# Map the *Yukon*

## A Warship Becomes an Artificial Reef

Andrew G. Abouna


**When the San Diego Oceans Foundation sank a Canadian Destroyer, it wasn't an act of war. Rather, it was a brilliant way to turn a wartime relic into an environmentally friendly artificial reef that could provide hours of pleasure for divers, increase San Diego tourism, and provide an economical alternative for decommissioning mothballed warships. To select a sink site, ensure safety in the reef environment, generate revenue, and create maps that are readable 100 feet below the water's surface, SDOF employed geospatial technologies.**

*Andrew G. Abouna* is a director with the San Diego Oceans Foundation. He is also a Scuba Schools International (SSI) Advanced Open Water Instructor, a GIS instructor at a local university, and works full-time as a GIS and MIS coordinator for the city of San Diego. He can be reached at yukondiver@altavista.com.

Photos above by Herb Gruenhagen and Andrew Abouna
Composite created by Connie J. Gorham

Several miles offshore of Point Loma aboard a San Diego harbor pilot boat, eight volunteers motored toward the *HMCS Yukon* as it arrived from Vancouver, British Columbia. As the 50,000 horsepower tug pulling the *Yukon* slowed to a few knots, our pilot boat came alongside, rising and falling in the 6-foot swells. In turn, each volunteer leapt across the gap between the two vessels and climbed aboard the *Yukon* using its Jacob's ladder. Once aboard the deserted vessel, we scrambled to our posts. Mine was forward to handle the 4-inch diameter bow lines in preparation for mooring the ship at San Diego.

The rigorous effort of hauling up three sets of hundred foot, sea-soaked line was the beginning of my two-year adventure preparing the *Yukon* for her metamorphisis from a Canadian warship to a premier artificial reef located just offshore of San Diego, California. Part of this adventure involved using GIS to create maps and a host of map-related graphics in support of "Project Yukon."

Although not her first visit to San Diego, this port call would be the *Yukon*'s last. The SDOF had arranged for this final sailing of the 336-foot long, 6-deck, 2,900-ton retired Canadian Destroyer Escort. Its plans called for making the ship available for anyone to see, or rather explore, but there would be only one way to do it — by diving as deep as 100 feet below the waves.

It took several years of planning, generous sponsorship, and thousands of hours of volunteer efforts, to ready the ship for its new home in Wreck Alley (see "Sink Site Selection" sidebar). Preparing the ship for sinking meant making it environmentally friendly and diver safe by cleaning it of contaminants as well as cutting huge holes in its sides and interior to permit the flow of nutrient-rich ocean currents. Volunteers created the bulk of these openings by cutting the 3/8- inch steel and aluminum hull using various methods. Navy personnel who conducted specialized training on the ship performed the shape charge work while volunteer Milt Beard cut most of the holes using a gas torch.

That done, the ship was towed to its current site and sunk on July 14, 2000, a day ahead of schedule and *not quite* according to expectations. The plan had called for sinking the ship in a controlled fashion by detonating shape charges in a bow-to-stern sequence. But the ship took on water the first evening after it was moored and flooded early. Regardless, the project was a huge success.

### The GIS connection

The mapping effort for Project Yukon was designed to ensure that divers could safely explore the vessel without becoming lost in its many decks. Maps would also serve as a valuable resource should a diver ever need to be rescued. Additionally, it provided the project with a valuable revenue stream.

Courtesy of ARSBC

With Point Loma in the background, the *HMCS Yukon* leaves San Diego in 1963 for exercises.

Courtesy of SDOF

On May 6, 1999, the *Yukon* made her final journey into San Diego Bay by tug (above). The following year, she was cleaned of contaminants, significantly remodeled, and thoroughly mapped in preparation for her role as an artificial reef (below).

Andrew Abouna

As a member of the Project Yukon Safety Committee, I had volunteered to complete the mapping tasks during a meeting in February 1999. An avid diver and dive instructor with a keen interest in the environment, as well as a GIS professional, I knew nothing about the layout of a destroyer class ship. That would all dramatically change in the months to come.

