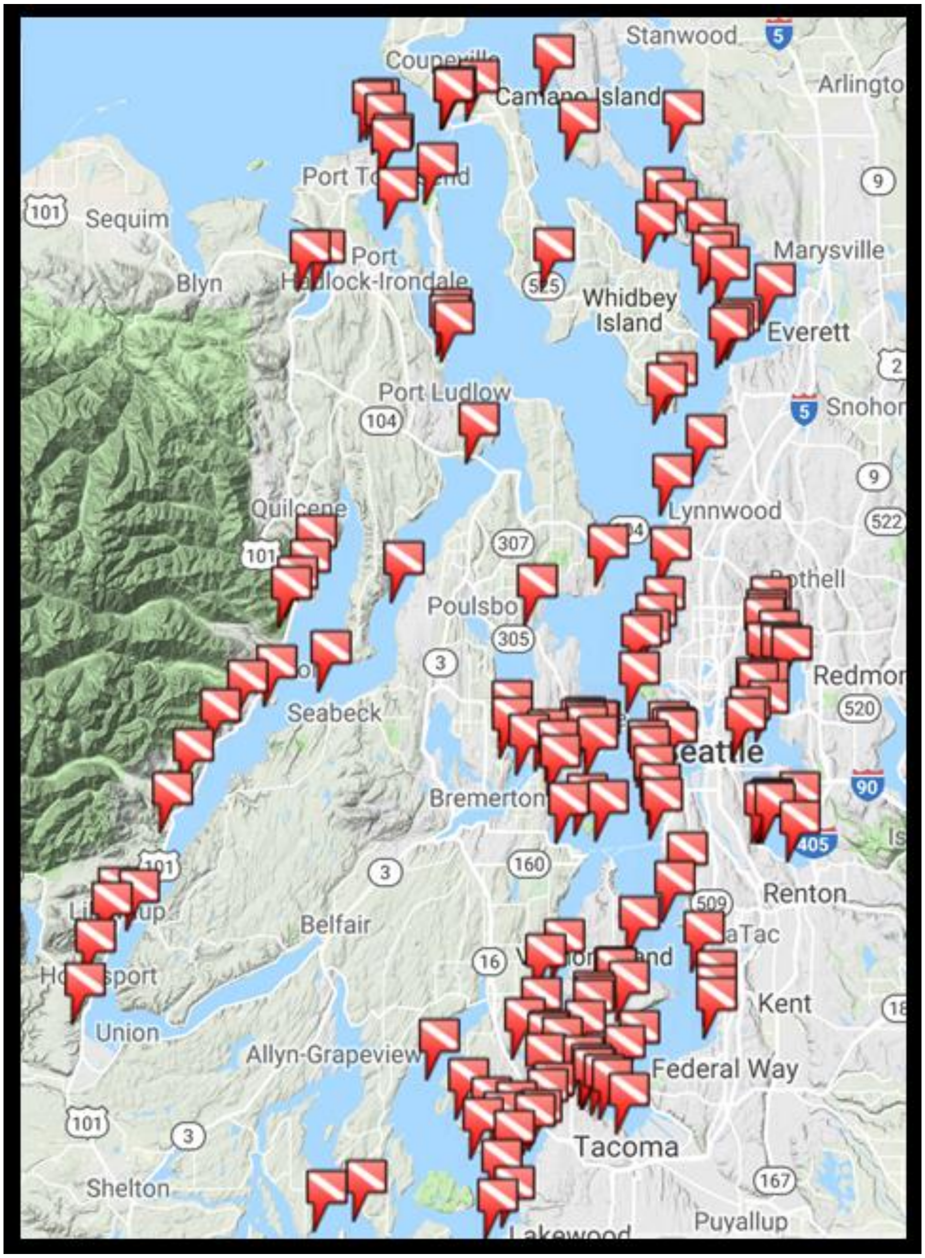
DIVE PLANNING FOR OPEN WATER STUDENTS

PUGET SOUND EDITION



Kosta Koeman

Deep Adventures

SDI Open Water Instructor #25110

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Gareth Lock (https://www.thehumandiver.com/) for allowing his article to be included in this document. Introducing open water students to human factors in diving helps instill awareness and safe diving practices in the new (and experienced) diver.

Revision History

Release	Date	Comments
1	21-09-2018	Original release
2	27-02-2019	Significant additions include adding metric units, stress factor k and use industry standard of 30 feet / 9 meters per minute for ascents, checklists, links to resources.

Disclaimer

This document is provided “as is” with no liability assumed for information provided herein. Scuba diving is an activity with inherent risks, which includes risk of severe injury or death. Proper and extensive training and experience are required to provide some level of safety. This document is not a substitute for either training or experience. The risk of injury, including death, is always a possibility that every diver must accept when diving. The diver alone is responsible for their own safety. The author of this document disclaims all liability, including for any injuries, deaths, or property damage that may result from the use of information provided in this document. This document has been reviewed for errors, but there is no guarantee that errors are not present. In addition, best practices evolve over time, thereby the information in this document may be obsolete. Due to the variations in which knowledge may be applied, the information in this document cannot be held to be universally valid.

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Introduction

Dive planning is an important topic for new divers to master in order to maximize the enjoyment of diving immediately after certification. I have written this document as a supplement to the open water courses I teach. The information provided here has had a remarkable impact on my students' confidence to dive with their classmates after completing their open water courses. I hope that it helps divers, from yet-to-be-certified open water students to instructors who wish to go beyond agency materials for teaching dive planning.

For you, the open water student, this document is primarily targeted towards your in-progress open water course. I have divided it into two sections: essentials for your open water course and post-open water. Because you are already learning so much information in your open water course, I am careful to not overwhelm you with too much information, as according to the theory of interference, exposing you to too much information results in you learning less. And that is simply counterproductive. The essential section is for you to use when you and a dive buddy create a dive plan for your last open water dive. The post-open water section is to be used as a reference after your course and you explore new sites.

I hope this document improves your ability to plan dives so you will go out with confidence and safely enjoy diving new sites within your level of training and experience. Scuba diving is one of the most amazing activities you will ever experience, one that will take you to amazing places all over the world, making lasting friendships with people you otherwise never would have met. Feel free to reach out to me at my email address: *kosta { dot } koeman { at } gmail { dot } com* for <u>any</u> questions or to provide feedback.

For you, the open water scuba instructor, I hope this information helps you help your students to be confident and be able to thoroughly plan dives at new sites within their level of training. While the emphasis in this document is for the Puget Sound region, you can easily provide your students with an addendum for dive sites in your area. Feel free to contact me as well with the email address provided above with feedback or questions. I welcome any and all input.

Future revisions of this document will be released based upon feedback.

Goals of this document

This primary goal of this document is to give students and new divers the tools that they need to be confident to dive with similarly experienced divers, and to not depend on experienced divers or instructors to guide them.

The level of information provided in this document is extensive, and too cumbersome for the experienced diver. **This document is to help students plan their dives in the early stages of their diving.** Think of parts of this document as training wheels for diving. Eventually you will take the wheels off and not look back.

By presenting a plan based on this document to their instructor who provides feedback, new divers will have the ability and confidence to plan and execute more dives in similar conditions as to where they were certified.

For the open water student, I want you to understand and be able to use the following information:

- Basic dive planning in specifying a simple objective, route, maximum time, maximum depth, and gas planning
- Gas consumption rates, how they are measured, and how they are used in dive planning
- How to determine your swim speed
- Estimating the amount of gas reserves you need at any particular depth that is sufficient to handle an out-of-gas emergency at any time
- The training wheels: how much gas you expect to have at anytime in your dive based upon a charted course. You will stop doing this when you are confident that you have enough gas for your dive and simply have to monitor your cylinder pressure against the rock bottom gas values.

These items are fundamental for creating a thorough dive plan and make up the essential dive planning section.

It is unreasonable to absorb all the content in the post-open water section. For the time being, it is best you refer to that section as a guide when planning dives after your course. Eventually, you'll be using that information automatically. But for the purpose of learning, you should be able to be determine the amount of gas you will be have throughout your dive. And this should give you confidence.

For the certified diver and beyond, some of this information is already known to you. I hope that it is organized in a manner that strengthens your ability to develop a thorough and safe dive plan.

Essentials for Your Open Water Course

Overview

Dive planning includes information gathering, choosing an objective for a dive, specifying maximum depth and time, and determining turn pressure. All aspects need to be discussed and agreed upon by all members of the dive team, typically of two or three divers. For four or more divers, it is best to break the group up into dive teams of two or three. Diving in large groups has a risk in which no one is responsible for anyone else, and fatalities have occurred.

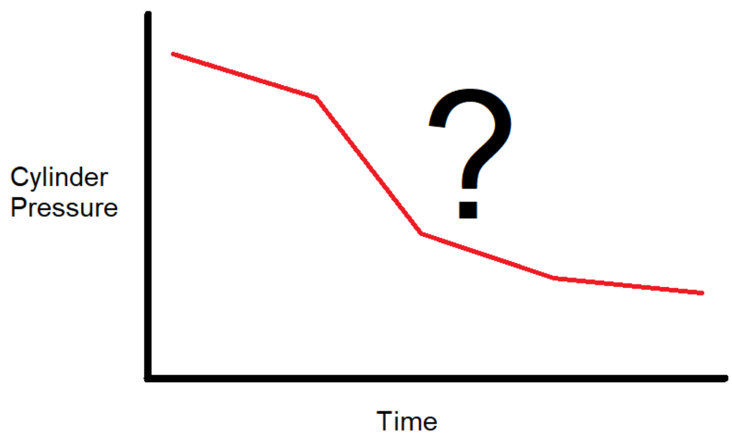
Information gathering focuses on site selection, weather and water conditions, buddy selection, and more. Because this is already done for you in your open water course, information gathering is discussed in the post-open water dive planning section. Information gathering is quite detailed and is difficult to remember everything at first. Fortunately, because this process is performed above water, starting before you reach the dive site, use the post-open water course section as a reference until you have absorbed all the information and have developed a routine.

This essentials section focuses on what you will be using when planning your own dive as part of your open water course.

It is important that everyone involved is comfortable with the dive plan. If at any time you do not feel comfortable with a dive, including during your open water class, it is imperative that you do not dive that plan. Do not succumb to peer pressure or misplace trust in a pushy instructor (they do exist) that wants to shuttle you through the course to give you certification. **Remember, any diver can end any dive for any reason**. If you are not comfortable, speak up, as dive plans can be adjusted to accommodate everyone you and your buddies.

Scuba diving should be fun, including all your courses. Though I will admit, I understand that students often find mask removal and replacement particularly unpleasant in cold water. I still wish to emphasize to the new or yet to be certified diver that you always have the right to call a dive and should be confident to exercise that right at any time. **Do not dive with people who fail to recognize and respect that right.** A good instructor will take your reservation and adjust the dive lesson plan. A bad instructor will not.

The rate at which you consume gas and swim rates[1] are key pieces of information for creating a dive plan, as you need to know approximately how much gas you should have in your cylinder throughout your dive and how long you expect to reach different points. Not only do you need to ensure that you have enough gas in your cylinder to complete your dive, but also enough to be able to handle a catastrophic gas loss for one person in your dive team.



Gas consumption rates are typically described using two different terms: RMV: Respiratory Minute Volume, the volume of gas that passes in and out of the lungs in one minute; and SAC: Surface Air Consumption, the rate in terms of pressure that a person consumes gas at the surface. It is the RMV that is used to calculate the SAC rate for cylinders of different sizes.

In non-emergency situations, you should return to the surface with a minimum of 500 psi / 50 bar in your scuba cylinder. When starting the 3-minute safety stop, you should have at least 700 psi / 60 bar.

In emergency situations where one diver suffers a catastrophic loss of breathable gas, it is still possible to have a 3-minute safety stop at 15 feet / 5 meters with proper planning. It is the intent of this document to provide guidelines on how to safely plan a dive such that if a catastrophic gas loss occurs, the dive team can calmly handle this emergency. The dive team achieves this with a high level of certainty when they planned their dive to have sufficient gas to

[1] Gas consumption rates and swim rates are covered in the SDI Solo Diver and Underwater Navigation courses, respectively. I have included determining both in the open water course I teach as they are fundamental for accurate dive planning.

return to the surface safely if this exceptionally rare event occurs. The amount of gas estimated to be needed[2] to ascend sharing gas with a buddy is called rock bottom gas.

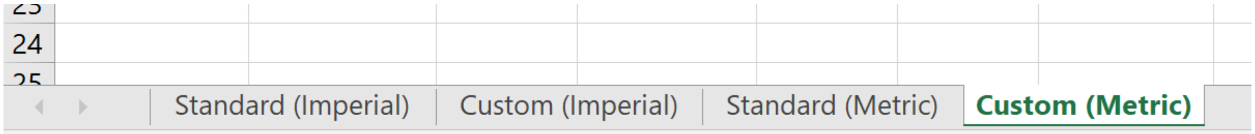
In the appendix, I've described a process for determining your own gas consumption rate. Throughout this document, I use standard gas consumption rates:

- Imperial: 0.75 cubic feet per minute
- Metric: 20 liters per minute[3]

An addendum to this document is the Excel file, *RockBottomGasCalculations.xlsx*, which provides the formulas for determining rock bottom gas values where the parameters can be modified so that you can create new rock bottom gas tables. These parameters are:

- stress factor
- RMV
- cylinder size
- ascent rate
- time it takes for two divers to share gas and begin ascent
- safety stop time (could be zero, if you so decide)

There are four sheets provided. The standard imperial and metric sheets have the turn pressure for standard cylinders. The custom imperial and metric sheets are useful for printing out tables that you can laminate and mount to a wrist slate.



You can also record this information in wetnotes or a wrist slate. I personally recommend the use of wrist slates with the rock bottom gas values on the top slate so that it is always viewable as shown in the imperial and metric examples below.

[2] It is impossible to determine exactly how much gas two divers would need to reach the surface at a safe rate as the impact of increased gas consumption from stress can only be guessed. And that guess may be too low. This is one of the risks of diving.
[3] 0.75 cubic feet is approximately 21.2 Liters

I recommend that you study the calculations performed in that file to understand how different parameters affect gas requirements. You are encouraged to manually perform calculations when completing the knowledge reviews instead of the information provided in the appendix or using the Excel file.

Safety stop: yes or no?

A decision that you must make with your dive buddies is whether you include the gas required for a safety stop in your gas reserves. As stated in the disclaimer, scuba diving is an activity that includes risk. The amount of risk you assume when diving is determined by how you plan for a dive. Many divers have a tendency to take risks in order to maximize the length of time they dive, squeezing every single cubic inch/centimeter that they can out of their cylinders. The motivation for this is understandable, as diving is such an amazing experience. Unfortunately, this can lead to unsafe diving habits, justified by the normalization of deviance (Graham Savill and Steve Lewis wrote a great blog posts on that topic here and here).

