Guidelines for Sump Rescue

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Though the people who contributed to this come from many organizations and backgrounds, this document is not endorsed by any organization.
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I. Introduction

This document provides guidelines for sump rescue. Sumps are underwater cave passages with at least one end continuing in dry cave. Cavers may become trapped beyond a sump when normally dry cave passage floods, or divers traveling beyond the sump suffer a problem preventing their normal return.

Every sump rescue is different, with different tasks combined in myriad ways. It will be up to you to decide which tasks to execute and when. We provide factors to consider and a recommended method for each task. If you need to modify a method, you should consult with your fellow rescuers to come to a consensus. As an example, it is frequently the case that sumps are safer to dive solo than in buddy teams. This is a decision that should be assessed and agreed upon by the wider team.

This document has been written for both the experienced sump diver and for rescue personnel with no diving experience. It does not contain information about general cave diving or cave rescue. There are many books for the former, and the Manual of U.S. Cave Rescue Techniques is a good source for the later.

There are at least five different roles that directly contribute to the diving aspects of a sump rescue. Personnel may perform more than one role. Divers conduct reconnaissance in and beyond sumps, transport supplies through sumps, modify sumps for trafficability, and assist patients through sumps. Dive supervisors lead teams of divers. They assign tasks to individual divers, represent the divers at meetings, and look out for the welfare of the divers. Dive site managers supervise dive sites by tracking dive status, conducting inspections, and improving site operations and conditions. Sustainment personnel requisition and maintain supplies and equipment, package supplies, and help transport supplies and equipment to and from dive sites. Lastly, dive planners develop plans to help the divers succeed, and document diving activities.

Failure Analysis

The reason patients are prevented from leaving the cave on their own can be traced to a combination of three primary variables: Patient, Equipment, and Passage. Assessing the involvement of these variables in a particular incident will help you craft the rescue plan. The rescue may be a self-rescue, a snap rescue by a search team, or a deliberate rescue operating with a full set of information, rescuers, and equipment. These primary variables are similar to the Patient, Passage, and Team variables used for planning dry-cave self-rescue. Note that the Equipment variable has been added because some form of diving equipment is needed for all non-trivial sumps. No use for a Team rescue variable has been found for assessing the inability to exit through a sump.

The *Patient* variable focuses on the people trapped beyond the sump. They may not have the skills to travel on their own through a sump. They may not be in a psychological state to move through a sump. They may be injured. Their injury may prevent them from traveling to and/or through the sump.

The *Equipment* variable focuses on SCUBA diving equipment. The patient's breathing gas supply may be depleted or damaged. If they have a rebreather, it may be damaged. They may not be able to control their buoyancy, whether through a broken buoyancy control device, lost weights, etc. Experienced divers do not need lights to follow a guideline in an emergency, but they may have decided it was safer to wait for working lights. In a deep sump, a dive computer is needed for managing decompression. If the sump is long, their Diver Propulsion Devices (DPVs) may not be functional. Their scuba harness may be broken and not able to keep all their SCUBA tanks and other equipment together. They may have taken their exposure suit off on the far side of the sump and some fault is preventing them from using it again.

The *Passage* variable focuses on the physical characteristics of the sump. The guideline may be missing, tangled into a rat's nest, run through a line trap, etc. There may have been a rock or mud collapse in the sump, blocking it. There may be a very strong current in the sump. Lastly, the passage may have used to be a dry passage and is now a sump caused by rain or other water flow.

Common Situations

Historical analysis shows that the primary way to categorize sump rescues is by whether the sump is permanent or temporary. If the sump is permanent, then anyone needing rescue must have been experienced enough with scuba diving to have gotten through the sump in the first place. They were not able to return through the sump on their own because either they were injured and have become a Patient, lost or broke some of their Equipment, or the Passage is either blocked or has a guideline problem. Sump rescuers regularly practice for the worst-case scenario of getting an injured patient to and through a sump, but equipment and passage problems are far more common. Because of this, if rescuers are prepared to repair or share equipment, and can safely travel to the patient, then these rescues are usually comparatively easy.

Rescues from temporary sumps are far more common than permanent sumps. The most common cause is that a rainstorm trapped dry cavers. The Patients are usually cold, hungry, etc, but rarely injured. They do not have any SCUBA Equipment. The Passage is now underwater and rarely has a guideline through it. The most dangerous situation here is that the water may rise to completely submerge the area where the patients have taken refuge, or their area may be so small that they use up all the oxygen. The priority is to get a rescuer to the patients as quickly as possible to find out what their needs are. The team can then either wait for the water to go down, help the patients swim out of the cave under their own power, or immobilize the patients and have the rescuers swim them out.

II. Rescue Tasks

1. Respond to a Suspected Sump Rescue Incident

When responding to a suspected sump rescue incident, there are a set of actions and policies that are applicable in all countries.

a. Cordon off the area to control people going into / out of the cave
b. Establish the Law Enforcement Officer (LEO) in charge of the scene
c. Establish a Command Post. Establish a Public Relations post further away from the rescue activity.
d. Halt all dives until the rescue / recovery is complete
e. Reserve access to the area for police, ambulances, divers, etc.
f. Only the LEO in charge, or a designated representative, will talk to news media
g. Locate and detain all witnesses and persons who might help in the rescue
h. Look after relatives and friends of the patient(s)

2. Enlist Cave Divers to Support a Sump Rescue

In the event of a cave rescue where cave divers may be needed, it is best to have them arrive at the incident site as soon as possible. Do not just put them on alert. Cave divers need time to ready their equipment and gather information about the dive environment. If the patients are believed to be behind a permanent or rising sump, you will want to send the divers into the sump right away. The patients will be suffering from the cold and may be in a chamber with diminishing oxygen or that may fill to the ceiling. If the patients are behind a temporary sump, you can have the divers rehearse their tasks at another local body of water while you make other preparations.

Request more divers than you think you will need. Divers will wear out quickly and their equipment will break. Keep divers who have worked together before with each other. Use a diver to lead the group of divers. This will insulate them from pressure from people who do not understand the risks involved in their work.

If you put out a public request for cave divers, you will need a way to vet those who answer the call. Divers must be very physically fit, as they will need to move heavy and awkward equipment through the cave, swim against currents, and/or tow patients. They should have certification cards showing they are trained in cave diving. They must have an equipment configuration appropriate to the site, usually side-mounted. Ask them about their last sump dive. They should tell you a story including low visibility and confined passages with at least one end of the trip including traveling through dry cave beyond/to get to the water. You should also call the diving officer of your local/national cave rescue service with their information. This is a high risk, high pressure operation and only highly experienced divers should be utilized if possible. Do not delay response while waiting for the absolute best diver if an adequate diver is available sooner though.

Divers without the requisite experience can still be useful. They can help the actual divers prepare. They can conduct inspections. They can also assist the operations and logistics teams with what experience they do have.

Make sure to note the source and status of scuba equipment used in a rescue. Divers will almost certainly use their own personal equipment, especially in the early stages of a rescue. Take photographs of all the equipment each diver brings and try to take an inventory. This will help with any post-incident damage or loss claims.

3. Conduct Reconnaissance of a Flooded Cave

There are two forms of sump reconnaissance during a rescue. Dry cavers and cave rescue managers generally conduct the first form. During a search for missing cavers, when search teams encounter a sump they believe the missing party is behind, they will need to conduct an initial reconnaissance of the sump. This initial gathering of data collects the information needed in order to decide whether to bring in divers. It also collects information divers can use to improve their dive planning. See Appendix A for a checklist.

Once cave divers enter the sump, they will conduct the second form of reconnaissance. They will conduct a far-side reconnaissance to check every possible exit from the sump to see if the missing cavers are beyond them. They will need to check ceiling cracks along the sump to see if the cavers might have climbed up out of the sump. As they complete checking each sump exit, they should mark the far-side as searched in order to keep other searchers from duplicating their work. Note that a far-side reconnaissance assumes the cavers are beyond one of the sump exits and not deceased in the sump.

If the sumped passage is unmapped or known to contain multiple routes, a search plan will be needed. A plan may be as simple as going right at every fork and backtracking as needed. The majority of sumps have a very low rate of forking. Finding the forks and continuing segments is often challenging though, especially in limited visibility. One tip is that if you swim out of a small tunnel into an area that appears to exit to the surface, first check for any continuing underwater leads. A silt cloud may be following you and if you go to the surface immediately you may not be able to find any other underwater passages once the visibility drops.

It is important to check whether there is a guideline going into the sump. This will never be the case in recently flooded passage but will usually be the case with a pre-existing sump if the missing cavers are beyond it. In frequently dived caves there may be a permanently installed guideline, and so the presence of a guideline may not indicate anything. If there is a guideline, divers can follow it to try to find the missing people. This prevents them from needing to do a full search of other passages. If there has been a lot of current or the line was poorly placed, then it may run through tight areas that divers cannot fit through ("line traps").

Evidence of Other Cave Divers:

- Disturbed silt or marks on the floor or roof, especially near restrictions

- Disturbed or cut guideline
- Equipment on the floor (lights, cutting device)
- Bubbles on the ceiling
- Stage tanks
- New line, personal markers, jumps

When a diver surfaces in a sump there is no guarantee that the chamber will contain breathable air. The chamber may contain a variety of other gases. If the chamber is small and many people have passed through it, then those previous people may have depleted the oxygen supply. You may consider having divers bring air quality monitors with them and use those before they stop using their regulators. Such monitors need to be calibrated with air from a SCUBA cylinder before the reading is taken. Chambers with running water moving through them will replenish their oxygen and remove their CO_2 faster than chambers with still water.

When a diver surfaces on the far side of a sump, they will need to check that area for the missing persons. Historically, trapped cavers with limited supplies have stayed in the closest spot to the sump where they can sit out of the water. This may be some ways away from the sump and out of sight and hearing. Cavers with more resources have historically continued their caving activities and only periodically return to the sump to check its status. Few have left markers to let rescuers know where they were. The smell of feces and urine though will let rescuers know the missing persons have been nearby.

As cave divers check each sump exit, they should note details about the exit in case it needs to be used by others coming and going through the sump. As an example, not all sump entrances and exits are right beside walking passage. The divers may need to use climbing hardware to get out of a water-filled pit to dry passage. If bolting is required, can the divers stand somewhere or will they be floating in the water while they install the first few bolts?

If you find the missing cavers, be cautious when you first encounter them as they may rush you and/or try to steal your equipment in order to flee the cave. If you can, remove and store your scuba equipment where they cannot get to it before you approach them. Alternately, they may think they are hallucinating and not believe you are real. This is more likely if they are alone and have been in the cave a long time.

Surfacing Inspection List:

- **A**ir quality
- Mental **C**oherence of the patients
- **M**edical condition of the patients
- **E**xit plan

The priorities for the patients will be air, heat, water, and food. Add some items to your personal equipment to help with these. A garbage bag or space blanket, candle, and matches will enable them to build and use a Palmer Furnace. Sugary snacks and potable water will quickly restore their energy level. Bring more than you would normally carry so that you do not need to give up your own personal emergency supplies.

Gather information from the patients. The missing cavers may have separated and you may have only found some of them. There may be additional people in the cave that you did not know about. Collect the name of everyone you've found, their medical status (current and historical), and if they know of anyone else not present. See Appendix B for an example form to fill out.

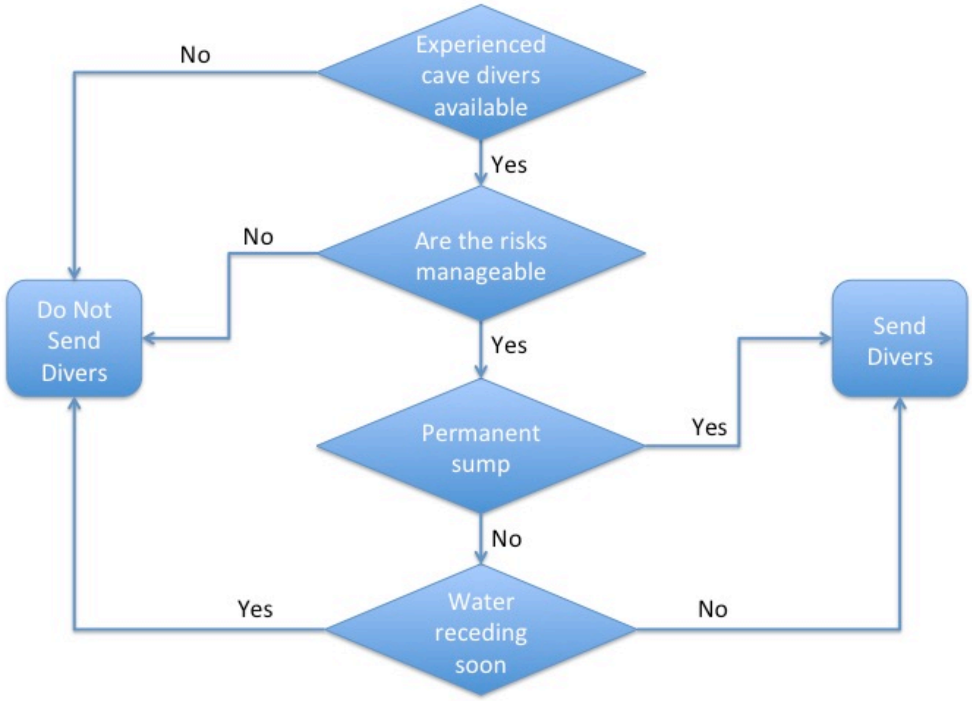
If you need to leave the patients, leave something tangible behind. In numerous incidents trapped cavers who were visited by a rescuer who then left reported wondering if they had hallucinated the event. Moving water may wash away your footprints, removing further evidence that you were ever there. By leaving something unique with the patients, they can be assured that you were there and help is on the way.