**Learning the ropes.** Though I began research related to mapping the *Yukon* months before she arrived, I conducted most of the mapping work while the ship was docked in San Diego and completed the task about a month before she sank. My primary task was to create a detailed layout of the ship to use in both dry and wet conditions. The map needed to represent the final layout of the ship (after the holes had been cut and deck revisions completed), clearly showing all of the compartments on each deck and every opening in, through, and out of the entire ship. With six decks and enough compartments to support the daily operations of a destroyer-class ship with a crew of about 200, there was a lot of detail to digitize. Table 1 lists the number and name of each deck, together with its general function and approximate number of compartments. Also listed in the table are the number of openings into or out of each deck.

To derive the ship's detail, I used maps from several sources including ARSBC and SDOF. I also obtained declassified Canadian Navy drawings that were left aboard the ship. Unfortunately, each of these sources had a different scale, none used a coordinate system, and, of course, all were hard-

## Sink Site Selection

The *Yukon* now rests in the San Diego Underwater Recreation Area, more affectionately known as Wreck Alley (see Figure 1). This area had undergone a detailed review by the Naval Ocean Systems Center (NOSC) in the late 1950s for the construction of the Navy Electronics Laboratory Tower. (Note that the tower is now also an artificial reef identified as "N.O.S. Tower" in this map.) The NOSC review had included studies of the bottom composition ranging from about 60 FSW to the edge of the continental shelf.

Using results from the NOSC studies and bathymetric maps, John Boyer, Project Yukon safety committee and site selection subcommittee leader, preselected a potential sink site. Employing GPS for navigation, a team of divers located the site by boat, then conducted underwater surveys of the area to determine if it was generally flat and devoid of permanent, preexisting marine life.

Because this initial site was deeper than 100 FSW, though, the San Diego Lifeguard Service eventually deemed it inappropriate. Following their guidelines, the site selection team then chose and surveyed a new, similar site with a depth of 100 feet, which is where the *Yukon* now rests.

Also, because the *Yukon* is almost 100 feet tall, it would create a navigational hazard if sunk at this depth. Therefore, we had to remove about 20 feet of the aluminum signal mast during the ship preparation phase.

