ARCHAEOLOGICAL DIVING IN LOW VISIBILITY OR ZERO VISIBILITY

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Typical low-visibility conditions. *Photos by Dan Lynberg*

1. CONTEXT

Many archaeological sites lie in coastal, estuarine, or riverine waters with strong currents, mud bottoms, and bad visibility. Even if conditions are poor, work can proceed safely and yield positive results if the divers are competent and comfortable. Trained divers can get good data in bad water.

2. NEEDS

a. Diver safety and comfort

Black water increases the risks and stresses of diving. Unfamiliarity and lack of visibility breed fear and increase stress and air consumption. Entanglements, overheads, and other hazards cannot be seen and are more difficult to escape. Gauges may be impossible to read. Murky waters are often polluted, increasing the risk of infection or disease from a minor scratch or cut.

Projects must be conducted with the highest standards of personal safety and the best practices of scientific diving. Safety requires increased underwater teamwork, topside support, and advanced planning. With proper preparation, good gear management, and good diving skills the problems can be avoided or minimized and the tasks successfully completed. Essential skills for individuals include buoyancy control, underwater navigation, equipment configuration, and non-horizontal positioning. Essential skills for buddy teams include communicating, recognizing problems, and assisting when necessary. Those skills are discussed in detail in Section 4 below.

Divers must be prepared for all eventualities. Black water skills are best acquired by being taught how to respond appropriately to the lack of vision. Comfort requires a calm, positive attitude and an understanding of the realities to be confronted.

Task-oriented diving requires the diver to focus on the work to be done. Diving becomes a tool, not an end in itself. Skills therefore must be automatic and reflexive, which usually requires the gradual accumulation of experience over time. To minimize stress, the tasks assigned for a dive must be realistic, and the time to perform those tasks must be adequate.

Some techniques developed for river, cave, and cavern diving may be useful in low-visibility diving. See Taylor, 1990; van Tillburg, 1994; von Maier, 1991; and Zumrick et al., 1988.

b. The buddy system

The buddy system does not diminish the need for self-sufficiency. Despite a greater need for underwater teamwork, diving in black water is close to solo diving because divers cannot easily communicate visually (von Maier, 1991). It may be difficult for one diver to know if his buddy has a problem and to intervene effectively. Self-reliance and cooperation are both essential.

There is a role for each diver in the buddy team. Usually, one diver is the leader and the other follows for safety and for tasks that require two. For example, when measuring a large object one diver holds the tape at a reference point and the other moves to take measurements at other points. When using a circle search one diver might hold the line at the center while the other swims the circle. When following a linear bearing one diver navigates by compass while the other diver searches.

Signals use sound, touch, or prearranged pulls along measuring tapes or buddy lines. When two divers separate to take measurements over a long distance the measuring tape serves as a buddy line for communication between them. Although not in visual contact, they must maintain that connection. If separation does occur, one diver might remain stationary and use audible signals to call the other; or one might surface while the other deploys a buoy; or they both might surface; or, on some sites, a prearranged rendezvous point might be established. The "lost contact" procedures for each dive must be specified in advance.

c. Collecting good data

Despite bad conditions, site data still must be reliable, accurate, and complete — or else there is no point in diving. Measuring tapes must lie straight and true. Measurements must be accurately taken and legibly recorded. All the important features on the site must be found and surveyed to create a complete site map. Turbid water makes the task slower, harder, and more challenging, but also more interesting and rewarding.

3. GEAR

a. Generally

Each diver must ensure his gear is serviced by a qualified technician annually or as recommended by the manufacturer, test all gear before arriving on site, and bring his own spares. Basic gear for each diver includes, but might not be limited to, the following:

- ✓ cut- and abrasion-resistant dive suit, gloves and hood with adequate thermal protection;
- ✓ regulator with "octopus" rig;
- ✓ no snorkel;
- ✓ knife and EMT shears;
- ✓ large light and smaller back-up light;
- ✓ non-fouling wreck reel;
- ✓ watch;
- ✓ console-mounted compass, depth gauge, and pressure gauge;
- ✓ marker buoy with float and anchor;
- ✓ slate with two pencils;
- ✓ folding ruler; and
- ✓ 50- or 100-meter measuring tape.

Contact with sharp or toxic objects can easily occur, so body and hand protection is needed even in warm water. A slight injury can inconvenience other divers and disrupt the project.

An "octopus" rig is needed to share air or inflate lift bags.

Snorkels are entanglement hazards. Wear your mask strap under your hood.