You should be making a conscious decision, not a subconscious one, on the amount of risk you wish to assume when diving. It isn't just about you, as your death will impact your family, friends, and especially any dependent children you may have. I don't write this to scare you, but to encourage you to create a dive plan with a level of safety matching the level of risk you wish to assume. Once you are a certified diver, you alone are responsible for your safety when diving outside of training. Not your previous instructor. Not the training agencies. Not any authors (like me) of any dive training material. Not even your dive buddy. Just you. And only you.

Remember that recreational diving is diving within no decompression limits. The decompression limits of various algorithms are based on theoretical models. Safety stops provide an extra safety margin. So, when you decide whether or not to include additional gas reserves for a safety stop, you are trading off extra security against DCS[4] versus extra bottom time. The choice is yours.

Objective

The objective is basically what does the team want to accomplish during a dive. This could be to see a wreck from the outside, take pictures (possibly in a small area), explore a large area, or simply just to have fun and look around at random! Whatever the objective may be, it must be performed within the limits of depth, time, and turn pressure of your dive plan. Ideally, the discussion of what to see would be based on a dive site map. I have included links in the appendix for finding Puget Sound dive site maps online.

Depth

The depth is specifying maximum depth for the dive. Do not exceed the maximum depth for which any of the team members are certified or experienced. The maximum depth is also important for selecting optimal enriched air gasses, a topic addressed in an enriched air specialty course. See the SDI Computer Nitrox Diver course for more information.

[4] One may experience DCS while still diving within the NDL of the algorithm used. There are many factors to DCS which are outside of the scope of this document.

Time

The maximum dive time is determined from different constraints. The most important ones are the time in which you would consume the available gas in your cylinder and your no decompression limit (NDL) for the planned depth. Other time constraints can be caused by your tolerance, or lack thereof, to cold or a personal obligation/appointment after the dive.

For determining your NDL, dive tables are the most conservative, as these are based upon a square profile. Dive computers[5] calculate the NDL continuously based upon an algorithm. Some algorithms are more conservative than others. You should always follow the guidance of the most conservative computer in your team when diving. Ideally, you would have matching algorithms to ensure everyone will have similar NDL times on their dive computers.

Turn pressure

The turn pressure is the aspect that requires an extensive explanation. You want to finish your dive with at least 500 psi / 50 bar in your cylinder. There are three types of gas volume which can be used in calculations, defined as follows:

1. Total gas: the entire gas in one's cylinder(s)

2. Reserve gas: the amount of gas that should be in your cylinder when you reach the surface to provide some safety margin. I recommend using rock bottom gas: the pure minimum gas volume required to ascend slowly from specific depths while sharing air. Sharing air is to address the worst possible scenario where the team starts to turn and a dive buddy has a catastrophic gas loss. Rock bottom gas is sometimes referred to minimum gas and I will be using terms interchangeably.

3. Available gas: the amount of gas that can be used during the dive, which is the total gas minus the reserve gas or rock bottom gas for a specific depth.

The three methods of calculating turn pressure that will be covered in this document are:

1. Rule of halves
2. Rule of thirds
3. Rock bottom gas

There are other methods used that are used for overhead (cavern, cave and wreck) environments that are beyond the scope of this document.

Rule of Halves

This method involves diving the available gas and dividing it in half. Half of the available gas is used on the way out, and the other half on the way in. The problem with this sort of a plan is that it does not take emergencies into consideration. If at the deepest depth (and usually the turn pressure is reached) there is a problem with an air source, the two divers may not have sufficient air to safely ascend. This method is not recommended except for shallow dives of 40 feet / 12 meters or less where the surface is not far for performing an emergency swimming ascent.

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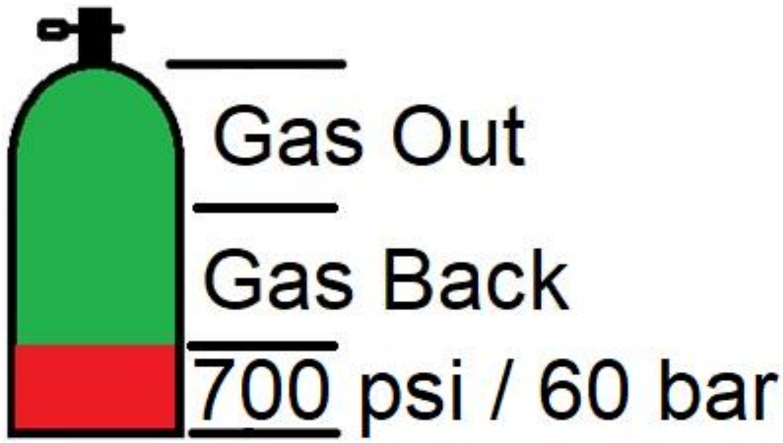
[5] I recommend dive computers that implement the Bühlmann ZHL-16C algorithm as these algorithms are backed by peer-reviewed studies, and resources are available for understanding the algorithm.

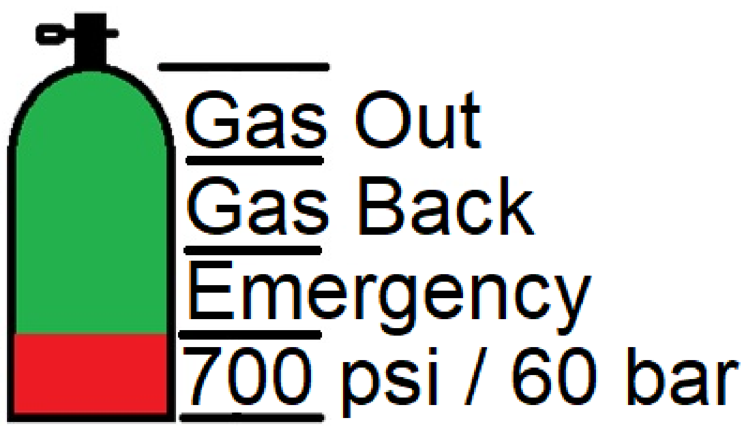


To determine the turn pressure with this method, one subtracts the reserve pressure required for a safety stop (700 psi, 60 bar) from the total pressure. The difference is divided in half and subtracted from the total gas.

Imperial	Assuming a high-pressure tank is filled to 3400 psi, subtracting 700 psi yields 2700 psi. Subtracting half that amount (rounded down to 1300 psi) provides a turn pressure of 2100 psi.
Metric	Assuming a 12-liter tank is filled to 232 bar, subtracting 50 bar yields 180 bar. Subtracting half that amount (90 bar) yields a turn pressure of 140 bar.

Rule of Thirds

This method involves diving the available gas and dividing it by three. One third of the available gas is used on the way out, one third on the way in, and one third is reserved for emergencies. This method is often used in technical diving, such as a dive that has decompression requirements, inside a cave, or a wreck; and also, in recreational cavern diving which limits are often pushed due to divers having insufficient equipment and training for handling emergencies without direct access to the surface. In these cases, going to the surface in the case of a problem is not an option. Problems take time to be resolved, and this requires extra gas.



There are also virtual overhead environments, such as diving in an area where there is boat traffic. While divers must comply with laws with a dive flag, boaters often are unaware of these laws or outright disregard them. From a safety point of view, an open water dive in such an environment is categorized as a virtual overhead environment. Using the rule of thirds is appropriate for determining turn pressure for diving in these conditions.

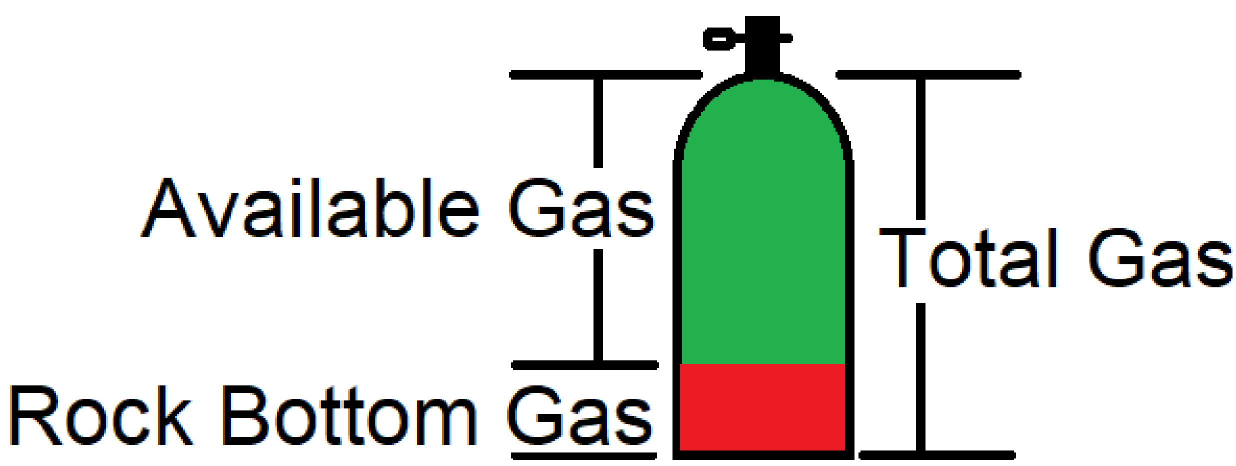
Imperial	If a high-pressure tank was filled to 3400 psi and keeping 700 psi in reserve for the start of the safety stop, one third of the difference is 900 psi. This results in a turn pressure of 2500 psi.
Metric	If a cylinder was filled to 232 bar, and keeping 55 bar for the start of the safety stop, one third of the difference is about 60 bar. This results in a turn pressure of 170 bar.

This method is typically not used in recreational diving, especially at tropical dive destinations, as people want to maximize bottom time and return to the surface with 500 psi / 50 bar. I recommend the next method: rock bottom gas.

Calculating Rock Bottom Gas Requirements

The concept behind rock bottom gas is to ensure that in the case of catastrophic gas loss that a dive team can ascend safety sharing air, from depth. Fortunately, gas loss is not instantaneous, allowing you to get to your buddy to share gas. But depending on the cause of catastrophic gas laws, you may have little time. The article Life Ending Seconds 3000 to ZERO in 72 Seconds gives the results of time measurements of a cylinder emptying from different causes. Remember that if you consumed some gas, you will have even less time.

While modern, properly maintained scuba equipment is extremely reliable, every device has a small probability of failure. This is so small that the probability of two divers having their gear fail during the same dive is treated as zero probability. Using rock bottom gas for determining turn pressure is appropriate for shore dives where there is not a virtual overhead environment caused by boat traffic, or diving directly below/from a boat.



To calculate the rock bottom gas in terms of volume, one uses the following equation for each stage in an emergency ascent:

$$\textbf{Gas Consumed}_{\textbf{stage}} = \textbf{k x C x A x T}$$

The variables in this equation are:

- k: a stress factor
- C: gas **c**onsumption rate at the surface
- A: average pressure expressed in **A**TAs
- T: **t**ime

The formula provided in this document is derived from the minimum gas formulate I learned when I took GUE Fundamentals, a gatekeeper course for GUE's technical training: Gas Consumed = CxAxT. GUE uses a single calculation for the gas required, combining the ascent time with the time for two divers to share air (always one minute). This results in the time to ascend to be 1 minute + depth/ascent speed (10 feet / 3 meters per second). There is no safety stop included.

I have separated the gas calculations for rock bottom gas into the three stages of the ascent:

- Divers establish sharing gas and prepare for ascent
- The ascent to the surface
- An optional, but recommended, safety stop

The stress factor, **k**, compensates for the increased gas consumption rate caused by the stress of a team member being out of gas and/or a slower ascent rate than what is used in the calculations. I would suggest a factor of 3 or greater for new divers. A value of 3 is the starting point, as it may be insufficient for divers who are prone to be nervous. For experienced divers who are calmer (but more likely to have redundant air sources), a smaller stress factor value may be appropriate.

I recommend studying the impact of changing stress parameters in the accompanying excel file, *RockBottomGasCalculations.xlsx*. Including/excluding gas reserves for a safety stop has an enormous impact on the turn pressure, as does different stress factors and obviously RMV values. The studies I have found related to the increase gas consumption rate were performed by the Health and Safety Executive and the St. Thomas's Hospital Medical School in London. The conclusion that I make as a layperson is that under stress, gas consumption can easily increase by a factor of two or greater. Depending on your skill level, you may wish to increase the amount of expected time it would take for you and your buddy to share air from 1 minute to 2 or more minutes.

There is no one size fits all, which is why I chose to release the Excel file, rather than have tables in the appendix with predetermined values.

While I did have tables in the first revision of this document which were a derivative of the GUE equation broken into three stages, I removed them as I wanted the individual diver to make their own conscious decisions. There was some push back by experienced divers for the conservatism. In the first revision, I did not introduce the stress factor, but rather used the GUE emergency ascent speed of 10 feet / 3 meters per minute that compensates for that. Ascending at that rate takes effort, and in reality, as long as neither diver sharing gas is panicking, the ascent rate should be around 30 feet / 9 meters per minute.

I consistently received feedback to use the industry standard ascent rate of 30 feet / 9 meters per minute, and therefore introduced the stress factor in the second revision for calculating rock bottom gas requirements.

I maintain my recommendation to inexperienced divers, who are not going very deep, to still use more conservative values, and include a safety stop for a reserve. Knowing you have plenty of gas in the unlikely case of an emergency should put you at ease, and thus reduce your stress and gas consumption needs.

Fortunately, for you, the newly certified diver, you will not (I hope you will not at least) be diving immediately below 60 feet / 18 meters, so you need not be concerned for the gas requirements at deeper depths. Once you have the training and experience to dive deeper, then you will likely be using different stress and RMV values as well.

Calculating Average Surface Air Consumption Rate

Imperial	The standard average RMV rate used for a single diver is 0.75 cubic feet of gas per minute. Therefore, the value **C** used in the examples in this document for two divers is 1.5 cubic feet per minute. This value is higher than most, but not all, divers' actual RMV rate. In the exceptions, the stress factor **k** should be doubled or more.
Metric	The standard average RMV rate used for a single diver is 20 liters of gas per minute. Therefore, the value **C** used in the examples in this document for two divers is 40 liters per minute. This value is higher than most, but not all, divers' actual RMV rate. In the exceptions, the stress factor **k** should be doubled or more.

Calculating Average Pressure

The actual rate in which gas is consumed is proportional to the pressure at depth. For gas consumption purposes, we don't measure depth in feet or meters, but in absolute atmospheric pressure (ATA). The ATA at depth in saltwater is calculated as Depth/33 + 1 (Imperial) and Depth/10 + 1 (metric). The average ATA for when traveling between two points is:

$$\frac{D1 + D2}{2 \times 33} + 1$$

Equation 1. Average Pressure Between Two Points (Imperial)

$$\frac{D1 + D2}{2 \times 10} + 1$$

Equation 2. Average Pressure Between Two Points (Metric)

For example, when diving in saltwater at 33 feet or 10 meters, the pressure is 2 ATA. The air consumption rate for two divers sharing air at that depth would double to 3 cubic feet / 40 liters per minute.