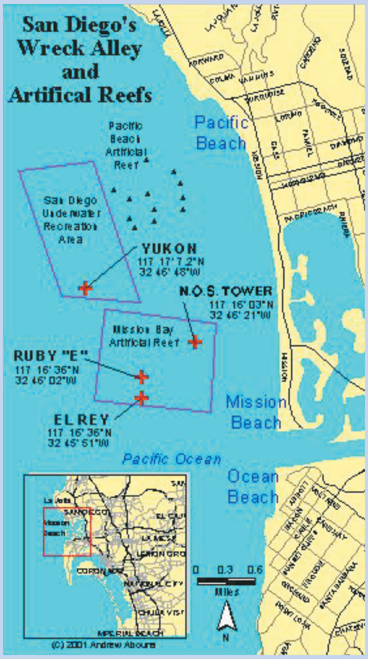



**FIGURE 1** Using U.S. Navy studies and bathymetric maps, SDOF chose the *Yukon*'s new home in Wreck Alley.

## Glossary

**ARSBC:** Artificial Reef Society of British Columbia

**FSW:** Feet of seawater

**HMCS:** Her Majesty's Canadian Ship

**SDOF:** San Diego Oceans Foundation

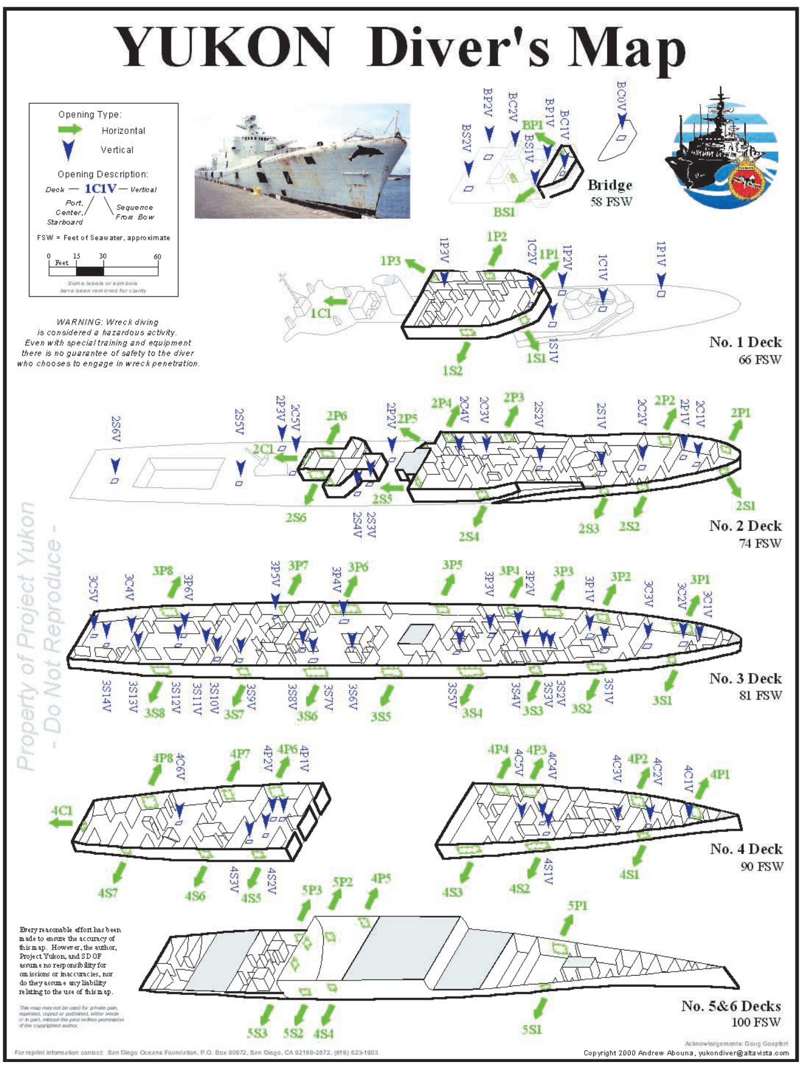
**TABLE 1** Decks of the *Yukon* Artificial Reef

| Deck | Name | Function | Compartments | Openings[1] |
|---|---|---|---|---|
| 01 | Bridge | Helm | 1 | 9 |
| 1 | Ops | Tactical operations | 14 | 16 |
| 2 | Main | Officer's quarters, communications | 34 | 31 |
| 3 | Burma road | Ship's business, dining[2] | 53 | 55 |
| 4 | Mess | Seaman's mess, engine and boiler rooms[3] | 31 | 50 |
| 5 | Engine/Boiler | Engine and boiler rooms | 2 | 6 |
| 6 | Engine/Stores | Engine room, stores, magazines | 30 | 15 |

1. Note, some vertical (ceiling/floor) openings are shared between decks. Also, some holes were not made because of the untimely sinking of the *Yukon*, therefore, the actual number of total ship openings is 116, which is fewer than shown in Table 1 and on the "*Yukon* Diver's Map."

2. In Canadian (and British) Naval parlance, the term 'dining' is used for eating area, rather than mess as used by the U.S. Navy; on Canadian ships 'mess' refers to sleeping area.

3. The boiler room was sealed off prior to sinking to prevent access to this confined area.




copy. The first step in the mapmaking process, then, was to scan and screen digitize these source maps to create a separate layer for each deck.

Initially, I digitized the complete structural detail of each deck into separate themes in the GIS. Although many interior panels of the ship were removed to permit safe passage by divers, the ship's full detail was needed to help ensure that all of the compartment walls, doorways, and hatches lined up properly. Having detailed maps was also very useful during my surveys and work on the ship when Ship Supervisor Douglas Goepfert and I checked the map for accurate representation of the new holes and the removal of interior walls.

I also digitized the hardcopy source maps to the same scale, and the relative locations of all walls, doorways, and eventual openings were correlated to ensure positional accuracy. Consistent scale between the decks and accurate relative positional accuracy were some of the key criteria that went into preparing the deck layers. Because the final map product was planned to be no larger than an E-size (22 × 34 inch) plot with a scale of about 1 inch equals 18.5 feet, greater map precision beyond relative position was not needed.

