FINAL REPORT

CRITERIA FOR DETERMINING SAFE WATER CONDITIONS FOR UNDERWATER OPERATIONS

by

Daniel D. McGeehan
Research Scientist

and

Lynn Samuel
Research Technician

(The opinions, findings, and conclusions expressed in this report are those of the authors 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

March 1984
VHTRC 84-R30

BRIDGE RESEARCH ADVISORY COMMITTEE

TABLE OF CONTENTS

ABSTRACT

Virginia Department of Highways and Transportation employees trained in the use of SCUBA inspect certain of the Department's bridges and provide a degree of quality control for inspections done under contract. Safety standards to be followed in diving operations by these employees have been established in accordance with OSHA guidelines and are stated in the "Procedures Manual for Compressed Air Diving (SCUBA MODE)."

The objective of the research reported here was to supplement these standards by developing criteria by which a given body of water can be evaluated to ensure that reasonable planning is sufficient to minimize hazards. Water characteristics such as depth and current, evaluations of the surrounding water, information concerning access to the water, and the significance of various types of pollution were considered in the study.

CRITERIA FOR DETERMINING SAFE WATER CONDITIONS FOR UNDERWATER OPERATIONS

by

Daniel D. McGeehan
Research Scientist

and

Lynn Samuel
Research Technician

INTRODUCTION

The need for frequent inspections of bridges spanning bodies of water has been a concern of highway and transportation departments for years. Presenting particular difficulty is the inspection of the bridge substructure below the water. The acquisition of data during such an inspection is complicated and the technical expertise of the engineer is diminished by the potentially hostile conditions under which data must be obtained. Although most bridges have been constructed to meet, and often to exceed, maximum safety specifications, many of these are now 20, 30, 40, or more years old. Thus, the effects of time are becoming increasingly evident, and more frequent assessments of their condition will be required.

Studies such as Scour Around Bridge Piers, sponsored by the Federal Highway Administration; Below-the-Waterline Maintenance and Repair of Bridge Substructures, sponsored by the Transportation Research Board's NCHRP program; and a recently initiated study entitled Assessment of Deficiencies and Preservation of Bridge Substructures Below-the-Waterline reflect a concern at the national level.

Other studies have focused on the legal responsibility of highway and transportation departments to comply with design, safety, and maintenance guidelines. Studies reported in such publications as The Law and Roadside Hazards, sponsored by the Insurance Institute for Highway Safety, and in the NCHRP's Research Results Digest (see selected bibliography) have concluded that states are responsible for developing procedures that ensure the safety of their transportation systems. Further, they have noted that a department could be found negligent if failure to comply with these procedures should result in an accident.

There is an urgent need to establish procedures for conducting inspections on bridge substructures below the water, and the Virginia Department of Highways and Transportation has two options available for this activity: using commercial divers or Department employees trained as divers. Traditionally, it has exercised the first option for large, movable spans and the second for small bridges. However, there has been a reluctance on the part of the bridge engineer or supervisor to use Department divers where conditions seem hazardous. This reluctance is justifiable and is based on a lack of information or guidelines. The solution is to provide those responsible for initiating bridge inspections with enough information to enable them to decide when Department divers should be used. Seldom would a body of water be determined safe for a working dive without some preparation before diving. Consequently, any guideline which states that a given body of water would not be hazardous for Department divers should be supplemented with information on the preparatory measures to be employed.

Although this report concerns activities of department divers engaged in bridge inspections, not sport divers, the factors which contribute to the sport divers' accidents are germane. The similarities between the two activities include the use of SCUBA and the divers' freedom to decide under what conditions they will dive. In most commercial operations, the diving mode is surface supplied and the conditions under which the divers work is dictated by time available and the limitations of a contract.

Typically, diving accidents can be avoided by using proper equipment, obtaining the proper training, adhering to proper safety procedures, and being aware of the possible hazards. Information obtained from the National Underwater Accident Data Center at the University of Rhode Island indicates that fatalities among sport divers resulted from equipment failure, poor weather conditions, entrapment, entanglement, medical problems, poor physical conditioning, inexperience, or lack of recent experience.

Equipment failures usually were due to a faulty regulator which could not provide sufficient air at depth or which would free flow. Poor weather conditions usually resulted in diver injury when heavy surf or current caused loss of control. Preexisting medical problems were cited in several fatalities resulting from heart failure. Accidents resulting from diver fatigue or failure to react in an emergency were attributed to poor conditioning (heart failure fell into this category, too). Lack of experience pertaining to the number of hours or dives, recent activity, or familiarity with diving situations was cited in many accidents in which rapid ascents resulted in air embolisms. It is important to note that about 50% of the reported diving accidents occurred in less than 50 ft. (15.2 m) of water.

The Virginia Department of Highways and Transportation has prerequisites for its divers which should minimize the potential for these kinds of problems. According to the procedures manual proposed for adoption by the Department,(1) all divers will have an annual physical examination, equipment will be maintained under a prescribed schedule, and divers will be advised to maintain minimum levels of physical conditioning.

This report is intended to supplement the Department manual by citing possible hazards associated with diving under typical inspection conditions.

SCOPE

Ideally, this project would have resulted in the compilation of a directory of all bridges which have a portion of their substructure in water deeper than 5 ft. (1.52 m). This directory would classify the water under the bridge as appropriate for Department divers or as dangerous. For those waters deemed appropriate, a set of instructions for measures to be taken preparatory to the dive would be stated. However, there were so many bridges in this category that developing a complete directory would not be feasible. Consequently, the objectives were to (1) develop criteria by which a given body of water or conditions can be judged as appropriate or too dangerous for Department divers, and (2) compile a list of those waters judged to be too dangerous for Department divers.

METHODOLOGY

The methodology consisted of four phases: a computer search of Department bridges to identify those over water, a survey of the bridges on the list to determine which have substructures in depths 5 ft.* (1.52 m.) or greater, the development of criteria for Department divers, and the compilation of a list of unsafe waters.

EVALUATION

The focus of this evaluation was restricted to Department divers who are trained to use equipment referred to in this report as routine SCUBA gear, which typically includes the following:

Diver

1. Two scuba tanks with reserve breathing air supply and backpack
2. One regulator with submersible pressure gauge
3. Buoyancy compensator and CO_2 cartridges
4. Wet suit (hood, booties, gloves)
5. Weights
6. Weight belt
7. Knife
8. Dive light
9. Depth gauge
10. Watch, (bottom-timer)
11. Mask

---

*This depth was selected to indicate the initial depth at which divers would be needed to conduct inspections.

12. Snorkle
13. Fins
14. Dive bag
15. U. S. Navy decompression tables
16. Department dive manual

Dive Team

1. First aid k
2. Backboard
3. 2-way radio
4. Dive log and records
5. Dive flag
6. Safe diving manual
7. Ladder
8. Ropes
9. Dive lights
10. Boat
11. Lift bags
12. Floats
13. Buoys

Other equipment, such as dry suits, surface air, etc., is not used by the Department. Situations requiring this equipment, referred to in this report as "special equipment", should be avoided.

