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The Remediation of Underwater Legacy Environmental Threats (RULET) Risk Assessment for Potentially Polluting Shipwrecks in U.S. Waters

Lisa Symons
National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, 1305 East-West Highway, Silver Spring, MD, 20910 USA

Jacqueline Michel
Research Planning, Inc., 1121 Park Street, Columbia, SC, 29201 USA

James Delgado
National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, 1305 East-West Highway, Silver Spring, MD, 20910 USA

Danielle Reich and Debbie French McCay
RPS ASA, 55 Village Square Drive, South Kingstown, RI, 02879 USA

Dagmar Schmidt Etkin
Environmental Research Consulting, 41 Croft Lane Cortlandt Manor, NY, 10567 USA

Doug Helton
National Oceanic and Atmospheric Administration, Office of Response and Restoration, 7600 Sand Point Way, NE, Seattle, WA, 98115 USA

ABSTRACT 299454:

Although there are approximately 20,000 shipwrecks in U.S. waters, we now know that most of them are unlikely to be substantial pollution threats. Using initial screening factors (age, location, construction material, propulsion type, type, and size), 573 wrecks were identified as potentially containing larger amounts of oil. Secondary screening factors that relied on archival research and original documents for details, such as structural integrity and potential cargo and bunker capacities, reduced the list to 87 wrecks known or suspected to pose a substantial pollution threat. The majority of these are associated with World War II casualties in the Battle of the Atlantic. As of 2013, the average age of each wreck is 83 years old, as many were built or retrofitted for service during WWII. A consequence analysis consisting of oil spill trajectory and fate modeling and an assessment of ecological and socio-economic resources at risk was conducted for the 87 wrecks. Based on vessel pollution potential factors and ecological/socio-economic impact scores, a final relative risk score was assigned to each. Further assessments to determine the vessel condition, amount of oil onboard, and feasibility of oil removal action were recommended for seventeen vessels with known locations. Other recommendations included surveys of opportunity to identify the actual or best-guess location of each wreck in applicable oil spill contingency plans (so that if a mystery spill occurs, the wreck(s) can be investigated as a possible source), monitoring the condition of known wrecks, surveys to locate wrecks with unknown locations, and outreach to local communities. Recent surveys leveraged assets engaged in other activities, yielding additional information on a number of the high and medium priority targets. Although, this process has validated the existence of vessels of concern in U.S. waters that need to be reflected in area spill contingency plans, NOAA can now state that the coastline

of the U.S. is not littered with "ticking time bombs" as previously believed. This assessment puts reliable bounds on the potential oil pollution threats from wrecks and helps delineate a path for determining risk for wrecks with as yet unconfirmed locations. The USCG can plan accordingly for monitoring, in-water assessments, and pollution recoveries as appropriate, rather than waiting for the potential harm these wrecks could cause to coastal areas. These findings are reassuring in light of earlier global analyses with much higher estimates such as that of the IOSC 2005 white paper (Michel et al., 2005).

INTRODUCTION:

A series of "mystery spills" in national marine sanctuaries and along other areas of the U.S. coast made it clear to resource trustees that an understanding of the level of risk associated with shipwrecks was critical to the protection and management of these coastal and marine resources. It was also clear that no existing dataset could characterize the scope and scale of the issue. Thus, in 2002, the National Oceanic and Atmospheric Administration (NOAA) started to compile the internal Resources and UnderSea Threats (RUST) database to address potential threats within the boundaries of and up to 50 nautical miles outside of national marine sanctuaries (Overfield, 2005; Madrigal, 2008). This internal database was established to develop an initial inventory of both historically significant resources that could be at risk from an oil spill, as well as an inventory of sites that could pose a threat to marine and coastal resources. The project soon grew beyond the scope of the National Marine Sanctuary System and encompassed threats and resources in all U.S. waters. Of the 30,000 sites in RUST, there are over 20,000 wrecks in U.S. waters and at least 10,000 or so other sites that include planes, munitions dumpsites, hazardous materials dumpsites, abandoned wellheads, pipelines, and other miscellany dumped "out of sight and out of mind." RUST was useful for specific limited queries, typically associated with mystery spills, and for contingency planning near and within National Marine Sanctuary System sites. However, it was not an effective risk assessment tool in its original form, in that it did not address the larger question of how to characterize potential pollution threats on a national level in a manner that could be incorporated into spill response planning (Zelo et al., 2005). In particular, the database lacked reliable information on the potential oil contents of these wrecks, and had limited ability to easily identify potentially oil polluting wrecks from the larger dataset, which includes many older wooden vessels that have largely disintegrated with the passage of time. With 16 potentially polluting wreck assessment and recovery actions in U.S. waters over the last 23 years, a growing public awareness of the issue and concerns about being able to appropriately characterize the risk was continuing to press on resource trustees and the spill response community.