## The *Yukon* Diver's Map

The primary map product I created was the *Yukon* Diver's Map (see Figure 2 ). The map features a cutaway view of the ship, the location and identification of all 116 openings, estimated depths of each deck, and a photo of the prepared ship prior to sinking. To help present the most amount of information about the ship, while still preserving clarity, I chose a perspective view for the map. In the diver's map each deck was positioned, or stacked atop one another to portray a cutaway of the ship.

Because the controlled sinking of the ship did not occur as planned, the ship is not resting on her keel as intended, but on her port side. This means that — because I created the maps assuming the sinking would go as planned — the mapped depths of the decks are somewhat incorrect. For instance, the shallowest portion of the ship is now at about 55 FSW, depending on tide, instead of the planned 35 FSW for the bridge superstructure. The other result of the early sinking is that the 6 port and starboard exterior holes and the 2 forward interior holes on Decks 5 and 6 were not cut with shape charges. Had these holes been made as planned, a controlled sinking of the ship would have occurred, allowing her to flood and sink bow-first. Then, as the ship sank, its bow would have touched the sandy bottom first steadying the descent

**FIGURE 2** The *Yukon* Diver's Map (left) was designed so that it could be easily converted to supplemental mapping products and be readable underwater.

of the aft part of the ship so that she would end up resting on her keel. Now that the ship is on its side, however, many divers feel the ship is more like a real wreck. Although she's not sitting as planned, she was placed in the precise location intended.

**Logical labeling.** A very important feature of the *Yukon* Diver's Map is that all 116 holes are identified and labeled in a logical yet simple fashion. As shown in the map legend, the hole numbering system is straightforward: the first character is the deck number; the second indicates port, center, or starboard lateral position; the third character is the sequence or hole number of the lateral position type; and, if there is a fourth character, it will be a 'V' to indicate that the hole can be traversed vertically.

There are two types of holes, or openings, that are defined by how a diver could swim through it — horizontally or vertically. These hole types are symbolized on the map for easy recognition above and below the water. And because color disappears as water depth increases, symbology was very important to the readability of the map.

**Color choice.** Color standards were especially important because color disappears as water depth increases due to the absorption of the visible light spectrum through the medium of water. At the *Yukon*'s depth, the green and blue coloring differentiating the horizontal and vertical holes would appear black. Therefore the *Yukon* Diver's Map was designed so that hole labeling would be discernable using text orientation, arrow and line types, and label description. Such symbology, which would also help minimize task-loading the diver, was designed as follows.

| Symbology | Horizontal openings | Vertical openings |
|---|---|---|
| Line color/type | Green hatched lines | Solid blue lines |
| Arrow color/type | Green arrow with tail | Blue arrow heads |
| Text angle | Horizontal | Vertical |

**Riveting signs.** To help divers better navigate the ship, we also printed the labels that appear on the map onto 6-inch square signs made of Lexan plastic. SDOF volunteer Kai Schumann created and physically riveted them onto the ship at each opening. This allows a diver to precisely locate and reference each exterior and interior opening of the ship. The riveted signs are located at the forward edge of each hole so that in low visibility situations a diver can determine the bow direction of the ship by seeing or feeling the location of the sign.

**Dive planning.** The benefits of the map and ship signage are many. Safe diving depends on a number of things, not the least of which is planning. By using the layout and signs on the map and ship, a diver can predive each portion of the ship. Because the ship is so large — taking as many as 30 dives to fully explore — proper planning and logging of dives therefore becomes important not only for a safe and decompression-free dive, but also to help ensure that a diver sees all of the ship.

