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LETTER AND COMMENTS FROM U S EPA REGION I REGARDING RESOURCE CONSERVATION AND RECOVERY ACT FACILITY INVESTIGATION NSY PORTSMOUTH ME
3/13/1990
U S EPA REGION I

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EPA Comments on RCRA Facility Investigation Proposal
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FINAL

UNITED STATES ENVIRONMEN
REGIO

J.F. KENNEDY FEDERAL BUILDING, BOSTON, MASSACHUSETTS 02203-2211

CERTIFIED LETTER - RETURN RECEIPT REQUESTED

March 13, 1990

Mr. Thomas M. Hagge
Captain, CEC, USN
Public Works Officer
Portsmouth Naval Shipyard
Portsmouth, NH 03804-500

Dear Mr. Hagge:

We have reviewed the "RCRA Facility Investigation (RFI) Proposal for Portsmouth Naval Shipyard, Kittery, Maine" (Revised August 1989) and the supplemental information that was submitted in February 1990. Attached to this letter are our comments on these submittals. We have also incorporated comments from the State of Maine Department of Environmental Protection.

The Navy must respond to these comments within forty-five (45) days of receipt of this letter. We request that the Navy develop a checklist that indicates where in the revised proposal each of the responses to these comments appear. If additional information is submitted in the revised proposal that is not in response to a specific this should also be indicated in the checklist.

Upon receipt of your revised RFI Proposal EPA will either approve, disapprove, or modify the revised proposal. Failure to comply with completing the response to the comments on the RFI Proposal may result in an enforcement action. EPA reserves the right to issue a Notice of Noncompliance if the proposal does not meet the technical adequacy that is required by the permit.

Please be advised that you may request a meeting with EPA to discuss these comments. To arrange such a meeting please contact Jeri Weiss at (617) 573-9637.

Sincerely,

Mary Jane O'Donnell

Mary Jane O'Donnell, Chief
ME/NH/VT Waste Regulation Section

enclosure

cc: Pamela Parker, ME DEP
James Tayon, USN Portsmouth Naval Shipyard
Linda Resta, USN Northern Division

ATTACHMENT 1

Comments on RCRA Facility Investigation Proposal
Portsmouth Naval Shipyard Kittery, Maine

GENERAL COMMENTS

The RCRA Facility Investigation Proposal (RFI) covers the major requirements of the HSWA permit that the Environmental Protection Agency issued to Portsmouth Naval Shipyard on March 10, 1989. However, there are still a number of requirements that have not been adequately addressed or were not addressed as of February 12, 1990. The items requiring revision are noted in the section specific comments. These deficiencies must be corrected prior to EPA's approval of the RFI Proposal.

Our general concern is that the proposal lacks enough specificity to produce an investigation that will be capable of determining the rate, extent and concentration of releases to the environment from the Solid Waste Management Units (SWMUs) that were identified in the permit. First, information regarding the **criteria** for decision making is frequently not expressed in the proposal. Secondly, tasks are frequently not expressed in terms of relevance to the **objectives** that they are to accomplish. Finally, the **rationale** for specific actions is often missing. Throughout our comments we will note where the criteria, objectives, and rationale are missing and/or need clarification.

The introduction to the RFI proposal provides a general description of the data quality objectives (DQOs) for the project. Several of the DQOs need further definition. How will the data generated from chemical analyses, from the samples collected during the RFI, be used to support the objectives of the project? There are multiple uses for the data that will be gathered during the RFI including: 1) determining the rate and extent of contamination; 2) as a basis for determining the need for interim corrective measures; as well as 3) as a basis for the public health and environmental risk assessment. The DQOs for the project must be developed for each of the applicable sections. A guidance document you may find helpful is "Data Quality Objectives for Remedial Response Activities" (US EPA, EPA/540/G-87/003) March 1987. The need for DQOs will be noted throughout the comments.

Please note the State of Maine Department of Environmental Protection (DEP) comments have been incorporated into this attachment. An asterisk (*) denotes the comments that were made exclusively by DEP. Comments that are preceded without a section number and page are from the supplemental information that was received in February.

SECTION 1 - INITIAL FACILITY CHARACTERIZATION REPORT

General Overview

The major deficiencies of this section concern the review and summary of background information for the site. The discussion of previous investigative reports, Section 1.4, does not provide the necessary analysis of how this information will be used in the proposed investigation of the facility. It also appears that the review of previous investigations is incomplete. As noted below, there are some reports that may pertain to the investigation of Portsmouth Naval Shipyard that have not been included in this section.

Additional information pertaining to the site hydrology and ground water may be available. It is probable that geotechnical data or studies used for construction purposes exist for the site. These usually include monitoring wells for obtaining water levels to determine whether dewatering is necessary during construction and boring data on soil types for determining construction methods. The availability of this type of information should be explored and used as a basis for developing a conceptual model of the site hydrology.

Some information gathered during the removal of the underground storage tanks was included in the supplemental material, but it appears to be incomplete. Sampling was conducted during the removal of the battery acid tank and waste oil tanks. The permit requires reporting this information under Special Permit requirement I.a.2., and I.a.3. The sampling results for SWMU 11 is referenced in the additional material submitted, but it is not included in the appendix.

Page Specific Comments

Page 1-3 The definition of 'ria' shore line should be explained. According to the "Encyclopedia of Geomorphology" (Fairbridge, 1968) the term 'ria' is applied to non-glaciated coastal areas.

Page 1-5 The text mentions "thin veneers of glacial till." The thickness and continuity of these veneers are important. This should be a component of the RFI investigation.

Page 1-5 Boring logs from the investigation around Building No. 86 should be evaluated and presented.

Page 1-6 It is unclear from the proposal how the fracture trace study, conducted by the Army Corps of Engineers, will be used. The RFI Proposal states that, "Data obtained from the DRMO and JILF

subsurface investigation will be used to confirm the validity of this study if it is revealed that the bedrock aquifer will be adversely impacted." The proposal also states that "information contained in this study has been incorporated in the design of the proposal." This suggests that the Fracture Trace Study is being used although there are questions regarding its validity.

What type of data from subsurface investigations at the DRMO and JILF will be used to confirm the validity of the fracture trace study? Two methods for validating the fracture trace study include locating borings along the lineaments determined by the study, and obtaining oriented cores.

Page 1-12 We assume the fracture trace study will be used in the event that subsurface investigations indicate that the bedrock aquifer has been adversely impacted. It is not clear how subsurface investigations will reveal whether the bedrock aquifer has been adversely impacted as only shallow monitoring wells are proposed for these areas. Since the Till ranges from 0 (zero) to twenty (20) feet, the fracture study should be used evaluate to where the bedrock may be impacted.

The proposal states that the continuity of the soil/sediment horizons are unknown. This should be addressed during the investigation.

Page 1-12 There is no reference for "Lyman fine sand loam."

Page 1-15 The description of water flow in the estuary should be viewed as a regional concept. It will be necessary to study whether the water flow in the portion of the estuary near the shipyard may be successfully modeled. If there are localized basins, these could form sinks where dense compounds could collect.

EPA requests a copy of the studies that are mentioned in the text including: Ridley and Ostericher, 1960; Ebasco, Inc. 1968; Jackson and Moreland, 1969.

Page 1-26 The text states "Ground water levels... are likely controlled by the thickness of glacial till and fill material or former tidal flats." Explanation regarding how the ground water levels are controlled is not provided.

Page 1-26 to 1-28	Examples could be provided regarding how ground water flow directions are affected by thickness and composition of overburden, bedrock-overburden, contact-surface dip and tidal influences.
Page 1-28	The proposal states that ground water flow direction will be addressed as part of the RFI. This is not addressed in the proposed work plan.
Page 1-29*	The intertidal area is also ecologically important.
Page 1-31*	The use of both scientific and common names is confusing. One form should be chosen and used consistently.
Page 1-33*	References should be made to how contaminants can affect the species within the food chain itself not just the human receptors. This should be addressed at both the individual and population level.
Page 1-36*	Commercial fishing is a significant part of the regional economy yet it is not mentioned in the analysis of possible economic impacts of contamination in the region.
Pages 1-37 to 1-43	Section 1.3, Previous Investigative Activities, summarizes some of the previous studies that have been conducted at the Shipyard. However, evaluation and analysis of the significance of these studies is missing. Additionally, the results of the earlier studies have not been used extensively to develop strategies for the subsequent investigations in the work plan. The primary purpose of reviewing previous investigations is to gain a thorough understanding of the work that has been already done to provide supplemental direction for the current investigation.
Page 1-37	Specific information regarding the 100,000 cubic yards of dredge material should be provided. Where in the landfill was this material deposited? From the description it appears to have been put into the Jamaica Island Landfill (JILF), but its exact location should be defined. Additionally, the chemical contaminants of the overburden at the dredge site should be summarized. More specifics pertaining to how the dredged material has been "contained to minimize release of contaminants from the dredge spoils to the Piscataqua River" should be included in Initial Facility Characterization Report.

Page 1-38 Although the supplemental Initial Assessment Study (IAS) was not reviewed, the findings from the document were presented. This document should be reviewed, since reporting of this investigation is required by the Permit under section II.A.1.a.2 and section II.A.2.

Page 1-40 The proposal should provide a comparison of what was disposed of, (eg Table 1-4) with what was tested and what will be tested under the proposed investigation.

Page 1-40 Provide the source(s) for Table 1-4.

Page 1-42 Information from the 1971 report that is referenced in the RFA ("Study Report of Solid Waste Disposal Methods at Portsmouth Naval Shipyard" 6/25/71) should be reviewed as required by the permit under Section II.A.1.a.2 and Section II.A.2. This report allegedly identifies incinerator waste at the landfill and its significant contribution to ground water pollution. No mention is made of wells installed or actual data on ground water quality in the vicinity of the landfill.

Page 1-45 When the detection of chemical constituents is presented the constituents that were sampled for and their detection limits should also be included.

Page 1-45* Portsmouth Naval Shipyard has made it clear that the dredging performed to deepen the berth areas was not done to remove contaminated sediments. This should be made clear in the proposal.

Page 1-47* Based upon photographs on file at the shipyard it appears that the landfill was receiving waste through 1982. This should be noted.

Page 1-47 In the description of the JILF, SWMU #8, the RFI Proposal briefly describes the construction of a clay barrier wall that was constructed when the dredge material from berths 6, 11, and 13 was put in the landfill. Additional as-built construction information, including a vertical cross-section of the encapsulating structure, would be useful to evaluate the hydrology of the site and the effectiveness of the barrier. Reporting of this data is required by the permit under Section A.3.

Page 1-47 The JILF received over 100,000 cubic yards of dredge material not 10,000 as reported.

Page 1-47	Figure 9-1 is missing.
Page 2 to 5	Bibliography for the references should be provided for Section 1.4, "Waste Characteristics, Migration and Dispersal." The intention of the toxicity evaluation in the Initial Facility Characterization is a qualitatively evaluation. The toxicity data should be based upon a literature search and references should be provided. Permissible concentrations must be based upon the hierarchy presented in the Supplemental Risk Assessment Guidance (see comments in section 15).
Page 5	The proposal states that SWMU No. 11 is representative of SWMU No. 26. This is unacceptable, quantity and toxicity information is required for each SWMU.
Page 7*	For SWMUs 13, 16, 21, 23 and 27 the statement is made that "no mitigation is required." This is drawing a conclusion before the study has begun. The purpose of this section is to investigate what mitigation efforts have been conducted to date.
Page 12 to 17	The Special Permit Requirement A.1.f requires the identification of potential receptors to include contaminants that have been released from SWMUs, which include all populations and environments. The summary provided in the proposal should include a discussion of populations that may have been affected from both current and historic releases.
Page 14	The precision tests referenced for SWMU No. 11 is missing.
Page 17	Section 6.3 does not address the background monitoring plan; number of downgradient monitoring wells and justification of downgradient monitoring wells. The objectives and the rationale for the background monitoring and downgradient monitoring wells should be provided in the proposal.

SECTION 2 PRELIMINARY INVESTIGATION OF CORRECTIVE MEASURES

General Overview

In Part II Section A.2, Preliminary Investigation of Corrective Measures, the HSWA Permit requires that, "The RFI Proposal shall identify the potential corrective measure technologies that may be used on-site or off-site to contain, treat, remedy and/or dispose of the contamination resulting from the releases of hazardous waste and/or hazardous constituents from the SWMUs listed in Attachment I. This Preliminary Investigation shall summarize all prior investigations and identify field data that needs to be collected during implementation of the RFI to facilitate the technical evaluation and selection of the final corrective measure or measures (e.g., compatibility of waste and construction materials, information to evaluate effectiveness, treatability of wastes, etc.)."

Corrective measures will be identified and screened in the CMS (Permit Condition II.J.) based on the fully defined nature and extent of contamination, as defined by the RFI. Item II.A.2, of the permit, is intended to identify preliminary response actions and more particularly, the technologies that potentially will be most useful in remediation contamination.

Once the existing site information has been analyzed and a conceptual understanding of the site is obtained, potential remedial action objectives should be identified for each contaminated medium and a preliminary range of remedial action alternatives and associated technologies should be identified. This identification is not meant to be a detailed investigation of alternatives. Rather, it is intended to be a more general classification of potential remedial actions based upon initially identified potential routes of exposure and associated receptors. The identification of potential technologies at this stage will help ensure that data needed to evaluate them (e.g., Btu value of wastes to evaluate thermal destruction capabilities) can be collected during the RFI. In addition, the early identification of technologies will allow earlier determinations as to the need for treatability studies.

Technologies that may be appropriate for treating or disposing of wastes should be identified along with sources of literature on the technologies' effectiveness, applications and cost. Please note, EPA will consider cost only in the event that more than one corrective measure provides equal protection of human health and environment. Further assistance in the investigation of technologies is provided in the "Technology Screening Guide for Treatment of CERCLA Soils and Sludges" (U.S. EPA, September 1988). Innovative technologies and resource recovery options should be included if they appear feasible.

To the extent practicable, a preliminary list of broadly defined alternatives (i.e., technologies, or technology combinations) should be developed that reflects the goal of presenting a range of distinct, viable options to the decision-maker. This list may therefore include as appropriate a range of alternatives in which treatment that significantly reduces the toxicity, mobility, or volume of waste is a principal element; and perhaps one alternative that involves containment with little or no treatment. The list should be limited to only those alternatives that are relevant and carry some significant potential for being implemented at the site. In this way, the preliminary identification of remedial actions will allow an initial identification of applicable regulations, and permit requirements, and will help focus subsequent data-gathering efforts.

The identification of data needs is the most important part of the requirements of II.A.2. in the permit; data needs are identified by evaluating the existing data and determining what additional data is necessary to develop and evaluate technologies and combinations of technologies considered for site remediation. This section should list or reference the compounds of interest, the desired detection limits and the analytical methods used for the detection of those compounds. It is important while creating these data quality objectives to determine if the proposed detection limits for the analytical method are sufficient to satisfy the specific remedial response objectives.

It is anticipated a complete analysis of data requirements by the Permittee under II.A.2. may lead to a conclusion that additional data are needed. If additional data are needed, the intended uses of the data are identified, strategies for sampling and analyses are developed, DQOs are established, and priorities are assigned according to the importance of the data in meeting the objectives of the RFI.

Section 2 of the RFI Proposal, entitled, "Preliminary Identification of Corrective Measures" essentially provides an outline for the Corrective Measures Study required under Special Permit Conditions Part II, H, I, J, and K. It further provides Tables 2-1 through 2-3 which outline "Remedial Action Technologies" for the following SWMUs, respectively.

- Jamaica Island Landfill (SWMUs 8 and 9);
- DRMO (SWMU 6); AND
- Bulk Liquid Storage Tanks (SWMUs 10, 11, 12, 13, 16, 21, 23, 26, 27).

Please note that SWMU 5, the Industrial Waste Outfalls, was not addressed at all in this section. This SWMU should be included in determining corrective measures that are likely to be pursued and,

more importantly, any specific data needs or information pertinent to the corrective measures study.

This section of the RFI Proposal, much of which will likely be applicable to the Corrective Measures Study, does not provide the specific information required in the HSWA Permit Condition II.A.2. We recommend that this section be modified to provide identification of potential corrective measure technologies and the associated data needs and required field/laboratory investigations based on a conceptual model using existing knowledge of the nature and extent of contamination at the facility. Also, the detailed description of the proposed Corrective Measure Study process is inappropriate in this section and should be reserved and presented in the Corrective Measures Study Proposal.

Page-Specific Comments

Page 2-1 to 2-18	As mentioned above, this section of the RFI Proposal essentially provides an outline for the Corrective Measures Study required under Special Permit Conditions H, I, J, and K. We believe this section of the RFI Proposal should concentrate solely on identifying potential corrective measure technologies and their associated data needs. The requirement to submit a Corrective Measures Study Proposal and a Corrective Measures Study Report are contingent upon receiving approval of proposed Media Protection Standards, which are developed during the RFI and the PHERE. We do not believe this section of the RFI Proposal is appropriate to discuss the details of a Corrective Measures Study.
Page 2-10*	Tentatively identify any special remedial options that will address the problem of the acetylene and chlorine cylinders.

SECTION 3 SURFACE GEOPHYSICAL INVESTIGATION

General Overview

This section clearly identifies the rationale for conducting geophysical survey. These are acknowledged on the bottom of page 3-1 of the RFI Proposal:

- helping determine the profile of the bedrock surface;
- improving accuracy and confidence levels in hydrogeologic investigations;
- location of monitoring wells; and

- reducing project time and costs.

Further acknowledgement of seismic refraction technique is described on page 3-9 in the proposal under "Purpose/Approach." However, seismic refraction is only proposed as a possible second phase of investigation for the Jamaica Island Landfill.

EPA concurs with the rationale and objectives stated by the permittee in using geophysical techniques. The RFI proposal provides a basis for not investigating SWMUs 6 and 9. This justification is not acceptable. We require seismic refraction work throughout this facility wherever ground water contamination is likely or known and monitoring is likely to occur. Although the proposal alludes to the infeasability of applying geophysics to the DRMO and Fuel Oil Pipeline it should have been explicit as to how, for example seismic refraction surveys would not be beneficial.

The proposal should elaborate how the factors in the first paragraph on page 3-1 (last sentence) and any other factors will be applied in decisions for using the various geophysical methods.

Page Specific Comments

Page 3-1 The proposal asserts that the ground penetrating radar will assist in confirming monitoring well locations at the mercury burial sites. How will this be done? Is the presumption that the subsurface stratigraphy and hydrology are well enough understood and only the location of the burial sites is needed? This does not appear to be a supportable presumption.

Page 3-5 In describing the methodology of the magnetometer survey, the RFI Proposal notes that the response of the instrument is directly proportional to the mass of the ferrous object and inversely proportional to the distance to the object raised to the third power. The equation provided in the text should therefore be $I=m/d^3$ not $I=1/d^3$.

Page 3-8 The RFI Proposal states that geophysical survey data will be reduced and contoured using Golden Software graphics package. Although use of this package will reduce drafting time, this software package can produce contour maps which contain misleading artifacts. These artifacts are commonly generated by "edge effects" or in areas where the data are scarce and the fitting program does not adequately smooth contours. When contour maps are computer generated, EPA recommends that they be manually

edited to remove false features.

Page 3-10 No source of the historical data is provided for figure 3-1, showing former location of tidal flats.

SECTION 4 SOILS INVESTIGATION

General Overview

This section presents the purpose, methodology and decontamination procedures for the test borings/rock coring and surface soils investigations at SWMUs #6, #8, #9, #27 and the underground storage tanks. The investigations proposed address all sampling locations required by Special Permit Condition A.4.
One of the primary objectives of this RFI is to acquire enough data to support the corrective measures study. Developing appropriate remedial actions for the facility requires that the nature, extent and risks associated with the wastes be evaluated. Consideration of the facility as a whole is necessary here. The RFI Proposal must address the problematic obstacles to obtaining data in the interior of the JILF. The RFI proposal should lay out a strategy for obtaining data on the nature and extent of wastes, and geotechnical properties of wastes, cores, and natural substrate.

One of the deficiencies noted in this review is the lack of appropriate background soil samples (from both surface and subsurface locations). Without historical background and fill background samples for comparison, it may not be possible to adequately define the impact on the site due to specific site operations. In particular, if the site is extensively covered with fill material, there may be widespread contamination inherent to the fill. Background samples of fill would assist in defining such a condition.

The RFI Proposal also states that several activities will be performed but does not give enough of the specifications, (criteria, objectives and rationale) to evaluate whether the approach is appropriate. Although EPA acknowledges that the details of many field activities need to be defined in the field, based on field decisions or field observations, the strategies for making these decisions should be clearly outlined. For example, the Proposal includes test pits along the former pipeline route, but does not describe the objectives or strategies for locating the test pits or the anticipated depth or number. Also, a proposed approach for obtaining necessary subsurface information on the JILF wastes should be provided.

Throughout this section, as well as other sections of the RFI Proposal, references are made to several analytical parameters (TCL Organics, TAL Inorganics, RCRA Metals, Priority Pollutant Metals).

EPA requires, at a minimum, the Appendix IX parameter list for at least the first round of analyses for sampling of all media. After this initial screening a smaller parameter list can be developed to screen for specific contaminants that were found in the initial screening once non-detects are verified. This issue will be discussed in more detail in the comments on the Quality Assurance Project Plan (QAPP) section.

In this section the Data Quality Objectives should be defined for each sampling plan that is proposed. The proposal should provide a description of all compounds for each parameter, listing the detection limits and method references for each compound.

Page Specific Comments

Page 4-1 The RFI Proposal states that "The subsurface geology at the DRMO Storage Yard is not well defined," and seven (7) test borings are proposed at this site. Since eight (8) borings were previously drilled in this relatively small area, it is not clear what the perceived data gaps may be. How has the information from this previous effort been used to justify the number and location of the eight (8) borings? The rationale and justification for the proposed seven (7) test borings to twenty feet must be provided.

Page 4-2 What is the source(s) for figures 4-2 and 4-6?

Page 4-1 to 4-7 EPA recommends that at least one test boring be located in an area considered not to be impacted by DRMO activities to provide samples for background data. Without background data, it will not be possible to distinguish contamination due to DRMO activities from naturally occurring heavy metals in the soil or contamination which is due to the fill material itself. For example, if dredge materials or other anthropogenic fill have been used to create land over a widespread area of the base, the filled area may contain elevated levels of heavy metals. The wide extent of "background" contamination could impact the corrective measures alternatives at a particular SWMU.

Page 4-8 The rationale for installing ground water monitoring wells in the test borings as described at the top of page 4-8 must be provided. There appears to be a presumption that these locations are adequate. The basis for this presumption has not been made. The general reference to the "Final Confirmation Study" (FCS) will not suffice. Further the design of the monitoring and sampling program must be described in terms of the objective(s) for the SWMU.

Page 4-8 Blow counts should be reported.

Page 4-8 The sampling methodology indicates that soil samples will be obtained at five (5) foot intervals. This is not acceptable. Continuous split spoon sampling should be undertaken. Samples subject to volatile and semi-volatile compound analyses must not be composited. Additionally, the rationale for selecting sample locations should include bias for field indications of contamination including field screening methods.

Page 4-8 The description of SWMU 6 incorporates the field procedures, decontamination and health and safety. This doesn't seem appropriate. The latter two would not be expected to differ particularly from area to area and should be covered in the Quality Assurance Project Plan and the Health and Safety Plan.

Page 4-11 What will the criteria be for determining how representative samples will be obtained for grain size distribution, Atterburg limits and moisture content? ASTM guidelines should be used.

Page 4-11 Where are the locations of borings that will be completed in bedrock? Will the rock cores be chemically tested? What is the rationale for choosing five (5) foot depths in the bedrock.

Page 4-12 It may be advisable to keep a head of clean, uncontaminated water on the hole in order to minimize the disturbance of the clay.

Page 4-13 All auger cuttings must be drummed, tested and evaluated as to whether they meet the definition of a hazardous waste under 40 CFR Part 261. All materials meeting the definition of a hazardous waste under that section must be handled and managed in accordance with the standards in the Code of Federal Regulations and state regulations.

Page 4-13 Well screens should be finished in bedrock to determine the nature of the hydraulic connection between the overburden and consolidated aquifers and to confirm the quality of ground water in bedrock. This procedure is particularly relevant at the DRMO where confining layers are not expected (see page 4-11 'Confining Layers').

Page 4-13 The general reference to the FCS for the 'Surface Soil Sampling Plan' to justify the approach to this component of the program is not sufficient. The proposal must provide the rationale for this approach as related to the program objectives for this unit.

Page 4-13 The parameters for analyses should initially consist of the hazardous constituents of Appendix IX and all other chemicals which could reasonably be derived from the SWMU. Subsequent analyses may be some subset of these initial parameters after non-detects are verified.

Page 4-13 to 4-14 The sampling locations for the surface soil sampling plan must be based on program objectives. The locations must be described in relationship to how they address those objectives.

Page 4-13 to 4-14 The surface soil sampling program should also include at least 2 samples from areas considered to be upgradient and not impacted by DRMO activities. These samples will serve as background data. (See comment to pages 4-1 to 4-7.)

Page 4-16 Samples that will be analyzed for volatile organic compounds must not be homogenized.

Page 4-18 Surface and subsurface soil sampling programs should employ the same parameter list (see general comment).

Page 4-18 Grain size analysis should be conducted on the surface soil samples. These data will be useful in interpreting the chemical data and in evaluating the air transport pathway in the risk analysis.

Page 4-18 The RFI Proposal states, "If a tightness test confirms a tank system failure, test results will be reported as required in 40 CFR 280, Subpart E, and applicable State of Maine regulations." EPA also recommends that the tightness test procedure also comply with the requirements of 40 CFR 280.43(c). The text of this paragraph is also ambiguous. Will a soil investigation be conducted only if the tank fails the tightness test? What will be used as the failure criterion, i.e. threshold leakage rate?

The paragraph also states that soil samples will be collected and analyzed for "contaminants of concern," but these are not specified. (Please see

the general comment referring to analyses of constituents.) The soil collection and analysis should be a part of the Supplemental Tank Investigation as referenced in Special Permit Condition C.7.

Page 4-18 (Section 4.2.2) The RFI Proposal states that test pits will be located along the former pipeline route, but the number, location, depth, and width of the test pits will be determined in the field. Information must be provided or criteria listed indicating how it will be applied in selecting the locations, number, depths, and widths of the pits. The objectives of this investigation should be specifically described and the sampling strategy should be presented in terms of these objectives.

Page 4-21 The proposal should describe the manner in which the sampling program for the JILF addresses the objectives for investigating this unit. For example the statements regarding peripheral sample locations for providing maximum information possible about the site are meaningless and fail to provide the justifications required by the permit.

Page 4-21 The sampling methodology indicates that soil samples will be obtained at five (5) foot intervals. This is not acceptable. Continuous split spoon sampling should be undertaken. Samples subject to volatile and semi-volatile compound analyses must not be composited. Additionally, the rationale for selecting sample locations should include bias for field indications of contamination including from field screening.

Page 4-21 The third paragraph indicates that during the test boring program, one sample per boring will be collected and analyzed for "health and safety reasons." It is not clear what this means. The specific analyses for health and safety should be described in the Health and Safety Plan.

Page 4-21 The RFI Proposal states that "boring/coring data will be incorporated with the geophysical data in the design of the subsequent ground water investigation." EPA recommends that as many of the boring locations as reasonably possible be located along geophysical lines so that the geophysical data can be calibrated against actual subsurface observations from the borings. As a result, subsurface stratigraphy along geophysical lines may be interpolated between borings using the borings

as reference points.

Page 4-21 to 4-25 What is the target depth for the subsurface boring and soil sampling proposed for the periphery of the Jamaica Island landfill?

The RFI Proposal specifies that five (5) feet of rock core will be obtained. Is sampling for chemical analysis intended to continue to the top of bedrock?

Page 4-21 The Proposal states, "Based on the discretion of Hart's on-site hydrogeologist, one sample per boring may be collected and analyzed for health and safety reasons." The justification and proposed analytic parameters should be discussed in the Health and Safety Section. Paragraph 3 on page 4-24 calls for 11 samples to be analyzed for TCL Organics and TAL Inorganics. Are these the health and safety samples mentioned in the text? How do these samples relate to the other samples to be collected from the borings?

Page 4-21 The proposal discusses the need to understand both natural and artificial variables when designing and locating monitoring wells. The Proposal should investigate the preferred migration pathways, the presence of freshwater/saltwater interfaces, and fluctuations in groundwater elevations prior to designing and locating monitoring wells.

Page 4-22* Using olfactory measure in screening samples for laboratory analysis poses an undue risk and must not be utilized.

Page 4-24 The sampling methodology indicates that soil samples will be obtained at five (5) foot intervals. This is not acceptable. Continuous split spoon sampling should be undertaken. Samples subject to volatile and semi-volatile compound analyses must not be composited. Additionally, the rationale for selecting sample locations should include bias for field indications of contamination including field screening.

All auger cuttings should be drummed, and must be tested and evaluated as to whether they meet the definition of a hazardous waste under 40 CFR Part 261. All materials meeting the definition of a hazardous waste under that section must be handled and managed in accordance with the standards in the Code of Federal Regulations and in accordance with

state law.

To this end, the constituents to be measured should be identified. The proposal should describe possible handling methods and criteria for selection.

The RFI proposal should commit to submitting an additional proposal supporting the monitoring well program for EPA approval. The proposal indicates that the soil sample interval will be determined in the field. The proposal should describe the criteria to be applied in the field for selecting this interval and how the criteria relate to the program objectives for this unit. The approach appears different than that described for the DRMO Storage Area. Why would these approaches be different? Are the objectives different?

Page 4-24 The last paragraph discusses sampling parameters for the JILF. Samples for VOC analyses should not be composited. The parameter list described in this paragraph does not appear to be the same as those described in the preceding paragraph. Why are these lists different? Are the objectives different?

Page 4-25 Rationale related to the objectives for studying the Mercurial Burial Site is required for selecting sample locations and depths, boring depths, well location, well depths, etc. This information is required by the permit.

Page 4-25* It is imperative that samples are collected from the uppermost layer of the tidal flat deposits. The industry norm for sampling is every five feet and/or at any change in lithology. The Maine DEP feels strongly that the upper two feet of the deposits are carefully characterized by taking closely spaced samples, for example every four inches for the first foot also taking into consideration the before mentioned parameters.

Page 4-25* The buried tidal flats under the landfill should not be considered a confining layer or an aquiclude as referred to in this reference until this is supported by data.

Page 4-25 EPA recommends that air quality monitoring during drilling around the mercury burial sites be expanded to include real time field screening for mercury vapor (e.g. with a Jerome mercury vapor analyzer).

This will supplement the health and safety monitoring, and will also assist in determining the nature and extent of the wastes.

SECTION 5 GROUNDWATER HYDRAULICS INVESTIGATION

General Overview

In accordance with the Special Permit Condition A.5, the SWMUs addressed in this section of the RFI Proposal include SWMUs 6, 8, and 9. The permit requires that the hydrogeologic monitoring establish variations in groundwater flow due to seasonal, temporal, tidal effects and artificially induced changes. The proposal indicates that only variation in temporal effects will be noted.

Although the slug test will be useful, the proposal should acknowledge that this test will yield only local data. All assumptions must be presented in the analysis of the results of this test such as, the effects of well installation techniques.

Page Specific Comments

Page 5-1 Where possible, both rising head and falling head measurements should be made.

Page 5-2 Table 5-1 specifies frequency for water level measurements during the monitoring well slug tests. The total elapsed time is estimated to be 1,000 minutes (about 16.7 hours). If measurements are collected over the course of several hours, tidal effects may be exhibited in the wells. The RFI Proposal should include a method of correcting the data for tidal effects simultaneously with the slug tests. This may consist of placing transducers in several wells at the same time that the slug test is performed. Tidal effects estimated from the untested wells may be "subtracted" from the tested well. Note that there will be some interpretation necessary in determining the correction factors; wells will generally experience a lag in their response to tidal changes which may vary with distance from the shoreline.

Page 5-2 The proposal states that "any water generated will be discharged to the site." This is not acceptable. Water should be contained, tested and evaluated as to whether it meets the definition of a hazardous waste under 40 CFR Part 261. All materials meeting the definition of a hazardous waste under that section must be handled and managed in accordance

with the standards in the Code of Federal Regulations and in accordance with state laws.

SECTION 6 - HYDROGEOLOGICAL MONITORING PLAN

General Overview

This section of the proposal presents the methods of monitoring well installation and development as well as the study purpose and methodology for ground water sampling for each of the SWMUs required by Special Permit Condition A.6. Applicable guidance for evaluating this section includes the "RCRA Technical Enforcement Guidance Document" (EPA, 1986) (TEGD).

This section's main deficiency is the intent and strategies for the hydrogeologic investigations are inadequately addressed. For example, well location and overall purpose of the wells, (i.e., monitoring water table, vertical gradients, etc.) could be put forth in this proposal. The goals and objectives of the RFI will dictate overall strategies for monitoring well placement and design. The criteria that will be used in the decision making process should be clarified. It might be helpful if a decision matrix is presented with all the criteria that will be considered for determining the monitoring well placement.

It doesn't appear that the results of the geophysics survey or the soil gas survey will be incorporated into any decisions regarding the hydrogeological monitoring plan. It appears that the expected saturated thickness is based on very little data. The proposal should indicate that more geophysical investigations would be proposed to provide this information, as necessary.

Other deficiencies that should be addressed in this proposal include:

A justification of how wells will provide a reliable indication of downgradient ground water quality.

The expected use of the soil gas survey.

Page Specific Comments

Page 6-1 to 6-2

The proposed wells are intended to be screened across the "full vertical extent of saturated sediments, taking into account tidal fluctuations." On page 4-13, the RFI Proposal describes the monitoring well installation procedure for the DRMO site as follows: "Upon completion of the coring, the core hole will be filled to the top of bedrock with bentonite. A monitoring well will then be constructed above the bedrock." The Proposal further states, "Drilling and soil sampling for the subsequent phase of monitoring well installation will be performed [at the landfill] in the same manner as described in Section 4.1.1 [the DRMO facility]." EPA interprets these statements to mean that the Navy proposes to install the monitoring wells at the landfill so that they are screened from the top of bedrock to the top of the intertidal zone. If this is not the case, the Proposal should be more explicit regarding the strategy and goals of the monitoring well installation.

Screen lengths should not be greater than 10 feet, (or 15 feet if the screen crosses a fluctuating water table). Deeper well screens should not exceed five feet in length. If the aquifer of interest is more than 25 feet thick, a well cluster at the site would provide additional information regarding ground water quality and the vertical ground water gradient. Well clusters would also be recommended if confining or semiconfining units are encountered during drilling.

According to Enclosure A, the perimeter of the landfill is locally less than 5 or 6 feet above the mean high tide elevation. The well construction described in the proposal calls for sand to 2 feet above the screen, a 1-foot sand choker collar, and a 2-foot bentonite seal. These measurements may need to be modified if the ground surface is too close to the top of the screen. EPA suggests that a 6-inch choker collar may be adequate in wells with such limitations.

Page 6-2*

The proposal should specify the diameter of the monitoring wells. If this is not available, define the criteria for the selected diameters of the monitoring wells.

Page 6-2

Table 1-4 indicates that information exists

concerning the variety of contaminants at the JILF. This information should be identified in order to propose well screen material.

Page 6-2 The proposal indicates that the DRMO will have 0.01 slot size screens. The rationale for this decision should be provided in the proposal. Grain size analysis from soil studies is one parameter that should be considered when determining the appropriate screen slot size.

Page 6-4 The proposal states that monitoring wells will be developed using a WaTerra pump system equipped with "high density polyethylene (HDPE) tubing." The EPA Region I Quality Assurance Office does not consider polyethylene an acceptable material for use in ground water monitoring well installation and sampling.

Page 6-5 The proposal describes well development based partially upon stabilization, but the paragraph concludes that "development may continue until 10 to 15 well volumes are produced." Criteria for measuring successful well development should be proposed as turbidity measurements; such as five (5) nephelometric units.

Page 6-5 The proposal also states that development water from wells in the DRMO will be discharged to the site. The development water should be contained, tested and evaluated as to whether it meets the definition of a hazardous waste under 40 CFR Part 261. The proposal should acknowledge that all materials meeting the definition of a hazardous waste under that section must be handled and managed in accordance with the standards in the Code of Federal Regulations and applicable state standards.

Page 6-6 The proposal states that continuous water level measurement data will be obtained for a twenty-four (24) hour period in one upgradient and one downgradient well. EPA recommends that more than two wells be tested in order to provide information regarding the direction and rate of ground water flow. Water-level fluctuations that result from tidal influences may also be used to calculate hydraulic conductivity (K) provided that there is a minimum of 48 hours of continuous data. This technique may be used to supplement horizon specific slug tests and pump tests on site. References can be found in two papers attached to these comments: "Cyclic Fluctuations in Water Level as a Basis for

Determining Aquifer Transmissibility" (Ferris, 1952) and "Use of Water Levels in Estimating Aquifer Constraints in a Finite Aquifer" (Rorabaugh, 1960).

Page 6-7 Provide the source(s) for Figure 6-2.

Page 6-8 The proposal states, "The number and placement of monitoring wells [at Jamaica Island landfill] can not be determined in this work plan because of the current lack of information. It is anticipated that 8 wells (3 upgradient and 5 downgradient) may be installed." What is the basis for deriving the number of wells? What additional information will be used to locate the proposed wells? Is it possible that some of the wells will be installed through the wastes, or are the monitoring wells intended to be installed in 8 of the 11 soil borings proposed for the perimeter of the landfill?

The RFI Proposal needs to be more explicit about the placement of monitoring wells. It is not apparent from this document how additional information obtained from the borings will be used to determine monitoring well locations. The Proposal should develop a conceptual model of site hydrogeology based on existing information and locate monitoring wells based on this conceptual model and by explaining the criteria for basing decisions.

Page 6-8 Encountering an aquiclude should not preclude the proposal from installing deep wells. The proposal should explain what further analysis is necessary for understanding the degree to which any low permeability layers might prevent the migration of contaminants to deeper portions of the site. This analysis should be proposed with a compliance schedule.

Page 6-8 to 6-10 The proposal should provide the rationale for the depth of the well screens in the JILF. Proposed overburden wells are designed so that they are screened above the top of bedrock, and the bedrock wells are designed as open holes drilled through casing which will extend 2 feet into bedrock. The depth of bedrock well screens should be based upon information from the literature and more importantly corings into the bedrock. Zones of primary and secondary permeability should be targeted for well screens.

Page 6-9* Identify the material to be used in the annular space in between the four (4) inch borehole walls.

Page 6-13 There is no rationale provided for the different parameter lists that are indicated for the DRMO and the JILF. As stated previously, the initial parameters for analyses should consist of hazardous constituents of Appendix IX and all other chemicals which could reasonable be derived from the SWMUs. Subsequent analyses may be some subset of these initial analyses.