In March 2010, the U.S. Congress provided NOAA a one-time $1M appropriation to provide recommendations to the U.S. Coast Guard (USCG) about which wrecks posed the most significant potential pollution threats to socio-economic and ecological resources in U.S. waters. Congress directed this assessment to focus on the threat of oil pollution rather than munitions and other hazardous materials. In May 2013, NOAA completed an iterative, multi-disciplinary process and delivered the Risk Assessment for Potentially Polluting Wrecks in U.S. Waters, a national assessment of the most significant potentially polluting wrecks in U.S. waters to the USCG (NOAA, 2013). This national report was accompanied by risk assessments for the 87 priority wrecks in the dataset known as the Remediation of Underwater Legacy Environmental Threats (RULET). The RULET risk assessments for each wreck include historical information, an archaeological assessment, probabilistic spill trajectories for both the Worst Case Discharge (all of the oil potentially onboard both as fuel and cargo), and Most Probable Discharge (10% of the worst case volume, as a rough estimate of the loss of one tank or a chronic leak over time), and an assessment and scoring of impacts to the ecological and socio-economic resources at risk. These assessments provide the USCG, as the Federal On Scene Coordinator (FOSC) for the coastal and marine waters, information critical to making decisions in their respective areas of responsibility. NOAA made the national report and the 87 risk assessments accessible to the public via a dedicated web page http://sanctuaries.noaa.gov/protect/ppw/.

METHODS:

Determining Useful Products

NOAA and the USCG spent a considerable effort determining the most critical information needed to support to both the contingency planning process and FOSC requests to the National Pollution Fund Center (NPFC) for assessment and recovery funds. It was important that the assessments provide the necessary information to help the FOSC determine whether a wreck was an imminent and substantial threat and where it ranked in priority to other response and preparedness issues within their region. NOAA and USCG discussed the types of rankings that would be the most useful and whether all the wrecks should receive a relative numeric ranking across the nation. It was felt that a straight numeric ranking could cause several issues. First, it would imply a level of certainty that would not be sustainable without *in-situ* verifications for each wreck. Secondly, and perhaps more importantly, it would not take into consideration the local and regional issues that may elevate the concerns about a wreck. Thus, the decision was to use high/medium/low rankings for both the Worst Case and Most Probable Discharges to provide a nationally comparable dataset that could then be incorporated into Area Contingency Plans and also be used to address local concerns and even local or regional politics that could elevate or suppress the NOAA-identified priorities. The initial risk assessment packages were pilot-tested with two districts with variations both in terms of their awareness of the issue and the types of potential targets. Districts 1, 5, and later 13, and USCG Headquarters Office of Marine Environmental Response Policy all made constructive suggestions that helped inform the analytical process. The NPFC was also engaged to address any potential concerns from its perspective. This iterative process was important to ensure that the overall project addressed the larger scale issues of potentially polluting wrecks. As the resulting risk assessment does not conform to ISO31000: 2009 standards, nor does not conform to ISO vocabulary. Rather the vocabulary and principles used should be familiar to USCG and spill planning, preparedness, and response personnel as it was developed to address the specific needs of the USCG and U.S. spill response community.