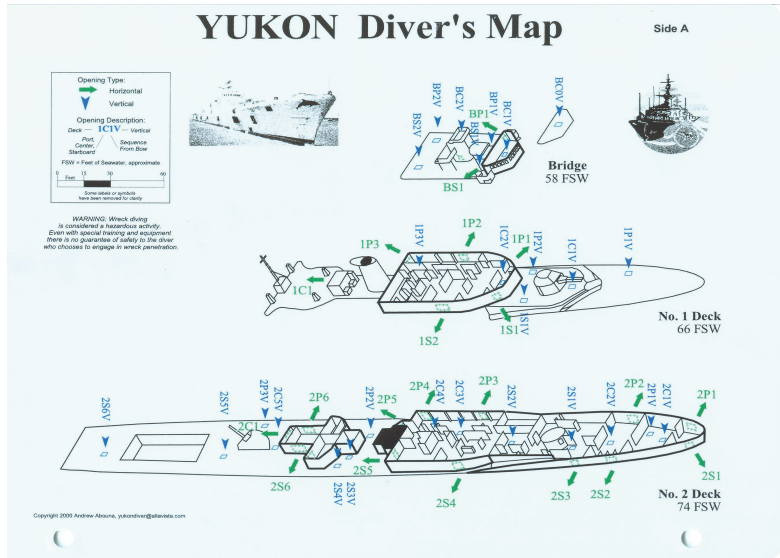



**FIGURE 3** Reproduced from the diver's map, the two-sided map slates are specifically designed for underwater use.

To further help divers enjoy the wreck, a number of *Yukon* Diver's Maps were strategically placed inside the ship. Clearly indicated on each map is its respective location on the ship using the traditional "You Are Here" text. These maps were also laminated and riveted to the ship behind Lexan plastic.

**Lifesaving maps.** The *Yukon* Diver's Map and its numbering system could also help in rescue efforts if there is ever a lost diver on the vessel. Time and air supply are two life-governing variables in the underwater environment, so the sooner a lost diver is found the greater the chance for a positive outcome. Because the ship is so large it would be very difficult to describe to rescue personnel where a lost diver might be. And it could be equally difficult to rescue personnel to quickly find a specific location.

Thankfully, no emergency situations have occurred, but if one did, the map could make a rescue much easier and quicker, hopefully increasing the likelihood of success. With this in mind, I presented the map and explained its use to the City of San Diego Lifeguard Services before the ship was sunk.

Lee Peterson

The author (above right) and fellow volunteer Jay Schwartz (left) remove a sponsorship banner from the *Yukon* shortly after her sinking. Note the author is using a dive slate.

## Dripping with revenue

The most significant reproduction of the diver's map is the *Yukon* Diver's Map slate (see Figure 3). This is a waterproof version of the map that enables a diver to take the map with them underwater. Traditional dive slates generally comprise a blank piece of plastic, a pencil, and a lanyard to keep the slate from float-

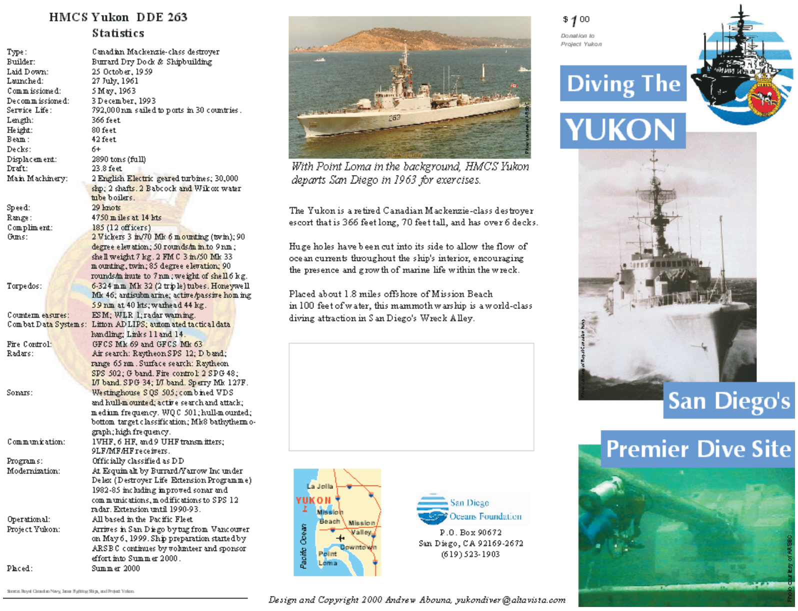



**FIGURE 4** To educate the public and advertise the project, the author used GIS to create and lay out a four-color Project Yukon brochure.

ing away. Writing on a slate enables a diver to make notes about their dive plan before entering the water, record information during a dive, and communicate with a dive buddy. Our slate is even more useful as it includes a map of the *Yukon* Artificial Reef.

