Test Plan for the Performance Evaluation of the Maritime Solutions Inc. Ballast Water Treatment System

Maritime Environmental Resource Center

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1. Background and Objectives of MERC Technology Evaluations

The Maritime Environmental Resource Center (MERC) is a State of Maryland initiative that provides test facilities, information, and decision tools to address key environmental issues facing the international maritime industry. The primary focus is to evaluate the mechanical and biological efficacy, costs, and logistical aspects of ballast water treatment systems and to assess the economic impacts of ballast water regulations and management approaches. A full description of MERC structure, products, and services can be found at www.maritime-enviro.org.

To address the need for effective, safe, and reliable ballast water treatment systems to prevent the introduction of non-native species, MERC has developed as a partnership between the Maryland Port Administration (MPA), Chesapeake Biological Laboratory/ University of Maryland Center for Environmental Science (CBL/UMCES), U.S. Maritime Administration (MARAD), National Oceanic and Atmospheric Administration (NOAA), Smithsonian Environmental Research Center (SERC), and University of Maryland (UM) to provide independent performance testing and to help facilitate the transition of new treatments to operations. Treatment evaluation efforts will also take advantage of expertise and the rigorous technology evaluation format/process developed by the Alliance for Coastal Technologies (ACT, www.act-us.info). ACT is NOAA-funded distributed testbed, headquartered at CBL/UMCES, dedicated to fostering the development and adoption of effective and reliable sensors for studying and monitoring coastal environments.

The following protocols describe how MERC will evaluate the performance characteristics of the Maritime Solutions, Inc. (MSI) Ballast Water Treatment System through objective and quality assured "pilot-scale" testing (dockside testing at a flow rate of 200m^3/hr). This new test plan is a follow-on to initial MERC evaluations conducted in 2008 and includes refinements to protocols and testing facilities. Results from valid tests in 2008 will be combined with data collected during the spring of 2009 (described below) and presented in a final report.

The goal of this specific MERC evaluation is to provide shipping lines, regulators, and flag states with an independent and credible assessment of treatment performance under realistic conditions. Therefore, the data and information on performance characteristics will cover legitimate information that users need and will compare performance against the International Maritime Organization (IMO) D2 regulatory discharge standards.

It is important to note that MERC itself does not certify technologies or guarantee that a technology will always, or under circumstances other than those used in testing, operate at the levels verified. MERC does not label or list technologies as acceptable or unacceptable but will present results in a way that can be used to determine regulatory compliance by appropriate agencies of certification societies. Final reports on technology performance will be reviewed by the MERC Advisory Board and provided to MSI and the MERC funding agencies prior to public release.

2. Introduction to Technology

The MSI Ballast Water Treatment System (UV), patent pending, designed to exceed IMO alternative treatment requirements for low to moderate flow rate shipboard applications, utilizes Ballast Safe Filtration Company's proprietary self-cleaning filter design to separate the components of the influent ballast water in its primary treatment stage. As a primary treatment, the filter is intended to remove silt and sediment, organic materials and all organisms >25 microns (nominal) in size from the influent ballast water and then immediately return these materials back to the source waters in a small fraction of the water stream. The remaining 'clean' water stream is then treated by Hanovia UV In-Line+ UV units in a secondary treatment stage to address the remaining organisms <25 microns. Equally as significant as the capability of its two treatment stages, the MSI System (UV) has been fully integrated and is controlled by a proprietary ABB Instrumentation water quality monitoring and flow control system designed to assure and document effective treatment by continuously monitoring a number of water quality parameters including total suspended solids (TSS) and UV transmission rate, automatically adjusting flow rate to assure proper treatment, and recording all required water quality and system operation parameters.

3. Protocols for Pilot-Scale Evaluations for the MSI Treatment System

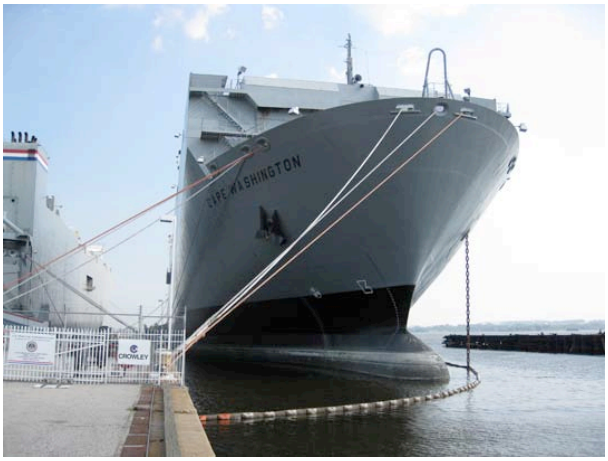
Basic Experimental Design:

The specific protocols described below are based on the IMO G8 guidelines and the US Coast Guard supported ETV protocols under development. The fundamental approach of MERC is to conduct independent, scientifically-sound, rigorous, and quality assured evaluations of ballast water treatment systems. Therefore, MERC relies on challenging ambient conditions found in the Chesapeake Bay, and does not artificially augment test waters, to avoid artifacts and the potential to overestimation of system performance (see Table 1). For example, rapid changes in physical conditions (such as salinity or total suspended solids) as ambient organisms are being brought in with ballast water may cause significant mortality, independent of treatment. Similarly, concentrating natural assemblages of plankton on nets, and introducing them into ballast water being pumped into tanks, can often result in significant handling associated mortality. Given the unpredictable physical and biological conditions found in all natural waters, IMO G8 MEPC 58/23 ANNEX 4, Part 2, Section 2.3.36 is used by MERC as the standard for a valid test trial: “If in any test cycle the average discharge results from the control water is a concentration less than or equal to 10 times the values in regulation D-2.1, the test cycle is invalid”.

Table 1. Ranges of various physical and biological parameters in ambient water during the testing season (March/April – October/November) in the Port of Baltimore in comparison to ETV/USCG and IMO G8 recommended challenge conditions. Port of Baltimore data collected by MERC and various academic and agency studies or monitoring efforts in the general location of the *Cape Washington* (Patapsco River).

Parameter	Proposed ETV/USCG†	Recommended IMO G8‡	Historic Ranges* Port of Baltimore
Temperature (^{o}C)	10 - 35	–	4 - 28
Salinity (psu)	5 - 25	3 - 32	5 - 15
Total Suspended Solids (mg/l)	17 - 24	> 50	1 - 60
Particulate Organic Carbon (mg/l)	1 - 2	> 5	0.5 – 6.0
Dissolved Organic Carbon (mg/l)	4 - 8	> 5	2 - 10
Zooplankton (> 50 μm) / m^3	> 10,000	> 100,000	10,000 - 150,000
Phytoplankton (10 - 50 μm) / ml	> 100	> 1,000	500 – 10,000
Heterotrophic Bacteria cfu / ml	> 1,000	> 10,000	10,000 - 10,000,000

† Generic Protocol for the Verification of Ballast Water Treatment Technologies: Draft v4 2008, US EPA Environmental Technology Verification (ETV) program under contract to US Coast Guard.
‡ IMO Guidelines for the Approval of Ballast Water Management Systems (G8), October 200, Annex 4 Resolution MEPC.174(58).
* TSS, POC and DOC (2004-2007) MD DNR Chesapeake Bay Water Quality database: www.chesapeakebay.net/data_waterquality.aspx. Zooplankton (1998 – 2002) and phytoplankton (2004-2007) Chesapeake Bay Program: www.chesapeakebay.net/data_plankton.aspx. Bacteria (1998 – present) Cowell and Huq, University of Maryland; Louis et al. 2003, AEM 69:2773-2785.



MERC will evaluate the biological efficacy of the MSI filtration + UV ballast water treatment system onboard the MARAD vessel M/V *Cape Washington* while docked in Baltimore Harbor, Maryland (right). The ballast system of the *Cape Washington* has been modified to allow for water at a flow rate of 400m^3/hr to be split equally, and delivered simultaneously, to a "control" (untreated) ballast tank and a "test" (passing first through the treatment system) ballast tank, each at 200m^3/hr. The ship's ballast tanks to be used for the required holding time of five days are essentially identical in size (~ 650 m^3) and structure. Each tank will be filled to approximately 250 m^3 for test trials. A detailed drawing of the modified ship ballast system can be found on page 14.

Care was taken in the design of the MERC *Cape Washington* test systems so that water entering the control and test tanks is handled (e.g., passing through same pump and similar piping) as close to identical as possible, aside from passing through the MSI treatment system for treatment. Three test system performance runs have been conducted to assure that water in both control and test tanks have near identical physical and biological conditions. While initial physical and biological conditions are subject to natural variability, the MERC test system itself

is not a source of mortality (data available upon request). The test ballast tank will also drained and manually rinsed/cleaned prior to conducting the first evaluation trial, and rinsed/flushed with 20 – 30 m^3 of potable water and drained completely between trials, to avoid the possibility of residual live organisms in the bottom of the empty test tank influencing results.