The following account and evaluation of work conducted during the study is given under four phases cited in the methodology.

Pollution is discussed in additional detail in the Appendix because information relating to diving activities in polluted waters is in the developmental stages. The information is important and necessary for the protection of divers but can not be concisely presented.

Computer Search

A search of the Bridge Division's inventory of structures was requested. For each structure, the retrieval included the following information: name of the county or city in which it was located, the route, a description or name of the associated water, location of nearby intersecting routes, size of surrounding drainage areas, navigational permit requirement, type of structure, date built, date reconditioned, and identification number.

The computer search listed information on 10,277 bridges, but the information was not sufficient for identifying those bridges associated with water deeper than 5 ft. (1.52 m.). Consequently, a method was devised for locating those bridges and selecting a sample to be surveyed.

Sample Selection

The information from the computer search was correlated with state maps to identify bridges most likely to have substructures in water deeper than 5 ft. (1.52 m.), and 419 sites were selected in seven of the eight construction districts. The Richmond District was eliminated from this preliminary survey since information concerning diving conditions was available from the Department divers working there.

Survey of Waters

The survey team visited the selected sites and collected information described on the form shown in Figure 1. Of the 419 sites, 95 were found to be in water deeper than 5 ft. (1.52 m.), and 15 shown on Table 1 were selected for the underwater survey. The criteria used to select the 15 were: (1) age of the structure, to evaluate bottom conditions around new and older structures; (2) geographic location, to evaluate conditions that would be typical across the state; and (3) type of water, to evaluate a cross section of water conditions Department divers might experience.

Water Name	Structure No.	Photograph Date	District	County	Rte. No.

Current	Surface	Bottom	Water Depth		Visibility		Pollution Tested	
Still	___	___	< 5 ft.	___	0 ft.	___	Yes	No
Slow	___	___	> 5 ft.	___	1 to 5 ft.	___		
Rapid	___	___	Measured	___	5 to 10 ft.	___		
Measured	___	___			> 10 ft.	___		

Figure 1. Criteria for determining safe water conditions -- initial survey. Note: 1 ft. = 0.31 m.

The underwater survey was conducted by the researchers to gain familiarity with problems divers might encounter in performing routine inspection work. Problems which would not be obvious unless this type of survey was conducted include diver fatigue, changes in current and temperature at increasing depth, bottom conditions, and debris around and in the water. The waters surveyed are described in Table 1.

Table 1

Sites Surveyed

Site Number	Location & Description
Culpeper District	
1	Rivanna Reservoir The South Fork of the Rivanna River under bridge on Route 678
2	Rivanna Reservoir The South Fork of the Rivanna River under bridge on Route 601
3	Occoquan Reservoir The Occoquan River under bridge on Route 663
4	Prince William County The Occoquan River under bridge on State 123
5	Fairfax County The Occoquan River under bridge on Interstate 95
Bristol District	
6	South Holston Reservoir The South Holston Lake under bridge on Route 670
Fredericksburg District	
7	Greys Point The Rappahanock River under bridge on Route 3

Richmond District

8 Benjamin Harrison Bridge
The James River under the Benjamin Harrison Bridge on Route 10

9 Buggs Island Lake, South Hill
Portion under bridge on Route 1

10 Lake Gaston, South Hill
Portion under bridge on Route 712

11 James River
South of Richmond near the Wilton plantation
Opposite the I-95 interchange at Chippenham Parkway

Salem District

12 Claytor Lake
Portion under the bridge on Route 672

13 Smith Mountain Lake
Portion under bridge on Route 122

Staunton District

14 Luray
The South Fork of the Shennandoah River under the bridge on Route 675

Suffolk District

15 Nansemond River
Portion under Route 125

Fifty dives were conducted in the 15 selected locations. Several dives were performed on long spans which might have significantly different conditions between the shores. The data from this survey are given in Table 2 and discussed in the following section on the development of criteria for safe waters.

Criteria Development

The criteria developed for use in designating waters as being safe were based upon the typical conditions found in the underwater survey. They included water characteristics (depth, visibility, current, temperature), activities prevalent in the surrounding water, information concerning access to the water, and the equipment usually used by the divers. In the following sections explanations of these conditions will be given by stating the potential problem, by describing the typical situation throughout the state, and suggesting the procedures to be used in deciding upon the use of Department divers.

Depth

The Problem

Fresh water has a weight of 62.4 lb.(2.7 kg.) and seawater a weight of 64.2 lb.(31 kg.). The weight produces pressure on the diver as he descends, and this affects the rate at which air (the gas he is breathing) is absorbed by his body tissues. The pressure is equal to about 1 atmosphere for every 34 ft.(10.5 m.) of fresh water or 33 ft.(10 m.) of seawater.

To enable the absorbed gases to be expelled from the body at a safe rate and to avoid decompression sickness, the diver must limit his stay at varying depths as prescribed in the U. S. Navy Dive Tables. An alternative to staying within the no- decompression limits of a dive is to perform decompression stops prescribed in the Navy dive tables while ascending. This procedure requires special training and equipment -- and is prohibited for Department divers.

Table 2

Summary of Water Conditions

Site No.	Maximum Depth, ft.			Visibility, ft.			Current, kn.			Season Variation in Temp.	
	6-30	30-60	>100	<1	1-5	5-10	<1	1-2	>2	Yes	No
1	x			x			x			x	
2	x			x			x			x	
3	x			x				x		x	
4	x			x				x		x	
5	x			x			x			x	
6		x			x			x		x	
7	x					x		x		x	
8			x			x	x			x	
9		x		x				x		x	
10	x				x		x			x	
11	x			x			x			x	
12	x				x			x		x	
13		x			x		x			x	
14	x				x				x		x
15	x				x				x	x	

Note: 1 ft. = 0.31 m.; 1 kn. = 0.5144 m./s.

Typical Conditions

This survey found that the typical water in which divers would be working would be relatively shallow (see Table 3). Of the 95 bridges found to have substructures in water deeper than 5 ft. (1.53 m.), 79 were in water between 6 to 30 ft. (1.82 m. to 9.2 m.) deep; 12 in water between 31 ft. to 60 ft. (9.5 m. to 18.4 m.) deep; 3 in water 61 ft. to 100 ft. (18.6 m. to 30.4 m.) deep; and only 1 was in water > 100 ft. (30.4 m.) deep. Therefore, the water encountered by Department divers would generally not be hazardous judging by depth alone.

