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Final

Ecological Risk Assessment
Lower Reaches of Bousch Creek

Naval Station Norfolk
Norfolk, Virginia

NAVFAC
Naval Facilities Engineering Command
NAVFAC MID-ATLANTIC

Prepared for

Department of the Navy
Naval Facilities Engineering Command
Mid-Atlantic

Contract No. N62470-02-D-3052
CTO-0173

July 2010

Prepared by

CH2MHILL

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Virginia Beach, Virginia

Executive Summary

This report contains an ecological risk assessment (ERA) for the Lower Reaches of Bousch Creek, Naval Station Norfolk (NSN), Norfolk, Virginia. This ERA was conducted in accordance with the *Navy Policy for Conducting Ecological Risk Assessments* (CNO, 1999) and the Navy guidance for implementing this ERA policy (NAVFAC, 2003).

Objectives

The general objectives of this ERA were to identify and describe the source areas associated with the Lower Reaches of Bousch Creek, describe the ecological setting of Bousch Creek, develop an ecological conceptual model for the Lower Reaches of Bousch Creek, and present and evaluate analytical data collected in October 2009 to support the evaluation of potential risks in the Lower Reaches of Bousch Creek.

Site Description

Bousch Creek is located entirely on NSN. The creek channel has been significantly altered from historic conditions and most of the bordering vegetated wetlands have been filled as part of facility development. Currently, portions of the creek are lined or walled with concrete. The creek has been channelized over most of its length and it flows through underground culverts over part of its length, including the entire length (3,900 feet) of the Lower Reaches (Figure 1-1). The downstream end of the 3,900-foot underground culvert is the creek's outfall to Willoughby Bay.

Twenty-nine outfalls discharge directly to Bousch Creek between its headwaters near the Camp Allen Landfill (CAL) and its confluence with Willoughby Bay (Figure 3-1). Most of these outfalls carry storm water runoff not associated with a regulated industrial activity. Most of the complex of remnant tributaries that comprises the Bousch Creek system are influenced by the daily tides. Salinity is greatest in the lower portions of the creek complex with the headwater areas, which are not influenced by daily tidal flow, generally consisting of freshwater. The salinity in the system also fluctuates regularly based upon the point in the tidal cycle and the amount of freshwater input from precipitation events due to runoff. Substrate type is somewhat variable within the creek system, but most sediments are composed of silt-clay, are soft and dark, are rich in organic matter (especially in the wetland areas), and give off a sulfide odor when disturbed.

Ecological Risk Assessment Results

The use of the Lower Reaches of Bousch Creek by ecological receptors is minimal and transitory, resulting in minimal exposures and potential risk. Receptor groups are limited to fish and aquatic invertebrates that may transit the underground culvert at periodic intervals associated with the tidal cycle and receptor life cycles. However, these organisms could be

exposed at the points immediately adjacent to the outfalls to the Upper Reaches of Bousch Creek and to Willoughby Bay.

Source areas in the Upper Reaches related to Installation Restoration Program (IRP) sites have been remediated. Similarly, remedial actions are in progress at IRP-related source areas within the Lower Reaches to address soil and groundwater contamination, which do not appear to have impacted the Lower Reaches of Bousch Creek. Volatile organic compounds (VOCs), the principal chemicals of concern in groundwater, have not been an issue in the surface water and sediments of the creek for ecological exposures based upon the ERAs that have been conducted to date. Transport of soil-related chemicals also does not appear to be a significant transport pathway to the Lower Reaches of Bousch Creek. Thus, the principal remaining sources associated with the Lower Reaches are discharges from the numerous outfalls. The one industrial outfall discharging to the Lower Reaches of Bousch Creek (Outfall 408) is regulated under the Virginia Pollution Discharge Elimination System. Storm water discharges associated with the remaining outfalls are addressed by the facility storm water management plan. Spills and other releases of petroleum-related materials (such as fuel) are addressed under the facility management plans related to these issues.

Surface sediment data collected in October 2009 at both ends of the Bousch Creek culvert (Lower Reaches) were compared with literature-based screening values and No Observed Effect Concentration (NOEC) values developed using site-specific toxicity test data during the ERA for the Upper Reaches. According to the decision rules outlined in the Sampling and Analysis Plan (SAP) for the October 2009 sampling (CH2M HILL, 2009), if there are significant exceedances of key evaluation criteria (i.e., NOEC values) for the chemicals of concern (COCs) identified in the ERA for the Upper Reaches of Bousch Creek (a number of metals and pesticides, polychlorinated biphenyls [PCBs], and polycyclic aromatic hydrocarbons [PAHs]) or potentially related to IRP source areas in the Lower Reaches (a number of VOCs), risks will be indicated. Based upon the results of the risk characterization, namely no exceedances of NOEC values based upon mean concentrations for any of the Upper Reach COCs and no detections of chlorinated VOCs, no unacceptable ecological risks are indicated.

Based upon the findings of this ERA, no further investigation or action is recommended for the Lower Reaches of Bousch Creek as related to potential ecological exposures associated with IRP sites.

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Acronyms and Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
AS/SVE	Air Sparging/Soil Vapor Extraction
AST	Aboveground Storage Tank
BERA	Baseline Ecological Risk Assessment
BTAG	Biological Technical Assistance Group
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CAL	Camp Allen Landfill
CAP	Corrective Action Plan
CASY	Camp Allen Salvage Yard
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Chemical of Concern
COPC	Chemical of Potential Concern
CS	Confirmation Study
EPC	Exposure Point Concentration
EqP	Equilibrium Partitioning
ERA	Ecological Risk Assessment
HQ	Hazard Quotient
IAS	Initial Assessment Study
INRMP	Integrated Natural Resources Management Plan
IRP	Installation Restoration Program
IRI	Interim Remedial Investigation
IWS	Industrial Wastewater Sewer
LTM	Long-Term Monitoring
MDL	Method Detection Limit
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
NOEC	No Observed Effect Concentration
NSN	Naval Station Norfolk
O/WS	Oil/Water Separator
ORP	Oxidation-Reduction Potential
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
ppt	parts per thousand
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation

SAP	Sampling and Analysis Plan
SEM/AVS	Simultaneously Extracted Metals/Acid Volatile Sulfide
SERA	Screening Ecological Risk Assessment
SLC	Screening Level Concentration
SMDP	Scientific Management Decision Point
TAL	Target Analyte List
TCE	Trichlorothene
TCL	Target Compound List
TOC	Total Organic Carbon
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VDEQ	Virginia Department of Environmental Quality
VOC	Volatile Organic Compound
VPDES	Virginia Pollution Discharge Elimination System
WWTP	Wastewater Treatment Plant
µg/kg	Micrograms per kilogram
µg/L	Micrograms per liter

SECTION 1

Introduction

This report contains an ecological risk assessment (ERA) for the Lower Reaches of Bousch Creek, Naval Station Norfolk (NSN), Norfolk, Virginia. Figure 1-1 shows the location of Bousch Creek.

1.1 The Ecological Risk Assessment Process

ERAs are conducted using a tiered, step-wise approach and are punctuated with Scientific Management Decision Points (SMDPs). SMDPs represent points in the ERA process where agreement on conclusions, actions, or methodologies is needed so that the ERA process can continue (or terminate) in a technically defensible manner. The results of the ERA at a particular SMDP are used to determine how the ERA process should proceed, for example, to the next step in the process or directly to a later step. The process continues until a final decision has been reached (i.e., remedial action if unacceptable risks are identified, or no further action if risks are acceptable). The process can also be iterative if data needs are identified at any step; the needed data are collected and the process starts again at the point appropriate to the type of data collected.

This ERA was conducted in accordance with the *Navy Policy for Conducting Ecological Risk Assessments* (CNO, 1999) and the Navy guidance for implementing this ERA policy (NAVFAC, 2003). The Navy ERA policy and guidance, which describe a process consisting of eight steps organized into three tiers, are conceptually similar to the 8-step ERA process outlined in U.S. Environmental Protection Agency (USEPA) ERA guidance for the Superfund program (USEPA, 1997). For both sets of guidance, Steps 1 and 2 involve conducting a Screening ERA (SERA) based on very conservative assumptions. The Baseline ERA (BERA) represents Steps 3 through 7. The BERA uses more realistic assumptions and site-specific data to refine the risk estimates from the SERA for components that fail the initial screen. Step 8 addresses risk management issues. The major differences between the Navy ERA policy/guidance and the USEPA ERA guidance are: (1) the Navy policy/guidance provides clearly defined criteria for exiting the ERA process at specific points; (2) the Navy policy/guidance divides Step 3 (the first step of the BERA) into two distinct sub-steps (Steps 3A and 3B), with a potential exit point after Step 3A; and (3) the Navy policy/guidance incorporates risk management considerations throughout all tiers of the ERA process.

The screening (preliminary) problem formulation is the first step of an ERA and establishes the goals, scope, and focus of the SERA. Step 1 of the ERA process is intended to answer two main questions: (1) do complete exposure pathways exist; and (2) are sufficient data available to conduct the SERA? If no complete exposure pathways exist, the ERA process terminates at Step 1 with a conclusion of negligible risk. If one or more complete exposure pathways are known, or likely to exist, the ERA process continues to Step 2, but only evaluates those pathways determined to be critical. An evaluation of the available data is then conducted to determine if the data are adequate to support the SERA. If not, additional

data are collected before the ERA process continues. The second step of the ERA process involves conducting a screening exposure assessment, a screening effects assessment, and a screening risk calculation (risk characterization).

The results of the SERA are used to evaluate the potential for unacceptable ecological risks based upon very conservative assumptions. If the results of the SERA suggest that further ecological risk evaluation is warranted, the ERA process proceeds to the BERA (Steps 3 through 7), which is a more detailed phase of the ERA process, for the pathways, chemicals, receptors, and areas identified by the SERA. As indicated above, the first step of the BERA (Step 3) is divided into two distinct sub-steps in Navy ERA guidance.

Step 3 of the USEPA ERA guidance consists of the following activities (USEPA, 1997):

- Refinement of the Chemicals of Potential Concern (COPCs) from the SERA.
- Further characterizing the potential ecological effects of contaminants.
- Refining information on contaminant fate and transport, complete exposure pathways, and receptors potentially at risk.
- Selecting assessment endpoints.
- Refining the conceptual model and risk hypotheses from the SERA.

Step 3A of the Navy policy/guidance (refinement of conservative exposure assumptions) corresponds to the first activity listed above for the USEPA ERA guidance. In Step 3A, a refined evaluation of exposure estimates is conducted using more realistic assumptions and additional methodologies relative to those used in the SERA, which is intended to be a very conservative assessment. Examples of more realistic exposure assumptions include using central tendency (e.g., mean) estimates rather than maximums for media concentrations, bioaccumulation factors, and exposure parameters. Examples of additional methodologies include consideration of background and upgradient concentrations, bioavailability, and detection frequency (CNO, 1999; NAVFAC, 2003).

If risk estimates (and the associated uncertainty) are acceptable following Step 3A, the site meets the conditions of the exit criterion specified in the Navy policy/guidance. If the Step 3A evaluation does not support a determination of acceptable risk within acceptable uncertainty, the ERA process continues to Step 3B. This possible exit point is not present in the USEPA ERA guidance.

Step 3B of the Navy policy/guidance (problem formulation) corresponds conceptually to the last four activities listed above for Step 3 of the USEPA ERA guidance. In Step 3B, the preliminary conceptual model from the SERA is refined based upon the results of the Step 3A evaluation to develop a revised list of key receptors, critical exposure pathways, key COPCs, assessment endpoints, measurement endpoints, and risk hypotheses. Based upon the refined conceptual model, the lines of evidence to be used in characterizing risk are determined. Agreement on the refined conceptual model, COPCs, exposure pathways, endpoints, and risk hypotheses constitutes the SMDP at the end of Step 3 in both Navy and USEPA ERA guidance.

Following the completion of Step 3, a decision point is reached with two potential outcomes. If the refined risk estimates are acceptable for each selected assessment endpoint, the investigation proceeds to risk characterization (Step 7) to document this conclusion, and the ERA process terminates. If the uncertainties associated with the refined risk estimates are unacceptable and/or the risk estimates indicate that unacceptable risks may exist, site-specific studies might be required and the ERA process continues (Steps 4 through 6).

Step 7 consists of the documentation and synthesis of the information and data identified in Steps 1 through 3 (no additional study) or Steps 1 through 6 (additional study). In this step, risk is evaluated and characterized using both quantitative and qualitative methods. Conclusions are made as to whether or not there is a reasonable potential for unacceptable ecological risk, and if there is a potential for ecological risk, the magnitude of that risk. The results of the completed BERA (Step 7) are used to make any necessary risk management decisions (Step 8) related to current or future risks. Possible decisions include:

- There is adequate information to conclude that no unacceptable ecological risks exist. The assessment should stop at Step 7.
- There is adequate information to conclude that ecological risks warrant remedial action. Whether or not remedial actions are taken, and the specific actions taken, will depend upon a number of risk management factors such as the results of any human health risk assessments and the potential impact of the remedial action itself on the habitats and biota present. This analysis would occur as part of Step 8.
- There is not adequate information to estimate risk or the risk estimate is believed to be too conservative or uncertain to recommend remediation. The assessment should be refined.