EMT shears are needed for steel fishing leaders. For easy access and to reduce entanglement knives and shears should be worn on the HP hose, power inflator hose, BC shoulder strap, or other location near the chest. The diver must be able to find it, free it, use it, and put it back in its sheath by feel even if entangled. Knives must be sharp. Shears must be sharp and tight.

Each diver should carry a primary light and a back-up light. Powerful lights are essential. Cave lights are best. A strong light may be seen at a short distance in black water and will illuminate gauges. Lights should be checked for operation and batteries replaced or recharged before every dive. Handheld lights should be carried in a BC pocket, but detachable when needed.

The wreck reel should hold at least 50 meters of abrasion-resistant line. The line can be used as a buddy line, for taking bearings, for ascent, or for deployment of a buoy. Divers should use different colors to distinguish their lines from other divers' lines, entanglements, or baselines.

Bright colors can be seen even in low visibility. Reel lines should be fairly thick, say 1/8-inch, to reduce snarling and "bird-nesting."

It is nearly impossible to read digital gauges and watches in black water. Analog devices are much better. Gauges should be worn at chest level, not stuffed into a BC pocket. An instrument console is important, because wrist-mounted instruments can easily get fouled or ripped off.

Each diver should carry a small buoy to signal the boat if assistance is needed or to mark a submerged object. He must be able to deploy the buoy without getting tangled in its line. It is best if each diver uses a different color buoy.

Slates must be big enough to carry all the drawings and notes that will be made during the dive, but small enough to be handy. A 12-inch (30cm) plastic square with a ruler or scale on the edge is best. It should have a lanyard, a way to carry pencils (2B or softer), and perhaps a polymer eraser. Surgical tubing or a tube made of duct tape can hold pencils and eraser when not in use. The Paper Mate ® SharpWriter ® mechanical pencil with eraser works well.

Notes, drawings, and data should be recorded on Mylar™ sheets so they can be cleaned and protected after the dive and photocopied at leisure. The Mylar™ should be attached with duct tape, not metal clips. Immediately after each dive the diver should ensure the sheets are complete and legible, and correct them as necessary. The sheets are then rinsed in fresh water, air dried, and sprayed with fixative (Krylon™ or hair spray) to prevent smudging or accidental erasure.

All gear must be carried close to the body, not dangling. Gauges and emergency gear must be immediately accessible. Other items should be carried in a pocket or pouch. Strap ends should be taped down. Other entanglements or "endanglements" must be corrected. The Dive Supervisor should personally check every diver before every dive to ensure his gear is appropriately rigged.

b. Tank valves

If the tank valve becomes entangled or rubs against structure the diver must ensure the valve is fully open and was not partly or fully closed by the entanglement or contact. The tank should be worn high enough on the back for the diver easily to reach the valve.

A "J" valve provides an extra layer of safety when the water is so murky that the diver cannot read his pressure gauge. However, the "J" valve must be properly rigged, the diver must be able to move the handle, and he must periodically ensure the handle has not been flipped accidentally to the reserve position. A "J" valve is **not** an acceptable substitute for an alternate air source.

c. Alternate air source

Divers must have an alternate air source if there is any risk of entanglement or entrapment, or if the dive depth and environment might prevent or restrict emergency access to the surface. The alternate source can be a pony bottle or doubles. Doubles may be yoked or independent. Yoked doubles are preferred.

d. Sharing air

A diver should normally breathe from the regulator that he will give to a buddy who needs air. That way, the diver who needs air will know where to get it and will know it works.

That regulator should be fitted with a long hose, 2 meters or 7 feet. The hose must not be so long or loose that it gets entangled, nor so short that it prevents the safe administration of air. The hose must not be wrapped around the donor diver’s neck. It may be wrapped around his body or

tucked into flexible bands (inner tube, surgical tubing, or bungee cords) on the tank or the side of the BC so it does not become entangled but is immediately and fully available to the buddy. The hose may require a 45° or 90° swivel that allows it to run downward next to the diver's body and under the arm to reduce entanglement risk but allow free use by the other diver.

The other second stage — the one the donor will use when sharing air — should have a short hose and be held by a loop of surgical tubing just below the chin where it is immediately available to the donor but will not get snagged or fouled with mud.

e. Jon lines

Each diver should carry a 2-meter Jon line, with an eye in one end and a dog clip in the other, to use as a buddy line, as a holding line to maintain position, or for short circle searches.

f. Boat gear

The equipment, supplies and information needed on the dive boat include everything normally required by Coast Guard rules and by good seamanship, plus the following:

- ✓ dive plan that lists emergency assistance facilities, local hospitals, and the nearest recompression chamber;
- ✓ marine VHF radio to call the Coast Guard or other emergency assistance (Channel 16);
- ✓ GPS unit to know and report your exact position, especially at sea;
- ✓ tools and generic dive spares (O-rings, mask and fin straps, extra weights, &c.);
- ✓ drafting instruments, pencils, pens, graph paper;
- ✓ medical oxygen (O_2) kit;
- ✓ first aid kit, with antiseptics, bandages, seasick pills, and jellyfish sting wipes;
- ✓ ALFA and diver-down flags;
- ✓ diver recall signals;
- ✓ float line of 50 to 200 meters (depending on depths and currents) for surface extension from the boat;
- ✓ life ring with a floating line to be thrown to a surfaced diver;
- ✓ long boathook; and
- ✓ short lines to hold surfaced divers, lift bags, and other equipment alongside the boat. These lines should be attached to cleats and ready for immediate use.

4. DIVE SKILLS

a. Planning

(1) Safety

All dives should be conducted by two-diver buddy teams under a Divemaster protocol. The pre-dive briefing will cover procedures for safety, communications, and loss contact; diver recall signals; task assignments; and potential risks.

Decompression dives and penetration of underwater structures should never be attempted in low visibility. Dives deeper than 10 meters (33 feet) must include a 3-minute safety stop at 4.5 meters (15 feet). Dives should end when tank pressure reach a specified level, such as 800 psi for dives

shallower than 15 meters (50 feet) or 1,000 psi for deeper dives. In all cases, dives should end when the assigned tasks are completed.

Repetitive dives may be required, but conservative tables should be used for surface intervals and repetitive bottom times.

Whenever divers are in the water a stand-by buddy team must be ready for immediate entry in an emergency or to assist the divers in the water. The boat crew must maintain a continuous watch for bubbles and emergency buoys. When a diver deploys an emergency buoy the stand-by team enters the water with a spare tank and regulator, descends the buoy line to the diver, assists as needed, and ensures that the diver in distress and his buddy are safely recovered. The stand-by team usually will be the divers scheduled to dive next in sequence after the in-water team. Only one dive team should be in the water at a time, to minimize interference and silt disturbance.

The Divemaster shall log the following information for every diver on every dive:

- ✓ breathing gas, tank size(s), and tank pressure(s);
- ✓ time when the diver enters the water;
- ✓ time when the divers begin their descent;
- ✓ expected time to surface, at 30 feet (9 meters) per minute ascent plus a safety stop;
- ✓ time when each diver surfaces;
- ✓ time when each diver exits the water, and
- ✓ tank pressure when exiting the water.

(2) Task loading

Individual and team skills must be considered when assigning tasks, to minimize stress and frustration and to maximize the efficient use of time and other resources.

b. Communications

(1) Boat to diver

A general recall signal and an emergency recall signal will be established and reviewed by all divers before water entry. Because of difficulties in reading watches in turbid water and the increased likelihood of distraction while concentrating on tasks, a time limit for each dive should be set. A general recall signal should be made to the dive team two minutes before their scheduled ascent, and again when they should start their ascent. A separate, distinct, emergency recall signal should be available for urgent, life-threatening situations. Signals may include hammering on the boat's hull, hammering on a partially submerged bell, an underwater horn, firecrackers, or revving the boat's engine.

(2) Diver to boat

Depending on conditions, the plan might provide that an individual diver's buoy will be used only to call for help. In other cases it might be used to mark objects for further work. Divers can carry a buoy or small lift bag to mark objects, plus a safety sausage to call for help.

(3) Diver to diver

Underwater signals use hand squeezes, pulls on a buddy line or measuring tape, and sounds. A prearranged code allows effective communication without visual contact. It is important to realize that sound localization underwater is imprecise although transmission of sound is

enhanced. Because the available range of tactile or audible signals is small, signals should be tailored for the specific dive. For example, if the dive will involve measurement of features two tugs or squeezes or grunts could mean "go to the next feature." On another dive to recover an object with a lift bag the same signal might mean "blow the bag."

One distinct signal, such as three tugs, should be used only for emergencies.

Other signals can be improvised. For example, to relay a measurement or a distance, one diver can hold the other diver's hand and poke his palm the correct number of times, with a line to separate units. Palm pokes will not be confused with the hand squeezes used for other messages. If using metric units, 3.6 meters (12 feet) would be three pokes, a line, and six pokes — the same way it would be written (see Section 4.f (3), below). If using feet and inches the same signal would mean 3' 6" (1.1 meters).

c. Gear management

Entanglement is possible or even likely. Each diver should be as trim as possible and be aware of snag hazards on his rig. Tanks, valves, fins, knives, wrist-mounted instruments, and weight belts easily foul on fishing lines, nets, cables, ropes, or even seaweed or grass. In many cases the diver will not be able to see what he is tangled in. Managing dive gear and minimizing the risk of entanglement before and during the dive will make problems less likely and easier to correct.

