Designing a Submerged Oil Recovery System

February 11, 2011

Kurt A. Hansen,
U.S. Coast Guard R&D Center,
1 Chelsea Street
Groton, CT, 06355

Bill Hazel
Marine Pollution Control
8631 West Jefferson
Detroit, MI 48209

Leo Guidroz
American Pollution Control
Oil Stop Division
1208 Peters Road
Harvey, LA 70058

Dr. Gregory W. Johnson
Alion Science and Technology
216 Broad St. Suite 204
New London, CT 06320

ABSTRACT

For spills of submerged oil, current methods are inadequate to find and recover the oil with responders having to reinvent the techniques on each occasion. The Coast Guard R&D Center (RDC) has embarked on a multi-year project to develop a complete approach for recovery of spills of submerged oils. This paper describes the multi-phased approach which addresses detection of oil on the bottom and development of a recovery system. The designs for three vendors are presented for recovery systems. Prototypes are currently being built and will be tested later in 2011.

BACKGROUND

Even though heavy (sinking) oils have historically accounted for a small percentage of spills, environmental and economic consequences resulting from a spill can be high. Heavy oils can sink and destroy shellfish and other marine life populations in addition to causing closure of water intakes at industrial facilities and power plants. The underwater environment poses major problems, including: poor visibility, difficulty in tracking oil spill movement, colder temperatures, inadequate containment methods and technologies, and problems with the equipments' interaction with water. The National Academy of Science recognized these issues and developed a report that provided a baseline for responders (NRC 1999).
But many 32 of the techniques have rarely been used; with divers being utilized as the primary option in most cases.

Since the NRC study, other work has been done to analyze the techniques (Elliott 2005). The International Maritime Organization (IMO) sponsored a forum in 2002. (Brown et al. 2002, Parthiot 2002, Cabioc'h 2002). While efforts have focused on the first problem of finding the oil (Parthiot 2004, Hansen 2009, Hansen and Fitzpatrick 2009) little has been done on recovery efforts although there have been lessons learned during specific responses. A workshop, co-sponsored by RDC in December of 2006 also reemphasized research needs. (CRRC 2007) A study and summary of past experiences especially with respect to the two latest spills was funded by RDC (Michel 2008) and a behavior study was funded by the United Kingdom Maritime and Coastguard Agency (Rymell 2009). This paper describes the next step of developing an integrated system that can provide the full operational capabilities of detection and recovery of oil sitting on the bottom of the sea floor.

SPECIFICATIONS FOR RECOVERY TECHNIQUES

The typical method of recovering oil on the bottom of the sea floor is for a diver to take down a suction hose so that a pump can move the oil to the surface. For shallow spills the pump is located on a vessel or pier, and it discharges into some type of holding tank. For deeper oil submersible pumps are attached to the diver's hose and intermediate pumps may also be needed at the surface. The issues with this approach are lack of visibility and endurance for the diver, concerns about diver safety and the large amount of water and sediment collected along with the oil. In addition, the methods used for the separation of the oil from the other components vary as the oil, sediment and water temperature change. The main objective of the specifications is to define a fully integrated system that includes detection, recovery and waste processing. The specifications are designed to overcome the lack of visibility and endurance of divers in addition to handling a large amount of water and sediment along with the oil during the actual recovery. The specifications are:

- Detects and identifies any heavy oil on the sea floor with 80% certainty
- Geo-references oil locations to within 5 meters in accuracy
- Disperses minimal amounts of oil or bottom material into the water column
- Provides recovery for all sea floor conditions
- Operates in fresh and sea water conditions
- Operates in water depths of up to 200 feet
- Is easy to operate and requires minimal training and maintenance
- Is easily de-contaminated and durable
- Operates in water currents at the surface of up to 1.5 knots
- Deploys and operates in up to 5 foot seas
- Operates during the day and night
- Sets up within 12 hours of arriving on site
- Viscosity: Operates in the range of 2000-100,000 centiStokes
- Includes a decanting system that can handle the heavy or refloating oil
- Includes a process to complete "polishing" of the resultant water for disposal
- Has minimal impacts on benthic resources

It was recognized that not all of the specifications could be evaluated during a test in a tank but could be described in the design documentation.