An element highlighted in discussions with USCG was the need to compare risk for vessels with verified locations against those with only last-known reported locations. The intent and need was to be conservative in the analysis and to not exclude wrecks unless archival or contemporary records clearly showed that a wreck had been salvaged, cleared by aerial bombing or wire drags, or clearly had no remaining structural integrity. Reports from recreational divers addressed questions of structural integrity and facilitated ruling out sites. For example, the *E.M. Clark* looks to be substantially intact based on remote sensing and photography; however, diver reports helped establish that severe corrosion and degradation have rendered all the cargo and bunker tanks on this wreck open to the elements.

It was clear that the RULET risk assessment needed to provide enough information to screen through the large number of vessels, address a broad range of concerns from state and federal resource trustees of both natural and cultural resources, and provide USCG a credible assessment of both the ecological and socio-economic probabilities and consequences of significant releases from the wrecks. The assessments also had to work within the existing spill contingency planning process, and be accessible to industry, academia, and the general public who are interested either in a specific wreck or potential local or regional impacts from potential leakage from wrecks.

Figure 1 outlines the process applied in characterizing and prioritizing the individual wrecks in the RUST database to develop the smaller subset in the RULET database.

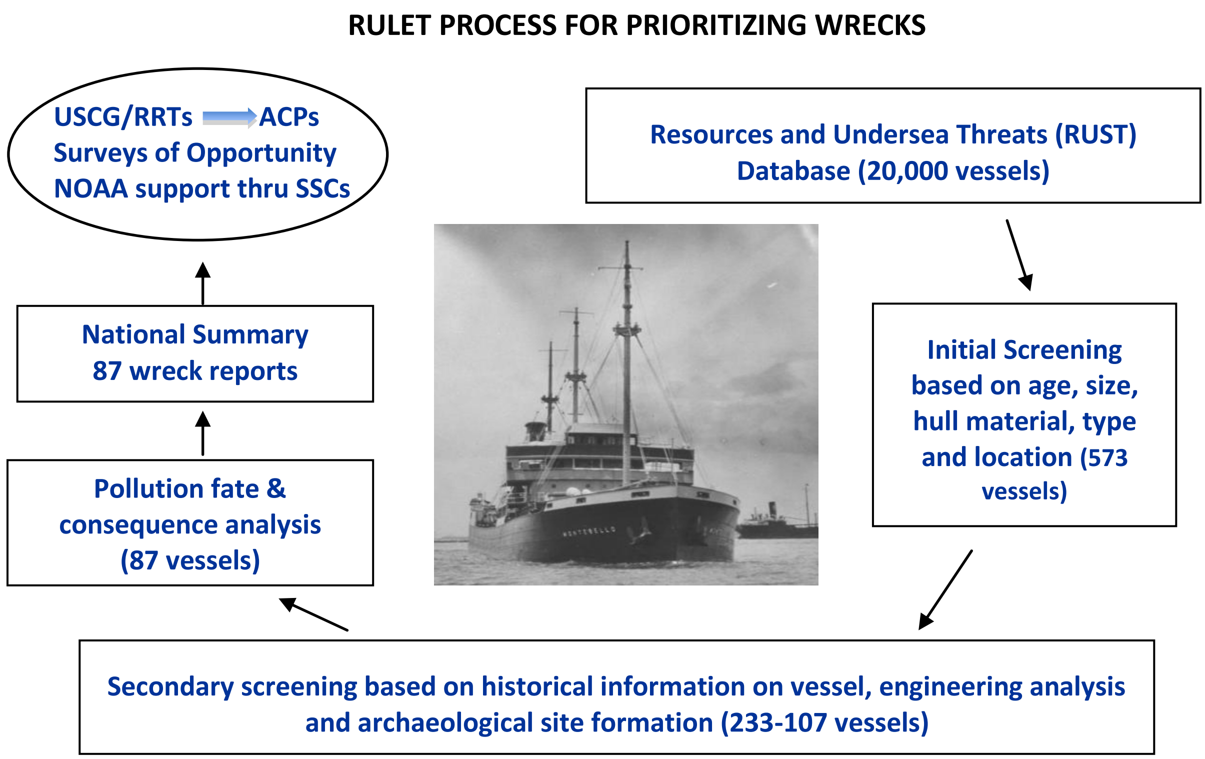

Figure 1. Diagram shows the iterative process for identifying RULET wrecks.

