moveable Span: No 1, Yes 2	1	2	1
Geographic Location			
Weather: Freezing unlikely 1, Moderate 2, Probable 3	2	1	2
Velocity of Water Flow: Placid 1, Moderate 2, Rapid 3	2	3	1
Water Chemistry: Fresh 1, Salt 2	1	2	1

Table 1 continued

Variables	Bridges		
	A	B	C
Economic Considerations			
Replacement Cost Low 1, Moderate 2, High 3	3	2	2
Repair Cost Low 1, Moderate 2, High 3	2	2	1
Detour Length Short 1, Moderate 2, Long 3	2	3	1
Structural Evaluation			
Inspection Experience Good 1, Fair 2, Poor 3	1	3	1
TOTAL	22	29	17

Summary:

Bridge A

Located on I-95 over the Occoquan River in Northern Virginia, fresh water, low current, stationary span, high traffic volume.

Bridge B

Located on Rte. 125 in Suffolk, brackish water, fast current, moveable span, moderate traffic volume.

Bridge C

Rivanna reservoir on Rte. 601 in Albemarle County, fresh water, slow current, stationary span, low traffic volume.

The highest value a structure could receive is 36, which is an indication of a need for inspection as soon as reasonably possible. A low score of 13 would indicate that the structure would be in the last group to be inspected.

Bridge A was rated 22, or 61% of the highest possible score; bridge B was rated 29, or 81% of the highest possible score; and bridge C 17, or 47% of the highest possible score. These scores, based on the variables considered in setting these priorities, were consistent with expectations resulting from actual underwater inspection of these bridges.

Developing Inspection Procedures

Levels of Inspection

Levels of inspection are used by the Navy and most underwater contractors to generally define the work to be accomplished during an inspection. The levels are defined as follows:

Level I

A level I inspection is a basic inspection (a "swim-by"). This level does not entail cleaning or detailed measurements. The objective is to gather data based upon observations, either visual, photographic, or videotaped.

The level I inspection should follow the as-built plans of the structure with the intention of detecting obvious major damage or deterioration due to overstress, corrosion, or extensive biological growth or attack. This level of inspection is intended to be part of an initial evaluation of the exterior surface of piers, pilings, footings, etc.

Level II

A level II inspection obtains more information than is provided by the level I. This level may involve cleaning and simple measurements using calipers, measuring scales, and probes or ice picks to estimate the depth of cracks or other damage. At times, more sophisticated measurements are required at level II. For example, if simple measurements indicate a potential problem, a few detailed measurements may help to confirm this indication.

Level III

A level III inspection is a highly detailed one. At this level, nondestructive techniques (such as coring), material sampling, and in-place surface hardness testing may be required. Commonly, the level

III inspection will require cleaning preparatory to conducting tests and obtaining photographic or video representations.

Contractor Tasks

This section suggests the types of tasks to be performed by a contractor conducting an initial inspection and a follow-up inspection. (More detailed inspection procedures are given in the "North Carolina DOT's Underwater Inspection General Operations Procedures and Safe Practice Manual," compiled by the Bridge Division of the North Carolina DOT.)

Initial Inspection

Initial inspections are usually slated for bridges or groups of bridges for which there is documentation of previous inspections.

The general task would be level I inspection to note any obvious defects such as extensive spalling or scour. (Follow-up inspections would be scheduled where necessary.) At this level of inspection, a group of structures could be quickly evaluated to establish baseline data.

Three areas of the structure should be observed in a swim-by inspection: the area around the mean water level to detect damage from cycles of freezing and thawing or from boat collisions; the areas from the mean water level down to the mud line should be observed at every 10-foot interval and around the circumference of the pier; and finally, the area at the mud line. The data from a mud line inspection would include condition of footing, extent of scour, the amount of debris collected around the pier, the condition of underground cables, and, if appropriate, soil samples from the mud line for chemical analysis.

Follow-up Inspections

Follow-up inspections will be either level I or level II, depending upon the results of any previous inspections. The purpose of a level II inspection would be to gain detailed data. Usually, this would involve light cleaning with steel brushes or scrapers and photographic or video documentaion. The use of a computer program would facilitate the evaluation of structures and the scheduling of future inspections.

When inspections indicate possibly serious damage, cleaning and testing may require use of a water blaster. With this equipment, water can be applied to the structure under pressures ranging from 6,000 to

15,000 psi. At 6,000 psi, the jet would clean marine growth, and pressures near 15,000 psi would reveal loose or damaged material. Pressures above 15,000 psi could cause damage to strong concrete. It is important that the pressures to be used be agreed upon by the contracting parties and that this agreement be documented.