Page 6-13 All sampling procedures should conform to EPA Protocols such as TEGD and "Test Methods for Evaluating Solid Waste" (EPA 1986; referred to as SW-846). For example, three (3) well volumes, rather than three to five, should be purged prior to sampling. Sampling procedures should include testing for immiscibles prior to purging (see attachment).

The purge water should be contained, tested and evaluated as to whether it meets the definition of a hazardous waste under 40 CFR Part 261. All materials meeting the definition of a hazardous waste under that section must be handled and managed in accordance with the standards in the Code of Federal Regulations and applicable state standards.

Page 6-14 The RFI Proposal states that ground water samples for metals analysis will be filtered using a 0.45 micron filter. The proposal should provide justification for filtering ground water samples and using this size filter. Samples collected for volatile organic analyses should not be subjected to field measurements. Samples that will be analyzed for PCBs should not be filtered.

A recent article "Ground Water Sampling for Metals Analysis" by R.W. Puls et al, may help you in determining the rationale for using filtered versus unfiltered analysis. You may consider for some portion of the initial round of sampling that the samples be analyzed unfiltered, in order to include total metals adsorbed onto suspended sediments and evaluate the maximum extent of contamination.

Page 6-14 The Proposal should be more explicit regarding the strategy and goals of the monitoring well installation. As previously stated, screen lengths should not be greater than 10 feet (or 15 feet if

the screen crosses a fluctuating water table). Well clusters should be proposed where screens do not provide sufficient coverage of the aquifer.

Page 6-15 The discussion regarding the procedure for collecting field blanks is confusing. The proposal states "A field blank will be obtained prior to dedicating the bailer to their respective wells by pouring distilled water through the clean bailer and into lab prepared sample bottles." Is each bailer going to have an associated field blank? Would this occur during the first sampling episode with the bailer dedicated to a particular well thereafter?

The number of field blanks and replicates are unclear. Table A-3 indicates that only one (1) field blank will be sampled for QA/QC purposes.

SECTION 7 SUBSURFACE GAS CHARACTERIZATION

General Overview

As required by the Special Permit Condition A.7., a subsurface gas characterization is proposed for the SWMU #8, the JILF.

The proposal states that time integrated collection yields statistically superior results when measuring flux rates. Is the flux rate of primary concern in this situation? It may be more appropriate to investigate the affect of the tides on the volatilization of the organics, rather than planning on obtaining an average. If tides will effect soil gas concentrations then measurements should be made when the concentrations are likely to be greatest.

The proposal should evaluate potential impacts on soil gas measurements from geology. Since the soil gas plumes are dependent upon the movement and transport through the soil it will be necessary to first have a conceptual understanding of the geology of the unit prior to developing the soil gas survey. Tracer(s) parameters must be proposed based on the knowledge of the contaminants and vertical profiling proposed to identify the appropriate depths to monitor for the tracer(s).

The assumptions and limitations of the field methods must be part of the evaluation of the results. Below are two sources that may provide additional information in developing the strategy for the soil gas survey:

1) "Soil Gas Sensing for Detection and Mapping of Volatile Organics," Environmental Monitoring Systems Laboratory, Las Vegas, Nevada. 1987.; and

2) "Interim Final RCRA Facility Investigation (RFI) Guidance Vol. II Soil, Ground Water and Subsurface Gas Releases" (EPA) May 1989.

Page Specific Comments

Page 7-1 The proposal states that sampling points will be "subject to field call." The criteria for making these determinations must be stated in the proposal.

Page 7-1 The proposal indicates that a single depth for collecting soil gas samples will be used. Justification for using a single depth, rather than multiple depth probes should be provided in the proposal. The appropriate depth(s) should be determined by vertical profiles as described in reference number one (1) above.

SECTION 8 SEDIMENT CHARACTERIZATION

General Overview

Special Permit Condition A.8 requires that the RFI Proposal include a surface water/sediment characterization proposal to evaluate releases from SWMUs #5, #6, #8, #9 (surface water), and #5, #6, #8, #10, #26, and #27 (sediment). This section does provide sediment characterization plans for all SWMUs except #26, the Mobile Oil/Water Dumpsters. No justification is provided for the elimination of SWMU #26 from this section of the proposal. Based upon information in the RFA, there have been numerous discharges to coastal waters caused by overflow of the bilge slop and waste oil tanks. The location of these spills should be identified in the Facility Characterization Report and the sampling plan for sediments should address those areas.

The additional material submitted by the Portsmouth Naval Shipyard states that the new submittal replaces section 8.2 of the RFIP. These comments are based on the interpretation that section 8.2.2 and the remaining sections of the Sediment characterization of the proposal will remain, as presented in the original. These sections refer to the specific sampling plans for the sediment study.

The RFI Proposal states that surface water characterization studies will be proposed as a separate work plan at a later date, when more data are available. EPA agrees that more data on ground water and

surface water flow and discharges may be necessary to adequately design an appropriate surface water sampling plan. However, the overall strategies and decision points should be discussed here. A surface water characterization study is required by the permit and a phased approach may be permissible under the current permit conditions. Please note, that the study must be completed within the eighteen months from the approval of the RFI proposal, as required by the permit.

The proposal does not include any sediment sampling in the Piscataqua River south of the DRMO storage area. Samples from the non-dredged area of the river should be included as part of the sediment characterization report.

This section of the proposal lacks the required justification for the tasks that it proposes. For example, core sample depths are determined to be 10"-12" and 16"-18", without providing the criteria or rationale that was used to reach this decision it appears to be arbitrary. The location of samples for analysis of the river sediment should be based upon the knowledge of the tidal sediment movement and areas known to be a depositional environment.

It is important for all sediment samples to be analyzed for grain size as well as Total Organic Carbon (TOC).

Page Specific Comments

Page 8-1 to 8-4 EPA agrees that sampling of the surface water from the Piscataqua River and the Great Bay Estuary System should be conducted, after additional information regarding on-site contaminant sources and pathways becomes available. The water columns of marine systems are highly dynamic and variable. Successful detection and quantification of contaminant release attributable to the shipyard depends upon prudent placement of sampling stations, the locations of which should be based upon knowledge of on-shore sources. An approach similar to this has been used in a Risk Assessment Pilot Study of the Davisville, RI, Naval Construction Battalion Center. This study is available to the public, therefore I have been able to attach copies of the workplan and other relevant material.

Page 8-1 The proposal indicates nine (9) catch basins will be studied in the DRMO however, only eight (8) are marked on the map in Enclosure B.

Page 8-1 The objectives for the catch basin study are inadequately addressed in the proposal. For example, the catch basin survey could focus on system design as a migration pathway for ground

water. Methodologies described for examination of off-site transport of contaminants, e.g., for the sediment characterization in the catch basin, do not allow for comparison of contaminant migration through time. Homogenization of vertical sediment cores would mask any increase or decrease in migration; knowledge of such changes may be of great value in determining appropriate remedial actions.

Page 8-4 Sediment samples for volatile organic analyses should not be homogenized. The basis for, and specification of, the number and location of cores should be provided.

Page 8-4 The description of benthic sediment sample collection and analysis is very general, and does not reflect an appreciation of aquatic sampling methodologies currently available, or of environmental processes affecting contaminant transport and fate. For example, the implied homogenization of the top 0 - 4 inches of sediment may mask contaminant signals. Additionally, there is no indication that granulometry will be examined as a covariate of contaminant level. Some additional consideration along these lines is necessary.

Page 8-6 The proposal should provide the rationale for the number and location of samples as related to the program objectives for the this investigation. This should include rationale for varying the parameter list for this investigation as described on page 8-9. Why isn't cyanide included as a parameter since many of the tanks are reported to contain cyanide?

Page 8-7 Three surface sediment samples in the Clark's Island Embayment are proposed to be located in the "hot spot" defined in the Loureiro Report (1986). These locations should be more clearly defined in Enclosure A or Figure 8-1.

Page 8-7 The text is not clear regarding the optimum approach in an exploratory study. Is the text referring to both judgmental and systematic methods for sampling?

Page 8-9 What is the significance of two samples from the surface sediment samples from SWMU 10, the Battery Acid Tank No. 24. Does a migration pathway analysis support these sampling locations?

Page 8-9 What is the rationale for excluding PAHs in the analysis for the Fuel Oil Spill Area (SWMU 26)?

Page 8-9 Based upon the proposal only one sample will be collected fifty (50) feet from each Industrial Waste Outfall. It is possible that this sampling approach will fail to capture the extent and gradient of contamination, if contamination is found at the site. An alternative sampling approach is to design a sampling grid that transects radially outward from the industrial waste outfalls. Additionally, no samples should be taken from areas that have been dredged.

Page 8-9 The Proposal suggests that the Industrial Waste Outfalls will be tested for different parameters than other sediment samples. Given the variability in transport mechanisms a pathway analysis should take place and be described. Since contaminants from each SWMU could appear in many different locations, a comprehensive parameter list should be applied to all outfall samples. The parameters for analysis should initially consist of hazardous constituents of Appendix IX and all other chemicals which could reasonably be derived from the SWMU. Subsequent analyses may be some approved subset of these initial analyses.

Page 8-11 The Proposal does not provide rationale, as it relates to the project objectives, for the location of the gravity cores proposed for the river. Additionally, a pathway analysis would be useful for this area as well.

Page 8-11 River sediment samples should be analyzed for the same constituents upstream and downstream; so samples are analyzed for the same parameters as the sediment samples proposed for offshore of the individual sites (including SWMU 8, 10, 27, and 5). It may also be useful to perform grain size analyses on all or a subset of the sediment samples for two reasons:

- The level of contamination may be a function of particle size (as well as TOC), since many organic compounds tend to be preferentially adsorbed onto small particles such as clays.

- Grain size data will assist in the fate and transport analysis for the surface water/sediment pathway.

Page 20 The supplemental information proposes that the results from the sediment study will be compared

sampling conducted previously. Data must be provided to ensure that the two sampling events are comparable.

Page 20 The statement "Recommendation for a surface water characterization will be developed as a separate work plan for EPA approval" is confusing. The permit requires a surface water characterization to be completed within the eighteen (18) months of the approval of the RFI Proposal.

Page 21 The Surface Water/Sediment Characterization required by the permit includes "characterization of all permanent and intermittent water bodies within the facility boundaries..." Therefore, the fresh water ponds must be included in the surface water characterization. More explanation should be provided in determining how the ponds will be studied (the objectives) and what criteria will be used.

SECTION 9 TANK INVESTIGATION

General Overview

Special Permit Condition A.9 requires that the facility conduct tank investigations at SWMUs #11, 12, 13, 16, 21 and 23. This section of the RFI Proposal describes the approach to the tank investigations to be conducted at the required SWMUs and at SWMUs #10, 26 and 27. Special Permit Condition C.7 requires that the facility prepare a Tank Investigation Report which contains all the results of waste characterization analysis and tank inspections. If the need for further investigation is indicated, the Tank Investigation Report shall propose a Supplemental Tank Investigation Report which characterizes contaminants of the ground water or soil.

The general strategy for conducting the Tank Investigation, as detailed in this section, includes: (a) review of inventory records and tank testing; (b) determination of the present chemical characteristics of the tank contents; and (c) conducting a soils investigation to verify the presence of contamination. It is not clear whether item "c" is intended to be performed as part of the RFI or as the Supplemental Tank Investigation. Section 14 of the RFI Proposal indicates that soil sampling will be part of the RFI. If this is the case EPA believes that the sample collection strategy should be provided, either here or in Section 4.

The text indicates that the only soil investigation proposed at this time is at Berth 6. This may not be acceptable as there is more to proving that a tank has not had releases than tightness testing of the tank proper.

Page Specific Comments

Page 9-3 The present volume of material in each tank should also be estimated by measuring depth to product or water and also measuring the tank diameter. Using facility records, the total capacity of the tank may be obtained, and this information may then be used to calculate the volume of liquid plus sludge in the tank. An interface probe may be used to determine whether more than one liquid phase is present in the tank, from which the quantity of each liquid may be calculated. Alternatively, water-sensitive paste may also be used when "sticking" the tank to determine if there is water floating on the top or at the tank invert.

Page 9-3 The analytical list for the waste characterization is limited. The list should include all products as possible waste components, a description of the processes from which the waste was generated and possible contaminants from previous analyses. For example, unspecified rinse water (SWMUs 13 and 16) could be anything; spent cleaning solutions (SWMUs 21 and 23) are likely to contain organics; and waste oil (SWMU 26) could have contained halogenated compounds depending upon the source and use.

Why are TPH and TCL volatiles/semi-volatiles omitted? If separate phase liquids are present what parameters will the laboratory be instructed to analyze for? Where tank contents cannot be verified the tank contents should be analyzed for Appendix IX constituents.

Page 9-4 The proposal should describe the methods for determining the extent of soil contamination at leaking tanks to provide a measure of the completeness and success of the removal effort. There appears to be a presumption here that existing conditions are representative of all historical conditions. Why should this presumption be valid? The records search should be able to provide information regarding how well the history of these tanks is understood.

Page 9-4 According to 40 CFR 280.43(c), the tank tightness test must also be capable of detecting 0.1 gallons per hour leak rate while accounting for the effects of thermal expansion or contraction of the product, vapor pockets, tank deformation, evaporation or condensation. The RFI Proposal further states, "If a UST fails the tightness test, a second test will be conducted to confirm the results and to determine whether the tank or the piping system had failed." Will any leak rate recorded above the detection limit of the test method be considered a failure of the test? The failure criterion should be specified as 0.1 gallons per hour per hour. The tank should be separated from the lines before the second test is run, so that it will be possible to determine whether the leak is in the tank or the lines.

Page 9-6 The last paragraph of section 9.6 seems contradictory. It is not clear why the equipment will not be used to take samples directly. The decontamination liquids should be drummed, tested and evaluated as to whether they meet the definition of a hazardous waste under 40 CFR Part 261. All materials meeting the definition of a hazardous waste under that section must be handled, managed and transported in accordance with the standards in the Code of Federal Register and all applicable state standards.

Page 9-6 EPA will not endorse section 9.7 regarding corrective action requirements.

SECTION 10 BIOTA CHARACTERIZATION

General Overview

The RFI Proposal and the additional submittal "Portsmouth Naval Shipyard Checklist Requirements: HSWA Permit" suggest that the biota sampling program will be developed as a separate work plan when more information is available to identify the contaminants attributable to the facility. This approach is acceptable to the EPA, however within the current construct of the permit the Biota Report must be submitted within eighteen (18) months of EPA's approval of the RFI proposal.

The proposal states that the characterization will be developed from the pathway and contaminant level to the biota level. The current information provided in the proposal and the supplemental information is still vague. However, this approach may be

acceptable if: 1) the pathways and contaminants can be identified; and 2) if all levels of receptors are addressed.

Below are some references that may provide assistance in developing the biota characterization proposal. The material from the Risk Assessment Pilot Study of the Davisville, RI, Naval Construction Battalion Center is included as an attachment and should be helpful. Other references that may be useful include:

"Risk Assessment Guidance for Superfund Volume II Environmental Evaluation Manual Interim Final" United States Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, March 1989.;

"Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference" United States Environmental Protection Agency, Environmental Research Laboratory, Corvallis OR, March 1989.; and

"Supplemental Risk Assessment Guidance for the Superfund Program Part 2 - Guidance for Ecological Risk Assessments" United States Environmental Protection Agency Region I, Boston, MA, June 1989.

<u>Page Specific Comments</u>

Page 21 This section references Morozov et al (1986). This reference is not found in the bibliography.

Page 23 The statement "Recommendation for biota characterization will be developed as a separate draft work plan to be submitted to USEPA" is confusing and clarification should be provided. The permit requires that a biota characterization be completed.

SECTION 11 DATA COLLECTION QUALITY ASSURANCE PLAN

The Quality Assurance Project Plan is provided as Attachment A to the RFI Proposal. The review of that information is presented in Section 16 of EPA's comments.

SECTION 12 DATA MANAGEMENT PLAN

<u>General Overview</u>

This section presents descriptions of the technical database management system and the general procedures for technical and management data documentation. The plan generically addresses the majority of requirements listed in Special Permit Condition A.12.

In the use of any models or programs, such as those described in the text of this section, EPA also requires that the parameters are specified. The EPA requests that information be made available on $5^1/_4$ inch floppy disks in a compatible format such as dBase III+.

The contractor should identify field codes in advance of the RFI sample collection tasks in order to provide assurance that unique codes are assigned to samples and that all field and QC samples intended for collection are listed for field personnel.

Page Specific Comments

Page 12-3 Contour maps generated by computer software packages should be hand edited to remove artifacts caused by the fitting algorithm.

SECTION 13 HEALTH AND SAFETY PLAN

The Health and Safety Plan is provided as Attachment B to the RFI Proposal. The review of that information is presented in Section 17 of this document.

SECTION 14 PROJECT MANAGEMENT PLAN

General Overview

This section identifies the project team members and their organizations for conducting the RFI. A brief timeline of the project implementation schedule is also provided.

Page Specific Comments

Page 14-1 The Project Management Plan should identify a health and safety officer who has authority above the level of the project management, and who has overall responsibility for the development of the health and safety protocols appropriate for the facility.

Page 14-2 The Project Organization Chart, figure 14-1, should be updated to include the current Remedial Project Manager.

Page 14-5 (Revised Page 43) The timeline does not define the schedule for submittal of the biota and surface water characterization work plan. It also indicates that the biota study may not take place. Characterization of the biota is required by Special Permit Conditions A.10 and B.8. Additionally, the schedule does not clearly identify the time period for events such as soil sampling around failed tanks, or data validation.
The revised Project Implementation Schedule is illegible. The timeline should accurately represent the sequence of all the tasks that are proposed in the proposal and required by the permit. Also a key indicating what is meant by the dotted lines should also be provided.

SECTION 15 PUBLIC HEALTH AND ENVIRONMENTAL RISK EVALUATION

General Overview

The HSWA permit requires that the proposed PHERE address the potential for on-site and off-site exposures of human and environmental receptors to contaminants released from the SWMUs. A detailed review of the proposed PHERE indicates that the requirements of the permit are not adequately met, and the proposed methodology is not clearly described.

The PHERE should be a quantitative assessment of the risks that the facility may pose to human health and the environment. This process should be completely distinct from the risk management decisions that are made with the risk assessment data. Risk management is discussed in many places within this section, all of these references should be removed.

The methodology that is presented often lacks organization. The authors refer to several different guidance documents which present somewhat different risk assessment methodologies. For example, at times the PHERE is referred to as an "Endangerment Assessment" and appears to include methods from the Endangerment Assessment Handbook (EPA, 1985). At other times the PHERE is called a Health and Environmental Assessment (HEA), a term usually assigned to the assessment described in the RFI guidance document (EPA, 1989). However, the proposed PHERE methodology does not generally follow the RFI HEA methodology.

The guidance documents that should be used in developing the PHERE include:

- RCRA Facility Investigation (RFI) Guidance. Interim Final. Office of Solid Waste. U.S. EPA. EPA 530/SW-89-031 (OSWER Directive 9502.00-6D). May 1989.

- Risk Assessment Guidance For Superfund Human Health Evaluation Manual Part A. U.S. EPA 5401/1-89-002 (Office of Emergency Remedial Response) December 1989.

- Supplemental Risk Assessment Guidance for the Superfund Program. Draft Final. U.S. EPA Region I Risk Assessment Work Group. EPA 901/5-89-001. June 1989.

From the evidence presented in the work plan it appears that the project sampling and analysis planning efforts will not reflect the needs of the risk assessment project team. Coordination between the risk assessment project team and the sampling is required during the implementation of the RFI.

The data quality objectives required for conducting the risk assessment are not clearly addressed. Will the detection limits for the analyses performed during the RFI be adequate to meet the data objectives of the quantitative risk assessment?

Finally, the PHERE proposal does not adequately describe the environmental evaluation that will be conducted. The shipyard is located on the Piscataqua River, a tidal estuary and potentially sensitive environment. Commercially important species are also present. The environmental evaluation must address both the terrestrial and aquatic environment. It may be coupled with the biota characterization task of the RFI (Section 10 of the Work Plan). Even if the details of the environmental assessment cannot be determined until a later phase of the RFI, a general discussion of the study should be included in the PHERE proposal, identify early data needs and procedures to satisfy those needs.

Page Specific Comments

Page 15-1 In Section 15.1 (Introduction) and at other points, the evaluation is described as an HEA, an endangerment assessment, and a risk assessment. These terms originate from different EPA directives and imply somewhat different methodologies. The PHERE requires that a quantitative risk assessment be conducted, not an endangerment assessment.

Page 15-1 Section 15.1 states that the PHERE will assess human health and environmental risks associated with contaminants found in "ground water, soil, sediment and surface water at or adjacent to the site." The air pathway may also need to be evaluated, as well as the biota pathway (ingestion of fish).

Page 15-2 The second paragraph states that "a properly prepared HEA . . . will minimize remedial cost and reduce future liabilities at the site." There is no justification or basis for this statement.

Page 15-2 The first paragraph in Section 15.3 (Methodology) indicates that the evaluation will consider impacts to public welfare. Public welfare considerations are normally considered in an Endangerment Assessment (EA) but are not considered in an HEA.

Page 15-3 The "Supplemental Risk Assessment Guidance for the Superfund Program" prepared by EPA Region I (EPA, 1989) is also a relevant guidance document. The new "Risk Assessment Guidance for Superfund Human Health Evaluation" supercedes the 1986 document "Superfund Public Health Evaluation Manual." The "Endangerment Assessment Handbook" (USEPA, August 1985) and the "Toxicity Handbook--Principles Related to Hazardous Waste Site Investigations" (USEPA, August 1985) are no longer applicable guidance documents. These references should be deleted from the proposal. The guidance documents recommended for ecological assessments, mentioned previously, should also be included in this summary. EPA expects that all appropriate worksheets and calculations as described in the "Supplemental Risk Assessment Guidance" will be incorporated into the final report.

Page 15-3 It is unclear what is meant by the statement "However, the recommendations for performance of the HEA may be modified to reflects HART's experience in completing risk assessments and the specific concerns of the site." Pursuant to the permit the permittee should use the current operative guidance.

Page 15-3 The concept of "risk versus safety, and 'acceptable' risk" should not be included as part of PHERE. These concepts are risk management decisions and should not be included in the quantitative risk assessment as required by the PHERE.

Page 15-3 Section 15.3.1 (Contaminant Identification)

describes the process of identifying indicator chemicals based on "inherent toxicological properties, migration potential in various media, site specific concentration and degree of exposure and implications for public health." Frequency of detection and chemical class must also be considered. In addition, indicator chemicals should be selected separately for the different environmental media.

The identification of indicator compounds appears to be scheduled after the collection of the environmental data. The workplan should demonstrate how the risk assessment project team will interact with the field operations team in collecting relevant data before the implementation of field activities.

Page 15-4 In the first sentence, the "computer-based screening process" used for indicator chemical selection should be described.

Page 15-4 The second sentence describes the indicator chemicals as those posing "the greatest public health risk." However, a separate set of indicator chemicals may be required for the environmental assessment depending on the pathways, habitats, and species evaluated. The proposal should acknowledge this point.

Page 15-4 The third sentence states that the initial list of indicator chemicals "will be derived from a comparison of environmental concentrations to known USEPA-established exposure limit criteria and standards." Comparisons with standards and criteria should not be used to select indicator chemicals initially. The "Supplemental Guidance for Superfund" provides guidelines for selection of indicator chemicals.

Page 15-4 The "Risk Assessment Guidance for Superfund" requires justification for deleting chemicals, rather than selecting specific indicator chemicals. The concern for obtaining a "manageable" list of chemicals is reduced, due to the use of computers and spreadsheets to summarize information.
It is also important to identify which constituents are responsible for the greatest risk.

Page 15-4 Section 15.3.2 (Exposure Assessment) does not address the specific HSWA permit requirements for evaluation of exposure pathways, as set forth in

Part D, Section 1a-1h of the permit task outline. The outline calls for consideration of current and future local uses of ground water and surface water; human use of the facility and adjacent land; description of biota; and the identification of sensitive human and environmental populations.

Page 15-4 The first paragraph indicates that models will be used to define exposure pathways and exposed populations. These models should be described.

This section should apply a more qualitative approach to the initial identification of potential/actual exposure pathways. The pathways should include the environmental medium/media by which contaminants migrate and exposed/target populations. Detailed exposure assessments can follow the initial screening efforts for pathway analysis. The use of mathematical models for exposure, fate and transport is a necessary element to estimate exposure point concentrations.

Page 15-4 The comparison of predicted concentrations to ARARs, criteria, advisories, etc. should be done in addition to the risk assessment.

Page 15-5 The second paragraph states that "the location at which the greatest individual exposure occurs will be identified" for each significant exposure pathway. Identifying the most exposed individual for each pathway is often complex and may involve mathematical models. The methodology for this analysis needs to be described.

Page 15-5 The second paragraph also states that "most probable" and "realistic worst case" exposure scenarios will be developed. The basic methodological differences between these two scenarios should be presented. Region I EPA suggests differentiating between most probable and worst case exposures by varying the exposure point concentrations (e.g., average versus maximum).

Page 15-5 The last sentence of the second paragraph states that use of the worst case scenario will provide a "conservative **over**estimate of potential risks." This is not necessarily true; it is usually considered to put an upper bound on potential risk estimates to protect sensitive receptors or the "most exposed individual."

Page 15-5 The subsection heading in the middle of the page indicates a discussion of the exposed population in the following subsection. Such a discussion is not provided in the subsection.

Page 15-5 The subsection titled "Estimation of Exposure Point Concentrations and Exposed Population" is difficult to understand. This section describes the calculation of daily intake but does not address the calculation of exposure point concentrations.

Acute and/or subchronic exposures should also be addressed to evaluate noncarcinogenic effects. The meaning and method of estimation of "short/long term concentrations" (third sentence) should be provided. In addition to the parameters listed for the calculation of daily intakes, frequency of exposure and relative absorption of contaminants should be included.

Page 15-6 The first sentence should include sediment as a medium for which intake will be estimated. Dermal contact with water, soil, and sediment should also be included as exposure routes. Inhalation as well as ingestion may also need to be addressed as exposure routes.

Page 15-6 The application of "standard assumptions" should be reviewed by EPA prior to use in the risk assessment.

Page 15-6 In the third sentence of Section 15.3.3 (Toxicity Assessment), it is not understood how "screening of exposure pathways" will be used in the toxicity evaluation.

Page 15-6 In the first paragraph of or the subsection titled "Comparison to Standards and Criteria/ Identification of ARARs" it seems inappropriate to state that ARARs will be used "to develop target clean-up levels for the site." This objective does not seem to be stated or implied in the HSWA permit. It should also be noted that comparison of concentrations with ARARs is not always health protective; ARARs are not always health based. The workplan could should discuss the development of media protection standards, where applicable.

Page 15-7 If a reference dose is not available on IRIS the hierarchy outlined in the "Supplemental Risk Assessment Guidance" should be followed.

Page 15-7 In Section 15.3.4 (Risk Characterization) it is stated that "measured concentrations in media" are compared to reference dose values and potency factors to assess noncarcinogenic and carcinogenic risks. This is incorrect, the exposure **dose** must be used in these evaluations. To estimate carcinogenic risk, the dose is usually multiplied by -- not compared to -- the potency factor. In addition, the stated comparisons will not "judge the degree and extent of risk to .... welfare and the environment." Public welfare impacts might include effects on property values and commercial fisheries. A welfare analysis is not usually a part of a quantitative risk assessment.
Environmental impacts cannot be evaluated on the basis of reference doses and carcinogenic potency factors derived for humans.

Page 15-7 The scope and format of the final report could be better described.

Page 15-8 The first paragraph describes the assessment of noncarcinogenic effects and the potential effects of chemical mixtures. It should be noted that the hazard index method for the additive effects of indicator chemicals should be applied only to chemicals displaying the same or similar noncarcinogenic effects with respect to toxic endpoint or target organ.

Page 15-8 The second paragraph indicates that the PHERE will include an evaluation of the "acceptability" of the estimated risks. This is more appropriate in the context of the risk management process and is outside the scope of the actual risk assessment.

Page 15-8 The Risk Characterization section does not address the evaluation of environmental impacts. Both terrestrial and marine environment should be included. If environmental impacts will be evaluated in the context of the biota characterization (Section 10 of the Work Plan), this should be noted.

Page 15-8 The Risk Characterization should explicitly state that risk characterization will be based upon an integrated risk, on a chemical specific basis, for all routes of exposure.

SECTION 16 QUALITY ASSURANCE PROJECT PLAN

(ATTACHMENT A)

The intent of the Quality Assurance Project Plan, stated in Special Permit Condition A.11, is as follows:

> "The RFI Proposal shall include a proposed plan to document all monitoring procedures (sampling, field measurements and sample analysis) performed during the investigations to characterize the environmental setting, the source, and the contamination to ensure that all information, data and resulting decisions are technically sound, statistically valid, and properly documented. At a minimum, the Data Collection Quality Assurance Plan shall include the following:
>
> a. Data Collection Strategy
> ...
> b. Sampling Plan
>
> The Sampling Plan shall contain all the elements of the "Sampling Plan" outlined in the Guidance on Remedial Investigations Under CERCLA in addition to the following: ...
>
> c. Field Measurements
> ...
> d. Sample Analysis Plan
> ..."

The Quality Assurance Project Plan (QAPP) does not contain all of the above elements for all the SWMUs listed as requiring action under the permit. The outline of the sections included in the plan does appear to address all required items. However, the listed sections are not complete with respect to the data typically required in a QAPP. A reference document that may help with applicable guidance is the "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans," (QAMS-005/80).

The Data Collection Quality Assurance Plan (QAPP) has not been written to conform to the requirements of the HSWA Permit. It is neither formatted to follow the permit nor indexed in any way to aid the reader in locating the specific information required by the permit.

The QAPP makes repeated, general references to other documents. The references are not specific and often the titles used in the QAPP do not correspond closely with the section titles in the referenced documents. For example, the Subsurface Gas Analysis Plan (SGAP) corresponds with the Subsurface Gas Characterization. Using consistent nomenclature within the proposal would be helpful to the reader. The QAPP would be far more useful if abstracts and

summaries of critical information were presented in the QAPP itself.

The QAPP should have a section on Data Quality Objectives. This section could include data collection strategies which recaps the important site factors and statistical considerations which have shaped the data collection plan.

As stated previously, EPA recommends conducting an Appendix IX analysis for the first round of sampling. After the constituents have been identified than more narrowly defined lists can be implemented.

Will the organic parameters be analyzed following criteria in the 2/88 Organic Statement of Work? Will the 2/88 Organic SOW deliverables apply? If so, the proposal must reference the 2/88 Organic Statement of Work. If not, a list of the analytical and extraction methods must be provided for each analyte.

The QAPP should have a comprehensive summary table of all samples by locations as required by permit conditions A.11.b.5. This table should also include a list of QC samples as well as footnotes or narrative text which explains the strategy for selection of specific QC samples. The list of QC samples must conform to the type and frequency required by the method referenced, i.e. CLP SOW.

The proposed number of field measurements necessary to give statistically significant results is not adequate. How will the three consecutive readings during the well development indicate that these measures are in agreement? Will a specific statistical test be conducted to measure this?

The section on proposed field measurements only addresses groundwater sampling. This section should address all the sampling events that will require field measurement.

No evaluation of the methods listed for total petroleum hydrocarbons (TPH) phenols, or total organic carbon (TOC) (RAI SOPs QA-070 (et seq), QA-074 (et seq), and QA-104.2) is possible since these SOPs are not included in the document. What is the purpose of screening for TPH, how will the data be used?

No definition of the PCB method is included. RAI lists EPA Method 608/8080 (RAI SOP QA-055) as one of its analytical methods. While these methods are applicable if the Aroclor identity is retained by the mixture, the migration of any potential PCBs through sediments and weathering effects caused by differences in degradation rates, volatility, and solubility of the various isomers makes this identity retention unlikely. EPA 680 (or the CLP modification), which analyzes for PCB congener classes, is recommended as a substitute.

A description of the intended uses for the data, and the necessary level of precision and accuracy for such uses has not been provided on a matrix/SWMU-specific basis.

The Permit (Section A.11.b.1) requires the facility to make provisions for measuring all necessary ancillary data. Ancillary data are not discussed as such in the QAPP. Section 4.1 refers to the Site Hydrogeologic Investigation Proposal but not relative to ancillary data. Section A.11.b.2 requires that the permittee describe conditions under which sampling should be conducted. Proposed conditions are not discussed as such in the QAPP. Section 4.1 refers to the Site Hydrogeologic Investigation Proposal but not relative to proposed conditions. For example, sampling of ground water in a zone of tidal influence should be performed at a predetermined tidal level. The justification for the tidal level chosen should also be provided.

Will the Appendix IX compounds be extracted and analyzed according to criteria in the appropriate CLP-SOW or SW846, third edition? If you are not using these methods you must provide the analysis and extraction methods for each analyte.

Page Specific Comments

Signature Page All appropriate signatures are not provided.

Page A-5 This section states that "An internal reviewer...will be responsible for providing review of project documents and reports..." What specific documents will be reviewed? Is data validation included in this review?

Page A-6 The section for Analytical Parameters is in section 4.2, not 4.3 as stated in the text.

Page A-6 Section 3.1 states:

"QA targets for accuracy and precision are stipulated in the 'Standard Operating Procedure' (standard procedure) for each analytical parameter."

The description above does not provide adequate detail concerning the necessary level of precision and accuracy required to meet the intended uses of the data. A summary should be provided which lists precision and accuracy goals by SWMU and analyte. Goals for precision and accuracy for each analytical parameter should be included in this section. This will serve to:

- summarize the data quality objectives (DQOs) for each parameter or parameter groups for adequacy review;
- provide data quality goals for those parameters not included in the CLP list (e.g., total phenols, TOC);
- provide guidance for parameters for which data quality objectives are defined by CLP but specific corrective actions are not defined (e.g., metals);
- provide specific DQOs for the project in the case of changes of the CLP DQOs, since CLP DQOs change periodically with revisions to the methodologies; and
- provide a basis for comparability of this program's data to that provided in past programs.

Page A-7 With the unknown nature of the contamination in the DRMO area, the list of metals to be analyzed should not be limited to the Priority Pollutant metals. It is recommended that an Appendix IX analysis be conducted for the first round of sampling.

Page A-8 Section 3.4 states: "The methods used for the collection and analysis of samples from this site, as documented in the RFI Proposal and this QAPP, are expected to provide comparable data." A statement that data will be comparable to data gathered during other programs should be made.

Page A-10 Table A-1 lists TAL inorganics, priority pollutant metals and cyanide as parameters for analysis, even though the TAL list includes (as a subset) the priority pollutant metals and cyanide. Appendix IX analysis should be used for the first round of sampling.

Page A-16 Calibration for field instruments, including the pH and specific conductivity meters, must be in compliance with all applicable EPA methods. This should be stated in this section. The EPA methods will provide requirements for calibration, precision, accuracy, and other quality control parameters that may not be in the manufacturer's instrument manual.

Page A-18 In the first paragraph, this section states, "The analytical laboratory will review appropriate quality control data to assure the validity of the analytical results." This does not qualify as data validation according to the National Data Validation guidelines. The data validation must be performed by persons independent of the laboratory. If the analysis will be conducted under the CLP reporting requirements, as stated in Section 4.2 of the QAPP, then all deliverables must conform to CLP requirements. This includes that a complete data package be kept and made available to the EPA on request in order for the EPA to conduct an independent validation of the data.

Page A-18 The second paragraph provides a list of organic and inorganic QC parameters which will be included in the QA/QC report. This is not the complete list of CLP deliverables. This section should either list all of the CLP deliverables or reference the deliverables identified in the SOW.

Page A-19 The third paragraph indicates that the data evaluation will be based upon three documents (identified as items 1,2, and 3). The three documents listed in this section are outdated. They should be as follows:

1. "Laboratory Data Validation, Functional Guidelines for Evaluating Organics Analysis" February 1, 1988.

2. This is now included in item 1.

3."Laboratory Data Validation, Functional Guidelines for Evaluating Inorganic Analysis"
June 13, 1988.

Page A-21 This section indicates that inorganic and organic testing will be performed in accordance with the CLP Statements of Work. The specific (and most current) SOW should be identified.

A definition of each type of QA/QC sample along with complete description of how each sample is collected should be provided, either in this section or in the sections which describe the sample collection.

Page A-21 Section 8.2, Field Internal OC Checks, states that "Field blanks will be collected throughout the sampling events for each matrix." How many field blanks will be collected and for which specific

matrices?

Page A-23 Table A-2 indicates that sediment samples analyzed for Phenols will be analyzed by EPA Method 604 or EPA Method 8040. EPA Method 604 is for water samples only; it cannot be used for soil samples because it contains no extraction procedures. Therefore, the notation should indicate that the samples will be analyzed for Phenols using EPA Method 8040 only. If Method 604 will be used, than appropriate extraction procedure must be provided.

Page A-24 Table A-3 lists RCRA metals for the mercury burial sites for both soils and ground water, and priority pollutant metals for well borings. While these lists do differ somewhat, it is recommended that Appendix IX is used for the first round of sampling.

A specific lists of individual parameters should be included in the QAPP to define specific analyses on specific samples (e.g., expand on tables A-2 and A-3 to include analyses and analytical methods).

Page A-25 Table A-4, as well as Tables A-2 and A-3 do not list matrix spikes as QC samples. CLP protocols require a pair of matrix spikes for organic analyses and a matrix spike and sample duplicates for inorganic analysis.

Page A-32 Section 11 is entitled "Specific Routines to Assess Precision, Accuracy and Completeness of Data". The section is comprised of the following statement:

"The procedures have been presented in previous sections of this QAPP (Section 3, 4, 5, 6, 7, 8 and 9)."

Although Section 8 does provide a list of QC samples. The other referenced sections provide no additional information on methods and procedures proposed to assess the precision, accuracy and completeness of the measurement data. Consequently, procedures for assessment of precision accuracy and completeness are not presented in the QAPP.

This section should also provide a description of proposed measures to assure that the following data sets can be compared to each other as required by Special Permit Condition A.11.a.3.

Specific procedures for monitoring the laboratory's ability to meet the DQOs should be included. These

should include evaluation of such parameters as surrogate and matrix spike recoveries, calibration checks, and evaluation of blanks (both field and laboratory).

Page A-33 Specific corrective actions in case non-attainment of DQOs (e.g., when will resampling be considered as a viable corrective action or what will be done if Precision & Accuracy goals are not achieved?) should be defined.

Appendix C to the QAPP
RAI Quality Assurance Plan.

Title Page This version of RAI's Quality Assurance Plan is dated 7/88. Is this the most recent version?

Page 2-3 Individuals should be named in the Organization chart.

SECTION 17 HEALTH AND SAFETY PLAN
ATTACHMENT B

EPA suggests that monitoring ambient air for mercury vapor be performed during intrusive activities around the mercury disposal sites.

Page B-7* The EPA Standard Operating Procedures Guidance for the upgrading of personal protection is when the organic vapors in the breathing zone are greater than background but less than or equal to five (5) parts per million.

Page B-8* How are airborne particluates monitored?