1.2 Scope of the ERA

The focus of this ERA is on the Lower Reaches of Bousch Creek, defined as the reach of Bousch Creek that encompasses the 3,900-foot underground culvert connecting Bousch Creek to Willoughby Bay (Figure 1-2) and is proximate to the LP-20 area, Site 20, and Site 23. Potential ecological risks in the Upper and Upper-Middle Reaches of Bousch Creek, which comprise the remainder of the Bousch Creek system and have been addressed together under the generic name “Upper Reaches”, were previously evaluated as part of the Step 7 ERA for the Upper Reaches (CH2M HILL, 2006a).

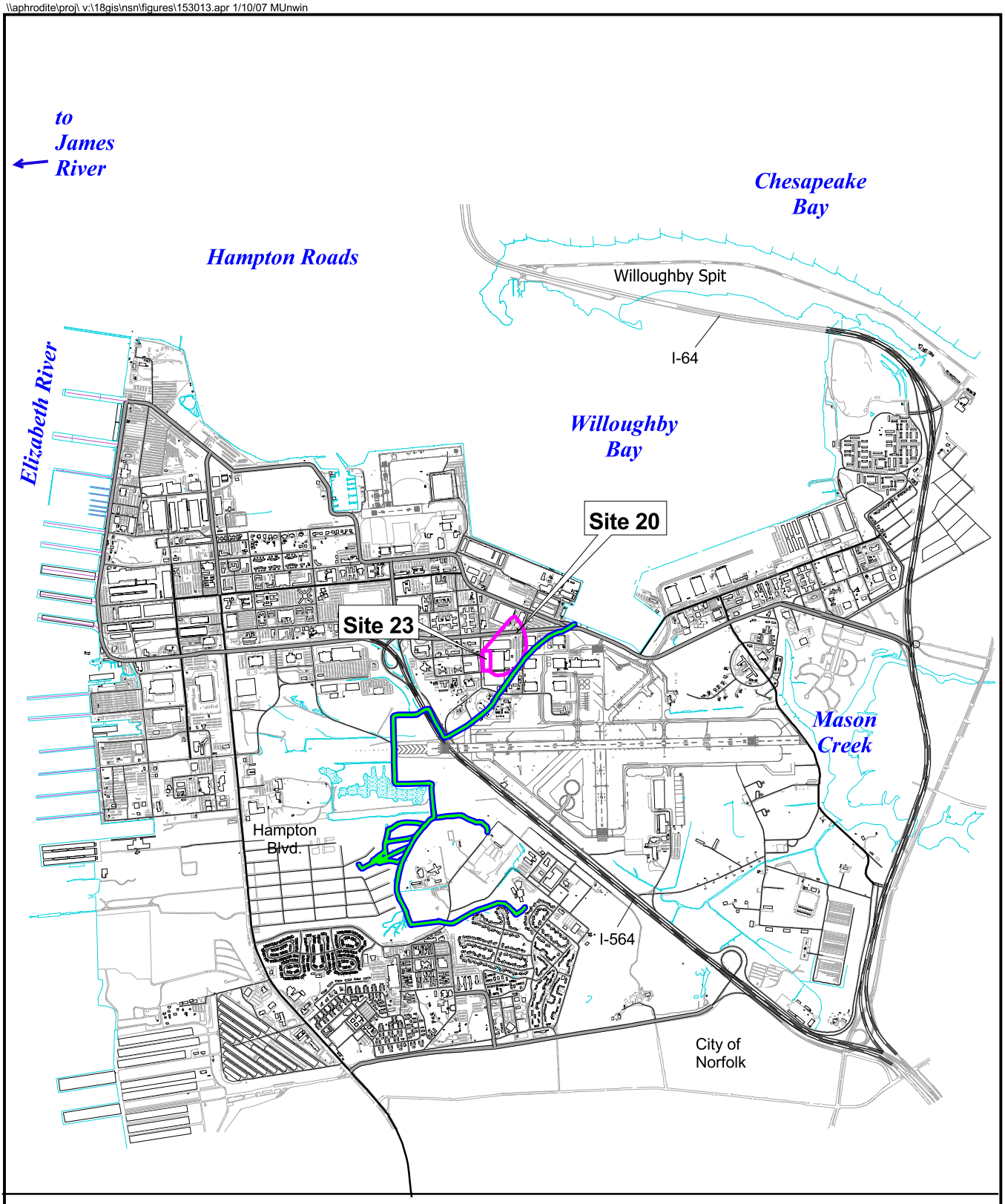
The conceptual model developed as part of this evaluation is limited to potential ecological exposures and receptors. Potential human exposures are not evaluated.

1.3 Report Organization

This report is divided into the following sections:

- **Section 1 - Introduction.** Describes the ERA process, outlines the scope of the ERA, and outlines the report organization.
- **Section 2 - Facility Background.** Describes the facility history and the environmental setting of NSN.
- **Section 3 - Problem Formulation.** Describes the source areas associated with the Lower Reaches of Bousch Creek, describes the ecological setting of Bousch Creek, summarizes the available analytical data, and develops a conceptual model.
- **Section 4 - Exposure Assessment.** Estimates potential exposures of ecological receptors to source-related contaminants.
- **Section 5 - Effects Assessment.** Describes the various lines of evidence used to estimate effects.
- **Section 6 - Risk Characterization.** Integrates the problem formulation, exposure assessment, and effects assessment to characterize potential risks to ecological receptors.
- **Section 7 - Uncertainties.** Identifies and discusses the sources of uncertainty in the ERA and evaluates their potential impacts on the risk conclusions.
- **Section 8 - References.** Lists the citations for all references cited in the report.

Supporting technical data are provided in appendices.



Bousch Creek

Site Boundaries

N

0 1600 3200 Feet

Figure 1-1
Location of Bousch Creek
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, Virginia

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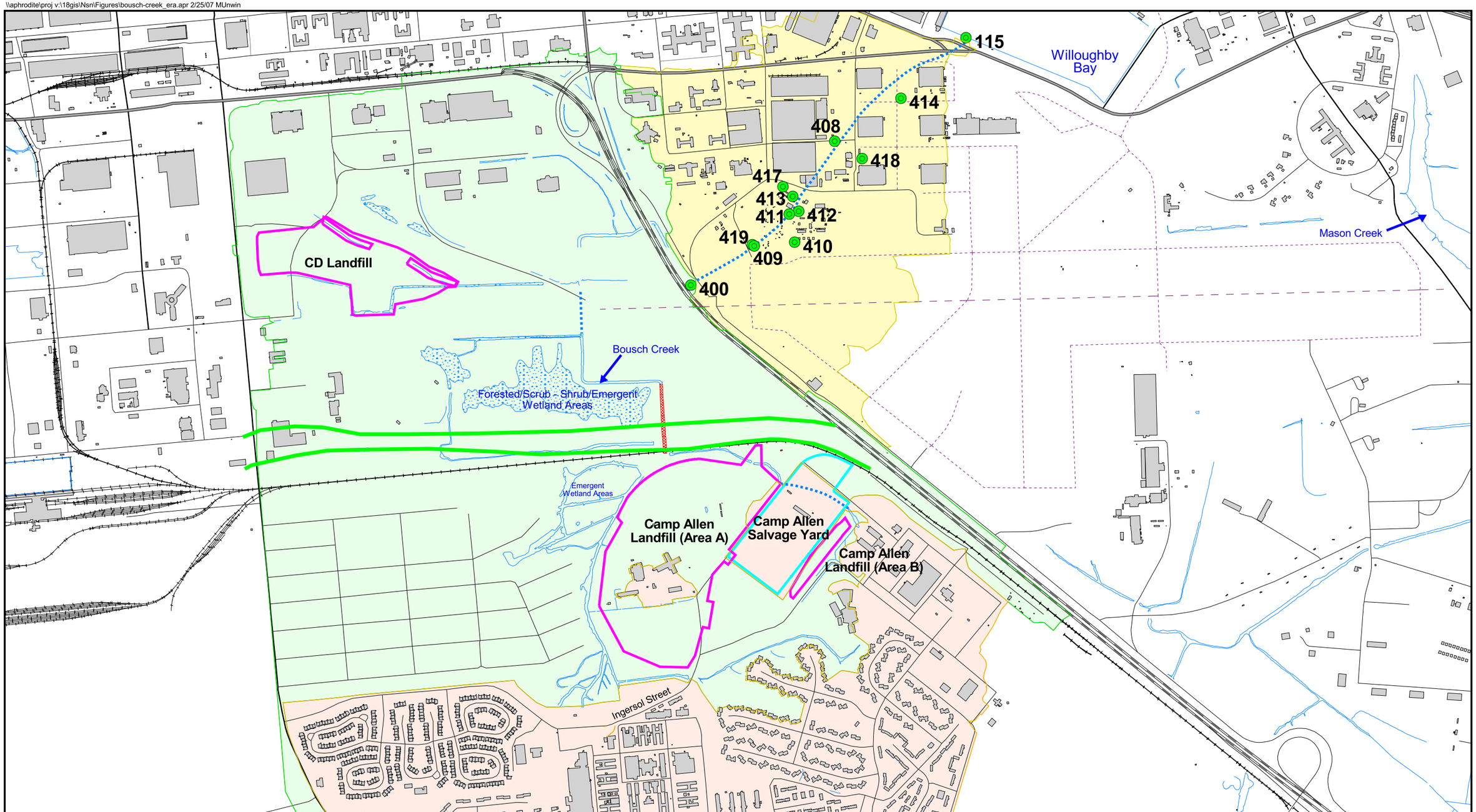

LEGEND

- Proposed I-564 Corridor (Approximate)
- Underground Culvert
- Concrete Lined
- Outfall

Bousch Creek Storm Basins

- Lower Reach
- Middle Reach
- Upper Reach

N

0 1000 2000 Feet

Figure 1-2
Location Map
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, Virginia

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SECTION 2

Facility Background

This section describes the facility history and general environmental setting (e.g., habitats and biota) of NSN. The description of the environmental setting was extracted largely from the latest Integrated Natural Resources Management Plan (INRMP, July 1997) for NSN. The description of the ecological setting for the Lower Reaches of Bousch Creek (LP-20 area) is provided in Section 3 as part of the problem formulation.

2.1 Facility History

NSN is the largest naval base in the United States and is situated on 4,631 acres of land in the northwestern portion of Norfolk, Virginia (A.T. Kearny, 1992). NSN is bounded by Willoughby Bay to the north, the confluence of the Elizabeth and James Rivers to the west, and the City of Norfolk to the south and east. A portion of the eastern facility boundary is formed by Mason Creek (Figure 1-1).

NSN includes approximately 4,000 buildings, 20 piers, and an airfield. The western portion of the facility is a developed waterfront area containing the piers and facilities for loading, unloading, and servicing naval vessels. The remaining portions of the facility consist of a combination of industrial, commercial, and residential uses. Residential and recreational areas also border the facility to the south, east, and northeast.

NSN began operations in 1917, when the U.S. Navy acquired 474 acres of land to develop a naval base to support World War I activities. Bulkheads were built along the coast to extend available land and, after dredge and fill operations, the total land under Navy control was 792 acres. An additional 143 acres of land was acquired and officially commissioned for a naval air station in 1918. From 1936 through 1941, improvements to the piers and an expansion of supply/material handling facilities were also completed. During World War II, a power plant, numerous runways and hangars, a tank farm, and several housing complexes were completed, with the total area of the facility expanding to more than 2,100 acres. After World War II, NSN continued to acquire land through various land transfers and dredge and fill operations conducted in the areas of Mason Creek, Bousch Creek, and Willoughby Bay.

NSN provides support to vessels, aircraft, and other activities. NSN also houses many tenants, each performing different operations involving the servicing and maintenance of vessels and aircraft. The service and maintenance of ships includes utilities hook-up, on-board maintenance, and coordination of ship movements in the harbor. Additional functions include loading, unloading, and handling of fuels and oils used aboard the vessels. Ship and aircraft repair operations consist of paint stripping, patching, cleaning, repainting, engine overhauls, and sandblasting.

2.2 Environmental Setting

This section describes the general environmental setting (including physiographic features, habitat, and biota) of NSN. A description of the environmental setting of the Lower Reaches of Bousch Creek (LP-20 area) is included in Section 3 as part of the problem formulation.

2.2.1 Physiographic Features

The major physiographic features of NSN and the immediately surrounding area are described in the following subsections.

Climate and Meteorology

The climate in the vicinity of the facility is moderate with relatively mild winters. Warm summers are frequently tempered by northeasterly winds from the Atlantic Ocean. The mean minimum annual temperature for this region is 50.5°F and the mean maximum annual temperature is 68°F, with average monthly temperatures ranging from 41.2°F in January to 78.6°F in July. Prolonged periods of cold weather seldom occur in this area and the daily minimum temperature rarely drops below 20°F.

Precipitation is well distributed throughout the year. Average annual precipitation is 46.25 inches, with a monthly maximum of 6.5 inches occurring during July. Snowfall averages 9.1 inches per year, with most occurring during December and January. Most snowfall melts within 24 hours. The average growing season is 244 days.