Risk Assessment Approach

The RULET risk assessment approach essentially has three components:

- **Vessel Risk:** Qualitative analysis of the likelihood that there will be an oil release from a wrecked vessel and the consequences of that release with regard to the volume of oil leakage.

- **Oiling Risk:** Analysis of the probability that there will be oil exposures to the water column, water surface, and shoreline over thresholds known to cause impacts to ecological and/or socioeconomic resources, and the magnitude or degree of that oil impact given that there is a hypothetical release of oil of a certain volume.
- **Ecological and Socio-Economic Impact Risk:** Analysis of the probability that there will be oil exposures to water column, water surface, and shoreline resources over thresholds known to cause impacts to ecological resources at risk (EcoRARs) and socio-economic resources at risk (SRARs), and the magnitude or degree of that oil impact given that there is a hypothetical release of oil of a certain volume.

This assessment used several disciplines to gain as comprehensive an understanding of an individual wreck as possible from existing archival records and other sources. An assessment of the physical integrity of the vessel was developed based on understanding of how the vessel was built and/or retrofitted and how the casualty occurred. Marine archaeologists well versed in the typical changes that sunken ships undergo over time due to time, weather, ocean currents, and anthropogenic impacts (known as site formation processes) provided qualitative information regarding the likely integrity of each wreck. An iterative narrowing of criteria and extensive research helped to narrow down the population of vessels to 87 wrecks that were assessed for potential pollution impacts to socio-economic and ecological resources (Figure 2).