If the starting or endpoint is the surface, one of the values will be zero and the equation can be simplified to:

$$\frac{D}{2 \times 33} + 1$$

Equation 3. Average Pressure on Ascent/Descent To/From the Surface (Imperial)

$$\frac{D}{2 \times 10} + 1$$

Equation 4. Average Pressure on Ascent/Descent To/From the Surface (Metric)

Imperial	If calculating the rock bottom gas requirements for a descent to 60 feet (the pressure at 60 feet is 2.8 ATA), the average pressure would be 60/(2x33) + 1 = 1.9 ATA.
Metric	If calculating the rock bottom gas requirements for a descent to 18 meters (the pressure at 18 meters is 2.8 ATA), the average pressure would be 18/(2x10) + 1 = 1.9 ATA.

Calculating Ascent Time

The ascent rate of 30 feet / 9 meters per minute is the dive industry standard, deemed safe by research conducted by the Navy. If divers are expected to have difficulty meeting this ascent rate, it must be factored into increased the stress factor **k** or lowering the ascent rate in the calculations.

Putting It All Together

Now that determining the combined surface air consumption rate, average pressure in atmospheres, and time to ascend has been discussed, an example of the rock bottom gas requirements for an ascent from 60 feet is calculated. Note that the gas required results are in cubic feet and always rounded up. I will use the conservative stress factor value of 3. The gas requirement in terms of cubic feet for when divers share air and prepare to ascend from 60 feet / 18 meters is as follows:

Imperial

Stress Factor		Gas consumed per minute per ATA (cu ft / min)		Average ATA		Time in minutes		Gas Required (cubic feet)
3	x	1.5	x	2.8	x	1	=	13

Metric

Stress Factor		Gas consumed per minute per ATA (L / min)		Average ATA		Time in minutes		Gas Required (liters)
3	x	40	x	2.8	x	1	=	340

The gas requirement in terms of cubic feet for the ascent is as follows:

Imperial

Stress Factor		Gas consumed per minute per ATA (cu ft / min)		Average ATA		Time in minutes		Gas Required (cubic feet)
3	x	1.5	x	1.9	x	2	=	18

Metric

Stress Factor		Gas consumed per minute per ATA (L / min)		Average ATA		Time in minutes		Gas Required (liters)
3	x	40	x	1.9	x	2	=	460

The gas requirement for an optional safety stop is calculated as follows:

Imperial

Stress Factor		Gas consumed per minute per ATA (cu ft / min)		Average ATA		Time in minutes		Gas Required (cubic feet)
3	x	1.5	x	1.5	x	3	=	20

Metric

Stress Factor		Gas consumed per minute per ATA (L / min)		Average ATA		Time in minutes		Gas Required (liters)
3	x	40	x	1.5	x	3	=	540

The rock bottom gas requirements when including a safety stop for any depth is the summation of these three values. In this example, at a depth of 60 feet / 18 meters, the total gas requirement is:

Total Gas Requirements

Imperial	51	cubic feet
Metric	1340	liters

The rock bottom pressure for imperial cylinders is determined by the following equation:

$$\text{Rock bottom pressure} = \text{Cylinder maximum pressure} \times \frac{\text{Gas Requirement}}{\text{Cylinder Volume}}$$

When calculating the rock bottom pressure for metric cylinders, the cylinder “maximum” pressure is set to 1 since metric cylinders dimension is based on the volume of the cylinder, not the amount of gas that will be in the cylinder at the rated pressure. The rock bottom pressure simplifies to the gas requirement in liters divided by the cylinder volume.

Using an aluminum 80 (77.4 cubic feet of air when filled to 3000 psi) / 11L (a commonly used tank in many warm water dive destinations) as an example, this tank has. Using ratios, the rock bottom pressure would be (rounded up to the next highest 100 psi / 10 bar value):

Imperial						
3000 psi	x	51 cubic feet	/	77.4 cubic feet	=	2000 psi
Metric						
1 bar	x	1340 liters	/	11 liters	=	140 bar

The rock bottom gas method for depth method has the advantage in that once a team of divers ascends to a new depth, every member will have gas greater than the minimum gas value for that new depth, and thus there is more time to dive. However, one must ensure that the no decompression limit is not exceeded.

The benefits of this method are shown with the following example and using the accompanying Excel file for rock bottom gas/turn pressure values for various depths and cylinder sizes.

Two divers with AL80/11L cylinders dive to a depth of 60 feet / 18 meters. Once one of them hits the turn pressure of 1100 psi / 70 bar, they ascend to a depth of 40 feet / 12 meters where now the turn pressure is 1000 psi / 60 bar. Both divers initially have at least just under 1100 psi/ 70 bar in their scuba cylinders when they reach 40 feet / 12 meters, so they can continue to dive at that depth until one of their SPG values drops to 1000 psi / 60 bar. The using the accompanying Excel file, one can see how in a deep dive, one can have a multi-level dive within a dive, ascending once the rock bottom gas value is reached or reaching no decompression limits, whichever comes first. Divers using these tables should also use a dive computer to track in real time their theoretical nitrogen absorption.

Let’s use the example in the above paragraph. In the first part of dive, the divers spent 30 minutes at 60 feet / 18 meters. According to the Navy dive tables (provided in the appendix), the divers would be at pressure group F.

GROUP DESIGNATION

*Highest repetitive group that can be achieved at this depth regardless of bottom time.

Depth (feet)	No-Deco Limits (min)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Z
10	Unlimited	57	101	158	245	426	*										
15	Unlimited	36	60	88	121	163	2[illegible]7	297	449	*							
20	Unlimited	26	43	61	82	106	1[illegible]3	165	205	256	330	461	*				
25	595	20	33	47	62	78	[illegible]7	117	140	166	198	236	285	354	469	595	
30	371	17	27	38	50	62	[illegible]6	91	107	125	145	167	193	223	260	307	371
35	232	14	23	32	42	52	[illegible]3	74	87	100	115	131	148	168	190	215	232
40	163	12	20	27	36	44	[illegible]3	63	73	84	95	108	121	135	151	163	
45	125	11	17	24	31	39	[illegible]6	55	63	72	82	92	102	114	125		
50	92	9	15	21	28	34	[illegible]1	48	56	63	71	80	89	92			
55	74	8	14	19	25	31	[illegible]7	43	50	56	63	71	74				
60	60	7	12	17	22	28	33	39	45	51	57	60					
70	48	6	10	14	19	23	28	32	37	42	47	48					
80	39	5	9	12	16	20	24	28	32	36	39						

A 0:10 2:20*
B 0:10 1:17 1:16 3:36*
C 0:10 0:56 2:12

Using Bühlmann tables, divers spending 30 minutes at 18 meters would put the divers in pressure group D.

Buhlmann Sea Level (0-700M) No Decompression Dive Tables

Depth: Metres	Nitrogen Group Designation							
	A	B	C	D	E	F	G	H
9	25	37	55	81	105	130		
12	19	25	37	57	82	125		
15	16	20	29	41	59	75		
18	14	17	25	33	44	51		
21	12	15	22	28	35			

Using the Navy tables, after spending 30 minutes at 60 feet and ascending to 40 feet, the divers will have 55 minutes of residual nitrogen.

Repetitive Dive Depth (feet)	Repetitive Group at the End of the Surface Interval															
	Z	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
10	**	**	**	**	**	**	**	**	**	**	**	427	246	159	101	58
15	**	**	**	**	**	**	**	**	450	298	218	164	122	89	61	37
20	**	**	**	**	**	462	331	257	206	166	134	106	83	62	44	27
25	†	†	470	354	286	237	198	167	141	118	98	79	63	48	34	21
30	372	308	261	224	194	168	146	126	108	92	77	63	51	39	28	18
35	245	216	191	169	149	132	116	101	88	75	64	53	43	33	24	15
40	188	169	152	136	122	109	97	85	74	64	55	45	37	29	21	13
45	154	140	127	115	104	93	83	73	64	56	48	40	32	25	18	12

Subtracting 55 from the maximum time allowed at 40 feet,163 minutes, the maximum time the divers can spend at 40 feet is 108 minutes, a safe margin from exceeding the NDL.

Using the Bühlmann tables, after spending 30 minutes at 18 meters and ascending to 12 meters, divers will have 57 minutes of residual nitrogen.

Buhlmann Repetitive Letter Group Table								
"0"	Fly	Surface Interval Time (H:mm)						
Hours	Hours							
2	2	A						
2	2	0:20	B					
3	3	0:25	0:10	C				
3	3	0:30	0:15	0:10	D			
4	3	0:45	0:25	0:15	0:10	E		
8	4	1:20	1:15	0:45	0:30	0:20	F	
12	5	2:10	1:40	1:15	1:00	0:45	0:25	G
24	7	5:40	4:00	3:00	2:10	1:35	1:05	0:50

Depth: Metres	A	B	C	D	E	F	G
			NEW GROUP DESIGNATION				
9	25	37	55	81	105	130	154
12	19	25	37	57	82	111	137
15	16	20	29	41	59	88	115

Subtracting 57 from the maximum time allowed at 12 meters,125 minutes, the maximum time the divers can spend at 12 meters is 68 minutes, a safe margin from exceeding the NDL

Determining RMV Rate

To determine your RMV, you need to swim at a sufficient (and constant) depth for a sufficient time period in order to have a sufficient change in pressure that is needed to calculate a reasonably accurate gas consumption rate.

Depths around 50 feet / 15 meters and times of at least 10 minutes are adequate. Longer dive times are helpful for determining one's RMV rate more accurately, but one is limited to the gas in one's cylinder and no decompression limits. The change in pressure from the beginning to the end of the timed swim is recorded. This is converted to volume by dividing the change in pressure by the rated pressure of the tank and then multiplied by the volume of that tank.

Imperial	A diver swims for 10 minutes at 50 feet and the difference in tank pressure from the beginning to the end of the swim is 500 psi. The diver is using an aluminum 80 tank. The volume of air consumed is 500 psi / 3000 psi * 80 cubic feet = 13.3 cubic feet. The pressure at 50 feet in atmospheres is 50/33 + 1 = 2.5. The RMV is calculated as 13.3 cubic feet / (10 minutes * 2.5 atmospheres) = 0.53 cubic feet per minute.
Metric	A diver swims for 10 minutes at 15 meters and the difference in tank pressure of a 12L cylinder from the beginning to the end of the swim is 30 bar. The RMV is calculated at 12L * 30 / (10 minutes * 2.5 atmospheres) = 15 liters per minute.

Using a wrist mounted dive computer makes monitoring the time and depth more convenient and is recommended. A slate (preferably one on the wrist) or wetnotes are needed for recording the starting and ending pressures when doing the constant depth timed swim.

When dive planning, you may want to increase your RMV by multiplying it by some factor **k** to account for current and other stress factors. What is the value of **k**? The answer is that it depends and you need to determine that value over time for different dive conditions. When I teach, due to the psychological stress of monitoring my students for safety, my gas consumption rate is higher than when I dive for pleasure, even though I am typically moving less than when on a fun dive.

Determining Your Swim Rate

When taking the SDI Underwater Navigation course, one of the tasks you will complete is determining your swim speed. This is important to know for dive planning. When planning for a dive where you decide to create a detailed dive, choose the value for the slowest diver. Also, as shown in that example, use an even slower swim speed for points of interest. After all, you want to spend the time to enjoy those areas, and you want to plan accordingly to have realistic gas amounts throughout your dive.

To determine your swim speed, you need to swim a measured distance twice (once in each direction) to account for any current. A distance of 100 feet / 30 meters is sufficient. You may not need measuring tape. A spool or reel with 100 feet / 30 meters or so (you need to know the exact amount of line you will be using) is a reasonable means to gauge distance.

You will set up this line that is tight between two points at the same depth in order to accurately determine your swim speed. You will need to use a timer on your dive computer and a slate or wetnotes to record the time it takes you to swim the measured distance in both directions. The average time is what you will use to determine your swim speed.

If you are planning to taking pictures or video in the future, you will want to repeat this exercise at that time, as cameras can introduce a significant amount of drag that will slow you down.