Page B-18* The State of Maine's Site Manager is Pamela Parker at (207) 289-2651.

Page B-18* A map with highlighted access routes should be available.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
GROUND WATER BRANCH
Washington 25, D.C.

GROUND-WATER
HYDRAULICS SECTION

Contribution No. 1
April 1952

CYCLIC FLUCTUATIONS OF WATER LEVEL AS A BASIS FOR DETERMINING AQUIFER TRANSMISSIBILITY

By
John G. Ferris

This contribution was orginally prepared as a technical paper from the United States for presentation in August 1951 at the Brussels Assembly of the International Union of Geodesy and Geophysics. Although it will ultimately appear in the Assembly proceedings, as published by the International Association of Hydrology, the paper is considered of sufficient interest to warrant interim release and distribution by the Geological Survey.

In coastal areas, wells near bodies of tidal water frequently exhibit sinusoidal fluctuations of water level, in response to periodic changes of tidewater stage. Inland, the regulation of a surface reservoir often produces correlative changes of ground-water stage in wells adjacent either to the reservoir or to its attendant stream. As the stage of the surface water rises, the head upon the subaqueous outcrop of the aquifer increases and thereby either increases the rate of inflow to the aquifer or reduces the rate of outflow therefrom. The increase in recharge or reduction in discharge results in a general recovery of water level in the aquifer. On the subsequent falling stage this pattern is reversed. When the stage of the surface body fluctuates as a simple harmonic motion a train of sinusoidal waves is propagated shoreward through the sub-outcrop of the aquifer. With increasing distance from the sub-outcrop, the amplitude of the transmitted wave decreases and the time lag of a given maximum or minimum increases.

If there is no suboutcrop, but the aquifer is confined by an extensive aquiclude, the rise and fall of the surface-water stage changes the total weight upon the aquifer. Resultant variations in compressive stress are borne in part by the skeletal aquifer and in part by its confined water. The relative compressibilities of the skeletal mass and the confined water determine the ratio of stress assignment and the net response of the piezometric surface to the surface force.

The problem of potential distribution within a semi-infinite solid, with the face at $x = o$, normal to the infinite dimension and subjected to periodic variations of potential, was long ago analyzed and the solution employed by Angstrom (Carslaw, pp. 41-44) to determine the thermal conductivity of various solids. Similar analyses have been used by other investigators to determine the conductivity of the earth, the penetration of diurnal and annual temperature waves, and the flow of heat in the walls of a steam-engine cylinder. The physical nature of these problems is quite analogous to our problem of the aquifer having a suboutcrop under tidewater or a regulated surface stream. Consequently, these solutions provide a ready pattern for evaluating the hydrologic counterpart.

Assume a homogeneous aquifer of uniform thickness and of great areal extent shoreward - that is, normal to the strike of the suboutcrop. Assume also that water is released immediately with a decline in pressure and at a rate proportional to that decline. As a further simplification, assume that flow is unidimensional and that the aquifer is fully penetrated by the surface-water body that propagates the cyclic fluctuations. In those situations where the aquifer is not fully penetrated or where it is under water-table (unconfined) conditions the analysis will still be satisfactory if (1) the observation well is far enough from the suboutcrop so that it is unaffected by vertical components of flow and (2) the range in cyclic fluctuation at the observation well is only a small fraction of the saturated thickness of the formation. The fundamental differential equation for the linear flow of water in an aquifer intersected by a stream may be written as follows (Ferris, 1950, p. 286):

$$\frac{\partial^2 s}{\partial x^2} = \frac{S}{T}\frac{\partial s}{\partial t} \qquad (1)$$

in terminology adapted to this problem

- s = net rise or fall of ground-water stage with reference to the mean stage over an observed period.
- x = distance from suboutcrop to observation well.
- t = time elapsed from convenient reference node within any cycle.
- S = coefficient of storage
- T = coefficient of transmissibility

Let s_o designate the amplitude or half range of stage fluctuation of the surface body. The problem resolves then to finding the particular solution of equation (1) that will satisfy the following boundary condition:

$$s = s_o \sin\omega t \qquad \text{at } x = o \tag{2}$$

The mathematical development leading to the particular solution of the differential equation is given in considerable detail by Ingersoll, Zobel, and Ingersoll (1948, pp. 46-47) and only the final form is repeated herewith, as

$$s = s_o e^{-x\sqrt{\omega S/2T}} \sin\left(\omega t - x\sqrt{\frac{\omega S}{2T}}\right) \tag{3}$$

If we designate the period of the uniform tide or stage by t_o in accord with Jacob (1950, p. 365) then ω may be expressed in radians per time unit as $2\pi/t_o$ and equation (3) becomes

$$s = s_o e^{-x\sqrt{\pi S/t_o T}} \sin\left(\frac{2\pi t}{t_o} - x\sqrt{\frac{\pi S}{t_o T}}\right) \tag{4}$$

Equation (4) defines a wave motion whose amplitude rapidly decreases with distance x as given by the factor $s_o e^{-x\sqrt{\pi S/t_o T}}$. When the aquifer response is due to loading rather than head change at the suboutcrop the amplitude factor should be reduced (Jacob, 1950, p. 356) by the ratio $[\alpha/(\alpha + \theta\beta)]$, where α is the vertical compressibility of the skeletal aquifer, β is the compressibility of the water, and θ is the porosity of the sand. While values of β, the compressibility of water can be obtained from published tables of physical data, little information is available to estimate α, the vertical compressibility of the aquifer and this factor may vary considerably. The principal guide to the magnitude of α would be correlative data from similar aquifers where pumping test results have established its value.

From equation (4) the range of ground-water fluctuation at an observation well at a distance x from the suboutcrop is given by

$$s_r = 2\, s_o e^{-x\sqrt{\pi S/t_o T}} \tag{5}$$

It is of interest to note from the form of equation (5) that the slower the fluctuation of the surface tide - that is, the greater the value of t_o, the greater is the range of stage within the aquifer.

Let t_l denote the lag in time of occurrence of a given maximum or minimum ground-water stage following the occurrence of a similar surface stage. Then, from Ingersoll, Zobel, and Ingersoll (1948, p. 48), the expression for t_l is as follows:

$$t_l = x\sqrt{\frac{t_o S}{4\pi T}} \tag{6}$$

The apparent velocity of transmission of the wave through the aquifer is

$$v_{ap} = \frac{x}{t_l} = \sqrt{\frac{4\pi T}{t_o S}} \tag{7}$$

Equation (7) indicates the apparent velocity of a given maximum or minimum and does not pertain either to the rate of pressure transmission (Muskat, 1939, p. 669) or the apparent rate of pressure transmission (Jacob, 1940, p. 585) within the aquifer.

The wave length is obtained as

$$\lambda = v_{ap}\ t_o = \sqrt{\frac{4\pi t_o T}{S}} \tag{8}$$

Physically there would be little opportunity in ground-water hydrology to obtain a snapshot view of the sinusoidal wave train, as would be required to employ equation (8).

During half the cycle water flows through the suboutcrop into the aquifer; in the other half it flows out again. The quantity of flow per half cycle is determined with the aid of Darcy's law.

$$Q = TIL$$

where L is the length of suboutcrop across which the flow occurs, and where I, as given by Ingersoll, Zobel, and Ingersoll (1948, p. 49), is:

$$I = \frac{\partial s}{\partial x} = s_o e^{-x\sqrt{\omega S/2T}}\left(-\frac{\omega S}{2T}\right)\left[\sin\left(\omega t - x\sqrt{\frac{\omega S}{2T}}\right) + \cos\left(\omega t - x\sqrt{\frac{\omega S}{2T}}\right)\right] \tag{9}$$

It is convenient to set up the integral for the quantity of flow per unit length of suboutcrop. Because the gradient $\partial s/\partial x$ is not i phase with s, the limits of integration are determined by noting from inspection of equation (9) that at $x = 0$ the gradient is zero at $t = -\pi/4\omega = -t_o/8$, reaches a minimum at $t = \pi/4\omega = t_o/8$, and returns to 0 at $t = 3\pi/4\omega = 3t_o/8$.

$$\frac{Q}{L} = -T \int_{-t_o/8}^{3t_o/8} \left(\frac{\partial s}{\partial x}\right)_{x=0} dt \qquad (10)$$

$$\frac{Q}{L} = -T \int_{-\pi/4\omega}^{3\pi/4\omega} \left(\frac{\partial s}{\partial x}\right)_{x=0} dt \qquad (11)$$

$$\frac{Q}{L} = s_o\sqrt{\frac{2t_oST}{\pi}} \qquad (12)$$

To illustrate the applicability of these methods to field prob lems, data are presented for three riverside observation wells at the Ashland station of the municipally owned water supply of the City of Lincoln, Nebraska. A map of the well station is shown as figure 1. Automatic water-stage recorders are operated on observation wells 1 to 3 inclusive, and at the river gage on the Platte River at the crossing of U. S. Highway 6. A geologic section from west to east through supply well 2 is reproduced as figure 2. Typical records from the autographic charts for the river-stage recorder and observation well 1 are reproduced as figure 3.

Observation wells 1, 2, and 3 are respectively 42, 106, and 252 feet from the edge of the river at a normal stage. Each well is screened and developed in the upper part of the aquifer. From records for the river-stage recorder and the three observation wells for the period September 23 to 29, 1950, the ratio of ground-water fluctuation to river change was computed for the ris ng and falling limb of each cycle. These stage ratios are summarized in table 1. The period of the river fluctuation, computed for each limb of each cycle, ranged from

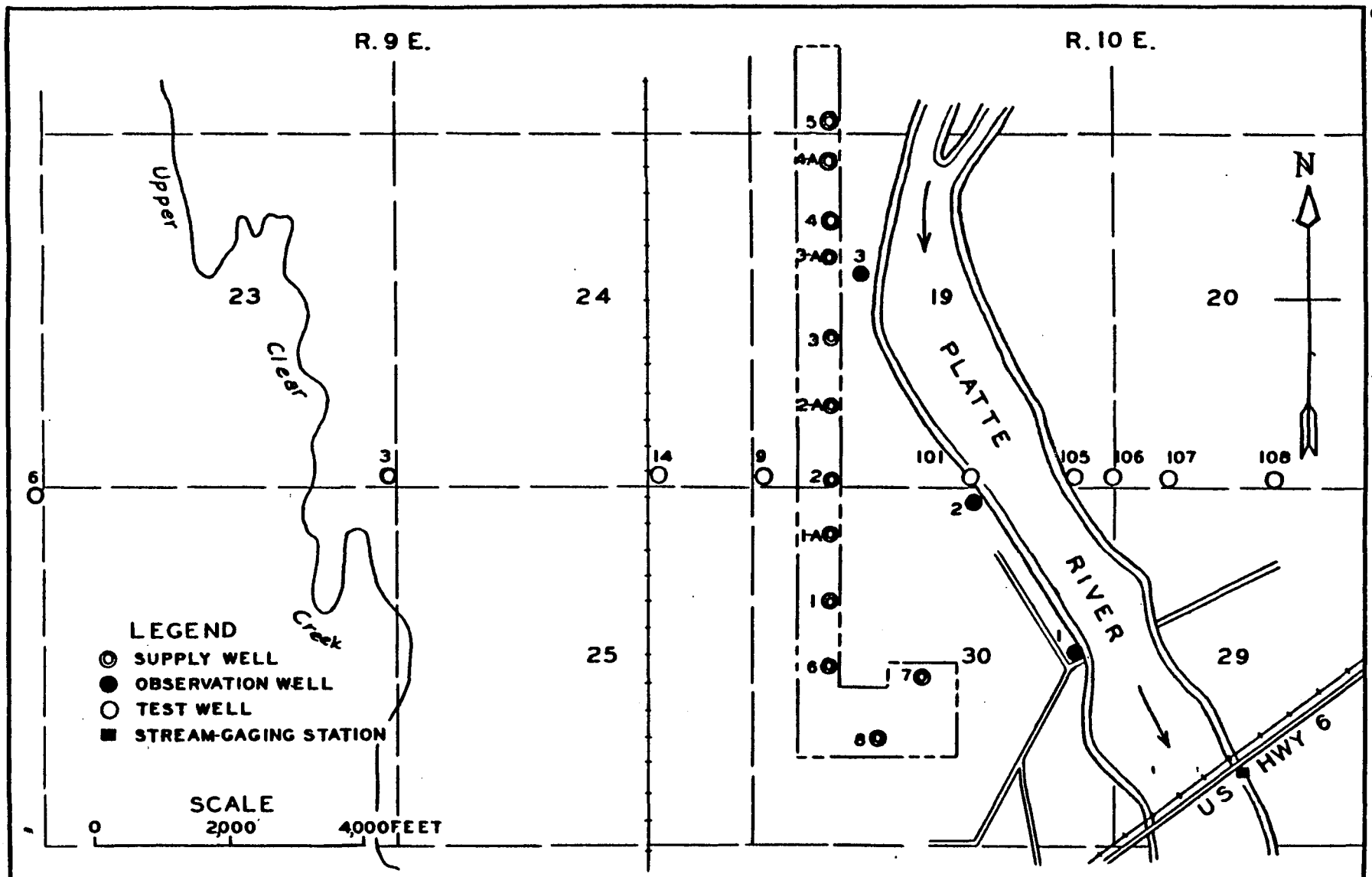

FIGURE 1.-MAP SHOWING A PORTION OF THE CITY OF LINCOLN WELL STATION AT ASHLAND, NEBR.

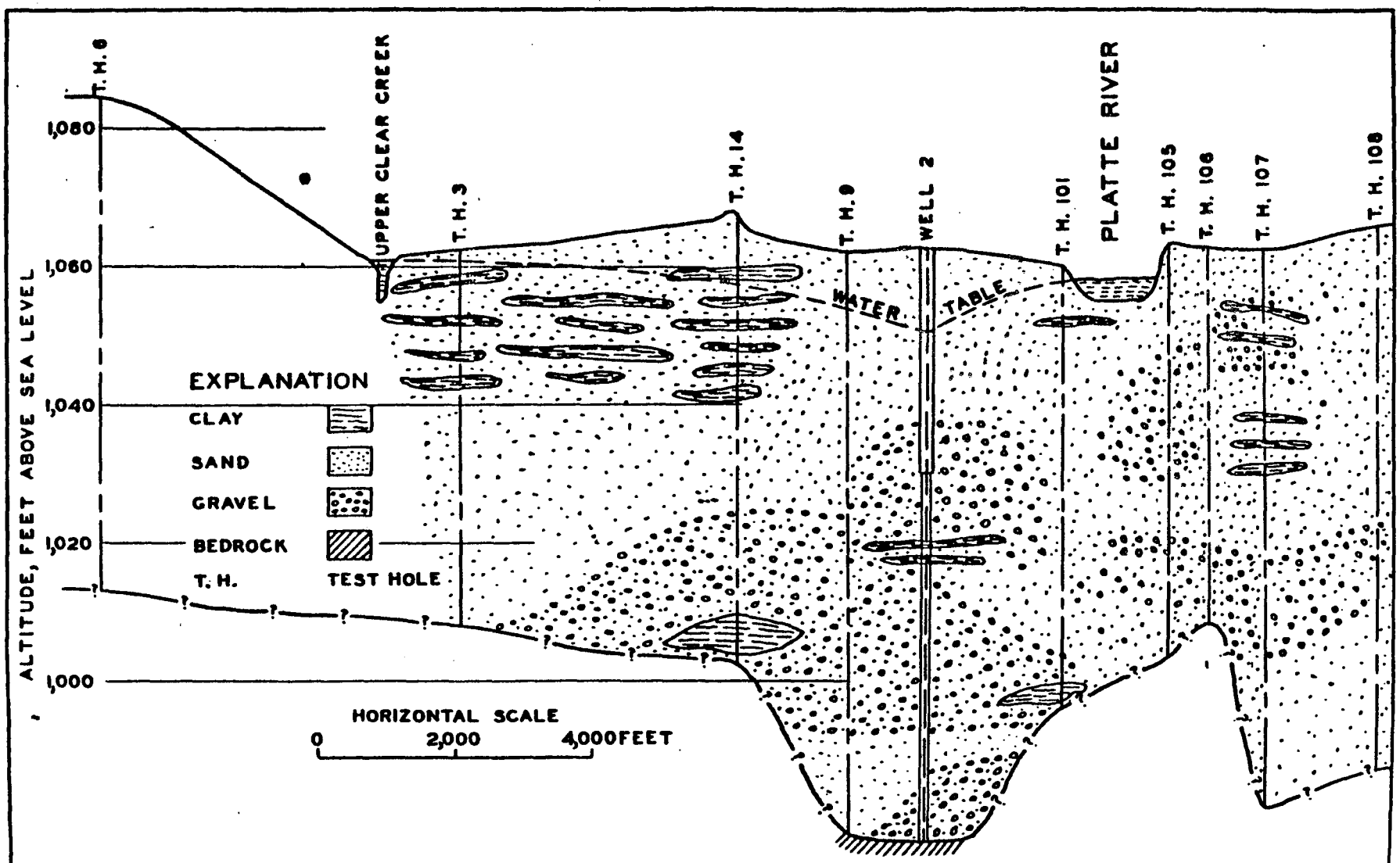

FIGURE 2.- GENERALIZED GEOLOGIC SECTION FROM WEST TO EAST THROUGH SUPPLY WELL 2 OF THE CITY OF LINCOLN AT THE ASHLAND, NEBR. WELL STATION.

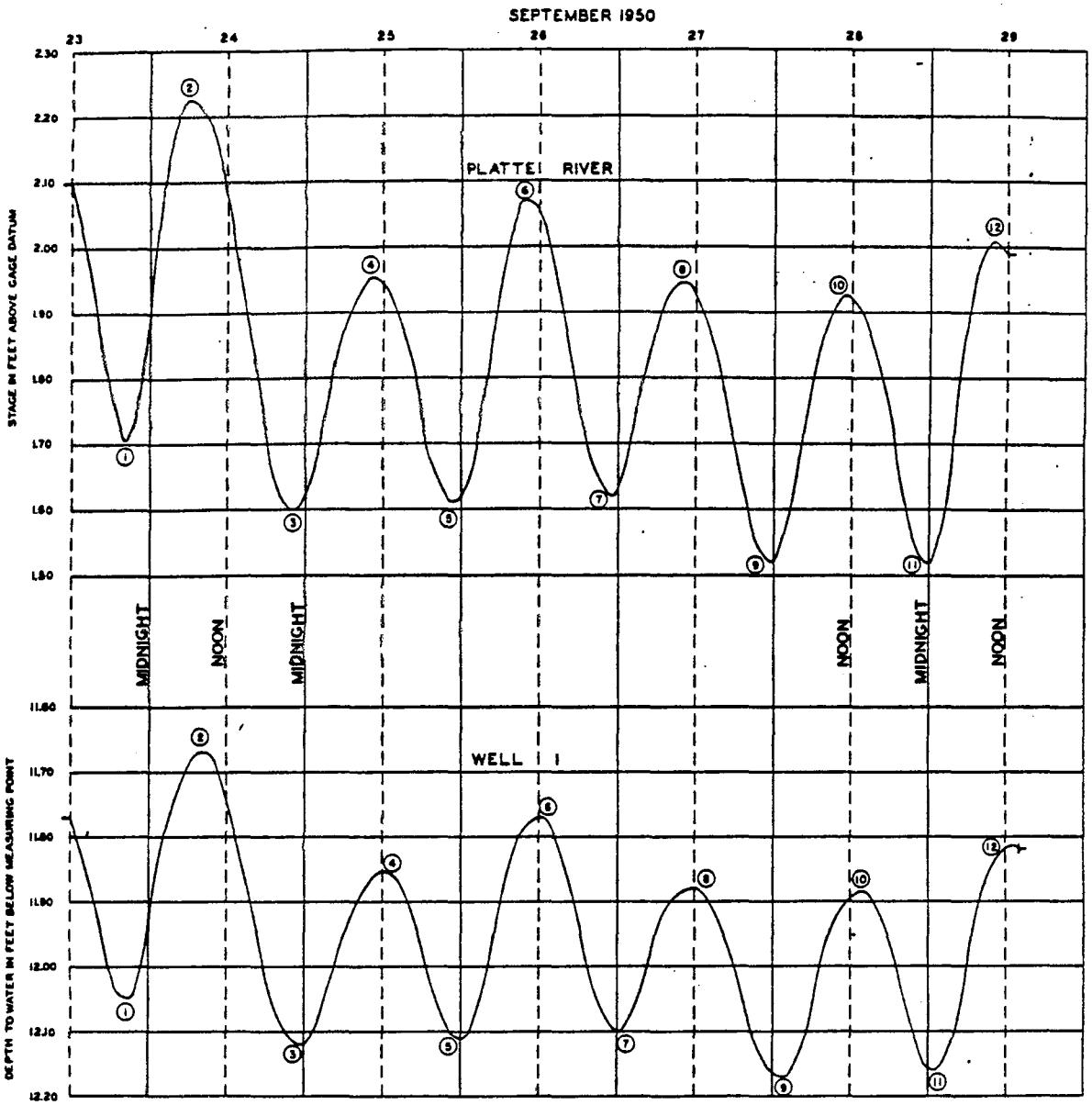

FIGURE 3-GRAPH SHOWING THE STAGE OF THE PLATTE RIVER AND THE WATER LEVEL IN OBSERVATION WELL 1 OF THE CITY OF LINCOLN AT THE ASHLAND, NEBR. WELL STATION.

Table 1. Ratio of the recorded range of ground-water stage in observation wells 1, 2, and 3 as compared to the stage range of the Platte River at Ashland, Nebr.

Reference numbers of fluctuation a/	Well 1		Well 2		Well 3	
	Rising stage	Falling stage	Rising stage	Falling stage	Rising stage	Falling stage
1-2	0.73		0.52		0.35	
2-3		0.71		0.56		0.46
3-4	.77		.54		.31	
4-5		.76		.56		.29
5-6	.74		.59		.26	
6-7		.73		.56		.29
7-8	.69		.47		.28	
8-9		.71		.56		.20
9-10	.72		.52		.33	
10-11		.68		.51		.37
11-12	.71		.53		.14	
Averages	.73	.72	.53	.55	.28	.32
	0.72		0.54		0.30	

a/ See figure 3.

20.5 hours to 31.0 hours and averaged 24 hours or 1 day. To apply the stage-ratio data, equation (5) is adapted for use with gallon-per-day-per-foot units, as follows:

$$s_r = 2s_o e^{-4.8x\sqrt{S/t_oT}} \tag{13}$$

$$\frac{s_r}{2s_o} = e^{-4.8x\sqrt{S/t_oT}}$$

$$\log_{10}\left(\frac{s_r}{2s_o}\right) = -2.1x\sqrt{\frac{S}{t_oT}} \tag{14}$$

$$2.1\sqrt{\frac{S}{t_oT}} = \frac{-\log_{10}\left(s_r/2s_o\right)}{x} \tag{15}$$

The logarithmic quantity $(s_r/2s_o)$ is in effect the ratio of the range of ground-water stage to the range of river or tide stage. The form of equation (15) suggests the use of a semilogarithmic plot of the logarithm of the range ratio versus the distance x for each observation well. Thus the right-hand member of equation (15) represents the slope of this plot, and if the change in logarithm of the range ratio is selected over one log cycle then the numerator of this slope expression reduces to unity. Thus equation (15) becomes

$$2.1\sqrt{\frac{S}{t_oT}} = -\frac{1}{\Delta x} \tag{16}$$

A more convenient form is gained by removing the radical

$$4.4\left(\frac{S}{t_oT}\right) = \frac{1}{\Delta x^2}$$

$$T = \frac{4.4\Delta x^2}{t_o} S \tag{17}$$

As indicated by equation (17) it is necessary that S, the coefficient of storage, be known in order to evaluate T, the coefficient of transmissibility. However, reasonable estimates of S can be made if it is known whether the aquifer is locally artesian or nonartesian which generally can be determined from studies of well logs and water-level records.

From the stage-ratio data of table 1, a semilogarithmic plot, figure 4, was constructed. Using the Δx value indicated for one log cycle, $t_o = 1$ day, and assuming various S values for water-table conditions, as suggested by the section of figure 2, equation (17) yields the following:

$$T = \frac{4.4 \cdot (540)^2 S}{1} = 1{,}300{,}000\ S$$

$$T = 130{,}000 \quad \text{if} \quad S = 0.10$$

$$T = 190{,}000 \qquad S = 0.15$$

$$T = 260{,}000 \qquad S = 0.20$$

$$T = 320{,}000 \qquad S = 0.25$$

At the suboutcrop where $x = o$, the range of the aquifer response, s_r, is equal to the river or tidal range $2s_o$, or $s_r/2s_o$ approaches unity as x approaches zero. Thus, the negative x value noted on figure 4 at the range ratio of unity represents the effective distance off shore to the suboutcrop.

The withdrawal of ground water from the numerous municipal wells nearby is relatively steady, except for minor changes in rate and distribution of pumping. These changes are more apt to disturb the time of maxima or minima observed than the ratio of well-to-river change. Further, the compressed time scale of the water-level recorders limits interpolation for this purpose to a greater degree than does the gage-height scale. Any variations in the effective screen resistance of each observation well would also tend to distort observations of maxima or minima timing. The wide range in the observed lag of maxima and minima shown by table 2 may result from any one or a combination of several of the aforementioned causes. To apply the time-lag data, equation (6) is modified as follows:

$$t_1 = \frac{x}{2}\sqrt{\frac{St_o}{\pi T}}$$

$$t_1^2 = \frac{x^2 St_o}{4\pi T}$$

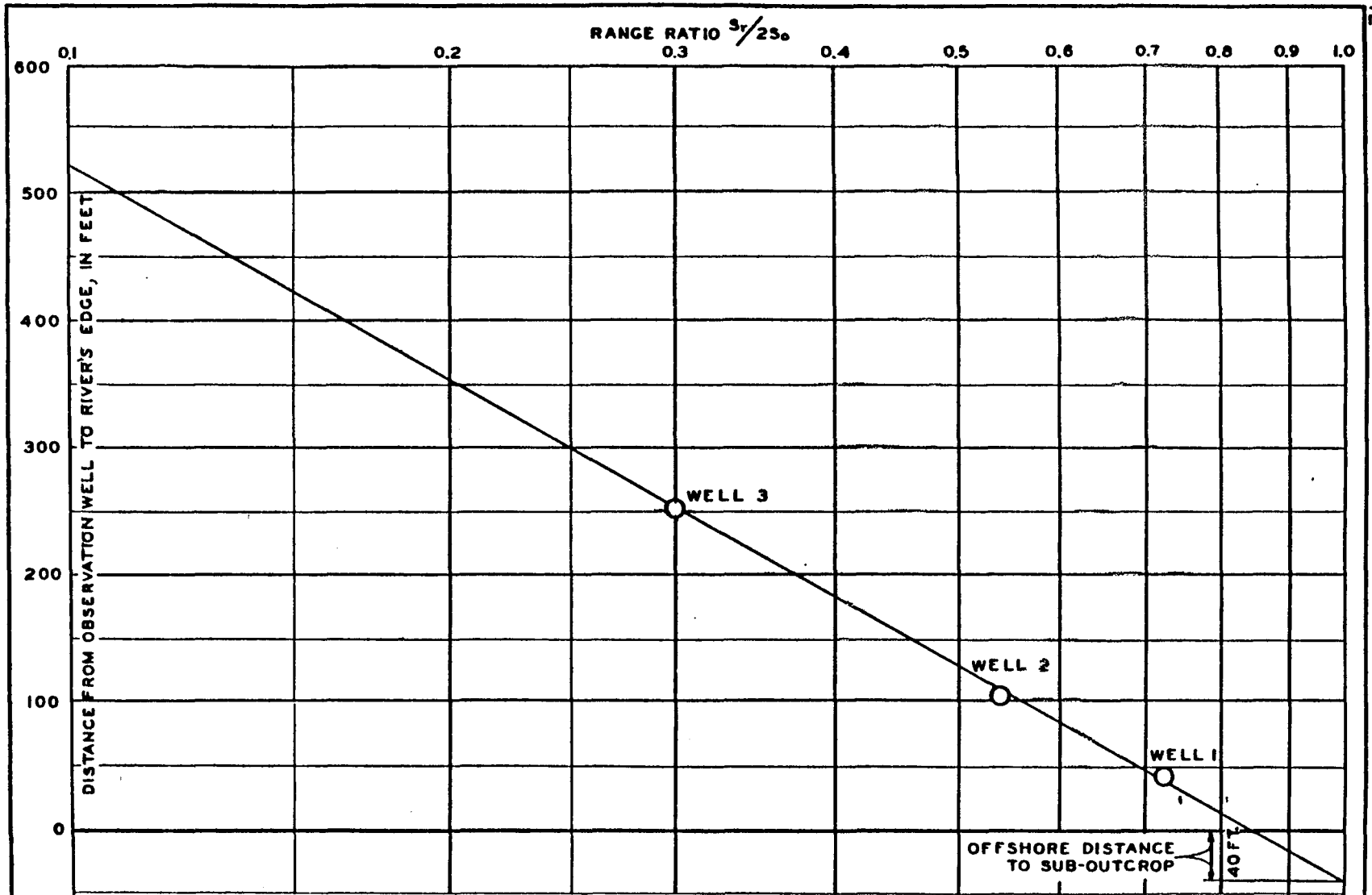

FIGURE 4.-SEMILOGARITHMIC PLOT OF THE RATIO OF GROUND-WATER STAGE TO STREAM STAGE VS. THE DISTANCE OF THE OBSERVATION WELL FROM THE CYCLIC STREAM.

Table 2. Time lag, in hours, of minimum or maximum ground-water stage relative to Platte River stage, as recorded by observation wells 1, 2, and 3 at the Ashland well station of the City of Lincoln, Nebr.

Reference number of fluctuation a/	Well 1		Well 2		Well 3	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1	1.25		3.75		--	
2		2.50		3.50		6.00
3	2.00		4.00		7.50	
4		2.25		2.75		6.75
5	1.75		3.75		6.75	
6		2.25		3.25		5.75
7	1.50		4.00		6.50	
8		2.00		2.50		5.50
9	2.50		4.00		7.00	
10		2.75		2.25		6.75
11	2.25		3.75		6.75	
12		2.50		2.50		5.50
Averages	1.90	2.40	3.90	2.80	6.70	6.00
	2.1		3.3		6.3	

a/ See figure 3.

$$T = \frac{x^2 S t_o}{4\pi t^2} \tag{18}$$

For T in gallons per day per foot and t_o and t_1 in days, equation (18) becomes

$$T = \frac{0.60\ x^2 S t_o}{t_1^2} \tag{19}$$

The average values of t_1, the time lag, are plotted for each well in figure 5. The slope of this graph is x/t_1 which appears in equation (19) at the square exponent. Substituting in equation (19) the slope coordinates noted on figure 5 there results

$$T = \frac{0.60 \times \overline{250}^2 \times 1}{(5/24)^2}\ S$$

$$T = 860{,}000\ S$$

$$T = 86{,}000 \quad \text{if} \quad S = 0.10$$

$$T = 130{,}000 \qquad S = 0.15$$

$$T = 170{,}000 \qquad S = 0.20$$

$$T = 220{,}000 \qquad S = 0.25$$

At the suboutcrop, where x = 0, the time lag, $t_1 = 0$. The negative value of x indicated by figure 5 at the $t_1 = 0$ axis is the effective distance off shore to the suboutcrop.

The large difference between the coefficients of transmissibility indicated by the stage-ratio method as compared to the time-lag method may reflect the influence of the nearby pumping in distorting the gage height and time of each maximum or minimum. The T estimates obtained by both methods and resultant averages are summarized in table 3.

Considerable refinement of the T estimates would be possible by expanding the time scale on the water-stage recorders through the use of daily time gears in lieu of the normal weekly gears. It would also be desirable to make the studies during periods when the rate of withdrawal by the nearby supply wells is constant. A more adequate test of these methods might be possible with a profile line of observation wells

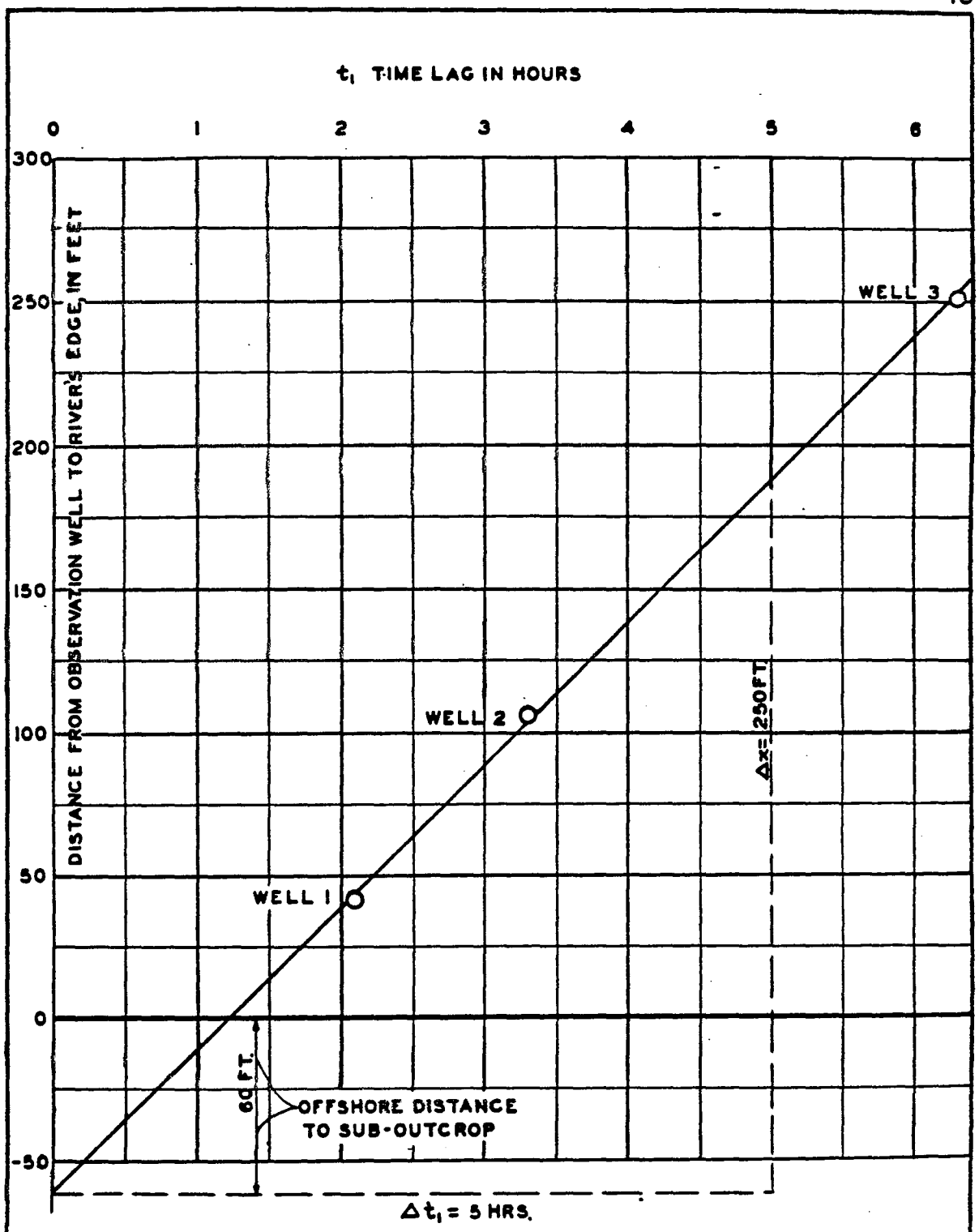

FIGURE 5.- PLOT OF TIME LAG VS. DISTANCE OF OBSERVATION WELL FROM SUB-OUTCROP.

Table 3. Summary of determinations of the coefficient of transmissibility by stage-ratio and time-lag methods.

Method	T, coefficient of transmissibility, in gallons per day per foot			
Coefficient of storage	S=0.10	S=0.15	S=0.20	S=0.25
Stage-ratio method	130,000	190,000	260,000	320,000
Time-lag method	86,000	130,000	170,000	220,000
Average	110,000	160,000	220,000	270,000

at right angles to the edge of the fluctuating surface-water body and in an area remote from heavy pumping.

It is reported that the saturated thickness of alluvial deposits in the well field area averages about 70 feet. Using this thickness and the average T values of table 3, the average permeability in gallons per day per square foot is 1,600 for S=0.10; 2,300 for S=0.15; 3,100 for S=0.20; and 3,900 for S=0.25. In comparison, gradient studies by the city, based on water-table contour maps, indicate an average permeability of 2,200 gallons per day per square foot.

The above-indicated values of the coefficients of transmissibility and storage should be considered as tentative, pending the completion of other hydrologic studies in the Ashland area. However, these data serve to demonstrate the applicability and usefulness of the methods described for analyzing cyclic fluctuations of ground-water level. Although their greatest use will be in areas of tidal streams and seas or near regulated streams and lakes, it was shown by Rambaut (1901, p. 235) that these methods can also be applied with fair results to variations that resemble periodic motion but are limited in duration to a single maximum or minimum. Thus, the response of an aquifer to the passage of a flood crest in a hydraulically connected stream may lend itself to this analysis. A logical extension from this generalized problem of a simple sinusoidal motion would be to study the applicability of the unit functions or delta functions of electrical-network analysis to the response of aquifers to complex patterns of recharge from precipitation or to the response of a stream to various rainfall-runoff patterns.

Acknowledgments

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their hearty cooperation and considerable effort in making these data available.

Authors note

Before preparation of this report was completed, an excellent report on cyclic fluctuations of ground-water level was published by Werner and Noren (1951, pp. 238-244). The work of the author, though of subsequent date, represents an independent analysis made without prior knowledge or advance notice of their coincidental research.

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INTERIM GUIDELINES AND SPECIFICATIONS FOR PREPARING QUALITY ASSURANCE PROJECT PLANS

QAMS-005/80

Office of Monitoring Systems and Quality Assurance
Office of Research and Development
United States Environmental Protection Agency
Washington, D.C. 20460

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Mention of trade names or commercial products does not constitute EPA endorsement or recommendation for use.

ABSTRACT

The Agency-wide quality assurance policy stipulates that every monitoring and measurement project must have a written and approved Quality Assurance (QA) Project Plan. A QA Project Plan is a written document, which presents, in specific terms, the policies, organization (where applicable), objectives, functional activities, and specific QA and quality control (QC) activities designed to achieve the data quality goals of a specific project(s) or continuing operation(s). The QA Project Plan is required for each specific project or continuing operation (or group of similar projects or continuing operations). The QA Project Plan will be prepared by the responsible Program Office, Regional Office, Laboratory, contractor, grantee, or other organization.

This document describes the sixteen elements which must be considered for inclusion in all Quality Assurance Project Plans, and establishes criteria for plan preparation, review and approval. All QA Project Plans must describe procedures which will be used to document and report precision, accuracy and completeness of environmental measurements.