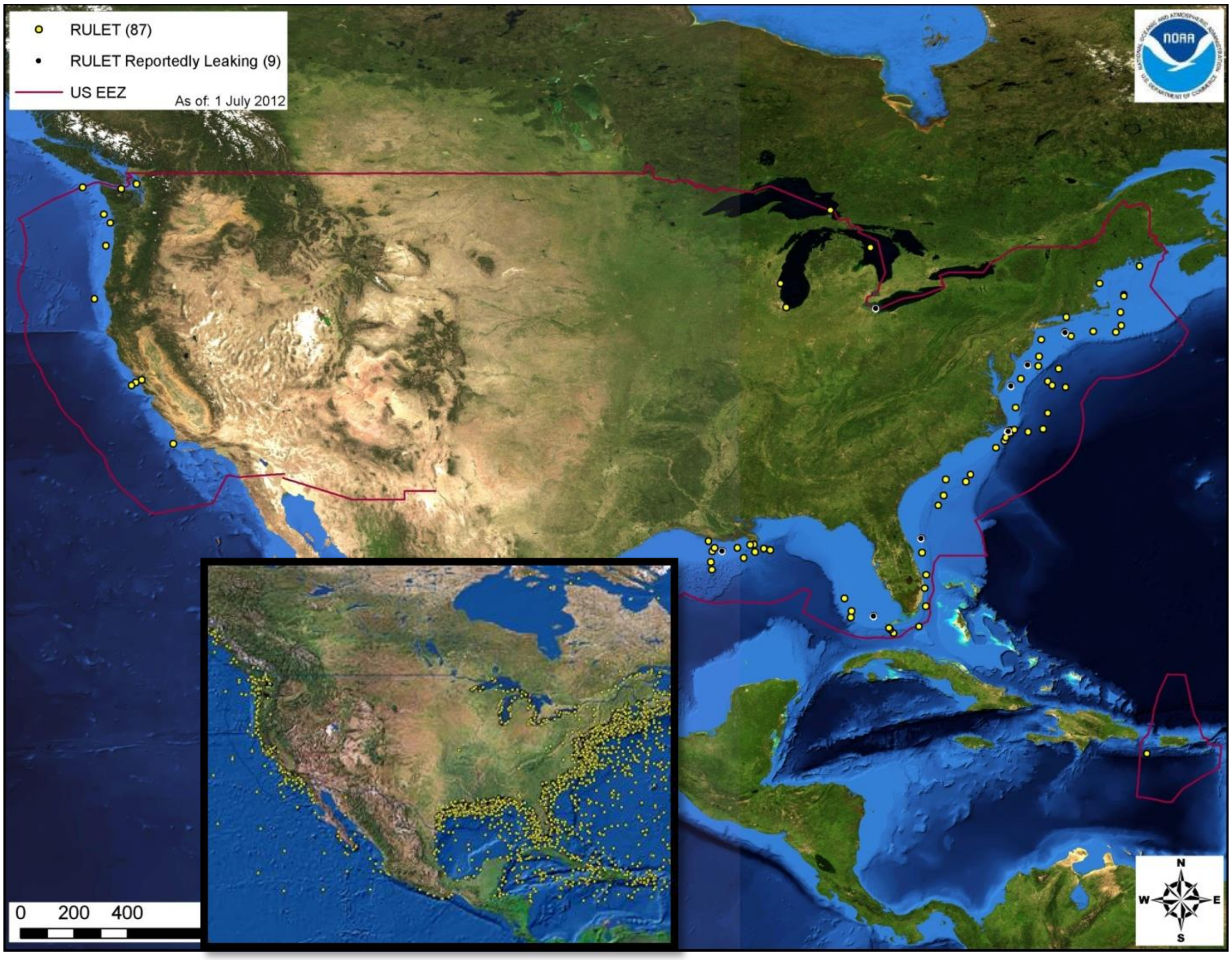

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Figure 2. The inset shows the 30,000 targets in the Resources and UnderSea Threats (RUST) database, the larger graphic shows the final 87 targets analyzed in the NOAA Remediation of Underwater Legacy Environmental Threats (RULET) project.

In the next step of the assessment (as seen in Figure 1), stochastic (probabilistic) oil spill trajectory and fates modeling was conducted for five different release volumes (100%, 50%, 10%, 1% and .01% of the worst case volume). The modeling random sampling of long-term wind and current records to vary the environmental factors that could affect the trajectory and behavior of released oil. The probabilistic pollution modeling was not done for all 87 vessels due to resource constraints; rather, some vessels were grouped by generalized oil type and location. The outputs from the models provided statistical information on both the probability and the magnitude of spill-related impacts, quantified as the areas of water surface, volumes of water, and lengths of shoreline (by shoreline type) oiled above effects thresholds for both ecological and socio-economic resources. These datasets were used to develop regression models of impacts versus volume of oil spilled, so that impacts could be estimated for any potential release volume from each wreck.

The model results were then used to assess the socio-economic and ecological risks of different spill volumes. In this assessment, *risk* means evaluating both the *probability* of an event occurring and the *impacts* or *consequences* of that event, such that:

Risk = Probability x Consequences

The model output provided the probability of oil exposure above selected thresholds. Ecological and socio-economic resources at risk information from the Environmental Sensitivity Indices (ESIs) (at the water surface, in the water column, and along the shoreline) were scored based on their presence in the impact areas and their sensitivity to oil exposure for both the Worst Case and Most Probable Discharge volumes. Table 1 shows an example risk factor score summary for the EcoRARs and SRARs for the Most Probable Discharge volume from the *Cities Service No. 4* (1,200 barrels of light fuel oil) located in Long Island Sound.

The final risk score for each vessel was a combination of the vessel pollution potential score and the three scores for each of the EcoRARs and SRARs, for a total of seven criteria with three possible scores for each criterion (Low=1, Medium=2, and High=3). Thus, the total possible score is 21 points, and the minimum score is 7 points. The resulting range in scores assigned to the overall category rank and number of wrecks in each category by release scenario is shown in Table 2. A detailed explanation of all the risk factors and the scoring methods is provided in the final report (NOAA, 2013).

Table 1. Ecological (EcoRAR; top) and socio-economic (SRAR; bottom) risk scores for the Most Probable Discharge of 1,200 bbl of light fuel oil from the *Cities Service No. 4*.