MERC will conduct a maximum of four new test trials of the MSI filtration + UV system onboard the *Cape Washington* in 2009 to determine its ability to meet IMO D2 ballast water discharge standards. The inability to successfully complete (without interruption) an individual test trial, or to meet D2 discharge standards for a particular test trial, will be considered a "failure". If a failure is determined to be a result of problems associated with the MERC test system or process (e.g., problem with ship's ballast system), the test trial will be discarded and repeated. If the failure is determined to be a result of the MSI treatment (e.g., a mechanical failure in the MSI system resulting in an interruption of treatment during a test run or a failure to meet D2 standard for one or more parameters), the results will be noted and included in the final report. Depending on the nature of the failure, one failure on the part of the MSI treatment system may result in the termination of testing prior to the maximum of four test trials. This decision will be made by MERC Senior Management in consultation with MSI staff.

This evaluation will be based on physical and biological characterization of water upon ballasting (uptake of water) and comparisons of organisms in control versus treated water after a five-day, in-tank holding time for the different D2 biological categories. Results will also be presented as concentration of viable organisms per biological category in treated water upon discharge versus IMO D2 standards.

Sampling Design:

Five sequential samples will be taken for each of the following: (A) initial/intake conditions, just prior to the split of control and treated water, (B) initial conditions just downstream of the MSI system during filling of test tank, (C) control water upon discharge after a five-day holding time, and (D) treated water upon discharge after a five-day holing time. Sample volumes and details of the physical, chemical, and biological analyses for each sample are described below. A detailed drawing of the MERC *Cape Washington* test setup and sampling design is available on page 15.

All samples collected to quantify live organisms or water quality will be taken by inline sampling of ballast water during the initial filling or during discharge of water from the ship's tanks by sample ports place in appropriate filling or discharge pipes. All sample ports include a valve and sample tube with a 90^o bend towards the direction of flow, placed in the center of the piping system (based on the design developed and validated by the US Naval Research Laboratory, Key West Florida).

A total of 10 identical conical bottom mesocosms (shown below) have been installed on the *Cape Washington* to allow for precise and controlled sampling during each test trial. Five replicate mesocosms are used to sample initial, challenge conditions at the start of each trial, prior to the split in water to control and test tanks. The second five mesocosm are used to sample after water has passed through the MSI treatment during the initial filling of the test tank. At the end of each trial (after five-days), five mesocosms are used for sampling water from the control tank, and the second five mesocosm for water from the test tank. At each sampling time (initial and after holding time), the designated five mesocosms will be filled to approximately 1.05 m^3 in sequence over 75 to 80 minutes of the 90 minutes required to fill or drain the ship's ballast tanks (i.e., sampling takes place > 80% of the time during filling or draining of tanks). Immediately

after filling of each mesocosm (< 15 minutes), physical parameters of the water will be measured (see below), and then the precise samples volumes described below will be collected for each biological and water quality categories by gravity draining through a bottom valve and tubing. Each mesocosm has been calibrated and marked with known volumes to assure accurate sample collection. Each mesocosm will also be rinsed thoroughly with potable water for a minimum of three times after each use and kept clean and dry between uses.

MERC test and sampling system on the *Cape Washington*.

Quantifying Physical Conditions:

Temperature, salinity, dissolved oxygen, chlorophyll fluorescence, and pH will be measured every 15 minutes during the test trials by two identical multi-parameter probes (calibrated according to manufactures specification) placed, one each, into the control and test tanks. A third hand-held instrument will be used to measure temperature, salinity, and dissolved oxygen of water in each replicate sample (described above) as it is collected.

Initial inline samples (three replicates, 500 ml each) of ballast water during the filling of the control and test tanks will also be collected, filtered, and analyzed for the water quality parameters of particulate organic carbon (POC), dissolved organic carbon (DOC), and total suspended solids (TSS). Sample analyses will be conducted using standard US EPA methods by the certified CBL/UMCES Nutrient Analytical Services Laboratory (www.cbl.umces.edu/nasl). Details can be found in "Protocols for Verifying the Performance of In Situ Chlorophyll Fluorometers" ACT PV05-01 (www.act-us.info/evaluation_reports.php).