DESIGN CONCEPTS

Three vendors were awarded contracts to develop designs to meet the specifications. The prime vendors teamed with other companies to provide additional expertise. Each vendor has addressed the detection, recovery and processing of the recovered material.

REMOTELY OPERATED VEHICLES (ROV) SYSTEM

A design concept called Sea Horse (SEagoing Adaptable Heavy Oil Recovery SystEm) has been designed using ROVs. It uses high-resolution sonar coupled with highly accurate 3-D positioning, ROVs and commercially available generators and pumps. Two ROVs have been identified as potential options for this system. In developing a system that fills the niche of a lightweight system, the three major aspects considered to be crucial were: mobility, flexibility, and low cost. This design should provide the ability to deploy multiple small systems and to respond rapidly.

Detailed System Design

The complete Sea Horse system consists of three major subsystems: detection, recovery, and decanting plus auxiliary equipment. (See Figure 1).

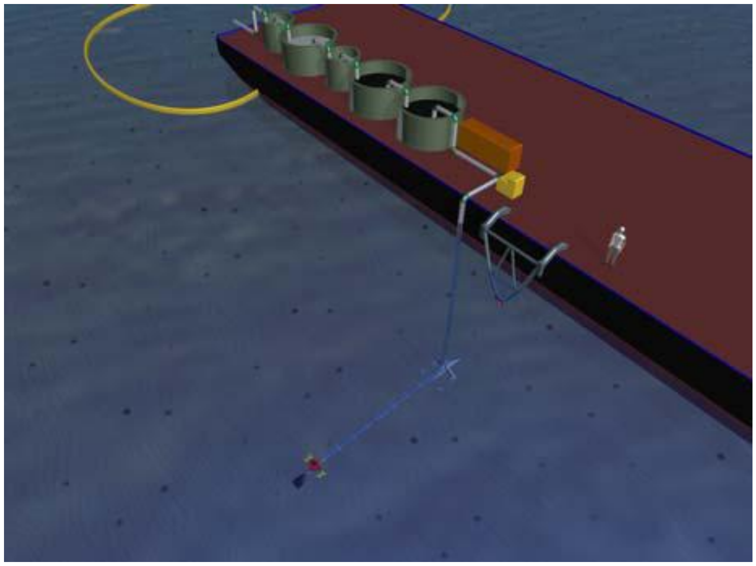

Figure 1: Detection System

A sonar system (preferably a multi-beam system) is temporarily mounted on a vessel of opportunity (survey vessel) for wide-area searching. The navigation system, plus Global Positioning System (GPS) receiver and a heading/roll/pitch sensor, is mounted on the survey vessel for georeferencing the sonar data. A combination of commercial-off-the-shelf (COTS) and custom-developed software is used to identify 99 oil in the sonar imagery. An inexpensive "mini" ROV is used for underwater confirmation of oil. (See Figure 2).