Dead bodies require a different set of procedures. Treat the area as a crime scene. Try not to disturb the body or equipment. Identify the person to the best of your ability. In the USA, members of the International Underwater Cave Rescue & Recovery (IUCRR) organization are best trained to document the scene. In most countries in the world, the police will take charge of the operation if they haven't already. If they are not available, photograph or videotape the body and equipment, and write down a complete inventory of what you find. Do not assume any gas in their cylinders is safe to breath. In general, do not attempt to recover the body on a reconnaissance trip. Leaders may decide to leave the body if recovery would be too dangerous. Your documentation will aid this decision and the creation of the death certificate.

4. Decide Whether or Not to Send Divers

The two most important decisions in a sump rescue are whether to send cave divers into a sump, and whether to bring patients through a sump or leave them on the far side to complete the rescue in another way. In many cases, the best decision is not to send divers. Most incidences of people stuck beyond sumps involve unexpected rainstorms that temporarily seal off part of a cave. The rain will stop soon, the water will drain, and the missing party will exit suffering only from hunger and cold. Obviously good local knowledge is vital.

The principal exception to this rule is when the water is not expected to go down soon, if ever. This may be from a weeklong rainstorm, or cave divers exploring dry cave beyond a permanent sump when something went wrong. In these cases, the only hope for the patients may be that cave divers are able to get to them quickly. You will need to consider many factors when making this decision. Many of these factors can only be determined with confidence by an exploratory dive.



Factors to Consider When Deciding Whether to Send Cave Divers:

a) How likely is the missing party to be beyond the sump?
b) When will the sump lower or can it be lowered?
c) What is the temperature of the cave?
d) What medical conditions are affecting the missing party?
e) What food and water does the missing party have available?
f) How experienced / competent is the missing party?
g) What are the diving conditions within the sump like?
    a. Visibility
    b. Current
    c. Tight spaces
    d. Temperature
    e. Depth
    f. Length
    g. Mapped / Unmapped
    h. Contaminated water
    i. Ancient stable cave vs poorly shored mine tunnel
    j. Condition, type, and thickness of any pre-existing dive line
h) Are trained cave divers available who are experienced in conditions like these and willing to go?
i) Are there any special legal considerations?

5. Manage a Dive Site

You will likely want or need to maintain a base or command post at the near side of a sump. This is a natural transition point. Cavers and material will change their transportation mode here. Porters will stage themselves here. The method of communicating through the cave may also change.

Every base needs some form of command post, staging area for personnel and equipment, method of controlling traffic and communication, and means of logistical support. Most normal in-cave bases will have one to three people. They will maintain a log of messages, transiting personnel, and transiting equipment. They will note where transiting personnel were headed and what their mission was. They should mark off areas for the storage of equipment and where task forces can rest in between assignments. Larger or longer-term bases will need to be periodically resupplied. They should have a plan for dealing with refuse and human waste.

Bases at sumps have special tasks and special needs. As sump divers traverse the sump, they will need a protected area to enter and leave the water. Try to facilitate low-silting methods of entering the water, though this may be impossible. You will want to install hand lines for difficult entrances. If the water continues past the entrance, place a rope beyond the diving area to fence off the wrong direction. Mud and dive equipment do not mix well. Reserve the cleanest location for staging scuba equipment. A tarp on the ground may help.

If the water is at the bottom of a pit, you will need to rig several ropes. You will want a rope for climbing up and down the pit. Your divers may not be experienced climbers and so you should consider additionally belaying them. You will also need ropes for hauling and lowering equipment and the patients.

There will be a guideline through the sump. It will be tied off in two locations on both sides of the sump. One if not both tie offs on each side will offer direct vertical access to the surface. Try to tie off where it will be above the water even if the water rises. A bombproof rope should be laid through the sump before any rescue operations commence, even if a guideline is already present.

Managing the dive site includes tracking the divers and controlling movement. Track when each diver enters the water and when he or she returns. In the early stages of reconnaissance, you may wish to have a rescue diver on standby with a designated time to enter the water if the sump diver has not returned. If later the sump becomes a well-traveled route, you should still have a plan for if you have not received a status update about someone on the other side for some period of time. If you have communication with the far side of the sump, consider limiting traversal to one person in the sump at a time.

Help the divers to stay mentally positive. They will be under a high degree of stress. They will need to work with scared and hurt patients, or dead bodies. They will be working in very dangerous conditions and will worry that the success of failure of the operation is being placed solely on them. Make sure there is someone with good people skills to chat with the divers, who also knows to be quiet when they are working on equipment.

The needs of divers exiting the sump will vary by the stage of the rescue. Always collect a brief report from the diver once they surface and before they get busy with their equipment and forget any information. Expect the diver to be cold and in need of support getting out of their dive equipment and onto the shore where they can re-warm. Keep divers out of the water as much as possible so they do not get hypothermia, which can happen in even very warm water. If a diver has to climb a long way from the water to the base after the dive, this exertion will increase their risk of developing decompression sickness (the bends). Reduce their load as much as possible and have them spend some time on the surface of the water off-gassing the inert gas that has built up in their body.

When a patient traverses the sump, the priority is to quickly transition them to their next mode of transport. This may involve having a stretcher ready by the water with a team to finish packing the patient and move them along.

The divers and the person controlling movement of the divers into and out of the water should do specific safety checks. See Appendix C for a list. See Appendix D for a list of checks to perform after dives. See Appendix E for a set of forms you might use. These all provide a secondary check that everything is OK. Information recorded about how much breathing gas was used will guide future decision-making. It will also screen out cylinders that must be refilled. Place cylinders that must be replaced in a specially marked area so that no one accidentally tries to use them. If you cache dive equipment at the dive site, then you should provide periodic reports about its status.

Monitor and regularly report the water conditions at the base. Install some form of meter or marker so that you can track changes in the depth of the water. Changes in water temperature may indicate a changing ratio between water that has been underground a long time and fresh water from the surface, perhaps because of a storm. The Current Operations team running the rescue needs this information as well as regular weather reports to help guide their decision making.

6. Provide Logistical Support to a Dive Site

Getting supplies to a sump through dry cave has its challenges. Scuba tanks are large and heavy. The average large cylinder weighs over 35 lbs. / 16 kg. You should use one porter per tank and one to two additional porters to help with each diver's personal equipment. Empty tanks must be transported to the exit of the cave for re-filling, and weigh almost as much. Try to send tanks in pairs, as single tanks do no good. If a cylinder is dropped, the valve may be damaged and rendered unusable. If the cylinder is punctured, it may explode and aluminum shards may injure anyone nearby. This is very rare but porters should still be told to be careful. Consider installing additional hand lines to help porters carrying this large heavy equipment.

Do not attach regulators to scuba tanks until they arrive at the dive site. Regulators are fragile and will break if a tank is dropped on top of one. Full cylinders should travel with screw-in (DIN) plugs to protect the valve threads. Valves are easily dented and the DIN plugs will help prevent this. Solid DIN plugs will prevent the loss of breathing gas if the valves are accidentally opened during transport. You will need to keep an adjustable crescent wrench at the dive site to help remove a DIN plug if the valve was opened during travel. Some groups use DIN plugs with holes in them to prevent the need for wrenches at the risk of losing breathing gas.

For sidemounting, each tank should be pre-rigged for use. Each tank should have one hose clamp around its base. Using strong cord, tie a 1-2" / 3-5cm leash onto a brass or stainless-steel bolt snap and trap the leash against the tank with the hose clamp. The divers will help you get the bolt snaps in the right spot on the tanks. You can transfer clamps and bolt snaps between tanks with a flat head screwdriver if needed but this increases wear and tear. Ideally the tanks do not have plastic "boots" on their bottoms. These help them stay standing but can also be snag hazards in the cave.

Consider stockpiling a small reserve of scuba tanks on the far side of the sump in case a diver damages or depletes one on the way in. These can be used later as part of an extraction. For long sumps, emergency gas supplies should be staged along the underwater route before any rescue attempt.

You will need to refill scuba tanks as they are used. Most rescues will happen through sumps less than 30M / 100' deep and so air can be used in the tanks. Deeper sumps will require the use of special mixed gasses including helium. Divers using rebreathers will require their scuba tanks of pure oxygen to be refilled. You will need a way to refill scuba tanks at the cave from a purpose-made dive compressor. This should only be operated by someone skilled in its use.

Transport scuba weights to the dive site for the divers. Each diver may need as much as 30 lbs. / 14 kg. Weights and weight belts may be needed for the patients. Weights may also be needed to adjust the buoyancy of supply containers (dry tubes) being ferried through the sump. Use solid lead weights of varying size. Do not use beanbags as they fall apart in cave environments. Porters moving weights must not attach the weights to themselves. If they fall into a pool of water, the weights may pull them down. They must be able to drop the weights and escape.

Surveillance must be kept on other low parts of the cave. If the sump exists because of a recent / ongoing rainstorm then other parts of the cave may flood as well. This may trap or kill rescuers. The rescue management team must include this hazard in their risk management briefing. Areas with a high risk of flooding that would trap rescuers should have a watch kept on them or be frequently patrolled. Rescue teams can report changes to low risk areas if they know to look for changing conditions while traveling. Consider an agreed evacuation signal (e.g. whistle blasts).

7. Provide Logistical Support Through a Sump

Cave rescuers must provide logistical support to the far side of the sump. When discovered, the patients have likely been out of contact with the surface for an extended period, and their supplies have run low or out. They are cold. It will likely be a further extended time until the patients are able to come through the sump. Using one method or another, you will need to get them supplies quickly and regularly.

There are two primary methods of moving equipment and supplies during cave rescues. The most popular method involves having each rescue team bring all the equipment they need with them. The team travels from the entrance of the cave to the patients, performs their tasks while staying in the cave for no more than forty-eight hours, and then exits the cave. The other method has a team stay with the patients for longer periods of time. Other teams haul supplies with them to the in-cave team, and then immediately exit the cave to get ready for another trip. A good example of when to use the later method is when you must bring in a doctor who is not an experienced caver. Instead of having them travel back and forth and risk injury, safely get them to the patients once and then keep them supplied in the cave.

Keeping the patients warm will be an ongoing effort. Dry clothing, an insulated pad to sit on, and protection from wind will help a lot. The patients may be wearing wetsuits. Wet wetsuits suck the heat out of the wearer, especially while they are idle. If for one reason or another you cannot remove the wetsuits from the patients, one option is to put hot water bottles inside the wetsuits. Bring a stove, pot, and bladders for this.

After providing for the immediate needs of the patients, the top priority should be establishing communications from the cave entrance to the patients' location. This will significantly improve coordination. Cave Link radio is the best option but cannot be used in some locations, such as America, due to electromagnetic interference from nearby power lines.

The patients may need a full supply of camping gear. This includes lights, food, sleeping bags, tarps, inflatable pads, and medical supplies. Try to standardize on lights with the same battery type, such as 18650 batteries. Patients' hygiene needs will include a way to dispose of bodily waste without polluting their source of drinking water. Rescuers should investigate whether the water is safe to drink even with filtering, or whether potable water must be transported in. Messages from loved ones and other aides to mental wellbeing should also be considered. On each trip, returning divers should bring an inventory list of what supplies are where, a list of which people are where, and the status of each item and person.

Pay attention to the organization of supply movements. In some situations, it is OK to give a team a mission and then allow them to select the equipment they think they will need. When providing sustainment beyond a sump, assign someone to design the loads that will be transported. That person will make sure that everything needed is packaged together. They will compare their requirements against what is known to already be with the patients. They will ensure compatibility amongst the supplies. The transport team should conduct an inspection, but they leave the supply selection to the expert. It is so difficult to transport supplies to and through a sump that someone must be put in charge of the effort.

The most difficult part of providing sustainment beyond a sump is transporting the supplies through the sump. The difficulty of properly adjusting buoyancy and trim for containers cannot be overstated. Some dry bags are useable for shallow sumps. Sealable PVC or metal tubes are more reliable but are hard to find or make. Some items can be carried within divers' drysuits. Finally, an inner tube 'pig' is a very low-tech way of creating a dry container. Use a large inner tube from a tractor tire. Place items inside and seal the ends either with metal clamps or by tying them. Some leakage may occur so place everything into a plastic bag first.

Weights to make the containers neutrally buoyant can be placed inside or attached outside. Weights placed inside are more secure but also take up space. A supply of small weights that can be clipped onto the containers should also be transported to the sump. These will be used for fine-tuning. Note that returning an empty supply container through a sump for reuse is even more difficult, as now the container is empty and thus even more buoyant. Filling it with water may overcome this.