The wind velocity is less than 12 knots 80 percent of the time and winds seldom exceed 20 knots. The wind direction is generally southwest in the early winter, spring, and early summer, with the highest velocity usually occurring during hours of darkness. However, northeasterly winds prevail about 25 percent of the time with the highest velocity occurring during daylight hours.

The geographical position of NSN is south of the normal path of storms originating in the higher latitudes and north of the usual track of hurricanes and other tropical storms. At times, tropical storms do pass near or through the area. Typically, these storms have little effect other than greater than normal tides and higher wind velocities. Winds of hurricane force have occurred, on average, once every seven years. The mean tidal range in Hampton Roads is 2.5 feet (LANTDIV, 1979).

Topography

NSN lies within the Atlantic Coastal Plain. The elevation ranges from sea level at the northern and western borders of the facility to approximately 15 feet above mean sea level in the southeastern portion of the facility. Willoughby Bay (to the north) and the Elizabeth River (to the west) are the principal surface water bodies receiving surface drainage from the facility.

Soils

Soil surveys for the Sewell's Point area, which includes NSN, were completed by the U.S. Department of Agriculture, Natural Resource Conservation Service in 1983. Soils at NSN generally consist of fine sands and silts, with a thickness of 20 to 40 feet and low to

moderate permeability. Relatively impermeable sediments, composed of silt, clay, and sandy clay, typically underlie this upper layer of soils. Together, these strata have a combined thickness of about 60 feet. The average permeability of soils in Norfolk County is less than 2.5 inches per hour (INRMP, July 1997).

Table 2-1 summarizes the relative abundance of the major soil types found on NSN. These major soil types include:

- *Urban and Udorthents* - These soils are found in areas where the land surface is covered by impervious materials such as asphalt, concrete, or buildings, or where the native soils have been disturbed or altered during construction or excavation activities. About 86 percent of NSN is covered with these soils. Permeability and available water capacity of these soils vary.
- *Bojac Fine Sandy Loam and State Fine Sandy Loam* - These soils, which are deep, nearly level, and well drained, are defined as Class I soils well suited for agricultural activities. About 10 percent of NSN is covered with these soils.
- *Munden Fine Sandy Loam and Tetotum Fine Sandy Loam* - About 2.5 percent of NSN is covered with these soil types, which are deep, nearly level, and moderately well drained. These soil types are defined as Class II soils, suitable for growing vegetation.
- *Augusta Fine Sandy Loam and Dragston Fine Sandy Loam* - Less than 1 percent of NSN is covered with these soil types, which are deep, nearly level, and somewhat poorly drained. These soil types are defined as Class II soils, suitable for growing vegetation except in poorly drained areas.

Additional descriptions of the characteristics of these soils are provided in the soil survey report (USDA, 1983). Soils at NSN are not generally susceptible to erosion due, in part, to the generally level topography. With the exception of man-made excavations (e.g., drainage canals) and exposed shorelines, the potential for soil erosion is minimal on the facility.

There are approximately 572 acres of prime farmland on NSN. These areas contain mostly Class I and Class II soils which produce high yields with minimal inputs of energy. Because these soils represent some of the best and productive natural soils, efforts are made to retain these areas as undisturbed sites (INRMP, July 1997).

Surface Water Bodies

Four major surface water bodies occur on, or directly adjacent to, NSN (Figure 1-1). These water bodies are: (1) the Elizabeth River, which borders the facility to the west; (2) Willoughby Bay, which borders the facility to the north; (3) the remnants of Bousch Creek, which are located in the center of the facility and connect to Willoughby Bay; and (4) Mason Creek, which is located in the eastern portion of the facility and also connects to Willoughby Bay. The river and bay are both tidal estuaries connected to the Chesapeake Bay, while portions of both creeks are also tidally influenced.

Although some surface water runoff from the western portion of NSN discharges directly to the Elizabeth River, the majority of the facility lies within the watershed of Willoughby Bay. Most of the surface water runoff on NSN flows either to Mason Creek or to the remnants of Bousch Creek, both of which connect to Willoughby Bay via a system of subsurface pipes

and open ditches. A total of 172 outfalls on NSN drain directly (59) or indirectly (113) to Willoughby Bay. Twenty-nine of these outfalls discharge directly to Bousch Creek (Figure 2-1).

The northernmost channel of Mason Creek traverses NSN and empties into Willoughby Bay via a sub-grade aqueduct. The main channel of Bousch Creek, along with most of its bordering vegetated wetlands, was filled in and replaced by a network of drainage ditches and sub-grade pipes during the development of NSN, which occurred primarily around the time of World War II (early to mid 1940s). This system of narrow ditches and pipes, which is still called Bousch Creek, is interspersed throughout the central portion of NSN (Figure 1-2). Bousch Creek empties into Willoughby Bay via a 3,900-foot underground culvert (Figure 1-2). Most portions of Mason Creek and the Bousch Creek system on NSN are tidally influenced. The salinity varies by area, point in the tidal cycle, and inputs from surface flow (runoff).

The reported 100-year, static-water flood elevation on NSN is 8.5 feet above mean sea level (A.T. Kearny, 1992). Therefore, the portions of NSN adjacent to Willoughby Bay and the Elizabeth River are within the 100-year floodplain.

Geology and Hydrogeology

NSN is located within the outer Atlantic Coastal Plain physiographic province, which is characterized by low elevations and gently sloping relief. A large portion of the facility was developed from marine-deposited sediments consisting of sands, silts, and clays. Much of the original soil has been altered by grading and filling operations during the development of the facility. Some of the fill contains considerable amounts of shells, gravel, and cobbles. The soil material originated from marine deposits laid down in recent geologic times (USDA, 1983).

NSN is underlain by more than 2,000 feet of gently sloping sandy sediment, ranging in age from recent to Lower Cretaceous. The uppermost geological unit is the Columbia Group, which is composed of the Sand Bridge Formation and the underlying Norfolk Formation. The Columbia Group is approximately 60 feet thick. The upper 20 to 40 feet consist of unconsolidated fine sands and silts of low to moderate permeability. The lower 20 to 40 feet consist of relatively impermeable silt, clay, and sandy clay. The Yorktown Formation underlies the Columbia Group, and is approximately 90 to 100 feet thick in the vicinity of the facility. It consists of moderately consolidated coarse sand and gravel with abundant shell fragments.

The two significant aquifer systems in the area are the water table (surficial) aquifer in the upper 20 to 40 feet of the Columbia Group, and the underlying Yorktown Aquifer. The surficial aquifer is thin and consists of discontinuous heterogeneous sand and shell lenses. The depth to the water table is generally less than 8 feet. The Yorktown Aquifer is semi-confined beneath a clay layer in the upper Yorktown Formation. Water-bearing zones in the Yorktown Aquifer consist of fine to coarse sand, gravel, and shells.

2.2.2 Habitats and Biota

This section briefly describes the habitats and biota on NSN. The specific habitats associated with the Bousch Creek system, and the biota that are likely to occur there, are described in Section 3.

Habitat Types

There are eight general habitat types currently found on NSN (INRMP, July 1997; Figure 2-2) as summarized below:

- *Hardwood forest (approximately 10 acres)* - Hardwood forests consist of live oak, willow oak, and southern red oak and are scattered throughout the urban area of the facility in small (less than 1-acre) stands.
- *Pine forest (157 acres)* - Pine forests consist largely of planted loblolly pine stands.
- *Mixed forest (143 acres)* - Mixed forests occur in stands that range in size from 0.2 to 56 acres. Age and species composition vary by area. Tree species include sweetgum, black cherry, American holly, willow, willow oak, live oak, white oak, red oak, mulberry, sassafras, black locust, red cedar, and loblolly pine.
- *Improved fields (504 acres)* - Improved fields are areas of herbaceous vegetation that receive intensive maintenance. These include mowed fields, landscaped areas, drill fields, athletic fields, and parade grounds.
- *Semi-improved fields (21 acres)* - Semi-improved fields are areas that receive periodic recurring maintenance, but not at the rate or intensity applied to improved fields. These fields presently contain many early successional species of introduced herbaceous plants and young red cedar. Fields are mowed at irregular intervals.
- *Unimproved fields (187 acres)* - Unimproved fields are defined as fields which do not currently receive any recurring maintenance. These areas are dominated by a variety of herbaceous plants and small woody shrubs.
- *Wetland areas (316 acres; Figure 2-3)* - Wetland types currently found on NSN include Estuarine Subtidal Unconsolidated Bottom (14.8 acres), Estuarine Intertidal Emergent (2.5 acres), Estuarine Intertidal Unconsolidated Shoreline (0.49 acres), Palustrine Emergent (197.9 acres), Palustrine Forested (0.24 acres), Palustrine Scrub-Shrub/ Emergent (45.8 acres), Palustrine Scrub-Shrub (51.4 acres), and Palustrine Unconsolidated Bottom (borrow pit; 3.0 acres).
- *Urban land (3,292 acres)* - The majority of NSN is classified as urban land. The degree of urbanization varies from heavily urbanized areas, such as operations areas, to moderately urbanized areas, such as residential and administrative areas. Heavily urbanized areas contain little or no vegetation. Moderately urbanized areas contain maintained lawns along with native and ornamental shrubs and trees.
- *Surface water.* The major surface water bodies within and surrounding NSN include the Elizabeth River, Willoughby Bay, Bousch Creek, and Mason Creek.

Flora

A detailed inventory of the flora on NSN has not been conducted. However, a list of the plant species which may occur on NSN has been compiled as part of the 1997 INRMP. This list is contained in Tables 2-2 (general) and 2-3 (wetland areas).

Fauna

A detailed inventory of fish and wildlife resources on NSN has not been conducted. A list of avian species occurring at NSN was developed by the U.S. Fish and Wildlife Service as part of the Fish and Wildlife Management Plan for NSN (Audet, 1988, as cited in INRMP, July 1997). The list includes 317 species of birds, which represent 78 percent of all bird species known to occur in Virginia. This list includes resident, wintering, spring and fall migrant, accidental, and hypothetical species that may occur at NSN, or in the immediate vicinity. Avian species that may occur at NSN are listed in Table 2-4. As identified in the 1988 Fish and Wildlife Management Plan, 36 species of terrestrial mammals may occur on NSN (Table 2-5). Five species of marine mammals may be seen on rare occasions in the waters of the Lower Chesapeake Bay-Hampton Roads vicinity (Table 2-5).

A comprehensive survey of reptiles and amphibians has not been conducted on NSN. The reptilian and amphibian species that may occur on or adjacent to NSN, as identified in INRMP (1997), include 1 siren, 12 salamanders, 19 toads and frogs, 10 turtles, 4 sea turtles, and 32 lizards and snakes (Table 2-6).

A list of 62 species of fish that may use the waters occurring on or surrounding NSN was developed for the 1988 Fish and Wildlife Management Plan (INRMP, July 1997; Table 2-7). Sixteen species of crustaceans and 12 species of mollusks have been reported from the lower Elizabeth River. Hampton Roads and the lower James River support large populations of oysters, hard clams, soft-shelled clams, and blue crabs. During the summer, blue crabs are also abundant in Willoughby Bay and Mason Creek (INRMP, July 1997).

Rare, Threatened, and Endangered Species

There are no legally protected rare, threatened, or endangered plant species confirmed on NSN. However, a small stand of Virginia pinweed (*Lechea maritima* var. *virginica*), a Virginia threatened plant species, was identified on the narrow strip of land immediately north of Interstate 64 (INRMP, July 1997). The Willoughby oak tree (a single tree) has special historic significance, but the species is not listed as rare, threatened, or endangered.

At the time the INRMP for NSN was prepared (1997), there were six federally endangered, three federally threatened, and three federal candidates for listing that may have occurred in the general vicinity of NSN. Most of these potential occurrences represent transient birds or marine mammals. Some represent historical records from the Norfolk area. The only threatened or endangered species that has been sighted in recent times, either on or near NSN, are the American peregrine falcon (*Falco peregrinus*) and the West Indian manatee (*Trichechus manatus*). Although confirmed sightings of peregrine falcons have been made at NSN, this species was removed from the federal list on August 25, 1999. In late September 1995, a lone manatee was sighted in the Mason Creek Bridge Road area of Willoughby Bay. This manatee had been observed during the summer on the east coast as far north as Boston and was evidently heading south at the time of its visit to NSN (INRMP, July 1997).