The use of color video is desirable for inspections when damage is suspected or when an initial inspection has indicated potential damage, or for documentation for reference. The use of color video enables an engineer on the superstructure to observe conditions below the water. In many circumstances where a diver becomes "task fixated" he will see only what is directly in front of him and may miss obvious details. With the aid of color video, an engineer on the surface can communicate with and guide a diver. The video film can be retained for analysis and documentation.

Sampling

Inspections are necessary to provide data to enable decisions that will protect the users of structures and an agency's capital investments. Inspecting the entire portion of the structure underwater would provide the most reliable data; however, because of limited resources, total inspections are not always possible. The problem is to develop a valid sampling model for inspections of bridge substructures underwater.

There is very little literature from research on this subject and no valid sampling formula is available. The main difficulty in developing this formula is that of determining the required size of the sample population. In addition to the variables which relate to the structure, such as age, material, and construction quality, environmental factors that affect the structure must be considered. To determine that all the piers in a given structure are homogeneous enough to constitute a population, at least additional variables of scour, damage from collisions, and freeze-thaw damage must be considered.

The results of a literature search indicate that there is not enough information available to validly state that all piers in a given group are affected in a predictable manner. It is improbable that a population could be defined based on available data.

Selecting a Contractor

If sampling is unavoidable, the worst case approach is suggested. The approach would be based upon the answer to a question such as, What number of elements in a given structure could be eliminated without the probability of the structure failing? Then, the remaining elements should be inspected.

Contractor Selection

The regulations governing the use of contractors are spelled out in the Virginia Department of Highways and Transportation's DPM 6.8. Generally, all work over $10,000 must be awarded by competitive sealed bids or by competitive negotiations. Contracts of an emergency nature and single-term contracts of less than $10,000 are exceptions. The important factor in issuing contracts is to ensure that those bidding are qualified to perform the task.

Competitive negotiations appear to be more advantageous than sealed bids for underwater work. Many times the tasks to be performed can be specifically stated; however, the options available to perform these tasks are not always clear to the contracting agency. In negotiating a proposed contract, the guidance of a potential contractor may increase the quality of the inspection and benefit all parties.

The qualification of an underwater contractor is especially important because the work he is to perform is "out of sight." Several factors should be considered when attempting to prequalify potential contractors. Contractor experience, personnel qualifications, and available equipment are discussed below based upon information received from the Naval Facilities Engineering Command located at the Washington Navy Yard in Washington, D. C., and several underwater contracting companies.

Contractor Experience

A contractor with experience in underwater inspections likely is able to assess existing structural damage and accurately predict potential damage from the data he obtains. This is especially important on level I inspections, because the diver is the only one to observe the structure. His ability to describe his observations to a large degree determines whether the engineer in charge of the inspection declares the structure sound or calls for a level II inspection. Contractors whose primary activity is underwater inspections should be distinguished from those that engage only in underwater construction or salvage. The latter should not be eliminated, but should not be accepted solely on the basis of having performed underwater work.

Contracting firms that routinely conduct inspections of bridges employ structural engineers, draftsmen, etc., but for underwater inspections, they subcontract to a diving firm. Because most highway and transportation agencies have highly qualified structural engineers, for efficiency they should work directly with the firms that perform the underwater operations.

Personnel Qualifications

In most cases, for their own benefit, contractors engage divers who they believe to be competent. The most important consideration is the diver's experience -- the number of dives he has made, number of hours spent under water, type of training, type of work performed, and recency of work.

Rather than stating that a diver should have a specific minimum qualification, the employer should discuss with him some typical training and how it would relate to bridge inspection tasks.

The National Association of Underwater Instructors, Professional Association of Underwater Instructors, SCUBA Schools International, YMCA, and other agencies train sport divers. A basic certification can be awarded after class and pool training and a minimum of two qualifying dives on open circuit SCUBA. Usually a basic certified diver will be informed that he now has a "license to learn." He might then obtain experience, either formal or informal, that would enable him to perform the type of work required in bridge inspections.

Initially, sport diver training is conducted under the most favorable conditions and normally does not involve extensive use of tools. The tasks performed in inspecting the typical bridge substructure are done in zero visibility, after entering the water from a boat or barge, and might have to be done in unfavorable weather. The diver must be experienced enough to concentrate on the task and not his diving skills. Many times he will have to rely on his experience to the extent that he can operate his equipment by feel -- he will be unable to see it.

While extensive work in cold water requires that the divers wear dry suits, most sport divers have not been trained in their use. The use of surface supplied air, full face masks or helmets, and communications are required in many situations.

The Navy, National Oceanic and Atmospheric Agency, and commercial training facilities routinely give divers advanced training that includes performing under adverse (not dangerous) conditions tasks typical of those required in inspections of underwater structures.

Available Equipment

The equipment to be used by the contractor should be stated and the availability of that equipment should be verified prior to the issuance of a contract. This will ensure that the contractor and his employees have experience with the equipment and that work will not be delayed because the equipment cannot be obtained.