Suggested Procedure

The maximum depth of the water at all dive sites should be estimated by dropping a "shot line" if possible. The depth attained by the divers should be recorded and no-decompression and repetitive dive tables should be followed. In general, depths to 40 ft. (12.2 m.) should not present a hazardous situation if no other compromising situations exist. The bottom time for a single, no-decompression dive to 40 ft. (12.2 m.) is 200 minutes, which allows ample working time. Dives to 60 ft. are practical for short periods of work and dives to 100 ft. or greater should be prohibited. Table 4 outlines the suggested procedures for dives to varying depths. If possible, the deepest dive should be performed first, with dives to consecutively shallower depths following.

Visibility

The Problem

Interactions between light and water are different from those between light and air. Light refraction, absorption, and scattering alter the diver's perceptions and result in an inability to identify objects or make accurate judgements. This situation may hamper accuracy in recording data. Poor visibility can also be a safety problem, because the diver cannot identify objects that may snag on his equipment, impair his movement, or injure him.

Table 3

Bridges in Sample Classified by District and Depth

Depth, ft.	Bristol	Culpeper	Fredericksburg	Lynchburg	Salem	Staunton	Suffolk	Total
0-5	73	70	4	66	90	20	3	326
6-10	4	11	3	10	23	2	4	57
11-30	1	6	6	1	5	0	3	22
31-60	1	4	1	0	3	0	2	12
61-100	1	0	0	0	1	0	1	3
> 100	0	0	0	0	1	0	0	1
TOTAL	80	91	14	77	123	22	13	421

Note: 1 ft. = 0.31 m.

Table 4

Suggested Procedures for Depths to 100 ft.
(All dives to be planned within no-decompression limits)

Depth, 100 ft. maximum	Single dive, no-decompression	Repetitive dive, no-decompression
10-40	OK	OK
41-60	OK	OK (Limited)[1]
61-80	OK	with qualification[2]
81-100	Restricted[3]	No
> 100	No	No

Note: 1 ft. = 0.31 m.

[1]At depths near 60 ft. (18 m.) long surface intervals are required to allow bottom time great enough to perform any but the shortest tasks. Repetitive dives to shallower depths may be practical.

[2]Repetitive dives at depths between 60 and 80 ft. (18 m. and 25 m.) usually are impractical for performing significant work. Again, repetitive dives to shallower depths may be practical.

[3]No-decompression time at this depth is limited to between 25 and 30 minutes for the initial dive. The required surface interval needed to continue work at this depth makes operations at this depth impractical.

Typical Conditions

Visibility of less than 1 ft. (0.31 m.) is typical in Virginia waters. "Dark water" can result from the lack of available natural light or from suspended particles in the water. The lack of available light can be caused by any condition which prevents light from penetrating the water (e.g., overcast weather conditions, overhanging structures, or deep water). In this type of dark water, the use of artificial light restores visibility. In some circumstances, the typical procedures used to condition the eyes for night vision will speed the diver's adaptability to dark conditions.

When suspended particulate matter is the cause of dark water, the diver must rely on his ability to identify things around him by his sense of touch. The use of artificial light will do little to increase his visibility; in fact, much akin to using car headlights in fog, the reflection of the light from contact with the suspended particles will only decrease the diver's degree of attained night vision.

Suggested Procedure

Since dark water is a constant problem, divers must be trained to work under conditions of limited visibility. A descent line should be used to enable the diver to execute a controlled foot first descent. The use of lights under favorable conditions should be standard. The use of "back-up" lights (small lights carried as standard equipment) is advisable. In turbid water where lights are of little advantage, the use of guidelines is essential.

Current

The Problem

To work in a current the diver must expend much more energy to maintain orientation, a stable position, and concentration than in calm water. This effort results in early fatigue, hampers efficiency, and is a possible diving hazard.

Typical Condition

Virginia waters range from placid, except for wind influence, to extremely strong currents. Many reservoirs have little current except when dam gates are opened. The rivers have varying currents, weak during dry seasons, strong after heavy rains or thaws. Rivers near the ocean vary with tidal currents.

Suggested Procedure

The procedures used should have four objectives: to aid the diver in maintaining stability, to aid in orientation, to provide a safety line to the surface, and to provide a safety line downstream to prevent uncontrolled drifting on the surface.

The types of precautions that can be taken are:

- generally, if the current is variable, postpone operations or plan operations for times when the current is diminished (0 to 0.5 kn.to 0.2572 m/s.)

- restrict diving to downstream side of structure where current is broken up

- set guidelines for divers' use on the structure being inspected

- use safety lines downstream

- modify SCUBA gear and provide special equipment

Temperature

Problem

Water has a specific heat approximately 1,000 times greater than that of air, and heat conductivity in water is approximately 24 times as great. Consequently, the body will lose heat much faster in the water than in the air. Heat loss can impair the diver's ability to gather data accurately. When the core temperature of the human body falls below 97° F. (36°C.). physiological malfunctions begin. Brief exposures may result in an inability to manipulate tools or to access and recall data accurately. However, temporary amnesia may occur at core temperatures of around 93°F.(34°C.), and at core temperatures between 86°F.(30°C.) and 90°F.(32°C.) cardiac irregularities may result in unconsciousness. Below these temperatures, the diver's ability to effectively operate ceases.

Typical Conditions

The waters in Virginia are seasonally variable and surface temperatures range from 90°F.(32°C.) in the summer to around 36°F.(2°C.) in the winter. Ice diving should not be considered for Department divers. Thermoclines, a layer or layers of water between the surface and the bottom in which temperatures may change noticeably, as much as 20°F.(11°C.), exist in most of the deeper waters . Most conditions indicate that a 1/4 in. (0.64 cm.) wet suit should be worn. Dry suits are appropriate for prolonged dives in water temperatures below 60°F.(16°C.).

Suggested Procedures

Protective clothing for the working diver is routinely used. This clothing includes working coveralls, wet suits, hot water, and variable volume dry suits. Each type of clothing has its benefits as explained below.

Working coveralls allow the diver more freedom of movement than the wet suit or dry suit. The thermal protection afforded by this clothing is minimal, but protection against cuts and abrasions is sufficient in warm water.

The wet suit is designed so that water is allowed to enter the suit next to the diver's body. Heat generated by the body warms the water and the insulation of the suit retains the heat. For most dives, the wet suit is suitable for either thermal protection or protection against cuts and abrasions. After prolonged exposure to cold water, however, the body loses its capacity to generate enough heat to maintain the water temperature inside the suit and the diver becomes chilled.

The dry suit, as its name implies, will keep the diver dry but will not provide thermal protection. Thermal protection is provided by special thermal underwear, which can protect the diver in cold water for extended lengths of time. By varying the type of thermal underwear, the suit may be made suitable for use in a wide range of temperatures. The Department divers do not use the dry suit, nor are they trained in its use. Therefore, when water temperatures are below 60°F. (16°C.) the divers will become chilled within an hour. Divers should avoid diving in water with temperatures of less than 50°F. (10°C.)