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1.0 INTRODUCTION

Environmental Protection Agency (EPA) policy requires participation by all EPA regional offices, program offices, EPA laboratories and States in a centrally-managed quality assurance (QA) program as stated in the Administrator's Memorandum of May 30, 1979. This requirement applies to all environmental monitoring and measurement efforts mandated or supported by EPA through regulations, grants, contracts, or other formalized means not currently covered by regulation. The responsibility for developing, coordinating and directing the implementation of this program has been delegated to the Office of Research and Development (ORD), which has established the Quality Assurance Management Staff (QAMS) for this purpose.

Each office or laboratory generating data has the responsibility to implement minimum procedures which assure that precision, accuracy, completeness, and representativeness of its data are known and documented. In addition, an organization should specify the quality levels which data must meet in order to be acceptable. To ensure that this responsibility is met uniformly across the Agency, each EPA Office or Laboratory must have a written QA Project Plan covering each monitoring or measurement activity within its purview.

2.0 DEFINITION, PURPOSE AND SCOPE

2.1 Definition

QA Project Plans are written documents, one for each specific project or continuing operation (or group of similar projects or continuing operations), to be prepared by the responsible Program Office, Regional Office, Laboratory, Contractor, Grantee, or other organization. The QA Project Plan presents, in specific terms, the policies, organization, objectives, functional activities, and specific QA and quality control (QC) activities designed to achieve the data quality goals of the specific project(s) or continuing operation(s). Other terms useful in understanding this document are defined in Appendix A.

2.2 Purpose

This document (1) presents guidelines and specifications that describe the 16 essential elements of a QA Project Plan, (2) recommends the format to be followed, and (3) specifies how plans will be reviewed and approved.

2.3 Scope

The mandatory QA program covers all environmentally-related measurements. Environmentally-related measurements are defined as all field and laboratory investigations that generate data. These include (1) the measurement of chemical, physical, or biological parameters in

the environment, (2) the determination of the presence or absence of pollutants in waste streams, (3) assessment of health and ecological effect studies, (4) conduct of clinical and epidemiological investigations, (5) performance of engineering and process evaluations, (6) study of laboratory simulation of environmental events, and (7) study or measurement on pollutant transport and fate, including diffusion models. Each project within these activities must have a written and approved QA Project Plan.

3.0 PLAN PREPARATION AND RESPONSIBILITIES

3.1 Document Control

All Quality Assurance Project Plans must be prepared using a document control format consisting of information placed in the upper right-hand corner of each document page:

- Section Number
- Revision Number
- Date (of revision)
- Page

3.2 Elements of QA Project Plan

Each of the sixteen items listed below must be considered for inclusion in each QA Project Plan:

(1) Title page with provision for approval signatures

(2) Table of contents

(3) Project description

(4) Project organization and responsibility

(5) QA objectives for measurement data in terms of precision, accuracy, completeness, representativeness and comparability

(6) Sampling procedures

(7) Sample custody

(8) Calibration procedures and frequency

(9) Analytical procedures

(10) Data reduction, validation and reporting

(11) Internal quality control checks and frequency

(12) Performance and system audits and frequency

(13) Preventive maintenance procedures and schedules

(14) Specific routine procedures to be used to assess data precision, accuracy and completeness of specific measurement parameters involved

(15) Corrective action

(16) Quality assurance reports to management

It is Agency policy that precision and accuracy of data shall be assessed on all monitoring and measurement projects. Therefore, Item 14 must be described in all Quality Assurance Project Plans.

3.3 Responsibilities

Intramural Projects - Each Project Officer working in close coordination with the QA Officer is responsible for the preparation of a written QA Project Plan for each intramural project that involves environmental measurements. This written plan must be separate from any general plan normally prepared for the project (see caveat presented in Section 6). The Project Officer and the QA Officer must ensure that each intramural project plan contains procedures to document and report precision, accuracy and completeness of all data generated.

Extramural Projects - Each Project Officer working in close coordination with the QA Officer has the responsibility to see that a written QA Project Plan is prepared by the extramural organization for each project involving environmental measurements. The elements of the QA Project Plan must be separately identified from any general plan normally prepared for the project (see caveat presented in Section 6). The Project Officer and the QA Officer must ensure that each extramural project plan contains procedures to document and report precision, accuracy and completeness of all data generated.

4.0 PLAN REVIEW, APPROVAL AND DISTRIBUTION

Intramural Projects - Each QA Project Plan must be approved by the Project officer's immediate supervisor and the QA Officer. Completion of reviews and approvals is shown by signatures on the title page of the plan. Environmental measurements may not be initiated until the QA Project Plan has received the necessary approvals, unless emergency response is necessary. A copy of the approved QA Project Plan will be distributed by the Project Officer to each person who has a major responsibility for the quality of measurement data.

Extramural Projects - Each QA Project Plan must be approved by the funding organization's Project Officer and the QA Officer. In addition, the extramural organization's Project Manager and responsible QA official must review and approve the QA Project Plan. Completion of reviews and approvals is shown by signatures on the title page of the plan. Environmental measurements may not be initiated until the QA Project Plan has received the necessary approvals. A copy of the approved QA Project Plan will be distributed by the extramural organization's Project Director to each person who has a major responsiblity for the quality of the measurement data.

5.0 PLAN CONTENT REQUIREMENTS

The sixteen (16) essential elements described in this section must be considered and addressed in each QA Project Plan. If a particular element is not relevant to the project under consideration, a brief explanation of why the element is not relevant must be included. EPA-approved reference, equivalent or alternative methods must be used and their corresponding Agency-approved guidelines must be applied wherever they are available and applicable.

It is Agency policy that precision and accuracy of data shall be assessed routinely and reported on all environmental monitoring and measurement data. Therefore, specific procedures to assess precision and accuracy on a routine basis during the project must be described in each QA Project Plan. Procedures to assess data quality are being developed by QAMS and the Environmental Monitoring Systems Support Laboratories. Additional guidance can be obtained from QA handbooks for air, water biological, and radiation measurements (References 1, 2, 3, 12, 17, and 18).

The following subsections provide specific guidance pertinent to each of the 16 components which must be considered for inclusion in every QA Project Plan.

5.1 Title page

At the bottom of the title page, provisions must be made for the signatures of approving personnel. As a minimum, the QA Project Plan must be approved by the following:

A. For intramural projects
   1. Project Officer's immediate supervisor
   2. QA Officer

B. For extramural projects
   1. Organization's Project Manager
   2. Organization's responsible QA Official
   3. Funding organization's Project Officer
   4. Funding organization's QA Officer

5.2 Table of Contents

The QA Project Plan Table of Contents will address each of the following items:

- Introduction.
- A serial listing of each of the 16 quality assurance project plan components.
- A listing of any appendices which are required to augment the Quality Assurance Project Plan as presented (i.e., standard operating procedures, etc.).

At the end of the Table of Contents, list the QAO and all other individuals receiving official copies of the QA Project Plan and any subsequent revisions.

5.3 Project Description

Provide a general description of the project, including the experimental design. This description may be brief but must have sufficient detail to allow those individuals responsible for review and approval of the QA Project Plan to perform their task. Where appropriate, include the following:

- Flow diagrams, tables and charts.
- Dates anticipated for start and completion.
- Intended end use of acquired data.

5.4 Project Organization and Responsibility

Include a table or chart showing the project organization and line authority. List the key individuals, including the QAO, who are responsible for ensuring the collection of valid measurement data and the routine assessment of measurement systems for precision and accuracy.

5.5 QA Objectives for Measurement Data in Terms of Precision, Accuracy, Completeness, Representativeness, and Comparability

For each major measurement parameter, including all pollutant measurement systems, list the QA objectives for precision, accuracy and completeness. These QA objectives will be summarized in a table. (See Table 1 for example of format.)

All measurements must be made so that results are representative of the media (air, water, biota, etc.) and conditions being measured. Unless otherwise specified, all data must be calculated and reported in units consistent with other organizations reporting similar data to allow comparability of data bases among organizations. Definitions for precision, accuracy and completeness are provided in Appendix A.

Data quality objectives for accuracy and precision established for each measurement parameter will be based on prior knowledge of the measurement system employed and method validation studies using replicates, spikes, standards, calibrations, recovery studies, etc, and the requirements of the specific project.

5.6 Sampling Procedures

For each major measurement parameter(s), including all pollutant measurement systems, provide a description of the sampling procedures to be used. Where applicable, include the following:

Table 1

EXAMPLE OF FORMAT TO SUMMARIZE PRECISION, ACCURACY AND COMPLETENESS OBJECTIVES

Measurement Parameter (Method)	Reference	Experimental Conditions	Precision, Std. Dev.	Accuracy	Completeness
NO_2 (Chemiluminescent)	EPA 650/4-75-011 February 1975	Atmospheric samples spiked with NO_2 as needed	<±10%	±5%	90%
SO_2 (24 hr) (Pararosaniline)	EPA 650/4-74-027 December 1973	Synthetic atmosphere	<±20%	±15%	90%
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•

- Description of techniques or guidelines used to select sampling sites.
- Inclusion of specific sampling procedures to be used (by reference in the case of standard procedures and by actual description of the entire procedure in the case of nonstandard procedures).
- Charts, flow diagrams or tables delineating sampling program operations.
- A description of containers, procedures, reagents, etc., used for sample collection, preservation, transport, and storage.
- Special conditions for the preparation of sampling equipment and containers to avoid sample contamination (e.g., containers for organics should be solvent-rinsed; containers for trace metals should be acid-rinsed).
- Sample preservation methods and holding times.
- Time considerations for shipping samples promptly to the laboratory.
- Sample custody or chain-of-custody procedures (to be described later in this document).
- Forms, notebooks and procedures to be used to record sample history, sampling conditions and analyses to be performed.

5.7 Sample Custody

Sample custody is a part of any good laboratory or field operation. Where samples may be needed for legal purposes, "chain-of-custody" procedures, as defined by the Office of Enforcement, will be used. However, as a minimum, the following sample custody procedures will be addressed in the QA Project Plans:

A. Field Sampling Operations:

- Documentation of procedures for preparation of reagents or supplies which become an integral part of the sample (e.g., filters, and absorbing reagents).

- Procedures and forms for recording the exact location and specific considerations associated with sample acquisition.

- Documentation of specific sample preservation method.

- Pre-prepared sample labels containing all information necessary for effective sample tracking. Figure 1 illustrates a typical sample label applicable to this purpose.

- Standardized field tracking reporting forms to establish sample custody in the field prior to shipment. Figure 2 presents a typical sample of a field tracking report form.

B. Laboratory Operations:

- Identification of responsible party to act as sample custodian at the laboratory facility authorized to sign for incoming field samples, obtain documents of shipment (e.g., bill of lading number or mail receipt), and verify the data entered onto the sample custody records.

- Provision for a laboratory sample custody log consisting of serially numbered standard lab-tracking report sheets. A typical sample of a standardized lab-tracking report form is shown in Figure 3.

(NAME OF SAMPLING ORGANIZATION)

SAMPLE DESCRIPTION _____

_____

PLANT: _____ LOCATION: _____

DATE: _____ _____

TIME: _____ _____

MEDIA: _____ STATION: _____

SAMPLE TYPE: _____ PRESERVATIVE: _____

SAMPLED BY: _____

SAMPLE ID NO.: _____ - - - - _____

LAB NO. _____

REMARKS

Figure 1. Example of General Sample Label

W/O No. _____ Page____

FIELD TRACKING REPORT: _____
(LOC-SN)

FIELD SAMPLE CODE (FSC)	BRIEF DESCRIPTION	DATE	TIME(s)	SAMPLER

Figure 2. Sample of Field Tracking Report Form

W/O No. _____ Page ____

LAB TRACKING REPORT: _____ - _____ - _____
(LOC-SN-FSC)

FRACTION CODE	X	PREP/ANAL REQUIRED	RESPONSIBLE INDIVIDUAL	DATE DELIVERED	DATE COMPLETED

Figure 3. Sample of Lab-Tracking Report Form

- Specification of laboratory sample custody procedures for sample handling, storage and dispersement for analysis.

Additional guidelines useful in establishing a sample custody procedure are given in Section 2.0.6 of Reference 2, and Section 3.0.3 of Reference 3, and References 13 and 14.

5.8 Calibration Procedures and Frequency

Include calibration procedures and information:

- For each major measurement parameter, including all pollutant measurement systems, reference the applicable standard operating procedure (SOP) or provide a written description of the calibration procedure(s) to be used.
- List the frequency planned for recalibration.
- List the calibration standards to be used and their sources(s), including traceability procedures.

5.9 Analytical Procedures

For each measurement parameter, including all pollutant measurement systems, reference the applicable standard operating procedure (SOP) or provide a written description of the analytical procedure(s) to be used. Officially approved EPA procedures will be used when available. For convenience in preparing the QA Project Plan, Elements 6, 8 and 9 may be combined (e.g., Sections 5.6, 5.8 and 5.9).

5.10 Data Reduction, Validation and Reporting - For each major measurement parameter, including all pollutant measurement systems, briefly describe the following:

- The data reduction scheme planned on collected data, including all equations used to calculate the concentration or value of the measured parameter and reporting units.
- The principal criteria that will be used to validate data integrity during collection and reporting of data.
- The methods used to identify and treat outliers.
- The data flow or reporting scheme from collection of raw data through storage of validated concentrations. A flowchart will usually be needed.
- Key individuals who will handle the data in this reporting scheme (if this has already been described under project organization and responsibilities, it need not be repeated here).

5.11 Internal Quality Control Checks

Describe and/or reference all specific internal quality control ("internal" refers to both laboratory and field activities) methods to be followed. Examples of items to be considered include:

- Replicates
- Spiked samples
- Split samples
- Control charts

- Blanks
- Internal standards
- Zero and span gases
- Quality control samples
- Surrogate samples
- Calibration standards and devices
- Reagent checks

Additional information and specific guidance can be found in References 17 and 18.

5.12 Performance and System Audits

Each project plan must describe the internal and external performance and systems audits which will be required to monitor the capability and performance of the total measurement system(s).

The systems audit consists of evaluation of all components of the measurement systems to determine their proper selection and use. This audit includes a careful evaluation of both field and laboratory quality control procedures. Systems audits are normally performed prior to or shortly after systems are operational; however, such audits should be performed on a regularly scheduled basis during the lifetime of the project or continuing operation. The on-site systems

audit may be a requirement for formal laboratory certification programs such as laboratories analyzing public drinking water systems. Specific references pertinent to systems audits for formal laboratory certification programs can be found in References 19 and 20.

After systems are operational and generating data, performance audits are conducted periodically to determine the accuracy of the total measurement system(s) or component parts thereof. The plan should include a schedule for conducting performance audits for each measurement parameter, including a performance audit for all measurement systems. As part of the performance audit process, laboratories may be required to participate in analysis of performance evaluation samples related to specific projects. Project plans should also indicate, where applicable, scheduled participation in all other inter-laboratory performance evaluation studies.

In support of performance audits, the Environmental Monitoring Systems/Support Laboratories provide necessary audit materials and devices and technical assistance. Also, these laboratories conduct regularly scheduled inter-laboratory performance tests and provide guidance and assistance in the conduct of systems audits. To make arrangements for assistance in the above areas, these laboratories should be contacted directly:

Environmental Monitoring Systems Laboratory
Research Triangle Park, NC 27711
Attention: Dr. Thomas R. Hauser, Director

Environmental Monitoring and Support Laboratory
26 W. St. Clair Street
Cincinnati, OH 45268
Attention: Mr. Robert L. Booth, Director

Environmental Monitoring Systems Laboratory
P.O. Box 15027
Las Vegas, NV 89114
Attention: Mr. Glen Schwitzer, Director

5.13 Preventive Maintenance

The following types of preventive maintenance items should be considered and addressed in the QA Project Plan:

- A schedule of important preventive maintenance tasks that must be carried out to minimize downtime of the measurement systems.
- A list of any critical spare parts that should be on hand to minimize downtime.

5.14 Specific Routine Procedures Used to Assess Data Precision, Accuracy and Completeness

It is Agency policy that precision and accuracy of data must be routinely assessed for all environmental monitoring and measurement data. Therefore, specific procedures to assess precision and accuracy on a routine basis on the project must be described in each QA Project Plan.

For each major measurement parameter, including all pollutant measurement systems, the QA Project Plan must describe the routine procedures used to assess the precision, accuracy and completeness of the measurement data. These procedures should include the equations to calculate precision, accuracy and completeness, and the methods used to gather data for the precision and accuracy calculations.

Statistical procedures applicable to environmental projects are found in References 1, 2, 3, 12, 17, and 18. Examples of these procedures include:

- Central tendency and dispersion
  - Arithmetic mean
  - Range
  - Standard deviation
  - Relative standard deviation
  - Pooled standard deviation
  - Geometric mean
- Measures of variability
  - Accuracy
  - Bias
  - Precision; within laboratory and between laboratories
- Significance test
  - u-test
  - t-test
  - F-test
  - Chi-square test

- Confidence limits
- Testing for outliers

Recommended guidelines and procedures to assess data precision, accuracy and completeness are being developed.

5.15 Corrective Action

Corrective action procedures must be described for each project which include the following elements:

- The predetermined limits for data acceptability beyond which corrective action is required.
- Procedures for corrective action.
- For each measurement system, identify the responsible individual for initiating the corrective action and also the individual responsible for approving the corrective action, if necessary.

Corrective actions may also be initiated as a result of other QA activities, including:

(1) Performance audits

(2) Systems audits

(3) Laboratory/interfield comparison studies

(4) QA Program audits conducted by QAMS

A formal corrective action program is more difficult to define for these QA activities in advance and may be defined as the need arises.

5.16 Quality Assurance Reports to Management

QA Project Plans should provide a mechanism for periodic reporting to management on the performance of measurement systems and data quality. As a minimum, these reports should include:

- Periodic assessment of measurement data accuracy, precision and completeness.
- Results of performance audits.
- Results of system audits.
- Significant QA problems and recommended solutions.

The individual(s) responsible for preparing the periodic reports should be identified. The final report for each project must include a separate QA section which summarizes data quality information contained in the periodic reports.

6.0 QUALITY ASSURANCE PROJECT PLANS VERSUS PROJECT WORK PLANS

This document provides guidance for the preparation of QA Project Plans and describes 16 components which must be included. Historically, most project managers have routinely included the majority of these 16 elements in their project work plans. In practice, it is frequently difficult to separate important quality assurance and quality control functions and to isolate these functions from technical performance activities. For those projects where this is the case, it is not deemed necessary to replicate the narrative in the Quality Assurance Project Plan section.

In instances where specific QA/QC protocols are addressed as an integral part of the technical work plan, it is only necessary to cite the page number and location in the work plan in the specific subsection designated for this purpose.

It must be stressed, however, that whenever this approach is used a "QA Project Plan locator page" must be inserted into the project work plan immediately following the table of contents. This locator page must list each of the items required for the QA Project Plan and state the section and pages in the project plan where the item is described. If a QA Project Plan item is not applicable to the work plan in question, the words "not applicable" should be inserted next to the appropriate component on the locator page and the reason why this component is not applicable should be briefly stated in the appropriate subsection in the QA Project Plan proper.

7.0 STANDARD OPERATING PROCEDURES

A large number of laboratory and field operations can be standardized and written as Standard Operating Procedures (SOP). When such procedures are applicable and available, they may be incorporated into the QA Project Plan by reference.

QA Project Plans should provide for the review of all activities which could directly or indirectly influence data quality and the determination of those operations which must be covered by SOP's. Examples are:

- General network design
- Specific sampling site selection
- Sampling and analytical methodology
- Probes, collection devices, storage containers, and sample additives or preservatives
- Special precautions, such as heat, light, reactivity, combustability, and holding times
- Federal reference, equivalent or alternative test procedures
- Instrumentation selection and use
- Calibration and standardization
- Preventive and remedial maintenance
- Replicate sampling
- Blind and spiked samples

- Colocated samplers
- QC procedures such as intralaboratory and intrafield activities, and interlaboratory and interfield activities
- Documentation
- Sample custody
- Transportation
- Safety
- Data handling procedures
- Service contracts
- Measurement of precision, accuracy, completeness, representativeness, and comparability
- Document control

8.0 SUMMARY

Each intramural and extramural project that involves environmental measurements must have a written and approved QA Project Plan. All 16 items described previously must be considered and addressed. Where an item is not relevant, a brief explanation of why it is not relevant must be included. It is Agency policy that precision and accuracy of data must be routinely assessed and reported on all environmental monitoring and measurement data. Therefore, specific procedures to assess precision and accuracy on a routine basis during the project must be described in each QA Project Plan.

REFERENCES

1. Quality Assurance Handbook for Air Pollution Measurement Systems. Volume I - Principles. EPA-600/9-76-005, March 1976.

2. Quality Assurance Handbook for Air Pollution Measurement Systems. Volume II - Ambient Air Specific Methods. EPA-600/4-77-027a, May 1977.

3. Quality Assurance Handbook for Air Pollution Measurement Systems. Volume III - Stationary Source Specific Methods. EPA-600/4-77-027b, August 1977.

4. Systems Audit Criteria and Procedures for Ambient Air Monitoring Programs. Currently under development and available from address shown in Reference 1 after July 1, 1980.

5. Techniques to Evaluate Laboratory Capability to Conduct Stack Testing.

6. Performance Audit Procedures for Ambient Air Monitoring Programs. Currently under development.

7. Appendix A - Quality Assurance Requirements for State and Local Air Monitoring Stations (SLAMS). Federal Register, Vol. 44, No. 92, pp. 27574-81, May 10, 1979.

8. Appendix B - Quality Assurance Requirements for Prevention of Significant Deterioration (PSD) Air Monitoring, Federal Register. Vol. 44, No. 92, pp. 27582-84, May 10, 1979.

9. Appendix E - Quality Assurance Requirements for Continuous Emission Monitoring Systems (CEMS). To be submitted as a proposed regulation to amend 40 CFR 60.

10. Test Methods for Evaluating Solid Waste - Physical/Chemical Methods. EPA SW-846, 1980.

11. Quality Assurance Guidelines for IERL-CI Project Officers. EPA-600/9-79-046. December 1979.

12. Handbook for Analytical Quality Control in Water and Wastewater Laboratories. EPA-600/4-79-019, March 1979.

13. NEIC Policies and Procedures Manual. Office of Enforcement, EPA-330-9-78-001, May 1978.

14. NPDES Compliance, Sampling and Inspection Manual. Office of Water Enforcement, Compliance Branch, June 1977.

15. Juran, J. M. (ed), Quality Control Handbook. Second Edition, McGraw Hill, New York, 1962.

16. Juran, J. M. and F. M. Gryna, Quality Planning and Analysis. McGraw Hill, New York, 1970.

17. Handbook for Analytical Quality Control and Radioactivity Analytical Laboratories. EPA-600/7-77-088, August 1977.

18. Manual of Analytical Quality Control for Pesticides and Related Compounds in Human and Environmental Samples. EPA-600/1-79-008, January 1979.

19. Procedure for the Evaluation of Environmental Monitoring Laboratories. EPA 600/4-78-017, March 1978.

20. Manual for the Interim Certification of Laboratories Involved in Analyzing Public Drinking Water Supplies - Criteria and Procedures. EPA 600/8-78-008, August 1978.

APPENDIX A

GLOSSARY OF TERMS

AUDIT:

A systematic check to determine the quality of operation of some functon or activity. Audits may be of two basic types: (1) performance audits in which quantitative data are independently obtained for comparison with routinely obtained data in a measurement system, or (2) system audits of a qualitative nature that consist of an on-site review of a laboratory's quality assurance system and physical facilities for sampling, calibration, and measurement.

DATA QUALITY:

The totality of features and characteristics of data that bears on its ability to satisfy a given purpose. The characteristics of major importance are accuracy, precision, completeness, representativeness, and comparability. These characteristics are defined as follows:

- Accuracy - the degree of agreement of a measurement (or an average of measurements of the same thing), X, with an accepted reference or true value, T, usually expressed as the difference between the two values, X-T, or the difference as a percentage of the reference or true value, 100 (X-T)/T, and sometimes expressed as a ratio, X/T. Accuracy is a measure of the bias in a system.

- Precision - a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is best expressed in terms of the standard deviation. Various measures of precision exist depending upon the "prescribed similar conditions."

- Completeness - a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct normal conditions.

- Representativeness - expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition.

- Comparability - expresses the confidence with which one data set can be compared to another.

DATA VALIDATION

A systematic process for reviewing a body of data against a set of criteria to provide assurance that the data are adequate for their intended use. Data validation consists of data editing, screening, checking, auditing, verification, certification, and review.

ENVIRONMENTALLY RELATED MEASUREMENTS:

A term used to describe essentially all field and laboratory investigations that generate data involving (1) the measurement of chemical, physical, or biological parameters in the environment, (2) the determination of the presence or absence of criteria or priority pollutants in waste streams, (3) assessment of health and ecological effect studies, (4) conduct of clinical and epidemiological investigations, (5) performance of engineering and process evaluations, (6) study of laboratory simulation of environmental events, and (7) study or measurement on pollutant transport and fate, including diffusion models.

PERFORMANCE AUDITS:

Procedures used to determine quantitatively the accuracy of the total measurement system or component parts thereof.

QUALITY ASSURANCE:

The total integrated program for assuring the reliability of monitoring and measurement data. A system for integrating the quality planning, quality assessment, and quality improvement efforts to meet user requirements.

QUALITY ASSURANCE PROGRAM PLAN:

An orderly assemblage of management policies, objectives, principles, and general procedures by which an agency or laboratory outlines how it intends to produce data of known and accepted quality.

QUALITY ASSURANCE PROJECT PLAN:

An orderly assembly of detailed and specific procedures which delineates how data of known and accepted quality data is produced for a specific project. (A given agency or laboratory would have only one quality assurance program plan, but would have a quality assurance project plan for each of its projects.)

QUALITY CONTROL:

The routine application of procedures for obtaining prescribed standards of performance in the monitoring and measurement process.

STANDARD OPERATING PROCEDURE (SOP):

A written document which details an operation, analysis or action whose mechanisms are thoroughly prescribed and which is commonly accepted as the method for performing certain routine or repetitive tasks.

Extract of publication no. 52 of the I. A. S. H.
Commission of Subterranean Waters, pp. 314-323 1960

(1)

USE OF WATER LEVELS IN ESTIMATING AQUIFER CONSTANTS IN A FINITE AQUIFER (*)

M. I. RORABAUGH
U.S. Geological Survey Tallahassee, Florida

SUMMARY

Methods of estimating the aquifer constant T/S (transmissibility coefficient divided by storage coefficient) from natural fluctuations of water-levels in observation wells are described for the case of a finite aquifer having parallel boundaries. Equations adapted from heat-flow theory indicate that water levels fall exponentially with time, but only after sufficient time has elapsed for the profile shape to stabilize. After this critical time, T/S may be computed from the slope of the recession at any well. In applying the method to a field problem, the effects of vertical components of flow in the discharge area were eliminated by the use of an imaginary boundary. An analysis by finite differences on a profile is discussed. The latter method may be applied to aquifers where repetitive recharge makes the use of the recession method impractical.

RÉSUMÉ

Le rapport décrit les méthodes pour évaluer la constante de la nappe T/S (Coefficient de transmission (T = épaisseur moyenne de la nappe multiplié par perméabilité relative) divisé par le coefficient d'emmagasinement) d'après les fluctuations naturelles dans des puits d'observation dans le cas d'un nappe finie ayant des faces terminales parallèles. Les équations adaptées de la théorie de la chaleur indiquent que les niveaux piézométriques baissent exponentiellement en fonction du temps, mais seulement après qu'un temps suffisant se soit écoulé poirque le profil ait pu se stabiliser. Selon ce temps critique la constante T/S peut être calculée d'après l'inclinaison du profil de relèvement dans n'importe quel puits. Dans le cas où cette méthode a été appliquée à un problème pratique, les effets des composantes verticales du flux dans la région de décharge furent éliminés par l'emploi d'une limite imaginaire. La discussion de l'analyse par différences finies sur un profil est presentée.

Cette dernière méthode peut être appliquée à des nappes aquifères où une alimentation répétée rend l'emploi de la méthode de récession impraticable.

1. INTRODUCTION

A problem frequently encountered in the field is the appraisal of ground-water supplies in aquifers of limited extent. In most cases the best method for determining aquifer constants (T, coefficient of transmissibility; and S, coefficient of storage) is a field pumping test. However, where the aquifer boundaries are known, a preliminary appraisal can sometimes be made at much less cost by analysis of natural waterlevel fluctuations in wells. This discussion will be limited to the case of an aquifer having parallel boundaries. Examples are a long island or peninsula, an aquifer bounded by parallel streams, and an aquifer bounded by a stream and a valley wall (fig. 1).

A number of investigators (see References) have presented equations for groundwater flow to streams, ditches, or tile drains, covering a variety of steady-state and transient conditions. In solving field problems the more complicated equations can be applied after the aquifer coefficients have been determined. However, the derivation of the aquifer coefficients from field data is not always easy because of the nature of

(*) Publication authorized by the Director, U.S. Geological Survey.

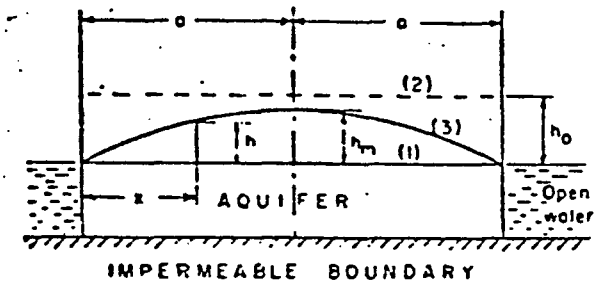

Fig. 1 — Sketch of aquifer boundary conditions: (1) initial water level; (2) water level after instantaneous recharge; (3) receding water level.

the equations. The field investigator must then simplify the equations or adjust the conditions of the problem to approximate the theory. It is the purpose of this paper to demonstrate simplified, yet satisfactory, methods of estimating aquifer characteristics from water-level data.

2. Theory

Assume a situation as shown in figure 1. The aquifer is described as thick relative to h_0, is wide relative to its thickness, and is underlain by impermeable material; its side boundaries are vertical and fully penetrating; and it is uniform, isotropic, and homogeneous. The initial water table was everywhere horizontal. Recharge, which raised the water table by the amount h_0, was instantaneously applied at time $(t) = 0$.

The equation for describing one-dimensional flow in a system having these boundaries is found in a number of heat-flow books (example: Ingersoll, Zobel, and Ingersoll, 1948, p. 125). In terms of ground-water symbols:

$$h = h_0(1/a) \sum_{m=1}^{\infty} \left[e^{-m^2\pi^2 Tt/4a^2 S}(2a/m\pi)(1 - \cos m\pi) \sin(m\pi x/2a) \right] \qquad (1)$$

where h is the water level at point x (see fig. 1) at any time, t, after an instantaneous water-table rise of h_0 at time t_0; T is the coefficient of transmissibility (permeability times aquifer thickness); S is the coefficient of storage; and a is the half-width of the aquifer. Axis of ordinates is taken at edge of aquifer and boundary conditions are:

$h = 0$ at $x = 0$ and $x = 2a$, for all values of t

$h = h_0$ at $t = 0$, for all values of X

$dh/dx = 0$ at $x = a$.

At the midpoint of the aquifer (at $x = a$), equation (1) simplifies to

$$h_m = h_0(4/\pi)(e^{-\pi^2 Tt/4a^2 S} - (1/3)e^{-9\pi^2 Tt/4a^2 S} + (1/5)e^{-25\pi^2 Tt/4a^2 S} - \ldots)$$

Equation (1) is equivalent to those used by Glover (Dumm, 1954, eq. 2) and Maasland (1959, p. 553, eq. 12).

After sufficient time has elapsed, all but the first term in equation (1) and (2) become very small and may be neglected. The question of critical time cannot be treated lightly. When $Tt/a^2S = 0.2$, the error in h resulting from dropping terms will be about 0.6 percent. For $Tt/a^2S = 0.15$, the error will be about 1.8 percent.

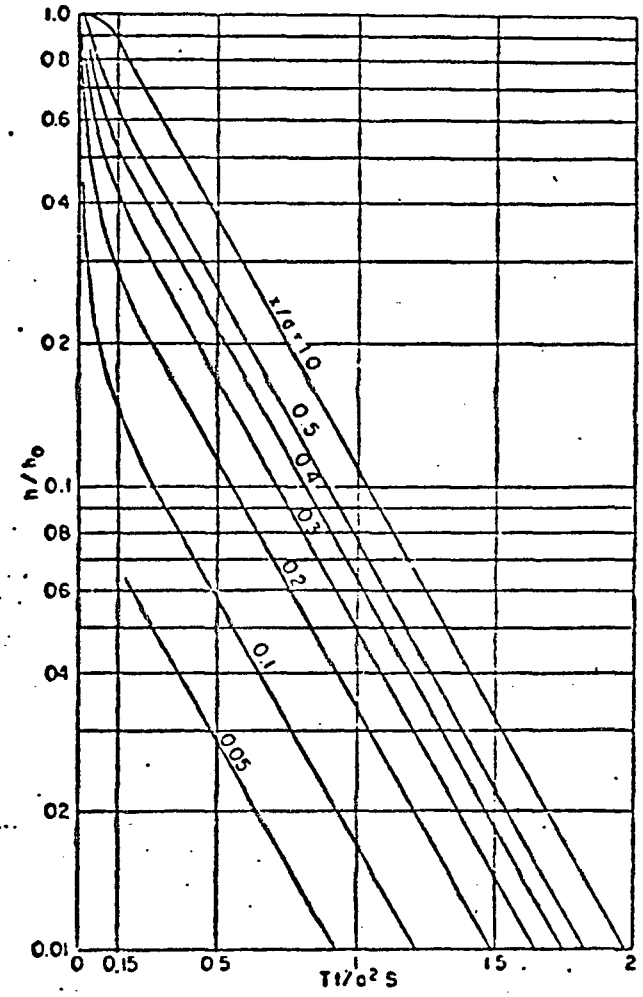

Figure 2. Relation h/h_0 vs Tt/a^2S according to equation (1).

Figure 2 shows a dimensionless plot as defined by equation (1). Note that all the recession curves approach straight lines only when $Tt/a^2S >$ about 0.15. As an example of the magnitude of critical time, consider an island 5,000 feet wide; $T = 50{,}000$ gpd/ft and $S = 0.2$; then $t_c = 0.15\ a^2S/T = 28$ days.

When $Tt/a^2S > 0.15$, equation (1) reduces to

$$h = h_0(4/\pi)e^{-\pi^2Tt/4a^2S}\sin(\pi x/2a) \tag{3}$$

and defines the straight-line segments of the recession curves shown on figure 2.

For the midpoint of the water-table profile

$$h_m = h_0(4/\pi)e^{-\pi^2Tt/4a^2S} \tag{4}$$

Figure 2 indicates that, after the critical time, water levels at any well will decline exponentially with time. A solution for T/S for the aquifer is obtained from the slope of the semilog recession. Write equation (3) for two points (t_1 and t_2) on the recession curve

$$h_1 = h_0(4/\pi)e^{-n^2Tt_1/4a^2S}\sin(\pi x/2a)$$

$$h_2 = h_0(4/\pi)e^{-n^2Tt_2/4a^2S}\sin(\pi x/2a)$$

From which

$$T/S = 4a^2 2.303\log(h_1/h_2)/\pi^2(t_2 - t_1) = 0.933a^2\log(h_1/h_2)/(t_2 - t_1) \qquad (5)$$

Equation (5) is equivalent to the equation for log slope given by Kraijenhoff (1959, p. 855).

Equations (1) through (5) are based on the assumption of a horizontal water table prior to the recharge. In nature recharge will be irregular and will be superimposed on a decaying profile. Inasmuch as the equations are linear, water levels are cumulative. After a sudden recharge, recessions for the increment of head related to that event will follow equation (1). After sufficient time the incremental recession becomes exponential with time and, when combined with residual effects from preceding events, the total head recedes with the same log slope as that for a single event. The critical time at which the semilog solution is applicable is a function of T; S; a; the ratio of sudden water-level rise, Δh, to residual head, h; and the position (x coordinate) of the observation well. For $\Delta h/h = 0.2$, the deviation of the straight line from the true head is about 2 percent at $Tt/a^2S = 0.06$; for $\Delta h/h = 0.1$, the deviation is about 2 percent at $Tt/a^2S = 0.04$.

3. Field problem

In 1950-51 field studies were made in connection with appraisal of water supplies on the Fair Point Peninsula, Fla. The aquifer is about 5,500 feet wide and 100 feet thick. The material is predominantly medium to fine sand and varying amounts of shells, peat, and clay occurring as intermixtures and also as lenses.

Water-level data were obtained from shallow driven wells on a line across the peninsula (fig. 3). This figure shows that tides affect the levels in wells T-20, T-19, and T-1; therefore, data for these wells will not be used. Inspection of figure 3 shows also that the water-level profiles are eccentric, the ground-water divide lying north of the centerline. Eccentricity could result from unequal distribution of rainfall. However, if this were the case the divide should move toward the centerline during the 6-month recession. Inasmuch as the divide did not change position it is concluded that the permeability is higher on the south than on the north side. Because the divide did not move, each side of the island may be treated as a separate problem.

3.1. *Discharge boundaries*: Equations (1) through (5) are based on the assumption of fully penetrating discharge boundaries ($h = 0$ at $x = 0$ and $2a$). For the field problem discharge is through an inclined bay floor. Flow is essentially horizontal at the shoreline. Beyond this point there are both horizontal and vertical components of flow as water is discharged through the floor of the bay. The problem is solved by replacing the discharge area by an imaginary vertical fully penetrating boundary. The boundary is located by projecting the profiles.

Because it is often more convenient to measure distance from the ground-water divide, equation (3) is transposed so that the origin of x coordinates is at the divide.

$$h = h_0(4/\pi)e^{-n^2Tt/4a^2S}\cos(\pi x'/2a) \qquad (3a)$$

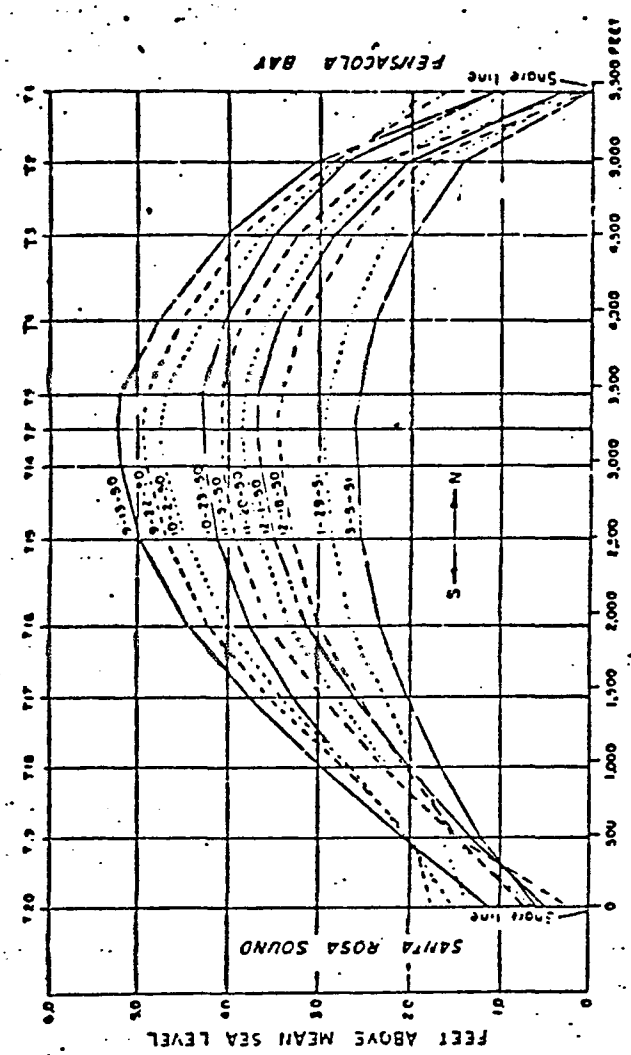

Figure 3. Profiles of water table across Fair Point Peninsula, Santa Rosa County, Fla.