Table 2-1
Soil Types Present on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Soil Index Symbol	Soil Name	Percent of Total
2	Urban Land	35.6
10	Urban Land-Udorthents Complex	13.3
12	Udorthents, Loamy	35.0
14	Udorthents, Clayey	2.5
24	Bojac Fine Sandy Loam	1.7
26	State Fine Sandy Loam (0-2% Slope)	8.6
34	Munden Fine Sandy Loam	2.2
36	Tetotum Fine Sandy Loam	0.3
42	Dragston Fine Sandy Loam	0.5
45	Augusta Fine Sandy Loam	0.1
W	Water	0.2

From INRMP (1997)

Table 2-2
Plant Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Notes
Herbaceous Plants		
Achillea millefolium	Yarrow	
Agropyron repens	Quackgrass	
Agrostemma githago	Corncockle	
Allium canadense	Wild onion	
Allium vineale	Wild garlic	
Amaranthus retroflexus	Pigweed	
Ambrosia artemisiifolia	Ragweed	W
Andropogon gerardi	Big bluestem	
Andropogon glomeratus	Bushy bluestem	
Andropogon virginicus	Broomsedge bluestem	
Anthemis cotula	Mayweed	
Apocynum cannabinum	Dogbane	
Arctium minus	Burdock	
Arundinaria tecta	Switchcane	
Asclepias syriaca	Common milkweed	
Barbarea vulgaris	Yellow rocket	
Brassica kaber	Wild mustard	
Brassica nigra	Black mustard	
Campsis radicans	Trumpet creeper	
Capsella bursa-pastoris	Shepherds purse	
Carex complanata	Blue sedge	
Carex lurida	Lurid sedge	
Cassia fasciculata	Showy partridgepea	W
Cenchrus pauciflorus	Sandbur	
Centaura cyanus	Batchelors buttons	
Cerastium vulgatum	Mouse-ear chickweed	
Chenopodium album	Lamb's quarter	
Chrysopsis graminifolia	Grassleaf goldaster	
Cicuta maculata	Water hemlock	
Cirsium arvense	Canada thistle	
Cirsium vulgare	Bull thistle	
Coreopsis lanceolata var. villosa	Thickleaf coreopsis	
Crotalaria sagittalis	Arrow crotalaria	
Croton capitatus	Woolly croton	
Ctenium aromaticum	Toothachegrass	
Cuscuta spp.	Dodder	
Cynodon dactylon	Bermudagrass	
Cyperus esculentus	Yellow nutsedge	
Cyperus rotundus	Nutgrass	
Cyperus virens	Green flatsedge	
Dactylis glomerata	Orchardgrass	
Daucus carota	Wild carrot	
Desmodium ciliare	Littleleaf tickclover	W
Digitaria ischaemum	Smooth crabgrass	

Table 2-2
Plant Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Notes
Digitaria sanguinalis	Large crabgrass	
Diodia teres	Buttonweed	
Echinochloa crusgalli	Barnyardgrass	
Eleocharis microcarpa	Annual spikesedge	
Eleusine indica	Goosegrass	
Erigeron strigosus var. beyrichii	Daisy fleabane	
Eryngium vuccifolium	Button snakeroot	
Eupatorium album	White eupatorium	
Eupatorium capillifolium	Dogfennel	
Eupatorium hyssopifolium	Hyssopleaf eupatorium	
Eupatorium rotoundifolium	Roundleaf eupatorium	
Euphorbia maculata	Spotted spurge	
Euphorbia supina	Prostrate spurge	
Festuca arundinacea	Kentucky 31 tall fescue	
Geranium carolinianum	Carolina cranesbill	
Glechoma hederacea	Ground ivy	
Helenium amarum	Bittersneezeweed	
Helenium tenuifolium	Bitterweed	
Helianthus angustifolius	Swamp sunflower	
Hibiscus trionum	Mallow	
Ipomoea hederacea	Morning glory	
Ipomoea purpurea	Annual morning glory	
Juncus biflorus	Twinflower rush	
Juncus effusus	Common rush	
Juncus scirpoides	Needlepod rush	
Juncus tenuis	Poverty rush	
Lactuca scariola	Prickly lettuce	
Lamium amplexicaule	Henbit	
Lepidium virginicum	Peppergrass	
Lespedeza striata	Common lespedeza	W
Liatris acidota	Slender gayfeather	
Medicago lupulina	Black medic	
Mollugo verticillata	Carpetweed	
Muhlenbergia expansa	Cutover muhly	
Muhlenbergia schreberi	Nimblewill	
Oxalis stricta	Yellow wood sorrel	
Panicum angustifolium	Narrowleaf panicum	
Panicum dichotomiflorum	Fall panicum	
Panicum rhizomatum	Spreading panicum	
Panicum virgatum	Switchgrass	
Paspalum dilatatum	Dallisgrass	
Paspalum floridanum	Florida paspalum	
Pferidiumaquilinum var. pusedo caudatum	Southern bracken fern	
Phytolacca americana	Pokeweed	
Plantago aristafa	Bracted plantain	

Table 2-2
Plant Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Notes
Plantago lanceolata	Buckhorn plantain	
Plantago major	Plantain	
Poa annua	Annual bluegrass	
Polygonum convolvulus	Wild buckwheat	
Polygonum erectum	Erect knotweed	
Polygonum oviculave	Knotweed	
Polygonum pennsylvanicum	Pennsylvania smartweed	W
Polygonum persicaria	Lady's thumb	
Portulaca oleracea	Purslane	
Prunella vulgaris	Heal-all	
Rhynchosia difformis	Hairy rhynchosia	
Rhynchospora globularis	Pinehill beakrush	
Romex acetosella	Sheep sorrel	
Rudbeckia hirta	Black-eyed susan	
Rumex crispus	Curly dock	
Rumex obtusifolius	Broadleaved dock	
Setaria glauca	Yellow foxtail	
Setaria viridis	Green foxtail	
Sida spinosa	Wiry sida	
Solanum carolinense	Horse nettle	
Solidago odora	Fragrant goldenrod	
Soncluis arvensis	Perennial sow thistle	
Sorghastrum nutans	Yellow indiangrass	
Sorghum halepense	Johnsongrass	
Sporobolus junceus	Pineywoods dropseed	
Sporobolus poiretii	Smutgrass	
Stellaria media	Common chickweed	
Taraxacum officinale	Dandelion	
Thlaspi arvense	Fanweed	
Trifolium repens	White clover	
Typha angustifolia	Narrow-leaved cattail	
Vicia angustifolia	Wild vetch	W
Xanthium pennsylvanicum	Cocklebur	
Shrubs and Woody Vines		
Amelopsis arborea	Peppervine	
Asimina triloba	Pawpaw	W
Berchemia scandens	Alabama supplejack	
Bignonia capreolata	Crossvine	
Callicarpa rubella	American beautyberry	W
Craetaegus marshallii	Parsley hawthorn	W
Craetaegus uniflora	One-flower hawthorn	W
Cyrilla racemiflora	Swamp cyrilla	W
Gelsemium sempervirens	Carolina jessamine	
Hamamelia virginia	Witch-hazel	
Hypericum hypericoides	St. Andrews-Cross	

Table 2-2
Plant Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Notes
Ilex cassine	Dahoon	
Ilex glabra	Gallberry	W
Ilex vomitoria	Yaupon	W
Lonicera japonica	Japanese honeysuckle	W
Myrica cerifera	Southern wax myrtle (bayberry)	W
Parthenocissus quinquifolia	Virginia creeper	W
Rhododendron serrulatum	Hammocksweet azalea	
Rhus copallina	Shining sumac	W
Rhus glabra	Smooth sumac	W
Rhus radicans	Poison ivy	P,W
Rhus typhina	Staghorn sumac	W
Rhus vernix	Poison sumac	P
Rubus spp.	Dewberries, blackberries, raspberries	W
Sambucus canadensis	American elder	W
Smilax bona-nox	Saw greenbrier	W
Smilax glauca	Cat greenbrier	W
Smilax laurifolia	Laurel greenbrier	W
Smilax rotundifolia	Common greenbrier	W
Smilax smallii	Lanceleaf greenbrier	W
Symplocos tinctoria	Common sweetleaf	
Vaccinium arboreum	Tree sparkleberry	W
Vaccinium vacillans	Low blueberry	W
Viburnum acerifolium	Mapleleaf viburnum	W
Viburnum dentatum	Arrowood viburnum	W
Viburnum rufidulum	Rusty blackhaw	W
Vitis aestivalis	Summer grape	W
Vitis rotundifolia	Muscadine grape	W
Trees		
Acer rubrum	Red maple	
Acer saccharinum	Silver maple	
Carpinus caroliniana	American hornbeam	
Carya aquatica	Water hickory	W
Carya cordiformis	Bitternut hickory	W
Celtis laevigata	Sugarberry	
Celtis occidentalis	Hackberry	
Chamaecyparis thyoides	Atlantic white cedar	
Chronanthus virginicus	Fringetree	
Cornus florida	Flowering dogwood	W
Fagus grandifolia	American beech	W
Fraxinus pennsylvanica	Green ash	
Ilex cassine	Dahoon	
Ilex opaca	American holly	W
Juglans nigra	Black walnut	W
Juniperus virginiana	Eastern red cedar	
Liquidambar styraciflua	Sweetgum	

Table 2-2
Plant Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Notes
Liriodendron tulipifera	Yellow poplar	
Magnolia grandiflora	Southern magnolia	
Magnolia virginiana	Sweetbay	W
Nyssa aquatica	Water tupelo	W
Nyssa sylvatica	Black gum (tupelo)	W
Ostrya virginiana	Eastern hophornbeam	
Oxydendrum arboreum	Sourwood	W
Persea borbonia	Redbay	
Pinus echinata	Shortleaf pine	
Pinus taeda	Loblolly pine	
Pinus virginiana	Virginia pine	
Platanus occidentalis	American sycamore	
Populus deltoides	Eastern cottonwood	
Prunus serotina	Black cherry	W
Quercus alba	White oak	W
Quercus falcata	Southern red oak	W
Quercus falcata var. pagodaefolia	Cherrybark oak	W
Quercus laurifolia	Laurel oak	W
Quercus lyrata	Overcup oak	W
Quercus michauxii	Swamp chestnut oak	W
Quercus nigra	Water oak	W
Quercus phellos	Willow oak	W
Quercus rubra	Northern red oak	W
Quercus stellata	Post oak	W
Quercus virginiana	Live oak	W
Salix nigra	Black willow	
Sassafras albidum	Sassafras	W
Taxodium distichum	Bald cypress	
Ulmus alata	Winged elm	
Ulmus americana	American elm	
Ulmus pumila	Siberian elm	
Ulmus rubra	Slippery elm	

From INRMP (1997)
W - Denotes important wildlife food and cover plants
P- Denotes poisonous plants

Table 2-3
Dominant Vegetation of Wetland Areas on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Common Name	Scientific Name	Wetland Status[1]
Herbaceous Plants		
American threesquare	*Scirpus pungens*	FACW+
Asiatic dayflower	*Commelina communis*	FAC-
Black needlerush	*Juncus roemerianus*	OBL
Broom sedge	*Carex spp.*	FACW
Chicory	*Cichorium intybus*	UPL
Cocklebur	*Xanthium chinense*	UPL
Common reed	*Phragmites communis*	FACW
Crabgrass	*Digitaria spp.*	--
Cutgrass	*Leersia spp.*	--
Daisy fleabane	*Erigeron strigosus*	FACU+
Dock	*Rumex spp.*	--
Dune grass	--	--
Dwarf spikerush	*Eleocharis parvula*	OBL
English plantain	*Plantago lanceolata*	UPL
False nettle	*Boehmeria cylindrica*	FACW+
Fellow	--	--
Fine-lined sneezeweed	*Helenium tenuifolium*	UPL
Goldenrod	*Solidago spp.*	--
Japanese clover	*Lespedeza striata*	FACU
Large saltmarsh aster	*Aster simplex*	OBL
Marsh fern	*Thelypteris thelypteris*	FACW+
Marsh foxtail	*Alopecurus pratensis*	FACW
Marsh mallow	*Althaea officinalis*	FACW+
Marsh-elder	*Iva frutescens*	FACW+
Meadow foxtail	*Alopecurus geniculatus*	OBL
Mistflower	*Eupatorium coelestinum*	FAC
Moth mullein	*Verbascum blattaria*	UPL
Narrow-leaved cattail	*Typha angustifolia*	OBL
Panic grass	*Panicum spp.*	--
Penny-wort	*Hydrocotyle spp.*	OBL
Peppergrass	*Lepidium spp.*	--
Purple top sedge	*Carex spp.*	--
Queen Anne's lace	*Daucus carota*	UPL
Rose mallow	*Hibiscus moscheutos*	OBL
Royal fern	*Osmunda regalis*	OBL
Saltmarsh cordgrass	*Spartina alterniflora*	OBL
Saltmarsh fleabane	*Pluchea purpurascens*	OBL
Sandspur	--	--
Seaside goldenrod	*Solidago sempervirens*	FACW
Sedge	*Cyperus spp.*	--
Sedge	*Carex lurida*	OBL
Smartweed	*Polygonum spp.*	--
Smooth paspalum	*Paspalum repens*	OBL
Soft-stem rush	*Juncus effusus*	FACW+

Table 2-3
Dominant Vegetation of Wetland Areas on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Common Name	Scientific Name	Wetland Status[1]
Spearscale	*Atriplex patula*	FACW
Sweet white clover	*Melilotus alba*	FACU-
Water hemlock	*Cicuta maculata*	OBL
Yellow sow thistle	*Cirsium horridulum*	FACU-
Woody Plants		
Atlantic white cedar	*Chamaecyparis thyoides*	OBL
Black cherry	*Prunus serotina*	FACU
Eastern red cedar	*Juniperus virginiana*	FACU
Greenbrier	*Smilax spp.*	--
Groundsel-tree	*Baccharis halimifolia*	FACW
Japanese honeysuckle	*Lonicera japonica*	FAC-
Loblolly pine	*Pinus taeda*	FAC-
Mulberry	*Morus spp.*	--
Poison ivy	*Rhus radicans*	FAC
Red maple	*Acer rubrum*	FAC
Smooth sumac	*Rhus glabra*	UPL
Southern red oak	*Quercus falcata*	FACU-
Swamp rose	*Rosa palustris*	OBL
Sweetgum	*Liquidambar styraciflua*	FAC
Virginia creeper	*Parthenocissus quinquifolia*	FACU
Wax myrtle	*Myrica cerifera*	FAC
Willow	*Salix spp.*	--
Willow oak	*Quercus phellos*	FAC+