When you plan sustainment beyond a sump, the number and durability of underwater containers you have will play a factor. If the containers are not durable, you should only use them around the sump. Use other containers to transport supplies to the dive site and then transload to the underwater containers. If you have a limited number of underwater containers you will increase the priority for tracking them and returning them to the exit side of the sump for re-use.

Sump rescues have additional equipment considerations. If there is no dry ground where the patients are located, hammocks may get them out of the water. Hammocks will need bolting equipment for their anchors. Battery powered heating vests don't provide as long-lasting comfort as blankets but are much easier to transport. Be cautious about cooking stoves and chemical heaters. There may be no way for the fumes to dissipate and so they may cause a hazard. Regular supplies of hot water via Thermos may assist.

Keep as few people on the far side of the sump as possible. More people means more supplies you must deliver. Also consider the air on the far side. If a chamber is small then the people inside will use up the oxygen. The more rescuers you send, the faster the oxygen levels will decrease and carbon dioxide will increase. You may be able to improve the oxygen levels with hoses from outside or by releasing oxygen from scuba tanks, but this is untested and largely theoretical.

8. Provide Logistics Through Multiple Sumps or Long Distances

In most sump rescues there will be a single sump, or a series of short sumps, between the cave entrance and the patients. Rescuers will be able to travel from the surface to the patients and back in a matter of hours. The rescuers will live outside the cave where there is easy access to food & water, sleeping arrangements, healthcare, and sunlight. On rare occasions though, the patients may be a very long way into the cave.

The patients may be so far into the cave that rescuers cannot do round trips to them in less than one day. This may be because of sheer distance or because of obstacles such as multiple sumps with long distances in between. In this situation you will keep one set of sump divers with the patients and will use other sump divers as porters to move supplies closer to them. The porters will live on/closer to the surface where they can recover better. This scheme will minimize the amount of supplies needing to be moved deep into the cave.

As an example, consider a long cave with a sump in its middle and injured cavers at the end of the cave. A pair of sump divers with good medical skills will stay with the patients to stabilize them. In the meantime, other rescuers will prepare the sump and rig the cave for the patients' extraction. A separate set of sump divers will regularly travel from the surface with supplies, will pass through the sump, and will leave the supplies before returning. The divers with the patients will travel towards the sump to pick up the supplies before returning to the patients. If they cannot meet at the supply point at the same time, which is likely, then communications will need to be set up.

9. Communicate Through a Sump

Communicating through a sump is similar to regular cave-rescue communication. Messages may be couriered by divers carrying plastic writing slates or pieces of waterproof paper, e.g. Rite in the Rain or Mylar. Couriers should be the last option. They are slower than other methods and their notes are more likely to get lost or smeared. Every time you send a diver through a sump they will stir up silt and degrade the visibility. Avoid sending divers with no other task than couriering messages.

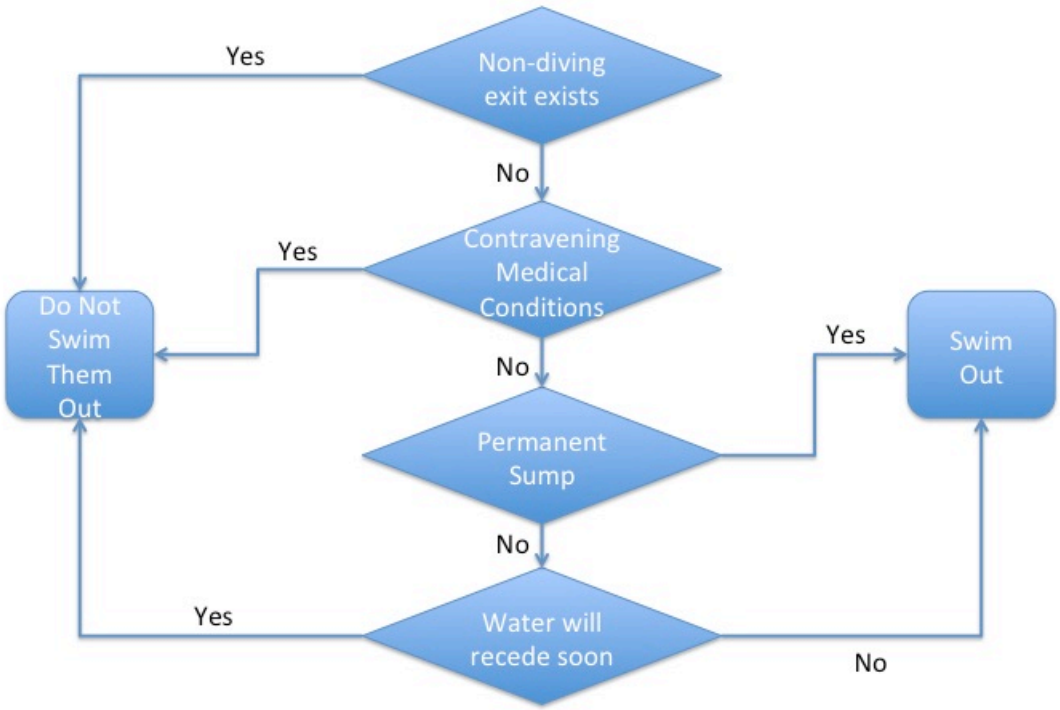
Wire can be run through a sump to link telephones on both sides. Wire cable is much heavier than the nylon string that cave divers are used to using. The first time a diver lays cable, it should be their only task. Inspect the wire beforehand to ensure that none of the metal will be exposed underwater, which could electrocute divers. Poorly run wire can be an entanglement hazard. Thought should be given on how to minimize the entanglement hazard; either cable tie the wire to the guideline, or lay it well out of the way of underwater traffic. If using wire, ensure divers carry wire cutters in addition to their standard line cutters in case they cannot untangle themselves. Michie phones are cheap and reliable and an excellent way to rapidly establish communications through all but the longest sumps. They rely on a single wire and pose no electrocution risk.

Cave radios are an excellent device to use. Special low frequency cave radios are a quick and usually reliable way of setting up communications during a rescue. Cave Link can transmit text messages and is now used by all the UK and NZ rescue teams and has largely replaced wire. Cave Link has the advantage that it need not be continuously monitored. However, it is expensive to purchase. Cave radio is still rarely used in the U.S. because most rescues have not needed it, and because of interference by U.S. power transmission towers.

Whenever a message is relayed through a sump, the people on both sides responsible for communication should follow standard communication protocols. They should log the message destination and sender, subject, and date. They should confirm receipt by the far side and record if they could not confirm it. Divers coming through a sump may bring verbal messages. This should be avoided, but if it happens then the message should be fully copied by personnel on the far side.

10. Decide Whether or Not to Bring the Patients Through a Sump

The ultimate goal is to get the patients back to the surface as quickly as possible without significantly worsening their condition. Every form of care for the patients is better on the surface. Patients should only be kept underground to stabilize their condition or while waiting for parts of the cave to be rigged for easier travel. The cases when you should not move the patients are the exception, and so we will deal with these.



If the sump is temporary then you should usually wait for it to go away. In many caves a large rainstorm will cause part of the cave to flood and block a passage. Soon after the rain stops the water will go down. The patients will be able to exit. They will be cold and malnourished but this is safer than having non-cave divers try to make their own way out. If the sump is only a long duck under then this may not apply.

If the sump is relatively permanent, then certain medical conditions may warrant against diving them out. This may be due to a spinal injury, multiple arm and leg injuries, major torso trauma, severe blood loss, or a serious head injury. It is unwise to dive a victim out under the following circumstances:

- With the patient unconscious or having been unconscious, or with a significant head injury.

- With a significant chest injury – a pneumothorax ascending back to the surface could probably be managed emergently at the completion of the dive.
- With a significant abdominal injury – air entrapment and injury.
- Where decompression will/may be required.
- Where there has been significant blood loss.
- Where there is altered consciousness for any reason (e.g. hypothermia, diabetes, other medical event).

You should also look for another non-diving way to remove them from the cave. There may be other unknown dry passages through which to access the surface. Given enough time and money, a hole can also be bored straight down to them. These decisions will always represent a difficult risk-benefit equation.

11. Create a Sump Rescue Plan

Once you have stabilized the situation and decided to extract the patient from beyond the sump, you will need to create a plan. This involves deciding how to create the plan, doing the planning, and then giving the plan to the team that will execute it. Each of these actions will scale with the size of the incident response team.

Planning is a deliberate process and planning a sump rescue is not an exception. The process begins with reconnaissance and information gathering. Your team then has the tools to begin. If your rescue team is small, then the leader should take some time to go off by him or herself, examine the factors, create a plan, and get ready to present it. If the team has several people working to track and organize the incident, then the commander should designate one person to work on examining upcoming needs and creating plans. That person will give their draft plan to the commander to assess before briefing it to the rest of the team. For large organizations, you will have one team tracking current operations while a fully resourced separate team prepares for future operations. The current-operations team will receive regular updates and instructions from the future-operations team, and then manage the execution of the plans.

One of the best divers should be put on the planning team. Their experience and perspective are crucial for creating feasible plans. If you need to give a diver to a planning team or other liaison duty and it does not hurt you to lose the person, you are probably sending the wrong diver. That diver may still be able to able to participate in the operation though.

Methods to Extract a Patient:

a. Lower the water
b. Dig or drill another entrance
c. Have them scuba dive out
d. Package them up and swim them out
e. Leave them in the cave and supply them until the water naturally goes down

As you create the plan, you will decide between several courses of action, and you will establish a task list. Try to avoid limiting your options too early in the process. You may only find the best method by fully investigating them all. At the end of planning, you will have identified tasks for each team and person, the reasons for doing them, and coordination measures so that everyone stays synchronized. Give everyone as much freedom to adapt to changing circumstances as possible.

Primary Steps for the Swimming Portion of a Rescue:

1. Get equipment to the patient's side of the sump
2. Train/mentally prepare the patient
3. Physically prepare the patient for the traverse
4. Get the patient into the water
5. Move the patient through the sump
6. Get the patient out of the water
7. Prepare the patient for onward movement

When developing plans, do not neglect the special logistical needs of diving. Managing supplies and keeping the rescue team rested and safe are critical activities. Most diving equipment is bulky and transporting it should be a deliberate operation. You may have a limited number of containers to transport supplies through a sump while keeping them dry. SCUBA tanks come in different sizes and with different types of valves; be sure to specify exactly what is needed. Divers in cold and/or deep water need adequate recovery time in between dives.

Once you have completed the plan, you will need to prepare the rescue team to execute it. This includes briefing the plan, making sure the team understands it, and then rehearsing the plan. Diagrams and terrain models of the cave are very useful visual aids to support your presentation. After the briefing, ask the audience questions to see if they understood you. People always get confused or distracted during briefings. Once you know that everyone understands their assigned duties, then you can rehearse. Rehearsals are very useful for identifying problems with the plan such as a lack of coordination or tasks that should have been included. If you have limited time, at least rehearse the most complex phase of the rescue.

For a sump rescue, the most complex phase will be getting the patient into the water and starting to move them. Often several people, especially the patient, will be using equipment and performing actions for the first time. One way to rehearse is to have someone pretend to be the patient, and then have the rest of the team simulate moving them into the water. First do this on dry ground, and then do it at the water's edge if possible. Practice several times. Once the team can perform the basic skills, perform more evolutions where you simulate something going wrong.

12. Lower the Water in a Sump

Lowering the water in a sump so that it can be swum instead of dived is preferable whenever practical. Remove the water faster than it enters. You can reduce the water going into a sump or you can speed up its exit. The water does not need to be completely removed, just removed enough to make an exit easier.

Sometimes the water in a sump is fed by a river or stream. It may be possible to temporarily dam or divert the stream. Whenever water is diverted or removed from a cave, make sure it does not re-enter the cave somewhere new. The down side to stopping the inflow to a sump is that the current may have been clearing silt out of the water. If near the coast, pay attention to tidal effects on the water flow. Consult a local geologist to learn about the flow of ground water in the area. You may be able to lower the water by drilling and pumping operations from the aquifer near the cave.

You may be able to naturally or mechanically speed up the exit of water from a sump. Is there rock or mud keeping water in the sump? See if you can remove this blockage. In one cave rescue, the flooded cave was upstream of a major dam. Releasing water from the dam lowered the water in the cave just enough for fresh air to reach the trapped cavers. You may also be able to siphon water out of the sump to another area.

A large proportion of sump rescues do wind up trying to use pumps to remove water. If using generators, ensure that exhaust fumes do not get sucked back into the cave. If the pumps are successful in lowering the water enough for an exit, bear in mind that the pumps could fail at any moment. Do not permit an exit unless the water has been lowered enough so that if the pumps failed during the exit and the water started to rise, people in the cave would still have time to reach safety.

You may not need direct access to the sump to use a pump. If a sump is linked to the local water table and is shallow, pumping from the sump also means pumping from the local water table. The reverse is true. You may be able to affect the sump by modifying the water table. You can lower the local water table which will in turn lower the water in the sump. Be aware that this requires significant pumping resources and will take a long time.