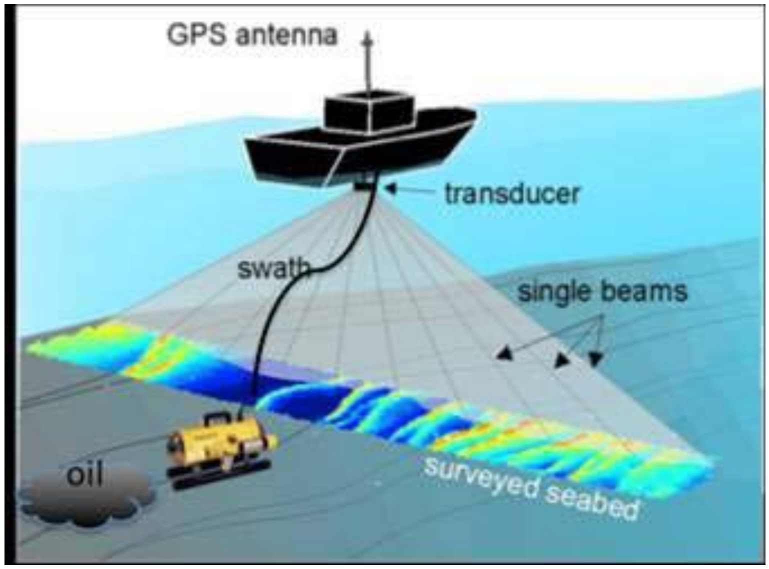

Figure 2: Detection System Configuration

Recovery System

The recovery system (See Figure 3) consists of the ROV-powered sled, the pump, the nozzle, and the hoses. The yellow cylinders on either side are the commercial ROVs. The pump (white) is mounted on the frame (gray) in the middle. The red box over the pump is the flotation-for-buoyancy compensation. An example nozzle (black) is shown on the intake side connected to the pump by the short green hose. The large (4-6”) discharge hose (black) is shown connected to the discharge side of the pump. The discharge hose also has flotation (white) strapped to it to keep the hose floating just off the sea floor. A multi-beam sonar is temporarily mounted to the recovery/decanting barge to track the ROV and help guide the Sea Horse. A system is mounted on the barge to geo-referenced the multi-beam sonar data.

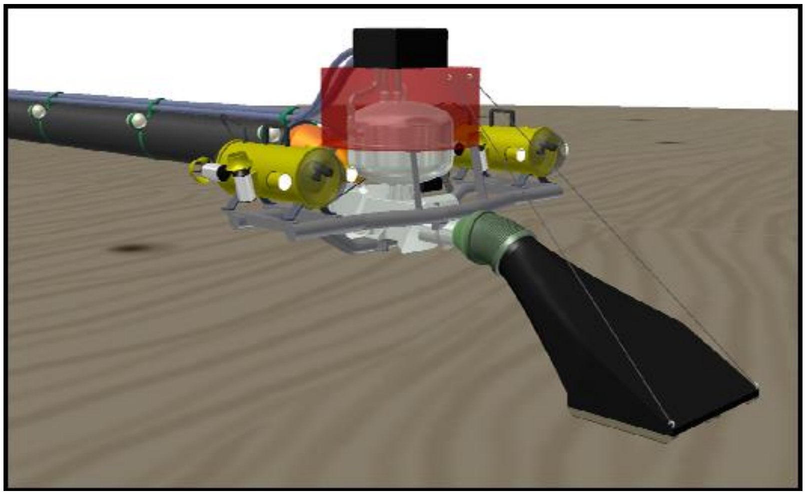

Figure 3: Sea Horse Recovery System.

Decanting System

The decanting system can be mounted on a barge or on the shore. It consists of a cascade of tanks acquired locally with the number of stages designed to suit a particular spill situation. The discharge of water and oil from recovery system goes into a first stage (settling) tank; heavy materials settle; and water is decanted into a second tank using a submerged pump inlet. Skimmers and/or sorbent snares are placed on top of downstream tanks and the liquid cascades down .into second and subsequent tanks. The "polishing" tank is filled with sorbent oil snares. Multiple lightweight devices with cyclic-acting pumps may allow uptake to be more efficient. The system is set up to be modular and can be configured to handle a variety of combinations of oil, water and sediment.