[1]OBL - Obligate wetland (>99% probability of occurring in wetlands); FACW - Facultative Wetland (67-99%); FAC - Facultative (34-66%); FACU - Facultative Upland (1-33%); UPL - Obligate Upland (<1%); Minus sign - tends to lower end of range; Plus sign - tends to higher end of range (Reed 1988)

Table 2-4
Bird Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Status
Accipiter cooperii	Cooper's hawk	
Accipiter gentilis	Northern goshawk	
Accipiter striatus	Sharp-shinned hawk	
Actitis macularia	Spotted sandpiper	
Aechmophorus occidentalis	Western grebe	
Aegolius acadicus	Northern saw-whet owl	
Agelaius phoeniceus	Red-winged blackbird	
Aix sponsa	Wood duck	
Ammodramus henslowii	Henslow's sparrow	
Ammodramus savannarum	Grasshopper sparrow	
Ammospiza caudacuta	Sharp-tailed sparrow	
Ammospiza leconteii	LeConte's sparrow	
Ammospiza maritima	Seaside sparrow	
Anas acuta	Northern pintail	
Anas americana	American wigeon	
Anas clypeata	Northern shoveler	
Anas crecca	Green-winged teal	
Anas discors	Blue-winged teal	
Anas penelope	Eurasian wigeon	
Anas platyrhynchos	Mallard	
Anas rubripes	American black duck	
Anas strepera	Gadwall	
Anhinga anhinga	Anhinga	
Anser albifrons	White-fronted goose	
Anthus spinoletta	Water pipit	
Aquila chrysaetos	Golden eagle	
Archilochus colubris	Ruby-throated hummingbird	
Ardea herodias	Great blue heron	
Arenaria interpres	Ruddy turnstone	
Asio otus	Long-eared owl	
Aythya affinis	Lesser scaup	
Aythya americana	Redhead	
Aythya collaris	Ring-necked duck	
Aythya marila	Greater scaup	
Aythya valisineria	Canvasback	
Bartramia longicauda	Upland sandpiper	
Bombycilla cedrorum	Cedar waxwing	
Botaurus lentiginosys	American bittern	
Branta bernicla	Brant	
Branta canadensis	Canada goose	
Bubo virginianus	Great horned owl	
Bubulcus ibis	Cattle egret	
Bucephala albeola	Bufflehead	
Bucephala clangula	Common goldeneye	
Buteo jamaicensis	Red-tailed hawk	

Table 2-4
Bird Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Status
Buteo lagopus	Rough-legged hawk	
Buteo lineatus	Red-shouldered hawk	
Buteo platypterus	Broad-winged hawk	
Butorides striatus	Green-backed heron	
Calcarius lapponicus	Lapland longspur	
Calidris alba	Sanderling	
Calidris alpina	Dunlin	
Calidris bairdii	Baird's sandpiper	
Calidris canutus	Red knot	
Calidris ferruginea	Curlew sandpiper	
Calidris fuscicollis	White-rumped sandpiper	
Calidris maritima	Purple sandpiper	
Calidris mauri	Western sandpiper	
Calidris melanotos	Pectoral sandpiper	
Calidris minutilla	Least sandpiper	
Calidris pusilla	Semipalmated sandpiper	
Capella gallinago	Common snipe	
Caprimulgus carolinensis	Chuck-will's widow	
Caprimulgus vociferus	Whip-poor-will	
Cardinalis cardinalis	Northern cardinal	
Carduelis flammea	Common redpoll	
Carduelis pinus	Pine siskin	
Carduelis tristis	American goldfinch	
Carpodacus mexicanus	House finch	
Carpodacus purpureus	Purple finch	
Casmerodius albus	Great egret	
Cathartes aura	Turkey vulture	
Catharus fuscescens	Veery	
Catharus guttatus	Hermit thrush	
Catharus minimus	Gray-cheeked thrush	
Catharus ustulatus	Swainson's thrush	
Catoptrophorus semipalmatus	Willet	
Certhia americana	Brown creeper	
Ceryle alcyon	Belted kingfisher	
Chaetura pelagica	Chimney swift	
Charadrius melodus	Piping plover	
Charadrius semipalmatus	Semipalmated plover	
Charadrius vociferus	Killdeer	
Charadrius wilsonia	Wilson's plover	
Chen caerulescens	Snow goose	
Chlidonias niger	Black tern	
Chondestes grammacus	Lark sparrow	
Chordeiles minor	Common nighthawk	
Circus cyaneus	Northern harrier	
Cistothorus palustris	Marsh wren	

Table 2-4 Bird Species That May Occur on Naval Station Norfolk Ecological Risk Assessment - Lower Reaches of Bousch Creek *Naval Station Norfolk, Norfolk, Virginia*		
Scientific Name	Common Name	Status
Cistothorus platensis	Sedge wren	
Clangula hyemalis	Oldsquaw	
Coccyzus americanus	Yellow-billed cuckoo	
Coccyzus erythropthalmus	Black-billed cuckoo	
Colaptes auratus	Northern flicker	
Colinus virginianus	Northern bobwhite	
Columba livia	Rock dove	
Columbina talpacoti	Common ground-dove	
Contopus virens	Eastern-wood pewee	
Coragyps attratus	Black vulture	
Corvus brachyrhynchos	American crow	
Corvus ossifragus	Fish crow	
Coturnicops noveboracensis	Yellow rail	*
Cyanocitta cristata	Blue jay	
Dendroica caerulescens	Black-throated blue warbler	
Dendroica castanea	Bay-breasted warbler	
Dendroica cerulea	Cerulean warbler	
Dendroica coronata	Yellow-rumped warbler	
Dendroica discolor	Prairie warbler	
Dendroica dominica	Yellow-throated warbler	
Dendroica fusca	Blackburnian warbler	
Dendroica magnolia	Magnolia warbler	
Dendroica palmarum	Palm warbler	
Dendroica pensylvanica	Chestnut-sided warbler	
Dendroica petechia	Yellow warbler	
Dendroica pinus	Pine warbler	
Dendroica striata	Blackpoll warbler	
Dendroica tigrina	Cape May warbler	
Dendroica virens	Black-throated green warbler	
Dichromanassa rufescens	Reddish egret	*
Dolichonyx oryzivorus	Bobolink	
Dryocopus pileatus	Pileated woodpecker	
Dumetella carolinensis	Gray catbird	
Egretta thula	Snowy egret	
Empidonax flaviventris	Yellow-bellied flycatcher	
Empidonax minimus	Least flycatcher	
Empidonax traillii	Willow flycatcher	
Empidonax virescens	Acadian flycatcher	
Eremophila alpestris	Horned lark	
Eudocimus albus	White ibis	
Euphagus carolinus	Rusty blackbird	
Euphagus cyanocephalus	Brewer's blackbird	
Falco columbarius	Merlin	
Falco peregrinus	Peregrine falcon	
Falco sparverius	American kestrel	

Table 2-4
Bird Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Status
Florida caerulea	Little blue heron	
Fulica americana	American coot	
Gallinula chloropus	Common moorhen	
Gavia immer	Common loon	
Gavia stellata	Red-throated loon	
Gelochelidon nilotica	Gull-billed tern	
Geothylpis poliocephala	Common yellowthroat	
Guiraca caerulea	Blue grosbeak	
Haematopus palliatus	American oystercatcher	
Haliaeetus leucocephalus	Bald eagle	
Helmitheros vermivorus	Worm-eating warbler	
Hesperiphona vespertina	Evening grosbeak	
Himantopus mexicanus	Black-necked stilt	
Hirundo rustica	Barn swallow	
Histrionicus histrionicus	Harlequin duck	
Hydranassa tricolor	Tricolored heron	
Hylocichla mustelina	Wood thrush	
Icteria virens	Yellow-breasted chat	
Icterus galbula	Northern oriole	
Icterus spurius	Orchard oriole	
Ictinia mississippiensis	Mississippi kite	*
Iridoprocne bicolor	Tree swallow	
Ixobrychus exilis	Least bittern	
Junco hyemalis	Dark-eyed junco	
Lanius ludovicianus	Loggerhead shrike	
Larus argentatus	Herring gull	
Larus atricilla	Laughing gull	
Larus delawarensis	Ring-billed gull	
Larus fuscus	Lesser black-backed gull	
Larus hyperboreus	Glaucous gull	
Larus marinus	Great black-backed gull	
Larus minutus	Little gull	
Larus philadelphia	Bonaparte's gull	
Larus pipixcan	Franklin's gull	*
Larus ridibundus	Common black-headed gull	
Laterallus jamaicensis	Black rail	*
Limnodromus griseus	Short-billed dowitcher	
Limnodromus scolopaceus	Long-billed dowitcher	
Limnothylpis swainsonii	Swainson's warbler	
Limosa fedoa	Marbled godwit	
Limosa haemastica	Hudsonian godwit	
Lophodytes cucullatus	Hooded merganser	
Loxia curvirostra	Red crossbill	
Loxia leucoptera	White-winged crossbill	
Melanerpes carolinus	Red-bellied woodpecker	

Table 2-4
Bird Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Status
Melanerpes erythrocephalus	Red-headed woodpecker	
Melanitta deglandi	White-winged scoter	
Melanitta nigra	Black scoter	
Melanitta perspicillata	Surf scoter	
Melospiza georgiana	Swamp sparrow	
Melospiza lincolnii	Lincoln's sparrow	
Melospiza melodia	Song sparrow	
Mergus merganser	Common merganser	
Mergus serrator	Red-breasted merganser	
Micropalama himantopus	Stilt sandpiper	
Mimus polyglottus	Northern mockingbird	
Mniotilta vira	Black-and-white warbler	
Molothrus ater	Brown-headed cowbird	
Morus bassanus	Northern gannet	
Myiarchus crinitus	Great-creasted flycatcher	
Numenius phaeopus	Whimbrel	
Nuttallornis borealis	Olive-sided flycatcher	
Nyctanassa violacea	Yellow-crowned night heron	
Nyctea scandiaca	Snowy owl	
Nycticorax nycticorax	Black-crowned night heron	
Oceanites oceanicus	Wilson's storm petrel	
Oceanodroma leucorhoa	Leach's storm petrel	
Olor columbianus	Tundra swan	
Oporornis agilis	Connecticut warbler	
Oporornis formosus	Kentucky warbler	
Oporornis philadelphia	Mourning warbler	
Otus asio	Eastern screech-owl	
Oxyura jamaicensis	Ruddy duck	
Pandion haliaetus	Osprey	
Parula americana	Northern parula	
Parus bicolor	Tufted titmouse	
Parus carolinensis	Carolina chickadee	
Passer domesticus	House sparrow	
Passerculus sandwichensis	Savannah sparrow	
Passerella iliaca	Fox sparrow	
Passerina amoena	Lazuli bunting	
Passerina circis	Painted bunting	
Passerina cyanea	Indigo bunting	
Pelecanus erythrorhynchos	American white pelican	
Pelecanus occidentalis	Brown pelican	
Petrochelidon pyrrhonota	Cliff swallow	
Phalacrocorax auritus	Double-crested cormorant	
Phalacrocorax carbo	Great cormorant	
Phalaropus fulicarius	Red phalarope	
Pheucticus ludovicianus	Rose-breasted grosbeak	

Table 2-4
Bird Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Status
Pheucticus melanocephalus	Black-headed grosbeak	*
Philomachus pugnax	Ruff	
Philophela minor	American woodcock	
Picoides borealis	Red-cockaded woodpecker	*
Picoides pubescens	Downy woodpecker	
Picoides villosus	Hairy woodpecker	
Pipilo erythrophthalmus	Rufous-sided towhee	
Piranga ludoviciana	Western tanager	*
Piranga olivacea	Scarlet tanager	
Piranga rubra	Summer tanager	
Plectrophenax nivalis	Snow bunting	
Plegadis falcinellus	Glossy ibis	
Pluvialis dominica	Lesser golden plover	
Pluvialis squatarola	Black-bellied plover	
Podiceps auritus	Horned grebe	
Podiceps grisegena	Red-necked grebe	
Podiceps nigricollis	Eared grebe	*
Podilymbus podiceps	Pied-billed grebe	
Polioptila caerulea	Blue-gray gnatcatcher	
Pooecetes gramineus	Vesper sparrow	
Porphyrula martinica	Purple gallinule	*
Porzana carolina	Sora	
Progne subis	Purple martin	
Protonotaria citrea	Prothonotary warbler	
Quiscalus major	Boat-tailed grackle	
Quiscalus quiscula	Common grackle	
Rallus elegans	King rail	
Rallus limicola	Virginia rail	
Rallus longirostris	Clapper rail	
Recurvirostra americana	American avocet	
Regulus calendula	Ruby-crowned kinglet	
Regulus satrapa	Golden-crowned kinglet	
Riperia riperia	Bank swallow	
Rynchops niger	Black skimmer	
Sayornis phoebe	Eastern phoebe	
Seiurus aurocapillus	Ovenbird	
Seiurus motacilla	Louisiana waterthrush	
Seiurus noveboracensis	Northern waterthrush	
Setophaga ruticilla	American redstart	
Sialia sialis	Eastern bluebird	
Sitta canadensis	Red-breasted nuthatch	
Sitta carolinensis	White-breasted nuthatch	
Sitta pusilla	Brown-headed nuthatch	
Somateria mollissima	Common eider	
Sphyrapicus varius	Yellow-bellied sapsucker	