Quantifying Viable Organism > 50 µm in size:

Exactly 1 m^3 of water from each replicate (n=5) initial, control, and treated mesocosm will be drained through a 35 µm (50 µm diagonal dimension) plankton net to concentrate the zooplankton for examination under a dissecting microscope. The proportion and total concentration of live versus dead organisms will be determined using standard movement and response to stimuli techniques and this live/dead analysis will take place within 2 hours of collecting the individual samples. Depending on concentrations, quantification of zooplankton in initial samples (upon ballasting) and control samples may require analysis of sub-samples and extrapolation to the entire 1 m^3. Zooplankton samples will then also be fixed with buffered, 10% formalin in 125ml Nalgene bottles and shipped to the SERC for additional taxonomic

evaluations. Total counts and general taxonomic classification will be conducted under a dissecting microscope at 25X, except for some taxa, which will be removed and identified using a compound microscope. Larval forms of invertebrates will be identified to higher taxonomic levels such as order (e.g., Decapoda) suborder (e.g., Balanomorpha) or class (e.g., Bivalvia). Adults will be identified to species in most cases.

Quantifying Viable Organism 10 - 50 µm in size:

Two liters of unfiltered water for each mesocosm will be collected immediately after filling, to determine concentrations of organisms in this size class using four distinct methods (A – D below). All samples will be held in amber Nalgene bottles and transported on ice to laboratories where analyses occur within 3 hours of collection. (A) One sub-sample from the initial 2 l will be fixed with standard Lugol's solution, and placed in a 250 ml amber Nalgene bottles to determine total cell abundances under an inverted compound microscope using grid settlement columns and phase contrast lighting. (B) A second 250 ml sub-sample will be stained using CMFDA (5-chloromethylfluorescein diacetate) as a selective live/viable indicator. Samples stained with CMFDA, are incubated and observed on a Sedgewick Rafter slide using a Leitz Laborlux S modified for epifluorescence. Cells are scored as live when showing strong fluorescence signature under excitation (some cells also showed motility). However, it is also widely accepted that these direct count and staining techniques have limitations (Lugol's does not selectively stain live or dead, various algal species take up CMFDA differently, and other particles in a sample can fluoresce). Therefore, analyses of chlorophyll are also conducted as a conservative indicator of viable organisms. (C) A third sub-samples is filtered (Whatman GF/F 0.7 µm pore, 2.5 cm diameter membrane) and frozen (-80^{o}C) until analysis of total active chlorophyll-a by the CBL/UMCES Nutrient Analytical Services Laboratory using US EPA Methods 445.0 for extractive/fluorometric techniques. (D) Finally a fourth sub-sample is used to determine chlorophyll levels after allowed to regrow under favorable conditions. Algae specific vitamins, minerals, and nutrients (Guillard 1975, F/2 formulation) are added to a sub-sample from each mesocosm and are placed in a standard algal culture light-dark regimen for 48 hours, prior to extractive chlorophyll-a analysis. An increase in chlorophyll, or positive regrowth, indicates that viable phytoplankton were in the samples, whereas chlorophyll levels at or below detection limits of the laboratory analytical method suggests that there was no viable phytoplankton. Although precise abundances of cells/ml cannot be determined for diverse communities of phytoplankton using these types of regrowth experiments, this is a conservative method used to determine the presence/absence of living organisms.

Quantifying Viable Indicator Pathogens:

A one-liter sample of water for each mesocosm is collected to determine concentrations of total heterotrophic bacteria and three specific indicator pathogens, *E. coli*, intestinal *Enterococci*, and toxigenic *Vibrio cholerae*. Total heterotrophic bacteria are enumerated by spread plate method using NWRI agar according to *Standards Methods for the Examination of Water and Wastewater* (21st edition, 2005). The presence and abundance of *E. coli* and intestinal *Enterococci* is determined using a commercially available chromogenic substrate method (IDEXX Laboratories, Inc.; Noble et al. 2003) and 10 ml and 100 ml water sample aliquots. Additionally, concentrations of culturable *E. coli* and intestinal *Enterococci* are determined using a standard USEPA method, namely, membrane filtration on mTEC agar (*E. coli*) (1 ml, 10 ml and 100 ml) and mEA agar (*Enterococcus*) (10 ml and 100 ml). Abundance of total and

toxigenic *V. cholerae* are calculated by filtration and selection on TCBS agar and enumerated using species-specific RNA colony blot (500 µl to 1 ml) and *ctxA* DNA colony blot (1-10 ml). Viable toxigenic *V. cholerae* is assayed with a commercial DFA kit specific for serogroup O1 (New Horizons Diagnostics) using monoclonal antibodies tagged with fluorescein isothiocyanate (FITC) (Hasan et al. 1994).