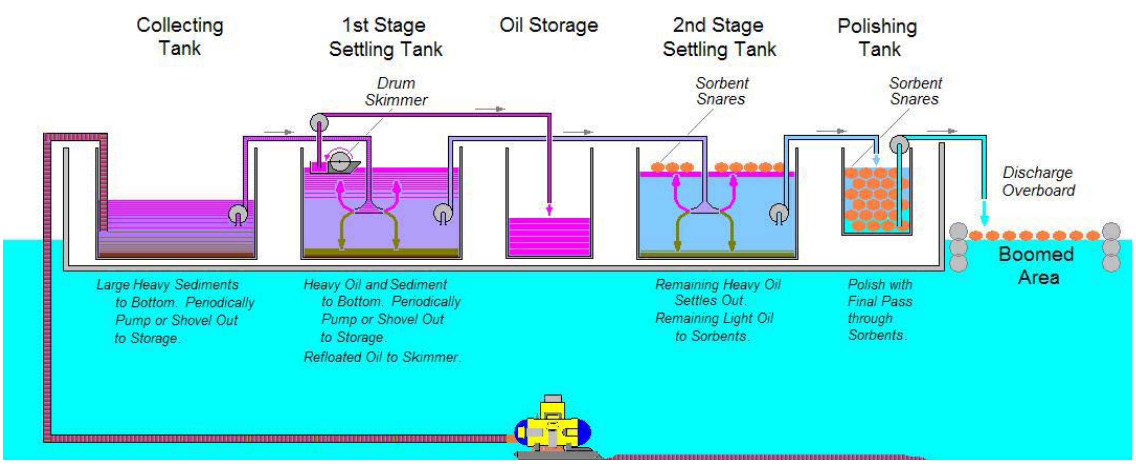

Figure 4: Schematic of General Purpose Decanting System.

CONCEPT OF OPERATIONS

The Concept of Operations (CONOPS) can be broken into two phases: detection and recovery.

Detection Phase

During the initial detection phase, the goal is to map out areas of submerged oil using a hull-mounted sonar system and a single ROV as described previously. This keeps the 144 amount of material to be shipped to a minimum and a small vessel can be used making it easier to rent a vessel on-scene. When the 145 software indicates a likely patch of submerged oil, the ROV is sent down to confirm this using video and high-resolution multi-beam sonar. The confirmed areas of oil are marked for immediate recovery because oil on the bottom of the sea floor can be highly mobile. Since the shipping and installation of these relatively small components are very quick and easy, this phase can commence within the 12-hour window. Detection operations can continue as needed.

Recovery Phase

Recovery of the oil requires a good deal more equipment to be on-scene and it is envisioned that most of this equipment would be sourced locally and then, assembled on-site. The barge can be anchored near the submerged oil patches, and the recovery phase can start. The same hull-mounted sonar used on the detection survey vessel is used on the barge to track Sea Horse and assist with guiding it to the located patches of submerged oil. Once all patches of oil within range are recovered, the barge is relocated to be near the next grouping of oil patches. The recovery operations can either use the detection confirmation ROV as part of Sea Horse or run detection in parallel with recovery operations using multiple ROVs and sonar systems.

Development Needed

There are two main areas of development: the pump and the image processing algorithms. The first pump option is a pneumatic-operated submersible pump manufactured by Chicago Industrial Pump Corp. that is referred to as their Pitbull pump; is attractive because of its low cost. It provides a flow rate of 40-80 gallons per minute (GPM). However, it is heavier than the alternative Lamor GT A20 pump and it may not work with the most viscous oil. In addition, the Pitbull pump will have limitations in its standard configuration. Testing will be required to determine the exact limitations in viscosities that can be handled and in pumping rates that can be expected. In the image-processing arena, work to date shows the potential for using multi-beam sonar for submerged o 170 il detection, but there are still a number of questions that need to be investigated before deployment of a prototype system. In Phase II we will determine how the frequency of the sonar impacts the picture and test multiple frequencies for enhanced recognition of oil. We will also investigate whether the bathymetry data can augment the amplitude of the backscatter sound to locate potential deep spots for accumulation of the oil. Further, since the recognition of oil pixels is tightly coupled to the choice of the threshold we plan to examine this aspect closely looking at statistical and Markov models and we will leverage the use of classic digital image processing algorithms.

SUBMERGED OIL RECOVERY USING A MANNED SUBMERSIBLE

Marine Pollution Control (MPC), of Detroit, Michigan, has developed and tested a new design concept for improved submerged oil spill response capability using proven and emergent technologies. The new design concept (See Figure 5) refines the pumping and reclamation systems, but replaces the requirement for a team of commercial divers through incorporation of a manned submersible connected to the surface by a robust, multipurpose marine umbilical system. A multi-stage separation process is also being refined.