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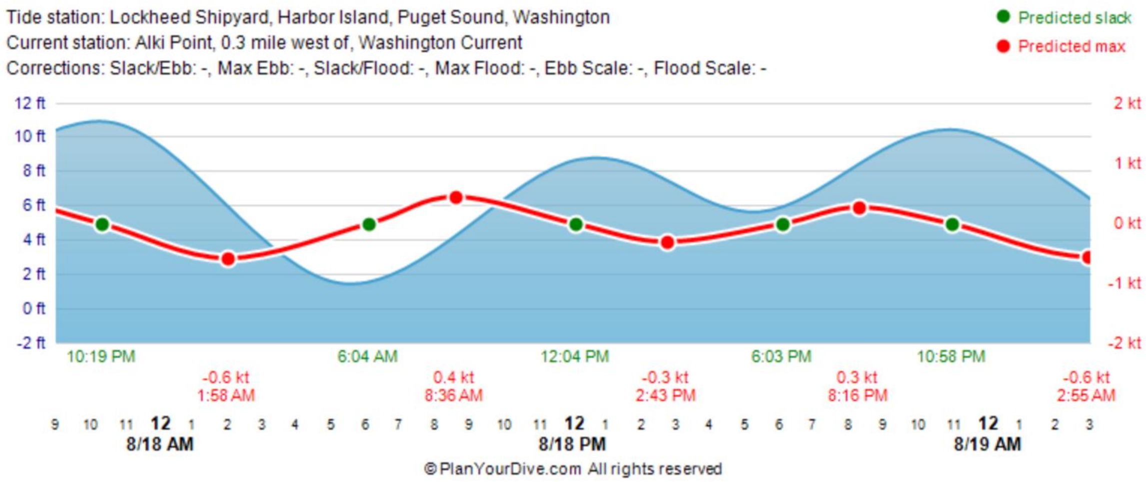
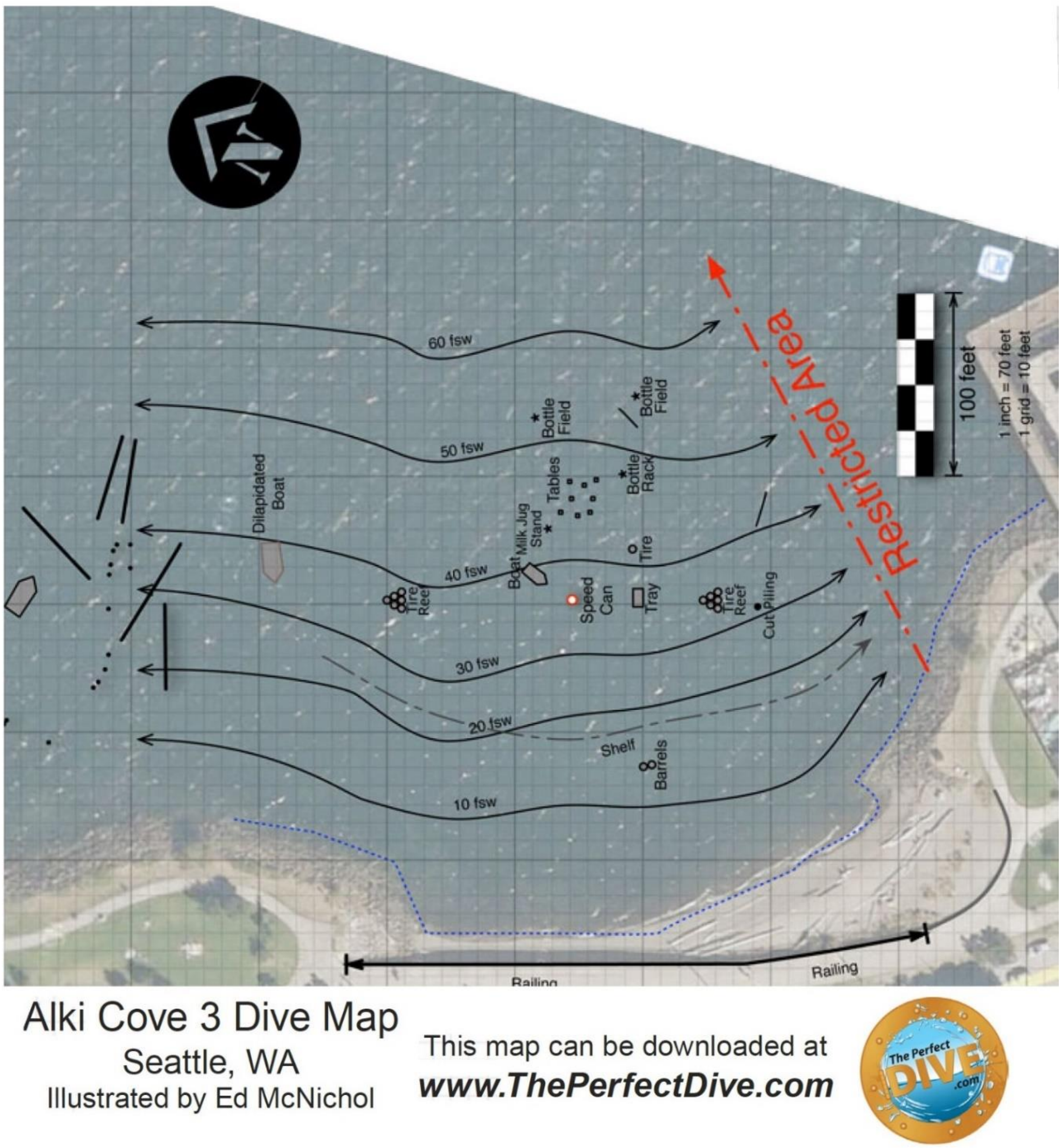
Example dive plans

Example dive site: Cove 3

Let's say you are planning a dive at Cove 3 on August 18, 2018. You want to swim out to the bottle field at 55 fsw / 17 msw and work your way to the dilapidated boat about 150 feet /45 meters away at 40 fsw / 12 msw.

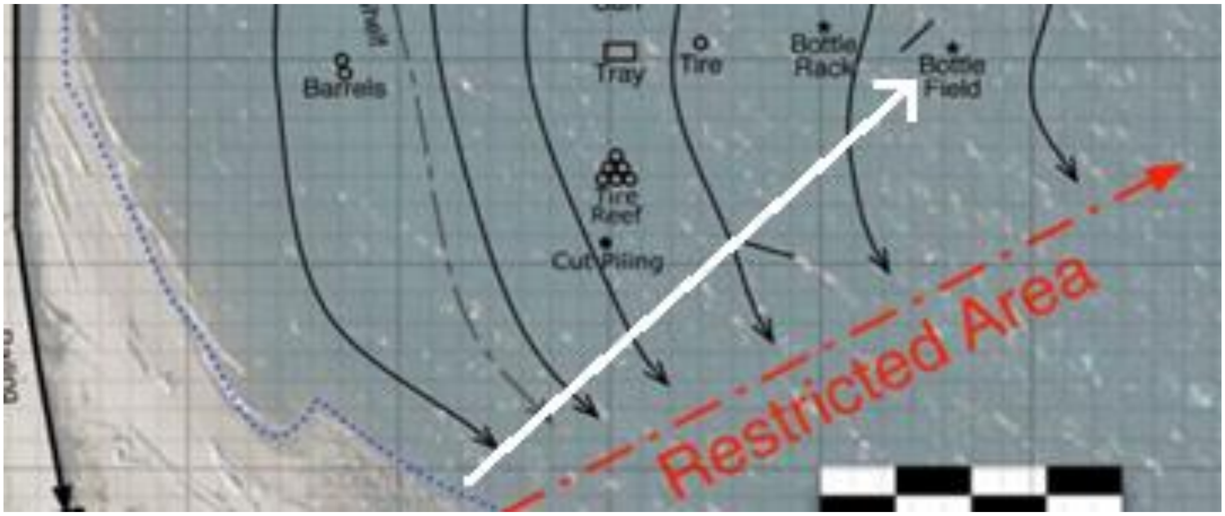


For the sake of planning, you will use a swim speed of 25 feet / 8 meters per minute, an RMV of 0.75 cubic feet / 20 L per minute. You plan on finishing each dive with a minimum of 500 psi / 50 bar in your cylinders. You will be using HP100 / 12L steel cylinders (100 cubic feet of gas at the rated pressure of 3442 psi / 2784 L when filled to the rated pressure of 232 bar). Because the current will be parallel to shore, you will not need to take current into account as you will not be swimming with or against it all that much. If you were, you'd definitely want to adjust your swim speed appropriately, especially if it significant. If the current is significant, you will want to adjust your RMV, more so when swimming into the current. When swimming against the current, you may want to double or even triple your RMV to account to the additional physical exertion.



Map 1. Cove 3, West Seattle

You first will swim about 200 feet / 60 meters in 60 degrees east of north from the southern end of shore to reach 55 fsw / 17 msw.



The average pressure in this part of the dive is calculated as 55 / (2 x 33) +1 = 1.8 ATA or 17 / (2 x 20) + 1 = 1.8 ATA. The time is calculated by dividing the distance by speed = 200 feet / 25 feet per minute = 8 minutes or 60 meters / 3 meters per minute = 8 minutes. We will use the RMV of 0.75 cubic feet and 20 L per minute for imperial and metric calculations. The gas expected to be consumed in this portion of the dive is calculated to be:

Imperial

Gas consumed per minute per ATA (cu ft / min)		Average ATA		Time in minutes		Gas Required (cubic feet)
0.75	x	1.8	x	8	=	11

Metric

Gas consumed per minute per ATA (L / min)		Average ATA		Time in minutes		Gas Required (liters)
20	x	1.8	x	8	=	290

To calculate the change in pressure, you will divide the expected volume of gas to be consumed by the rated volume of the tank multiplied by the rated pressure. The change is pressure is expected to be:

Imperial

Gas requirement (cubic feet)		Cylinder volume at rated pressure		Rated cylinder pressure		Change in pressure (psi)
11	/	100	x	3442	=	300

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Metric

Gas requirement (Liters)		Cylinder volume		Rated cylinder pressure		Change in pressure (bar)
300	/	12	x	1	=	30

At this point (8 minutes into the dive), your SPG should read 3100 psi / 200 bar. Using the supplementary Excel file, *RockBottomGasCalculations.xlsx*, we see that the rock bottom pressure including a safety stop for 60 fsw / 18 msw is 1800 psi / 140 bar, which we are well above by 1300 psi / 60 bar. Note: as you create your dive plan, always compare the expected gas to the rock bottom gas value for that particular depth to ensure that you are diving safely.

Next you will swim in a direction of 45 degrees west of north (315 degrees on your compass) and then follow the bottom at that depth to reach the tables (I like to call this area "Barroom Brawl"), exploring the items at that depth as you work your way over to dilapidated boat, a straight distance of approximately 150 feet / 45 meters, but we will use 200 feet / 60 meters to account for the exploration.

Because you are exploring, we will cut the speed in half to 12.5 cubic feet / 4 meters per minute. The expected gas consumption for this portion, you use the average depth of 48 fsw / 15 msw which has a pressure of 48 / 33 + 1 = 2.5 ATA or 15 / 10 + 1 = 2.5 ATA. The gas consumption rate is the constant 0.75 cubic feet / 20 L per minute. The time is now calculated with the slower speed = 200 feet / 12.5 feet per minute = 16 minutes or 60 meters / 4 meters per minute = 15 minutes (note the difference is due to rounding errors). The expected gas consumption for this portion of the dive is calculated as:

Imperial

Gas consumed per minute per ATA (cu ft / min)		Average ATA		Time in minutes		Gas Required (cubic feet)
0.75	x	2.5	x	16	=	30

Metric

Gas consumed per minute per ATA (L / min)		Average ATA		Time in minutes		Gas Required (liters)
20	x	2.5	x	15	=	750

The change in cylinder pressure for this amount of gas consumed is:

Imperial

Gas requirement (cubic feet)		Cylinder volume at rated pressure		Rated cylinder pressure		Change in pressure (psi)
30	/	100	x	3442	=	1100

Metric

Gas requirement (Liters)		Cylinder volume		Rated cylinder pressure		Change in pressure (bar)
750	/	12	x	1	=	70

24 minutes into the dive, your SPG should now read 2000 psi / 140 BAR. At this point we calculate that the turn pressure at 40 fsw / 12 msw is 1500 psi / 110 bar, 500 psi / 30 bar below your current pressure.

Finally, you will return straight to shore (240 degrees), about 275 feet / 84 meters away.

You will again be swimming at a rate of 25 feet / 8 meters per minute. The average pressure in ATA is 40 / (2 x 33) + 1 = 1.6 ATA or 12 / (2 x 20) +1 = 1.6 ATA. Consumption rate is 0.75 cubic feet / 20 L per minute. Time is calculated with distance divided by speed = 275 feet / 25 feet per minute = 11 minutes or 84 meters / 8 meters per minute = 11 minutes. The expected gas consumption is:

Imperial

Gas consumed per minute per ATA (cu ft / min)		Average ATA		Time in minutes		Gas Required (cubic feet)
0.75	x	1.6	x	11	=	14

Metric

Gas consumed per minute per ATA (L / min)		Average ATA		Time in minutes		Gas Required (liters)
20	x	1.6	x	11	=	360

The change in pressure is:

Imperial

Gas requirement (cubic feet)		Cylinder volume at rated pressure		Rated cylinder pressure		Change in pressure (psi)
14	/	100	x	3442	=	500

Metric

Gas requirement (Liters)		Cylinder volume		Rated cylinder pressure		Change in pressure (bar)
360	/	12	x	1	=	30

When you reach shore, your SPG will read 1500 psi / 110 bar. But wait, you need to account for the gas consumed during your safety stop at 15 feet. The pressure at 15 feet was previously calculated at 1.5. The gas consumption expected for the safety stop is:

Imperial

Gas consumed per minute per ATA (cu ft / min)		Average ATA		Time in minutes		Gas Required (cubic feet)
0.75	x	1.5	x	3	=	4

Metric

Gas consumed per minute per ATA (L / min)		Average ATA		Time in minutes		Gas Required (liters)
20	x	1.5	x	3	=	90

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The change in pressure is:

Imperial

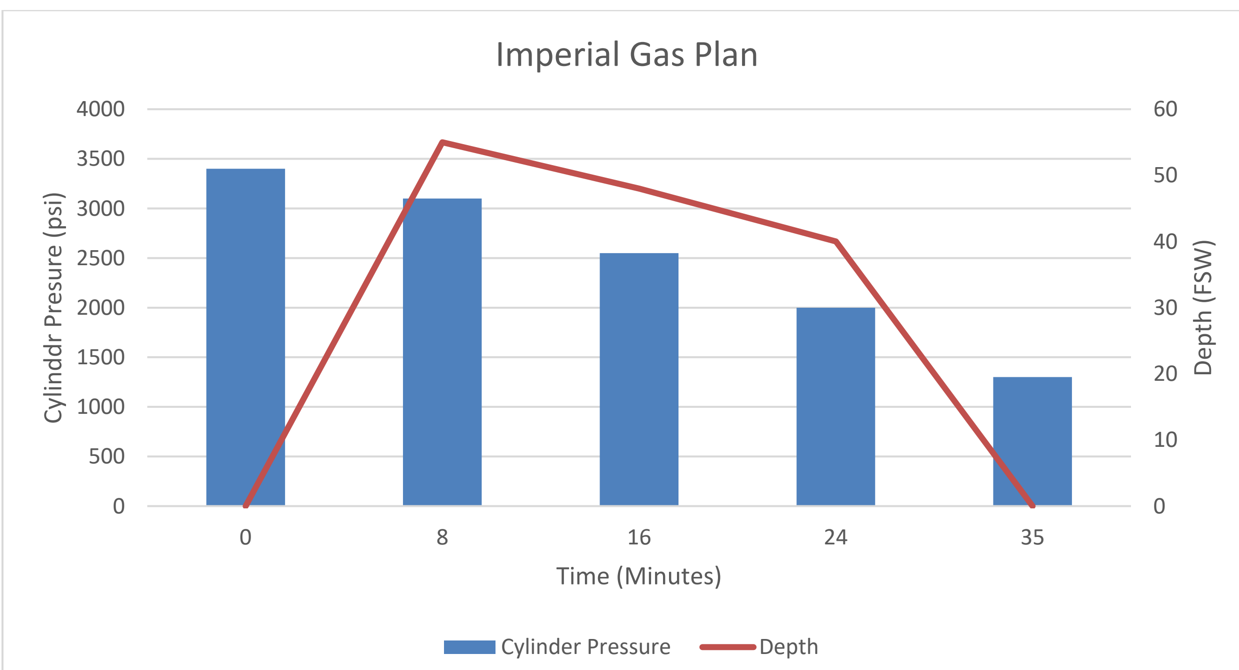
Gas requirement (cubic feet)		Cylinder volume at rated pressure		Rated cylinder pressure		Change in pressure (psi)
4	/	100	x	3442	=	200