Sample and Data Management:

We will take advantage of the established SERC ballast water sample labeling and databases format and structure for this evaluation. Sample-labels and record keeping check-lists will be generated using SERC protocols, and data will be stored both in existing SERC databases (servers) and in a MERC repository for analytical data.

Data Analysis:

Although multiple mesocosms, samples, and measures from each tank will be taken, to avoid pseudo-replication, the unit of replication for statistical analyses is each trial (n = 5 or 6). We assume that all measures for a single trial provide one estimate of treatment efficacy. Thus, treatment efficacy for any biological parameter is estimated as changes found before and after trial (percent reduction), and as the difference in concentration between treated water and IMO standards. This approach controls for variation due to temporal changes in environmental conditions.

4. Evaluation Schedule (planned dates based on current plan and may vary)

- MERC Test Plan for MSI finalized and Evaluation Agreement signed by March 27, 2009
- MERC evaluation of the MSI systems initiated by March 30, 2009
- MERC will complete sample analysis and compile data from the evolution by June 2009
- MERC will distribute a draft report on the performance of the MSI system for review by the MERC Advisory Board and MSI by August 2009
- MERC will submit a final report to MPA, MARAD, NOAA and MSI by fall 2009

5. Data Recording, Processing, and Storage

This section describes methods employed during data recording, processing, and storage to minimize errors and assure high quality analyses.

Documentation and Records:

A variety of data will be acquired and recorded electronically and manually by MERC partners (CBL/UMCES, SERC, and UM) during this evaluation. Operational information and results will generally be documented in field/laboratory record books and on the data sheet/chain-of-custody forms (see below). Copies of these raw data will be transferred to the MERC office, which will store it permanently along with the rest of the study data.

Data Review:

All data are to be recorded directly in the field/laboratory record book as soon as they are available. Records are to be written in water-proof ink and written legibly. Any corrections will be initialed by the person performing the correction, will be crossed out with a line (not blackened or white-out), and will be dated according to the date that the correction was made. These data will include electronic data, entries in field/laboratory record books, operating data from the MERC test facility, and equipment calibration records. Records will be spot-checked within two weeks of the measurement to ensure that the data are recorded correctly. The checker shall not be the individual who originally entered the data. Data entries shall be checked in general for obvious errors and a minimum of 10 percent of all records shall be checked in detail. Errors detected in this manner shall be corrected immediately. The person performing the review will add his/her initials and the date to a hard copy of the record being reviewed. The MERC staff member will place this hard copy in the files for this evaluation. In addition, data generated by each MERC staff will be provided to the MERC Program Coordinator and reviewed before they are used to calculate, evaluate, or report results.

6. Quality Assurance/Quality Control

Treatment performance evaluations are implemented according to the Test/QA plans and technical documents (e.g., Standard Operating Procedures) prepared during planning of the evaluation. Prescribed procedures and a sequence for the work are defined during the planning stages, and work performed shall follow those procedures and sequence. Technical procedures shall include methods to assure proper handling and care of test instruments. All implementation activities are documented and are traceable to the Test/QA plan and SOPs and to test personnel.

Analytical Laboratory Quality Control:

The analyses for Chlorophyll, TSS and POC shall have the following Quality Controls:

a. Blanks

Three times during the evaluation, analysis of blanks. These blanks will be collected weekly during sampling and should include Field Blanks (see Section 7.4.2).

b. Control Charts. Two types of control charts are used in laboratories: a mean chart for blanks and a range chart for replicate analyses.

Quality Control for Instrument Calibration:

The test instrumentation to be used in the evaluation will be calibrated by the MERC staff according to the SOPs for the instrumentation prior to use. A calibration log will be created for each instrument. The logs shall include at least the following information: name of instrument, serial number and/or identification number of instrument, date of calibration, and calibration results. These logs shall be provided to the MERC Program Coordinator and maintained in a master calibration file as part of the QA/QC records.

Laboratory Test Quality Control:

All analytical measurements are performed using materials and/or processes that are traceable to a Standard Reference Material. Standard Operating Procedures are utilized to trace all quantitative and qualitative determinations to certified reference materials. All metrology

equipment (analytical balances, thermometers, etc.) is calibrated using materials traceable to the National Institute of Standards and Technology (NIST) and maintained on a schedule to ensure accuracy.