Risk Factor	Risk Score			Explanation of Risk Score	Final Score
3A-1: Water Column Probability EcoRAR Oiling	Low	Medium	**High**	91% of the model runs resulted in at least 0.2 mi^2 of the upper 33 feet of the water column contaminated above 1 ppb dissolved aromatics	Low
3A-2: Water Column Degree EcoRAR Oiling	Low	**Medium**	High	The mean volume of water contaminated above 1 ppb of dissolved aromatics was 17 mi^2 of the upper 33 feet of the water column	
3B-1: Water Surface Probability EcoRAR Oiling	**Low**	Medium	High	1% of the model runs resulted in at least 1,000 mi^2 of water surface swept by at least 10 g/m^2 of oil	Low
3B-2: Water Surface Degree EcoRAR Oiling	**Low**	Medium	High	The mean area of water surface contaminated above 10 g/m^2 was 150 mi^2	
3C-1: Shoreline Probability EcoRAR Oiling	Low	Medium	**High**	97% of the model runs resulted in shoreline oiling above 100 g/m^2	Low
3C-2: Shoreline Degree EcoRAR Oiling	**Low**	Medium	High	The length of shoreline contaminated by at least 100 g/m^2 was 6 mi	

Risk Factor	Risk Score			Explanation of Risk Score	Final Score
4A-1: Water Column Probability SRAR Oiling	Low	Medium	**High**	91% of the model runs resulted in at least 0.2 mi^2 of the upper 33 feet of the water column contaminated above 1 ppb dissolved aromatics	Low
4A-2: Water Column Degree SRAR Oiling	Low	**Medium**	High	The mean volume of water contaminated above 1 ppb dissolved aromatics was 17 mi^2 of the upper 33 feet of the water column	
4B-1: Water Surface Probability SRAR Oiling	**Low**	Medium	High	0.5% of the model runs resulted in at least 1,000 mi^2 of water surface swept by at least 0.01 g/m^2 of oil	Med
4B-2: Water Surface Degree SRAR Oiling	**Low**	Medium	High	The mean area of water surface contaminated above 0.01g/m^2 was 200 mi^2	
4C-1: Shoreline Probability SRAR Oiling	Low	Medium	**High**	99% of the model runs resulted in shoreline oiling above 1 g/m^2	Low
4C-2: Shoreline Degree SRAR Oiling	**Low**	Medium	High	The length of shoreline contaminated by at least 1 g/m^2 was 8 mi	

Table 2. Summary for the final category ranks of Low, Medium, and High for the 87 wrecks.

Category Rank	Range of Scores	No. Wrecks for Worst Case Discharge	No. of Wrecks for Most Probable Discharge
High Priority	**15-21**	**36**	**6**
Medium Priority	**12-14**	**40**	**36**
Low Priority	**7-11**	**11**	**45**

DISCUSSION:

In each of the 87 individual wreck risk assessments, NOAA made recommendations for further action, as summarized in Table 3. For those wrecks for which the location is only generally known, the next step is to attempt to locate the vessel and gather additional information to determine its structural integrity and potential for oil remaining onboard. Figure 3 shows the locations of the wrecks that NOAA recommended be considered for further assessment.

Table 3. Summary of recommendations from all RULET risk assessments.

Vessel Scores	Possible NOAA Recommendations	Number of Vessels Receiving Recommendation
High (*+1 Medium*)	Wreck should be considered for further assessment to determine the vessel condition, amount of oil onboard, and feasibility of oil removal action	17
High & Medium (*Unknown Location*)	Use surveys of opportunity to attempt to locate this vessel and gather more information on the vessel condition	46
High & Medium	Conduct active monitoring to look for releases or changes in rates of releases	22
All	Be noted in the Area Contingency Plans so that if a mystery spill is reported in the general area, this vessel could be investigated as a source	87
All	Conduct outreach efforts with the technical and recreational dive community, as well as commercial and recreational fishermen who frequent the area, to gain awareness of changes in the site	87