By writing this equation for the water-level position in a well at the divide and again for one other well at point x_1 on the profile, at a time $t > 0.15a^2S/T$, and by taking the ratio of the two equations thus written there follows the relation

$$h_1/h_m = \cos(\pi x_1'/2a) \tag{6}$$

Location of the discharge boundary can be computed directly from equation (6); however, to average minor errors in data a graphical solution is used as shown on figure 4. As indicated on this figure, h/h_m is plotted on an arc cosine scale against x_1' (distance from the divide) on an arithmetic scale. This produces a straight-line plot of equation (6). The position of the discharge boundary is determined from the straight-line intercept at $h/h_m = 0$, which is 2,900 feet for the north side and 3,500

feet for the south side. It should be noted that it is not necessary to know the location of the ground-water divide; for this case use an arbitrary distance scale and determine the position of the divide at the intercept $h/h_m = 1.0$. If three wells and the distances between them are available, h_m and the location of both discharge boundaries can be determined from equation (6).

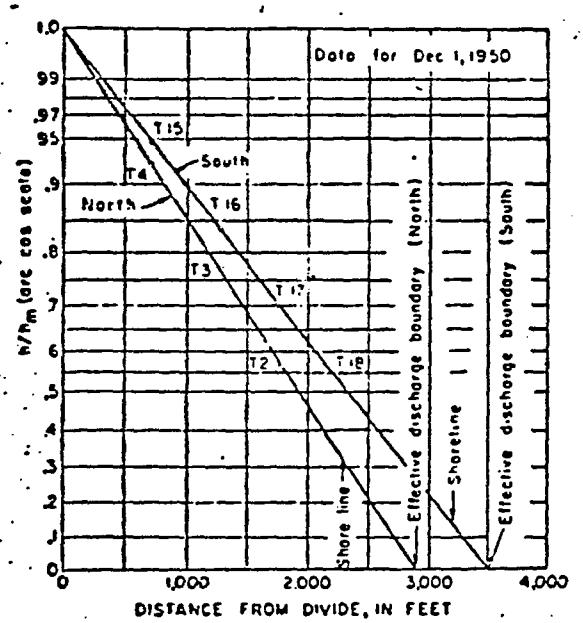

Figure 4. Graphical solution of effective distance to discharge boundaries

Offshore head loss is estimated from the position of the shoreline on figure 4. On the north profile 30 percent of the total head loss is in the discharge area; on the south profile, 15 percent. This type of plot would be useful in estimating head loss in the vicinity of tile drains and in comparing efficiencies of drains.

3.2. *Semilog solution for T/S*: Water-level recession data for selected wells are plotted on figures 5 and 6 (log h *vs* time). Water levels rose sharply at the end of August 1950 and again in March 1951 in response to extremely heavy rainfall. During the 6-month interval there were a number of rains of about 1 inch. Water levels in wells *T*-2 and *T*-17 responded to most of these storms. The other wells are located nearer the center of the peninsula; because of the higher land-surface elevation more time is required for downward percolation and recharge effects are subdued. However, that recharge did occur is shown by the shape of the recession curves. Straight lines were drawn giving weight to *T*-2 and *T*-17. From equation (5), using values for a as determined from figure 4, and the log slope from figures 5 and 6, T/S is computed as 131,000 gallons per day per foot for the north side and 171,000 *gpd/ft* for the south side.

A pumping test made at the ground-water divide (Heath and Clark, p. 33) determined $T = 34{,}000$ *gpd/ft* and $S = 0.23$, or $T/S = 148{,}000$ *gpd/ft*. The test

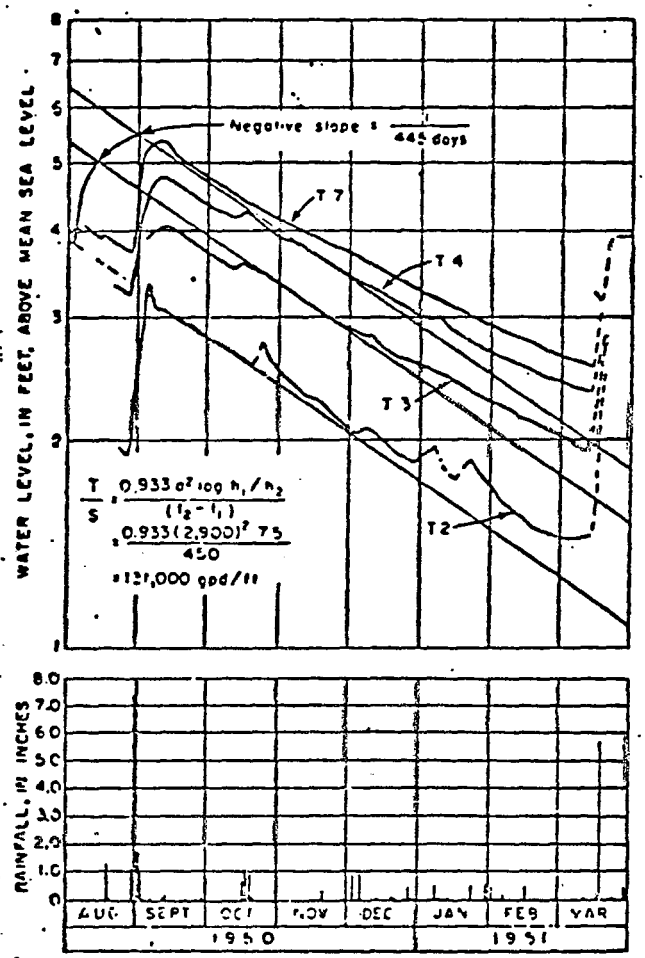

Figure 5. Plot of precipitation and water levels (north side Fair Point Peninsula, Fla.) and graphical solution of T/S.

sampled the aquifer on both sides of the divide and checks very closely with the average of the values determined from analysis of water levels.

Although the critical time for a semilog plot of the water-level recession curve to become a straight line is about 75 days (at divide) following a single recharge event, the conditions in this problem are much more favorable. For a rise (Sept. 1) equal to about half the initial head, the critical time is about 40 days at well T-7). Inspection of figure 2 shows that for x/a between 0.5 and 0.8, deviations from the straight-line recession curves will be much less than at the midpoint of the aquifer profile where $x/a = 1.0$. The recessions during the first part of October (figs. 5, 6) are considered to be very close to the straight-line condition sought. The small rises on the graph for T-2 are about as expected in accordance with parameter $x/a = 0.4$ on figure 2.

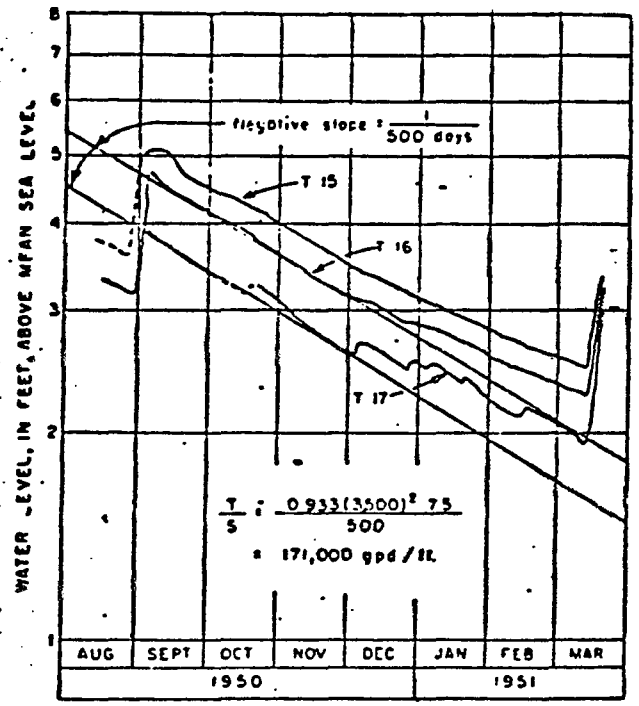

Figure 6. Graphical solution of T/S for south side Fair Point Peninsula.

3.3. *Stability of profile shape*: Data for *T*-2, *T*-3, and *T*-4 were plotted on figure 4 for various times. The north profile did not vary from its theoretical shape from October to March. On the other hand, the south profile did vary. Data for *T*-16, *T*-17, and *T*-18 for February or March when plotted on figure 4 fall above the profile shown. A new profile defines a larger apparent value of *a*. This instability may be caused by soil conditions being more favorable for recharge, or it might reflect movement of a salt-water wedge. Discharge conditions are apparently different on the two sides of the peninsula (fig. 4). On the north side, the indicated 30-percent loss of head beyond the shoreline and the location of the effective boundary 600 feet offshore indicates that the vertical permeability of the materials under the bay is low. On a declining water level, salt-water encroachment would be sluggish. On the south side only 15 percent of the head is lost beyond the shoreline and the effective discharge boundary is but 300 feet offshore. If the salt-water wedge moved landward during the recession, transmissibility would be reduced because of a smaller flow section and head-loss distribution would be increased in the discharge area. The added head losses would cause the higher plotting of data on figure 4 and would result in a larger apparent distance to the boundary.

3.4. *Steady-state method*: In extensive aquifers the foregoing analysis may not be applicable—for example, in the alluvial fill of the Ohio River valley. At Louisville, Ky., the width of the aquifer is about 20,000 feet; *T* is 80,000 *gpd/ft*;

S is 0.2; critical time to reach a straight-line recession will be about 3 years. Recharge increments are relatively small compared to h, and the profile approaches a steady-state parabola (Jacob, 1944, pp. 565-566).

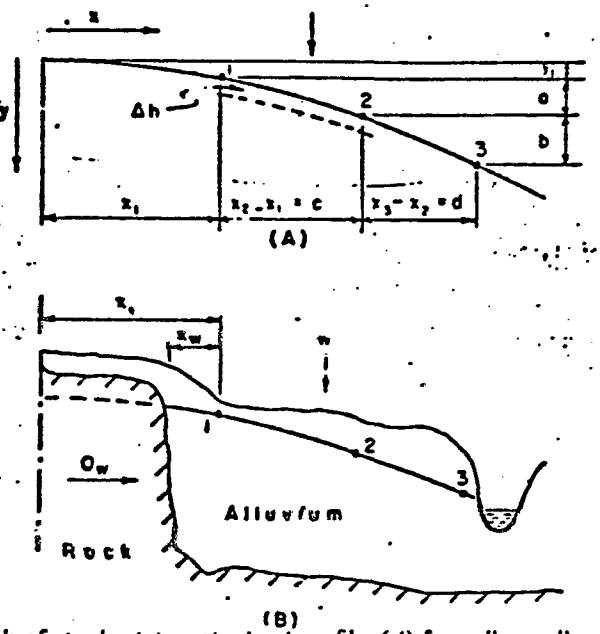

Fig. 7 — Sketch of steady-state water-level profile: (*A*) for valley wall and stream, or island; (*B*) for case with flow through a valley wall.

Consider the case shown on figure 7-*A*. Water levels are available at three points. Let w be recharge per unit area. Then

$$(dy/dx)T = wx \text{ or } dy = (w/T)xdx \tag{7}$$

$$\text{Integrating, } y = wx^2/2T \tag{8}$$

Write equation (8) for points 1, 2, and 3 and solve simultaneously; then the distance from point 1 to the ground-water divide is given by:

$$x_1 = (ad^2 + 2acd - bc^2)/2(bc - ad) \tag{9}$$

and

$$w/T = 2(bc - ad)/cd(c + d) \tag{10}$$

Equation (10) is useful only if w or T can be determined. It is usually possible to estimate S more closely than w or T. An expression in terms of T/S is developed as follows.

Assume that rainfall stops. The profile then begins to recede toward the shape expressed by equation (1). After it has receded an amount Δh in time Δt we may write the equation of change in storage between points 1 and 2

$$T\,dy_2/dx - T\,dy_1/dx = (\Delta h/\Delta_t)cS$$

Substitution of terms from equations (7) and (10) results in

$$T/S = (\Delta h/\Delta t)\,[cd(c + d)/2(bc - ad)] \tag{11}$$

This equation can be used if water-level data are available in three wells before and after a period of no rainfall.

Equation (11) was applied to wells *T*-3, *T*-4, and *T*-5 (fig. 3) for the period October 23-November 20 ($a = 0.20$ foot, $b = 0.53$, $c = 500$, $d = 580$, $\Delta h = 0.47$, $\Delta t = 28$ days). The result, $T/S = 132{,}000$ *gpd/ft*, is in close agreement with results of the pumping test and the semilog solution by equation (5).

3.5. *Leaky valley wall:* Frequently in dealing with river-valley problems, it is found that there is leakage through the valley wall into the valley fill. For this case (fig. 7-*D*) equation (9) determines x_1, the distance to an imaginary ground-water divide. In effect, the rock between the divide and the wall is replaced with alluvium similar to the valley fill. From study of the geology, the distance to the valley-wall, x_w, is known; then the leakage through the wall is

$$Q_w = w(x_1 - x_w)$$

or, substituting for w its equivalent as given by equation (10),

$$Q_w = 2T(bc - ad)(x_1 - x_w)/cd(c + d) \qquad (12)$$

In this paper discussion of methods of estimating aquifer constants from water levels has been limited to the case of parallel boundaries. Similar procedures can be used for more complicated conditions, such as a rectangular aquifer (surrounded by water on all four sides) or for a well near the end of a long island or peninsula (water on three sides). If the boundaries are known, an approximate solution for T/S can be obtained by analysis of water-level records. For the more complicated boundary conditions, it may be necessary to construct a type curve for a specific well location.

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EPA Superfund Ground Water Issue

Ground Water Sampling for Metals Analyses

Robert W. Puls and Michael J. Barcelona

The Regional Superfund Ground Water Forum is a group of ground-water scientists, representing EPA's Regional Superfund Offices, organized to exchange up-to-date information related to ground-water remediation at Superfund sites.

Filtration of ground-water samples for metals analysis is an issue identified by the Forum as a concern of Superfund decision-makers. Inconsistency in EPA Superfund cleanup practices occurs where one EPA Region implements a remedial action based on unfiltered ground-water samples, while another Region may consider a similar site to be clean based on filtered ground-water samples. RSKERL-Ada and EMSL-Las Vegas have convened a technical committee of experts in the areas of ground-water geochemistry, inorganic chemistry, colloidal transport and ground-water sampling technology to examine this issue and provide technical guidance based on current scientific information.

Members of the committee were Robert W. Puls, Bert E. Bledsoe and Don A. Clark of RSKERL; Michael J. Barcelona, Illinois State Water Survey; Phillip M. Gschwend, Massachusetts Institute of Technology; Terry F. Rees, USGS-Denver; John W. Hess, Desert Research Institute (EMSL-LV); and Nicholous T. Loux, ERL-Athens.

This document was written by Robert W. Puls and Michael J. Barcelona and edited by all members of the committee.

For further information contact Robert Puls, RSKERL-Ada, FTS 743-2262; Bert Bledsoe, RSKERL-Ada, FTS 743-2324; Jane Denne, EMSL-LV, FTS 545-2655.

The findings and recommendations of the committee were that use of a 0.45 micron* filter was not useful, appropriate or reproducible in providing information on metals mobility in ground-water systems, nor was it appropriate for determination of truly "dissolved" constituents in ground water. A dual sampling approach was recommended, with collection of both filtered and unfiltered samples. If the purpose of the sampling is to determine possible mobile contaminant species, the unfiltered samples should be given priority. This means that added emphasis is placed on appropriate well construction methods, materials and ground-water sampling procedures. For accurate estimations of truly "dissolved" species concentrations, filtration with a nominal pore size smaller than 0.45 microns was recommended. It was further concluded that filtration could not compensate for inadequate construction or sampling procedures.

Background/Support Information

Filtration of ground-water samples for metal analyses will not provide accurate information concerning the mobility of metal contaminants. This is because some mobile species are likely to be removed by filtration before chemical analysis. Metal contaminants may move through fractured and porous media not only as dissolved species, but also as precipitated phases, polymeric species or adsorbed to inorganic or organic particles of colloidal dimensions. Colloids are generally considered as particles with diameters less than 10 microns (Stumm and Morgan, 1981). Numerous investigators have suggested the facilitated transport of contaminants in association with mobile colloidal particles. Kim et al. (1984) suggested that sorption to ground-water colloidal material caused the mobilization of some radionuclides in Gorleben ground waters. Saltelli et al. (1984) studied americium percolation in glauconitic sand columns and attributed the unretained fractions to migrating colloidal species.

* Micron = μm = 10^{-6} meter

Superfund Technology Support Centers for Ground Water

Robert S. Kerr Environmental Research Laboratory
Ada, OK

Environmental Monitoring Systems Laboratory
Las Vegas, NV

These colloids were either homogeneous hydrous precipitates, or were formed from the adsorption of the radionuclide onto colloidal size mineral particles. Colloidal particles generated in batch experiments by Sheppard et al. (1979) were shown to adsorb significant quantities of radionuclides. Further work by Sheppard et al. (1980) concluded that the transport of radionuclides by colloidal clay particles must be considered in any contaminant transport model. Champlin and Eichholz (1968) showed that the movement of radioactive sodium and ruthenium in sand beds was associated with particulate matter of micron dimensions. Gschwend and Reynolds (1987) demonstrated that submicron ferrous phosphate colloids were suspended and presumably mobile in a sand and gravel aquifer.

Studies by Yao et al. (1971) and O'Melia (1980) indicate that colloidal particles in the range 0.1 to 1.0 micron may be most mobile in a sandy, porous medium. Kovenya et al. (1972) concluded that particles in the range 0.1 to 0.5 mm were most mobile in soil column studies. As much as 200 ppb copper, lead and cadmium was found associated with colloidal material in size range 0.015-0.450 mm by Tillekeratne et al. (1986). Rapid transport of plutonium (Pu) in core column studies by Champ et al. (1982) was attributed to colloidal transport, with 48% of the Pu associated with colloids in the size range 0.003-0.050 mm and 23% in the range 0.050-0.450 mm. Reynolds (1985) using carboxylated polystyrene beads ranging from 0.10 to 0.91 mm in size, recovered 45% of the 0.91 mm size beads, and greater than 70% of 0.10 and 0.28 mm size beads in laboratory sand column effluents.

Lake and estuarine studies by Baker et al. (1986) and Means and Wijayaratne (1982) demonstrated the importance of natural colloidal material in the transport of hydrophobic contaminants. Carter and Suffet (1982) found that a significant fraction of "dissolved"DDT in surface waters was bound to colloidal humic material. Takayanagi and Wong (1984) found over 70% of the total inorganic colloidal particles.

Analytical methods used to determine "dissolved" metal concentrations have historically used 0.45 micron filters to separate dissolved and particulate phases. If the purpose of such determinations is an evaluation of "mobile" species in solution, significant underestimations of mobility may result, due to colloidal associations. On the other hand, if the purpose of such filtration is to determine truly dissolved aqueous species, the passage of colloidal material less than 0.45 microns in size may result in the overestimation of dissolved concentrations (Bergseth, 1983; Kim et al. 1984; Wagemann and Brunskill, 1975). Kennedy et al. (1974) found errors of an order of magnitude or more in the determination of dissolved concentrations of aluminum, iron, manganese and titanium using 0.45 micron filtration. Sources of error were attributed to filter passage of fine-grained clay particles. Additionally, filtration of anoxic ground-water samples is very difficult without iron oxidation and colloid formation, causing a removal of previously dissolved species to be filtered. Filter loading and clogging of pores with fine particles may also occur, reducing the nominal size (Danielsson, 1981). Filtration should be viewed as only one approach for determining the "true" solution geochemistry of ground water, and others should be applied whenever possible.

Purpose of Sampling

It is important to identify the purpose of ground-water sampling before decisions regarding filtration, centrifugation or other phase separation techniques are made. Is it to determine the mobility of contaminants or to determine in situ aqueous geochemistry? The following definitions are also useful for consideration of this issue:

(1) Total Contaminant Load Per Unit Volume of Aquifer = Mobile + Immobile Species.

(2) Mobile Species = Dissolved + Suspended Species.

(3) Dissolved = Free Ions + Inorganic Complexes + Low Molecular Weight Organic Complexes.

(4) Suspended = Adsorbed + Precipitated + Polymeric + High Molecular Weight Organic Complexes.

For an assessment of mobility, all mobile species must be considered, including suspended particles acting as adsorbents for contaminants. While not all suspended species may necessarily be sufficiently mobile or toxic to pose a health risk, a conservative approach is proposed at this time until more definitive data are available. Contaminant transport models which account for an additional aqueous mobile colloidal phase have been proposed by Avogadro and DeMarsily (1984) and Enfield and Bengsston (1988).

A principle objective in a sampling effort for testing a geochemical speciation model is to obtain estimates of the free ion activities of the major and trace elements of interest. Since there are relatively few easily performed analytical procedures for making these experimental estimates, an alternative procedure is to test the analytically determined dissolved concentrations with model predictions including both free and complexed species. More and more remedial investigations are utilizing such models to make predictions about contaminant behavior based on dissolved concentrations. It is not the purpose of this report to suggest how to perform these analytical determinations, but as noted above, the use of a 0.45 micron filter as the operational definition of "dissolved" may be inappropriate. Analytical techniques such as ion selective electrodes, ion exchange and polarography may be more accurate. Research utilizing these and other techniques to correlate "dissolved" with filter size is recommended.

If one adopts the conservative approach with no filtration for contaminant mobility estimations, increased importance is placed on proper well construction, and purging and sampling procedures to eliminate or minimize sources of sampling artifacts.

Sources of Sampling Artifacts vs. "real" Ground-water Environment

The disturbance of the subsurface environment as a result of well construction and sampling procedures presents serious obstacles to the interpretation of ground-water quality results. Some degree of disturbance of natural conditions is inevitable. However, the impact of improper well construction and sampling techniques can permanently bias the usefulness and integrity of wells as sampling points. Several aspects of well construction and sampling procedures must be carefully considered to avoid errors associated with the introduction of foreign particles or the alteration of ambient subsurface conditions which may affect natural dissolved or suspended materials.

Well Construction

The design, drilling, and construction of monitoring wells have been identified as particularly important steps in the collection of representative water chemistry and hydrologic data. Several references have emphasized the minimization of both the disturbance and the introduction of foreign materials (USEPA, OSWER-9950.1, 1986; Barcelona, et al., 1983; Barcelona et al., 1985) because of the potential impact on water chemistry. The RCRA Technical Enforcement Guidance Document (USEPA, OSWER-9950.1, 1986) suggests that the well must allow for sufficient ground-water flow for sampling, minimize passage of formation materials into the well, and exhibit sufficient structural integrity to prevent collapse of the intake structure. It should be recognized, however, that the well must first provide a representative hydraulic connection to the geologic formation of interest. Without the assurance of this hydraulic integrity, the water chemistry information cannot be interpreted in relation to the dynamics of the flow system or the transport of chemical constituents.

More specific guidance is therefore necessary to maintain or restore the natural hydraulic conductivity of the formation in the vicinity of the screened portion of monitoring wells through the drilling, construction and development procedures. The literature on water well technology can be most helpful in this regard since minimal disturbances of the subsurface is a common goal in maximizing both the yield of water supply wells and the representativeness of water samples and hydraulic information from monitoring wells (Driscoll, 1986).

To insure the long-term integrity of monitoring wells, particularly with respect to excluding foreign particles and permitting the passage of mobile (i.e., dissolved and suspended) contaminants, specific items which should be observed are:

1) If no alternative to the use of drilling muds or fluids exists, these materials must be removed from the well bore and adjacent formations by careful well development (Driscoll, 1986). This guidance also applies to the removal of the low permeability "skin" which is caused by abrasion, oxidation and invasive muds which may seal the well bore from the screened interval and bias in situ determininations of hydraulic conductivity (Faust and Mercer, 1984; Moench and Hsieh, 1985; Faust and Mercer, 1985). Pumping rates during development should be documented and care should be taken not to exceed these rates during purging or sampling since further development and well damage may aggravate suspended particulate and turbidity problems even in properly designed wells.

2) The emplacement of grouts and seals to isolate the screened interval must be carefully done. The use of tremie pipes and frequent checking of the depth of emplacement of clay or cement grouts during well construction are strongly encouraged.

It is also important to take care to follow manufacturer's guidelines on the hydration of cement or expanding cement as grouts or seals. Excess water addition and grading of cement components or materials due to free fall through standing water can permanently damage the well's integrity (Evans and Ellingson, 1988).

3) Casing and screen materials must be selected to retain their integrity in the subsurface environment (i.e., avoid iron, steel), minimize bias to water samples and insure that screen openings are not reduced by the buildup of corrosion products or by compression (USEPA, OSWER-9950.1, 1986). These effects can be checked by repeat determinations of in situ hydraulic conductivity over the useful life of the well. Redevelopment and replacement of the well should be considered if deterioration or significant changes in hydraulic conductivity are observed. Erratic water level readings and sudden changes in turbidity or purging behavior of monitoring wells prior to sampling are warning signs of possible loss of material integrity.

4) Well design fundamentals with regard to the selection of a filter pack and screen size are among the most important issues in obtaining representative hydraulic and water quality information. The exclusion of fines, clays, and silts can be achieved by selecting the grain-size distribution for the filter pack by multiplying the 50-percent retained size of the finest formation sample by a factor of two (Driscoll, 1986). The filter pack material should be cleaned and washed free of fines to insure that extraneous contaminants or particles are removed. The well screen slot openings should be chosen to retain 90% of the filter pack material after development. In natural packed wells it may be advisable to select a screen slot size which will retain at least 50% of the finest material in the screened interval. Minimizing slot screen width however, often leads to greater time and energy spent in well development. The need to document well development procedures cannot be overemphasized.

Maintenance of the hydraulic performance of monitoring wells and the connection of wells to the zones of greatest hydraulic conductivity, where contaminant transport is most probable, should take equal importance to the collection of representative water quality data.

Purging and Sampling

Water that remains in the well casing between sampling periods is unrepresentative of water in the formation opposite the screened interval. It must be removed by purging or isolated from the collected sample by a packer arrangement prior to the collection of representative water samples. Water level readings must be made carefully to avoid the disturbance of fines or precipitates which may enter or form in the well due to chemical reactions or microbial processes and accumulate on the interior walls of the well casing screen or at the bottom of the well. Similarly, it is important to purge the stagnant water at flow rates below those used in development to avoid further development, well damage or the disturbance of accumulated corrosion or reaction products in the well. The use of certain sampling devices, particularly bailers and air-lift arrangements, should be discouraged in order to avoid the entrainment of suspended materials which are not representative of mobile chemical constituents in the formation of interest.

A note of caution should be voiced to encourage repetitive sampling of monitoring wells prior to judging the representativeness of determinations of hydraulic conductivity, water level readings and water quality data. The effects of the inevitable "trauma" due to drilling, sealing and development of monitoring wells can bias observations of water chemistry until the subsurface is allowed to equilibrate sufficiently (Walker, 1983). Estimates of the time to achieve equilibration vary substantially, particularly when drilling fluids are used in highly permeable formations

(Brobst, 1984; Driscoll, 1986); however, periods of weeks to several months may be necessary before even major ionic constituents of ground water equilibrate to previous levels (Barcelona, et al., 1988).

Recommendations for Sampling

In general, the zone of interest must be isolated, the sample pumped slowly to minimize turbidity and sample collected in such manner as to eliminate O_2 and CO_2 exchange with the atmosphere. No filtration for mobile metals determination is recommended. If the unfiltered values exceed maximum contaminant level concentrations for ground-water quality, additional analyses and re-evaluation of sampling artifacts are required. It should be emphasized that extreme differences between unfiltered and 0.45 mm filtered samples does not preclude the use of unfiltered data for risk assessment decisions. Significant particulate mobility may be occurring at such a site, and additional analyses with other larger filters (e.g. >0.45 mm) may be most appropriate given the current size estimates for upper limits for mobile particles.

Isolation of Sampling Zone

Isolation of the sampling zone is necessary to minimize the purge volume as well as to minimize air contact. This is especially important since Eh/pH conditions of the formation waters are notoriously sensitive to dissolved gases content. Inflatable packers can be used to achieve isolation of the sampling zone.

Pumping for Sample Collection

It is recommended that a positive displacement pump can be used. Other types of sample collection (e.g., bailing) may cause displacement of non-mobile particles or significantly alter ground water chemistry leading to colloid formation (e.g., vacuum pumps). Surging must be avoided, and a flow rate as close to the actual ground-water flow rate should be employed. Acknowledging that this may be impossible or impractical in some instances, a pumping flow rate based on the linear ground-water flow rate and open screen area is proposed, where

pumping flow rate ~linear GW flow rate x 2 x screen ht. x well radius x 10

While an initial approximation, flow rates around 100 ml/min have been used to successfully sample ground-waters in a quiescent mode.

Additional research is needed in this area, particularly with respect to the appropriateness of this generic equation. An inexpensive flow-through type cell set-up utilizing this approach was described by Garske and Schock (1986).

Assessment of Water Constituents While Sampling

Monitoring of the pumped ground water for dissolved oxygen, temperature, conductivity and pH aids in the interpretation or establishment of ground-water background quality. Gschwend and co-workers (personal communication) have observed that turbidity diminished dramatically after prolonged pumping, changing similarly, although possibly more slowly, than other water quality parameters (e.g., O_2, conductivity). An initial estimate proposed for time of pumping necessary to collect water from a formation is around two times the time required to get plateau values for the above parameters.

No Filtration for Mobile Fraction Determination

Those samples intended to indicate the mobile substance load should not be filtered. Steps to preserve their integrity, such as acidification, should be performed as soon as possible.

Filtration for Specific Geochemical Information

Any filtration for estimates of dissolved subsurface species loads should be performed in the field with no air contact and immediate preservation and storage. In-line pressure filtration is best with as small a filter pore size as practically possible (e.g., 0.05, 0.10 micron). Using a smaller pore size filter will require longer sample collection time, increasing the need for air exclusion from the sample (Laxen and Chandler, 1982; Holm et al., 1988). Polycarbonate membrane-type filters with uniform and sharp size cutoffs are recommended to minimize particle loading on the filter. Although membrane filters are more prone to clogging than fiber-type filters, the uniform pore size, ease of cleaning, and minimization of adsorptive losses from the sample tend to improve the precision and accuracy in the analytical data. The filter holder should be of material compatible with the metals of interest. Holders made of steel are subject to corrosion and may introduce non-formation metals to samples. Large diameter filter holders (e.g., > 47 mm) are recommended to reduce clogging and pore size reduction and for ease of filter pad replacement. The use of disposable in-line filters are suggested for convenience if of sufficient quality. Prewashing of filters should be routinely performed. Work by Jay (1985) shows that virtually all filters require prewashing to avoid sample contamination.

Quality assurance and quality control becomes increasingly important when adopting the above recommendations. The use of field blanks and standards for field sampling is essential. Field blanks and standards enable quantitative correction for bias due to collection, storage and transport. Analysis of the filters themselves and their particulate load is suggested as a check on mass balance and filtration effects on solid/solution separation efficiency.

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WORK/QUALITY ASSURANCE PROJECT PLAN

FOR

RISK ASSESSMENT PILOT STUDY
NAVAL CONSTRUCTION BATTALION CENTER
DAVISVILLE, RHODE ISLAND

PREPARED BY

TIMOTHY R. GLEASON
CORNELIA MUELLER
SAIC
EPA-ENVIRONMENTAL RESEARCH LABORATORY
NARRAGANSETT, RHODE ISLAND

PREPARED FOR

DR. GERALD PESCH
USEPA
EPA-ENVIRONMENTAL RESEARCH LABORATORY
NARRAGANSETT, RHODE ISLAND

APPROVALS

Gerald Pesch — 5/11/89
Dr. Gerald Pesch, Principle Investigator — Date

Al Beck, P.E. — 5/12/89
Mr. Al Beck, Project Officer — Date

George Morrison — 5/18/89
Mr. George Morrison, EPA-ERLN Q.A. Officer — Date

WORK/QUALITY ASSURANCE PROJECT PLAN

FOR

RISK ASSESSMENT PILOT STUDY
NAVAL CONSTRUCTION BATTALION CENTER
DAVISVILLE, RHODE ISLAND

1. PROJECT NAME: RISK ASSESSMENT PILOT STUDY, NAVAL CONSTRUCTION BATTALION CENTER DAVISVILLE, RHODE ISLAND

2. PROJECT REQUESTED BY: MARINE ENVIRONMENTAL SUPPORT OFFICE OF THE NAVAL OCEAN SYSTEMS CENTER

3. DATE OF REQUEST: APRIL, 1988

4. DATE OF PROJECT INITIATION: OCTOBER, 1988

5. PROJECT OFFICER: MR. AL BECK

PROJECT MONITOR: DR. GERALD PESCH

6. QUALITY ASSURANCE OFFICER: MR. GEORGE MORRISON

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Appendix 6: Work/Quality Assurance Project Plan for Allen Harbor Risk Assessment/Chromosomal Effects in Mammalian Tissue Culture

Appendix 7: Quality Assurance Program Plan for Environmental Research Laboratory - Narragansett

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7. PROJECT DESCRIPTION

A. Objective and Scope Statement

Allen Harbor at Naval Construction Battalion Center (NCBC) Davisville, R.I. has been closed for shellfishing by the RI Department of Environmental Management, due to suspected hazardous waste contamination from a landfill adjacent to the harbor. Analysis of sediment and bivalve tissues from Allen Harbor has shown increased levels of heavy metals and organics. The waste site may be a source of leachate and low-level contamination to the harbor. Information is needed to assess the potential long term impacts and identify risk management options. This project will develop and field validate ecological risk assessment methods. Ecological risk assessment involves quantitative estimation of the likelihood of adverse ecological effects resulting from exposure to toxic substances from hazardous waste sites. Ecological effects will be determined using toxicological and biomarker methodology. The completed risk assessment will support selection of remedial action or risk management of wastes. Monitoring will be conducted to measure the success of remediation technology.

Conduct cooperative ecological risk assessment at NCBC Davisville to determine the presence and extent of adverse impact and assist in selection of remedial alternatives. Verify the effectiveness of remediation and development of Risk Management Plan.

B. Data Usage

These data will be used to assess site specific ecological risks, if any, present in Allen Harbor and adjacent areas of Narragansett Bay. The information gathered will be used to characterize potential sources of contamination, characterizing the site (Allen Harbor and adjacent bay), describing the degree and extent of exposure, and determining the degree and extent of biological effects. This information and supporting information on marine environmental quality provide a context within which to evaluate the condition of Allen Harbor.

C. Technical Approach

This project will follow a risk assessment approach. Therefore, information will be gathered characterizing potential sources of contamination, characterizing the site (Allen Harbor and adjacent bay), describing the degree and extent of exposure, and determining the degree and extent of biological effects. These data will be used to assess site specific ecological risks, if any, present in Allen Harbor.

The specific objective of phase I is to determine whether or not there are environmental problems in Allen Harbor. The rationale for making this determination is to compare

measures of contamination and biological health in Allen Harbor to similar measures of contamination and biological health in Narragansett Bay. This information and supporting information on marine environmental quality provide a context within which to evaluate the condition of Allen Harbor. Emphasis is placed on sampling shellfish because of their ecological and commercial importance in Allen Harbor and Narragansett Bay.

Phase 1 - Information Gathering

1. Identify and collate all existing data.

Existing data and information are being gathered for Allen Harbor, Davisville/Quonset Point, and Narragansett Bay. Sources of information include the Navy, Navy contractors, the Coastal Resources Center at the University of Rhode Island, the Graduate School of Oceanography and the School of Ocean Engineering at the University of RI, the Narragansett Bay Project, the RI Department of Environmental Management, the RI Department of Health, the US FDA, the Army Corps of Engineers, the US EPA Laboratory at Narragansett, and the scientific literature.

2. Characterize sediments

The approach to sampling for this project (sediments and biota) will be to oversample initially and archive. A subset of samples will be analyzed. If the data indicate a need for further analyses, additional samples will be available. Since all samples will be from the same collections, there will be no question of comparability. Over sampling also guarantees available materials for other measurements if appropriate.

The approach to sample analysis (sediments and biota) will be to process composite samples. Compositing samples increases the statistical power of data analysis. This reduces the number of samples needed, thus speeding up the process and saving money. If the data indicate a need for further analysis, archived samples will be available.

a. Sediment samples (1 gal) will be collected from three locations on the face of the landfill in the immediate vicinity of visible seeps. One or more of these samples will be split for analysis by TRC. All of these samples will be analyzed by ERLN.

Number of samples	3 sediment

Sediments (1 gal) will be sampled with a clean scoop intertidally at three locations each within Allen Harbor, at Marsh Point, and at Coggeshall Cove on Prudence Island. These locations will be sampled also for soft shell clams, *Mya arenaria*. Aliquots of sediments from each location will be composited and analyzed. An intertidal station has been added on the south shore of Calf Pasture Point at a site allegedly contaminated with arsenic. This station will be sampled in the same manner as the other intertidal stations.

Number of samples 9 composite sediment

Sediments will be sampled subtidally on a grid of 11 stations within Allen Harbor, at 7 stations along a "T" shaped transect out of Allen Harbor (Fig. 1) and at Mount View (MV), Greenwich Bay(GB), North Jamestown (NJ) and at Potter Cove (PC) on Prudence Island (Fig 2). A Smith-McIntyre grab sampler will be used, five grabs per station in Allen Harbor and vicinity. The 4 stations representing mid-bay conditions (MV, GB, NJ, and PC) will be sampled 5 grabs per 5 locations per station for a total of 25 grabs per station. This ensures comparability of data for statistical purposes.

The top 2 cm of sediment will be saved from each grab. Aliquots from each of 5 grabs will be composited (1 gal total) for 5 Allen Harbor stations (selected from the 11 stations). Aliquots from each of 5 grabs per location will be composited for the 4 bay stations (MV, GB, NJ, and PC).

Number of samples 25 Composite sediment

Cores will be taken selectively within Allen Harbor to characterize sediment contamination to a depth of 30 cm (the estimated depth of disturbance due to shellfishing). Five cores will be taken and sampled at three depths (top, middle, bottom) within each core. These aliquots will be composited by depth.