All volumetric glassware must be calibrated as conforming to Class A. A valid certificate of calibration or compliance must be available for each item. If the item has been calibrated in-house, the laboratory shall have a documented record of the calibration data showing traceability to national standards. Since the capacity of volumetric glassware may change with use, the calibration should be verified at regular intervals. Volumetric capacity is normally determined gravimetrically, using water conforming to the MERC glassware calibration Standard Operating Procedure (SOP). Before starting, care will be taken to ensure that the glassware is clean.

Field Logs:

Standard uniform field logs will be maintained for the evaluation. These logs should report name of staff conducting fieldwork, date (month, day, and year), operating status of all equipment, and manual readings of environmental conditions.

Field Quality Control Samples:

Field quality control samples provide information on the potential for bias due to contamination of analytical results by sample collection, processing, shipping, and analysis. To ensure that the field sample collection and analysis procedures are properly controlled, field blanks and replicate samples will be taken three times during the evaluation. These will be analyzed in the same manner as the collected samples for Chlorophyll, TSS, and POC. Field blanks are generated under actual field conditions and will account for all sources of contamination that might be introduced to a sample including incidental or accidental sample contamination during the entire process of sampling, transport, sample preparation, and processing. While field blanks mimic sample collection and processing, they do not come in contact with ambient water.

Sample Custody:

All samples will be accompanied by the sample collection sheet and a Chain-of-Custody (COC) form.

The COC specifies time, date, sample location, unique sample number, requested analyses, sampler name, required turnaround time, time and date of transaction between field and laboratory staff, and name of receiving party at the laboratory. Proper labeling of sample bottles is critical. The COC is a mechanism by which a sample can be tracked through the various phases of the process: collection, shipping, receiving, logging, sample prep/extraction, analysis, and final data QA/QC review.

When transferring the possession of the samples, the transferee must sign and record the date and time on the chain-of-custody record. Custody transfers, if made to a sample custodian in the field, should account for each individual sample, although samples may be transferred as a group. Every person who takes custody must fill in the appropriate section of the chain-of-custody record. The MERC staff member is responsible for properly packaging and dispatching samples to the laboratory for analysis. This responsibility includes filling out, dating, and signing the appropriate portion of the chain-of-custody record. The original and one copy of the chain-of-custody record form should be placed in a plastic bag inside the secured shipping container with the samples. One copy of the chain-of-custody record form should be retained by

the MERC staff member at each MERC partner institution. The transportation case should then be sealed and labeled. All records should be filled out legibly in waterproof pen.

Sample Handling:

All collected physical, chemical, and biological samples will be handled in the same manner. Each sample will be dated and coded according to the appropriate sample sequence. The actual sample container will be labeled with a number for identification. Samples stored for any period of time shall be routinely inspected by the MERC staff member to assure proper preservation and label integrity. The storage containers and storage devices (e.g., freezers and locker) must be inspected routinely for proper operation and integrity. Results of all inspections shall be included in the sample records. All logs shall be duplicated weekly. The original shall be retained at the MERC partner site and a copy shall be sent to the MERC Program Coordinator.

Audits:

MERC Program Coordinator will perform a technical systems audit twice during the evaluation. The purpose of this audit is to ensure that the tests are being performed in accordance with the MERC Protocols, published reference methods, and any SOPs used. In this audit, the MERC Program Coordinator may review the reference methods used, compare actual test procedures to those specified or referenced in the Protocols, and review data acquisition and handling procedures. A technical systems audit report will be prepared, including a statement of findings and the actions taken to address any adverse findings.

MERC Program Coordinator will also audit approximately 10% of the evaluation data acquired during the tests to determine if data have been collected in accordance to the Protocols with respect to compliance, correctness, consistency, and completeness. The MERC Program Coordinator will trace the data from initial acquisition to final reporting.

Finally, each assessment and audit will be documented, and assessment reports will include the following:

a. Identification of any adverse findings or potential problems,
b. Response to adverse findings or potential problems,
c. Possible recommendations for resolving problems,
d. Citation of any noteworthy practices that may be of use to others, and
e. Confirmation that solutions have been implemented and are effective.

Corrective Action:

The MERC Program Coordinator, during the course of any assessment or audit, will identify to the MERC staff performing experimental activities any immediate corrective action that should be taken. If serious quality problems exist, the MERC Program Coordinator will consult with MERC Primary Investigators and is authorized to stop work. Once the assessment report has been prepared, the MERC Program Coordinator will ensure that a response is provided for each adverse finding or potential problem and will implement any necessary follow-up corrective action. The MERC Program Coordinator will ensure that follow-up corrective action has been taken.