I tested several methods of making the map waterproof, but the best method was creating a dive slate by silk screening the map onto polystyrene plastic. I employed the previously described map design standards (symbology) to make the map easier to read underwater. Several other factors needed to be considered as well. For instance, the slate couldn't be too large or cumbersome to carry or divers would not use it. Nor could the slate be too small so as to be unreadable. Easy use of the map was important to avoid task-loading the diver. Under the effects of several atmospheres of pressure, handling gear, and dive parameters, it is always best to minimize stress so as not to compromise safety.


SDOF also created this customized "Diver Down" flag and sticker in part using the GIS program.

**Refraction counts.** Fortunately, a natural phenomenon was working in my favor with regard to slate size and readability — refraction of light. A diver wears a mask on their face to create an air pocket about the eyes to allow them to see underwater. However, because a diver looks through two mediums — water and air — light rays are refracted as they reach the eyes. One affect of this refraction is that it makes objects appear 33 percent larger underwater, which means I was able to reproduce the map onto the slate 33 percent smaller than what would be needed to read the map at the same scale on the surface.

**So does size.** After several tests, the final size of the slate was 9.5 × 7.5 inches. This size also took into consideration the optimal number of slates that could be cut from large sheets of stock plastic. That, and the use of only three colors on the slate helped minimize costs while still ensuring an attractive and useful information source. The slate was also printed on both sides with half of the decks on each side. This gave enough room to clearly show each deck while keeping the slate to a single piece of material.

**Turn to side B.** To get the map onto the slates required several steps. First, I created side A and B map layouts in the GIS. Then I set the output resolution to high in the layout properties box and exported each layout as Postscript New (EPS), 300 dots-per-inch resolution files. Next, a local digital prepress company imported the EPS files into a graphics program to prepare industry-standard Pantone color film, or 'stats'. These files were then burned onto silkscreen by another firm, which then inked the map images onto the plastic supplied by yet another project sponsor.

After die-cutting the plastic to give rounded corners and hole punching the lower corners to permit the affixing of a lanyard, I had 1,400 final dive slates ready to sell for the project. All of these slates have since been sold for Project Yukon and more are on order. The slates were an important source of revenue for Project Yukon and retailed for only $10 each.

## The *Yukon* divers' brochure

Creating an informative brochure about the *Yukon* was also very important for educating the public and advertising the project and ship. After compiling information about the ship from the ARSBC, SDOF, and two books (*Jane's Fighting Ships* and *The Cadillac of Destroyers*), I was able to design a 4-color brochure that featured facts, pictures, and the *Yukon* Diver's Map. The entire layout and creation of the brochure was made using GIS, as shown in Figure 4.

The 8.5 × 11-inch, 3-fold brochure features two historic photos of the *Yukon* plus another photo of an already-reefed sister ship. The brochure included a host of ship specifications and Project *Yukon* information as well as a small location map of the *Yukon* sink site. This brochure has also led to donations to the project.

## Map wear

Yet another revenue source enabled by the GIS-based *Yukon* maps was the sale of t-shirts and sweatshirts. I created and sold more than 400 of these wearable maps. The back of the shirt features a large version of the map, which was underlined with the text "Loose Lips Sink Ships." On the front of the shirt was a stylized version of the well-known diver-down flag. The diver-down flag/project logo was also created using GIS and a prepress and silk screening process similar to that used for the slates.

**More GIS graphics.** GIS layout capabilities were also used to produce several other graphic products. One very important item that was used extensively following the ship's arrival in San Diego were identification badges for each ship worker and visitor. Color and text coding of the badge were used to indicate clearance level, enabling ship security volunteers to easily identify those with appropriate access. These security procedures were enacted primarily to restrict access for people unfamiliar with the ship, so as to protect them from the many hazards such as large holes having a 30-foot drop. After several months, access restrictions were reduced as volunteers became familiar with the ship.