Establishing the Content of Contracts

From the information gained in this study, the following outline of considerations to be contained in an inspection contract has been developed. Although highway and transportation agencies have a standard contract form, these considerations can be incorporated with little modification. The considerations are categorized as general requirements, administrative procedures and instructions, general criteria, study and analysis requirements, and report format.

General Requirements

The general requirements state the objectives of the project, for example to establish the general condition of all bridge substructures from 2 feet above the water line to the mud line, or to inspect a given location for possible damage resulting from boat or ship collisions, and specify the expertise the contractor is expected to provide, for example, capabilities in performing underwater inspections, assessing damage and deterioration, recommending repair techniques, and estimating repair costs. In addition, the estimated maximum length of time for completion of the project could be stated.

Administrative Procedures

The usual information such as channels of communication, schedule for reporting information, and submittal of vouchers usually is contained in this section. Especially with underwater contracts, task-oriented conferences between contractors and engineers-in-charge are important. The objective and frequency of these conferences should be stated.

Although the contracting agency should not specify how diving operations will be carried out, it should make a general statement about expected safe diving practices. For example, it could state that a thorough check of underwater conditions, as well as other conditions pertaining to the proposed work, will be made prior to all diving operations, and that all diving operations will be conducted in accordance with the best commercial safety standards.

General Criteria

This section briefly states that the contractor is responsible for the quality of his submittals, including editing, accuracy of figures, and reproduction quality.

Study and Analysis

The level of inspection required usually is not explicitly stated but is worded in the form of a guideline. The study and analysis section should include the extent to which the data gathered will be analyzed. In almost all underwater inspections, an analysis must be made by the contractor because in the initial swim-by his divers must decide what is significant and what is not. However, repair and cost analyses may not be desired, and this should be stated.

Specifications for on-site reporting should be stated. Basically, some type of daily log should be maintained. Information such as the locations of all observations showing elevations along each pier or pile, water depth referencing mean low water level, and the position of the pier or pile on the bridge should be recorded.

Report

The contents and the format of the inspection report are important because the report contains the data to be used in future studies and in scheduling follow-up inspections. A format for the final report is suggested in the following summary.

Formatting the Final Report

Title Page

This page should contain the reason for the contract (inspection), the structure inspected and its location, the name of the contractor, the agency awarding the contract, date, and any necessary disclaimers.

Preface

The preface should be about one or two paragraphs long and contain statements the contractor feels necessary to qualify his work. The statements may explain the contractor's understanding of the objectives of the work he has performed, the limitations of the data reported, and any unique circumstances about specific locations.

Executive Summary

This is basically a summary of the work performed, the results obtained, and supporting data.

Table of Contents

Figures

The data required to support findings and conclusions contained in the report, e.g., summary tables.

Photographs

Selected photographs that support or supplement the findings and conclusions of the report.

Introduction

This section gives a statement of general inspection procedures and describes the tasks performed. It may also describe the reporting procedures used during each task.

Activity Description

This section gives the location of the structure and a brief summary of the purpose of the inspection.

Inspection Procedures

This section describes the levels of inspections performed, the patterns of inspections followed, and the equipment used.

Structures Inspected

This section should contain as much data about the structures as would be needed to enable a duplication of the findings by a follow-up inspection. These would include --

- a description of the structure,
- the locations of observed conditions,
- an assessment of the conditions, and
- the methods of assessment.

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Conclusions and Recommendations

This section should contain conclusions drawn from the information collected and recommendations that follow from the conclusions.

Appendices

Appendices should be used to present extensive tables or charts such as daily logs, field notes, backup data for cost estimates, and backup computations of structural assessments that are not essential to the main body of the report but that would be of interest to the agency receiving the report.

Estimating Costs of Contracts

The calculation of a reasonable estimate of the cost for inspecting a given facility is difficult because of the variables unique to each structure. However, based upon cost estimates contained in contracts awarded by the Naval Facilities Engineering Command and discussions with railway agencies and contractors, a daily average manpower rate of about $500 a day can be estimated for one dive team. Variables associated with the size and location of the structure will obviously affect this average.

Cost items which routinely vary from structure to structure are those for overhead, travel or per diem, equipment rental, and transportation. Unexpected variables may generate additional costs, such as the need for emergency services and poor weather conditions. The extent to which the contracting agency provides bidders with accurate information, such as that on water depth, will determine the accuracy of estimates included in the bids.

There are hidden circumstances which can influence contract estimates and they are well known to most agencies. A contractor just starting in business may bid extremely low in order to establish contacts and a reputation, or a contractor between jobs may bid low to get a project so he can keep his divers employed. These circumstances may result in low cost, high quality work that benefits both the agency and the contractor; however, they should not be thought to provide a basis for establishing an artificially low rate.

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