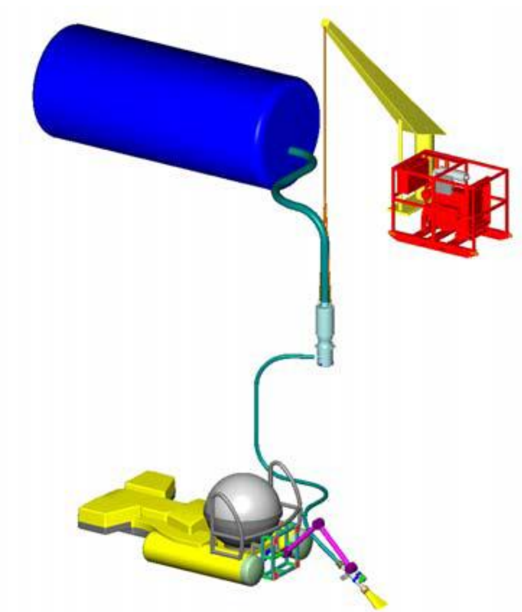

Figure 5: General Arrangement of the Design Concept
(MPC US Patent #7,597,811)

This innovative design o 203 offers a number of valuable performance benefits at depths up to and potentially exceeding 200 feet. The logistical capability of the submarine unit will allow for increased operational bottom time and will minimize health and safety hazards associated with submerged oil detection and recovery operations. Another critical benefit of the system is the virtual elimination of physical interaction with the contaminated bottom, increased access to areas where oil has accumulated, and reduced probability for contaminant dispersal. The system safely positions an oil recovery specialist at the site of a submerged oil mass, with a direct view of the work area and with enhanced oil detection sensors (other than visual) and recovery controls at hand, all while working within a comfortable 1 atmosphere chamber. (See Figure 6)

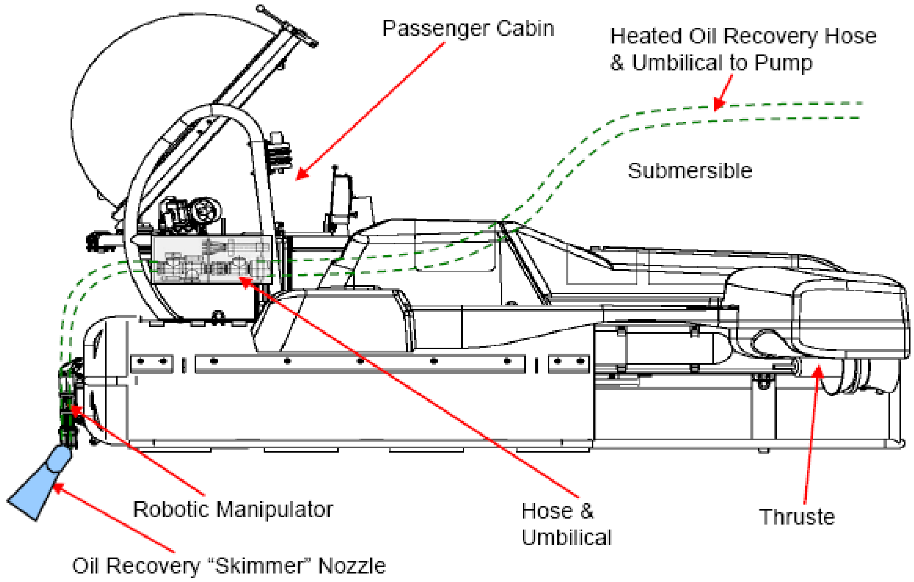

Figure 6 General Arrangement of the Manned Submersible Outfitted for Submerged Oil Surveillance and Recovery.

The system includes continuous voice and data transfer capability with support teams on the surface vessels above as well as geo-referencing data, live video and audio feeds, multi-sensor operator feedback functionality, subsurface lighting, and other related operational capacities and capabilities. Two subsurface enhanced oil detection technologies previously evaluated by the RDC (Hansen and Fitzpatrick 2009) have been worked into the design: oil discriminating multi-beam sonar and polarized fluorescence.