### Home port benefits

Acquiring and turning the *Yukon* into a very successful underwater artificial reef was a giant undertaking of volunteers and sponsors. During the approximate three years of the project, new friendships and partnerships were forged as hundreds of divers and interested citizens came together from different dive clubs, organizations, cities, counties, and even children's groups, all with a common goal — to ready the ship for sinking.

In more quantitative terms, the local diving industry, in particular the dive charter boat operators, have experienced their most prosperous year of business, with about a 60 percent increase in charter operations. Projections prior to sinking called for a $1 million a year increase in local tourism revenue resulting from interest in the *Yukon*.

The size and complexity of not only the project but also the ship required careful planning and processes (see "Reefing Ships" sidebar). One critical process, of course, was developing maps and graphics using desktop GIS software. From these maps and graphics came a wealth of information sources and revenue-generating products. These in turn helped to financially support the project, while providing important information to divers to help ensure a higher degree of adventure and safety on the *Yukon* Artificial Reef.

### Manufacturers

The primary software used for all of the GIS and graphics mapping work was ArcView from **ESRI** (www.esri.com). The computer hardware consisted of a Pentium III PC, a desktop OneTouch **Visioneer** (www.visioneer.com) and a large format scanner, printer, and plotter from **Hewlett-Packard** (www.hp.com).


### Acknowledgments

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## Reefing Ships —
## International Venture, National Model

Artificial reefs are objects that are sunk and allowed to become a marine habitat. Every coastal state has such objects, and Florida leads the nation with more than 430 reefed vessels. In addition to ships, reefs have been made out of cars, bridges, and old tires. Properly prepared reefs have many benefits. They provide badly needed habitat for ocean life as well as relieving tourist pressure on fragile natural ecosystems such as coral reefs. When it comes to obsolete military vessels, reefing costs much less than conventional scrapping methods, and is environmentally safer. Finally, reefing such ships as the *Yukon* help to preserve historically significant vessels.

The San Diego Oceans Foundation (SDOF, www.sdoceans.org) purchased the *Yukon* from the ARSBC (www.artificialreef.bc.ca). The ARSBC program obtains decommissioned Navy ships from the Canadian government and turns them into artificial reefs. After salvaging the valuable materials from the ship, cleaning up potential contaminants, and cutting internal and external holes in the ship, the ARSBC sinks the ship in a carefully orchestrated fashion to create artificial reefs in predetermined locations.

For some time, a similar idea had been building at SDOF — to take a decommissioned Navy warship, clean it of possible contaminants, make it safe to the environment and divers, then sink it to make a structure that enhances the aquatic environment by creating a self-sustaining ecosystem and a world-class diving attraction. Looking for an old ship to transform into a reef, SDOF first turned to the U.S. Navy. The Navy has a storage inventory of about 350 decommissioned ships. These ships are costly to maintain and could be even more expensive to dispose of. However, at that time the Navy was not interested in letting SDOF have a ship. So SDOF contacted ARSBC, and a year or so later the *Yukon* arrived in San Diego.

From the start of the project until the goal of sinking the ship was reached there were many obstacles. Even the transit of the *Yukon* from Vancouver, BC to San Diego was eventful. Somewhere off the coast of San Francisco in May, 1999, the main tow line between the *Yukon* and the tug broke because of 25 foot seas, forcing the *Yukon* adrift, riding the seas for a day and a half until a new line was secured. She wasn't too worse for this wear; although, when myself and two others inspected the dark, ghostly ship at port on May 6, 1999, we observed that a number of compartments were water-stained floor to ceiling from the sloshing of water.

Project Yukon is now a model for ship disposal. The complexity of cleaning, preparing, permit issuances, coordination with many local businesses and government agencies, and overall planning had never been done for a project like this before, anywhere, and with such success. With this in mind, a recent RAND Corporation (www.rand.org) report to the Navy has endorsed the process of reefing decommissioned U.S. Naval ships. With Navy and congressional approval, this could provide not only a large scale, nationwide opportunity to enhance the aquatic underwater environment by creating artificial reefs, it would also help build ecotourism in various parts of the coastal United States. In addition, a "wrecks-to-reefs" program would save a tremendous amount of money, as it is estimated that disposing of the approximate 350 ships using traditional methods would cost about $1.2 billion, compared with about $500 million for reefing.