Number of samples 3 composite sediment

An extensive survey of sediments from embayments surrounding Narragansett Bay, sponsored by the Narragansett Bay Project, will evaluate relative toxicity (using an amphipod assay) and chemistry. Allen Harbor is included in this survey (see Appendix 1).

b. Sediment samples will be analyzed extensively for metals, volatile organic compounds, and non-polar organic compounds likely to be present (see Table 1 and Appendix 2). The rationale is to develop a "working list" of contaminants for which all samples (sediment, water and organisms) will be analyzed. The initial "working list" is based on previously identified problem compounds in marine environments, existing information on the landfill at Allen Harbor and on Calf Pasture Point, and information generated by an extensive analysis of a preliminary subset of samples (sediment and quahog tissue). Additional compounds of particular concern will be identified by analyzing samples from the landfill. Tributyl tin analyses will be done by the NOSC laboratory at San Diego, Calif. on a subset of 4 samples, 2 from Allen Harbor and 2 from mid-bay at Mount View.

c. Sediment samples will be analyzed for grain size and total organic carbon.

d. Composite sediment samples from Allen Harbor and the 4 bay stations (MV, GB, NJ, and PC) as well as the Narragansett Bay Project sponsored survey of sedi-

ments will be tested with the amphipod assay (see Appendix 1). Two of these same stations (same sediment samples), one from Allen Harbor and one from Mount View will be tested extensively for Biomarker responses (see appendix 6).

e. An intercalibration exercise between ERLN and TRC will be done on sediments from the face of the landfill as well as on ground water samples from the test wells. These analyses will be extensive for metals and organic compounds.

f. Gas chromatography/Mass spectroscopy (GC/MS) will be conducted to determine what compounds are present in the sediments from Allen Harbor and the 4 bay stations. Particular attention will be given to compounds, if any, unique to Allens Harbor.

3. Characterize Water Column

a. Water column samples will be collected in Allen Harbor and at Station 7 (Fig. 3) of the Narragansett Bay Project stations in mid-bay for water column chemistry. These samples will be taken at and immediately after mean low water using teflon lined pumps and tubing. Analysis of these samples will be related to analysis of seeps on the face of the landfill. Timing of sampling will depend on "dry" periods and "wet" periods influencing seepage from the landfill.

b. (1) Chemical compounds identified by analysis of groundwater at the landfill and Calf Pasture Point, plus analysis of seeps and sediments from the face of the landfill, will be analyzed in the water column samples. These analyses will include metals and organics, including volatile organics (see 2b for rationale). Tributyl tin will be analyzed by the NOSC laboratory at San Diego, Calif. if warranted by results of sediments and organism analyses.

(2) At the time of sampling a temperature/ salinity profile of the water column will be measured in the field. If a sharp pycnocline exists, samples will be taken above and below it for chemical analysis. Dissolved oxygen will be measured on all samples taken.

(3) Bacteriological indicators will be measured in Allen Harbor waters by the US FDA. Supporting data are available from the RI DEM and the RI DOH.

c. Seepage from the landfill will be analyzed for contaminants. Measures of these contaminants, if any, will be used to identify the presence of a contaminant plume in Allen Harbor via water column sampling.

4. Evaluate biological resources of Allen Harbor and selected stations in Narragansett Bay.

a. The shellfish resources of Narragansett Bay, including Allen Harbor, are surveyed by the Rhode Island Dept. of Environmental Management. The sampling

for this project will be quantitative and will supplement existing quantitative information for soft shell clams, *Mya arenaria* and quahogs, *Mercenaria mercenaria*. Existing data indicate dense populations of both species in Allen Harbor. The oyster, *Crassostrea virginica*, is present but probably not in sufficient numbers to support a full sampling plan (RI DEM, personal communication).

(1) Samples of quahogs, soft shell clams, and oysters (Approximately 50 animals per station) will be collected at all designated stations (see Fig. 1 & 2) during the fall of 1988. These samples will be used to estimate resource density and condition indices. A subset of samples will be used to evaluate health via histopathological observations and for chemical analysis of tissue residues. The remaining samples will be archived for future chemical analysis if required. Quahogs and soft shell clams will be sampled quarterly for a year at a subset of stations (5 for quahogs, 3 for soft shell clams) for histological observations and condition indices.

(2) *Mytilus edulis* will be deployed at 4 stations in the spring and fall of 1989. One station will be in Allen Harbor, one immediately outside of Allen Harbor in Narragansett Bay, and at 2 standard mid-bay stations. Mussel cages are routinely located 1 meter above the bottom for 28 days. (5 replicate cages/station, 50 animals/ cage.) (see Appendix 3 for details.) Actual growth, as measured by shell length, and scope for growth, as measured by physiological parameters, will be determined for the mussels at each station. Composite mussel tissue samples, three per station per sampling date, will be analyzed for the same contaminants measured in the water column, sediments, and other shellfish.

Number of samples for chem. analysis.	24 composite tissue samples
Number of samples for physiology	64 organisms

(3) Because of its dense distribution and economic importance, the quahog will be used as the primary organism for evaluating benthic impacts. It is sedentary and filters large volumes of water, thus making it an ideal organism for evaluating environmental quality. It will be sampled at all subtidal stations (FIG 1 & 2) during the fall of 1988 for observations of resource density and size distribution. At a subset of 5 stations 5 composites of 5 animals each will be sampled for chemical analysis; 25 animals will be sampled at each station for condition index (shell length/whole weight/tissue wet weight ratios) and for histopathological examination. The latter observations will be made quarterly for one year at 5 stations.

Number of samples for chem. analysis	25 composite tissue samples (5 animals/ composite)
Number of samples for histology	500 individual animals (125 animals/season)

(4) The soft shell clam is very common in intertidal areas of the mid-and upper-bay areas, including Allen Harbor. It supports an active recreational fishery. It will be sampled intertidally at three areas; Allen Harbor, Marsh Point, and Coggeshall Cove plus the station on the south shore of Calf Pasture Point. Observations similar to those for the quahog will be made on the soft shell clam; 3 composites of 5 animals each will be sampled at each station for chemical analysis; 25 animals will be sampled at each station for condition index and histopathological examination. The latter observations will be made quarterly for one year at three stations.

Number of samples for chem. anal.	9 composite (5 animals/ composite)
Number of samples for histology	300 individual (75 animals/ season)

(5) The oyster will be sampled once, depending on availability, at two stations; Allen Harbor and the northeast side of Prudence Island. Observations similar to those made on the other bivalves will be made on the oyster.

Number of samples. for chem. anal.	6 composite tissue sample (5 animals composite)
Number of samples for histology	50 individual (25 animals/ station)

(6) A polychaete species will be sampled for tissue residue analysis if sufficient biomass is available at a station (10 g wet weight) within Allen Harbor and at least one appropriate reference station in the bay.

Number of samples for chem. anal.	6 composite tissue samples.

(7) Benthic community condition will be evaluated also using the REMOTS camera survey methodology. The Narragansett Bay Project is sponsoring a bay-wide survey and has agreed to include Allen Harbor in that effort.

5. Coordination with other governmental agencies and interested parties.

a. State of RI DEM personnel have reviewed the rationale and work plan and are in agreement with the proposed study of Allen Harbor. They have offered cooperation, data on bacteriological monitoring, and the use of their boat. Selection of sampling stations was done with input from Arthur Ganz of RI DEM.

b. An essential feature of this project is to collect data in a manner permitting comparison of conditions in Allen Harbor to conditions in Narragansett Bay. This permits evaluating Allen Harbor in the broad context of bay-wide conditions. This approach was welcomed by Caroline Karp. The NBP is cooperating by including Allen Harbor in at least 2 bay-wide surveys, a sediment survey and a REMOTS camera survey of benthic conditions. In the Allen Harbor Project sampling plan we included several N.B.P. quahog survey stations so as to facilitate comparison of tissue residue data between both projects.

c. FDA has expressed interest in being directly involved in this project. They will measure bacteriological indicators in Allen Harbor water, in ground water samples, and in a shoreline survey of Allen Harbor.

d. Coordination with EPA Region I is being done with Ron Jennings, the federal facilities Superfund representative, with Katrina Kipp, the federal director of the Narragansett Bay Project, and with Carol Wood and Charles Porfert QA officials for Reg 1.

e. On August 3, 1988, we met with representatives of TRC Environmental Consultants. The meeting was very fruitful. We agreed to remain in close communication throughout this project, to discuss and develop a QA/QC plan to ensure comparability of data between ERLN and TRC, to split samples for analysis as part of this effort, and to exchange pertinent information as appropriate.

f. Dr. James Quinn of the Graduate School of Oceanography, University of Rhode Island will be involved in this project and will analyze ground water samples, seepage samples, and sediment samples for volatile organic compounds. This is particularly important because of the high volumes of solvents likely disposed of at the landfill.

6. Evaluate Contaminant Exposure and Receptor Impact.

a. Contaminants of concern will be identified by extensive analysis of samples from the landfill and from Calf Pasture Point and by comparing detailed analyses of Allen Harbor samples to appropriate samples from Narragansett Bay. Con-

taminants possibly impacting Allen Harbor as well as those unique to Allen Harbor should be evident.

b. The water column and benthic evaluations of toxicity and tissue residue analysis should identify segments of the environment and species possibly threatened by contamination.

c. Areas of concern identified in Phase I of this study will be included for detailed study in Phase II.

7. A baseline ecological risk assessment of Allen Harbor based on measures of contaminant exposure and biological effects will determine if there is significant environmental impact in the harbor. Contaminant levels will be measured in the groundwater, in the water, and in the sediments. Biological effects include toxicity responses, measures of physiological and histological well being and chemical analyses of tissue residues. Statistical comparisons of data from Allen Harbor with data from Narragansett Bay will provide an initial assessment of differences. Correlation of contaminant concentrations and measures of biological effects will provide a baseline indication of ecological risks.

III. Phase II - Verification and Quantification of Toxicological Effects

The details of Phase II will depend on findings and information generated in Phase I. Work plan details of Phase II will be developed in consultation with the Navy, the other governmental agencies and interested parties.

D. Monitoring Parameters

Summary of Samples to be Processed

Phase - I

Sample Type	Number of Samples
<u>Chemical Samples</u>	
Water	
Groundwater	5
Seepage	6
Water column	8
Sediments	
Landfill	3
Intertidal	9
Subtidal	25
Cores	3

Total organic carbon	40
Grain size	40
Tissues	
M. edulis	24
M. mercenaria	25
M. arenaria	9
C. virginica	6
Polychaete	6

Sample Type	Number of Samples
<u>Biological Samples</u>	
Physiology	
M. edulis	64
Histology and Condition Index	
M. mercenaria	500
M. arenaria	300
M. edulis	200
C. virginica	50
Toxicology	
Amphipod assay	40
Biomarker assay	40
Bacteriology	FDA

Table 1. Compounds known to cause problems in marine environments and therefore, routinely analyzed at the U.S. Environmental Research Laboratory at Narragansett, R.I.

Parameter	Matrix	Units***	Detection Limits	Method	Reference	Maximum Holding Time
Volatiles	Sediment tissue seawater	PPB		Purge & Trap GC/MS	**URI SOP's	2 Weeks
Pesticides	Sediment tissue seawater	NG/G NG/G NG/L	0.6 0.6 0.3	Extraction/ GC-ECD	*EPA SOP's	Prior to extraction indefinite if frozen (sediments and organisms) or refrigerated (water)
F-1 (PCBs)	Sediment tissue seawater	NG/G NG/G NG/L	2 2 1	Extraction/ GC-ECD	*EPA SOP's	After extraction indefinite if stored in tightly sealed vials with maximum amount of solvent in vial. Must be stored in dark refridgerator.
F-2 (aromatic)	Sediment tissue seawater	NG/G NG/G NG/L	0.6 0.6 0.3	Extraction/ GC-MS	*EPA SOP's	
F-3 (more-polar)	Sediment tissue seawater	NG/G NG/G NG/L		Extraction/ GC-FID	*EPA SOP's	
Trace Metals						
Cr, Cu Pb, Ni, Ag	Sediment tissue seawater	µg/g µg/g µg/L	1-3 0.5-1.5 0.5-1.0	ICP ICP Graphite AA	*EPA SOP's	
Cd	Sediment tissue seawater	µg/g µg/g µg/L	1.0 0.5 0.1	ICP ICP Graphite AA	*EPA SOP's	6 months after extraction
Hg	Sediment tissue seawater	µg/g µg/g µg/L	0.1 0.05 0.5	Cold vapor AA Cold vapor AA Cold vapor AA	*EPA SOP's	*EPA SOP's referenced in appendix 2
Zn	Sediment tissue seawater	µg/g µg/g µg/L	0.5 0.3 0.05	ICP ICP Graphite AA	*EPA SOP's	**Method listed in section 12
Arsenic	Sediment tissue	µg/g µg/g	4 2	ICP ICP	*EPA SOP's	***Sed and tissue on dry wt. basis
TBT	sediment tissue	µg/g				

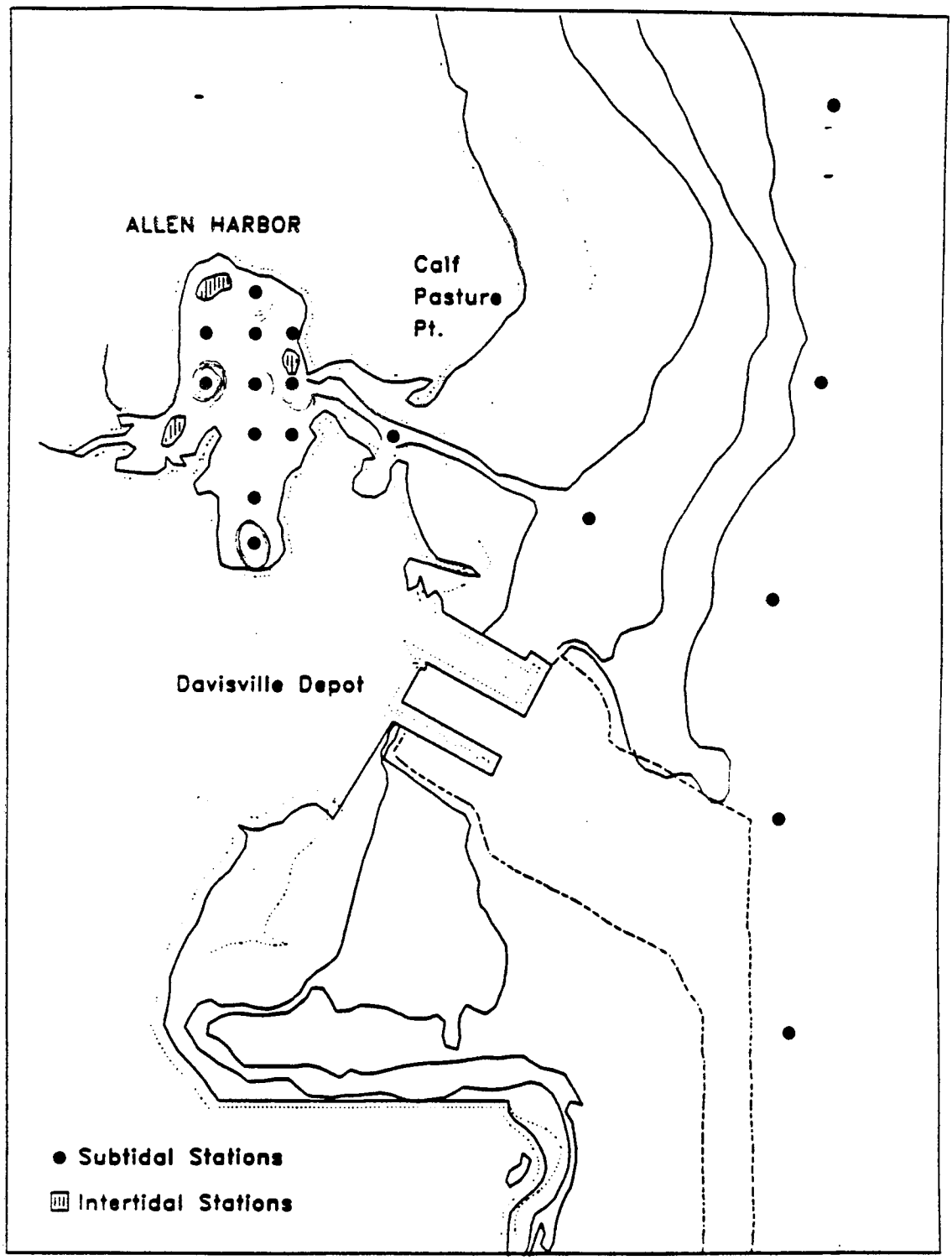


Figure 1. Station locations for Allen Harbor and nearby Narragansett Bay

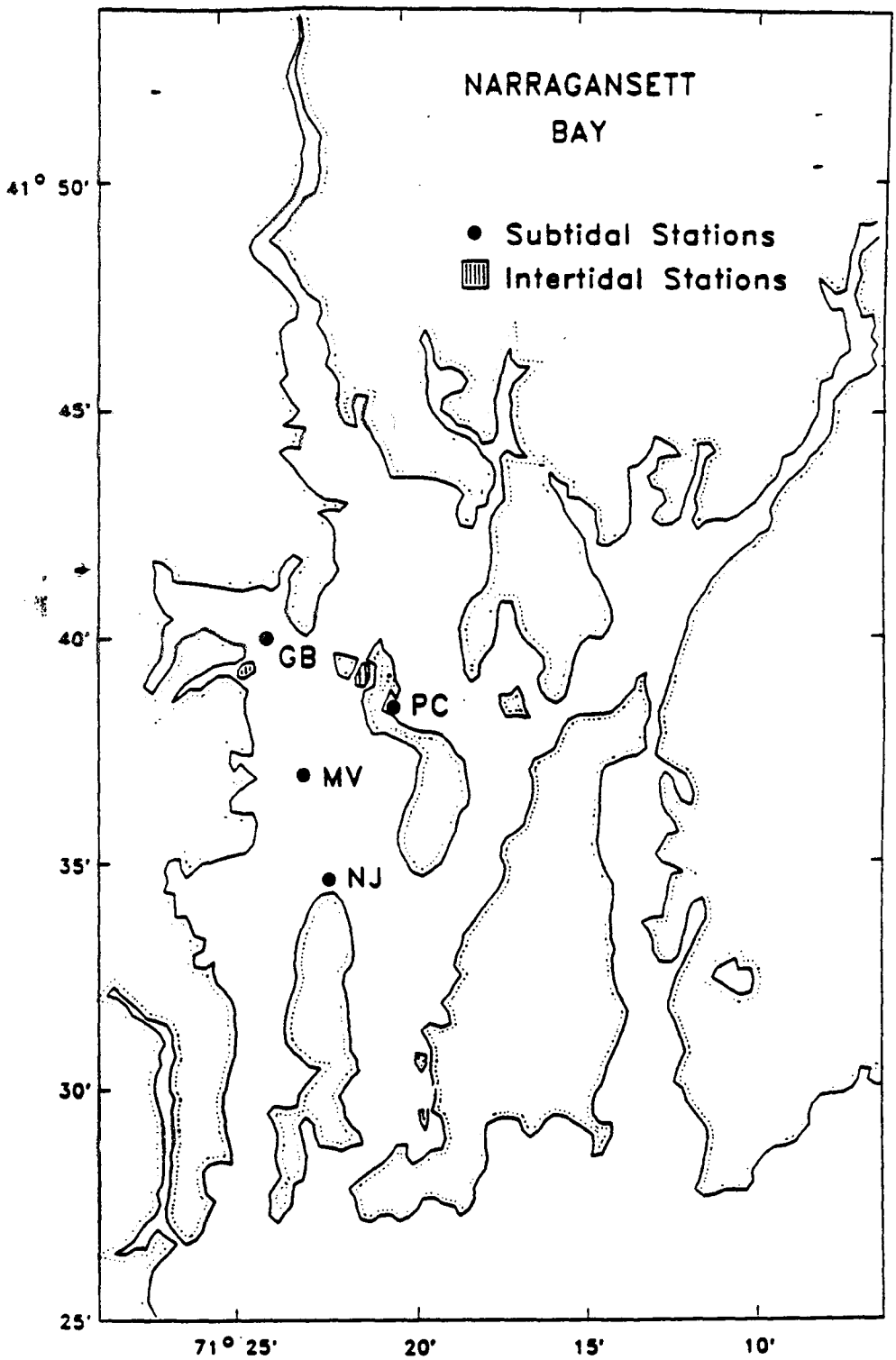


Figure 2. Station locations for characterizing sediments and shellfish in Narragansett Bay.

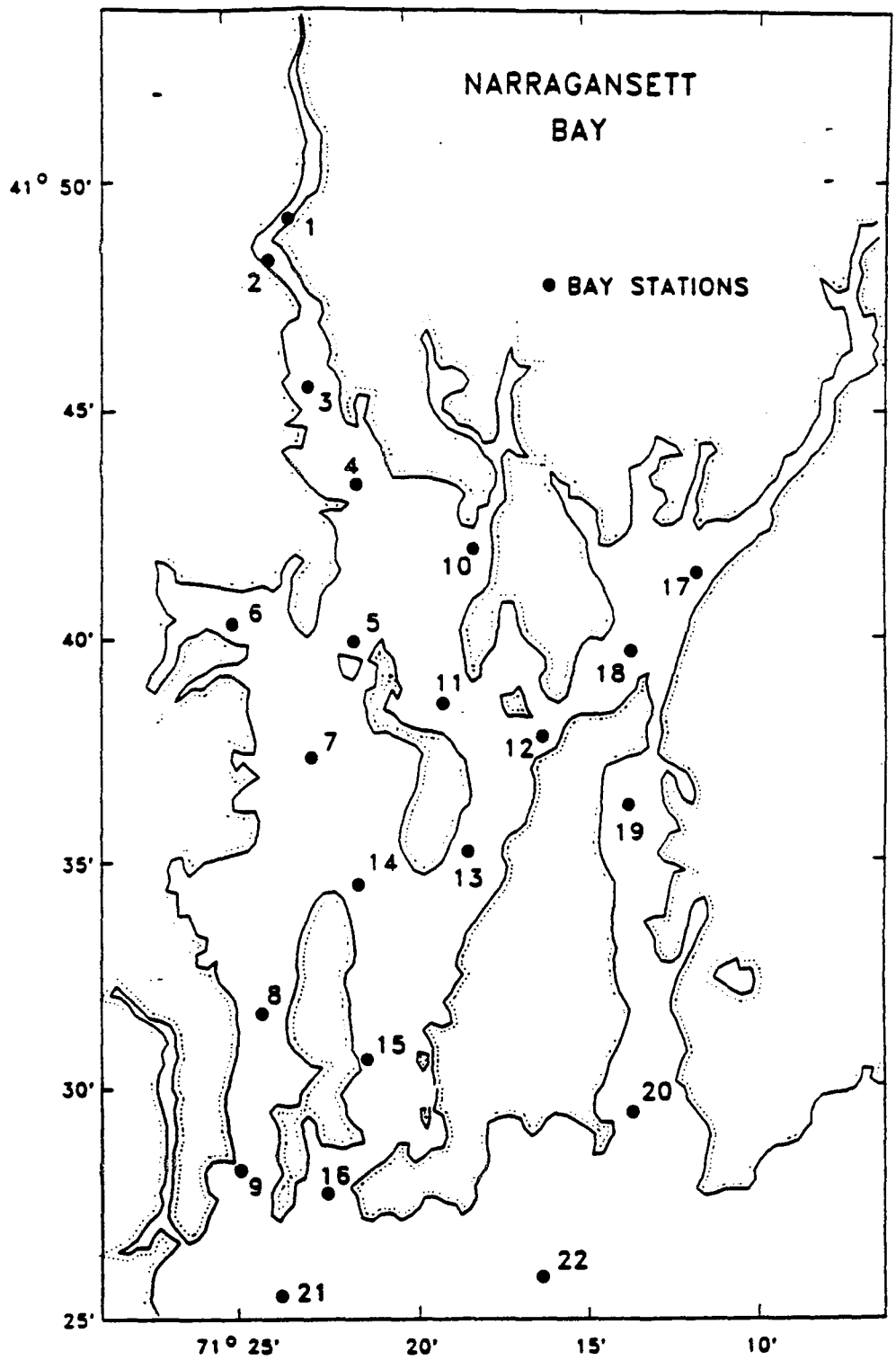


Figure 3. Station locations for Narragansett Bay synoptic water column survey.

8. PROJECT FISCAL INFORMATION

Funding will be provided to support this project in accordance with the requirements of the study, identified in the scope of work and agreed upon by NOSC and EPA-ERLN. No costs may be expended in excess of the agreed amount without notification and agreement by NOSC. NOSC is not responsible for expenditures of funds not obligated by NOSC.

PHASE - I

BUDGET ESTIMATE

Item	Cost ($k) Budget	EPA Match
Analytical Chemistry	129	20
Geophysical Analyses	0	2
Physiology	8	0
Histology	31.8	20
Toxicology	40	60
Bacteriology	15	0
Data Management	30	30
Supplies and Equipment	30	20
Ship Time	0	13
Field Collections	0	20
Project Management and Report Writing	0	25
Travel	5	0
Total	288.8	210

9. SCHEDULE OF TASKS AND PRODUCTS

QA/QC PLANS: Documents validity of data gathering and analysis.

DATA MANAGEMENT PLAN: Documents how data will be archived and processed.

HEALTH AND SAFETY PLAN: Documents worker and public health safety during field and laboratory investigations, in compliance with OSHA/CERCLA regulations.

PROGRESS REPORTS (Quarterly): Summerize significant progress achieved during previous quarter; documents cummulative expenditures of funds; presents planned work for next quarter; identifies problems or potential setbacks for managerial attention.

INTERIM REPORT (six months after initiation of current phase of experiment/data collection): Presents preliminary results and conclusions of data and information obtained; provides detailed evaluation of the abilty of selected methodologies and procedures to meet objectives and accomplish tasks identified in SOW.

FINAL REPORT: Technical report containing detailed analysis of methods and results of current phase of SOW. The technical report will contain abstract, introduction, methods/materials, results, discussion, bibliography and appropriate appendices. The technical report should fully document all aspects of the study performed as well as provide a clear and concise analysis and interpretation of the results, the relationship of the work to other published research, as well as the limitation/uncertainty of the results and conclusions.

RISK ASSESSMENT: Provides detailed analysis of ecological risks and methodologies of how they were derived. This document should provide information for use by risk managers and is supported by technical information contained in the final report(s).

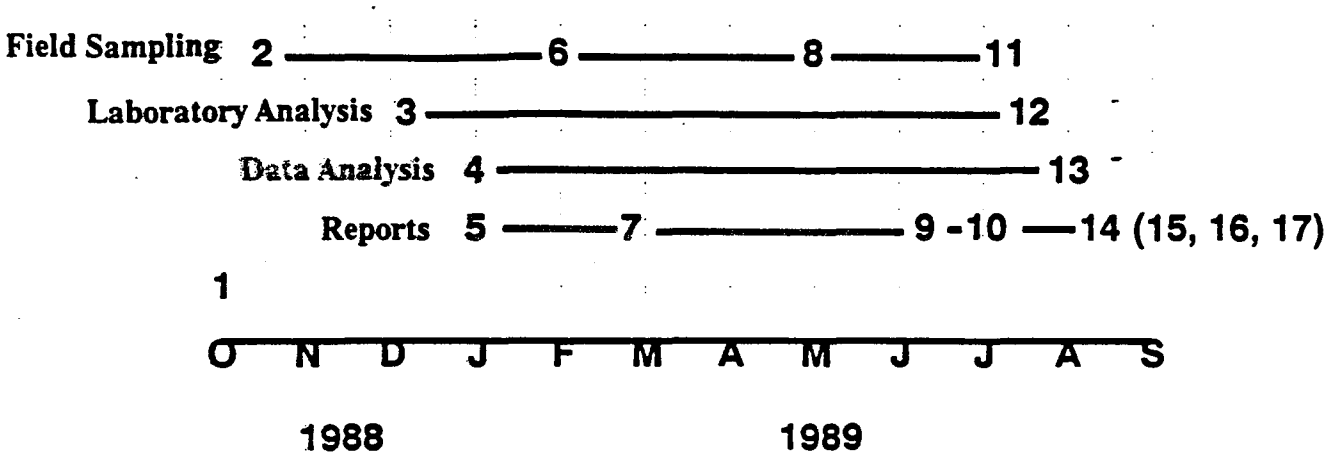
MONITORING PLANS: Contain concise descriptions of monitoring network to be established relative to thr decision requirements to be addressed. The monitoring plan should contain descriptions of sample locations, collection methods, chemical analysis methods, database requirements, and graphical and statistical analysis methods to be used. The monitoring plan should provide a clear objective statement and specifications on how to implement and carry out monitoring program.

DATA DUMP: Contains complete listing of all data, including sample location, analysis methods, raw and calibrated values, etc., compiled in tables and in computer readable files. It should be included as appendices to final report(s).

ECOLOGICAL EVALUATION CRITERIA: Monograph detailing important ecosystem variables to be used to evaluate effectiveness of remediation technology. Monograph should detail how to evaluate the criteria and the methodologies used to develop them.

PEER REVIEWED PUBLICATION: This is a paper published in a reputable peer reviewed journal or publication. The publication demonstrates the scientific quality of the work performed under this SOW and assures the scientific acceptance of new and emerging methodologies applied during the study.

See Figure 4.



1. Project initiation
2. First field sampling
3. Initiation of laboratory analysis
4. Initiation of data analysis
5. First Progress Report
   QA/QC Plans
   Data Management Plan
   Health and Safety Plan
6. Second field sampling
7. Second Progress Report
8. Third field sampling
9. Interim Report
10. Third Progress Report
11. Fourth field sampling
12. Completion of laboratory analysis
13. Completion of data analysis
14. Draft Final Report
15. Final Report
16. Baseline Risk Assessment
17. Monitoring Plans

Figure 4. Schedule of tasks and products.

10. PROJECT ORGANIZATION AND RESPONSIBILITY

Dr. Gerald Pesch (U.S. EPA, Environmental Research Laboratory (ERL-N), Narragansett, RI 02882, Tel. 401-782-3095) will be the Project Manager/Principle Investigator for this project. He will be responsible for the quality and timely completion of the project. He will also be responsible for data interpretation and for preparation and submission of reports.

Dr. Pesch will be assisted by three task leaders as shown in Figure 5. Ms. Cornelia Mueller (SAIC, ERL-N, Narragansett, RI 02879, 401-782-3050) will be the work assignment manager for SAIC employees as well as the laboratory coordinator for the project.

Data management will be the responsibility of Mr. Jeffery Rosen (CSC, ERL-N, Narragansett, RI 02879, 401-782-3048). Mr. Timothy Gleason (SAIC, ERL-N, Narragansett, RI 02879, 401-782-3113) will be responsible for coordination and logistics of field sampling activities.

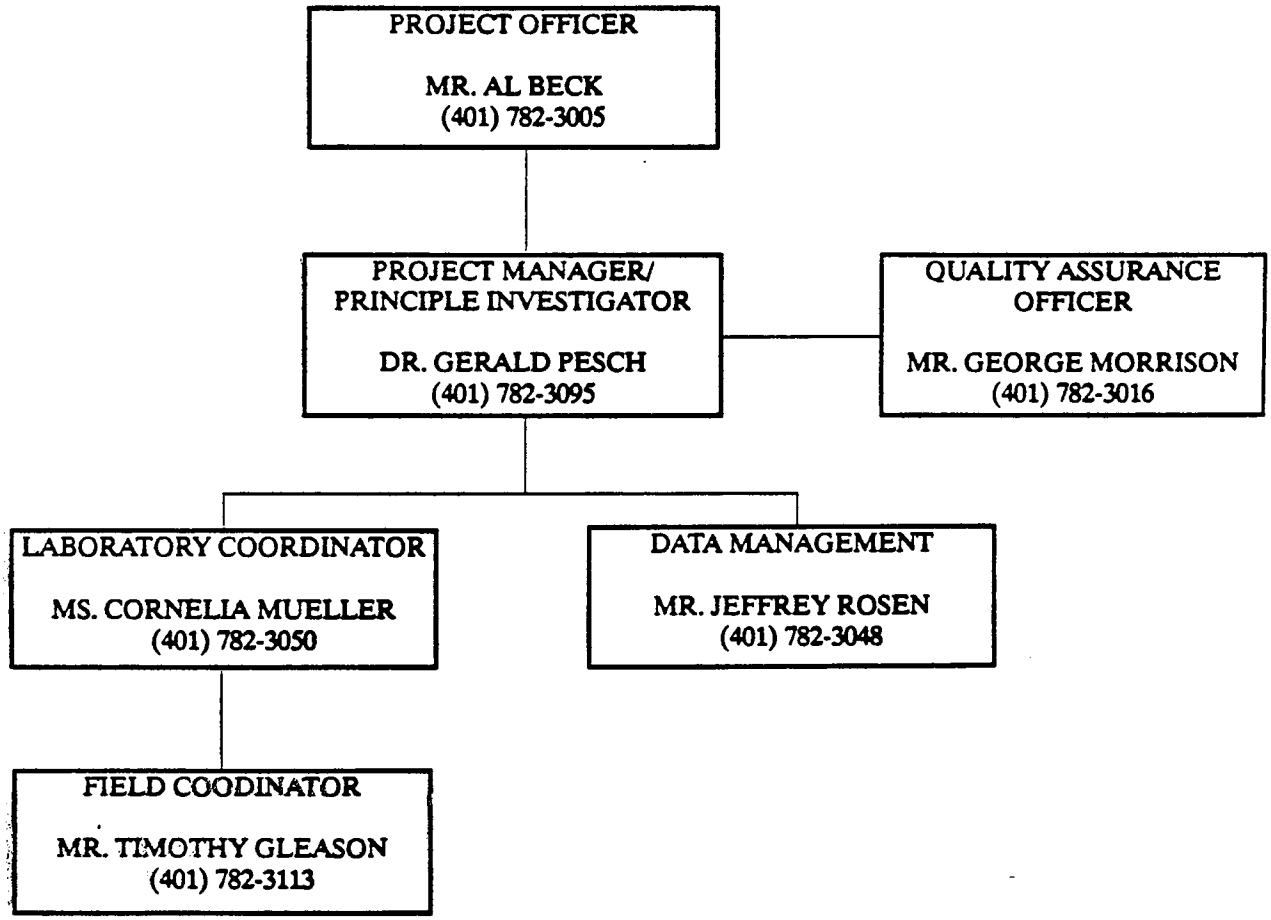


Figure 5. Project Organization and Responsibility

11. DATA QUALITY REQUIREMENTS AND ASSESSMENTS

Data quality requirements and assessments are characteristic of each particular analysis. The required quality and assessment of quality for each analysis are indicated below. In those instances where this information is not included, data quality will be the highest achievable through the implementation of standard good laboratory practices and the internal QA program at EPA-ERLN (Appendix 7).

I Chemistry

(A) Metals

Accuracy will be assessed as percent recovery of Standard Reference Materials (SRM). For sediments, Black Rock Harbor and NRC Canadian sediments will be used. For tissues, NBS certified oyster and mega mussel mush will be used. For water analyses, certified reference sea water, estuarine and river waters will be used.

Precicision will be measured as the relative standard deviation of homogenized samples. Several readings are done on each sample preparation. If standard deviation exceeds 5% the analyses will be repeated.

Test methods will be those employed in the Quincy Bay Project (appendix 8). Procedures will follow the same quality control and data quality assessment protocols and will meet the same data quality requirements specified by that project.

Completeness will be measured as the percentage of total sample collected that will be tested. Because extra samples will be collected from each sampling area, it is likely that completeness will be 100%. If a sample is lost or destroyed, this will be reported.

(B) Organics

Accuracy will be measured as percent recovery of blank samples spiked with a PCB standard mix (Arochlors 1242, 1254). If recoveries are not within 80 - 110 percent of the spike mixture, analyses conducted withing the batch will be repeated.

Accuracy will also be measured as percent recovery of a Standard Reference Material (SRM), Canadian Reference Sediment. Percent recovery of PCB's and pesticide in tissue will be by analyses of mega mussel mush in comparison to previously reported values. Precision will be measured as the relative standard deviation (RSD) between triplicate sample analyses.

Test methods will be those employed in the Quincy Bay Project (appendix 8). Procedures will follow the same quality control and data quality assessment protocols and will meet the same data quality requirements specified by that project.

Completeness will be measured as the percentage of total samples collected that will be tested. Because extra samples will be collected from each sampling area, it is likely that completeness will be 100%. If a sample is lost or destroyed, this will be reported.

(C) Volatile Organics.

A Tracor-purge and trap, capillary gas chromatographic-system will be used to analyze volatile organics compounds (VOCs) using EPA method 601 for halocarbons and method 602 for aromatic hydrocarbons. Dr. Quinn's laboratory has participated in two EPA laboratory evaluations and performance in both studies was very good. Presently, they routinely analyze a variety of natural water and soil/sediment samples for about 30 VOCs down to 0.1 parts per billion (ppb). They are also working on EPA method 502.2 and expect to be able to analyze about 55 of the VOCs down to 0.01 ppb in the very near future. The lab has the capability to analyze a wide range of environmental organic contaminants with good to excellent accuracy, precision and detection limits.

II Biology

(A) Scope for Growth (Mussels)

The scope for growth index is a relative measure of the physiological conditions of mussels between experimental and reference sites. The individual parameters used to measure scope for growth index are respiration rate, clearance rate and assimilation efficiency. Accuracy based on comparison to absolute numbers is not pertinent.

Precision will be monitored through the use of replicate samples at each station. There will be four replicates per station.

Based on previous work, it has been statistically determined that four replicates per station and two mussels per replicate are of sufficient sample size to obtain a representative sample from the area.

Test methods will be those employed in the New Bedford Harbor, Field Verification and Narragansett Bay Programs. Procedures will follow the same quality control and data quality assessment protocols and will meet the same data quality requirements specified by those programs.

Completeness could be affected by the loss of mussels in the field during deployment. Historically, in stations similar to Allen Harbor, this type of loss has been minimal. Therefore, we anticipate achieving 100% completeness.

(B) Histological Observations.

Histology is a highly specialized science. Years of experience and study are required to correctly interpret microscopic observation of tissue preparations and to assess the health and well-being of the organisms studied. These judgements rest on a weight-of-

evidence approach and past experience. Consequently, some of the QA/QC concerns associated with this science are unique.

Diagnosis of pathology observed during histological examination of marine organisms at ERLN is routinely confirmed by consultation with pathologists from hospitals, universities, and at the Registry of Tumors in Lower Animals at the Smithsonian Institution (U.S. Museum of Natural History, Wash. DC). These consultations involve review and discussion of actual slides containing tissue preparations from the organisms studied. Slides representing the most important findings are entered as case studies in the Registry. These slides are then available to anyone for review.

A nomograph was developed using data from past laboratory and field studies. This nomograph matches the desired degree of precision with appropriate sample sizes. For the first phase of this project, a sample size of 25 was selected for each species for each station. This sample size will provide an excellent indication of the presence or absence of pathology at each station.