QA/QC Document Control:

It is the responsibility of the MERC Program Coordinator to maintain QA/QC records, which shall include the following:

1) records of the disposition of samples and data.
2) records of calibration of instruments.
3) records of QA/QC activities, including audits and corrective actions.

7. Roles and Responsibilities

The evaluation is coordinated and supervised by the MERC Principal Investigator, Program Coordinator and MERC personnel. Staffs participate in this test by installing, maintaining, and operating the respective technologies throughout the test; operating the reference equipment, collecting the water samples, downloading the data from the instrument package, and informing the MERC Program Coordinator staff of any problems encountered. Manufacturer representatives shall train MERC staff in the operation of their treatment system. However, the proper installation, calibration, maintenance, and operation of the systems is ultimately the responsibility of the manufacturer. QA oversight is provided by the MERC Program Coordinator. In addition to aiding the development of these protocols, the MERC Advisory Board will be consulted during the evaluation in the event problems occur, will assist in the analyses of results, and will review the final Treatment Performance Report prior to release. Specific responsibilities are detailed below.

The MERC Principal Investigator has the overall responsibility for ensuring that the technical goals and schedule established for the evaluation are met and the final authority on decisions regarding this evaluation. The MERC Principal Investigator shall:

- Prepare the draft Test Protocols/QA Plan and Treatment Performance Evaluation.
- Revise the draft Test Protocols/QA Plan and Treatment Performance Evaluation in response to reviewers' comments.
- Finalize the Test Protocols/QA Plan and Agreement for this Treatment Performance Evaluation.
- Sign the Treatment Performance Evaluations Agreement on behalf of MERC.
- Aid in treatment system testing.
- Aid in the preparation of a final report on this Treatment Performance Evaluation.
- Provide final approval of the Treatment Performance Evaluation Report and submit it to MPA and MARAD.

The MERC Program Coordinator shall:

- Help prepare the draft Test Protocols/QA Plan and Treatment Performance Evaluations
- Help revise the draft Test Protocols/QA Plan and Treatment Performance Evaluations in response to reviewers' comments.
- Coordinate distribution of the final Test Protocols/QA Plan and Treatment Performance Evaluation.
- Coordinate testing, measurement parameters, and schedules.
- Ensure that all quality procedures specified in the test/QA plan are followed.

- Respond to any issues raised in assessment reports and audits, including instituting corrective action as necessary.
- Serve as the primary point of contact for manufacturers and MERC Testing Team.
- Ensure that confidentiality of proprietary manufacturer technology and information is maintained.
- Review the draft Test Protocols/QA Plan and Treatment Performance Evaluations.
- Conduct a technical systems audit (TSA) once during the evaluation.
- Audit at least 10% of the verification data.
- Prepare and distribute an assessment report for each audit.
- Verify implementation of any necessary corrective action.
- Determine if a stop work order should be issued if audits indicate that data quality is being compromised or if proper safety practices are not followed.
- Provide a summary of the audit activities and results for the verification reports.
- Review the draft Evaluation reports.
- Have overall responsibility for ensuring that the test/QA plan and MERC QMP are followed.

MERC Testing Team* shall:

- Assist in developing the Test Protocols/QA Plan.
- Perform sample collections and analyses as detailed in the test procedures section of the test/QA plan.
- One member of the Testing Team will conduct 10% data audit as described in QA procedures. This will be done for all data logs and electronically entered data.
- Provide all test data to the MERC Program Coordinator electronically, in mutually agreed upon format.
- Provide the MERC Program Coordinator access to and /or copies of appropriate QA documentation of test equipment and procedures (e.g., SOPs, calibration data).
- Provide information regarding education and experience of each staff member involved in the verification.
- Assist in MERC's reporting of their respective test facility's QA/quality control results.
- Review portions of the draft Performance Evaluations to assure accurate descriptions of their respective test facility operations and to provide technical insight on evaluation results.

*MERC Testing Team includes researchers from the University of Maryland Center for Environmental Science, Smithsonian Environmental Research Center, University of Maryland at College Park, University of Maryland Wye Research and Education Center, and the crew of the *M/V Cape Washington*. A complete list, with qualifications, is available upon request.