It is important that the person in charge of the dive observe the divers for signs of hypothermia and ensure that chilled divers are removed from the water to shelter where they can regain body heat.

Bottom Conditions

The Problem

Bottom conditions can entrap, entangle, or injure the diver. The dumping of household garbage and junk into waterways is a relatively common practice. Bridges offer ready access to the rivers, thus the diver can expect to come in contact with submerged debris in the course of an underwater inspection. Natural debris carried by fast water may lodge against bridge substructures and may impair the diver's mobility, especially in the man-made lakes where previously inhabited or timbered land was flooded. Monofilament fishing line is also a common obstruction. Thick mud on a bottom can cause suction on the diver's fins and cause entrapment, or a slick rocky bottom can be too slippery to work from.

Typical Conditions

Bottom conditions observed (Table 5) during this project were varied. Deep mud was encountered along the James River near Richmond. This made movement in shallow water extremely difficult and the use of fins on the bottom almost impossible.

Table 5

Bottom Conditions

Site No.	Sandy	Muddy	Litter	Natural Obstructions	Rocky
1		x	x	x	
2		x	x		
3		x			
4		x			
5		x	x	x	
6		x			
7	x				
8				x	
9		x	x	x	
10		x	x		
11		x	x		
12		x		x	
13		x			
14			x		x
15		x			

In the Shenandoah River near Luray, the bottom was rocky and slippery; movement with fins was awkward and potentially hazardous. Other conditions --shallow silt, sand, or pebbles -- were more common and presented no major problem.

Suggested Procedure

In most situations, fins can be used for entries and for work on the bottom. Where deep mud is present, fins should not be used on the bottom; to supplement the diver's loss of mobility, guide and safety lines should be employed. On slippery rocks, the use of wet suit booties or some type of tennis shoe is suggested (this problem usually exists in shallow water).

Surrounding Activities

Problem

The activities around the dive site can make an otherwise safe dive site hazardous. The hazards can be obvious, such as heavy boat traffic or the operation of a movable span; or it can be subtle, such as the periodic release of water from a dam that can increase the flow, the current, and the depth of the water in which the diver is working.

Surrounding activities can usually be controlled by planning the dive for off-seasons or intervals between operations.

Typical Situation

The variety of activities found around Virginia waters is extensive. In almost all areas, there is fishing. This almost ensures that there will be monofilament lines on the bottom. These lines can entangle a diver, and while this problem is potentially dangerous, it should not cause great concern.

Boat traffic in many of the lakes and reservoirs is heavy and can be a hazard to the diver. The diver is often distracted by the noise and, upon surfacing, can be severely injured by careless boaters.

The operation of a dam can be a hazard and can subject the diver to needless problems; however, the schedules are usually well known and can be modified with proper justification. Typical conditions found in the waters surveyed are depicted in Table 6.

Table 6

Surrounding Activities

Site No.	Boat Traffic	Fishing	General Recreational (Skiing, Swimming)
1	x	x	
2	x		
3			x
4			x
5	x	x	
6	x	x	
7	x		
8	x	x	
9	x	x	
10		x	x
11			x
12	x	x	
13		x	
14	x	x	
15	x	x	

Suggested Procedure

Once the type of activity has been determined, the proper scheduling of the diving will usually ensure safe conditions. For example, recreational boat traffic is usually heavier during weekends and summer months; consequently, planning dives for weekdays or the off-season may be all that is required.

Where scheduling dives to avoid hazardous situations is not possible, communications and warning systems may be needed. Barges and ships travel the James River frequently and at intermittent times; usually, a bridge tender can advise the Coast Guard of activities in the area and warn divers of traffic hazards. It should be common practice to use a dive boat and dive flag near which the diver can descend and surface.

Access Information

Problem

Gaining access to a potential dive site can at times pose problems in either safety or efficiency. From the safety aspect, "the exits should be sufficient to allow safely extracting a diver from the water under the worst conditions." This may mean that the entry point to the water and the exit point are different. It certainly means that the access point must be under the control of the dive team. Obviously, a hazardous situation would exist if a dive team member would need medical attention and the gates that provided access were locked. In terms of efficiency, the preparation, travel time, and hours needed to plan an inspection can be hampered if access to the site is delayed or if alternate access must be planned.

Typical Situations

The access problems encountered during this study included the following:

- the access to the dive site was available only by boat and over 1 mile (1.6 km.) from the site
- public and private organizations controlled a fence at the access point
- the access point could be reached only by foot through about 200 yd. (185 m.) of underbrush -- time constraints eliminated the use of a boat - access to the site was near to shore

Suggested Procedure

Determining primary and alternate access points to dive sites is part of dive planning. The schedules for controlled points should be obtained in addition to authorization to use private areas.

Table 7

Summary of Access Information

Site No.	Permission Required	Access Hours Controlled	Boat Required	Shore Operation
1	x		x	
2	x		x	
3	x			x
4				x
5			x	
6		x	x	
7			x	
8			x	
9			x	
10				x
11				x
12		x	x	
13			x	
14				x
15		x	x	

Pollution

Problem

The hazards for a working diver immersed in an environment containing a variety of contaminants have only recently been considered. Although information in this area is still largely anecdotal, accumulating evidence indicates that the risk is significant and that precautions should be taken to protect the diver.(2)

Water pollution can be divided into three general categories: thermal, microbial, and chemical. These categories are not mutually exclusive and, in fact, one may be a catalyst for the other. For example, water near a nuclear reactor may be warmer than is expected for the area and bacteria that normally could not survive would then have an environment ideal for growth. In some cases, thermal pollution has stimulated bacterial growth that may be hazardous for divers.

Polluted water may cause skin irritation, infection, or disease. The severity of a condition resulting from contact may range from a skin rash to terminal disease such as meningo encephalitis . However, most of these problems can be avoided by determining water quality, providing medical evaluation, preparing the divers, and using appropriate equipment.

Typical Conditions

Within the technical definition of pollution, to make physically impure or unclean or unfit for drinking or swimming, most of the water that divers will come in contact with will be polluted. However, with the proper pre- and post-dive precautions, most of the waters will have little effect on the divers working in them.

Water conditions change frequently, and unfortunately the degree of pollution cannot be evaluated visually. Water that appears to be clear may be contaminated, and water that is muddy or tinted due to algae may be undesirable for swimming or consumption, but present no significant hazard to the diver. Although thermal pollution may increase the probability of contamination, extremely cold water is no indicator of pure water.

During this study, waters that would be typical of those that Department divers would encounter were surveyed. Waters that obviously contained sewage, petroleum products, or other contaminants were not encountered.