Early recognition and communication of entanglement may prevent a bad situation from getting worse. In this way one diver may assist the other before both become entangled and release becomes more difficult. Movements should be slow and easy, rather than erratic or jerky, to keep entanglements to a minimum.

A diver may become so entangled that he must doff his fins or tank and BC to escape. This requires blind release techniques, which must be practiced in advance. Doff-and-don is an emergency option to be used only as a last resort, but all black-water divers must be capable of doing it by feel. For the greatest safety in doffing and donning the diver and the dive rig each should be weighted for approximately neutral buoyancy.

d. Buoyancy

For reconnaissance and general mapping divers should be neutrally buoyant with minimal weight. For detailed work on specific features, divers should wear approximately 10 pounds of extra weight to make it easier to stay on location. The choice between belts, integrated weights, tank weights, or a combination, is up to the diver. However, many dives will be in a head-down feet-up position, so integrated weights or back- or tank-mounted weights may not be suitable.

Working in an inverted, vertical position helps avoid stirring up silt. Divers must be able to clear their masks, adjust their buoyancy, and use their tools in that position. Archaeological diving usually requires limited horizontal movement. The diver may need to hover in one spot for much of the dive and should minimize bottom disturbance by eliminating unnecessary movements. Proper thermal insulation is important to maintain comfort during periods of immobility.

e. Navigation

To minimize site disturbance a specific entry point may be established. Typically that point will be a conspicuous feature with a temporary buoy, or a tag line to the dive boat's anchor. The dive boat should never anchor into the site itself, but should anchor so the wind or current will swing her near the site — but not directly over it in shallow water.

Once the entry point is established, each diver should conduct at least one familiarization dive to understand the site and to learn the routes and approximate distances to the features he will map.

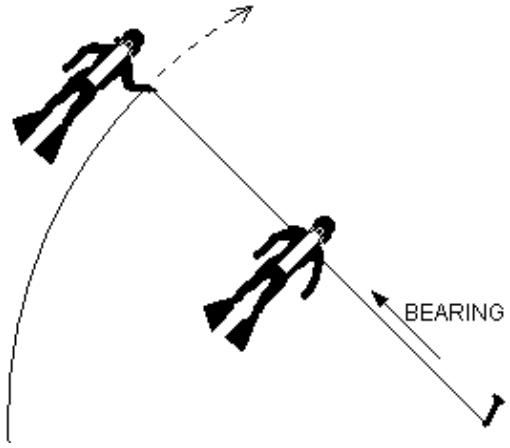
A diver must always know where he is on the site. A compass is needed to take bearings. Lines can be rigged to orient divers, to divide the site into segments for mapping, and as baselines for trilateration. The lines should be strong enough to help divers stay on site in current.

f. Archaeological research skills

(1) Searches: Most searches will be circular, using a radius line off an anchor or other fixed object. Wreck reels or dedicated radius lines can be used. The lines should be knotted at 2-meter intervals. Those intervals can be subdivided by hand.

When two divers make a circle search with the radius line anchored at the center, the diver swimming the outer circumference sets the radius and the pace, and keeps the line taut. He should mark the start of the circle to know when the circle is completed. Any kind of mark, such as an existing feature, a stick or a rock, will do. The second diver follows the mid-point of the line, and signals the outer diver if he sees the line get tangled on an obstruction.

To map an object found on a circle search, record the radius and the compass bearing or direction from the center to the object (the reciprocal of the bearing from the object to the center).



In order to help understand and remember the location and description of a feature, during the dive each diver should rehearse how he will describe and record it after the dive. Mentally putting it into words underwater will make it easier to recall after the dive.

(2) Trilateration: Divers should know basic trilateration techniques and the use of linear transects. Trilateration can be done off one or more baselines or off a series of features that have been mapped to each other. In turbid water, care is needed to ensure that all baselines and measuring lines lie straight and are not bent around a snag. A Zip-Loc bag of clear water can be used to read measuring tapes and rulers. Tracings, rubbings, and clay impressions can be made of small details. Larger details can be sketched by feel.

(3) Measurement techniques

Most measurements will be made with measuring tapes or rulers. It is important to make all measurements in the same units, i.e., feet and inches, feet and tenths, or meters and centimeters. Data should be transferred onto a Mylar™ sheet taped to a slate. Writing should be legible, big

and clear enough to read on the boat or on shore. Use dashes for decimal points. Two and a half meters should be written as 2—5, not 2.5, because the decimal may get lost or smudged off.