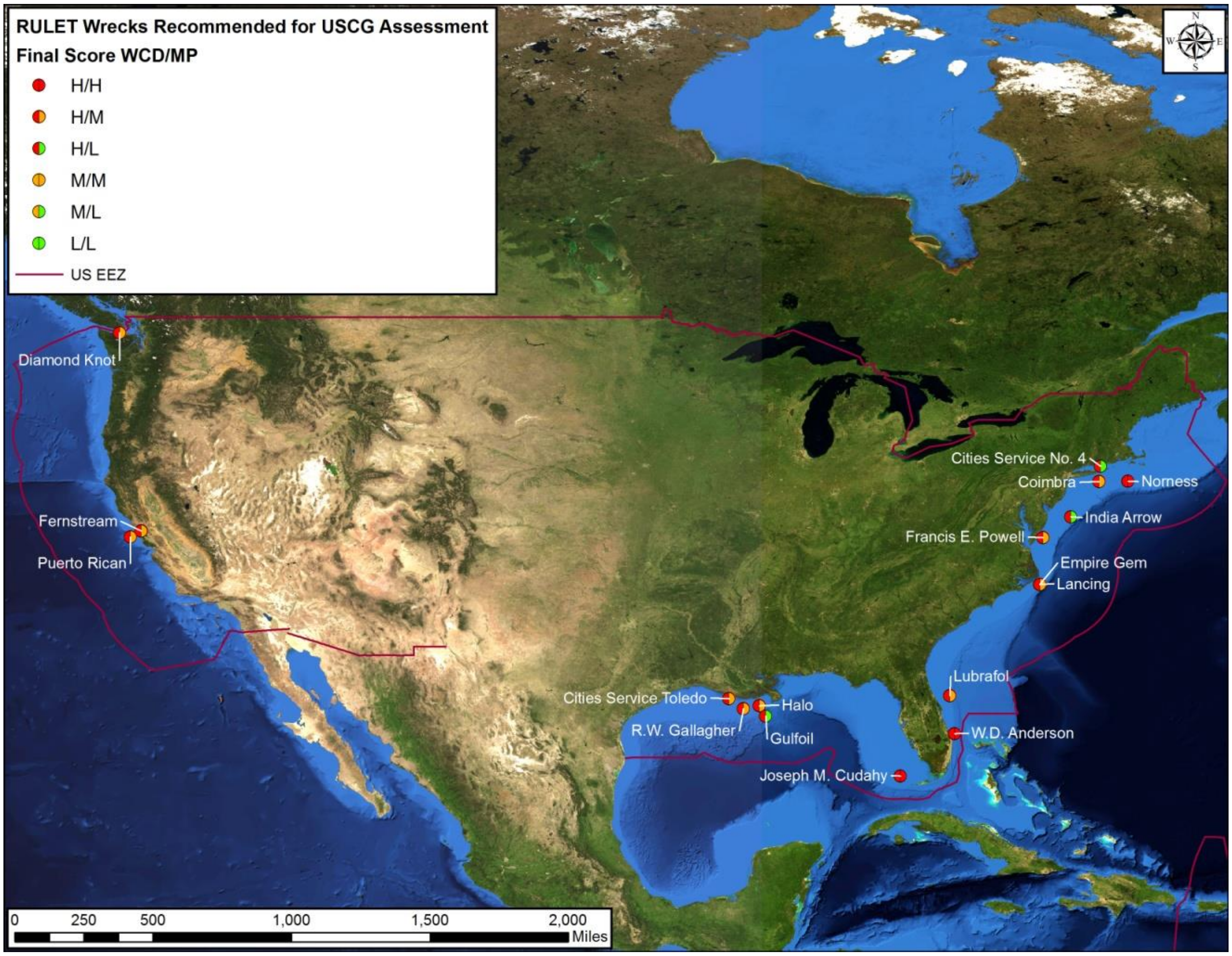

Figure 3. The locations of the 17 wrecks NOAA recommended that USCG consider for in-water assessments, showing both Worst Case Discharge and Most Probable Discharge for each wreck.

USCG districts and sectors are starting to incorporate the RULET data into local and regional oil spill contingency plans. The process of familiarizing the interagency Regional Response Teams; various District, Sector, and Area Committee personnel; interested members of industry; and the general public has been challenging. NOAA spent a considerable amount of time making presentations to Regional Response Teams, Sector and District personnel, as well as a broad range of industry groups including the Spill Control Association of America, the American Salvage Association, the Association of Petroleum Industry Cooperative Managers, the New Jersey Council of Dive Clubs, and the Lawyers Committee for Cultural Heritage Preservation. Interest in this topic originates from many different sources, from media interests; to salvage, diving, and spill response professionals looking to improve capabilities; to family members to trying to understand what happened to lost relatives. This breadth of interest has made fielding information inquiries from the press and others challenging, as expectations are widely different.