Design Concept Testing

The design concept, in prototype form, was field tested by MPC at two separate locations Lake Travis, Texas in 2006 and Detroit, Michigan in 2007. In both of these cases, the submerged oil recovery pumping apparatus was connected to a manned submersible device and was used in operational configuration to recover simulated oil from the bottom of a water body. Additional field testing of the pumping apparatus was performed in 2010 to refine design ideas and guide further development of the system.

Development

The second phase will consist of refinement of the equipment and building and testing prototype-specific components of the design concept at the OHMSETT (the National Oil Spill Response Research & Renewable Energy Test Facility) testing tank in Leonardo, N.J. using submerged oils. These tests, as currently envisioned in 2011, will include proof and baseline testing of the recovery and detection aspects of the system, as well as their deployment in conjunction with appropriate oil/water separation technologies to demonstrate overall system capacities. In the future, MPC intends to perform additional field testing of the pumping and detection apparatus in diverse marine environments to extend the operational capacity of the design concept. This will include enhancement of the pump and debris control as well as the development of options for the separation process.

SUBMERSIBLE DREDGE

The Sub-Dredge is a remote-controlled pumping vehicle designed by Tornado Motion Technologies (TMT) that also replaces the divers. It relies on an external detection system for initial detection, but utilizes underwater cameras for recovery. 250 The separation system is also standard, but is being refined.

Sub-Dredge

The key component of the entire system is the Sub-Dredge. With environmental consciousness being at the forefront of today's dredging operations, the Sub-Dredge was created to provide effective dredging with minimal turbidity and left-over residuals. The Sub- Dredge is un-manned and controlled safely from the surface and it is self-propelled on the sea floor by hydraulically driven tracks. Its patented EDDY Pump incorporates a hydro dynamically built volute, along with a precision-engineered geometric rotor. This combination allows it to generate much greater suction than any centrifugal pump; with production rates of up to 350 cubic yards per hour and 80 percent target materials. The suction head incorporates a rotating shroud to fend off larger rocks and debris. It can pump materials to the surface from 200 feet deep in single stage mode and up to 450 feet deep in double-stage (booster pump) mode. It is capable of going under, over, or around obstacles to efficiently remove sediment or oil. The most distinguishing feature of the Sub-Dredge is its ability to adjust the depth of contaminant removal in millimeter increments. This minimizes the volume of clean materials removed with the contaminants, while minimizing turbidity and re-dispersal of contaminants.

Figure 6: Sub-Dredge

The conical shape 270 of the rotating guard creates flat contact with the ground. Its capabilities enable it to pump at high production rates, to minimize over-dredging, and safely and to precisely remove contaminated sediments and submerged oil.

Top-Side Support

The goal of the Sub-Dredge is to target the contaminants and minimize the amount of non-contaminated sediments brought to the surface, but an appreciable amount of water will be expected along with the recovered oil. This concept will use hopper barges, holding geotextile dewatering tubes to collect sediments. The primary reception tanks for the Sub-Dredge's pumped materials will be mobile 'Frac' Tanks that are readily available throughout the coastal areas of the United States.

The first phase of separation will be to refloat the oil for physical collection using a conveyor belt oil skimmer; the open discharge will be splashed into an inverted cone-shroud installed in the frac tank. This method has shown positive results during "Orimulsion" recovery equipment testing. (Deis et. al. 1995)

The second phase of separation will be performed by the EVTN Voraxial® Separator (Figure 7) which is a patented, in-line, continuous-flow separator capable of pumping and simultaneously separating up to three components, such as oil, water, and solids.