Suggested Procedure

Although diving in polluted water is hazardous, there are preventative measures which should reduce the risk. The water should be tested, if possible, to determine the types of chemicals and biological pollution present. Divers should be currently immunized against diptheria, tetanus, smallpox, typhoid, and polio.(3) Only healthy individuals with no open cuts or sores should be allowed to dive. If injured during diving operations, the diver should be watched for signs of developing infection and not dive until the injury heals. The health of the diver should be monitored after diving operations, with any symptons of illness being reported to a medical authority. Since many of the diseases the diver may contact when working in polluted water are unusual in the general population, a medical officer familiar with dive-related problems should be consulted and accurate records of the location and nature of diving operations should be entered in a log book. The best method for protecting the diver who must dive in polluted water is suit encapsulation and a modified regulator to prevent aspiration of water droplets from the exhaust port.(4) Where such expensive equipment is not available and SCUBA and wet suits are the only alternative, thorough cleaning and decontamination of the equipment and divers should follow each dive. The diver should shower as soon as possible after the dive, using a disinfecting soap. NOAA recommends that the suit be machine washed in 50% bleach and hot water for 20 minutes and thoroughly rinsed.(5) This treatment would probably reduce the life of the suit, however.

A study testing methods of disinfection of suits found that spraying the suits, masks and regulators with surgical scrub type disinfectant significantly reduced microorganisms. Rubberized suits tend to be easier to disinfect than textured ones.

The diver's ears should be irrigated before and after each dive with 2% acetic acid solution to prevent swimmer's ear.

Heavy, protective footwear should be worn (thick soled wet suit boots). Care should be exercised when transporting equipment to the dive site.

A backup knife should be carried on the arm or bouyance compensator (B.C.) for use in the event of entanglement in monofilament line.

SUMMARY OF FINDINGS AND CONCLUSIONS

When the proper planning, training, and equipment are used, most waters are reasonably safe for diving operations. This evaluation of hazards was based on the equipment and training of the typical Department diver.

The equipment used is that available for typical sport SCUBA; the training required is a basic sport certification, but some divers have had informal on-the-job training.

Typical commercial equipment such as dry suits, hard hats, communication systems, surface air supply, and hyberbaric chambers are not available. The Department divers have not had training in the use of this type of equipment.

The typical water in Virginia is safe for employing Department divers when adequate pre-dive planning is conducted. One exception is the deep water near Smith Mountain Lake.

The factors to be determined by those responsible for employing Department divers are depth, visibility, current, temperature, bottom conditions, activities near the dive site, access to the site, and possible water pollution.

Depth

Water that does not exceed 40 ft. (12.4 m) in depth should not present a problem. The bottom time of the first dive, the surface interval required for a safe repetitive dive, and the time of the repetitive dives are all reasonable for safe and efficient work dives.

Water depths between 40 (12.4 m.) and 60 ft. (18.6 m.) allow for a maximum of one hour bottom time on the first dive. Repetitive dives, especially those of lesser depth than the first, afford sufficient work time with a reasonable surface interval.

Water depths of greater than 60 ft. (18.6 m.) have limited bottom time, with a maximum of 50 minutes at depths from 60 (18.6 m.) to 70 ft. (21.7 m.) and only 25 minutes at a depth of 100 ft. (31 m.); these are not recommended for routine work dives. Operations at depths in excess of

100 ft. (31 m.) should not be undertaken by Department divers.

Visibility

Visibility in typical Virginia waters is less than 1 ft. (3.05 m.). Working in low visibility water is not hazardous by itself. Carful planning and the use of equipment such as guidelines and descent lines should be routine. Any complicated operations should be practiced in clear water or on the surface before being performed in dark water.

Current

Currents in the waters of Virginia vary from almost placid to extremely rapid. In an extremely rapid current a diver equipped and trained as are the Department divers would not be able to perform efficiently. With planning, most diving can be conducted at times of diminishing current. In those waters influenced by tidal currents dives can be planned between tides; however, this time varies from day to day and is of relatively short duration. In mountain rivers, currents diminish with the onset of the dry season and, when possible, dives should be planned for this time.

Temperature

When dives are planned for late spring through early fall the water temperature should not present a problem for divers wearing 1/4 in. (.64 cm.) protective wet suits. In other times of the year, the temperature of the water should be determined. Generally, working in water above 60°F.(16°C.) is routine for a diver in a 1/4 in. (.64 cm.) wet suit. Prolonged dives in temperatures lower than the mid-50°F.(10°C.) point require dry suits.

Working divers should be observed for signs of overheating as well as for chilling. In either case, hyperthermia or hypothermia, the diver experiences physical malfunctions which will result in faulty judgement, unconsciousness, and, possibly, death.

Bottom Conditions

In most Virginia waters the bottom around bridge piers is cluttered with natural as well as man-made litter. The greatest hazards can be large logs or rocks, which are unstable; sharp metal, which can cut or puncture, or fishing lines that can entangle the diver. The best precaution is to conduct an orientation dive to identify and remove possible hazards. A small backup knife carried on the diver's B.C. or arm should be part of routine equipment when diving around bridges.

Surrounding Activities

Activities in and around a dive site can constitute a hazard. Among these activities are the operation of a dam, boat traffic, fishing, and construction.

Usually, diving operations can be coordinated so that potentially hazardous activities are completely mitigated. Dives in the vicinity of moveable spans should be coordinated with the bridge tender. The appropriate person in charge of dam operation or construction activities should be identified, and a written dive schedule should be filed with this individual.

As a routine practice, a float or dive boat with a dive flag should be used to protect divers upon descent and ascent.

Access Information

Information concerning access to a dive site is important for both the efficiency and safety of the dive. A great deal of dive planning and travel time can be lost when access to the site is controlled and proper authority for its use cannot be obtained.

When access, such as gates, is controlled by those other than the dive team, a potential safety hazard exists. An emergency exit from any dive operation should always be available.

Pollution

The individual and interrelated adverse effects of polluted waters on divers are complex. The best precautions are to protect the divers prior to diving with the prescribed inoculations, maintain clean wet suits, and provide the proper post-dive cleaning facilities for the divers.

Avoiding water which has been tested and declared contaminated should be routine for Department divers. Water that is suspected to be contaminated should be tested.

ACKNOWLEDGEMENTS

The authors extend appreciation to the representatives of the UNDERSEA MEDICAL SOCIETY (UMS), and the National Oceanic and Atmospheric Agency (NOAA) for providing information and guidance through their seminars, publications, and diving program. The Virginia Department of Highways and Transportation through the Bridge Division, district offices and Research Council contributed directly to the study.

Specifically appreciated was the interest shown and guidance provided by Charles W. Shilling, M.D., director of the UMS. The information received from Morgan Wells, director of the NOAA diving program, and through the seminars conducted by him, especially in the area of hazard evaluation, were extremely valuable.