Table 2-4
Bird Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Status
Spiza americana	Dickcissel	
Spizella arborea	American tree sparrow	
Spizella pallida	Clay-colored sparrow	
Spizella passerina	Chipping sparrow	
Spizella pusilla	Field sparrow	
Steganopus tricolor	Wilson's phalarope	
Stelgidopteryx serripennis	Northern rough-winged swallow	
Sterna antillarum	Least tern	
Sterna caspia	Caspian tern	
Sterna dougallii	Roseate tern	*
Sterna forsteri	Forster's tern	
Sterna hirundo	Common tern	
Sterna maxima	Royal tern	
Sterna sandvicensis	Sandwich tern	
Strix varia	Barred owl	
Sturnella magna	Eastern meadowlark	
Sturnus vulgaris	European starling	
Thryomanes bewickii	Bewick's wren	*
Thryothorus ludovicianus	Carolina wren	
Toxostoma rufum	Brown thrasher	
Tringa flavipes	Lesser yellowlegs	
Tringa melanoleuca	Greater yellowlegs	
Tringa solitaria	Solitary sandpiper	
Troglodytes aedon	House wren	
Troglodytes troglodytes	Winter wren	
Turdus migratorius	American robin	
Tyrannus tyrannus	Eastern kingbird	
Tyto alba	Barn owl	
Uria lomvia	Thick-billed murre	*
Vermivora celata	Orange-crowned warbler	
Vermivora chrysoptera	Golden-winged warbler	
Vermivora peregrina	Tennessee warbler	
Vermivora pinus	Blue-winged warbler	
Vermivora ruficapilla	Nashville warbler	
Vireo flavifrons	Yellow-throated vireo	
Vireo gilvus	Warbling vireo	
Vireo griseus	White-eyed vireo	
Vireo olivaceus	Red-eyed vireo	
Vireo philadelphicus	Philadelphia vireo	
Vireo solitarius	Solitary vireo	
Wilsonia canadensis	Canada warbler	
Wilsonia citrina	Hooded warbler	
Wilsonia pusilla	Wilson's warbler	
Xanthocephalus xanthocephalus	Yellow-headed blackbird	
Xema sabini	Sabine's gull	*

Table 2-4
Bird Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Status
Zenaida macroura	Mourning dove	
Zonotrichia leucophrys	White-crowned sparrow	

From INRMP (1997)
*Accidental, hypothetical, or considered extremely rare on the facility

Table 2-5
Mammal Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name	Status
Terrestrial Mammals		
Crytotis parva	Least shrew	
Eptesicus fuscus	Big brown bat	
Glaucomys volans	Southern flying squirrel	*
Lasionycteris noctivagans	Silver-haired bat	
Lasiurus borealis	Red bat	
Lasiurus cinereus	Hoary bat	
Lasiurus intermedius	Northern yellow bat	*
Lutra canadensis	River otter	*
Mephitis mephitis	Striped skunk	*
Microtus pennsylvanicus	Meadow vole	
Microtus pinetorum	Woodland vole	*
Mus musculus	House mouse	
Mustela frenata	Long-tailed weasel	
Myotis lucifugus	Little brown bat	
Myotis keenii	Keen's myotis	*
Nycticeius humeralis	Evening bat	
Ochrotomys nuttalli	Golden mouse	*
Ondatra zibethicus	Muskrat	
Oryzomys palustris	Marsh rice rat	
Peromyscus leucopus	White-footed mouse	
Peromyscus gossypinus	Cotton mouse	*
Pipistrellus subflavus	Eastern pipistrelle	
Plecotus rafinesquei	Eastern big-eared bat	
Procyon lotor	Raccoon	
Rattus norvegicus	Norway rat	
Rattus rattus	Black rat	
Reithrodontomys humulis	Eastern harvest mouse	
Scalopus aquaticus	Eastern mole	
Sciurus carolinensis	Gray squirrel	
Signodon hispidus	Hispid cotton rat	*
Sorex longirostris longirostris	Southeastern shrew	
Sylvilagus floridanus	Eastern cottontail	
Sylvilagus palustris	Marsh rabbit	
Synaptomys cooperi	Southern bog lemming	*
Tamias striatus	Eastern chipmunk	
Urocyon cinereoargenteus	Gray fox	
Marine Mammals		
Balaenoptera physalus	Fin-backed whale	*
Phoca vitulina	Harbor seal	*
Steno bredaneusis	Rough-toothed porpoise	*
Trichechus manatus	West Indian manatee	*
Tursiops truncatus	Atlantic bottle-nosed dolphin	*

From INRMP (1997)
* Most likely do not occur or considered rare on Naval Station Norfolk due to lack of suitable habitat

Table 2-6
Amphibian and Reptile Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name
Sirens	
Siren lacertina	Greater siren
Salamanders	
Ambystoma maculatum	Spotted salamander
Ambystoma opacum	Marbled salamander
Amphiuma means means	Two-toed salamander
Desmognathus auriculatus	Southern dusky salamander
Euryces bislineata bislineata	Northern two-lined salamander
Euryces longicauda guttolineata	Three-lined salamander
Necturus punctatus punctatus	Dwarf waterdog
Notopthalmus viridescens	Red-spotted newt
Plethodon cinereus cinereus	Red-backed salamander
Plethodon glutinosus glutinosus	Slimy salamander
Pseudotriton montanus montanus	Eastern mud salamander
Stereochulus marginatus	Many-lined salamander
Frogs and Toads	
Acris gryllus gryllus	Southern cricket frog
Bufo fowleri	Fowler's toad
Bufo quercicus	Oak toad
Bufo terrestris	Southern toad
Gastrophryne carolinensis	Eastern narrow-mouthed toad
Hyla chrysoscelis	Southern gray tree frog
Hyla cinerea cinerea	Green tree frog
Hyla crucifer crucifer	Northern spring peeper
Hyla femoralis	Pine woods tree frog
Hyla gratiosa	Barking tree frog
Hyla squirella	Squirrel tree frog
Limnaoedus ocularis	Little grass frog
Pseudacris brimleyi	Brimely's chorus frog
Pseudacris triseriata feriarum	Upland chorus frog
Rana catesbeiana	Bullfrog
Rana clamitans melanota	Green frog
Rana palustris	Pickerel frog
Rana sphenocephala	Southern leopard frog
Scaphiopus holbrooki holbrooki	Eastern spadefoot toad
Turtles	
Chelydra serpentina serpentina	Common snapping turtle
Chrysemys concinna concinna	River cooter
Chrysemys floridana floridana	Florida cooter
Chrysemys rubriventris	Red-bellied turtle
Chrysemys picta picta	Eastern painted turtle
Clemmys guttata	Spotted turtle
Kinosternon subrubrum subrubrum	Eastern mud turtle
Malaclemys terrapin terrapin	Northern diamond-backed terrapin
Sternothaerus odoratus	Stinkpot

Table 2-6
Amphibian and Reptile Species That May Occur on Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name
Terrapene carolina carolina	Eastern bog turtle
Sea Turtles	
Caretta caretta caretta	Atlantic loggerhead
Chelonia mydas mydas	Atlantic green turtle
Dermochelys coriacea coriacea	Atlantic leatherback
Lepidochelys kempi	Kemp's ridley turtle
Lizards and Snakes	
Agkistrodon contortrix mokasen	Northern copperhead
Agkistrodon piscivorus piscivorus	Eastern cottonmouth
Carphophis amoenus amoenus	Eastern worm snake
Cemophora coccinea copei	Southeastern scarlet snake
Cnemidophorus sexlineatus	Six-lined race runner
Coluber constrictor constrictor	Northern black racer
Crotalus horridus atricaudatus	Canebrake rattlesnake
Diadophis punctatus punctatus	Southern ring-necked snake
Elaphe guttata guttata	Corn snake
Elaphe obsoleta obsoleta	Black rat snake
Eumeces fasciatus	Five-lined skink
Eumeces inexpectatus	Southeastern five-lined skink
Eumeces laticeps	Broad-head skink
Farancia abacura abacura	Eastern mud snake
Farancia erythrogramma erythrogramma	Rainbow snake
Heterodon platyrhinos	Eastern hognose snake
Lampropeltis calligaster rhombomaculata	Mole snake
Lampropeltis getulus getulus	Eastern king snake
Lampropeltis triangulum temporalis	Coastal plain milk snake
Lygosoma laterale	Ground skink
Natrix erythrogaster erythrogaster	Red-bellied water snake
Natrix sipedon sipedon	Northern water snake
Natrix taxispilota	Brown water snake
Opheodrys aestivus	Rough green snake
Ophisaurus attenuatus longicaudus	Eastern slender glass lizard
Sceloporus undulatus hyacinthinus	Northern fence lizard
Storeria dekayi dekayi	Northern brown snake
Storeria occipiromaculata occipitomaculata	Northern red-bellied snake
Thamnophis sauritus sauritus	Eastern ribbon snake
Thamnophis sirtalis sirtalis	Eastern garter snake
Virginia striatula	Rough earth snake
Virginia valeriae valeriae	Eastern earth snake

From INRMP (1997)

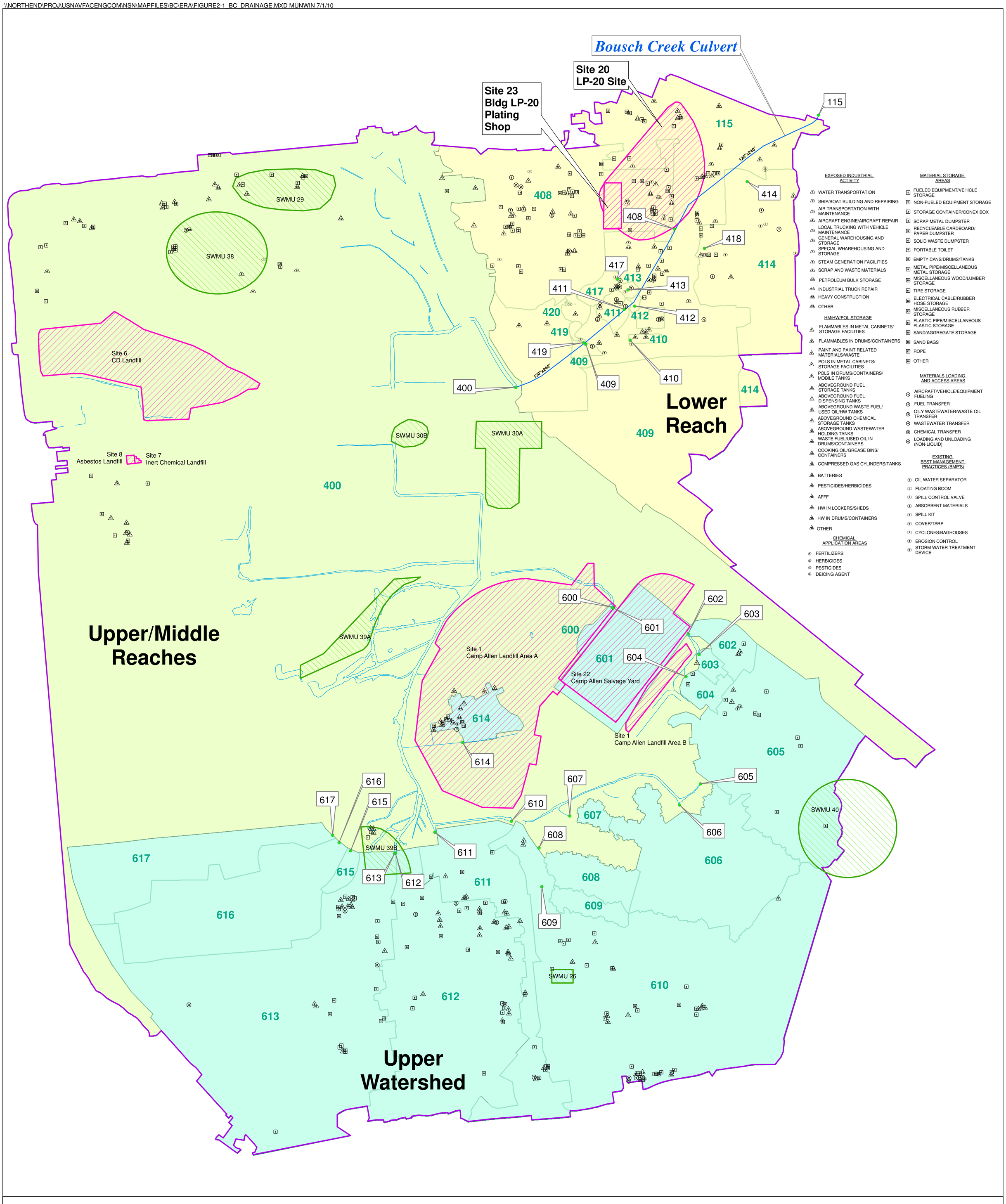
Table 2-7
Fish Species Documented in the Surrounding Waters of Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name
Alosa aestivalis	Blueblack herring
Alosa pseudoharengus	Alewife
Alosa sapidissima	American shad
Ammodytes spp.	Sand lance
Anchoa hepsetus	Striped anchovy
Anchoa mitchilli	Bay anchovy
Anguilla rostrata	American eel
Brevoortia tyrannus	Atlantic menhaden
Centropristis striata	Black seabass
Chasmodes saburrae	Striped blenny
Conger americanus	Conger eel
Cynoscion regalis	Weakfish
Cyprinus carpio	Carp
Dorosoma cepedianum	Gizzard shad
Esox niger	Chain pickerel
Etropus microstomus	Smallmouth flounder
Fundulus diaphanus	Banded killifish
Fundulus heteroclitus	Mummichog
Fundulus maialis	Striped killifish
Gambusia affinis	Mosquitofish
Gobiesox spp.	Clingfish
Gobiesox strumosus	Skilletfish
Gobiosoma bosci	Naked goby
Gobiosoma ginsburgi	Seaboard goby
Hippocampus erectus	Lined seahorse
Hypsoblennius hentzi	Feather blenny
Ictalurus catus	White catfish
Ictalurus natalis	Yellow bullhead
Ictalurus nebulosus	Brown bullhead
Ictalurus punctatus	Channel catfish
Leiostomus xanthurus	Spot
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Lepomis microlophus	Redear sunfish
Lophius americanus	Goosefish
Membras martinica	Rough silverside
Menidia beryllina	Tidewater silverside
Menidia menidia	Atlantic silverside
Menticirrhus spp.	Kingfish
Microgobius thalassinus	Green goby
Micropogon undulatus	Atlantic croaker
Morone americanus	White perch
Morone saxatilis	Striped bass
Mugil curema	White mullet
Notemigonus crysoleucas	Golden shiner