With pumps and electricity there is always the chance of electrocution. Having a maintenance plan, personnel, and supplies is an important consideration. The team running the pumps must regularly inspect for damaged or poorly installed wiring. If an electrical problem is found, you will need a way to keep rescue parties away from the affected area while maintenance is conducted. Electrocution may cause burns or stopped breathing; conditions that cave rescuers normally do not have to train for.

Lowering the water in a sump may cause more problems than it solves. Consider that in a stream passage you may be able to float a patient along. By lowering the water, you may create a dry stretch in between wet sections. Now the rescuers need to get out of the water, do a dry carry, and then get back into the water on the far side, all while lugging their heavy scuba equipment. This would significantly slow their travel.

13. Repair or Replace a Guideline

Anecdotal evidence and at least one study have shown that amongst experienced cave divers the guideline is the largest source of problems. The line may break, may travel through a line trap too small for people to fit through, or there may be no line at all. Even when there is a well-routed guideline, you may wish to replace it with a stronger line in anticipation of increased wear and tear.

If you find a broken guideline, you should repair it. Most cave divers carry a "safety spool" of line with them for situations like this. The details of how to repair broken guidelines, or guidelines run through line traps, are covered in cave diving courses. It should be noted though that this skill is rarely practiced. Performing this task in limited visibility with thick gloves on is difficult. If you suspect you will need to execute this task, practice ahead of time or be prepared to run a completely new line. Note that the more lines in a cave, the higher the risk of entanglement.

Consider improving the strength of the guideline going through the sump. Most cave explorers use thin nylon string. It is easy to work with and lots can be carried on a reel. It is also easy to break and will not stand up to the intense wear and tear of many rescuers tugging on it as they go back and forth through the sump. Better options include 9-11mm climbing rope, with 1/8" Dacron and 4-6mm polypropylene as alternatives. Improve the tie offs and endpoint anchors to make sure the line is secure and won't be dislodged.

If you plan to replace a guideline, give thought to how you will remove the old line. One method uses a two-diver team where the first diver runs the new line while the following diver reels up the old line. In one incident though, the second diver got in front of the first and they got separated, which resulted in the second having no guideline to the exit. You may consider leaving the old guideline in place, though this risks entanglement or confusion.

14. Modify a Sump to Increase Trafficability

You may need to modify a sump to increase trafficability. In addition to attempts to lower the water in a sump, you may need to widen a passage in order to make it easier to pass through equipment, large divers, or litter-bound patients. You may also want to strength the guideline going through a sump in order to reduce the odds of it breaking.

There are several ways to increase the width or height of a sump passage going through limestone. In an ideal case only a small piece of rock is restricting the passage. You may be able to use a pry bar or similar tool to move or break it. Swinging an object with enough force to damage a rock is difficult underwater. You may be able to gradually chip off pieces by wedging and prying though. If the restriction is near to dry passage you may be able to use an underwater jackhammer driven by an air compressor on the surface. These tools also work with hoses to scuba tanks.

Underwater explosives are another option. Det cord can be wrapped around projections. It or KinePak can also be jammed into crevices. Only use a command wire for detonation. Do not use any form of timer directly attached to the explosives, due to the possibility of something delaying the return of the diver who placed the explosives. Be very cautious about not using too large an explosive charge. The explosion may severely damage the passage and make it unusable instead of just inconvenient.

There are several safety factors to consider. If you are modifying a rock passage then try to modify the floor instead of the ceiling. A damaged ceiling can collapse and make things a lot worse. If you are using underwater machinery, the divers must be careful to use hearing protection. Explosives produce toxic fumes that can incapacitate cavers, especially in confined areas.

Instead of solid rock, a sump may be restricted by a pile of silt / mud / sand / smaller rocks. Though time consuming, this can be dug out. One option is to use many small buckets to scoop up the material and deposit it away from the restriction. If silt or mud, this will temporarily remove all visibility downstream.

Be cautious of triggering a landslide that may restrict passage downhill of where you are working. All sumps have slopes to dry ground at their start and termination. There may be significant loose rock and mud on these slopes, which can avalanche down and block the sump.

15. Calculate Breathing Gas Needs for a Rescue

When moving a patient through a sump, you will need to calculate how much breathing gas they will use. The International Marine Contractors' Association (IMCA) suggests that construction divers calculate dives using a Respiratory Minute Volume (RMV) of 35 liters (1.24 cubic feet) per minute and calculate their emergency needs with an RMV of 40 liters (1.4 cubic feet) per minute. This will seem like a very large quantity to divers used to performing a relaxed recreational dive with an RMV of 17 l/min or less. In a rescue you should assume your patients will be new to diving, cold, nervous, and working hard, and so we recommend planning the patient's breathing gas needs with an RMV of 40 l/min (1.4 cubic feet).

Whenever possible, the patient should use a single cylinder as opposed to the rescuer's likely side mount configuration. Do not expect patients to be able to exchange regulators. The regulator should have a short hose and a necklace, so the patient can easily locate it if they drop it. Steel cylinders may be better for the patient than aluminum. They will not become as positively buoyant, and have less risk of bursting if damaged. Procedures for sumps where a single cylinder of breathing gas is insufficient are covered in the "long sumps" chapter.

16. Move a Patient Through a Sump

When the decision is made to evacuate patients through a sump, the best method to use depends on the nature of the sump, and each patient's diving experience level and psychological state. Methods you might use with experienced and healthy cave divers will not work with someone who does not know how to swim. The movement of litter-bound patients is covered in another chapter. Non-divers can be given a crash course in diving and escorted through a sump, but only if they can be trusted to stay calm and compliant throughout the process. Moving patients through sumps is still an area of research and requires considerable caution.

Pre-Movement Checklist:

1. Is the patient as medically stable as possible?
2. Is the patient stable enough to survive the next phase?
3. Is there a clear plan for each phase of the move?
4. Is there a plan for any problems that arise during the move?
5. Is there a better alternative?

It is best to move a patient as part of a deliberate operation. In this case the patient and rescuers have complete and independent sets of diving equipment appropriate to their experience level and the sump. The patient knows what to expect, what is expected of them, and how to perform all necessary tasks. The sump guideline and all aparati for getting into and out of the water are in a high state of readiness. The alternative is a dynamic/snap move of the patient, which may be caused by any number of exigencies including lack of time. We will cover snap rescues at the end of the chapter and will otherwise assume all necessary support is in place for a deliberate patient movement.

If you need to rescue a qualified cave diver, you can lead them out of the cave. You should only need one escort diver per patient. The escort should swim in front of the patient in order to help them with navigation decisions. In low visibility this may include telling them to stop at every navigation decision and carefully guiding them through it. For particularly long/deep sumps, be ready to assist with stage bottles and other breathing gas tasks.

A patient who is a certified scuba diver but not a certified cave diver can swim through a sump with some additional care. Assume they do not know anything about navigating guidelines and that they have poor buoyancy control/trim/finning technique. You will need to teach them how to follow a guideline and what to do if something goes wrong. For equipment we recommend a simple sidemount harness and a single scuba tank. The single tank will simplify things for the evacuee and reduce their cross section, but they may roll to one side. Put their regulator on a necklace to ensure it is easily recoverable. Consider giving them a helmet with an underwater headlamp. This will prevent their need to use one hand to control a light. A second headlamp is even better to reduce the odds of them losing all their light.

The method of patient control will depend on the cave passage. If traveling through a large diameter sump, you can swim beside them and/or behind them. The escort(s) should be able to simultaneously swim beside the guideline and observe and control the patient. If you are moving through a small diameter sump then you should use two escorts, one in front and one behind the patient. This gives the best ability to control the patient in low visibility. Consider tieing a leash to the patient if they are inexperienced. If the sump is very short, i.e. a glorified duck-under, you can lead the patient through the sump without direct contact.

Patients without any scuba experience can also swim through a sump. Experienced cavers have little problem with small passages or limited lighting. You will need to give them basic training in scuba diving. See Appendix F for a basic syllabus. Practice diving with them in a cave pool if possible. The patient must wear a FFM. If traveling through a large diameter sump, you can use one escort though two or three is better, and the escort must control the patient's guideline contact and buoyancy. Use two escorts if traveling through a small-diameter sump, with an escort in front and behind them. If traveling through a duck-under, set the patient's BCD to be neutral in shallow water and then follow them through the sump.

In an emergency you may be able to conduct a rescue without a full set of diving equipment for the patient, or time to give them a full training session. The most likely emergency scenario is that a rescuer conducting a search for missing cavers during a flood event finds them in a location where they will likely not survive long enough for the rescuer to return with a full set of diving equipment. In this case if the rescuer feels the risk level is acceptable, he can let the patient breathe from the long hose of his scuba equipment and tow the patient through the sump. If the patient can maintain neutral buoyancy then the patient can grab the rescuer's crotch strap and swim behind the rescuer. The rescuer might also consider placing the patient beneath him to hold down or carry the patient. It should be stressed that **this is a very risky maneuver** that should not be attempted through a long sump.

When bringing a patient through a sump, ensure you are not physically tethered to them. At the end of the sump when your patient sees the air above the water they may try to swim up to the surface on their own. If you are physically tethered then this may result in an underwater wrestling match as you try to keep them under control. If you do use a tether/leash to avoid losing the patient, ensure you can release it at any moment.

Your patients may not speak the same language as you. In an ideal world a laminated diagram showing what to do will be available. This is unrealistic. You may still be able to sketch or pantomime the process. This increases the risk significantly. For a complex rescue, it is worth the time to bring in a local expert who speaks the language.

Reinforce to the evacuee that the number one rule is to stay calm and breath slowly. Do not give them a cutting device. Do not let them doubt that they will have enough breathing gas. Do not let them think they can grab onto you for help. Do not bind their hands or feet for your self-protection except in very special cases as this may lead to panic. Do reinforce that they are an active participant in the process and you are giving them the skills to rescue themselves. They are not a hapless victim and should not expect you to do everything. This will increase their odds of survival and long-term mental health.

17. Transport a Movement-Impaired Patient Through a Sump

In rare circumstances you will have a patient who must be extracted through a sump but cannot swim under their own power or be given regular scuba equipment and be towed. They will likely arrive at the sump unconscious and/or on a litter. This is a very difficult procedure but gives the patient better odds of survival than being left in the cave. In some ways this is easier than having a patient dive with you; you don't need to teach them to dive and you have full control over them in the water. In other ways it is more difficult. Litters are less maneuverable and flexible than people, and must be trimmed and adjusted for buoyancy. A litter-bound patient is sometimes known as a Stanton Inert Patient Package (SIPP). As a rescuer you have several options.

The best option is to not use a litter at all. If a patient has a well-splinted injured leg, they may still be able to scuba dive without the litter. Just because a patient cannot walk, it does not mean they cannot swim, pull himself or herself, or be pulled through the sump. Duct tape is a great splinting material when combined with a scuba fin or other body part. Bring the diver to the water in a litter as necessary, float them off the litter whilst supporting their head, attach their dive gear as required depending on the injuries and gently roll them into the prone “diving position” to assess whether all is well. Note that if the patient has an injured thumb, they will have major difficulties with any gear that requires squeezing.

Even if the patient has a suspected head or spinal injury, limited immobilization is still preferable to a full stretcher. The water will provide good spinal support. If someone has a broken neck with transected cord, they are probably not getting out alive. If they don’t have neurology already, gentle and careful management is probably a good compromise as it is only very rare subtotal lesions you are going to make worse.

The second-best option is to transfer them from a litter to some kind of spine board and harness. The Oregon Spine Splint (OSS) and Kendrick Extrication Device (KED) are examples. A spine board is far more maneuverable than a litter, as well as being easier to trim and get the buoyancy right. You can put a buoyancy control device (BCD) onto someone in a spine board, as well as attaching scuba tank(s).

If you plan to keep your patient on their litter, you will need to address several issues. Give the patient his or her own scuba tank. Place it between their legs if possible, with the valve at their feet. The litter plus patient will need to be properly weighted and trimmed. Have a set of small weights on hand that you can add to different parts of the litter to adjust trim. Bring zip ties to attach the weights. Do a buoyancy check by placing the patient and litter into the water and observing if the litter sinks on the patient’s exhale and rises on their inhale. Weight for the changing buoyancy of the patient’s tank as it empties. If the combination of patient and litter is negatively buoyant, place a BCD on the patient or litter, or strap a Delayed Surface Marker Buoy (DSMB) to the litter. Litters that are so negatively buoyant that they need additional floatation should be avoided. Wherever possible at least one of the diver’s arms should be free so they can contribute to mask clearing, ear clearing, and 2nd stage regulator adjustment.

You will want your patient to wear a full face mask (FFM) instead of using a normal scuba regulator. A FFM is easier for non-divers to use and **the only solution** for anyone with an altered conscious state. An injured but conscious diver may choose to use his or her own regulator instead of an FFM.