Thanks are extended to Dick Rutkowski, director of NOAA's diving and hyperbaric training facility in Miami, and Cliff Newell, unit diving supervisor at the NOAA Northeast Fisheries Center, Woods Hole, for sharing their experiences to help sort out that information which is still theory from that which is safe and practical.

John Andrews from the Bridge Division of the Virginia Department of Highways and Transportation contributed to the study by giving general support and guidance. Hazeltine Strothers was instrumental in providing the appropriate inventory data which facilitated the bridge survey. The bridge engineers throughout the districts are acknowledged for their contribution of time and for providing the needed information and equipment required for conducting surveys.

John Shelor, research technician supervisor, and Steve Blackwell, research technician, are to be thanked for conducting extensive surveys which provided the basic data for this study and enabled the researchers to spend needed time collecting the underwater information.

GLOSSARY

Air Embolism - An obstruction of blood flow caused by an air or gas bubble.

Ambient Pressure - The total pressure surrounding a diver.

Barotrauma - A pressure related injury.

Bends - A type of sickness or injury due to the formation of gas bubbles in the blood or tissues.

Bottom Time - The amount of time a diver spends on a dive measured from the time he begins his descent until he begins his ascent, usually calculated for the greatest depth obtained.

Buddy Breathing - An emergency ascent technique in which two divers use the same regulator and air tank.

Current - A horizontal movement of water.

Cylinder - Term used in diving to denote a compressed air SCUBA tank.

Dark Water - Term used to denote water with minimum visibility.

Decompression Sickness - See Bends.

FSW - Abbreviation for feet of seawater, usually refers to pressure equivalent.

Gauge Pressure - The pressure indicated on a gauge, which does not represent absolute pressure.

Hyperthermia - A debilitating condition brought on by exposure to excessive heat.

Hypothermia - A debilitating condition brought on by excessive loss of heat from the body.

Narcosis - A condition resembling drunkeness or euphoria. believed to be caused by breathing nitrogen at a high partial pressure (usually experienced by divers at depths > 100 ft. (31 m.).

Residual Nitrogen - Amount of nitrogen remaining in the body from previous dives.

SCUBA - An acronym meaning self-contained underwater breathing apparatus.

Sport Diver - A term that distinguishes those who dive for sport or enjoyment from those that dive for commercial purposes.

CITED REFERENCES

1. McGeehan, Daniel D., "Procedures Manual for Compressed Air Diving (SCUBA MODE)", Virginia Highway and Transportation Research Council, Charlottesville, Virginia, VHTRC 81-R27.

2. Lotz, William E., editor, Protection of Divers in Water Containing Hazardous Chemical, Pathogenic Organisms, and Radioactive Material, Bethesda, Maryland: UNDERSEA Medical Society, Inc.: CR 60 (CW) 2-1-83.

3. Pennella, John J., "U. S. Navy Diving in Polluted Waters", in Marine Technology Society Journal, Vol. 15, 1981.

4. Wells, Morgon J., and Urick, Steven, "Modification of the Drager Constant Volume Suit for Polluted Water Diving", in Protection of Divers in Water Containing Hazardous Chemicals, Pathogenic Organisms and Radioactive Material. Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60 (CW) 2-1-83.

5. Phoel, William C., NOAA's Requirements and Capabilities for Diving in Polluted Waters", in Marine Technology Society Journal, Vol. 15, 1981.

6. Coolbaugh, James C., "Protection of Divers in Biologically Polluted Waters"in Protection of Divers in Water Containing Hazardous Chemical, Pathogenic Organisms and Radioactive Material. Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60 (CW) 2-1-83.

SELECTED BIBLIOGRAPHY

Byrd, Tallamy, Macdonald, and Lewis, Assessment of Deficiencies and Preservation of Bridge Substructures Below the Waterline. Washington D.C., National Cooperative Highway Research Program

Fitzpatrick, James F., Sohn, Michael N., Silfen, Thomas E., and Wood, Robert H., The Law and Roadside Hazards, Charlottesville, Virginia, The Michie Company, 1974.

Gottlieb, Sheldon J., "Assessing the Potential of Microbial Hazards of Diving in Polluted Waters," in Marine Technology Society Journal, Vol. 15, 1981.

Joseph S. W., Daily O. P., Hunt W. S., Seidler R. J., Allen D. A., and Colwell R.. R., "Aeromonas Primary Wound Infection of a Diver in Polluted Waters", in Journal of Clinical Microbiology, 1979.

McGeehan, Daniel D., Procedures Manual for Compressed Air Diving (SCUBA Mode), Charlottesville, Virginia, Virginia Highway and Transportation Research Council, VHTRC 81-R27.

National Cooperative Highway Research Program, Research Results Digest, No. 79, "Personal Liability of State Highway Department Officers and Employees", Washington, D.C., Transportation Research Board, National Research Council, 1983.

Phoel, William C., "NOAA's Requirements and Capabilities for Diving in Polluted Waters," in Marine Technology Society Journal, Vol. 5, 1981.

Sayler, G. S., Nelson, J. D., and Colwell, R. R., "Distribution and Significance of Fecal Indicator Organisms in the Upper Chesapeake Bay," in Journal of Applied Microbiology, Vol. 30, 1975.

Seidler, R. J., et al., "Isolation, Enumeratin, and Characterization of Aeromonas from Polluted Waters Encountered in Diving Operations," in Journal of Applied Environmental Microbiology, 1980.

Shilling, Charles W., M. D., National Plan for the Safety and Health of Divers in their Quest for Subsea Energy Bethesda, Maryland, UNDERSEA Medical Society, January 1976.

Thomas, Larry W., "Legal Implications of Highway Departments' Failure to Comply with Design, Safety, or Maintenance Guidelines," in Research Results Digest, No. 129. Washington, D.C., National Research Council, Transportation Research Board, 1981.

U. S. Department of Commerce, National Oceanic and Atmospheric Administration, NOAA Diving Manual: Diving for SCIENCE and Technology, 2nd. ed., James W. Miller, Washington, D.C., Government Printing Office, 1979.

U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Protection of Divers in Water Containing Hazardous Chemicals, Pathogenic Organisms and Radioactive Material, Lotz, William E. editor, Bethesda, Maryland, UNDERSEA Medical Society, Inc. UMS: CR 60 (CW) 2-1-83.

U. S. Department of Labor, General Industry: OSHA Safety and Health Standards (29 CFT 1910), Washington, D.C., Government Printing Office, Revised November 7, 1978.

U. S. Department of the Navy, U. S. Navy Dive Manual, Vol. 1, Air Diving, NAVSEA 0994-LP-001-9010, Washington, D.C., Navy Department, Change 1, December 1975.