Table 2-7
Fish Species Documented in the Surrounding Waters of Naval Station Norfolk
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Scientific Name	Common Name
Opsanus tau	Oyster toadfish
Paralichthys dentatus	Summer flounder
Peprilus triacanthus	Butterfish
Perca flavescens	Yellow perch
Pomatomus saltatrix	Bluefish
Pomoxis nigromaculatus	Black crappie
Prionotus carolinus	Northern searobin
Prionotus evolans	Striped searobin
Pseudopleuronectes americanus	Winter flounder
Rissola marginata	Striped cusk-eel
Scomber scombrus	Atlantic mackerel
Scophthalmus aquosus	Windowpane
Sphoeroides maculatus	Northern puffer
Symphurus plagiusa	Blackcheek tonguefish
Syngnathus fuscus	Northern pipefish
Synodus foetens	Inshore lizardfish
Tautoga onitis	Tautog
Trinectes maculatus	Hogchoker
Urophycis chus	Red hake
Urophycis regius	Spotted hake

From INRMP (1997)



Legend

- Outfalls
- Bousch Creek Culvert
- Site Boundaries
- SWMU Boundaries
- Bousch Creek Watershed
- Lower Reach
- Upper/Middle Reaches
- Upper Watershed
- Outfall Subbasins
- Surface Water Features

N W E S

0 300 600 900 1,200 Feet

Figure 2-1
Bousch Creek Drainage Basin
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, Virginia

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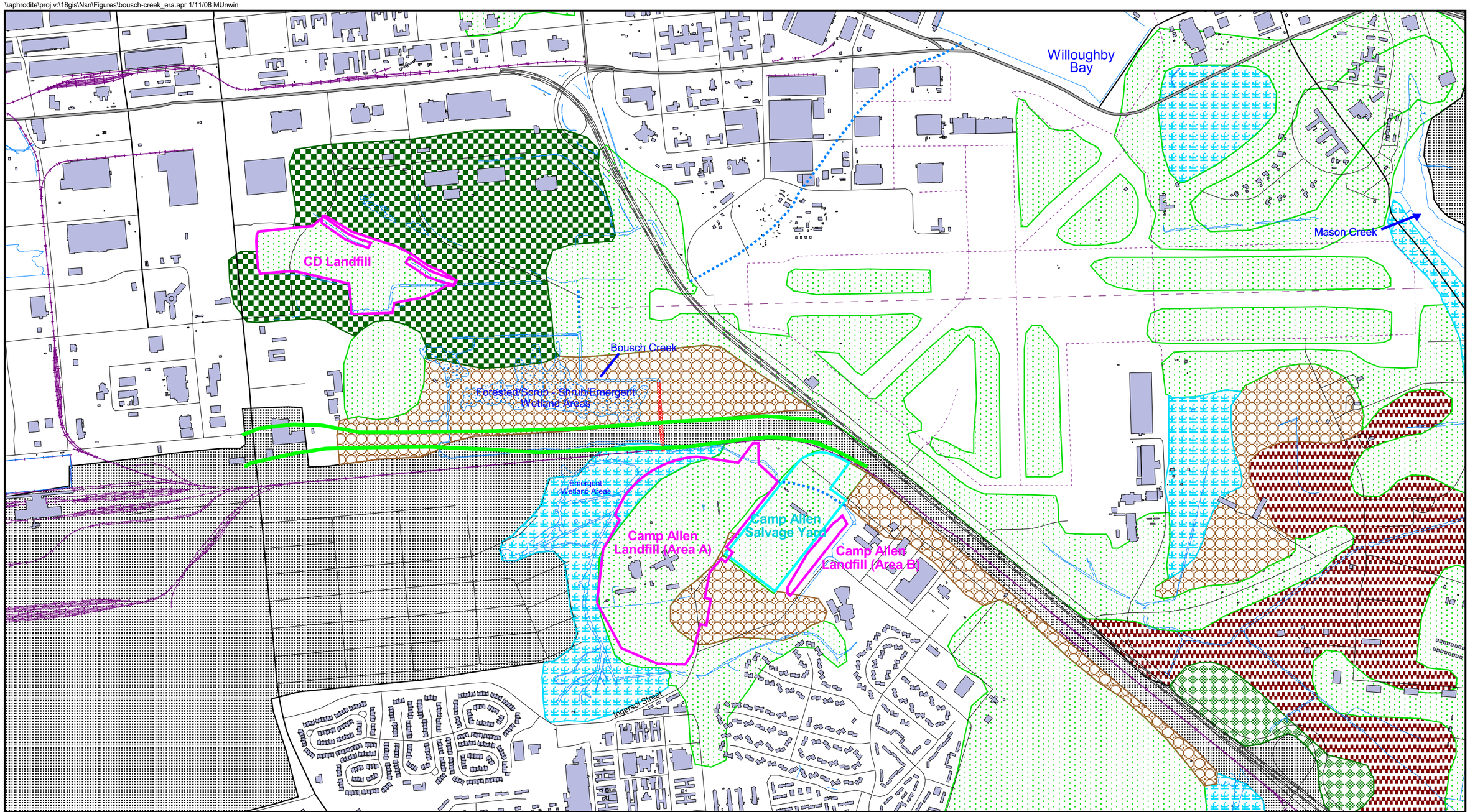

Legend

- Proposed I-564 Corridor (Approximate)
- Underground Culvert
- Concrete Lined
- Buildings

General Habitats

- Improved Fields
- Mixed Woods
- Off Base
- Pine Woods
- Semi-Improved Fields
- Unimproved Fields
- Wetlands
- Urban Areas

N

0 1000 2000 Feet

Figure 2-2
General Habitat Types
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, Virginia

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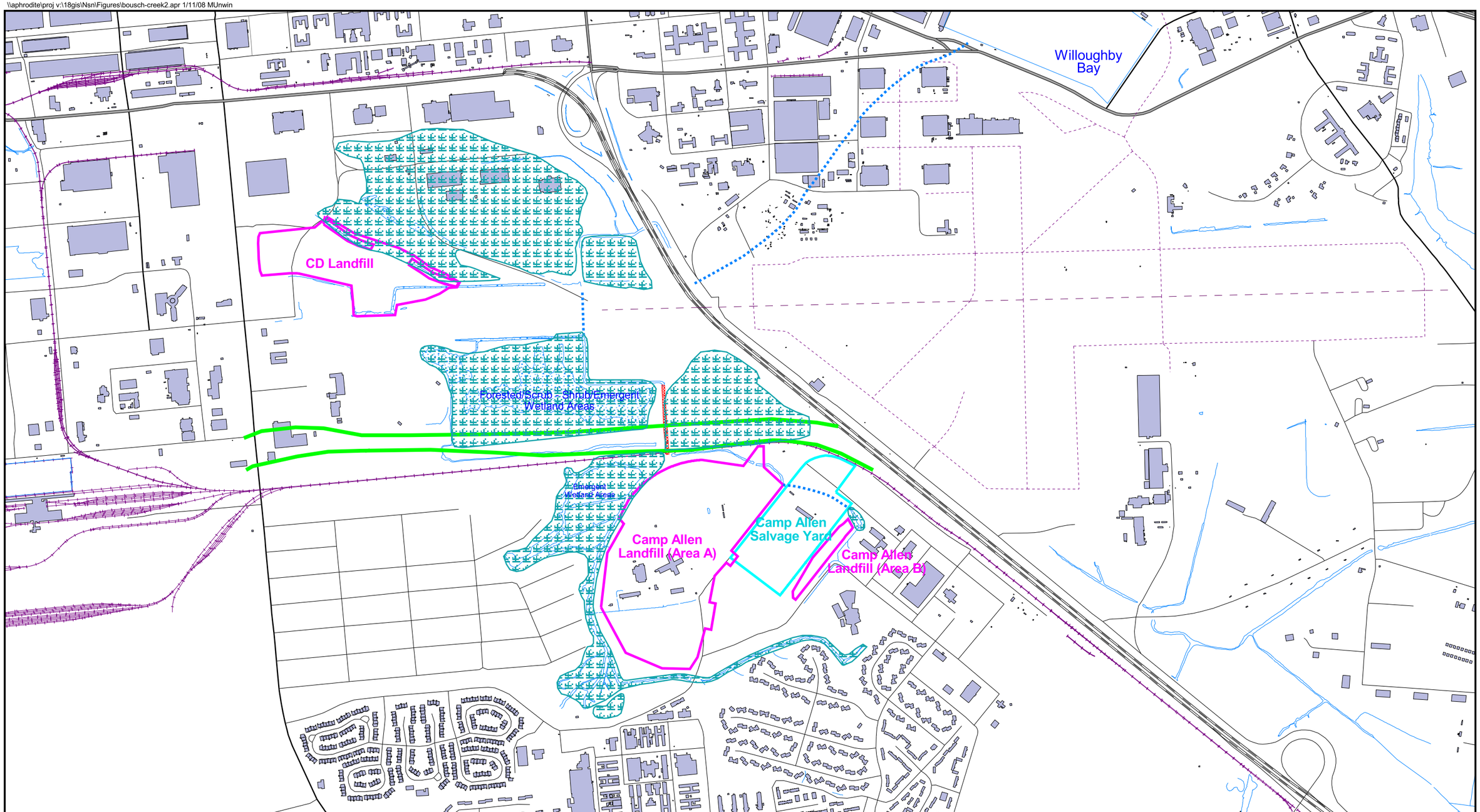

Legend

- Proposed I-564 Corridor (Approximate)
- Underground Culvert
- Concrete Lined
- Wetlands

N

0 1000 2000 Feet

Figure 2-3
Wetlands Associated with Bousch Creek
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, Virginia

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SECTION 3

Problem Formulation

Problem formulation establishes the goals, scope, and focus of the ERA. As part of problem formulation, the ecological setting of the Bousch Creek system is characterized in terms of the habitats and biota known or likely to be present. The types and concentrations of chemicals present in relevant media are also described based upon available analytical data. A conceptual model is developed that describes source areas, transport pathways and exposure media, exposure pathways and routes, and receptors. Assessment endpoints, measurement endpoints, and risk hypotheses are developed to evaluate those receptors for which critical exposure pathways exist. The fate, transport, and toxicological properties of the chemicals present in the Lower Reaches of Bousch Creek are also considered during this process.

3.1 Site Background and History

This section provides information on the Lower Reaches of Bousch Creek and the adjacent LP-20 area, which includes Installation Restoration Program (IRP) Sites 20 and 23. These sites, plus storm water flow, are the principal source areas in this reach of Bousch Creek.

3.1.1 Lower Reaches of Bousch Creek

During facility development in the early 1940s, portions of the Bousch Creek channel were filled and a concrete culvert was installed to provide drainage for the remnants of Bousch Creek. The headwaters of the creek consist of two branches which merge near the northwest corner of Camp Allen Landfill (CAL; Site 1). The creek then flows north (the creek channel is lined with concrete in this reach), then west, and then north again for about 2,000 feet before entering an underground culvert that transits the runway clear zone (Figure 1-2). Bousch Creek emerges from the underground culvert just north of the runway and flows north, then east, and then south before entering the 3,900-foot underground culvert which is referred to as the Lower Reaches of Bousch Creek. This underground culvert connects Bousch Creek to Willoughby Bay. Storm water flows from the entrance of the culvert at Outfall 400 and empties into Willoughby Bay through Outfall 115 (Figure 3-1).