Position the patient face down. The natural buoyancy of their lungs (coupled with the pressure differential between the depth of the second stage and the lungs) enlarges the alveoli, making it more efficient to exchange gas than it does when laying their back. On a face down patient, any water or saliva that enters the FFM will roll to the bottom of the mask, away from the patient, and so not enter their mouth or nose. A patient facing down is less likely to be dazzled by the lights of the rescuers, and being near the bottom of the passage, will see it passing by which is psychologically good. A face down position may also make it easier to equalize. One penalty with facing a patient down is that they must be facing up to purge any accumulated liquid from their FFM.

FFMs have special considerations. A helmet will be difficult to use with a FFM. The helmet may increase the odds of dislodging their FFM when it is bumped. Unlike a regular regulator, if a patient wearing a FFM on the surface runs out of breathing gas they will suffocate. You must constantly check the amount of breathing gas remaining even on the surface. The weight and buoyancy characteristics of a FFM may also put more load on a patient's neck than a standard regulator, although in an unconscious patient it may lift the chin and open the airway.

Be aware of your patient's psychological needs. Your patient will be terrified about being bound to a litter while underwater. They will want the opportunity to escape it if something goes wrong. The fate of the patient and litter are tied together, literally, so do not slack the binding. Even if your patient appears unconscious, still give them a full briefing about what is about to happen. Your patient may be able to hear you but not respond. Letting them know what to expect can only help. A conscious diver will be far more confortable if their arms are free and they are face down.

You will need to decide how many divers to send with the litter. In clear water, placing a diver in front of and behind the litter will increase propulsion, maneuvering, and the ability to handle the unexpected. A third diver can monitor the gas pressure in the patient's tank and control any buoyancy devices. In highly silty water, divers at opposite ends of the litter will have limited communication without special equipment such as electronic communications in FFMs or air horns. You may be able to use metal-on-metal tap codes for communication. A single diver will not suffer from miscommunication but may also become overwhelmed trying to manage the litter. Usually less is more when visibility is poor and communication is difficult.

You may wish to immobilize certain patients in order to move them through a sump. In the case of the 2018 rescue of the Thai football team, the rescue team heavily sedated the patients. One diver managed each patient. The patients wore positive pressure FFMs, which were supplied by a separate scuba tank. This technique kept the rescuers from needing to teach the evacuees how to swim, much less scuba dive. The divers generally swam with the patient beneath and slightly behind them in order to protect the FFM from getting jarred and letting water into the masks. If you choose to sedate your patient, ensure the medication does not interfere with breathing or increase saliva production. This will always remain a *very* high-risk option despite the success in Thailand.

There does not currently exist a solution for how to equalize the ears of an unconscious patient. A similar problem may exist if the patient has suffered severe facial trauma and cannot squeeze their nose when exhaling. You will likely need to accept that they will suffer severe ear pain and ruptured eardrums.

18. Move a Patient Through a Deep Sump

Rescues through sumps deeper than 30M/100' require special considerations. Scuba divers should use helium "trimix" in their breathing gasses to reduce the effects of nitrogen narcosis. Narcosis impairs divers' ability to focus. Breathing helium can accelerate cooling. The patient should breathe the same gas as the rescuers so that decompression calculations are easier. The maximum safe inspired oxygen levels may benefit the patient who has injuries or altered conscious state. Note that the use of helium in breathing gasses, and deep diving in general, requires special diver training.

First aid for all diving injuries is to breathe pure oxygen. This should continue at least until the symptoms are gone, the diver is instructed to stop by a medical expert, or no more oxygen or nitrox breathing gas is left. When conducting deep rescue dives, alert the nearest hyperbaric chamber facility. If the risk of decompression illness is high and the distance to the chamber more than an hour, you should consider having a helicopter on standby for a rapid low-altitude medevac.

19. Move a Patient Through a Long Sump

In rescue terms, a "long sump" is one in which the cylinders attached to the patient do not provide enough breathing gas for them to reach the end of the sump. The patient will need to use stage diving. The rescuers will have to help the patient exchange cylinders while underwater. This must be rehearsed. Cylinders should be placed no further apart than every 100M, or every 50M if the water depth is greater than 60M / 200'.

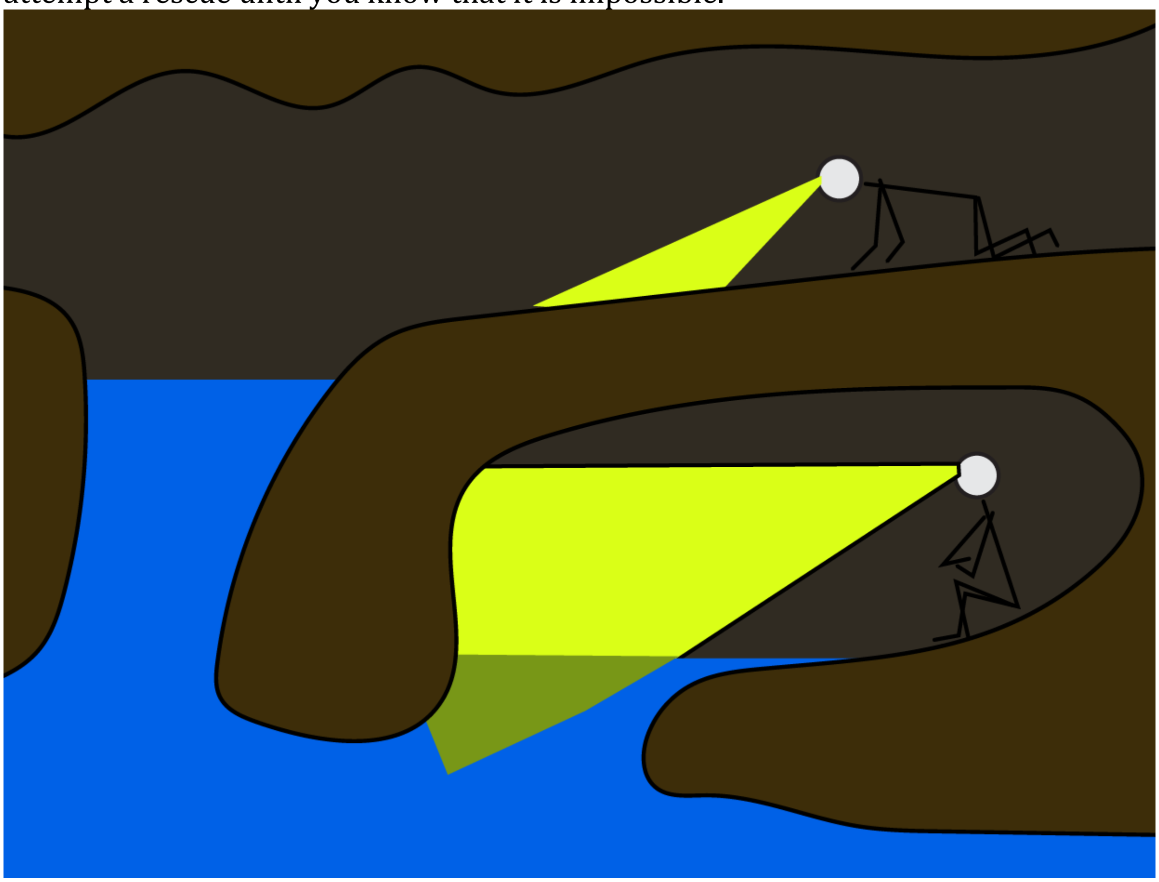
Ideally, the patient's breathing system should enable them to switch cylinders without having to change the regulator they are breathing from. This requires the use of quick connects. At this time the best quick connect is the Swagelok QC6. Put a male quick connect on each stage cylinder and a female quick connect on the breathing system. The system should have "back gas" tanks and the stage cylinder all plumbed into a gas block leading to a 2nd stage regulator. Breathing gas will flow from the back gas while the stage cylinder is being swapped. Each of the back gas 1st stages should also have a 2nd stage regulator that the patient can breathe from in the event of a failure with the gas block.

You must check on the status of the patient. Stop at 20% of the trip to verify that the patient is OK and that their equipment is not falling apart. If possible, also perform checks at 50% and 80% of the trip. The checks will be more efficient if you can do them at the same time that you are exchanging cylinders.

For very long sumps with large diameter passages, you may be able to use diver propulsion vehicles (DPVs) to tow a patient on a litter. This is a very complicated maneuver. It will require one diver + DPV towing the litter, and one diver + DPV behind the litter to keep it under control. The two divers must be very familiar with how each other maneuver with DPVs.

20. Rescue a Patient from an Underwater Air Bell

There are several examples of people fleeing from rising water, where the cavers travel to the highest underground room they can find, and then the water level rises above the top of that room. The air in their room does not escape, and so they wind up in an underwater air bell. All cases so far have been in mines or upside-down ships. The roofs of these rooms are impervious and so maintain the air bell. It is suspected that the roofs of cave rooms large enough for cavers to take shelter in will have micro fractures that will allow air to escape too quickly for a rescue to take place. This has not been proven though and you should still attempt a rescue until you know that it is impossible.



The top priority if you cannot immediately extract the patients is to refresh the air in the air bell. This will accomplish two things. If the patients have been in the air bell for any length of time, then the oxygen has been depleted and the carbon dioxide levels have gone up. The patients need fresh air. The second thing adding air will do is to prevent the air bell from getting any smaller. As the surrounding water rises, the pressure on the air in the air bell will also rise, and so the volume of air will shrink correspondingly.

During the 2003 Quecreek mine rescue, the rescuers first drilled a 6” shaft from the surface down into the chamber where the miners were sheltering. They ensured the mine shaft was pressurized so the air in the air bell did not immediately escape the moment the drill broke into the chamber. If they had failed to pressurize the shaft then the water would have pushed all the air out the new hole in the chamber's ceiling and the miners would have drowned. In the 1907 rescue of Modesto Varischetti in Australia, there was already an air hose going into his chamber to power his drill. It was repurposed to give him fresh breathing air.

The other major consideration is preventing decompression sickness (DCS), the "bends". The patients in the air bell will absorb increased levels of nitrogen into their bodies due to the high pressure of the air in the air bell. If they are returned to the surface too quickly during a rescue, they risk getting DCS. This can cause severe pain, paralysis, and even death. You will have to plan for a swimming rescue to take a vastly longer amount of time so that the patients can decompress.

An alternative is to bring portable mini decompression chambers to the rescue site. After the patients are removed from the water, you must thoroughly clean them and get them into a chamber within fifteen minutes. The chambers contain pressurized oxygen. Especially in the case of mine rescues, mine residue when placed in this environment can spontaneously combust.

21. Conduct a Sump Rescue in an Ice or Glacier Cave

Sump rescues in ice or glacier caves face special challenges. Obviously, the temperature plays a major part, although the risk of hypothermia is large in almost any cave. You must be able to create and maintain holes through any ice. You must be able to create anchors for guideline. Freezing water will cause problems for scuba equipment. If temperatures begin to warm, the cave walls will deteriorate faster.

Creating and maintaining holes in the ice on the cave-exit side of a sump is not overly difficult. You can usually create a hole with a large chainsaw. Be aware of the fumes. When you remove blocks of ice from the hole, make sure to move them to where they cannot slide back to re-block the hole. Keep the water moving to prevent the hole from re-freezing. Place snow or other materials around the hole to prevent the diver from freezing to the ice while entering or exiting. Consider using ice screws as anchors for cave guideline.

Creating and maintaining holes on the far side of a sump is much more difficult. Except for submarines breaching the ice in the arctic, this is not something anyone else has to do. Creating a hole may require an underwater jackhammer or explosives. If you cannot leave someone by the sump to keep it from re-freezing, be sure to bring an axe or even a chainsaw through the sump.

Very cold water causes problems for scuba gear. Scuba regulators will free flow if they ice up underwater. Scuba equipment that has been in the water and then is left on the surface will ice up as well if the air temperature is below freezing. In this case, consider leaving the equipment underwater. The zippers on divers' drysuits will freeze solid. Have large pots of boiling water ready to pour onto frozen clothing and equipment to temporarily unfreeze them. You must be prepared to quickly change the clothing on patients. If patients are wearing wetsuits, consider pouring warm water into their wetsuits immediately prior to and after the dive.

If temperatures rise during a rescue, other challenges will present themselves. Glaciers caves have large quantities of rocks and gravel held together by ice. Warming temperatures means the ice melts faster and you will need to deal with the loose or moving debris.

22. Keep a Patient Warm While Traversing a Sump

If you decide to move a patient through a sump, you will need to limit heat loss while they move, and then rewarm them after the trip. Water cools people twenty-five times faster than air. Safety is the top priority, but reducing the amount of time that patients spend in the water is a close second. Injured people are less able to warm themselves than non-injured. If possible, ensure the patient is well fed so they have the calories to burn for heat.

If the patient already has an exposure suit such as a wetsuit or drysuit, and is wearing it, then keep them in it. If they do not have an exposure suit, you should try to get them one. A well-fitting suit is ideal, but not the only criteria. Sometimes, quickly moving a patient from the cave is better than spending extra time to find the best suit. Getting the patient's body size should be done early so that you have time to find a properly sized exposure suit. You will then need to determine the amount of lead weights that when combined with the suit will make them neutrally buoyant.