Manufacturers shall:

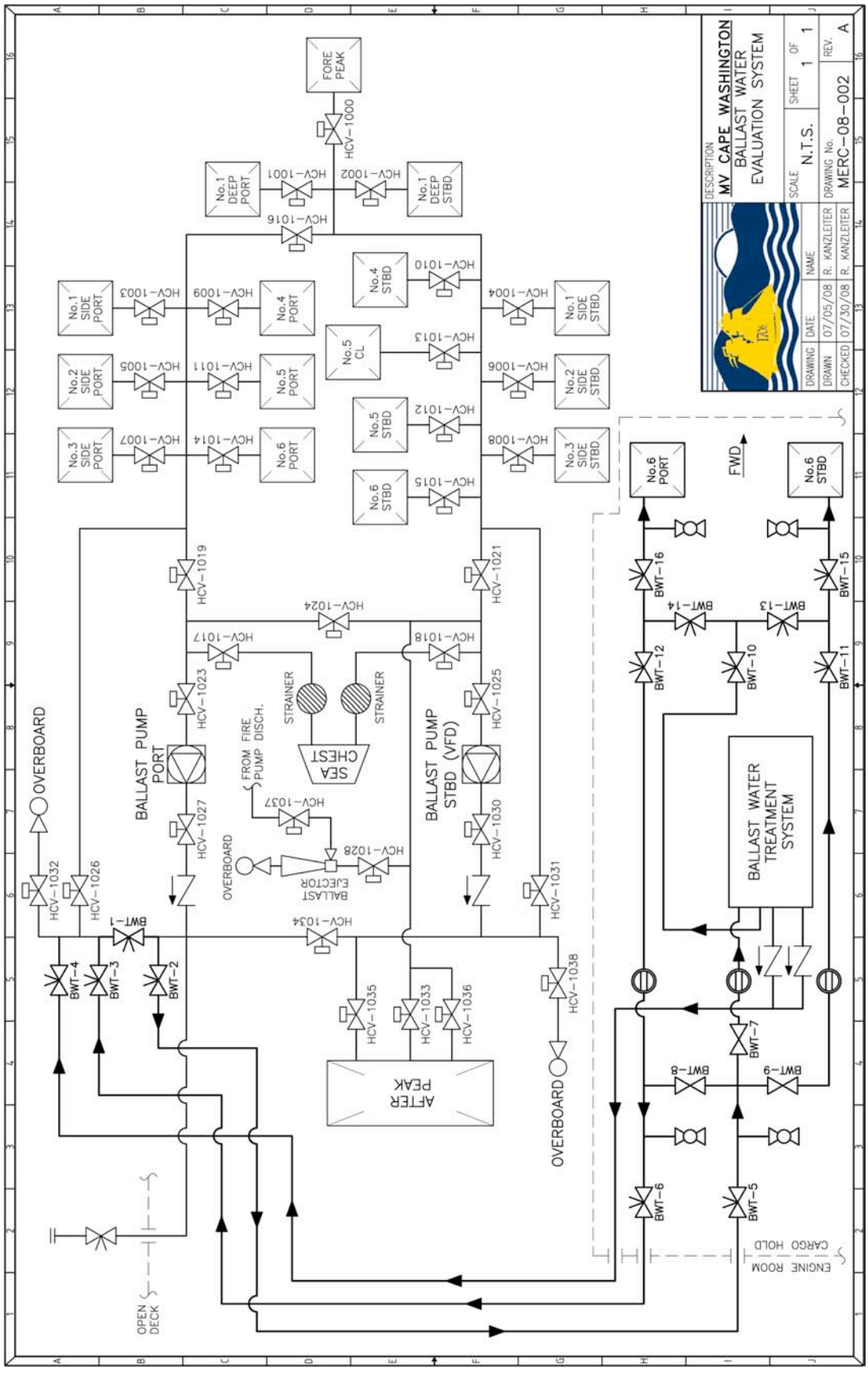
- Review the draft test/QA plan and provide comments and recommendations.
- Work with MERC to commit to a specific schedule for testing.
- Provide an operational treatment systems for the agreed upon test site.
- Aid in the installation, calibration and operation of treatment system for testing.
- Review and comment on draft Performance Report.

MERC Advisory Board* shall:

- Assist in developing the Test Protocols/QA Plan.
- Approve the final Test Protocols/QA Plan.
- Provide specific advice during testing.
- Review and comment upon draft Performance Report.

*A list of current MERC Advisory Board members, and their affiliations, can be found at www.maritime-enviro.org.

8. Modified *Cape Washington* ballast system to allow for treatment system testing by MERC.



9. MERC *Cape Washington* test setup and sampling design.