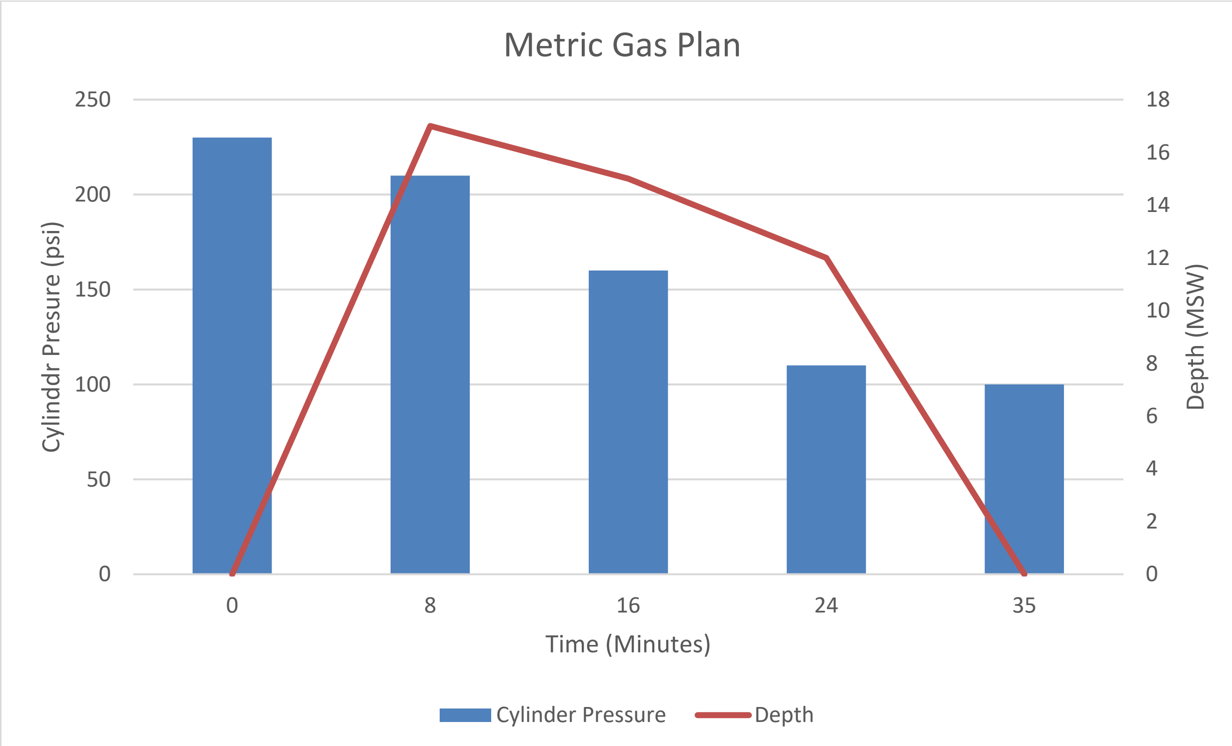
Metric

Gas requirement (Liters)		Cylinder volume		Rated cylinder pressure		Change in pressure (bar)
90	/	12	x	1	=	10

Factoring in the safety stop, you should be returning to the surface with 1300 psi / 100 bar, well above the minimum cylinder pressure that you should always return to the surface (500 psi / 50 bar). This is why I like rock bottom gas calculations. As long as you stay within your NDL, you can maximize dive time while ensuring that you have a save amount of gas in your cylinder at all times during your dive.

The dive can be described with the following graphs which provides a visual representation of as time versus tank pressure and depth. While it is perfectly acceptable to reach a specific depth earlier than planned but reaching the planned time pressure prior to the expected time requires a change in the depth.





Seeing that you would return to the surface with more gas than the minimum required, you can adjust your plan for a longer dive. For your first dives, I would recommend keeping such a dive plan. As you become more comfortable in the water, figure out a new path that will require slightly more gas. Iterate over several dives until you are planning dives where you gradually return to the surface much closer to the 500 psi / 50 bar minimum. I would recommend doing this at the same dive site. Remember to always stay above the rock bottom gas at depth and above with the NDL.

When creating a detailed dive plan, it is recommended to record on a slate or wetnotes the depth and expected cylinder pressure at different points in time. Include the direction taken at each segment, such as in the following tables:

Imperial

Direction	Ending segment time	Starting Depth	Ending Depth	Starting Pressure	Ending Pressure
060 degrees	8 minutes	Surface	55	3400	3100
315 degrees	24 minutes	55	40	3100	2000
240 degrees	32 (+3) minutes	40	Surface	2000	1300

Metric

Direction (degrees)	Ending segment time (minutes)	Starting Depth (meters)	Ending Depth (meters)	Starting Pressure (bar)	Ending Pressure (bar)
060	8	Surface	55	230	210
315	24	55	40	210	140
240	32 (+3)	40	Surface	140	100

Your total dive time will be 35 minutes (extra 3 minutes for the safety stop).

While it is unrealistic for you to calculate the amount of gas for each dive when mapping out a route for a recreational dive (you always do this for technical diving) as it is admittedly a tedious exercise, However, I strongly recommend that you work through this exercise during the last dive of your open water course where you and your dive buddy plan and execute a dive. It will help you develop a sense of how much gas you consume for different portions of a dive based on depth and time. I strongly recommend to all divers to train beyond the way they will dive, as that introduces a safety margin in terms of skill and knowledge.

Working with RockBottomGasCalculations.xlsx

When determining rock bottom gas values for various depths using the accompanying Excel file, you need to decide what values to enter to create tables that you will use during your dive according to the level of risk you wish to assume.

While this document uses the standard 0.75 cubic feet / 20 Liters of gas per minute, you and your dive buddy's RMV. Remember when determining the RMV, it isn't just yours that must be considered, but also that of your dive buddy. Using the standard values with a reasonable value is a good starting point with a reasonable stress factor.

Spend some time with the accompanying Excel spreadsheet and have an agreement with the level of risk you wish to assume, and like always, agree to accept the more conservative level of risk between you and your dive buddy.

Post-Open Water Dive Information Gathering

As mentioned earlier, the information in this section is largely addressed by your open water instructor. However, this section should be studied and used as a reference post certification to help guide you confidently plan dives. The contents of this section should be well understood by certified divers. When planning to dive, there are a number of questions that need to be answered when formulating a dive plan.

- The most basic question: where do you want to go diving? Which dive site?
- Is there a map available of the dive site or a detailed description? Great references for dive site information in the Puget Sound include http://theperfectdive.com/ and http://www.boydski.com/diving/pugetsound.htm.

- What are the items of interest to see? How do you plan to navigate underwater? Are there any hazards to avoid? Example: a fishing pier, boat traffic, cement with exposed rebar. How will you avoid/mitigate those hazards? If you have a laminated map that you can take with you, do so as no one has a perfect memory.

- What are the recent conditions at that site? You can check social media sites to inquire about recent conditions like on Facebook or Meetup.com, ScubaBoard.com, or nwdiveclub.com. Dive clubs, like the Pacific Northwest Dive Club (here and here) and Marker Buoy Dive Club, are also excellent sources of information. You also can contact local dive shops to get advice. Dive shops are also an excellent resource for finding dive buddies during shop dives. Here is a partial list of local dive shops' websites in the Puget Sound area:
    - 8diving.com
    - Hoodsportndive.com
    - LighthouseDiving.com
    - Octopusgardensdiving.com
    - Silent-World.com
    - TacomaScuba.com
    - TLSea.com
    - UnderwaterSports.com

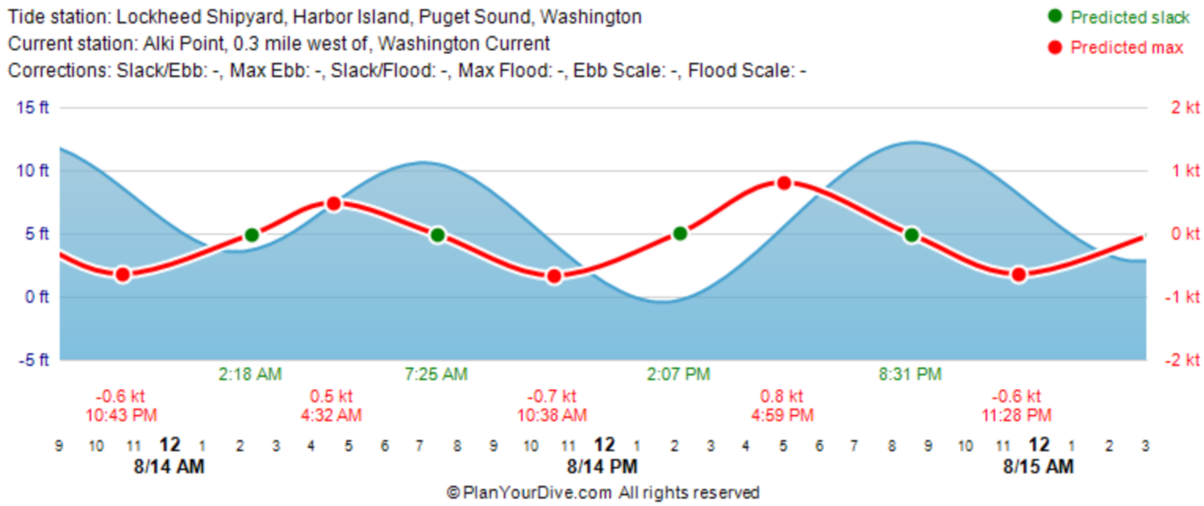
- What is the predicted tide and current information? Dive planning for current sensitive sites (high peak currents) is beyond the scope of this document as it is an advanced topic and not appropriate for open water students.

  There are some amazing dive sites in the Puget Sound: Day Island Wall, Deception Pass, Skyline Wall, Sunrise Beach, Keystone Jetty and others; that require additional knowledge determine when conditions are safest to dive. This knowledge includes understanding correction factors for nearby current reference stations and substations for flood and ebb slacks. If the term flood and ebb slack doesn't mean anything to you, that is okay, as you do not need to know for the dive sites that are appropriate for you.

  To learn more about planning (these terms and more) for such dive sites in the future, I encourage reading Stephen Fischnaller's book, *Northwest Shore Dives*. A link for buying the third edition is provided in the appendix. I highly recommend this book as the author intended for it to be used for advanced dive planning.

  I would also recommend joining shop dives or dive club dives to these sites for the first time as well. If you do this, talk to the organizer about how they determined the suitability for diving that day and time at that site.

  For low current dive sites, an excellent and popular website is http://www.planyourdive.com. In the future, when planning dives that are more advanced due to potential current and thus require more precise planning, a better source is https://tidesandcurrents.noaa.gov/noaacurrents/Stations?g=698.



- What is the weather report for that day? What is the predicted wind? Is the dive site protected or exposed to the wind when coming in from the predicted direction?

- Do you have all the equipment required? Examples: DSMB with a reel or spool for boat diving, a dive flag when shore diving, and backup lights that are fully charged for a night dive (primary dive lights are basically a requirement for diving during the day in the Puget Sound).

- Is your equipment serviced and functioning? You should check your gear prior to reaching the dive site so you can address any unexpected equipment issues. Be sure to check that your batteries are charged. In addition to the suggestion in Steve Lewis's blog post that I mentioned earlier, Graham Savill wrote a blog post about regulator pre-dive checks that is excellent. That post can be found here. A suggested checklist is provided in the appendix

- Is your save-a-dive kit fully stocked? A suggested save-a-dive kit is provided in the appendix

- With whom will you go diving? What are their skill levels? Are their skill levels sufficient for the dive site with the expected weather, temperature, and current conditions? Are they interested in the dive site?

- Do all members of your dive team have a dive insurance policy, such as from the Divers Alert Network (DAN)?

- Do you have an emergency plan for the site? Does everyone have a means of calling EMS? Does everyone have DAN's number (+1-919-684-9111) programmed into their phones (preferably on speed dial)? Do you have an address to provide to EMS were you to have an emergency? Who in your dive team has emergency oxygen and who is certified to provide it?

- What are the legal requirements to the location where you are planning? The state of Washington, requires that dive flags are always used when diving from shore. Municipalities often have their own regulations. The city of Kirkland in KMC 14.20.020 requires the use of a dive flag when more than 100 feet from shore in Lake Washington. This is relevant when diving the Valiant, a World War II plane at a depth of 120 ffw. The city of Seattle Harbor Patrol and King County have their own regulations which are quite similar.

Once you reach the dive site, you will need to evaluate and discuss additional items

- Your personal physical, mental, and emotional condition. Are you up for diving? If any of those items is not good, it is best not to dive. The ocean will always be there. Be wary of dive buddies who pressure you to dive. These are not safe dive buddies and it is best to not dive with them in the future. A dive buddy can thumb a dive at any time for any reason, even before the dive. This is something that must **always** be respected. No exceptions.

- Visibility. Just because you have experience diving the same site as you had in your open water class, if the visibility is worse, it may not be worth diving. You may introduce additional risk by diving when visibility is poor. Remember that you want to be able to see things, especially your dive buddy, while you dive. If the visibility is too poor, say less than 6 feet / 2 meters, do not dive. It is hard to see your buddy in such conditions (hard to see anything!). I would recommend diving with visibility of 10 feet / 3 meters or better if possible. Remember to stay close to your buddy when diving.

- Weather and water conditions. As weather and wind prediction are not 100% accurate, you still need to evaluate if the conditions are safe for diving. Will they be safe at the end of your dive when you exit the water?

- Emergency oxygen. Does anyone in your group have any and do all certified oxygen providers have access to it?

- Goal check. Are all members of your dive team in agreement on the dive objective?

- Entry/exit plan. Are you trained and experienced to deal with surge or waves if they exist? (a good reason to call the dive)

- Discuss lost buddy procedures: search for a minute and if you are not reunited with your dive team, ascend and meet up at the surface

- Equipment setup and self-check after assembly

- Hand signals review. This is especially important when diving with people for the first time.

- Buddy check. Use what is most comfortable for you. I personally recommend the top-to-bottom, right-to-left approach described in the appendix.

Once in the water, breath three times from each regulator and perform a bubble check where you look for bubbles leaking from the first and second stages and any hoses on your buddy. Your buddy will face down and face up for you to examine all the equipment. Also, you should breath three breaths from all second stages to ensure they are functioning properly.

Check the visibility as you get into the water. As I mentioned earlier, if the visibility is too poor, end the dive. The stress and risk taken when diving in poor visibility just is not worth it. Come back another day when conditions are better and enjoy your dive.

Advanced Dive Planning and Beyond

As you advance as a diver, there are some topics I would like to advocate learning. Besides the obvious improvement in skills through a rigorous course, I recommend learning about how to determine the safest time to dive in areas that have high currents. As you grow in skills and knowledge, you can dive when the current is higher, but you want to do this gradually. I have enjoyed diving the Tacoma Narrows when the currents were wickedly fast, fast enough to pull your mask off. It was much better than any roller coaster that I have had the pleasure of riding.

As I recommended earlier, please find Stephen Fischnaller's book, *Northwest Shore Dives* so that you may learn how to plan appropriate for diving Deception Pass, Keystone Jetty, and many other amazing dive sites throughout the Puget Sound.

In the appendix, I have listed a number of useful blogs by internationally known and respected diving instructors.

Finally, I recommend to all divers, from the newly certified open water, to the seasoned technical or cave diver, to learn more about human factors in diving. Gareth lock provides unique training in this topic that improve your ability to process information and make better decisions, not just in diving, but in many aspects of your life.

Review questions

Q1. Planning Aspects

Which of the following statements represent the four primary aspects of dive planning as outlined in this course? Select four answers.