You have several options when it comes to exposure suits. Wetsuits are made of thick neoprene. Snug wrist, ankle, and neck portions limit the amount of water coming in and out of the suit, and allow the wearer to warm the water up within the suit with their body heat. Drysuits prevent (almost) any water from entering the suit and keep the wearer warm by surrounding them with a layer of air. Drysuits are generally warmer than wetsuits, but can be fragile, and require special control of the trapped air. Wetsuits are preferred over drysuits for rescue except in very cold water.

You can place electrically heated garments under the exposure suit. These significantly increase the patient's warmth and do so without increasing buoyancy. Ensure the garment is rated for the depth of the dive. There are very rare cases of vests burning their wearers. Have the patient wear something between their skin and the garment. As an alternative to electical heat, placing hot water bottles within the exposure suit also helps.

The patient may have an injury that prevents them from easily putting on an exposure suit. This may be a broken arm or leg. Use a wetsuit in this case and cut the part of the wetsuit that will go over the injured body part open to ease the suit's donning. Use duct tape or similar to wrap the neoprene back around the body part and limit the exchange of water.

On the surface, dry wetsuits are warm, but wet wetsuits drain heat. This happens as water evaporates from the suit. As soon the dive(s) are complete, remove the patient from their wetsuit, dry them off, and rewarm them. If you need to keep the wetsuit on them between dives, having them at least strip it down to their waist is better than nothing. Medical personnel are accustomed to cutting clothing off of patients; prevent them damaging the suit if at all possible.

If a patient will be in a wetsuit in cold conditions for an extended period, you should take steps to prevent trench foot. Trench foot can occur in conditions below 61F / 16C and in as little as 13 hours, and can lead to infections. Additionally, long periods of time in wet wetsuits will lead to skin maceration, blisters, and infection. If infection has not occurred yet and conditions permit, periodically remove the patient from their wetsuit in order to dry and treat their skin. If you suspect infection, consider leaving the patient in their wetsuit to protect their skin from the environment. In almost all cases, quickly moving the patient out of the cave is the best solution.

III. Specialty Teams

In most sump rescues, there will only be a small number of sump divers. Those divers will have to perform every task. If you are lucky to have more than two divers, then the command team can start to assign them to do different special tasks.

1. Search

To mission of the Search team is to search the cave to find the patients. This small team will be the first to enter the sump. The member(s) should be divers who are familiar with the cave, if possible. Because they will have the best visibility, one of their special duties is to repair the guideline any time they see breaks, or see it running through areas where people cannot fit. They should mark any location where they see evidence from the missing cavers. After they find the patients, they should perform a quick assessment and one of them should exit the cave to let the command team know where the patients are, and what their needs are. If the Search team has more than one member, then they must decide whether to leave someone with the patients, or to have the whole Search team exit together. The Search team should be ready to perform the rescue themselves if they determine that the problem is very small and it is safe to do so.

2. Communications

The mission of the Communications team is to ensure regular and fast communication between any rescuers located with the patients, and with the command team. The best way to do this is to set up a radio or telephone system that can communicate between the different areas of the cave. If running a telephone wire system, ensure that it is not an entanglement hazard. If a radio or telephone cannot be used, then the Communications team must ensure that divers going through the sump(s) carry written messages with them. If no divers have passed through the sump in a long time, then a member of the Communications team must swim to the other side to give a status update and return with any new information. Because of this, the Communications team is at risk of running low on breathing gas and/or getting very cold.

3. Medical

The mission of the Medical team is to provide advanced medical care to the patient(s). This is a two-person team. One of the members must have advanced medical skills. The job of the second member is to assist the first member, especially if the first member is not an experienced sump diver. This team will wait for the Search team to find the patients and report about their status before traveling to the patient(s). This will help ensure the Medical team has the right equipment. If possible, the Medical team should focus on the patient(s) and not perform any other rescue-related tasks such as moving the patient(s). This will ensure they do not get distracted and overlook changes to the patients' health.

4. Equipment Transportation

Most specialty teams bring their own equipment with them into and out of the cave. The mission of Transportation teams is to bring in supplies that are more than one of the other teams can move. These may be large or heavy objects that another fast-moving team will need. This could also be food and medical supplies for people staying in the cave for an extended period, including of course the patients.

Transportation teams can be expected to help distribute news and instructions throughout the cave. They should avoid spreading gossip or discussing surface-level problems that will only distress the patients. This includes not discussing if anyone else has died during the incident.

Transportation teams must be frugal and careful with packaging materials. They should expect that there is a limited number of containers that can move supplies underwater, and that they are fragile. The team must prevent them being damaged or lost. Small weights for adjusting container buoyancy may also be in short supply.

5. Passage Modification

The mission of Modification teams is to make it easier and safer for the patients and rescuers to exit the cave by modifying the cave. This might involve adding rigging to make it easier to get into and out of the water. It might involve enlarging parts of the cave so that a stretcher can fit through them. Rescues are incredibly damaging to caves and so this team should avoid all unnecessary changes. They could enhance cave conservation by marking off parts of the cave for people to avoid.

Part of their work may involve using underwater explosives to widen or clear a passage. Be cautious of using too much explosives. Too large a blast will damage surrounding rock that may collapse and block the tunnel. Explosions stir up silt and alter the path of the water. Avoid using timer-based detonators whenever possible. Use command wires instead. Timer-based detonators may go off while divers are still in the water and cause major injuries.

6. Patient Movement

The mission of the Movement team is to move the patients through the sump(s) as quickly as possible while causing as little additional harm as possible. If needed, the Movement team will transport a litter to where their patient is. They can help with packing the patient into the litter. The movement team will move the patient if they cannot move themselves. They will monitor the patient's health and safety while moving them.

The Movement team can be organized in several different ways:

a) The Movement team works as a single large group. They stay together and move the patient through each sump. In between sumps, they are responsible for moving the patient and their own diving equipment over dry ground.
b) One or two members of the Movement team are assigned to every long dry passage in between sumps. They assist the main divers with

moving the patient and equipment between sumps. They may have brought special equipment to help with just that dry portion of cave.

c) There is a different Movement team assigned to each sump. When a patient is brought to them, they swim the patient through the sump. They then bring the patient to the next team at the next sump.

When organizing the Movement team, try to plan so that each diver travels into the cave to a certain location, does some work, and then exits. No diver should travel through a sump multiple times. This will conserve their breathing gas and protect them and their equipment. Try to clearly mark sections of the cave so that everyone will easily understand where their assigned area is.

IV. International Systems

1. Work within the U.S. Incident Command System

In America, a sump rescue will involve many elements of the Incident Command System (ICS). The Operations Section will obviously be involved, but the Planning Section, Logistics Section, and special staff like the Public Information Officer and Safety Officer will also play roles.

Within the *Operations Section* you should form a dive task force. This will obviously include the divers but will also include the porters who help to move and set up their equipment. Most porters can be re-tasked after they've moved the dive equipment. The divers may appreciate some help with getting kitted up and having a set of assistants who don't need to be retrained for each dive is useful. You should consider having three to four porters per diver if there is any distance to the sump. They will carry the cylinders, lead weights, and other tools.

The *Plans Section* will be busy in each stage of the rescue. In the initial stage this section helps guide the search as well as gathering data about the weather, local geography including the water table, and the names of available qualified cave divers. Divers must be certified cave divers with "sidemount" experience. Ideally, they will have recent experience with the site. The Plans Section will project ahead to set criteria for whether to bring the patients out of the cave right away, or leave them until conditions improve. It will develop a plan for improving sump trafficability and how to conduct an extraction. The Plans Section relies heavily upon input from the divers themselves. During a large rescue operation one of the most experienced divers should do little diving themselves and instead split time between working in the Operations and Plans Sections to keep things organized from a diving perspective.

Periodically, the command post (CP) will conduct a "seven-minute drill" to ensure that all personnel within the CP are aware of each team's status. This is sometimes known as briefing your "running estimate". Someone will need to be ready to brief the status of diving operations. In under one minute, they should be able to present current diving-related activities, the next set of dives, status of scuba supplies such as cylinders and underwater containers, and the number of active and available divers. This information will enable other sections to synchronize with you and update their plans.

The *Logistics Section* will need to acquire scuba resources to keep the divers supplied. This includes filling cylinders, getting lead scuba weights, charging electronics, and acquiring/building packaging to get supplies to the patients trapped beyond the sump (usually dry tubes). There are many different sizes and configurations of cylinders, so be sure to ask precisely what the divers need. You will need on-site air compressors with the proper filtering mechanisms. This will allow you to refill tanks locally instead of having to take them to the closest dive shop. Consider the need to boost oxygen or mix other gases for deep diving or rebreather operations.

The *Public Information Officer* (PIO) will have to handle questions about the diving aspects of the operation. The media will want to compare the rescue to the 2018 Thai cave rescue. PIOs should emphasize that cave divers take special training and use special equipment, and this enables them to manage the many risks. There are differences between a standard cave dive and a rescue though. Many sump rescues will involve minimal visibility and high flow, hence expectations should be kept low. The divers breathe from air tanks, not oxygen tanks. The PIO may need to put out requests for assistance. This may be for additional certified cave divers, portable air compressors, or other special diving or communications equipment.

The *Safety Officer* should be aware of scuba specific elements to monitor. During a sump rescue the largest hazard may be the weather. This will affect diving conditions and the possibility of other parts of the cave becoming cut off. Ensure there are clear written criteria for whether diving conditions are safe or not. These help prevent bending the rules later. Every cave diver knows that any person can cancel the dive at any dive and no recriminations will be made.

The Safety Officer has a few other areas to monitor. Be aware of the possibility of electrocution if pumps or communication systems are brought into the cave. Most diving during a rescue will be very shallow, rendering decompression illness “the bends” unlikely. Common scuba injuries include musculoskeletal issues due to the weight of the equipment, effects of the cold water, and general medical issues. You can call the Divers Alert Network (DAN) to immediately speak to a diving medicine expert, however medical care should be immediately available on site where possible. They will be needed when the patients appear in any case. Insist that all divers go through a pre-dive safety checklist right before they go under the water to double check that their equipment is properly configured.

V. Preparation and Training

1. Conducting Sump Rescue Training

Sump rescue training exercises allow the caving community and emergency responders to rehearse for future disasters. They provide a chance to validate techniques and new equipment. Many groups choose to train for the most difficult but least-likely scenario: an unconscious or paralyzed non-diver trapped behind a sump. Sump rescues are inherently dangerous and so you must take great care that the training does not kill anyone involved.

Sump rescue training takes place in four phases. In the first phase, conduct classroom training to describe the sump environment, basic techniques, and the team structure. In the second phase, conduct hands-on training with all the equipment in a dry environment. In the third phase, conduct a mock rescue with a real cave sump. Try to use a location where getting the patient in and out of the water requires thought and effort. Be sure to include the civilian authorities and emergency personnel who would be in charge, as well as the surface-support personnel. In the last phase, conduct an after-action-review to capture lessons-learned. If you have extra time, consider practicing the rescue with a dummy before you use a live "victim".

Take very great care to prevent accidents during the training. Ensure that some personnel have CPR training. Make sure an AED and emergency oxygen are present. Designate specific non-students – "angels" or "bats" – to monitor for safety and not do anything else. Before a live "patient" is taken into the water, pause the training exercise and allow the patient to double check his or her equipment. If the patient will be moved through a restriction, make sure a safety observer is present on both sides of the restriction. Ensure the patient has a way to escape from anything lashing them to a litter.

2. Preparing for Rescues at Specific Sites

Some cave passages are more likely to be the location of a sump rescue than others. As an example, a cave popular with local spelunkers and prone to flood quickly is ripe for disaster. It is prudent then to prepare ahead of time for a rescue there.

Survey the cave passage to identity important locations. These include restrictions and navigational decisions. Discern distances and likely water depths. Identify where you would go to wait if you were trapped within the cave. You can then prepare each of these locations. Consider pre-rigging a normally-dry cave passage with a rope to follow if it floods. Secure wiring and piping so they do not become entanglement hazards. Cache a supply of food, lights, and blankets in a location likely to stay dry.

Work with the people who be involved. Give a copy of the rescue plan to local authorities and to the call out person for anyone going into the cave. Periodically conduct a rescue exercise at the site. If any special equipment will be needed, make sure everyone knows where to get it from.

VI. Historical Vignettes

1. 1894 Austrian Cave Rescue

On 29 APR 1894 seven cavers entered Lurloch (Lurgrotte) cave in eastern Austria. Due to intense competition for cave discoveries, they entered even though there was heavy rainfall. The entrance of the cave flooded, trapping them inside. They were believed to have found higher ground to safely wait. Emperor Franz Joseph I approved a massive rescue effort.

One attempt at rescue included bringing in a diver from Trieste. The diver used a standard deep-sea brass helmet with surface supplied air. The entrance was small and so he had to enter feet first, pushing himself along. He soon gave a distress signal and had to be hauled out by his surface attendants. His air hose had become kinked. He entered a few more times to try to remove some of the logs and other debris that had washed into the cave, but each time ran into trouble and had to be hauled back out. He soon gave up.