Most of the wrecks in RULET are casualties from World War II's Battle of the Atlantic and are more than 70 years old, with some close to 100 years in age. Federal actions, such as oil pollution removal, should include an assessment of historical significance under Section 106 of the National Historic Preservation Act (NHPA) for any wreck more than 50 years old, as they can be irreplaceable time capsules for pivotal moments in American history. NHPA Section 106, or implementation of the Section 106 Programmatic Agreement, triggers a consultation process that will likely require documentation activities that can be incorporated into the initial remote sensing and in-water assessments (Symons 2014) Pollution recovery actions should be conducted in such a way as to minimize the potential impact to the historical integrity of the wreck. U.S. Merchant Marine vessels lost during WWI and WWII are also eligible for protection under the Sunken Military Craft Act, as these vessels were assigned to the War Shipping Administration. Many are either civilian or military gravesites and merit the deference and respect as such.

CONCLUSIONS:

So what does this mean for the pollution response community? The U.S. has taken a proactive step to better understand our pollution risks and may have provided a template for other nations to consider for similar assessments. In some parts of the world, munitions may be a more significant hazard than oil. While munitions and hazardous material cargos are a concern in the U.S., and their presence was noted on vessels as part of the risk assessment, they were outside the scope of this study. Just as all politics are local, each risk assessment must be tailored to local, regional, and national needs, as appropriate. While the RULET assessment was national in scope, the team was well aware that local and regional issues would be significant elements of any decisions the USCG undertakes in determining which wrecks which merit additional assessment and pollution removal activities. Under the Oil Pollution Act of 1990, the responsibility for making the decision on *in-situ* assessment and recovery activities rests with the USCG. The USCG is incorporating the 87 risk assessments into its Area Contingency Planning processes and is considering how to evaluate this information locally. For some Districts, RULET sites may not be the most significant priority in comparison to maritime domain awareness issues or vessel traffic management. Given that NOAA and the USCG have made all of the reports publically available and accessible, it provides a greater sense of transparency to the project and may provide the public some insight into spill preparedness planning activities.

While pollution recovery work can be funded by the Oil Spill Liability Trust Fund, surveys to locate or monitor a non-leaking wreck cannot. The USCG will need to work with local and regional partners and consider a broad range of sources to gain information on these sites. USCG is reaching out to local recreational divers; fishermen; and academic, governmental, and industry partners to provide additional “eyes on the water” and help monitor sites and identify wreck sites with unconfirmed locations. This “citizen science” approach can provide more information about specific RULET targets and result in a public that is more informed about spill response. This process inevitably will reveal more information about RULET sites that may rule them out as pollution threats or elevate the need for assessment as well as identify wrecks that may have been overlooked in the analysis.

RULET sites might be useful as scenarios for local or regional spill response exercises. RULET can be used as an opportunity to evaluate response and preparedness activities, to provide scenarios for ecological risk assessments, to evaluate alternative response technologies, or to test new remote sensing technologies that could be useful for everything from spill response to underwater exploration. Field tests of new equipment and training of personnel in the use of new equipment may also be options for surveys of opportunity, particularly for remote sensing equipment including ROVs, AUVs, and side scan sonar. This may be a more likely option for the wrecks that are in the middle range for risk. Another side benefit of RULET has been the ability to engage the public and increase awareness of contingency planning or spill response. This awareness may help generate a higher level of trust with the general public during a spill response.

NOAA's interests in shipwrecks include its roles as a scientific support coordinator to the USCG for pollution responses, as a manager of living marine and cultural resources, and as the nations' chart maker to ensure that wrecks are properly marked for safe navigation. The RULET risk assessment builds on NOAA's technical expertise and its role as trustee for coastal and marine resources. This integrated approach provides for an efficient and effective response, minimizing the harm to people, reducing negative impacts to the economy and enhancing environmental recovery.

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