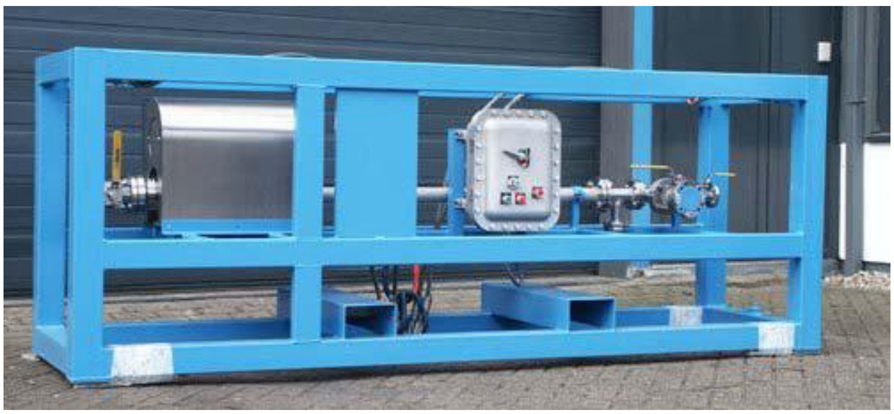

Figure 7: Voraxial Separator

The remaining wet solids will 295 be transferred from the frac tank to the geo bags housed in the hopper barge(s) for dewatering. The resultant liquid from the dewatering will be sent through the Voraxial for a third phase of oil/water separation. The resultant water from the second and this phase separation processes will be analyzed for suitability to discharge in-situ (See Figure 8).

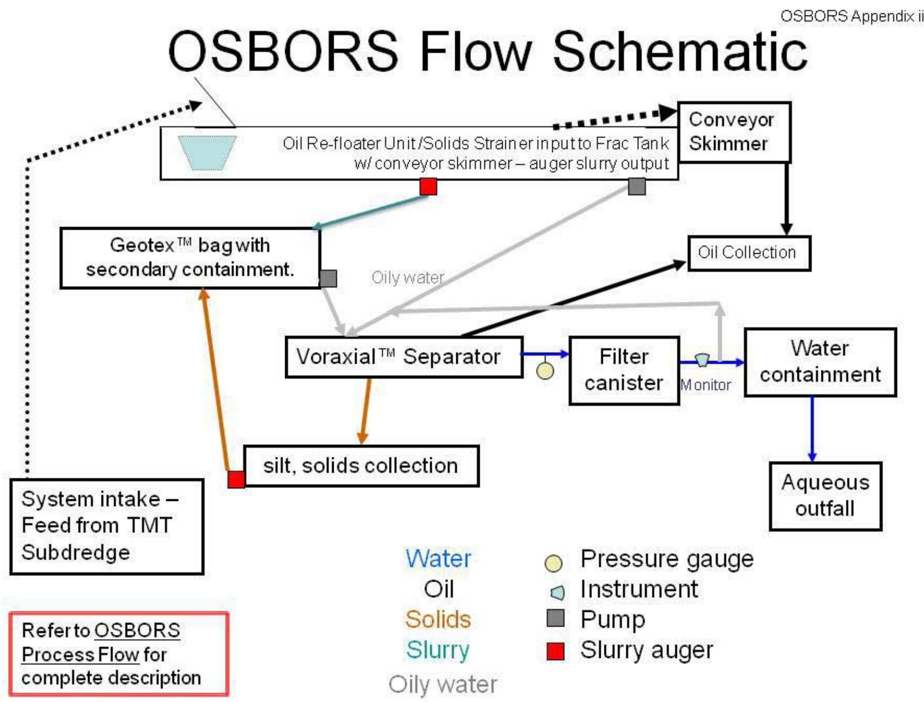

Figure 8: OSBORS Layout

Challenges and Modifications

The most glaring challenge facing the OSBORS team was the size and weight of the Sub-Dredge. The prototype unit weighed almost 18,000 pounds (8000 kilograms.). Its heavy-duty tubular steel structure and the electric motor driven 8-inch EDDY pump were the main contributors to the weight factor.

The team agreed that the high volume of the 8-inch EDDY pump was not necessary as a lower volume pump did not necessarily reduce the recovery rate. A 4-inch EDDY pump could provide the same discharge head; therefore sizing down did not translate to a loss of effective depth of operation.

A pump to be powered with a hydraulic drive, powered from a surface mounted prime mover has been designed to replace the heavy electric motor on the Dredge itself. With a smaller pump the size of steel tubing could be reduced to save more weight. The rubber track drives were widened to provide more stability and less incidence of sinking into softer silts. The addition of buoyancy compensation bags will further reduce the tendency to sink in softer silts.