The sampling program in this project was designed to compare representative samples from Allen Harbor to samples representing acceptably clean areas of nearby Narragansett Bay. Station locations were selected to accomplish this. Samples were collected randomly within stations to ensure proper representation of that location. To ensure that the histological observations are representative of the local population a minimum sample size of 25 was used. This sample size is based on a statistical review of past data. To ensure that the histological observations on each individual properly represent the state of health and well-being of that individual, all the major organ systems are carefully observed. This ensures that a standard and thorough set of criteria are used for collecting data of this type. For example, some pathologists limit their observations to a single organ (liver) and miss important responses in other organs. This deficiency is avoided at ERLN by routinely screening all major organ systems.

The histology program at ERLN has extensive experience in both laboratory and field studies. Laboratory studies often involved studying effects of toxicants (e.g. petroleum compounds and metals) on organisms where similar studies had been done in other laboratories. This permitted direct comparison of results. Some field studies have been on organisms and in locations studied by others. This again permits comparison of results. In all such cases ERLN results were noted for comparability and thoroughness. Relevant to this study, several other pathologists have sampled shellfish (particularly *Mya arenaria*) from Allen Harbor. In fact, ERLN staff sampled *M. arenaria* from Allen Harbor about 15 years ago. So comparability of results will be demonstrated within ERLN findings and among several other research efforts during this study.

For this project, the field sampling program was designed based on availability of the shellfish to be sampled. Therefore, enough biological material will be available to complete the experimental design. This includes sampling seasonally to observe developmental changes, particularly the reproductive cycle and any other seasonal changes that may occur.

(C) Biomarkers Sediment Toxicity Tests

Metabolic Cooperation Assay

Accuracy will be measured as relative percent recovery of 100 HGPRT$^-$ mutant cells from a mixed population of V79 cells exposed to chemical blanks (solvent controls) or various concentrations of sediment extract. Recovery of mutant cells is a measure of the extent to which gap-junctional intercellular communication (GJIC) is blocked by exposure of cells to a test agent. Accuracy within each test will be gauged to mutant recovery in cell populations receiving the established tumor promoter, phorbol myristate acetate (positive control). Cytotoxicity measurements will be made simultaneously. Test concentrations with a cytotoxicity of greater than 30% will be eliminated, since cytotoxicity itself can inhibit GJIC.

Precision will be measured by determining the standard deviation between ten replicate samples per concentration for effects on GJIC, and five replicate samples per concentration for cytotoxicity measurements. Two independent experiments will be conducted with all samples.

Inhibition of GJIC is a property of many tumor-promoting chemicals. Inhibition of GJIC in this assay will be considered indicative of the presence of tumor promoters in a sediment extract. However, a no effect result cannot be interpreted as meaning no tumor promoters are present in a sediment because:

a) complex mixtures may contain other substances that mask or reduce the effects of tumor promoters on GJIC.

b) only sediment extracts, rather than the sediment itself, can be tested in the assay.

c) although many tumor promoters do inhibit GJIC in this assay, not all tumor promoters exhibit this effect.

Samples will be prepared and analyzed by methods similar to those employed during the completed National Cancer Institute study (Appendix 9). Procedures will follow the same quality control and data quality assessment protocols and will meet similar data quality requirements as specified by that program.

Completeness will depend on the amount of chemistry support available to produce sediment extracts and fractions of extracts. Whole sediment extracts have limited value because of their complexity and the higher likelihood that they may contain substances that will mask the effects of any tumor promoters present. Fractionation of extracts and further testing will increase the completeness of the results.

Chromosomal Effects Assay

See Appendix 6.

(D) Amphipod Sediment Tests

See Appendix 5.

Physical Measurements

MODEL SBE 9 CTD UNDERWATER UNIT

DESCRIPTION

Conductivity, temperature, and pressure sensors are digitized in the Underwater Unit (fish) at 32 scans per second. Resultant data in Manchester Code is transmitted to the Deck Unit via single conductor armored cable. Fish power is supplied by the deck unit through the same cable. Standard sensors are SBE 3-01/F Thermometer, SBE 4-01/0 Conductivity Meter, and Paroscientific Digiquartz Model 4xK (specify 3000, 6000, or 10,000 psi range). An optional temperature sensor within the pressure transducer permits compensation for most of the ambient temperature related pressure errors. A Digiquartz Model 2900 transducer (specify 100, 200, 300, 400, or 900 psi) is optional at reduced price. Data interfaces and mounting for additional sensors (dissolved oxygen, fluorometer, transmissometer, etc.) are available.

SPECIFICATIONS

Measurement Range:

Temperature	-5 to +35 °C
Conductivity	0 to 7 S/m (0 to 70 mmho/cm)
Depth	0 to 6000 m (depends on range selected)

Accuracy:

Temperature	0.004 °C/year (typical, 0.01 per 6-months guaranteed)
Conductivity	0.0003 S/m/month (typical, 0.001/month guaranteed)
Depth	0.05% of full scale over the ambient temperature range of 0 to 25 °C (typical, 0.1% guaranteed) 0.02% with temperature compensation feature installed

Resolution:

Temperature	0.0003 °C
Conductivity	0.00004 S/m
Depth	0.004% of full scale

Response Time:

Temperature	0.082 sec (0.5 m/sec drop) 0.070 sec (1.0 m/sec drop)
Conductivity (pumped)	0.084 sec (0.5 m/sec drop) 0.070 sec (1.0 m/sec drop)
Conductivity (no pump)	0.170 sec (1.0 m/sec drop)
Depth	0.001 sec

Sensor Calibration:

Temperature
-1 to +31°C (CTD measurements outside this range may be at slightly reduced accuracy due to extrapolation errors). Calibration is by National Regional Calibration Center.

Conductivity
0 to 6 S/m. Calibration is by National Regional Calibration Center over the range 1.4 to 6 S/m. A 0 S/m point is self generated by the instrument when no water is in the cell.

Depth
0 to Full Scale, calibration by Paroscientific.

12. SAMPLING AND ANALYTICAL METHODS

Station locations will be determined by dead reckoning. By using navigation charts and sitings of immovable objects, sample stations can be located within several meters. Loran-C coordinates will be recorded for all subtidal stations. The Loran-C coordinates can then be used to return to the site at a later date. Compass sitings will also be used to identify stations.

Collection of Water Samples

Organic compounds. Samples of water are obtained at stations utilizing a Teflon-lined stainless steel braided hose and a pump equipped with a Teflon impeller. The hose is lowered to the desired sampling depth, and the sampling system is flushed with water for 5 min. prior to obtaining the water sample. Each sample (22 l) of water is pumped into a total of six glass bottles. The extraction of the samples is started immediately by the addition of 200 ml of CH_2Cl_2 to each bottle.

Inorganic compounds. Seawater samples for metals analysis are collected from the sampling depth using a pump and a nylon-reinforced, clear polyvinyl chloride (PVC) hose.

All parts of the pump contacting the seawater sample are made of Teflon or polypropylene. Each whole water sample (250 ml) is pumped from the sampling depth into precleaned polyethylene bottles.

Volatile Organic Compounds. See Appendix 3.

Collection of Biological Samples

Collection of soft shelled clams, *M. arenaria*, will be quantitative. Three 1m-square quadrats will be sampled per station. The depth of digging will be 12-14 inches and may vary due to substrate. All clams found within a quadrat will be placed into an individually labelled bag and returned to the laboratory for analyses.

Quahog, *M. mercenaria*, collection will also be quantitative. Professional quahog fishermen will be hired to collect quahogs. Catch per unit effort will be used as a measure of relative abundance.

Oyster, *C. virginica*, collection will be qualitative. A minimum of 25 oysters will be pryed from rocks and other objects at each of the sites

Mytilus edulis. All *M. edulis* used in the field studies are collected by scallop dredge from Narragansett Bay. In general, *M. edulis* are collected 1 to 2 days prior to field deployment. They are returned to the laboratory where 100 5- to 7-cm orgnisms are sorted and placed into each polyethylene basket. All baskets are place in holding tanks of flowing unfiltered seawater until deployed in the field.

Subtidal sediments in Allen Harbor and at a control station will be collected and seived through 1mm seives to determine whether or not the biomass of any one polychaete species is sufficient to support tissue residue analysis.

Collection of Sediments

Sediments (1 gal) will be sampled (top 2 cm) with a clean scoop intertidally at three locations each within Allen Harbor, at Marsh Point, and at Coggeshall Cove on Prudence Island. These locations will be sampled also for soft shell clams, *Mya arenaria*. Aliquots of sediments from each location will be composited and analyzed.

Sediments will be sampled subtidally using a Smith-McIntyre grab sampler. The top 2 cm of sediment will be saved from each of 5 grabs per station for a total composited 1 gallon per station.

Cores will be taken selectively within Allen Harbor to characterize sediment contamination to a depth of 30 cm (the estimated depth of disturbance due to shellfishing). Five cores will be taken and sampled at three depths (top, middle, bottom) within each core. These aliquots will be composited by depth.

Chemical Analyses.

See appendix 2.

Biological Analyses.

(A) Scope for Growth

The scope for growth (SFG) index is a measure of the energy available to an organism for production, both somatic and reproductive, after accounting for routine metabolic costs. The SFG value represents the instantaneous assessment of energy balance in an organism for that set of environmental conditions under which it is measured.

Calculation of the SFG index for *M. edulis* requires the measurement of four parameters: clearance rate, respiration rate, food absorption efficiency, and ammonia excretion rate. Measurements are completed under standardized conditions: temperature 15° C, salinity 30 ppt, and an algal concentration of 0.5 mg/l All SFG measurements for a given treatment are completed in the order shown below within 28 hr after termination of an experiment.

Clearance rate. Clearance rate is defined as the volume of water completely cleared of particles 3 microns in size during some unit of time. Mussels are placed into individual chambers through which 1 u filtered seawater flows at a rate of 75 ml/min. The unicellular alga *T-Iso* is added to the filtered seawater to deliver an incoming cell concentration of approximatedly 25,000 cells/ml (about 0.5 mg/l) to each chamber. Each chamber is gently aerated to ensure that complete mixing and no settling of algae occurrs. Mussels are allowed to acclimate in the chamber for at least 1 hr prior to any measurements. Incoming and outgoing particle concentrations for each chamber are then measured 3 times at 1-hr intervals with a Coulter Counter (Model TAII).

Respiration rate. Respiration rates are determined by isolating each mussel in a glass respirometer vessel fitted with a PO2 electrode. The electrode is connected to a Radiometer oxygen meter (Model PHM71) which is in turn connected to a strip chart recorder. The decline in PO2 is monitored on a strip chart recorder for approximatedly 30 min. Seawater containing algae (0.5 mg/l) is pumped into the vessel during an acclimation period at a rate of 80 ml/min to ensure that food is present in the chamber and that routine metabolic rate is measured.

Absorption efficiency. After completion of the respiration rate measurements, all fecal material is removed from each feeding chamber. This ensures that only the algae consumed during the SFG procedures is used in the absorption efficiency measurements. At the food concentration used in the SFG measurements, approximately 0.5 mg/l, no pseudofecal production occures. The mussels are allowed to feed overnight in the chambers, and the feces are collected from each chamber the following morning. Fecal material is dried for 24 hr at 100° C, weighed, ashed at 500° C for 4 hr, and reweighed to determine the ash-free dry weight:dry weight ratio. A similar procedure is completed with the cultured algae

to obtain the ash-free dry weight:dry weight ratio of the food. Absorption efficiencies are calculated for each treatment.

Ammonia excretion rate. Mussels are placed individually into HCl-stripped beakers containing 300 ml of 1-u filtered seawater for a period of 3 hr. Mussels are then removed and a 0.45-u filtered, 50-ml sample is collected from each beaker, deposited into acid-stripped polyethylene bottles, and stored in a freezer at -20° C until analyzed. Ammonia analyses are completed in duplicate for each sample.

After completion of the physiological measurements, the length and volume of each mussel are measured and the tissue excised, dried for 24 hr at 100° C, and weighted. The clearance rates, respiration rates, and ammonia excretion rates are standardized to the mean weight of all the mussels used in the treatment. This procedure is used instead of standardizing to a 1-g mussel by using allometric equations because all mussels are approximately the same length and weight. The use of allometric equations is necessary only when mussels of variable size and weight are used.

The weight-standardized values for each mussel are then used to calculate the SFG of each individual by substitution into the following equation:

$$\text{SFG (joules/hr)} = (C \times A) - (R + E)$$

where

C = clearance rate (L/hr) x food concentration (mg/ml) x food energy (joules/mg)
= joules/hr of energy assimilated

$$A = \frac{\text{\% organic content of food}}{\text{\% organic content of feces}} = \text{\% absorption efficiency}$$

$$R = \frac{\text{oxygen consumed or heat produces (ml } O_2\text{)}}{\text{time (hr)}}$$
= joules/hr of energy lost through respiration

$$E = \frac{\text{ammonia excreted } (\mu\text{M of } NH_4\text{-N})}{\text{time (hr)}}$$
= joules/hr of ammonia produced

The following energy conversions were used to calculate SFG:

1 mg of *T-Iso* = 4.5×10^7 cells
1 mg of *T-Iso* = 19.24 J
1 ml O_2 respired = 20.08 J
1 mg NH_4-N = 24.56 J

The energy content of *T-Iso* was determined by filtering a volume of the algae onto preweighed glass filters, drying them at 100° C for 24 hr, and reweighing them to determine the algal dry weight. They were analyzed then using the dichromate wet oxidation method to determine oxygen consumed and the resultant energy content.

(B) Histopathological Protocol

Soft shelled clams, mussels and quahogs are opened between the mantle and the valve with a shellfish knife. Whole animals are then placed in Helly's fixative for 15-30 minutes, sectioned on a sagittal plane along 95% of the midline, and reimmersed in fixative for overnight duration. During final trimming the midline cuts are finalized and the animals are transectioned. Tissue quadrants are trimmed to 2-3 mm, washed overnight, embedded in paraffin, cut at 6 u and stained with Harris Hematoxylin and Eosin.

The oysters are opened with an oyster knife inserted into the ligament and twisted to separate the valves. The knife is then used to loosen and separate the mantle and adductor muscle, removing the dorsal valve. Oysters are removed from the ventral valve by separating the adductor muscle at point of attachment. Whole oysters are placed into Helly's fixative for 15-30 minutes, removed and sagittally sectioned along 95% of the midline and returned to the fixative overnight for 16 to 24 hours. Oysters are sectioned transversely through the body mass during final trimming. Sections are cut adjacent to the pericardial cavity oriented towards the anterior region of the animal. Each half is then cut parasgittally into sections 2-3 mm in thickness, washed overnight in a water bath, embedded in paraffin, cut at 6 u and stained with Harris Hematoxylin and Eosin.

The histopathological protocol is designed to allow evaluation of all major organ system with light microscopy.

(C) Biomarker Measurements

V79 Metabolic Cooperation Assay

The Chinese hamster V79 metabolic cooperation (V79/MC) assay is currently being explored as a short-term test to identify tumor promoters. This assay is based on the discovery that the phorbol ester tumor promoters inhibit the gap junctional-mediated transfer of low molecular weight molecules (metabolic cooperation) between cultured cells. Since this discovery, many structurally diverse promoter have been reported to inhibit metabolic cooperation (MC) between a variety of cell types.

The V79/MC assay utilizes co-cultivated mutant (HGPRT-) and wild-type (HGPRT+) Chinese hamster V79 lung fibroblasts. The mutants are deficient in the enzyme hypoxanthine-guanine phosphoribosyl transferase (HGPRTase). In addition to normal

purine bases, HGPRTase catalyzed the biotransformation of certain abnormal based, such as 6-thioguanine (6TG), that are lethal upon incorporation into DNA. Thus, 6TG is toxic to wild-type cells but not to HGPRTase-deficient cells, unless mutant and wild-type cells establish physical contact. If contact occurs, gap juncton will form between cells, allowing the exchange of cytoplasmic components. Under such conditions, the toxic metabolite of 6TG (6-thioguanine monophosphate) is passed from wild-type to mutant cell, resulting in the death of both cell types. In the V79/MC assay, this phenomenon of mutant cell killing via MC in the presence of 6TG is used to identify and quantitate the effects of test chemicals on MC. Tests are conducted with an excess of wild-type cells to ensure physical contact between the two cell types. Under such conditions, mutant cells are killed upon exposure to 6TG unless 'rescued' by test chemicals that inhibit MC. Thus, the capacity of test chemicals to suppress MC is measured as an increase in mutant cell survival over background. It is also possible for chemicals to enhance MC. This situation is detected as a decrease in mutant cell survival below background.

The V79 lung fibroblast has a limited capacity to metabolize xenobiotic compounds and no exogenous metabolizing system is currently used in MC assays. Thus, observed responsed are assumed to result from effects induced by unmetabolized substances. Although criteria for determining the validity of individual assays and for assessing the significance of assay responsed have been suggested, there is presently no generally accepted, single set of criteria. In this laboratory, the effects of chemicals on MC are assessed only at concentrations permitting at least 70% relative cell survival. Thus, the effects of test chemicals are assessed essentially at non-cytotoxic concentrations. Responses are presently evaluated by application of the statistically conservative, two-fold-increase rule. Inhibition of MC is significant if experimental mutant survival exceeds solvent control mutant survival by a factor of two or more. Enhancement of MC is significant if the reverse is true. Otherwise, test agents are considered to have no effect on MC. A detailed experimental protocol for the V79/MC assay as performed in this laboratory has been published and is available upon request.

Chromosomal Effects Assasy

See Appendix 6.

(D) Amphipod Sediment Tests

See Appendix 5.

13. SAMPLE CUSTODY PROCEDURES

No formal chain of custody records are maintained. A field notebook is maintained containing such information as loran coordinates, compass bearings, depth, site description, sample number and replicate. Each sample collected is labelled with sample number (for referencing the above information), date collected, date received, sample description, storage and processing information, and person responsible. Sediments will be stored in the laboratory at 4 C in a locked cooler until used, and will be logged in and out of this cooler

as needed. Clams and oysters will be placed in labelled bags and stored frozen. Either Ms. Mueller or Dr. Pesch will be responsible for distributing samples to the appropriate analysts.

The remaining samples will be frozen and archived.

14. CALIBRATION PROCEDURES AND PREVENTIVE MAINTENANCE

Calibration and standard systems checks for Analytical Chemistry are available in Appendix 2.

All other equipment will be maintained as necessary or as prescibed by ERL-N's quality assurance officer and Good Laboratory Practices.

15. DOCUMENTATION, DATA REDUCTION AND REPORTING

See accompanying Data Management Report.

16. DATA VALIDATION

All data reported will be checked for errors in transcription, calculation, or computer input, and all sample logs and data forms will be reviewed to ensure that requirements for sample holding and integrity, data quality assessments, and equipment calibration have been met. Data which do not meet these requirements will either not be reported or will be reported with an explanation of problems encountered.

17. PERFORMANCE AND SYSTEMS AUDITS

This project will be conducted under the EPA-ERLN internal QA program (Appendix 6), using standard good laboratory practices.

18. CORRECTIVE ACTION

Quality assurance problems will be identified in the course of the ERL-N QA program. The Quality Assurance Officer will assess the extent of the problem and in concert with the Principle Investigator recommend corrective action. This action and its results will be fully documented in the final report.

19. REPORTS

All reports and deliverables developed under this statement of work must obtain the approval for public release from the Commanding Officer, NCBC Davisville, before publication. Draft reports are subjected to inhouse EPA review and are then forwarded to the the Navy and allowed thirty days review for interim reports and sixty days for review of final reports and other deliverables. Final drafts will obtain Navy approval for public release by the Commanding Officer, NCBC Davisville, before publication by NOSC as Technical Reports.

Open literature publications will obtain a statement of approval for public release prior to publication of the final manuscript and in accordance with the MOA.

Section 9 contains a description of all reports to be generated.

ASSESSING THE IMPACT OF HAZARDOUS WASTE DISPOSAL SITES ON THE ENVIRONMENT: CASE STUDIES OF ECOLOGICAL RISK ASSESSMENTS AT SELECTED NAVY HAZARDOUS WASTE DISPOSAL SITES#

Robert K. Johnston[1*], Paul E. Woods[2], Gerald G. Pesch[3], and Wayne R. Munns, Jr.[4]

1. Naval Ocean Systems Center
Code 522
San Diego, Ca 92152-5000

2. Institute of Wildlife and Environmental Toxicology
Clemson University
Clemson, SC 29634

3. Environmental Protection Agency
Environmental Research Laboratory
27 Tarzwell Drive
Narragansett, RI 02882

4. Science Applications International Corporation
27 Tarzwell Drive
Narragansett, RI 02882

* Author to whom correspondence should be addressed

ABSTRACT

The current status of ecological risk assessments being conducted for hazardous waste disposal sites located at Naval Air Station (NAS) Whidbey Island, WA, and Naval Construction Battalion Center (NCBC) Davisville, RI, are reported. The sites being investigated at NAS Whidbey Island include a fire fighting training area, a pesticide disposal site, and the air station's runway ditches. Toxicological impacts are being evaluated using starling (Sturnus vulgaris) nesting and reproductive biology as an indication of contaminant migration into the food chain. Toxicological impacts are also being monitored in small mammals, hawks, owls, herons, and selected prey species located on or near the hazardous waste disposal sites.

The sites being investigated at NCBC Davisville are a landfill and disposal site located directly adjacent to Allen Harbor and Narragansett Bay. Ecological impacts are being assessed by characterizing the sediment and water quality in Allen Harbor and nearby Narragansett Bay and evaluating the toxicological impact on quahog clams (Mercenaria mercenaria), soft shell clams (Mya arenaria), oysters (Crassostrea virginica), mussels (Mytilus edulis), and amphipods (Ampelisca abdita). In addition, biomarker assays are being conducted to evaluate the mutagenic potential of sediments collected from Allen Harbor and the surrounding Narragansett Bay.

The sampling designs and rationale being used for the investigations at NCBC Davisville and NAS Whidbey Island are presented. The procedures for incorporating the toxicology data into the remedial investigation and feasibility study process, and supporting the development of risk management plans are also discussed.

Paper presented at the 14th Annual Army Environmental R&D Symposium, 14-16 November 1989, Williamsburg, Va

INTRODUCTION

Remedial actions conducted at hazardous waste disposal sites must meet cleanup levels that will insure protection of human health and the environment (Comprehensive Environmental Response Compensation and Liability Act, 42 U.S.C. 9604 (a)). The development and application of biological assessment methods to determine the impact of disposal sites on the environment is the focus of the research described in this paper. Biological assessment techniques are required to provide the data necessary to conduct ecological risk assessments of the impact of disposal sites on the surrounding environment. Ecological risk assessment involves quantitative estimation of the likelihood of adverse ecological impact resulting from exposure to toxic substances (Beck and Conner 1987). Ecological risk assessments are accomplished by collecting data relating exposure levels to biological effects (Gentile et al. 1989) and provide a framework for interpreting and predicting potential adverse impacts (Phelps and Beck 1989). With appropriate assessment techniques it will be possible to obtain direct measures of environmental health and implement monitoring programs to assess and verify the environmental risks of hazardous waste disposal sites.

Demonstrations of biological assessments aimed at assessing the ecological risk of hazardous waste disposal sites are currently being conducted at the Naval Air Station (NAS) Whidbey Island, Washington, and the Naval Construction Battalion Center (NCBC) Davisville, Rhode Island. At NAS Whidbey Island the impacts of three disposal sites on wildlife and the surrounding environment are being evaluated. The sites being investigated are a former fire school, a pesticide disposal area and the runway ditches. At NCBC Davisville a landfill and disposal area located directly adjacent to Allen Harbor in Narragansett Bay are being investigated to determine the impact of leachate from the disposal sites on shellfish and sediment quality of Narragansett Bay.

The toxicological assessment for NAS Whidbey Island is being performed by The Institute of Wildlife and Environmental Toxicology (TIWET), from Clemson University, Clemson, SC, in cooperation with Huxley College of Environmental Studies, Western Washington University, Bellingham, WA. The risk assessment at NCBC Davisville is being executed under a cooperative research agreement between the Naval Ocean Systems Center, San Diego, CA, and the Environmental Protection Agency Environmental Research Laboratory, Narragansett, RI, with the cooperation and assistance of the Narragansett Bay Project, Providence, RI, the Food and Drug Administration Northeast Technical Services Unit, Davisville, RI, and the University of Rhode Island Graduate School of Oceanography, Narragansett, RI.

RELATIONSHIP OF TOXICITY ASSESSMENTS TO THE REMEDIAL INVESTIGATION PROCESS

The relationship of toxicity assessments to the remedial investigation and feasibility study (RI/FS) process at hazardous waste sites is outlined in Figure 1 (Johnston and Lapota 1989, Lapota et al. 1989). The RI/FS can consist of three phases: information gathering, verification and evaluation of site conditions, and, if required, remediation. Onsite investigations carried out in accordance with EPA Superfund Guidance (EPA 1986) are primarily concerned with quantifying site contamination levels, and relating those levels to potential health risks. The objective of the toxicology studies described in this paper is to determine the toxicological impact of the disposal site on the surrounding environment.

During the toxicology study data are collected to determine exposure levels and the consequences of exposure to receptor organisms. The toxicology study seeks to answer the question: Is there a toxicological impact? If the answer is no, the goal for the second phase of the toxicology study is to confirm the nonimpact and provide monitoring data necessary for site closure. However, if significant toxicological impacts are detected then the goal of the second phase will be to provide a detailed evaluation of the impact. This information will be necessary to determine what corrective action is required and evaluate toxicity reduction during feasibility studies of remedial options. If remediation is required, the toxicity data will be used to measure the effectiveness of cleanup and help determine when remediation can be terminated. Interaction between the toxicology and onsite investigations is required to assure that the data collected are complementary and comparable. Obtaining complementary and comparable data can be accomplished by intercalibrating analytical methods to be used (A in Figure 1), providing significant information feedback to facilitate an accurate description of toxicological effects and contaminant source and loading (B and C in Figure 1), and the selection of appropriate cleanup levels (D in Figure 1) (Johnston and Lapota 1989, Lapota et al. 1989).

DESCRIPTIONS OF SITE INVESTIGATIONS

Toxicology Demonstration Project at NAS Whidbey Island, WA

The Naval Air Station (NAS) Whidbey Island has been proposed for addition to the National Priorities List (NPL). Twenty eight sites have been recommended for investigation as part of the Navy's Installation Restoration Program (NEESA 1984a, SCS Engineers 1987). NAS Whidbey Island is located in a fairly pristine area of the Puget Sound and provides habitat for a variety of game birds, water fowl, and mammals. The endangered peregrine falcon and the threatened bald eagle have been sighted in areas on NAS Whidbey Island and a great blue heron colony is also located on the air station. Beaches and bays around NAS

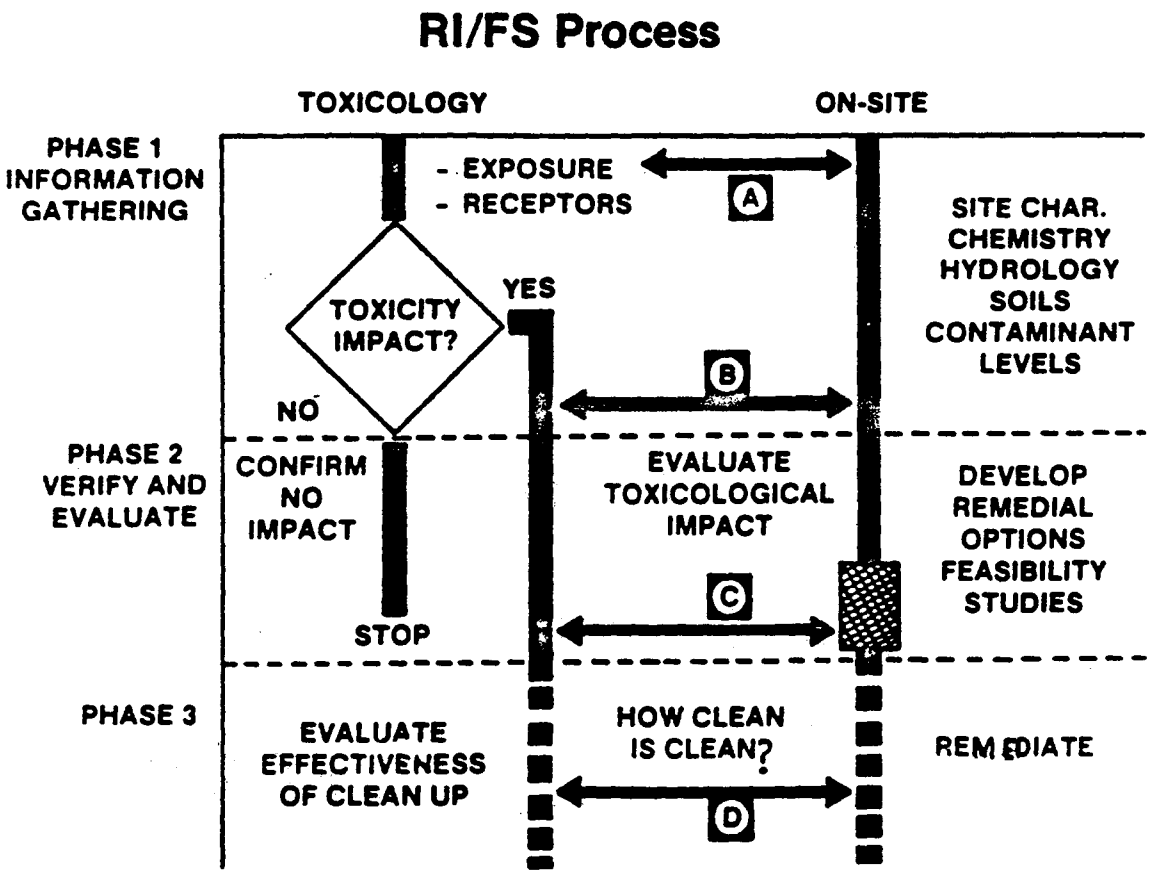


Figure 1. Integration of toxicological assessment information into the Remedial Investigation and Feasibility Study (RI/FS) process (Johnston and Lapota 1989).

Whidbey Island are popular fishing and shellfish gathering areas. Past disposal practices may have contaminated lowland areas and the accumulation of persistent and biomagnifying contaminants could affect higher order predators and humans (NEESA 1984a). The primary purpose of the toxicological investigation is to determine if contaminants from disposal sites are significantly impacting wildlife and degrading environmental quality. The study will also demonstrate the effectiveness of in situ toxicological assessment techniques.

The sites selected for toxicological assessment are the Clover Valley Fire School, the Pesticide Disposal Area, and the Runway Ditches. These sites were selected for evaluation based on the possible presence of surface contamination and concern for migration of contaminants into the food chain (TIWET 1989).

The contaminants of concern at the Clover Valley Fire School include aromatic hydrocarbons and heavy metals released when waste oils were burned during fire fighting training exercises conducted between 1951 and 1966. An estimated 50,000 to 75,000 gallons of waste fuels contaminated with solvents, oils, and paint strippers were burned and disposed of at the fire school (NEESA 1984a). The Pesticide Disposal Area was used for rinsing equipment used during insecticide and herbicide applications. During the period between 1973 and 1983 a variety of pesticides, including 2,4D, malathion, and chlordane were disposed in a dry well located at the site (NEESA 1984a). The network of ditches around the air station's runways comprises the third site being investigated. The ditches run south and east of the runway and collect runoff from the flight line as well as from storm sewers near the hangar operations area, and eventually discharge into a marshy area around Dugualla Bay in the Puget Sound. Since 1965 jet fuels, waste cleaning solvents, caustic agents, motor oils, paints, and paint thinners have been periodically spilled around the air station's flight line and hangars and washed into the runway ditches (NEESA 1984).

The approach of the toxicological investigation of impacts from the disposal sites is designed to assess the extent and nature of possible contamination using free-living species residing on the sites of interest (TIWET 1989). Assessments of reproductive success and biochemical function are being made between populations sampled on the disposal sites and populations sampled from sites which have no known history of contamination. To accomplish this goal several parallel lines of inquiry among different animal species are being conducted. Additionally, organic chemical analyses of soil and invertebrates will be conducted to determine which contaminants are likely to be incorporated into the food chain.

Food chains are frequent pathways for environmental contaminants to penetrate into biological communities. Numerous studies from both agricultural (Anderson et al. 1982, Telford et al. 1982, Stoewsand et al. 1986) and natural settings (Cooke 1973, Rudd et al. 1981) have demonstrated extensive contamination

from anthropogenic sources.

A representation of a simplified food web, emphasizing the monitored species is shown in Figure 2. This generalized figure shows the complexity of the ecosystem at NAS Whidbey Island. Plants may accumulate soil contaminants and expose herbivorous insects (e.g., grasshoppers) and mammals (e.g., voles), and omnivorous mammals (e.g., mice), which in turn will expose animals feeding on higher levels of the food web. The primary route of exposure is being assessed with the European starling (Sturnus vulgaris). Starlings feed on carnivorous insects, herbaceous insects, grubs, earthworms, and larvae of various insects which may be living in close association with the soil. Many of the latter organisms are particularly important as detritivore-decomposer organisms. Plant materials become important food sources on a seasonal basis (Feare 1984). Consequently, starlings may be exposed to a wide array of contaminants in the grazing (e.g., grasshoppers, catepillars) and detritivore food chains (e.g., earthworms). Other possible routes of exposure are being assessed by evaluating toxicological impacts on small mammals, primarily mice, voles and shrews, and birds of prey, such as the northern harrier (Circus cyaneus) and great blue heron (Ardea herodias).

The primary investigatory tool used at the Clover Valley Fire School and the Pesticide Disposal Area is the enhanced avian bioassay. The starling presents numerous advantages as an indicator wildlife species. In general, birds possess characteristics which tend to maximize their exposure to environmental contaminants. First, birds possess high metabolic rates with attendant elevated food intake rates. Secondly, their complex air sac respiration system (Fedde 1976) is structurally unique and maximizes inhalation exposure. Finally, birds frequently dust bathe and use surface water for bathing. Behaviors such as these would likely result in increased dermal exposures through contact with contaminated soils and surface water.

The starling is an introduced species which is abundant throughout most of North America (Robbins et al. 1983) and is frequently considered a pest. Starlings are easily induced to nest in artificial nest boxes (Figure 3) facilitating experimental manipulations and assuring investigators of a viable experimental population to work with (Robinson et al. 1988). Starlings usually feed within 200 m of their nest site (Feare 1984) and frequently feed closer if resources allow (Tinbergen 1981). Thus starlings should forage a substantial amount of time within the confines of the study sites. At nesting time the parents may have difficulty maintaining a positive energy balance when striving to feed their offspring. At this crucial juncture starlings are representative of most songbirds. Starlings have proven to be excellent research subjects in field studies exploring the effect of organophosphorus pesticides on wildlife (Robinson et al. 1988). The USEPA has recently issued a guidance document for starling nest box studies for use in determining

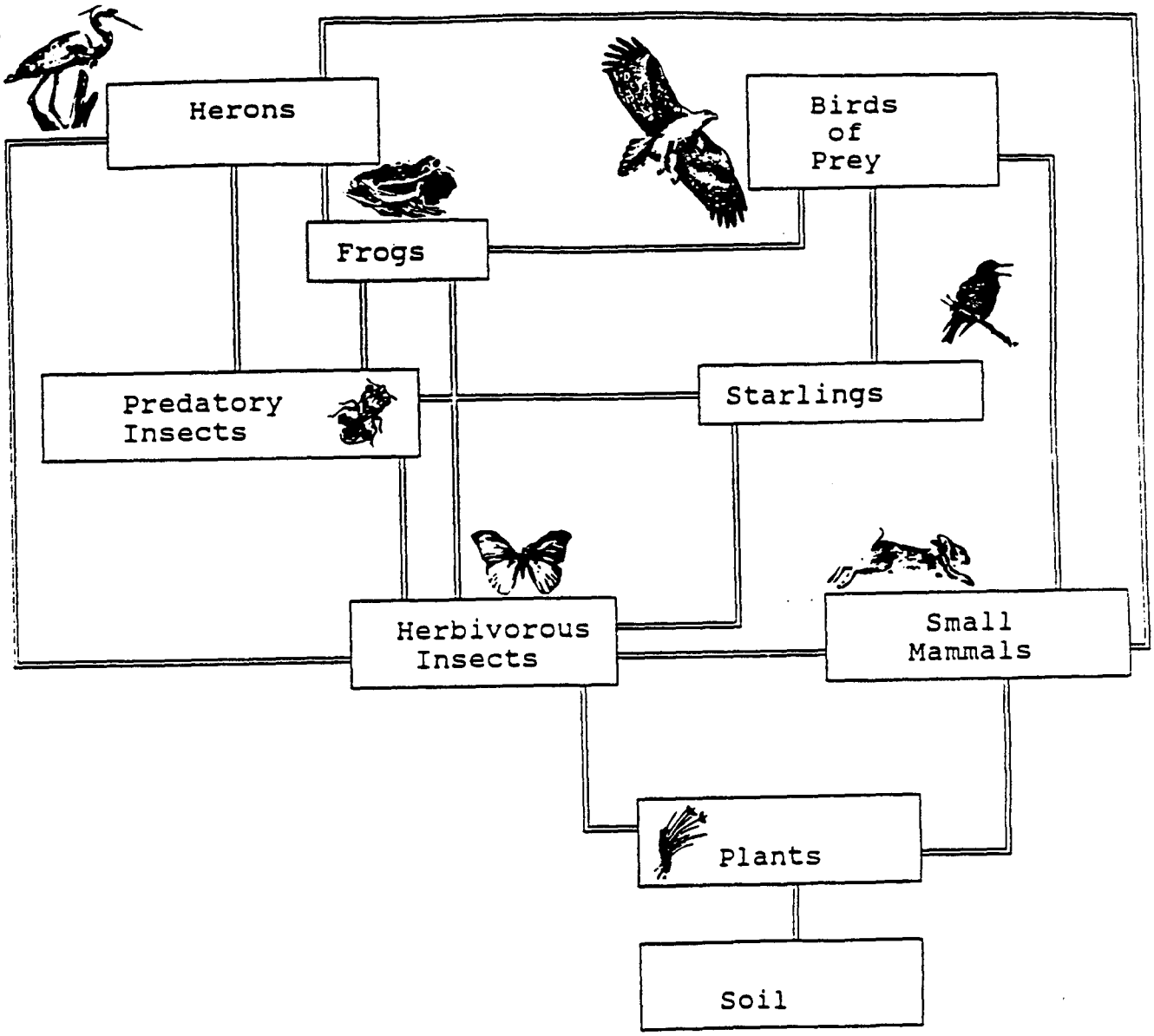


Figure 2. A diagram illustrating a simplified food web for NAS Whidbey Island. The soil compartment represents both the physical components of the soil and decomposer organisms such as earthworms. This extremely important component connects with virtually every other compartment. The small mammal compartment includes both herbivorous (e.g., voles) and carnivorous species (e.g., shrews). The birds of prey compartment contains both diurnal and nocturnal species (TIWET 1989).