If the water is too turbid to read measuring tapes, other techniques can be used. These include:

Body dimensions: Each diver should be able to use his body to obtain reasonably accurate measurements of a feature and its distance to other features. These techniques include ancient English measurement units that were originally derived from body parts:

inch:	length of the second digit of the index finger (1 – 1.5 inches, 2.5 – 4 cm)
hand:	width of the hand at the base of the four fingers (3.5 – 4.5 inches, 9–11 cm)
hand span:	tip of thumb to tip of little finger of outstretched hand (8– 9.5 inches, 20–24 cm)
cubit:	elbow to tip of middle finger (~ 18–20 inches; 45–50 cm)
yard:	nose to fingertip of outstretched arm (~33–36 inches; ~100 cm)
arm span:	hand to hand, comfortably spaced, moving sideways (~5 feet; 150 cm)
fathom:	fingertip to fingertip of outstretched arms (~6 feet; 2 m or 200 cm)

Movements: Each diver should know approximately how far he will move with normal fin kicks in still water. The technique needs to be adjusted for current, for moving cautiously in black water, and when trailing a tape or line. Other devices, such as a hand-held platform or "creeper" that is repeatedly advanced along a hard bottom, can be used to measure distances—but those devices may stir up the silt and further reduce the visibility.

5. TRAINING

New divers need training under controlled circumstances before trying to work in black water. Training can begin in a pool and continue in open water.

a. Pool work

(1) Black mask exercises

Pieces of a black plastic garbage bag can be held over the dive mask by rubber bands or tape. One layer will reduce vision enough to give the experience of low visibility. Holding gauges against the mask and shining a dive light through the side of the mask allows the diver to see his gauges. A double layer of garbage bag or a layer of duct tape will reduce visibility to zero.

When the diver is comfortable with low or no vision, the second exercise should be to measure and record the dimensions of an object small enough for one diver to hold.

Third, a buddy team should map an object so large that one diver can only touch one end. Several measurements should be taken, where one diver maintains at a fixed point and the other moves to other points.

Fourth, objects should be sketched by feel. This may be done during the black mask exercise, or blindfolded in a classroom. Objects may be of various size and complexity to show the difficulty of the work and to illustrate the types of errors commonly made when translating a mental image into a written picture. To start, a simple ball, a child's toy, or small wheel is difficult enough.

(2) Entanglement exercises

Entanglement in lines or nets can be a serious risk. In order to learn how to deal with it, divers should practice getting entangled under controlled conditions. Learning to relax and to evaluate and correct those situations instills the confidence and skill needed to work safely in open water.

b. Open Water work

High risk exercises should not be attempted in open water. Exercises in open water should develop skills gradually. They should include navigation from point to point, swimming along a line and a circular transect, and data recording. Transect work involves finding and mapping objects when swimming on a line, a bearing, or a circle. Data retrieval involves using trilateration or offsets to map an object in relation to other features or a baseline.

c. Gradation of sites

Competence and comfort take time to develop. Divers should undertake dives that are gradually more challenging in visibility, depth, the complexity of tasks and sites, and the fragility of sites. It is not realistic to expect a diver to be fully competent to map a deep, complex site until he or she has accumulated many hours of experience over the course of dozens or hundreds of dives in low visibility. Ideally, every dive will incrementally challenge the diver and add another skill to his or her repertory.

6. SUMMARY

The goal of underwater archaeological research is safely to collect reliable data. Properly done, each dive will be safe and will to contribute to the research product, i.e., a site map. But that takes training, practice, and experience. SAFETY FIRST!

7. FURTHER READING

Busuttili, M., M. Holbrook, G. Ridley and M. Todd 1987. *Sport Diving, the British Sub-Aqua Club Diving Manual*, Stanley Paul Publ., London, UK

Graver, D. 1985. *The NAUI Textbook II*. NAUI Publ., Montclair, CA

Taylor, L. 1990. *River Diving Technique*. *http://www.mindspring.com/~divegeek/rivertech.htm*

van Tilberg, Hans K. 1994. *Zero-Visibility Diving on the Maple Leaf*. International Journal of Nautical Archaeology, 23(4), 315-318. Harcourt, Brace & Company.

Von Maier, R. 1991. *Solo Diving: the art of self-sufficiency*. Watersport Publ., San Diego, CA

Zumrick, J.L., J.J. Prosser and H.V. Grey 1988. *NSS Cavern Diving Manual*. Nat. Speleol. Soc., Branford, FL.

Cave diving websites: *http://www.cavediving.com* and *http://www.safecavediving.com*

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