SUMMARY

Three unique systems have been designed that appear to meet the required specifications, although they have separate applications. The components should be useful in combination if other scenarios are encountered. The problems with using divers and standardizing the approach for future submerged oil spills will be solved, and future deployments could further refine the systems.

NEXT STEPS

The systems are scheduled to be built and tested at Ohmsett in the fall of 2011. Due to the depth limitations, parts of each system will need to be simulated. The test may not fully evaluate the capabilities of the decanting and polishing systems although multiple types of oil and sediment will be part of the testing process. A field test of the system is tentatively scheduled for 2012 so that the systems can show their full capabilities without oil.

NON-ATTRIBUTION POLICY

Opinions or assertions expressed in this paper are solely those of the author and do not necessarily represent the views of the U.S. Government. The use of manufacturer names and product names are included for descriptive purposes only and do not reflect endorsement by the author or the U. S. Coast Guard of any manufacturer or product.

REFERENCES

Brown, C. E., M. F Fingas, R. L. Gamble and G. E Mysliski. 2002. "The Remote Detection of Submerged Oil", 3*rd R&D Forum on High Density Oil Spill Response*, International Maritime Organization, Brest, France, March 11-13.

Cabioc'h, F. 2002, "Sunken Hydrocarbons and Chemical Products: Possible Responses and Available Methods", *3rd R&D Forum on High Density Oil Spill Response*, International Maritime Organization, Brest, France, March 11-13.
Coastal Research and Response Center (CRRC). 2007. Submerged Oil – State of the Practice and Research Needs, Durham, NH, December 12-13.

Deis, D.R., Tavel, N.G., Masciangioli, P., Villoria, C., Jones, M.A., Ortega, G.F., and Lee, G.R. 1997. "Orimulsion Research and Testing and Open Water Containment and Recovery Trials," *Proceedings 1997 International Oil Spill Conference,* American Petroleum Institute, 9 pages.

Elliott, J., "An Analysis of Underwater Oil Recovery Techniques 2005." *Proceedings 2005 International Oil Spill Conference*, American Petroleum Institute, 11 pages.

Fant, J.W. and K.A. Hansen. 2005. "U.S. Coast Guard Oil Spill Remote Sensing: Preliminary Laser Fluorosensor Studies", in *Proceedings of the Twenty-eighth Arctic Marine Oilspill Program Technical Seminar*, Environment Canada, Ottawa, ON, pp. 861-872.

Fant, J.W., and K.A. Hansen. 2006. "U.S. Coast Guard Laser Fluorosensor Testing", in *Proceedings of the Twenty-ninth Arctic Marine Oilspill Program Technical Seminar*, Environment Canada, Ottawa, ON, pp. 951-964

Hansen, Kurt A. 2009, "Research Efforts for Detection and Recovery of Submerged Oils," Proceeding of the 2009 *Interspill Conference*, May 12-14, Marseille, France.

Hansen, Kurt .and Michele Fitzpatrick. 2009, Heavy Oil Detection (Prototypes) –Report CG-D-08-09, US Department of Homeland Security, June 2009.

Michel, J. 2008, “Spills of Non-Floating Oils – Evaluation of Response Technologies: *Proceedings 2008 International Oil Spill Conference*, American Petroleum Institute. National Research Council (NRC) 1999. Spills of Non-Floating Oils, Risk and Response National Academy Press, Washington, D.C.

Parthiot, F., E. De Nanteuil, F. Merlin, B. Zerr, Y. Guedes, X. Lurtin, J.-M Augustin, P. Cervenka, J Marchal, J.P. Sessarego and R.K. Hansen. 2004, “Sonar Detection and Monitoring of Sunken Heavy Fuel Oil on the Seafloor”, *Proceeedings of the Interspill 2004 Conference*, Trondheim, Norway, June 14-17.

Parthiot, F. 2002, “Monitoring of Sunken Fuel Oils”, *3rd R&D Forum on High Density Oil Spill Response*, International Maritime Organization, March 11-13.

Rymell, Matthew, 2009, RP595, Sunken and submerged oils – behavior and response, A Report for the Maritime and Coastguard Agency, BMT Cordah Limited, February, 2009.