A. Objective

B. Current

C. Weather

D. Depth

E. Time

F. Turn Pressure

Q2. Rock Bottom Gas.

What does rock bottom gas requirement mean? What parameters are used to calculate rock bottom gas requirements?

____

____

____

Q3. RMV Rate of Two Divers Sharing Air

Which of the describes the most commonly used RMV rate when two divers are sharing air? Select one answer.

A. 0.75 cubic feet / 20 liters per minute.

B. 1.0 cubic feet / 30 liters per minute.

C. 1.5 cubic feet / 40 per minute.

D. 2.0 cubic feet / 60 per minute.

Q4. Ascent Rate

What conservative ascent rate is recommended for calculating rock bottom gas requirements?

__________________________ feet / meters per minute (circle one unit)

Q5. Safety Stop Gas Requirement

How much air is required for a 3-minute safety stop at 15 feet / 5 meters for two divers?

___________________________ cubic feet / liters (circle one unit)

Q6. Rule of Thirds

Describe the rule of thirds. When should this method be used for determining turn pressure?

____

____

____

____

____

Q7. Depth versus Pressure Table

Fill in the either the Imperial or metric table for pressure in ATA at specified depths.

Depth (feet)	Pressure in ATA
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	

Depth (meters)	Pressure in ATA
10	
15	
20	
25	
30	
35	
40	

Q8. Average Pressure When Ascending from Depth Table

Fill in the Imperial or metric table for average pressure in ATA when ascending from the specified depths.

Starting depth in feet for ascent	Average Pressure in ATA
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	

Depth (meters)	Average Pressure in ATA
10	
15	
20	
25	
30	
35	
40	

Q9. Total Ascent Time in an Emergency Where Air is Shared

Fill in the time required to ascend from the depths in the Imperial or metric table. Do not include the time to donate a regulator and share air or the safety stop time. Assume 10 feet per minute for Imperial, 3 meters per minute for metric. Round up to the nearest minute.

Starting depth for ascent (feet)	Time (in minutes) needed to ascend
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	

Starting depth for ascent (meters)	Time (in minutes) needed to ascend
10	
15	
20	
25	
30	
35	
40	

Note on maximum depth with a cylinder:

There is a rule of thumb that for Imperial units, one does not descend deeper in feet than the capacity of the tank. So, for an HP100, you would descend to a maximum depth of 100 feet. For a, HP117, you would descend no farther than 120 feet.

For metric units, you would descend no more than a hundredth of the capacity of the cylinder (in liters) in terms of meters. For a 12L steel cylinder that is filled to 232 bar, the volume of gas at that pressure would be 2780 bar. You would then descend no farther than 30 meters on this cylinder.

For this reason, you will only perform calculations for up to the safe depth for the respective cylinder sizes.

Q10. Gas Requirements at Depth to Share Air at Depth for One Minute

Fill in either the Imperial or metric table with the air volume required for two divers sharing air for one minute at depth. Assume an RMV of 0.75 cubic feet / 20 liters per minute per person.

Depth (feet)	Gas Requirements for Sharing Air
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	

Depth (meters)	Gas Requirements for Sharing Air
10	
15	
20	
25	
30	
35	
40	

Q11. Rock Bottom Gas Requirements for Ascending from Depth

Fill in the table for the rock bottom gas requirements for the depths.

Hint: the sum of the gas required for the safety stop (Q5), the gas used during the ascent (use the equation CAT: C is answered in Q3; A is provided in Q8; and T answered in Q9), and the gas required to establish sharing air at depth (Q10).

Depth (feet)	Rock bottom gas required (cu ft)
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	

Depth (meters)	Rock bottom gas required (liters)
10	
15	
20	
25	
30	
35	
40	

Q12. Turn Pressure for AL80

Fill in turn pressure for the depths listed in the table for an AL80 / 11 L aluminum scuba cylinder.

Note for imperial units: this cylinder has 77.4 cubic feet of air when filled to a pressure of 3000 psi.

Depth (feet)	Turn Pressure (PSI)
30	
40	
50	
60	
70	
80	
Depth (meters)	Turn Pressure (bar)
10	
15	
20	
25	

Q13. Turn Pressure for LP85

Fill in turn pressure for the depths listen in the table for an LP85 scuba cylinder.

Note: this cylinder has 85 cubic feet of air when filled to a pressure of 2640 psi.

If performing metric calculations, skip this question.

Depth (feet)	Turn Pressure (PSI)
30	
40	
50	
60	
70	
80	
90	

Q14. Turn Pressure for HP100, 12 L steel

Fill in turn pressure for the depths listen in either the Imperial or metric table for an HP100 /12 L steel scuba cylinder. Note for imperial calculations: this cylinder has 100 cubic feet of air when filled to a pressure of 3442 psi.

Depth (meters)	Turn Pressure (PSI)
30	
40	
50	
60	
70	
80	
90	
100	

Depth (meters)	Turn Pressure (bar)
10	
15	
20	
25	
30	

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Q15. Create a dive plan for Redondo Beach

Hint: follow the example for Cove 3. Plan a route based upon items of interest. As shown in the example, break up the dive into pieces, just like the Cove 3 example. The only right answer is one in which you always are above the rock bottom gas requirements and that you return to the surface with 500 psi / 50 bar. The point is to just work through the details of the example dive plan:

References

Dive Sites in Puget Sound

The Perfect Dive

Plan Your Dive

Emerald Sea Photography

Northwest Shore Dives, 3rd Edition by Stephen Fischnaller

Tide and Current Background Information

Tides and Water Levels (NOAA)

Plan Your Dive

Dive Charters

Bandito Charters

Lu Jacs Quest

Northwest Dive Charters

Ocean Quest

See Ya Diving

NakNek Charters

More Articles on Rock Bottom Gas and Gas Planning

Gas Management and Planning by Graham Savill

ROCK BOTTOM FOR RECREATIONAL DIVES by Brian Weiderspan

Understanding Gas Management by Bob Bailey

Basic Air Supply Management by Peter Rothschild

Useful Blogs

SDI Blog

Graham Savill's Blog

Andy Davis's collection of articles

Steve Lewis's blog

Appendix

Addressing fear

As an open water diver, you should be able to confidently plan dives that have similar conditions to the ones conducted in your open water dives during certification.

Laura Walton wrote an excellent blog post on fear and diving. When addressing this topic, it is important to address the source of the fear. Are you simply nervous about being underwater and having enough gas? Are you nervous due to a lack of confidence in your skills? Are you nervous about your equipment, such as due to a leaking mask?

If you are nervous about not having enough gas, I highly recommend going through the dive planning prescribed in this document. Remember that stress will cause an elevated gas consumption rate, so factor that into your plan to provide yourself a little bit of buffer. This means that use a larger value of k, the stress factor, in your minimum gas calculations, and also increase the RMV value that you use to calculate the amount of gas you expect to have throughout your dive. You should always have the exact amount of gas or more as you go through your dive, and this should give you confidence that your dive is going according to plan. If you find you have less, adjust your dive plan to your maximum depth. Signal your buddy for the change. As part of your hand signal review, agree upon this signal. I would suggest using the combination of "max depth", "switch", and then the new depth. Your buddy will respond with "okay" if once understood. See the following images for these hand signals. When planning your next dive, increase the RMV value you use a little bit more. As you get comfortable diving, your RMV will come down, as it has for hundreds of thousands of divers before you.

Signal for Max Depth

Signal for Switch

If you are nervous about your ability to perform skills that you learned in your open water course, my recommendation is to go back to practice those fundamental skills you while neutrally buoyant and trim. If you have difficulty in controlling your depth, you could be overweighted. Remember that the correct amount of weight is enough to keep you at your safety stop depth with an empty BCD and dry suit with a nearly empty cylinder (500 psi / 50 bar). If you empty your BCD and dry suit with a nearly empty tank at your safety stop and you sink, remove some weight and try again. If you start to ascend while breathing normally, you removed too much weight. Make sure that your weight is distributed such that you can maintain the horizontal position in the water column without sculling your hands or fins.

If you are nervous about an equipment problem, be sure to have your equipment checked out for proper operation. Ill-fitting masks are a common source of stress for new divers. While it is difficult to describe, when determining the fit of a mask, tilt your head back, put the mask on your face and without inhaling through your nose, have another person look for gaps in the mask against your face, particularly by your mouth. A properly fitting mask is the first piece of scuba gear you need to own.

If you find yourself nervous about a dive site, my recommendation is the same as for not having enough gas: go through the gas planning prescribed in this document. Over time, you will develop a sense of how much air you have based upon the time and depth of your dive.

If you still have fears for going out and diving with a buddy after following these recommendations, reach out to me. It doesn't matter whether you are on the other side of the world and will never be a student or customer of mine. The purpose of this document is to provide you the knowledge to be a confident, autonomous open water diver. My goal is to contribute to the confidence, knowledge, and skill set of as many divers as possible. So, do not hesitate to send me a message to the email address I provided at the beginning of this document.

Buddy Checks

There are a number of different acronyms used in open water courses to help students check that all equipment is in proper working order and to familiarize themselves with their buddy's gear. The problem I have found that in accelerated courses, these acronyms and the mnemonics used to remember them are often ineffective, as students forget the letters, the word corresponding to the letter, and/or all the items that are to be checked for each word.

Instead, I advocate students to use a modified equipment check that I learned when I took GUE Fundamentals. It is a thorough check, as you run your hands across your body and your equipment from the top-down and right-to-left.

This does not match the GUE equipment check, as GUE has a very specific equipment configuration. I will describe how I apply the top-down, right-to-left checks for the configuration that my open water students use: dry suit, backplate and wing BCD, and a long hose. I will also describe the checks for a jacket style BCD with integrated weights. One buddy will lead and go through each item, and the other will say "check" for matching equipment. If there is any difference in equipment, that gets covered after each sequence.

> On my head I have a hood (*check*), mask (*check*). My cylinder is in the proper position [I tilt my head back to ensure my head doesn't hit the first stage] (*check*). [To my dive buddy] Check that my valve is fully open and that my cylinder is secured (*check*) [you say check after checking your buddy's]. I breath from my primary regulator (on the long hose) 3 times (*check*) and my backup

regulator (on a short hose and bungeed around my neck) 3 times (*check*) [Note, you will repeat this in the water or you can conduct this in the water]

On my right arm, I have a glove (*check*), a compass (*check*), dive computer turned on and set to air [*or whatever gas you are using, it preferably should match with your buddy for having similar/the same NDL time but this is not a requirement*] (*check*). On my right shoulder D-ring, I have my long hose is clipped off and a dive light (*check*). Around my neck is my bungeed backup regulator and I can breathe off it three times (*check*). My dry suit inflates [press dry suit inflator] (*check*). My exhaust valve is fully open (*check*) and my dry suit deflates (*check*). My LPI inflates my wing [press LPI inflate button] (*check*) and deflates [press deflate button] (*check*). I can orally inflate my wing [orally inflate the wing] (*check*) and deflates using the butt dump [deflate using butt dump] (*check*) and the butt dump is secure [ensure butt dump valve is tight] (*check*). On my left shoulder D-ring is empty. On my left arm, I have a wrist slate (check), and a glove (*check*).

Starting from the right side on my harness belt, my buckle is firmly closed and secured under the crotch strap (*check*). Underneath is my weight belt firmly secured (*check*). On my left side of my harness belt, I have a cutting tool (*check*) and my SPG is clipped off on a D-ring and reads ### bar/psi [unclip to read] of air [or whatever gas mix you are using). (*check, my pressure is ### bar/psi with air/EAN##*) in a ### cubic foot / Liter cylinder.

In my right pocket, I have a whistle (check) and a collapsible snorkel (check), and in my left pocket a DSMB connected to a spool (check). {[only if you are in the water] On my feet I have fins (*check*)}. My long hose can be deployed [untuck the hose and hold it over your head with your left hand holding the hose next to the second stage and your right hand halfway to the end, then re-tuck it back into your belt] (*check*).

Initially, you will want to do this on land until you are proficient or anytime you are diving from a boat. Once proficient and for shore dives, you can do this standing in the water. After completing your equipment check on land or standing in the water, always conduct a bubble check in the water where you take turns lying face down and face up in the water while the other looks for bubbles revealing locations of leaks. When diving from shore or a boat where you do not have to conduct a negative entry[6], breath 3 times from each reg with your face in the water.

This is quite a long description isn't it? Much longer than a little acronym. However, an acronym is a simplification of checking the same list of equipment, but is not as systematic and more prone to error as you are not running your hands over all of your equipment in a methodical manner. But don't focus on its length. Focus on its thoroughness, as you are covering all your equipment in a systematic method. Repeating this process a few times will develop muscle memory. Visualize going through this process. You don't have to be in a long hose or backplate and wing to do this. You can be in a jacket style BCD. You follow the exact same routing: start with your head, from the right arm go across the top of your chest and top of your back, continue to your left arm. Move down a bit to your waist, continuing from your right side, across the middle, to your left side. If you are in a jacket style BCD with integrated weights, you

[6] A negative entry is where you enter the water negatively buoyant, so that you descend immediately. This is done when diving in a strong current and you are diving at a specific location, such as a reef or a wreck.

would check that the weights are secured and show your buddy how to ditch them in an emergency.

Checklists

It is useful to keep a check list of all equipment that you must pack for a dive trip, so that nothing is missed at the dive site and that everything is functioning.

In this section, different checklists should be used in order to resolve any issues as early as possible. It is always better to resolve any issues at home before you reach the dive site,

Equipment list

- Cylinder(s)
- Regulator assembly
- Dive computer
- Dive lights
- Mask
- Fins
- Snorkel
- Backplate & wing (or BCD)
- Weight belt
- Hood
- Dry suit
- Undergarment
- Whistle
- DSMB and spool
- Cutting devices
- Gloves

Equipment checks (before reaching the dive site)

The items that you should check prior to leaving for the dive site should include, but are not limited to:

- Regulator operation (using an IP gauge is not for average divers, but rather ones who services their own regulators)
- Check all parts of the entire kit: especially hoses, but also mouthpieces, webbing, buckles; etc.; for signs of corrosion, wear, or damage. Replace those parts. Hoses have a finite life
- Immerse regulator assembly and scuba cylinder in water to check for leaks.
- Pressurize regulator assembly. Close valve. Check that the pressure does not drop after 10 minutes.
- Breath your regulators until empty. Check that the SPG reads zero. Despite being a simple, mechanical device, SPGs do fail and can get stuck, making a diver think that more gas is in the cylinder than what actually is available to breath.
- Check that all batteries have sufficient charge (lights and dive computers). For example, Big Blue lights when turned on will indicate red for low charge, green for medium charge, and blue for mostly charged. If you use Big Blue lights, make sure the charge indicator is blue. Even during the day, dive lights are a requirement in the Puget Sound. Most dive computers will have a battery charge indicator.