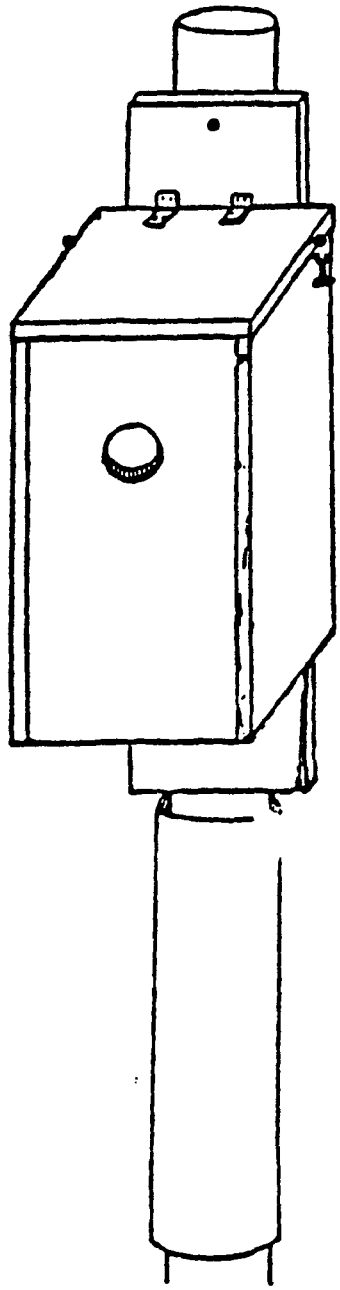


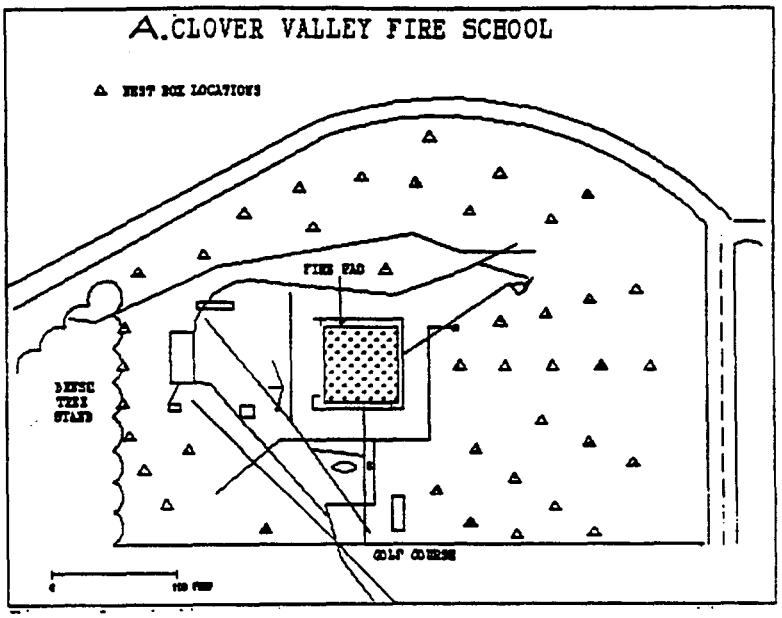
Figure 3. Nest box design used in the enhanced starling bioassay (IWT 1988).

effects of pesticides on nontarget organisms in agricultural settings (IWT 1989). The study at NAS Whidbey Island is the first use of the starling bioassay for assessing impacts of hazardous waste disposal sites.

Starling nest boxes have been erected at the Clover Valley Fire School and the Pesticide Disposal Area (Figure 4). An exposure gradient was created by placing the nest boxes in transects radiating out from the focal point of contamination in concentric rings. Starlings defend a territory which is normally less than 0.5 m in diameter around the nest hole (Kessel 1957), but on occasion the defended area extends to 10.0 m (Feare 1984), especially just before egg-laying. Therefore nest boxes on all sites were spaced a minimum of 12 meters apart (Figure 4) to reduce the possibility of intraspecific conflict. Statistical analyses of ecological endpoints such as clutch size, hatching success and fledging success will be conducted to determine differences along the exposure transects and differences between the disposal sites and three references sites located in Western Washington (TIWET 1989).

Based on past studies (Whitten et al. 1989, Robinson 1988, Brewer et al. 1988, 1989) up to 80% occupancy can be expected, with an average of four nestlings per box. During the first year of the study high occupancy was not achieved because nest boxes were erected too late in the season. In order to determine what food items adults starlings are feeding to nestlings, approximately 10% of the active boxes on each site were sampled for invertebrate prey items by taking crop samples. Crop sampling involves placing a restrictive ligature about the throat of the nestling. The ligature is tight enough to prevent swallowing but loose enough to avoid injuring the nestling. Ligatures are left in place for a short period of time (maximum one hour) and the food items are collected and analyzed for species composition and tissue burdens of contaminants in the juveniles' diet. Since post-fledging survival is key to parental reproductive success and the long-term survival of songbird populations, a subsample of juvenile hatchlings were banded before fledging. If there is no effect of the study sites on fledging survival and subsequent behavior, then return rates should be equal to those at the reference sites.

Small mammals have also been shown to be excellent indicator organisms in field studies of various contaminants (e.g., Anderson and Barrett 1982, Maly and Barrett 1984, Barrett 1988, Hall et al. 1989). Small mammals such as mice and shrews, live on the soil surface and some species burrow within the litter and upper levels of the soil itself, thereby maximizing chances of dermal exposure. Their diet is varied, and ranges from nearly strict herbivory (e.g., some voles, Microtus spp.) to an omnivorous (e.g., deer mice, Peromyscus maniculatus) and completely carnivorous condition (e.g., the shrews, Soricidae). Studies of small mammals were initiated on all three sites during spring and summer of 1989.



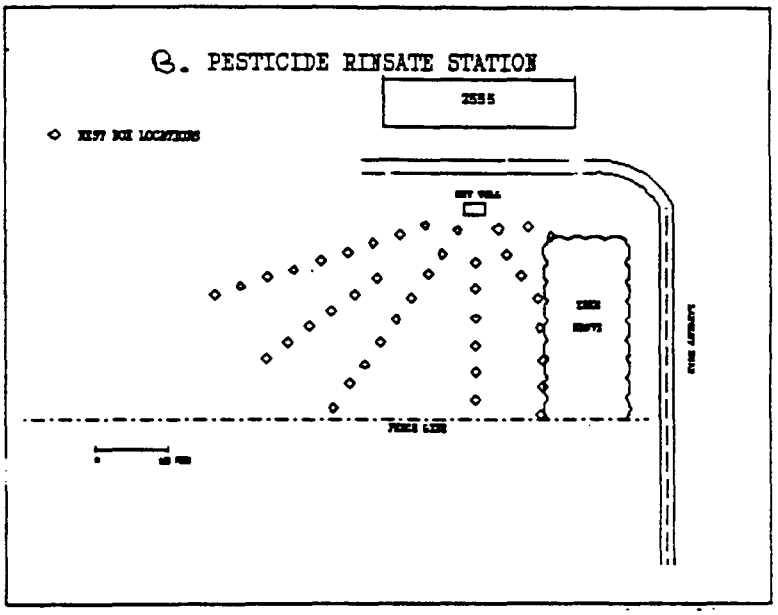


Figure 4. A digram illustrating the placement of starling nest boxes at the Clover Valley Fire School (A) and the Pesticide Disposal Area (B) (TIWET 1989).

Raptors, by virtue of feeding on higher trophic levels may be indicators of contaminants which move up through the food chain (Moriarity and Walker 1987). Red-tailed hawks (Buteo jamaicensis, great-horned owls (Bubo virginianus), western screech owls (Otus kennicottii), and northern harriers (Circus cyaneus) are being evaluated for radio-tracking to determine their feeding and foraging ranges. Owls and raptors feed quite extensively on small mammals and occasionally on songbirds. The pathway of contaminants from soil to vegetation to herbivore to carnivore is being evaluated by monitoring biochemcial responses in the raptors.

Herons are similar to raptors in their position on the food chain. Herons consume fish, amphibians, and small rodents. Observations on heron foraging will be conducted to determine where adults are feeding and prey items. The great blue heron colony will be visited twice to acquire nondestructive samples (e.g. fecal matter, discarded eggshells, and dead nestlings that have fallen from the nest). Methods using the chorio-allantoic membrane (CAM) of discarded eggshells has proven to be a useful technique in assessing the chemical burden of heron chicks in a nondestructive bioassay (Norman et al. 1989). Data obtained from the heron colony at NAS Whidbey Island will be compared to data previously collected from other heron colonies in the Puget Sound. If preliminary investigations indicate abnormal concentrations of contaminants, more in-depth studies will be planned for ensuing years. If no indications of impact are determined, a monitoring program will be established to verify on-going health of the heron colony.

The use of wildlife populations for the monitoring of chemical contaminant availability in the environment is enhanced by the evaluation of "marker enzymes" which respond to the presence of contaminants in the body (Lee et al. 1980, Payne et al. 1987, Rattner et al. 1989). These enzymes are found in the blood, liver, and brain of most species (Walker 1978). Marker enzyme response to contaminants can provide a measurable toxicological endpoint. A biochemical response, once traced back to an offending contaminant, can then serve as an indicator of toxic insult as well as a method to monitor mitigation attempts on the contaminated site. Biochemical evaluation of the wildlife on NAS Whidbey Island will entail the measurement of several bioindicator enzymes from the liver, brain, and plasma tissues of starlings, mice, and amphibians. In addition, tissue burdens of contaminants of concern will be analyzed to obtain a complete picture of exposure and toxicological effects. The complete sampling plan and protocols for the toxicology study at NAS Whidbey Island are documented in the work plan (TIWET 1989).

Risk Assessment Pilot Project at NCBC Davisville, RI

Allen Harbor, located in Narragansett Bay at the Naval Construction Battalion Center (NCBC) Davisville, RI, has been closed for shellfishing by the Rhode Island Department of Environmental Management due to suspected hazardous waste contamination from a landfill and disposal area adjacent to the harbor. The landfill, about 15 acres in size, received a wide variety of wastes including sewage sludge, solvents and paints, chromic acid, PCB contaminated waste oils, preservatives, basting grit, and other municipal and industrial wastes generated at NCBC Davisville and NAS Quonset Point between 1946 to 1972 (NEESA 1984b). Another site, located on Calf Pasture Point, was used for disposal of calcium hypochlorite, decontaminating solution, and chloride (NEESA 1984b). Previous analyses of sediment and bivalve tissues from Allen Harbor have shown increased levels of heavy metals and organics (TRC Environmental Consultants, Inc. 1986). The purpose of the risk assessment pilot project is to determine the impact of the disposal sites on environmental quality and shellfish resources in Allen Harbor and to develop and field validate ecological risk assessment methods.

During the first phase of the risk assessment consists of three components: waste site characterization, exposure assessment, and effects assessment. The site characterization portion of the study centers primarily on identification of chemicals residing in the disposal sites (TRC Inc 1988). The exposure assessment focuses on quantification of contaminant levels in the sediment and water column of Allen Harbor and reference areas in Narragansett Bay (EPA-ERL 1989a). The biological effects assessment evaluates toxicity responses of selected organisms, determines physiological and histological conditions of shellfish, and examines chemical bioaccumulation in shellfish tissues (EPA-ERL 1989a).

The primary responsibility for characterizing the Allen Harbor landfill resides with TRC Inc (TRC Inc 1988). Sample splits obtained from groundwater, visible seeps on the face of the landfill, and sediment samples adjacent to the face of the landfill were obtained for analysis by both Environmental Protection Agency Environmental Research Laboratory (EPA-ERL) and TRC Inc. The intercalibration exercise between EPA-ERL and TRC Inc ensures a good description of potential contaminant fluxes into Allen Harbor, accomplishes a quality assurance and quality control (QA/QC) check between EPA-ERL and TRC Inc, and assures that the two data sets will be complementary and comparable. In addition, the Food and Drug Administration Northeast Technical Services Unit (FDA-NETSU) and the University of Rhode Island Graduate School of Oceanography (URI-GSO) are also participating in the intercalibration procedure.

The degree of exposure to resident biota to contaminants from the Allen Harbor landfill is being identified by a qualitative and quantitative description of the contaminants in

sediments and seawater. The approach for sediment characterization consists of collection and analysis of an extensive grid of samples within Allen Harbor (Figure 5) and in reference stations in Narragansett Bay (Figure 6). One-gallon scoop samples were collected interidally at four locations each within Allen Harbor, Marsh Point (MP in Figure 6), and at two locations at Coggeshell Cove (CC in Figure 6) on Prudence Island. Soft shell clams (Mya arenaria) were also collected at these locations.

Subtidal sediments were collected on a grid of eleven stations within Allen Harbor, at seven stations along a "T" transect out of Allen Harbor (Figure 5) and at Mount View (MV), Greenwich Bay (GB), North Jamestown (NJ), and Potter Cove (PC) (Figure 6). A Smith-McIntyre grab sampler was used to obtain five grabs per station in Allen Harbor and vicinity (Figure 5). The top 2 cm of sediment was saved from each grab for subsequent analysis. The four stations representing mid-bay conditions (Figure 6) were sampled using five replicate grabs per five locations per station for a total of twenty five grabs per station. This scheme ensured comparability of data for statistical purposes.

Additional subtidal sediments were obtained at five selected stations within Allen Harbor by gravity coring to a depth of 30 cm, the estimated depth of disturbance due to shellfishing activity. Subsamples were taken from these cores at three depths (top, middle and bottom), and were composited by depth for subsequent analysis. To reduce the number of sample analyses, a subset of both intertidal and subtidal stations were selected for initial chemical determinations. If these results indicate the need for more detailed analysis the archived samples are available for examination. Since all sample were obtained in a single collection, comparability of results will be maintained. In addition, this method of sampling guarantees available material for other purposes. Aliquots from each of five replicate grabs were composited (1 gal total) for each of the Allen Harbor and mid-bay stations, thus reducing the number of chemical analyses needed without sacrificing the ability to detect strong chemical signals.

Chemical analyses were conducted for a "working list" (Table 1) of contaminants developed based on previously identified problem compound in marine environments, existing information on the disposal sites, and information generated by the extensive analytical screen conducted on a preliminary subset of samples. In addition to the analyses identified in Table 1, sediment and tissue samples (from Allen Harbor and from MV) were analyzed for organotin compounds by the Naval Ocean Systems Center (NOSC).

Water column samples were collected in Allen Harbor and at the MV station. Analysis of these samples was related to the analysis of seeps on the face of the landfill. Timing of sampling was scheduled so that samples were collected during

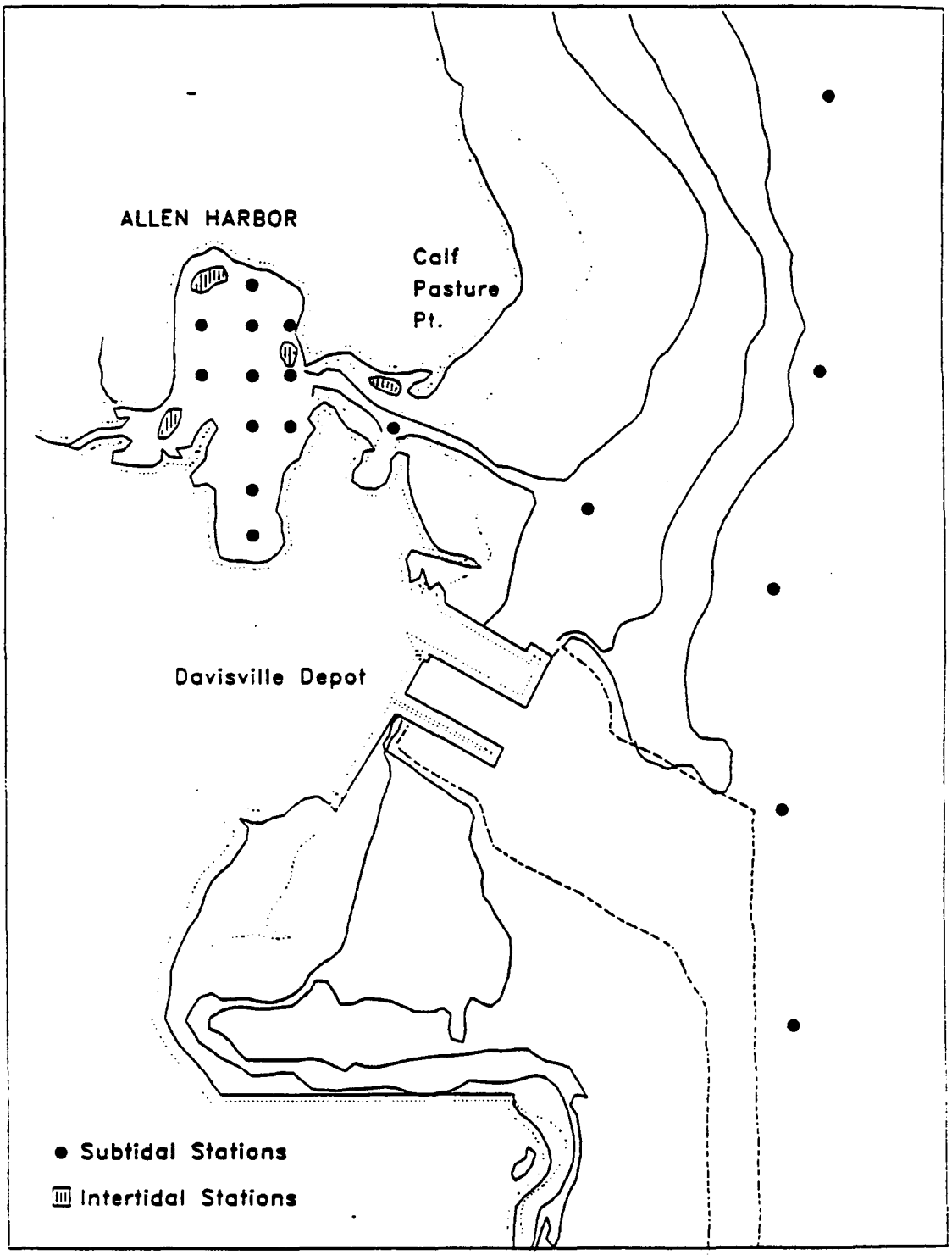


Figure 5. Station locations for characterizing sediments and shellfish in Allen Harbor and nearby Narragansett Bay (EPA-ERL 1989).

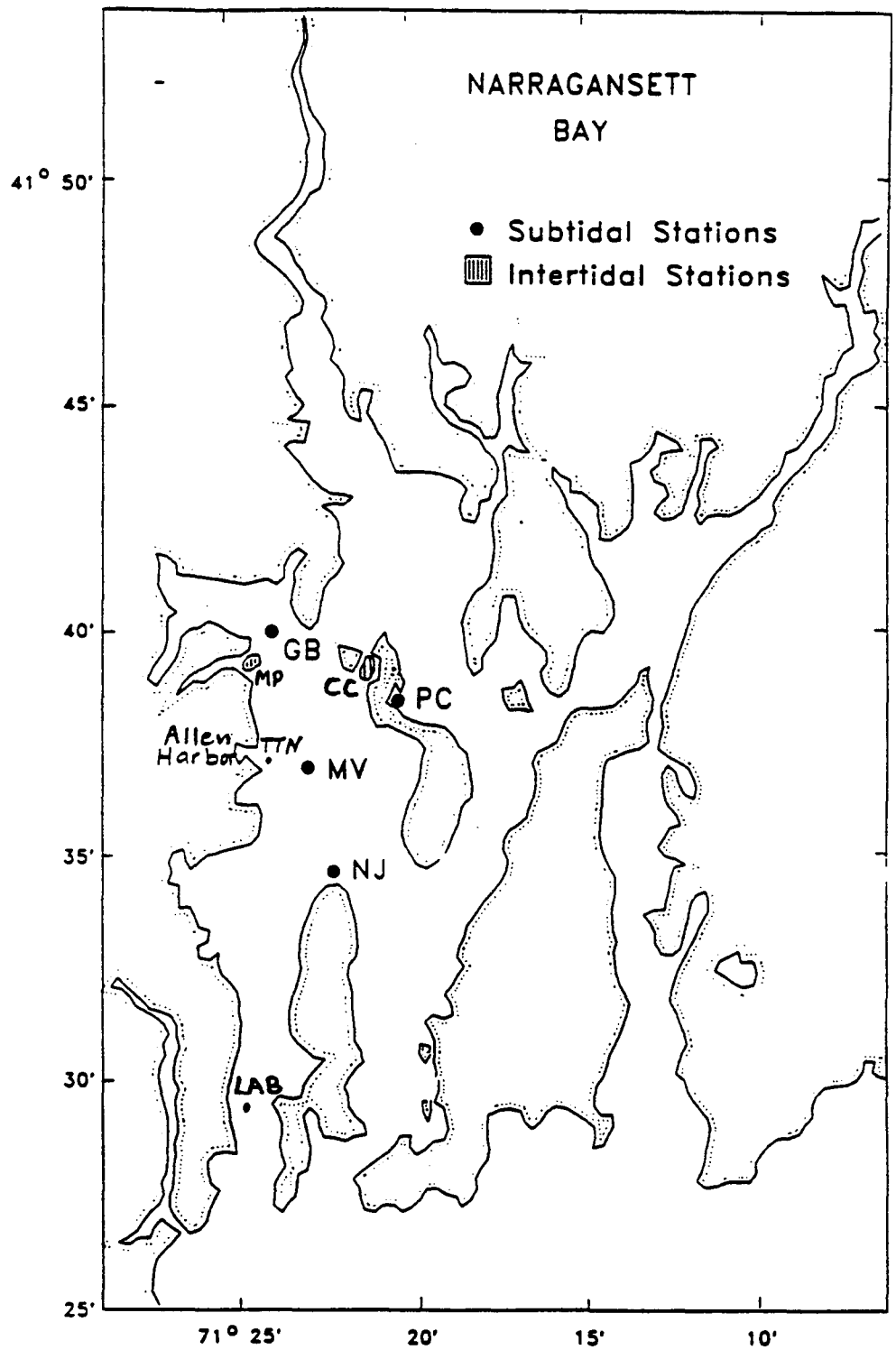


Figure 6. Reference stations locations for characterizing sediments and shellfish in Narragansett Bay (EPA-ERL 1989).

Table 1. Compounds known to cause problems in marine environments and therefore, routinely analyzed at the U.S. Environmental Research Laboratory at Narragansett, R.I.

Parameter	Matrix	Units***	Detection Limits	Method	Reference	Maximum Holding Time
Volatiles	Sediment tissue seawater	PPB		Purge & Trap GC/MS	**URI SOP's	2 Weeks
Pesticides	Sediment tissue seawater	NG/G NG/G NG/L	0.6 0.6 0.3	Extraction/ GC-ECD	*EPA SOP's	Prior to extraction indefinite if frozen (sediments and organisms) or refrigerated (water)
F-1 (PCBs)	Sediment tissue seawater	NG/G NG/G NG/L	2 2 1	Extraction/ GC-ECD	*EPA SOP's	After extraction indefinite if stored in tightly sealed vials with maximum amount of solvent in vial. Must be stored in dark refridgerator.
F-2 (aromatic)	Sediment tissue seawater	NG/G NG/G NG/L	0.6 0.6 0.3	Extraction/ GC-MS	*EPA SOP's	
F-3 (more-polar)	Sediment tissue seawater	NG/G NG/G NG/L		Extraction/ GC-FID	*EPA SOP's	
Trace Metals						
Cr, Cu Pb, Ni, Ag	Sediment tissue seawater	µg/g µg/g µg/L	1-3 0.5-1.5 0.5-1.0	ICP ICP Graphite AA	*EPA SOP's	6 months after extraction
Cd	Sediment tissue seawater	µg/g µg/g µg/L	1.0 0.5 0.1	ICP ICP Graphite AA	*EPA SOP's	
Hg	Sediment tissue seawater	µg/g µg/g µg/L	0.1 0.05 0.5	Cold vapor AA Cold vapor AA Cold vapor AA	*EPA SOP's	
Zn	Sediment tissue seawater	µg/g µg/g µg/L	0.5 0.3 0.05	ICP ICP Graphite AA	*EPA SOP's	
Arsenic	Sediment tissue	µg/g µg/g	4 2	ICP ICP	*EPA SOP's	

*EPA SOP's referenced in appendix 2

**Method listed in section 12

***Sed and tissue on dry wt. basis

"dry" and "wet" periods to identify whether there was a contaminant plume in Allen Harbor. Bacteriological indicators were measured by FDA-NETSU and volatile organics (VOCs) were quantified by URI-GSO.

The biological effects assessment portion of the study included toxicity response demonstrations, measurements of physiological and histological condition of bivalves, and quantification of chemical bioaccumulation in shellfish tissues. Shellfish were emphasized because of their ecological and commercial importance in Allen Harbor and Narragansett Bay. Approximately fifty animals of either quahogs (Mercenaria mercenaria) at subtidal stations or soft shell clams (Mya arenaria) at intertidal stations were collected at each station. Where present, oysters (Crassostrea virginica) were also collected. These samples were used to estimate resource density and condition indices. A subset of samples were processed for chemical analysis of tissue residues and to evaluate health via histopathological observations. The remaining samples were archived for future chemical analysis as required. Past experience has shown that tissue samples may be effectively preserved for many years by careful sealing and freezing (EPA-ERL 1989a).

Because of its dense distribution and economic importance the quahog is being used as the primary organism for evaluating benthic impacts. It is sedentary and filters large volumes of water, making it an ideal organism for evaluating environmental quality. Quahogs were sampled at all subtidal stations (Figures 5 and 6) during the fall of 1988 for observations of resource density and size distribution. At a subset of five stations corresponding to the subset of stations selected for chemical screening, five composites of five animals each were sampled for tissue burdens; twenty five animals were sampled at each station for condition index (shell length/whole weight/tissue wet weight ratios) and for histopathological examination. Quarterly sampling of quahogs will continue for a year at a subset of five stations for histological observations and determination of condition indices (EPA-ERL 1989a).

The soft shell clam is very common in intertidal areas of mid and upper Narragansett Bay including Allen Harbor, and its abundance supports an active recreational fishery. Samples of soft shell clams were obtained at the intertidal stations in Allen Harbor, Marsh Point, Coggeshell Cove and Calf Pasture Point. Observations similar to those for the quahog were made on the soft shell clam including analysis of tissue burdens, condition indices, and histopathology. The latter observations are being made quarterly for one year at three of the stations. Oysters were sampled once at two stations, Allen Harbor and CC. Similar observations are being made on the oysters.

Composite sediment samples from Allen Harbor and MV, GB, NJ, and PC, and selected sediments from the bay-wide Narragansett Bay Project survey were tested with the amphipod (Ampelisca abdita)

assay. A. abdita is a euryhaline benthic, tube-building, amphipod inhabiting fine intertidal and subtidal sediments. It is a filter feeder which ingests suspended particles and is a common food source for bottom fish. A. abdita has been shown to be sensitive to contaminated sediments and can be used to evaluate the relative toxicity of sediments (Redmond 1988). The amphipod assay was used to evaluate the relative toxicity of sediments collected in Allen Harbor and in reference areas of Narragansett Bay (EPA-ERL 1989a).

The physiological condition of water column organisms was examined using cages containing the blue mussel, Mytilus edulis (Figure 7). The mussels were collected from a clean reference site in Narragansett Bay and deployed in plastic mesh cages at four stations (four replicate cages/station, fifty animals per cage) for a spring and fall deployment period of twenty eight days. One station was located in Allen Harbor, and outside Allen Harbor in Narragansett Bay at TTN, MV, and LAB (Figure 6). Mussel cages were moored 1 m above the bottom. Clearance rate, assimilation efficiency, and respiration rate were determined for the mussels at the end of the deployment to calculate the scope for growth (SFG) index. The SFG index provides an integrated index of the mussels' physiological well-being and has been shown to highly correlated with environmental conditions and the presence of toxic contaminants (Nelson et al. 1987).

Sediment conditions in Allen Harbor were further evaluated through characterization of benthic community condition using the REMOTS camera system. This work was sponsored by the Narragansett Bay Project and the Allen Harbor stations were included as part of the bay-wide survey (SAIC 1989). Benthic habitat quality, organic enrichment, dissolved oxygen concentration, and the distribution of Clostridium perfringens were examined at fifty-nine stations in the bay to provide information on the sediment quality of areas of Narragansett Bay (SAIC 1989).

Biomarkers tests on two of the sediment samples collected for the amphipod assay, one from Allen Harbor and one from Mount View, were conducted to evaluate cytotoxicty and mutagenicity of contaminants in the sediments. The V79 Metabolic Cooperation Assay (V79/MC) was used as a short-term test to identify tumor promoters. The assay is based on the discovery that the tumor promoters inhibit the gap junctional-mediated transfer of materials between cells (EPA-ERL 1989a). The V79/Sister Chromatid Exchange Assay (V79/SC) was used to evaluate the mutagenic effects of the complex mixtures and fractions of contaminants extracted from the sediment. In this assay chromosomal damage is measured by induction of micronuclei in the interphase cell. Micronuclei represent acentric chromosome or chromatid fragments which give rise to one or more small secondary nuclei that are excluded from daughter nuclei. Sister chromatid exchange represents the the breakage and reciprocal exchange of identical DNA material between the two sister chromatids of a chromosome. Both micronuclei and sister

In Situ Array

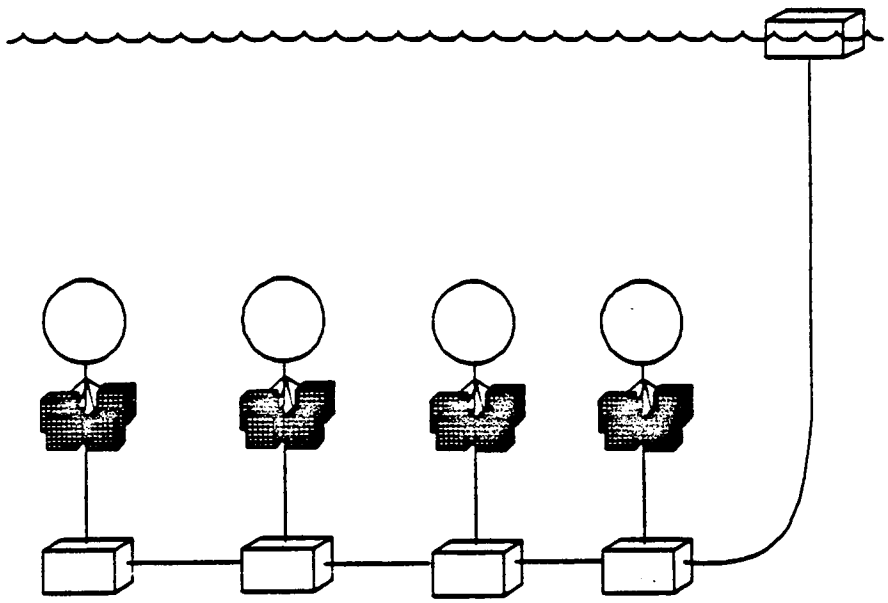


Figure 7. Mussels cages used to deploy mussels at stations located in Narragansett Bay, RI (Nelson et al. 1987).

chromatid exchanges have been found to increase in cells exposed to mutagenic compounds (Mueller et al. 1989).

The results obtained during the first phase of the risk assessment are summarized in the interim (EPA-ERL 1989b) and the draft final reports (EPA-ERL 1990). General observations show no dramatic differences in the chemical composition of the sediments collected from Allen Harbor and those from other areas of Narragansett Bay. Low bacterial counts and no evidence of sediment toxicity from the amphipod assay support this conclusion. The tissue residues and bacterial counts measured in Allen Harbor were also relatively low in comparison to other areas of Narragansett Bay. The histopathological observations and abundance estimates shows that the bivalve population in Allen Harbor is relatively healthy and the benthic community, as measured by the REMOTS system, is relatively undegraded. However, evidence of possible pollution impact on organisms in Allen Harbor was detected in the water column and benthos. Water column pollution stress was detected in sporadic elevated microbial levels and reduced SFG in mussels deployed in Allen Harbor, relative to reference areas. Impacts on benthic dwelling organisms were detected by elevated hemopoietic neoplasia in soft shell clams and elevated levels of tributyltin (TBT) in quahogs. It is not clear that these impacts can be attributed to the landfill and, in fact, are most likely a result of pollution entering Allen Harbor from runoff or boating activities at the marina located in the harbor (Milliken 1989, EPA-ERL 1990).

Work currently planned for the second phase of the risk assessment will address the contributions of the landfill to observable environmental impacts in Allen Harbor by partitioning exposure and toxicity amongst the potential sources. These sources include the landfill itself, runoff from storm drains and nonpoint sources, and effects from increased boating activity during the summer months. Additional sampling will address the relative affliction rates of neoplasia in soft shell clams in Allen Harbor and Narragansett Bay to determine if Allen Harbor is a locus of the disease or whether neoplasia is endemic to soft shell clams in Narragansett Bay. Results of these investigations will be interpreted within an ecological risk assessment framework. A long-term monitoring strategy will be developed to support the risk management plan (EPA-ERL 1989c).

BENEFITS OF ECOLOGICAL RISK ASSESSMENTS

The primary benefit of conducting the studies described in this paper is that direct measures of environmental health are made with actual exposure conditions which are related to biologically significant endpoints. This process provides the risk framework for interpreting and managing impacts from the disposal sites (Phelps and Beck 1989). Ecological risk assessment allows investigators to identify the source and extent

of the problem and delineate between hot spots and nonproblem areas that can be prioritized accordingly. Since ecological risk assessment is an emerging science, a potential drawback is that sometimes results can be ambiguous and subject to conflicting interpretations. Therefore, it is very important that decision criteria are selected that consists of: "... well defined, conveniently measured, and easily understood set of endpoints on which to base management action" (Phelps and Beck 1989, p2351). By selecting the proper endpoints for a particular ecosystem uncertainty can be quantified to allow reduction, rather than elimination, of risk and the identification of appropriate cleanup levels (Greenberg 1989).

Ecological risk assessments also provide information on ecotoxicity or how contaminants affect ecosystems. Continued studies of ecotoxicity will lead to the development of methods and databases that can provide a risk assessment framework for other applications and result in biologically-based models to assess risk, rather than the statistical models currently in use (Paustenbach and Keenan 1989). Finally, ecological risk assessments and monitoring programs can provide a direct verification of environmental safety. This information can be used to facilitate site closures and determine how clean a hazardous waste disposal site actually is.

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M-Scope) be used to measure depth to the surface of the ground water or light phase immiscibles. Whenever nondedicated equipment is used, procedures need to be instituted to ensure that the sample is not contaminated. Equipment should be constructed of inert materials and decontaminated prior to use at another well.

4.2.2 Detection of Immiscible Layers

The S&A plan should include provisions for detecting immiscible contaminants (i.e., "floaters" and "sinkers") where they would not be detected in an aqueous phase if the owner/operator manages wastes of this type at his facility. "Floaters" are those relatively insoluble organic liquids that are less dense than water and which spread across the potentiometric surface. "Sinkers" are those relatively insoluble organic liquids that are more dense than water and tend to migrate vertically through the sand and gravel aquifers to the underlying confining layer. The detection of these immiscible layers requires specialized equipment that must be used before the well is evacuated for conventional sampling. The S&A plan should specify the device to be used to detect light phases and dense phases, as well as the procedures to be used for detecting and sampling these contaminants.

Owner/operators should follow the procedures below for detecting the presence of light and/or dense phase immiscible organic layers. These procedures should be undertaken before the well is evacuated for conventional sampling:

1. Remove the locking and protective caps.

2. Sample the air in the well head for organic vapors using either a photoionization analyzer or an organic vapor analyzer, and record measurements.

3. Determine the static liquid level using a manometer and record the depth.

4. Lower an interface probe into the well to determine the existence of any immiscible layer(s), light and/or dense.

The air above the well head should be monitored in order to determine the potential for fire, explosion, and/or toxic effects on workers. This test also serves as a first indication of the presence of light phase immiscible organics. A manometer or acoustical sounder (for very shallow wells) will provide an accurate reading of the depth to the surface of the liquid in the well, but neither are capable of differentiating between the potentiometric surface and the surface of an immiscible layer. Nonetheless, it is very useful to determine that surface depth first to guide the lowering of the interface probe. The interface probe serves two related purposes. First, as it is lowered into the well, the probe registers when it is exposed to an organic liquid and thus identifies the presence of immiscible layers. Careful recording of the depths of the air/floater and floater/water interfaces establishes a measurement of the thickness of the light phase immiscible layer. Secondly, after passing through the light phase immiscible layer, the probe indicates the depth to the water level. The presence of floaters precludes the exclusive use of sounders to make a determination of static water level. Dense phase immiscible layers are detected by lowering the device to the bottom of the well where, again, the interface probe registers the presence of organic liquids.

The approach to collecting light phase immiscibles is dependent on the depth to the surface of the floating layer and the thickness of that layer. The immiscible phase must be collected prior to any purging activities. If the thickness of this phase is 2 feet or greater, a bottom valve bailer is the equipment of choice. The bailer should be lowered slowly until contact is made with the surface of the immiscible phase, and lowered to a depth less than that of the immiscible/water interface depth as determined by preliminary measure with the interface probe.

When the thickness of the floating layer is less than 2 feet, but the depth to the surface of the floating layer is less than 25 feet, a peristaltic pump can be used to "vacuum" a sample.

When the thickness of the floating layer is less than 2 feet and the depth to the surface of the floating layer is beyond the effective "reach" of a peristaltic pump (greater than 25 feet), a bailer must be modified to allow filling only from the top. Sampling personnel should disassemble the bottom check valve of the bailer and insert a piece of 2-inch diameter fluorocarbon resin sheet between the ball and ball seat. This will seal off the bottom valve. The ball from the top check valve should be removed to allow the sample to enter from the top. The buoyancy that occurs when the bailer is lowered into the floater can be overcome by placing a length of 1-inch stainless steel pipe (304, 316, 2205) on the retrieval line above the bailer (this pipe may have to be notched to allow sample entry if the pipe remains within the top of the bailer). The device should be lowered carefully, measuring the depth to the surface of the floating layer, until the top of the bailer is level with the top of the floating layer. The bailer should be lowered an additional one-half thickness of the floating layer and the sample collected. This technique is the most effective method of collection if the floating phase is only a few inches thick.

The best method for collecting dense phase immiscibles is to use a double check valve bailer. The key to sample collection is controlled, slow lowering (and raising) of the bailer to the bottom of the well. The dense phase must be collected prior to any purging activities.

4.2.3 Well Evacuation

The water standing in a well prior to sampling may not be representative of in-situ ground-water quality. Therefore, the owner/operator should remove the standing water in the well and filter pack so that formation water can replace the stagnant water. The owner/operator's S&A plan should include detailed, step-by-step procedures for evacuating wells. The equipment the owner/operator plans to use to evacuate wells should also be described.