The rest of the rescue team continued working. They dammed the water flowing into the cave and enlarged and cleared the entrance with explosives. After many days of work, they were able to bail out the sump and rescue all the patients alive. They had been trapped for 207 hours.

References:
Farr, Martyn. 2017. *The Darkness Beckons.* Vertebrate Publishing.
https://en.wikipedia.org/wiki/Lurgrotte (accessed 02 OCT 2019).

2. 1979 Anderson Spring Cave Rescue

On Saturday morning at 11:30 a group of 11 cavers entered Anderson Spring Cave on Pigeon Mountain near LaFayette, Georgia. These were student members of the Outdoor Club of Georgia Southwestern College, their leader Barry Beck (40), an assistant professor of geology, and Beck's son, Eric (13). The students, all in their late teens, included Cheryl Gillis, Tony Able, Mark McKoy, Tony Johnson, Mary Faye Smith, Warren Moore, Dennis Hudgins, Louis Pounds and Steen Madsen. Beck and his son were experienced cavers, the rest were not. All were well equipped with hard hats, spare lights, warm clothes and a lunch.

At between 3:00 and 3:30pm they neared the end of the large effluent stream passage, nearly a mile from the entrance. Lunch was eaten and Johnson, having lamp trouble, and Eric Beck, getting cold, decided to leave. The others continued to a breakdown choke and unsuccessfully explored it for an hour. At this point they decided to leave the cave.

Meanwhile, outside, a thunderstorm described by some as the worst in decades struck the southeast. Up to 15 inches of rain fell in some areas. Torrents of rain descended on Pigeon Mountain. As the cavers headed for the entrance the rising water was noticeable. Former drips from the ceiling were now gushing water. In the large passage the rising cave stream meant little, but the entrance area is constricted, so they hurried on. To their dismay they found the entrance passage nearly filled with water. Two students, McKoy and Able, wanted to push on out and received Beck's permission. Fortunately, the passage had not quite sumped and they exited successfully. The rest retreated upstream and climbed breakdown to an upper level to wait out the flood. They were wet to the neck but huddled together to stay warm and also exercised every hour. After 8 to 10 hours their clothing dried and their stay became quite tolerable.

In the meantime, the four who had left contacted the Walker County Civil Defense. Other agencies were alerted, and late Saturday an attempt was made to enter the cave but the force of water flowing out made this impossible. Sunday morning, four scuba divers from the Walker County Cave Rescue Squad were also beaten back by the water flow just inside the entrance. A member of the National Cave Rescue Commission coordinated the flying in by the Air Force of a special hypothermia treatment team from Virginia. At around 7 p.m. on Sunday two divers struggled through a 60-foot near-sump with a strong current of 45 degree water. One of the divers was a non-cave-trained teenager using a single AL80 scuba tank. When they entered the large passage, they found the cavers already prepared for an attempt at leaving. Using an extra regulator on one of the scuba tanks, the trapped cavers were escorted one-by-one through the 4-inch air space of the near-sump. The last person was out 33 hours after entering. The cavers were checked at a nearby hospital and found to be in good condition.

References:
Edgar Miller "7 Explorers Rescued from Cave Near LaFayette" The Chattanooga Times Monday, March 5, 1979 p 1, 2.
Associated Press "Cave Rescue" Bakersfield Californian Marcb 5, 1979 p 1, 2.
Editorial "Daring Diver Rescues Seven Trapped Cavers" Inside Connection (Southern Bell Telephone Company Newsletter) May 1979 p 1, 9.
Editor "Divers Save 7 Trapped in Cave" New York Daily News March 5, 1979.
Barry Beck "The Long Wait Underground" NSS News May 1979.

3. 1992 Rescue at Sleets Gill

On 19 March 1992, two cavers entered Sleets Gill cave in the U.K. for a day of caving. The entered in the early afternoon and planned on only a short trip. This was their first time in the cave but they were aware the cave tended to flood. They did not see any signs of flooding on their way in. The mid-point of the cave is the lowest part of the cave. When they reached the far end, they heard loud sounds that turned out to be from an underground stream that was overflowing into the main tunnel. They rushed to exit the cave but the low point was now flooded to the ceiling and they had to turn around. They found a high point to sit at, but the water continued to gradually rise.

Late in the evening their wives contacted the police to report them missing. They gave the police the information the cavers had written down about where they were going. The police located the cavers' car and alerted the local cave rescue group. This group sent divers with their cache of rescue equipment to the cave, which they now knew was flooded. It was early morning before everything was ready, and then two divers swam through the sump, laying line as they went. When they surfaced, they did not see the missing cavers. They had expected that if they were alive, they would stay right by the edge of the water. After walking for a while beyond the sump, the two divers found the cavers. They checked on the cavers' status and quickly exited the cave.

At this point the sump was about 250 meters long and the water was going down. The weather report showed that heavy rain would arrive by the late afternoon though. The incident leadership decided that the cavers would have to be scuba dived out of the cave. They used nine scuba divers to shuttle hot food & liquids and scuba supplies to the cavers. They used a wireless cave radio to communicate with the surface. It was a major logistical effort to plan and move all the equipment and support personnel to the proper places.

At the back of the cave, cave divers taught the cavers what to expect when they swam out. They also fitted them with wetsuits. The divers swam out the cavers one at a time in order to keep things simple. Two divers swam with each caver. There was a FFM for the first caver but only a regular mask and regulator for the second. Several times during the exit the cavers got tangled in the guideline. The divers were able to untangle them and keep them going. There was a major restriction right at the last part of the sump. The divers sent the cavers through this ahead of them. All the cavers and divers were able to exit the cave successfully in the early afternoon. Just as the last caver left the cave, the water started rising again. By mid-day the next day, the cave was completely flooded with no air spaces left.

References:
Sid Perou. 1992. Hard Decisions at Sleets Gill. https://www.youtube.com/watch?v=JokQmAwccsA (accessed 9 APR 2019).

4. 2004 Cuetzalán Cave Rescue

In March of 2004, a group of six British cave explorers were trapped in Cuetzalán Cave in Mexico. The six were part of a larger team of twelve explorers. Several inches of unforcasted rain fell while the six were inside the cave on a thirty-six hour trip. A low section of the cave flooded soon after the water started to rise, at 1800 on Wednesday the 16th. The explorers were all experienced cavers and responded by moving to a part of the cave that had never flooded. The area had a prepared underground camp with emergency supplies including food, sleeping bags, a cave radio, and two novels. The group started their trip with a ten-day supply of food. By using the cave radio, they were able to stay in touch with the rest of their team outside the cave.

The surface team initially waited several days for the water to go back down. When the water didn't go down, they informed the Civil Protection Agency in nearby Puebla on Sunday afternoon. The cavers declined rescue support by the local authority and instead requested a rescue by the British Cave Rescue Council (BCRC). The cavers were in good condition, though bored after finishing the two novels. Cave divers Richard Stanton and Jason Mallinson arrived from the UK on the 23rd. They had to teach several of the trapped cavers how to do simple scuba diving. Stanton and Mallinson swam with the cavers out of the cave one at a time through a 300-meter passage. All were out of the cave by the end of the day on Thursday the 24th, after spending eight days in the cave.

References:
Owen Bowcott. "Divers sent to rescue Britons trapped in flooded Mexican cave system" The Guardian 2004.
https://www.theguardian.com/uk/2004/mar/24/owenbowcott (accessed 16 APR 2019).

5. 2017 Mallorcan Cave Rescue

On Saturday 15 April 2017, Xisco Gràcia and his dive buddy Guillem Mascaró were cave diving in Sa Piqueta cave in Mallorca. They accidentally silted out their part of the cave and then found out that their guideline to the surface was broken. They were 1km into the cave system and on their way out when this happened. They swam to a nearby large air bell to confer after an hour of failed attempts to find and repair the guideline. Xisco decided to give his scuba tanks to Guillem so that Guillem would have enough breathing gas to swim out by another route while Xisco waited in the chamber for Xisco to return with help.

Xisco settled down in the room to wait for rescue. The chamber was 80m long by 20m wide with 12m of airspace above the water. Xisco took off his scuba equipment and found a rock to sit on to get out of the water. Two of his lights were out of power and the third was dieing. He left the light off except to periodically climb off the rock to go down to the water to drink. Dropping oxygen and increasing carbon dioxide contributed to halucinations about rescuers arriving. At one point he heard drilling above the room as rescuers attempted to drill down to him, but they had to stop due to technical problems.

Xisco's friend Bernat Clamor arrived in the room on Monday, Xisco's second day of waiting. The rescue team had had to wait for the silt to go down before attempting to swim to him. Bernat gave Xisco some glucose pouches for sustinance then returned to the surface to let the rescue team know they had found him. The team brought in full scuba tanks for Xisco and guided him out of the cave eight hours latter, sixty after he had entered. Xisco's core temperature had dropped to 32C/90F and he was taken to a hospital to recover. He was back to cave diving again a month later.

References:
Claire Bates. "Two days in an underwater cave running out of oxygen" BBC World Service 2017. https://www.bbc.com/news/magazine-40558067 (accessed 12 JUN 2019).

6. 2018 Team Stuck in La Cueva Peña Colorado

In April 2018 a team of sump divers were exploring the Peña Colorado cave system when unexpected rains raised the water level in the cave and trapped them for three days. Six cavers were in the cave during the storm. The water level went up so fast that they had to race from their campsite to higher ground. They were only able to bring four energy bars and one space blanket with them.

On the surface, Teddy Garlock was preparing to join them. Some of the cavers would be leaving the cave while Garlock was replacing them on the team and bringing in supplies. He swam through the first two sumps of the system without noticing any differences. When he arrived at the entrance to the third sump, the effects of the rise in the water were immediately visible. Diving equipment that others had left by the sump was now floating in a large pool, and the guideline was not visibile. The water had gone up ~11M/35'. He retrieved the floating equipment and found more while fishing around for the guideline. Using line spools that he had found, he was able to able to find the guideline and extend it out well above the new water level.

Garlock then set about trying to do the same on the far side of the sump. He followed the line to where it terminated, bringing his dry tube of supplies with him. The line ended well below the surface, he was out of extra line to use, and he did not know if he went up if there would be air above the water. Going up without a link to the guideline would also have meant losing the line. He tied the tube of supplies to the end of the line and turned around and swam out of the sump. He then left the cave and conferred with the other expedition members who were on the surface. They decided to wait two days for the water to go down, assuming the group inside the cave was safe.

Garlock returned to the cave two days later. The water had mostly returned to the pre-flood level. When he exited the third sump he met the six cavers who were getting ready to swim out of the cave. All were well, if cold and hungry. They exited the cave sixtynine hours after the flood event.

References:
Theodore Garlock. "'18 PEÑA COLORADA".
https://dirtbagdiver.com/expeditions/2018-pena-colorada/ (accessed 12 JUN 2019).

7. 2018 Thailand Boys Football Team Rescue

On 23 June 2018, twelve teenage Thai football (soccer) players and their assistant coach became trapped in Tham Luang cave. Heavy rains started while the teammates were caving, which flooded large portions of the cave and prevented them from exiting. Search and rescue efforts began within a few hours when they did not return home. Local scuba instructor Vern Unsworth had previously mapped the normally dry cave. He recommended that members of the BCRC be brought in to help with the rescue.

After over a week of searching, BCRC members Jonathan Volanthen and Richard Stanton found the team on 2 July. They were 4km from the cave entrance, which included at least 1.5km of now-underwater passage. The passage included many restrictions and line traps. The divers recorded their meeting with the patients on video. On 3 July seven Navy Thai SEAL members swam to the patients with food and medical supplies. Four, including one doctor, remained with them and were the last to exit the cave.

The rescue team explored several options for extracting the patients. This included using water pumps to lower the water level in the cave and attempts to divert water going into the cave. Attempts were made to find other entrances to the back of the cave. The chamber with the patients was several hundred meters underground with very rough terrain above them, and so no drilling was attempted. Over ten thousand workers and one hundred divers from many countries participated in the rescue effort. Eventually the weather forced the issue. New storms were coming into the area. The decision was made to swim the patients out of the cave as opposed to trying to leave them in place. It would be several months until the monsoons stopped and it was thought almost impossible to keep them supplied and healthy.

Cave divers swam the patients out between 8 and 10 July after rehearsing on the 7th. On each day, Australian anesthetist and cave diver Richard Harris and other cave divers swam to the patients. Each patient to be swum out was put into a wetsuit and fitted with a FFM. Scuba tanks were placed on their fronts to act as a keel and keep them face down. Harris estimated the weight of the patients and gave them a number of drugs to knock them out, including 5mg / kg of Ketamine. One cave diver swam with each patient, and there were long intervals between their departures in order to prevent running into each other underwater. Along the way each diver gave their patient 2-3 top up shots of 2.5mg / kg of Ketamine to keep them sedated. Support divers were staged along the exit route to help the divers move their comatose patients through the non-swimmable portions. Scuba tanks were also staged along the route to replace cylinders that were getting low. The tanks contained 80% oxygen to give the patients a slightly better chance of survival if there were problems with their breathing system. Each trip to the exit took around three hours and was in 20C/68F water. The patients were very cold by the end of the trip.