Dive Site

Once you reach the dive site and assemble your kit, be sure to include the following steps:

- Ensure that your cylinder(s) are fully open, not turned back at all
- Breath from each regulator
- Close your cylinders. Check that pressure doesn't drop. Then breath your regulators until empty. Check that the SPG reads zero.
- Ensure that the low-pressure inflator hose and dump valves are tightly closed

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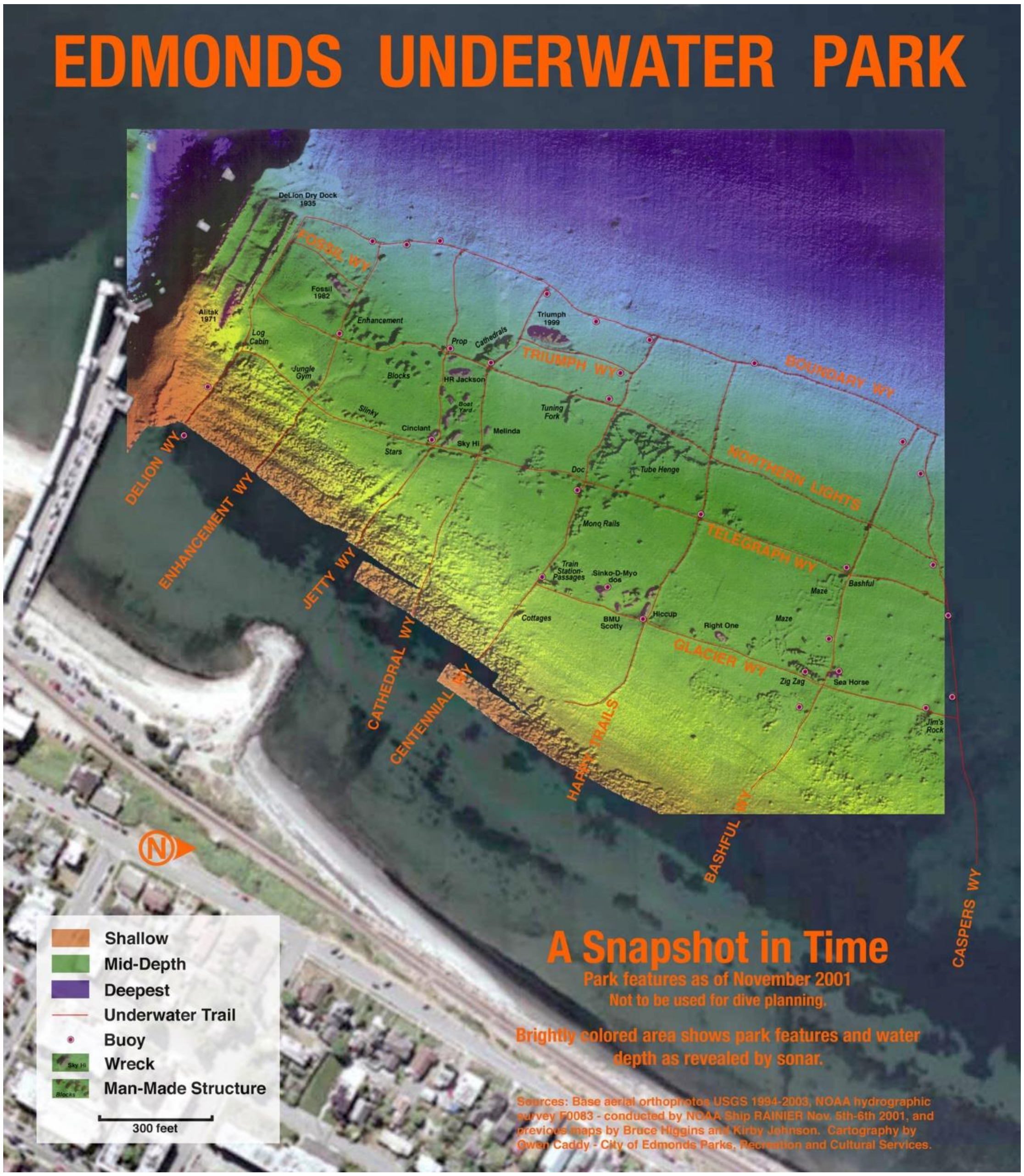
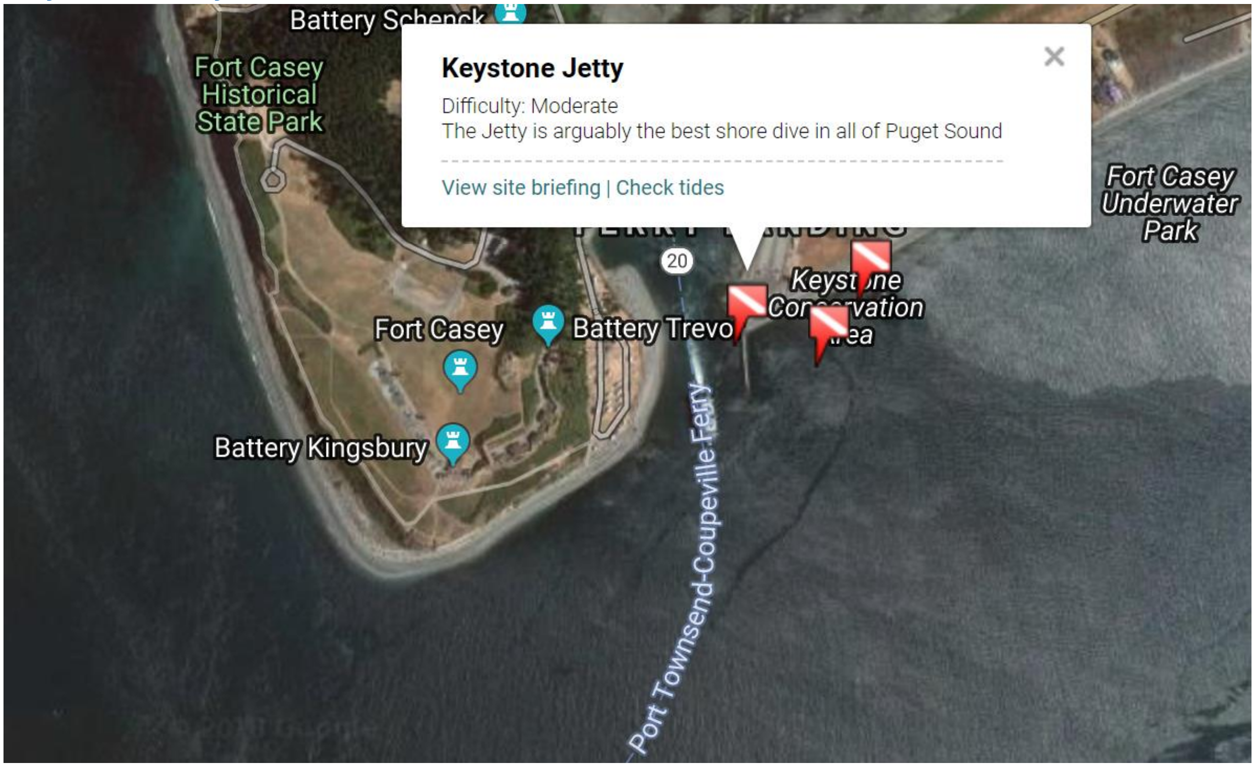
A couple of my favorite shore dive sites

Edmonds Underwater Park

Edmonds Underwater Park is the first marine park in the United States. Below I obtained a map from the official city of Edmonds website, however it is not to be used for dive planning. The correct map to be used for dive planning is obtained for $10 (cash only) at the Underwater Sports - Edmonds dive shop, just south of the park. This small purchase contributes to park maintenance and improvements, an effort driven by Bruce Higgins. For those interested in assisting, all you have to do is to meet Bruce at 9 am at the Edmonds Underwater Sports all Saturdays and Sundays. Do not call. Do not email. Just show up. Bruce is a wealth of knowledge for new and experienced divers alike.



Keystone Jetty



I am not providing an underwater map here, but some information that I feel is important for open water students to have for planning at more difficult dive sites like Keystone Jetty, my favorite shore dive in the Seattle area. On a Facebook dive page, I read from Eric Askilsrud the following advice for diving here:

"*If you want to make the drive up there more worth it with multiple dives with less current, go on days when the flood is ~1.5 knots or less at Admiralty. Splash an hour before low tide slack (it's best if the low tide isn't super low). Most importantly, check the wind forecast before you go... you don't want southerly winds.*

"Number one piece of advice you can give advice to ANY diver there is keep their reg in mouth on entrance/exit. The rocks are super slippery and often loose. Rogue waves come by. And if the wind picks up, it can get very bad. I've seen many people get turtled out there, and it's hard to get up. If you do get turtled best to have regs in mouth and then crawl backward to get in deeper water to stand back up."

Often it is best to join an experienced diver or a dive club when diving sites like Keystone Jetty. If you go to this site on a weekend and no one is there, you should take that as an indicator that the current conditions are not good for diving. You must be extra careful at Keystone Jetty as the last thing you want is for the current to drag you into the ferry lane. Always dive with a DSMB at this site for that particular contingency.

Dive Tables

Navy Dive Tables

GROUP DESIGNATION

* Highest repetitive group that can be achieved at this depth regardless of bottom time.

Depth (feet)	No-Deco Limits (min)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Z
10	Unlimited	57	101	158	245	426	*										
15	Unlimited	36	60	88	121	163	217	297	449	*							
20	Unlimited	26	43	61	82	106	133	165	205	256	330	461	*				
25	595	20	33	47	62	78	97	117	140	166	198	236	285	354	469	595	
30	371	17	27	38	50	62	76	91	107	125	145	167	193	223	260	307	371
35	232	14	23	32	42	52	63	74	87	100	115	131	148	168	190	215	232
40	163	12	20	27	36	44	53	63	73	84	95	108	121	135	151	163	
45	125	11	17	24	31	39	46	55	63	72	82	92	102	114	125		
50	92	9	15	21	28	34	41	48	56	63	71	80	89	92			
55	74	8	14	19	25	31	37	43	50	56	63	71	74				
60	60	7	12	17	22	28	33	39	45	51	57	60					
70	48	6	10	14	19	23	28	32	37	42	47	48					
80	39	5	9	12	16	20	24	28	32	36	39						
90	30	4	7	11	14	17	21	24	28	30							
100	25	4	6	9	12	15	18	21	25								
110	20	3	6	8	11	14	16	19	20								
120	15	3	5	7	10	12	15										
130	10	2	4	6	9	10											
140	10	2	4	6	8	10											
150	5	2	3	5	-												
160	5		3	5	-												
170	5			4	5												
180	5			4	5												
190	5			3	5												

WARNING:

Even strict compliance with these charts will not guarantee avoidance of decompression sickness. Conservative usage is strongly recommended.

Locate the diver's repetitive group designation from his previous dive along the diagonal line above the table. Read horizontally to the interval in which the diver's surface interval lies.

Next, read vertically downward to the new repetitive group designation. Continue downward in this same column to the row that represents the depth of the repetitive dive. The time given at the intersection is residual nitrogen time, in minutes, to be applied to the repetitive dive.

Surface intervals

Group	Z	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
A																0:10–2:20*
B															0:10–1:16	1:17–3:36*
C														0:10–0:55	0:56–2:11	2:12–4:31*
D													0:10–0:52	0:53–1:47	1:48–3:03	3:04–5:23*
E												0:10–0:52	0:53–1:44	1:45–2:39	2:40–3:55	3:56–6:15*
F											0:10–0:52	0:53–1:44	1:45–2:37	2:38–3:31	3:32–4:48	4:49–7:08*
G										0:10–0:52	0:53–1:44	1:45–2:37	2:38–3:29	3:30–4:23	4:24–5:40	5:41–8:00*
H									0:10–0:52	0:53–1:44	1:45–2:37	2:38–3:29	3:30–4:21	4:22–5:16	5:17–6:32	6:33–8:52*
I								0:10–0:52	0:53–1:44	1:45–2:37	2:38–3:29	3:30–4:21	4:22–5:13	5:14–6:08	6:09–7:24	7:25–9:44*
J							0:10–0:52	0:53–1:44	1:45–2:37	2:38–3:29	3:30–4:21	4:22–5:13	5:14–6:06	6:07–7:00	7:01–8:16	8:17–10:36*
K						0:10–0:52	0:53–1:44	1:45–2:37	2:38–3:29	3:30–4:21	4:22–5:13	5:14–6:06	6:07–6:58	6:59–7:52	7:53–9:09	9:10–11:29*
L					0:10–0:52	0:53–1:44	1:45–2:37	2:38–3:29	3:30–4:21	4:22–5:13	5:14–6:06	6:07–6:58	6:59–7:50	7:51–8:44	8:45–10:01	10:02–12:21*
M				0:10–0:52	0:53–1:44	1:45–2:37	2:28–3:29	3:30–4:21	4:22–5:13	5:14–6:06	6:07–6:58	6:59–7:50	7:51–8:42	8:43–9:37	9:38–10:53	10:54–13:13*
N			0:10–0:52	0:53–1:44	1:45–2:37	2:38–3:29	3:30–4:21	4:22–5:13	5:14–6:06	6:07–6:58	6:59–7:50	7:51–8:42	8:43–9:34	9:35–10:29	10:30–11:45	11:46–14:05*
O		0:10–0:52	0:53–1:44	1:45–2:37	2:38–3:29	3:30–4:21	4:22–5:13	5:14–6:06	6:07–6:58	6:59–7:50	7:51–8:42	8:43–9:34	9:35–10:27	10:28–11:21	11:22–12:37	12:38–14:58*
Z	0:10–0:52	0:53–1:44	1:45–2:37	2:38–3:29	3:30–4:21	4:22–5:13	5:14–6:06	6:07–6:58	6:59–7:50	7:51–8:42	8:43–9:34	9:35–10:27	10:28–11:19	11:20–12:13	12:14–13:30	13:31–15:50*

*** Dives following surface intervals longer than this are not repetitive dives. Use actual bottom times in the Air Decompression Tables to compute decompression for such dives.**

Repetitive Group at the End of the Surface Interval

Repetitive Dive Depth (feet)	Z	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
10	**	**	**	**	**	**	**	**	**	**	**	427	246	159	101	58
15	**	**	**	**	**	**	**	**	450	298	218	164	122	89	61	37
20	**	**	**	**	**	462	331	257	206	166	134	106	83	62	44	27
25	†	†	470	354	286	237	198	167	141	118	98	79	63	48	34	21
30	372	308	261	224	194	168	146	126	108	92	77	63	51	39	28	18
35	245	216	191	169	149	132	116	101	88	75	64	53	43	33	24	15
40	188	169	152	136	122	109	97	85	74	64	55	45	37	29	21	13
45	154	140	127	115	104	93	83	73	64	56	48	40	32	25	18	12
50	131	120	109	99	90	81	73	65	57	49	42	35	29	23	17	11
55	114	105	96	88	80	72	65	58	51	44	38	32	26	20	15	10
60	101	93	86	79	72	65	58	52	46	40	35	29	24	19	14	9
70	83	77	71	65	59	54	49	44	39	34	29	25	20	16	12	8
80	70	65	60	55	51	46	42	38	33	29	25	22	18	14	10	7
90	61	57	52	48	44	41	37	33	29	26	22	19	16	12	9	6
100	54	50	47	43	40	36	33	30	26	23	20	17	14	11	8	5
110	48	45	42	39	36	33	30	27	24	21	18	16	13	10	8	5
120	44	41	38	35	32	30	27	24	22	19	17	14	12	9	7	5
130	40	37	35	32	30	27	25	22	20	18	15	13	11	9	6	4
140	37	34	32	30	27	25	23	21	19	16	14	12	10	8	6	4
150	34	32	30	28	26	23	21	19	17	15	13	11	9	8	6	4
160	32	30	28	26	24	22	20	18	16	14	13	11	9	7	5	4
170	30	28	26	24	22	21	19	17	15	14	12	10	8	7	5	3
180	28	26	25	23	21	19	18	16	14	13	11	10	8	6	5	3
190	26	25	23	22	20	18	17	15	14	12	11	9	8	6	5	3

Residual Nitrogen Times (Minutes)

**** Residual Nitrogen Time cannot be determined using this table.**

† Read vertically downward to the 30 fsw repetitive dive depth. Use the corresponding residual nitrogen times to compute the equivalent single dive time. Decompress using the 30 fsw air decompression table.