APPENDIX A

DISCUSSION OF POLLUTED WATERS

Common opinion is that pollutants dumped into a body of water are rapidly dispersed and that the hazard to the marine environment and those exposed to it is reduced. Hydrographic research has shown, however, that it is not uncommon to find discrete water parcels in which pollution, salinity, temperature, etc., may differ considerably from the surrounding water, and the concentration of contaminants may be greater. The concentration of contaminants is definitely greater in the bottom sediment where contaminates settle and microbial fauna proliferate,(1) and this is where a lot of underwater inspection work is conducted.

Water pollution is generally divided into three categories: chemical, thermal, and microbial. In a given body of water, combinations of these three types may be present.

Chemical

Chemical pollution is contributed by the dumping of sewage and industrial effluent into waterways and from accidental spillage; e.g., that from oil or chemical tankers. River channels, ports or harbors, and open coastal water are the sites of the greatest amounts of chemicals spilled into the waters. A large variety of toxic chemicals enter the water, including petroleum products, acids, caustics, ammonia, alcohols, and other organic solvents. Contact with these chemicals can produce, among other effects, burns, headaches, nausea, and lung damage. Chronic effects from contact with petroleum products have included cancer, chemical pneumonia, central nervous system damage, and blood disorders.(2)

Thermal

Thermal pollution is primarily a product of using bodies of water to cool nuclear reactors. This practice elevates the temperature of the water and thus may alter the numbers and species of plant and animals in the water.

Microbial

Microbial hazards are encountered by divers on the shore and in the water. Primary among the diseases that may be contracted on the bank are those caused by organisms naturally found in the soil, e.g., clostridium welchii, the causative agent of gas gangrene, and clostridium tetani, responsible for tetanus.

In addition to microbial fauna naturally occurring in the water, some of which are known to be pathogenic, dumped sewage and wastes and agricultural runoff are sources of pathogenic bacteria and viruses. Potentially, all pathogenic organisms in the human population could be present in water contaminated by sewage; however, most microbial faunas introduced in sewage does not survive the water environment. Known exceptions are the waterborne diseases.

Although there are seasonal variations, a year's study of the Chesapeake Bay indicated that considerable levels of pollution indicator bacteria were present throughout the year, regardless of the temperature or salinity.(3) Water clarity is not an indicator of purity, since even when water vision is relatively clear, microbial counts may still be high.(4) However water turbidity that results from suspension of bottom sediment could indicate a high level of microbial fauna. Organisms, including viruses, have been shown to associate with bottom sediment.(5)

Physical

Among the issues that complicate the predictability of the adverse effects of various pollutants on the health of individuals in contact with them is the complexity of possible interactions between the different pollutants. Both chemical and thermal pollution can alter the microbial fauna (natural and introduced) in several ways. Sewage may contain nutrients that favor an increase in the overall population, or the chemical imbalance resulting from sewage and industrial effluent introduced into the water may promote the growth of certain species of microorganisms. For example, phosphates and nitrates promote the proliferation of the pathogenic bacteria Pseudomonas, Klebsiella and Aeromonas.(6) The biological degradation of organic material can result in reduced pO_2 levels which may encourage an increase in the population of anaerobic bacteria which are responsible for serious wound infection. Thermal pollution also potentiates the microbial population and selects for some species, especially those that thrive at higher temperatures (including potentially pathogenic species). Chemical pollution can encourage genetic mutation within the microbial population which could lead to subspecies with increased virulence. (7)

There are no studies available on the effects of short-term or long-term exposure of divers to polluted water. There are reports of incidents of chemical burns and infections as a result of diving in polluted water. (8) A recent study has indicated that divers are colonized by potential pathogens in the course of diving operations. Samples were obtained from divers' noses, throats, ears, and masks before and after dives in water around Norfolk, Virginia; Seattle, Washington; and New York, New York. These samples were evaluated for total quantity of bacteria present after diving and new species of pathogens present after the dive.

Contamination of SCUBA divers and their equipment as a result of diving was a consistent finding. (9,10) Although it is difficult to predict the combined effect of several pollution hazards on the diver, some synergism would be expected. For example, chemical burns can reduce the natural impermeability of the skin and body orifices to various microbial threats. (11) In the water, because of reduced vision and the diver's concentration on his task, contact with submerged debris is not uncommon. A serious significance of physical hazards is that cuts or puncture wounds resulting from them allows entry for microbial pathogens.

The effect of the pressurized aqueous environment on the human body produces additional variables. Hydration of the skin from immersion or from contact with an occlusive covering such as a diving suit can considerably increase the permeability of the skin to pollutants. (12) A significant complication of the pollution hazard to divers is that the pressures associated with diving may facilitate the introduction and increase the viability of pathogenic organisms. A case has been reported of an *Aeromonas* infection as a result of diving in polluted water. *Aeromonas* is an organism that generally does not infect healthy individuals, especially as a primary pathogen. (13) Chemical agents present in the water could also be forced into the tissues by increased pressures.

Wet suits admit and hold water from the environment. It has been documented that divers wearing SCUBA are contaminated by microorganisms during the course of diving operations.(14) Scanning electron microorganism studies have shown microorganisms clinging to the textured surfaces of suits and other equipment. Since adhesion is the first step in pathogenecity, those organisms found on the diver and his equipment after diving may be selectively those capable of causing an infection.(15)

Infections can enter the body through several routes, through the skin, especially if it is unusually permeable or cuts exist, through eyes, ears, and mouth passing from those to gastraintestinal or respiratory systems. An explanation follows of the problems and protection that the SCUBA diver has for each of the avenues.

Skin irritation is the most frequent complaint of commercial divers diving in polluted water.(16) This avenue of pathogen entry is perhaps the most difficult to evaluate since the variables are numerous and effects may be long-term. Even in the case of known response to chemical exposure, the skin of SCUBA divers would seem to be increased significantly by extended exposure to water and increased hydration. The close fitting wet suit would also maintain hydration as well as increased temperature of skin and superficial blood flow. The suit's foam material could trap chemicals so that repeated exposure to a variety of chemicals would result from subsequent dives. On the other hand, the diver is protected to an extent by the diluting of hazardous materials by the surrounding water and the relatively short duration of exposure, since his work time in the water is limited.

The thickness of the skin and variation in blood supply to different areas causes some parts of the body to be more sensitive or resistant than others to irritation from chemical agents. The palms, soles, and inner forearms tend to have poor penetrability while the underarms, scrotum, scalp, and face have good penetrability and are, therefore, more likely to exhibit skin irritation.(17)

Any interruption of the skin provides a route of entry for pathogenic organisms, which implies that diving with cuts, or skin irritation is inviting infection. Cases have been documented of secondary infections of cuts resulting from diving.

The design of the SCUBA regulator mouthpiece renders some exposure of the oral cavity to the surrounding water likely. Even if the regulator is retained in the mouth for the duration of exposure to water, a demand regulator may allow droplets of water to be aspirated or swallowed. (18) Removal of the regulator and its return to the mouth permits entry of a larger quantity of water. Since pathogenic bacteria capable of causing pneumonia and many gastrointestinal infections are commonly found in waterways (see Table A-1), this exposure is potentially hazardous.