All of the patients survived and fully recovered. One Thai Navy SEAL died while ferrying breathing equipment. Early on in the rescue, a team of searchers got trapped in the cave when the entrance to their tunnel sumped. No one knew they were missing. They were fortunate to be accidentally discovered by a scuba team and almost drowned during their hasty rescue due to panic. As the rescue was winding down, one of the pumps keeping the water level low failed and the remaining personnel in the cave had to rush to the exit.

8. 2019 Rescue from the Mill Pond Cave in Tennessee

Briton Josh Bratchley and two other British cave divers were exploring the Mill Pond cave in Gainesboro, TN on 16 APR 2019. The cave is 400 – 500' long, has many major restrictions, and has a floor of deep silt. The three and their local contact had previously dove to the end of the line in an air bell. They had decided they wanted to replace the #24 nylon guideline with stronger and thicker polypro line to improve safety for further exploration.

Bratchley and one of the other British cave divers entered the cave to replace the line. The other diver swam in front and was laying the polypro line. Bratchley swam behind him reeling in the #24 line. Approximately 250 – 275' into the cave they became separated when the other diver turned the dive. When he returned to the surface, he expected to see Bratchley but he wasn't there. He immediately went back into the cave to do a search. After that dive he called their local contact who came to the site with his own dive gear and continued the search. Searching continued until 2200. Visibility was completely gone and their breathing gas supplies were depleted. They believed Bratchley was safe in the air bell because the guideline he was reeling in continued to there. Bratchley was wearing a drysuit he had borrowed from the local.

The group decided to get new breathing gas and started to contact others. At 0100 they contacted emergency services. They spoke to British Cave Rescue at 0200. They decided it was safer to bring in someone with no emotional attachment, and called Edd Sorenson and Mike Young at 0300. The group returned to the cave at 0600 at the visibility had improved to 5-7'. Sorenson and Young flew to Nashville with their cave diving equipment and then were flown by a Tennessee State Highway Patrol helicopter to the dive site. Jason Richards had previously surveyed the cave but not created a map. He quickly did the cartography to give the team an improved planning tool. The team also located a photo of the air bell.

At approximately 1700 the incident commander gave a press update. He gave a summary of the dive incident without naming any of the participants. He did mention that they were known to be experienced cave divers. He then reported that rescuers were being flown in, would need about an hour to set up their equipment, and then diving would begin at around 1800 or 1830. He said the friends of the missing party believed he got separated about 400' back in the cave and they believed he would go to the air bell, where there was enough air for someone to stay for twenty-four hours or more. They showed a large printout of a line map of the cave. He said they were aware of the average cave passage size, max depth (40'), temperature (55F), and that swimming one way through the cave took around forty minutes. He said the missing party was wearing a drysuit. He noted that the water visibility for the cave had improved. He let the press know they would try to do another press update by 2200.

Edd Sorenson swam into the cave at 1800. Mike Young stayed on land by the entrance to the cave as a safety diver in case Sorenson did not return on time. The original estimate for the in and out dive trip was 2.5 hours. During his dive Sorenson found where the new guideline stopped, and ran a new guideline from there. He was able to find his way to the air bell at the back of the cave. When he surfaced in the air bell, Bratchley was 12' from him. Bratchley was calm and said to him, "Thank you, thank you, who are you?" Sorenson asked him a series of questions about his condition and his equipment. Bratchley had taken his gear off and put it on some mud near where he had been able to get out of the water and sit on a rock. Sorenson briefed him on how they would conduct the swim out, including how they would transition from his line back to the main guideline. Sorenson and Bratchley then swam out of the cave together. Sorenson's total time in the cave was approximately fifty minutes. Bratchley had been in the cave for twenty-seven hours. On the surface Bratchley was given a quick exam, refused further medical treatment, and said his only request was a pizza.

Appendix A: Sump Reconnaissance for Decision Makers

Information to collect for decision makers includes:

a. Is the water in the sump rising or lowering, and how quickly?
b. Is the water flowing or relatively still?
c. Does the water appear clear or muddy?
d. What parts of the cave are flooded or impassible?
e. What challenges to moving bulky scuba equipment exist along the path to the sump? Many cave divers are not (skilled) cavers and so vertical sections may prove a challenge for them.
f. Where are the low parts of the cave along the way to the sump that may also flood?
g. What indicators are there that missing people might be beyond the sump?
h. What does local knowledge say about the cave, known air spaces, flood durations, and historical rescues?
i. For each of the missing persons, what are their known medical considerations, and what is their experience level with caving, swimming, and scuba diving

Information that could help cave divers includes:

a. What is the water temperature?
b. How much dry area is available near the sump?
c. How far is the sump from the cave entrance?
d. Are there any restrictions visible that divers would have to swim through?
e. How deep is the water? If this is well known cave, how far has the water risen above its normal level? This can be in ranges, e.g. 5 – 10 meters or 30+ meters.
f. How long is the sump? This usually requires a pre-existing map.
g. Is there a guideline through the sump?
h. Are the missing cavers suspected to be behind recently flooded passage or are they sump divers behind a long-standing sump?
i. If the sump is the result of recent flooding, what was the passage like when it was dry?

Appendix B: Information to Collect Upon Finding the Missing Persons

For each person you discover, collect the following information:

a) Full name
b) Medical symptoms
c) Any allergies or medications
d) Any medical history you should know about
e) What they have been eating/drinking
f) How they got trapped in the cave
g) What supplies they have remaining
h) Knowledge of anyone else in the cave
i) Knowledge of any other dry/flooded passages or areas
j) Height, weight, body composition (muscular or obese), hand size, foot size – so they can be fit with a wet suit

Appendix C: Pre-Dive Safety Check

Divers should conduct these checks prior to descending below the water.

a) All scuba tanks are marked as to what gases they contain
b) All scuba tanks are fully open and the regulators work
c) The BCD can inflate and deflate
d) Their drysuit, if they have one, can inflate and deflate
e) All of their lights work
f) If they have a dive computer, it is on
g) They have their cutting tools
h) If in a permanent sump, they have line markers
i) They have a rescue spool
j) They have their mask, fins, and weights
k) They have everything they need for their specific dive mission
l) Their scuba tanks contain enough breathing gas for their mission

At a dive site the dive controller should perform the following prior to divers descending below the water.

a) Record the name(s) of the diver(s), time into the water, and mission
b) The pressure and gas mix in each scuba tank
c) Ensure the diver(s) have conducted the pre-dive safety check

Appendix D: Post-Dive Information Gathering

Conduct these inspections on a sump diver after they return from a sump dive.

a) Do they have any messages or information they were not able to write down?
b) Do they have/are there any emergencies that need immediate action?
c) What were the results of their dive?
d) Do they have any notebooks/slates to pass along?
e) If the cave is not completely mapped, can they sketch their route and what they saw?
f) How were dive conditions and what should other divers know?
g) How much gas is left in each of their scuba tanks?
h) What is the estimated remaining power in their lights and other battery powered devices?
i) What damage did their diving equipment sustain?
j) What was their dive time & depth, and when can they be ready for another dive?

Appendix E: BCRC Procedural Forms and Checklists

The British Cave Rescue Council uses the forms and checklists in this appendix to document their dive plan and ensure that dive pre-checks and post-checks have been completed.

Overall plan – who does what and when

Time	Who	Activity

Team diving plan

Diver 1	
Diver 2	
Diver 3 Note: maximum three in a team. Larger teams should be subdivided.	
All members of team understand the team goal	
Action to take if separated	
Any special signals needed agreed	
Plan of action agreed in case of other emergency	
Any shared resources such as extra emergency/deco cylinders discussed and calculations done to ensure sufficient redundancy for the team as a whole	
Familiarization with each other's equipment layout	

Checklist - rebreather diver pre-dive

Diver	
Type of rebreather	
Maximum depth/bottom time	
Planned decompression schedule (for multiple sumps, a computer simulation preferable)	
Mission	
Calculate max scrubber duration	
Diluent to be carried – mix gas, analyze and label cylinders	
O2 carried – fill cylinder and label	
Bail-out – mix gas, analyze and label cylinder Cross-check max PPO2	
Additional decompression cylinders needed (mixture, volume and depth) Mix gas, analyze and label cylinder	
Other equipment to be used (habitat, DPV, etc.)	

Checklist – rebreather diver at-dive

Diver	
Rebreather build complete, including electronics function test. Question age of batteries.	
Suit integrity	
All decompression/stage equipment previously tested and in place	
Diluent – check turned on and take manometer reading. Cross-check label of cylinder contents against pre-dive plan	
O2 – check label, check turned on and take manometer reading	
Bail-out – check turned on, cross-check labels against pre-dive plan, test function of demand valves	
Check loop for leaks	
Wing and suit inflators functional if separate suit inflation used check that cylinder is full	
Light check (main + spares)	
Dive computer + reserve functioning	
Ancillaries (reels, knife, cutter, line markers, spare mask, wet notes)	
DPV functioning	
Rebreather self-test and breathing drill complete	
Time in	

Checklist – rebreather diver post-dive

Diver	
Time out	
Check computer clear	
Any signs of decompression sickness or other barotrauma?	
Mission completed?	
Any problems encountered?	
Diluent SPG readings	
O2 SPG readings	
Bail-out SPG readings	
Report of position and status of decompression cylinders	
Report of position and status of other equipment used	
Note any equipment failures	

Checklist – OC diver pre-dive

Diver	
Equipment configuration	
Maximum depth/bottom time	
Planned decompression schedule (for multiple sumps, a computer simulation preferable)	
Mission	
Main gas supply to be carried – mix gas, analyze and label cylinders Cross check max PPO2	
Stage cylinders to be carried – mix gas, analyze and label cylinders Cross-check max PPO2	
Additional decompression cylinders needed (mixture, volume and depth) Mix gas, analyze and label cylinder Cross-check max PPO2	
Other equipment to be used (habitat, DPV, etc.)	

Checklist – OC diver at-dive

Diver	
Suit integrity	
All decompression/stage equipment previously tested and in place	
Main gas supplies turned on, take manometer readings, test function of demand valves, cross check labels against pre-dive plan	
Check configuration of cross-over manifold (if fitted)	
Stage tanks – check turned on, take manometer readings, test function of demand valves and cross-check labels against pre-dive plan	
Check for leaks in valves	
Wing and suit inflators functional, if separate suit inflation used check that cylinder is full	
Light check (main + spares)	
Dive computer + reserve functioning	
Ancillaries (reels, knife, cutter, line markers, spare mask, wet notes)	
DPV functioning	

Checklist – OC diver post-dive

Diver	
Time out	
Check computer clear	
Any signs of decompression sickness or other barotrauma?	
Mission completed?	
Any problems encountered?	
Main gas SPG readings	
Stage SPG readings	
Report of position and status of decompression cylinders	
Report of position and status of other equipment used	
Note any equipment failures	

Appendix F: Instructions for a Hasty Class in Sump Diving

a. Scuba tanks and regulators
b. Buoyancy and BCDs
c. Have them breathe from a regulator with their face in the water while not wearing a mask
d. Explain why not to hold their breath
e. Discuss scuba masks after they are comfortable without one. Have them put on their mask and put their head underwater so they can gain confidence with it.
f. Guidelines
g. How to pull and glide without dislodging the guideline
h. Fins and finning techniques. You will probably have them flutter kick.
i. What to do if they lose their regulator or the guideline, get entangled, their mask floods, there is a free flow, or they lose buoyancy control
j. Flashlight usage (optional)
k. Methods for staying calm, limiting their breathing rate, and requesting assistance. Have them practice breathing slowly underwater.
l. Explain that they should only remove the regulator from their mouth when the rescue diver tells them to. This will prevent them from spitting out the regulator too early before establishing buoyancy and handling other challenges.
m. Discuss the route through the sump
n. Make sure to quiz them and have them explain skills back to you in their own words
o. Do a verbal rehearsal of the whole dive

Appendix G: Equipment for a Sump Rescue Kit

When conducting a sump dive to search for missing cavers, there are a few small useful items you can bring with you in your pockets. If you find the missing cavers, you can give these to them to immediately improve their situation.

- A flashlight
- Energy bars
- A large garbage bag or space blanket
- Candles and matches or a lighter, for a Palmer Furnace
- Scuba o-rings, a wrench, a bungee cord, and a bolt snap

Be aware that if the cavers are in a small chamber, they should not use the candles. This would accelerate the depletion of the remaining oxygen.

If the cavers have been missing for more than a week, giving them energy bars may make things worse. The food may shock their system. Consult with medical professionals to select the right quantity and type of food that would be safe for them.

On this type of dive, a note pad is more useful than a dive slate. If you do not find the missing cavers but suspect they might be nearby, you can write them a note and leave it where they might find it. This will help their morale.

There may also be equipment that would prevent the need for your own rescue. What do you have that does not have a backup? What problems could you solve with some extra bungee, zip ties, a bolt snap, and a combination wrench / screwdriver? What could you break or lose while getting into/out of the water on the far side of the sump?

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