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Bühlmann Dive Tables

Buhlmann Sea Level (0-700M) No Decompression Dive Tables

Depth: Metres	A	B	C	D	E	F	G	H
	Nitrogen Group Designation							
9	25	37	55	81	105	130		
12	19	25	37	57	82	125		
15	16	20	29	41	59	75		
18	14	17	25	33	44	51		
21	12	15	22	28	35			
24	11	13	20	25				
27	10	12	18	20				
30	9	11	16					
33	8	10	14					
36	7	9	12					
39	7	10						
42	5	7						

Buhlmann Repetitive Letter Group Table

"0" Hours	Fly Hours	Surface Interval Time (H:mm)							
2	2	A							
2	2	0:20	B						
3	3	0:25	0:10	C					
3	3	0:30	0:15	0:10	D				
4	3	0:45	0:25	0:15	0:10	E			
8	4	1:20	1:15	0:45	0:30	0:20	F		
12	5	2:10	1:40	1:15	1:00	0:45	0:25	G	
24	7	5:40	4:00	3:00	2:10	1:35	1:05	0:50	H

Depth: Metres	A	B	C	D	E	F	G
	NEW GROUP DESIGNATION						
9	25	37	55	81	105	130	154
12	19	25	37	57	82	111	137
15	16	20	29	41	59	88	115
18	14	17	25	33	44	68	91
21	12	15	22	28	37	53	72
24	11	13	20	24	30	42	57
27	10	12	18	21	26	35	47
30	9	11	16	19	23	30	40
33	8	10	14	17	21	27	35
36	7	9	12	15	19	24	31
39	7	8	11	14	17	21	27
42	6	7	10	13	16	19	25
45	6	7	9	11	14	17	23
48	6	6	8	10	13	16	21
51	5	5	7	9	12	15	20
54	5	5	7	9	11	14	19

RESIDUAL NITROGEN TIMES (minutes)

WARNING:
Even strict compliance with these charts will not guarantee avoidance of decompression sickness, conservative usage is strongly recommended.

Locate the diver's repetitive group designation from the previous dive along the diagonal line above the middle table.

Next read horizontally back to the surface interval time reached and the new repetitive group designation. Continue downward in this same column to the row which represents the depth of the repetitive dive. The time given at the intersection is the residual time, in minutes, to be applied to the repetitive dive.

* Excluding Repetitive Group H Dives those following a surface interval of more than 12 hours are not repetitive dives. Use actual bottom times to computer decompression times

** All No Decompression Dives require at least a 1 minute stop at 6 m.

Why do divers keep breaking the "rules"?

By Gareth Lock

Authors note: Gareth Lock teaches an excellent seminar in Human Factors in Diving. I have taken this course and I recommend it to all divers, both brand new open water students to seasoned pros and technical divers. It is hard to describe, but I experienced far greater growth in terms of awareness and the ability to analyze situations than anything in my formal and informal education.

After a diving accident, it doesn't take long for the commentators and observers to look for the rules that were broken. "*They didn't monitor their gas.*" "*They weren't sufficiently experienced.*" "*They didn't do X, Y or Z…*" The design of rules, their application and subsequent rule-breaking is a complex topic. Applying a simplistic view to a complex problem won't help improve performance or safety.

Following an accident or near-miss, the speed by which the story is propagated across social media is staggering. Most of the early information transmitted is incomplete or false. Part of this is because it is just not known. It can also be that information which is available is converted using the internet version of the telephone.

"A friend told me…"

"I had a friend who told me this in confidence, don't pass it on. But this is what happened…"

The stories sometimes change beyond all recognition. For those who are involved, it becomes deeply distressing. This is especially true when stories gravitate to 'rule-breaking,' violations and just 'farm-animal stupid.'

Unfortunately, the real and honest truths rarely come out. This can be because society finds it easier to blame someone for breaking a rule (for a number of reasons) rather than looking to see why it made sense to them to do what they did.

If rules are regularly being broken in diving, wouldn't it be a good idea to understand why this is happening? It is if we want to improve diver performance and diving safety? Or is because we want to have the flexibility to manage the risks ourselves and not be constrained by more rules?

This article is the translation of a piece of work examining why anesthetists are likely to commit violations into the domain of diving. It shows there are often rational reasons behind these violations. If we want to really improve diving safety we need to understand what this local rationality is. Then we need to put measures in place to reduce the likelihood of their occurring. What we do not need to do is blame people for being stupid or apply the simplistic, "They should have known better…"

For those reading this who think you make conscious choices in all the decisions you make, including violations, the research from multiple domains shows this to be wrong. Most of your decision making is not actively controlled; It is subconsciously influenced.

Our behavior is a function of our personality and how the environment in which we operate impacts this.

What is a violation?

Professor James Reason's examination of human error created the well-known concept of the Swiss Cheese Model. This concept looks at failures within different levels of an operation or organization that could lead to an accident or incident. In this model, there are three layers of latent failures or conditions (organization, supervisor, and individual) and then a layer of active failures which included violations.

A violation may be defined as *a deliberate act that deviates from established protocols of practice*. However, to improve safety, this simplistic view doesn't help. This is because we need to take into account the *motivation* behind the *deliberate* aspect of this violation taking into account the social and physical environment in which the person was operating.

In other words, was the violation:

Situational: The only way to solve the problem was to break the rules (i.e., rescuing someone below the MOD of their breathing gas).

Routine: It had become the norm for the group to break the rules, making it easier to socially conform than to say no.

For a personal gain: Goal fixation or to gain something (i.e., time or money from the rule-breaking).

For an organizational gain: "You have to 'break these standards' because if you don't, I will find another instructor who will" (i.e., class sizes or the definition of *mastery*.)

To create a safer environment, we need to understand why the rules were broken. This need for greater understanding was the basis behind the paper I will be making reference to. (Phipps et al,(2008). Identifying violation-provoking conditions in a healthcare setting. Ergonomics, 51(11), 1625–1642. doi:10.1080/00140130802331617 (for those who are able to access academic papers).

The Risk/Benefit Argument

As we will see, breaking rules to achieve goals is often about determining how much benefit the actor (diver) will get by breaking/following the rules compared to the benefit/loss by not following them. This is risk management at its core. The majority of the time these decisions are being made on a fight/flight or emotional level and not on a rational, logical one.

The work by Kahneman and Tverskey on Behavioral Economics won them a Nobel prize. It showed that much of our decision-making is not rational nor logical. The challenge for diving safety and learning from experience is that, after an adverse event, we are able to apply logic and rationale using information which was not necessarily available to those involved. This is why it is easy to see that "those breaking the rules were *stupid*!" Critical thinking requires mental effort and humans are efficient (or lazy) depending on your viewpoint.

As part of this risk management process, we use biases and mental shortcuts to speed up the process. One of which is called outcome bias. The premise is that the more severe the outcome, the harsher we judge the (errant) behavior even if the activity itself is almost identical.

New research has also shown that 'near misses' are internally rationalized as success stories and not 'near failures'. Unless we are trained to recognize this fallacy and have a growth mindset (always looking for improvement which we can influence), we will continue to focus on the positive aspect of the outcome (*'we survived'*) and not how close to real failure we were. Consequently, we don't change our behavior. This is the start of the normalization of deviance process.

What did Phipps and his team find out about anesthetists breaking the rules?

The research team interviewed and observed 27 anesthetists during their normal work. They also interviewed the anesthetists using a set of standardized questions and then developed themes which highlighted three key areas and a number of subsections which would need to be addressed if safety and performance were to be improved.

The high-level topics are:

The Rule: This can be summarized as who (person or organization) wrote the rule, how much credibility do they have, and what punishment would occur if the rule was broken and they were caught. And, finally, clarity of the rule.

The Anesthetist: The themes that came from this subsection are the risk perception of the anesthetist, their experience and their expertise and the professional group norm when it comes to violations.

Situational or Organizational factors: Finally, the topics which related to this subsection were the time pressures the anesthetists were under, the amount of resources available, the design of the equipment and whether there were concurrent tasks which needed to be managed.

The Rule

In the context of diving, no published research has been carried out to understand why divers break rules. The majority of published data focuses on outcomes and not failed processes. In immature safety cultures, it is easy to blame individuals rather than look at the system and whether the rules are supporting positive or negative behaviors.

As such, we need to understand:

- What the rules consist of
- Who wrote them
- Their credibility in the context of the diver
- What the disciplinary or social castigation consequences would be if divers break them and they get caught

How clear the rule was to the diver

In the majority of cases, the rules are not really clear because there are so many varied standards across the industry. Defining what is 'right' is often difficult. We only know it was 'wrong' after the adverse event. Then we have the benefit of hindsight bias to join the dots and outcome bias to attribute severity.

An example would be *Always use a checklist' before a rebreather dive*. What checklist? Who wrote it? Is it operationally relevant and based on the application of effective training? Or is it seen as a liability limiting exercise to make up for ineffective training and attitude towards safety and performance?

The Individual

Moving to the individuals themselves we need to consider their own risk perception, experience, and expertise. We also must consider what the social norm is of the group if we want to understand why violations happen.

Risk perception is a funny thing. We can perceive the risk associated with an activity very differently than another diver who might be equally qualified and experienced. We can even perceive the risk differently at different times in our own lives, often becoming more risk-averse as we age.

The real difficulty is when we have never encountered a situation before and we try to assess the risk. In so doing, we make a 'best guess' using emotion rather than logic. This is why real experience, as well as technical skills, are so important.

You cannot be taught everything in a class and therefore you have to learn on the job. Crucially, *"…risk is seen as inherently subjective. It does not exist "out there," independent of our minds and cultures, waiting to be measured. Instead, risk is seen as a concept that human beings have invented to help them understand and cope with the dangers and uncertainties of life." (*Slovic, 1987*)* and therefore applying your measure of risk to someone else's situation is likely to end up with a flawed outcome.

As discussed in the human factors in diving micro-class, many of our decisions are not made in slow-time and with logic (System 2), but rather, are emotionally-biased based on mental shortcuts and the cognitive biases we use to navigate our complex and uncertain world (System 1). If we have the wrong information coming into the decision-making process because of a lack of experience, we shouldn't be surprised if the outcome is flawed. Such flawed outcomes are therefore likely to lead to violations or 'at risk' behaviors.

Finally, we need to consider the social norm of the group. Humans are simple beings. We like to be part of a group, a behavior developed thousands of years ago. This is because a group is more likely to be able to survive than a single person on the savannah.

However, to remain part of the tribe/pack, we needed to comply with the social norms. If those norms weren't complied with, you were ejected to be left fend for yourself. We still see this behavior in troops of primates now.

Despite millennia of development, our brains haven't moved on much. If the social norm of the group of divers we are part of, or want to be part of, is to take risks, it is much harder to be 'safe' and follow the rules. If a newcomer joins the group, he or she will conform too. This is why effective leadership is so important, especially when it comes to instruction.

Situational or Organization Factors

Human behavior is a product of the personality of the person and the environment they are in.

If people are rewarded for a certain activity and punished for something else, don't be surprised if they conform. This includes social media commentary by the way and not just employment or litigation punishment.

If instructors are rewarded for the number of certs issued by their manager (wages/keeping their job) or their organization and 'punished' if they don't achieve a throughput, don't be surprised if the instructors put quantity over quality.

If the client expectation is that they can take an Open Water Diver course and become a 'qualified' autonomous diver in two days, don't be surprised if that drives dive center behaviors because *'everyone else is doing it.'*

If reportable incidents are seen as a negative rather than an opportunity to learn and manage risk effectively, don't be surprised if accidents, incidents and near-misses, especially those involving violations, aren't reported.

As there is no real quality control in diver training that ensures what is in the standards is taught in every course by instructors across the globe, then drift is likely. Violations are a normal outcome of drift.

This lack of adherence to standards also applies to graduates of training courses. How do you maintain standards and reduce risk-seeking behavior in the real world when effective debriefs and defined standards are missing?

Finally, optimizing behaviors for organizational gain, which might include violations, should be seen as a positive way of improving the system for the local environment. However, it requires an understanding of the factors present.

Drift is normal, but understanding why the drift has happened and modifying processes accordingly in a proactive and informed manner is a good thing. It is normally known as innovation. Enforcing rules for the sake of them, without understanding the unintended consequences, can lead to safety and performance being compromised.

Summary

Solving complex problems with simple solutions never works. Divers are part of a complex system of human interactions with other divers, with organizations, with equipment, and with the environment. You can't write rules for complex environments, especially when you don't have an effective feedback mechanism so that lessons can be learned without fear of litigation.

So, before you look at violations or at-risk behaviors following an accident, incident or near-miss, consider the rule itself and the person involved and their peer-group. Finally, look at the situational or organizational factors present.

As I have written numerous times, divers don't get up in the morning and decide "Today is a good day to die." As such, whatever they were doing at the time will have made sense to them, even if that meant breaking the rules…whatever 'rules' mean in the context of a leisure activity with an inherent risk of death and a lack of supervision and quality control.

What now?

The Human Diver provides globally-unique training which encourages a change in perspective to look at high performance in divers and dive teams by applying knowledge, skills, and materials from high-risk domains such as military aviation to recreational and technical diving.

These programs are delivered via eLearning, webinar and face-to-face classroom-based sessions. They have gained praise from some of the world's top divers. You can find out more about how to improve your performance, and safety as a consequence, by following this link www.thehumandiver.com. Apply Human Factors. Master the Dive.