There are two known genuses of pathogenic organisms amoebae (Naegleria and Acanthamoeba) that enter the body via the nose and result in an acute meningoencephalitis that leads to death in from 2 to 7 days. Acanthamoeba can also lead to pulmonary or wound infection. Most cases have been associated with swimming in warm or thermally polluted fresh water. A large percentage of the cases have occurred in Virginia, particularly around Richmond. The presence of Naegleria has been established in Lake Anna. The number of cases is small (less than 150 worldwide), however, and the diver is afforded protection by his mask, since the organisms enter via the nose. The risk of infection would increase with long dives, a chronic mask leak, or the presence of a wound. (19)

External ear infections (Otitis externa) are probably the most common dive-related ailment. The most frequent etroligic agent is Pseudomonas aeroginosa, an aquatic organism. Bacteria levels are generally increased after a dive . Just wearing a hood increases bacterial levels in the ears of 50% of individuals, according to a recent study. Prophylactic measures can significantly reduce this problem. Organisms known to cause eye infections occur in the water, but the mask should afford considerable protection. Sinusitis could conceivably be caused by waterborne organisms, also. (20) Hyperbaric pressure and initiation from equalizing might contribute to the frequency of this condition in divers.

Table A-1

SOME INFECTIONS THAT MAY OCCUR FREQUENTLY IN DIVERS

EYES, EARS, NOSE & THROAT

Sinusitis

Otitis Externa

Conjunctivitis

Pharyngitis

CENTRAL NERVOUS SYSTEM

Amebic Meningitis

RESPIRATORY

GASTROINTESTINAL

Diarrhea, Dysentery

Hepatitis

SKIN

Secondary Wound Infections

CITED REFERENCES

1. Phoel, William C., "NOAA's Requirement and Capabilities for Diving in Polluted Waters," in Marine Technology Society Journal, Vol. 5, 1981.

2. McLellan, Steven A., "Analysis of Material Release Data to Determine the 'Typical' Spill Environment," in Protection of Divers in Water Containing Hazardous Chemical Pathogenic Organisms, and Radioactive Material. Bethesda, Maryland, UNDERSEA Medical Society, Inc.: CR 60 (CW) 2-1-83.

3. Sayer, G. S., Nelson, J. D., and Collwell, R. R., "Distribution and Significance of Fecal Indicator Organisms in the Upper Chesapeake Bay," in Journal of Applied Microbiology, Vol. 30, 1975.

4. Coolbaugh, James C., "Protection of Divers in Biologically Polluted Waters," in Protection of Divers in Water Containing Hazardous Chemical Pathogenic Organisms, and Radioactive Material. Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60 (CW) 2-1-83.

5. Colwell, R. R., and Grimes, D. J., "Microbiological/-Chemical Hazards to Divers in Polluted Waters," in Protection of Divers in Water Containing Hazardous Chemical Pathogenic Organisms, and Radioactive Material. Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60 (CW) 2-1-83.

6. Gottlieb, Sheldon J., "Assessing the Potential of Microbial Hazards of Diving in Polluted Waters," in Marine Technological Society Journal, Vol. 15, 1981.

7. Joseph, S. W., Walker, R. I. and Daily, O. P., "Microbial Insult to Diving Personnel: Perspectives on the Impact of Radioactive and Chemical Pollutants" in Protection of Divers in Water Containing Hazardous Chemical Pathogenic Organisms, and Radioactive Material, Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60 (CW) 2-1-83.

8. Pennella, John J., "U. S. Navy Diving in Waters Contaminated with Hazardous Material," in Protection of Divers in Water Containing Hazardous Chemical Pathogenic Organisms, and Radioactive Material.

Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60(CW) 2-1-83.

9. Seidler, R. J., Allen D. A., Lockman H., Colwell, R. R., Joseph S.W., and Dailey O. P., "Isolation, Enumeration, and Characterization of Aeromonas from Polluted Waters Encountered in Diving Operations" in Journal of Applied Environmental Microbiology, 1980.

10. Coolbaugh, James C., "Protection of Divers in Biologically Polluted Waters," in Protection of Divers in Water Containing Hazardous Chemical Pathogenic Organisms, and Radioactive Material. Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60 (CW) 2-1-83.

11. Gottlieb, Sheldon F., "Assessing the Potential of Microbial Hazards of Diving in Polluted Waters," in Marine Technology Society Journal, Vol. 15, 1981.

12. Daugherty, Gordon C., M.D., "Diving in Chemically-Polluted Water: An Overview of Basic Toxicology," in Protection for Divers in Water Containing Hazardous Chemical Pathogenic Organisms, and Radioactive Material. Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60 (CW) 2-1-83.

13. Joseph, S. S., Daily O. P., Hunt W. S., Seidler R. J., Allen, D. W., Colwell R. R., "Aeromonas Primary Wound Infection of a Diver in Polluted Water". Journal of Clinical Microbiology. Vol. 10, 1979.

14. Seidler, R. J., Allen D. A., Lockman H., Colwell R. R., Joseph S. W., Dailey O. P., "Isolation, Enumeration, and Characterization of Aeromonas from Polluted Waters Encountered in Diving Operations." Applied Environmental Microbiology, Vol. 39, 1980.

15. Joseph S. W., Walker R. I., and Daily O. P., "Microbial Insult to Diving Personnel: Perspectives on the Impact of Radioactive and Chemical Pollutants". in Protection of Divers in Water Containing Hazardous Chemical Pathogenic Organisms and Radioactive Material. Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 50 (CW) 2-1-83.

16. McLellan, Steven A., "Session Summary", in Protection of Divers in Water Containing Hazardous Chemical Pathogenic Organisms and Radioactive Material.

Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60 (CW) 2-1-83.

17. Daugherty, Gordon C., M. D., "Diving in Chemically-Polluted Water: An Overview of Basic Toxicology," in Protection of Divers in Water Containing Hazardous Chemical Pathogenic Organisms and Radioactive Material. Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60 (CW) 2-1-83.

18. Lettnin, H., "Polluted Water Diving: Diving Equipment for Diving in Contaminated Atmospheres, Especially in Radioactive Contaminated Water" in Protection of Divers in Water Containing Hazardous Chemicals, Pathogenic Organisms and Radioactive Material. Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60 (CW) 2-1-83.

19. Daggett, Pierre-Marc, "Protozoa from Polluted Waters; Potential Human Pathogens," in Marine Technology Journal, Vol. 15, 1981.

20. Coolbaugh, James C., "Protection of Divers in Biologically Polluted Waters", in Protection of Divers in Water Containing Hazardous Chemicals, Pathogenic Organisms and Radioactive Material. Bethesda, Maryland, UNDERSEA Medical Society, Inc. CR 60 (CW) 2-1-83.