Because the system is tidal, water flows from Willoughby Bay into the Bousch Creek system during the incoming portion of the tidal cycle. The concrete box culvert is 120 x 240 inches and extends northeast approximately 3,900 feet, ending at Willoughby Bay. Except for the two ends of the culvert, there are no known surface access points (such as manholes). A total of ten (underground) outfalls carry storm water into the Bousch Creek culvert within the Lower Reaches. Between Outfalls 400 and 115 lay Outfalls 408 through 414 and 417 through 419 (Figure 3-1).

3.1.2 Building LP-20 Site (Site 20)

Site 20, the Building LP-20 Site, is one of many large buildings located northwest of the main runway (Figure 1-1). Currently, the building houses the Public Works Center Transportation

Department. In the past, a portion of the building was used for aircraft engine overhaul and maintenance. Previous activities at the building included painting, x-ray facilities, cleaning and blasting, and a metal-plating operation. Waste products generated from these activities were transferred to the industrial wastewater treatment plant (WWTP) via underground piping. In addition, a large fuel storage area, known as the LP Fuel Farm, is also located south of the building. An underground pipeline extends from the Fuel Farm to Buildings LP-78 and LP-176 located east of the site. Over the years (1940s to 1990s), numerous spills or releases of wastewater and petroleum have been documented. Significant releases were associated with damage to underground wastewater lines during construction activities, and leakage of the underground petroleum pipeline (Baker Environmental, Inc., 1995). Currently, the building is used as a motor pool and for office space. Site 20 has been investigated as part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process and has an active remedy in place (see Section 3.4).

3.1.3 LP-20 Building Plating Shop (Site 23)

Site 23, the LP-20 Plating Shop, is located on the west side of Building LP-20 (Figure 3-1). Previous activities in the shop included disassembling, stripping, and re-plating metal parts. The shop contained seven process pits that extended beneath the concrete slab floor which were used for cleaning, stripping, and plating engine parts. The process tanks and equipment were also located in pits. The floor and pits were lined with corrosion resistant brick tiles. The shop also contained a drainage system for the collection of wastewater from the pits and delivery to the WWTP. In 2007, a removal action was conducted at Site 23 and a concrete floor was installed over the former plating shop floor and process pits. The site is now used for storage as warehouse space.

Site 23 is located within Site 20. As mentioned for Site 20, between the 1940s and 1990s, numerous spills or releases of wastewater and petroleum from the underground piping that extends from the Fuel Farm to Buildings LP-78 and LP-176 (east of the site) were reported. Significant releases were associated with damage to underground wastewater lines during construction activities and leakage of the underground petroleum pipeline. Site 23 has been investigated as part of the CERCLA process (see Section 3.4) and was closed out pursuant to a Record of Decision in 2009.

3.2 Ecological Setting

This section describes the ecological setting of the Bousch Creek system. The ecological setting for the entire NSN facility is provided in Section 2.

3.2.1 Habitats

Bousch Creek is located entirely on NSN, however, off-site runoff from Terminal Boulevard and the Glenwood Park Neighborhood, located to the southwest of the creek, drain into Bousch Creek. Additionally, groundwater discharges associated with the petroleum, oil, and lubricants remediation program also discharge into Bousch Creek. The creek channel has been significantly altered from historic conditions and most of the bordering vegetated wetlands have been filled as part of facility development. Currently, portions of the creek are lined or walled with concrete. The creek has been channelized over most of its length and it flows through underground culverts over part of its length. The Lower Reaches of

Bousch Creek are contained entirely within an underground concrete box culvert. Tidal water inundates Bousch Creek up to the point where Outfall 408 discharges into it (CH2M HILL, 1996).

The headwaters of the creek consist of two branches, the eastern branch, which flows west past the northern edge of the CAL, and the western branch, which flows west and then north along the southern and western edges of the CAL (Figure 3-2). Several small tributaries associated with bordering residential areas enter the western branch from the west. The two branches merge near the northwestern edge of the CAL. The creek then flows north (the creek channel is lined with concrete in this reach), then west, and then north again for about 2,000 feet before entering an underground culvert that traverses the overrun portion of the airfield runway. Three principal tributaries enter the creek from the west and one enters (through an underground pipe) from the east within this reach (Figure 1-2). Just downgradient of where Bousch Creek emerges from the concrete culvert, a tributary enters the creek from the west. The creek then flows north, then east, and then south before entering a 3,900-foot underground culvert (which comprises the Lower Reaches). Before the creek turns south, two tributaries that drain parking lots and commercial development enter the creek from the north. The downgradient end of the 3,900-foot underground culvert is the creek's outfall to Willoughby Bay (Outfall 115). Table 3-1 summarizes available habitat information from the Bousch Creek system.

Available data (Table 3-2) suggest that most of the remnant tributaries that comprise the Bousch Creek system are influenced by the daily tides. Exceptions include portions of the eastern branch of the creek, the extreme upper portions (east of Ingersol Street) of the western creek branch, and the upper portions of the four tributaries that enter the main creek channel from the west. Salinity is greatest in the lower portions of the creek complex (15 to 18 parts per thousand [ppt]) with the headwater areas (not regularly influenced by daily tidal flow) generally consisting of fresh water. The salinity in the Bousch Creek system also fluctuates based upon the point in the tidal cycle and the amount of freshwater input from precipitation events due to runoff.

Substrate type is somewhat variable within the creek system (Table 3-3) but most sediments are composed of fine sand and/or silt-clay, are soft and dark, are rich in organic matter (especially in the wetland areas), and give off a sulfide odor when disturbed. A few areas near roads are composed of mostly sand and are low in organic matter. Sediments in some areas of the creek had strong petroleum odors and released a visible sheen when disturbed. This typically occurred only in samples taken near the runway and near roadways (in particular, I-564). It is not known if the original bottom of the Lower Reach culvert is composed of concrete or consists of fill material placed in the area when the culvert was constructed. However, it is expected that some sediment has been deposited on the bottom of the culvert since it was constructed through tidal action and storm water inputs.

The LP-20 area originally consisted of a portion of the Bousch Creek channel. Following the channelization and filling of the Bousch Creek system, including the construction of the Lower Reach culvert, the LP-20 area was constructed as a maintenance facility for Base aircraft.

The area around the Building LP-20 site is almost completely developed, and few natural resources are present. The Naval Aviation Depot area itself has been highly disturbed due to

the construction of buildings, roads, and aircraft operations. Vegetation is currently limited to landscaped zones surrounding buildings and parking lots, or along roadways. All wetland areas formerly associated with Bousch Creek have been filled and none remain.

Willoughby Bay, at the downgradient end of the Lower Reaches of Bousch Creek, is a depositional area receiving tidal inflow from the James and Elizabeth Rivers and Chesapeake Bay. Surface water parameters were measured during a study performed by CH2M HILL in 1995. Samples were collected from one location in the center of Willoughby Bay during the spring, summer, and fall seasons at a depth of two to four meters. The sample location was established to minimize the influence of local discharges. The results show a slight variation in parameter measurements between seasons. Dissolved oxygen levels ranged from 8.6 milligrams per liter (mg/L) in the spring to 11.1 mg/L in the summer. The pH measured 7.8 in the spring, 8.5 in the summer, and 8.1 in the fall. Salinity measurements were the same in the spring and summer samples (23 ppt) with a slight decrease in the fall (20 ppt). The salinity profiles in the area during the sampling periods indicated that these waters were well mixed (CH2M HILL, 1999). Additional water column measurements were collected in the Bay near the Bousch Creek outfall during October 2009 sampling (Table 3-2). Salinity ranged from 11 to 15 ppt and pH was generally 8 or higher. The substrate in the immediate outfall area was littered with shellfish shells. Just outside of this area, surface sediments were composed mostly of fines (74 to 96 percent), total organic carbon (TOC) ranged from 2.4 to 4.5 percent, and pH ranged from 8.2 to 8.5 (Table 3-3). Sulfide levels were high enough such that Simultaneously Extracted Metals/Acid-Volatile Sulfide (SEM/AVS) ratios, an indicator of the bioavailability of certain metals, were well below one (indicating limited bioavailability).

3.2.2 Biota

Terrestrial biota within the Lower Reaches of Bousch Creek are expected to be limited in number and diversity due to the developed (industrial) nature of the area. The current land use in this area (industrial) is expected to remain the same for the foreseeable future.

The fish community throughout the Upper Reaches of the Bousch Creek system (Figure 3-2) was sampled in the fall of 2004 (see CH2M HILL, 2006a). No external physical abnormalities or lesions were observed in the fish collected from the Bousch Creek system in 2004. The resident fish community in Bousch Creek is composed of small fish species, primarily mummichogs (Table 3-4; Figure 3-2). Mummichogs were most abundant in the creek segments closest to the Willoughby Bay culvert (Figure 3-3). The mummichog (*Fundulus heteroclitus*) is an abundant permanent resident of the entire Chesapeake Bay. It is found in muddy marshes, channels, and grass flats. During the colder months, it may burrow in bottom silt or retreat to deeper waters. The mummichog is a typical resident of estuaries, particularly the mesohaline zone. This species can tolerate high temperatures, up to 34ºC at 14 percent salinity. Mummichogs feed on a wide variety of items, including small crustaceans, small mollusks, worms, insects, plants, algae, and other fishes (CH2M HILL, 2006a).

Larger fish species are relatively uncommon but include species such as striped mullet and spot. The presence of the 3,900-foot underground culvert connecting Bousch Creek to Willoughby Bay (the Lower Reaches) has likely discouraged the routine passage of the larger estuarine fish species like flounder and weakfish. Grass shrimp and blue crabs are

also present in the Upper and Upper-Middle Reaches of the creek (Table 3-4). Priest et. al. (2000) identified other aquatic species in Bousch Creek, including inland silverside (*Menidia beryllina*), bay anchovy (*Anchoa michilli*), menhaden (*Brevoortia tyrannus*), striped bass (*Morone saxatilis*), gizzard shad (*Dorosoma cepedianum*), and snapping turtle (*Chelydra serpentina*).

Benthic macroinvertebrates were sampled at 20 locations throughout the Upper Reaches of the Bousch Creek system in the fall of 2004 (CH2M HILL, 2006a). The Upper-Middle Reaches of the creek, where salinities are highest, were dominated by estuarine polychaetes (Table 3-5; Figure 3-4). Oligochaetes were generally dominant in the Upper-Middle and Upper Reaches where salinities were lower. Most of the taxa present within the system are relatively stress tolerant. Relatively few taxa were present at most locations, with only one or two taxa typically dominating the community at each location (Figures 3-5 and 3-6). Non-wetland areas within the Upper Reaches generally had the fewest taxa, but the highest densities, and were dominated by a single taxon, typically oligochaetes. The Upper-Middle Reaches of the creek typically had the greatest diversity of organisms (Table 3-6; Figure 3-7). The Lower Reaches were not accessibly for sampling but it is expected that the culvert area would support few if any macroinvertebrates, although these organisms are likely to be transported, seasonally, to and from the Upper and Upper-Middle Reaches via the culvert with the tidal flow.

3.2.3 Site Hydrogeology

Groundwater in the LP-20 area is sustained by precipitation and regional flow. In general, the unconfined aquifer is recharged by infiltration; the lower systems by regional flow and potentially from overlying units (Baker Environmental, Inc., 1996a). Recharge by infiltration at the site and surrounding areas is limited to unpaved areas. The construction and placement of the drainage network, particularly the Bousch Creek culvert, may also have effects on the localized movement of groundwater in the area; drainage lines could be partially permeable and locally intercept groundwater (ESE, 1991).

The depth to groundwater beneath the LP-20 area is typically five to six feet below ground surface (CH2M HILL, 2006b). General flow direction of the area groundwater was characterized during the Site 20 Remedial Investigation (RI) (Baker Environmental, Inc., 1996a). The groundwater flow across the site trends in a northeasterly direction, towards Willoughby Bay.

3.3 Summary of Available Analytical Data

A number of historical sampling events have occurred within the Bousch Creek system, although most of the available data are for the Upper Reaches of the creek near the CAL. A number of sampling events have occurred in the LP-20 area, which is adjacent to the Lower Reaches of Bousch Creek. Site 23 (LP-20 Plating Shop) is located within the boundary of Site 20 (the Building LP-20 Site), therefore, there may be an overlap in analytical data between the two sites.

To support this ERA of the Lower Reaches of Bousch Creek, seven sediment samples were collected in October 2009. The objective of the sediment sampling was to determine if IRP site releases have resulted in sediment contamination that poses an unacceptable ecological

risk in the Lower Reaches of Bousch Creek and/or subsequent transport to Willoughby Bay (in the vicinity of Outfall 115) at concentrations that may pose a potential ecological risk. These sediment samples are used in this ERA to determine if the magnitude and spatial distribution of sediment concentrations for analytical constituents (chemicals of concern; COCs) associated with known IRP source areas within the Bousch Creek system (a number of metals and pesticides, polychlorinated biphenyls [PCBs], polycyclic aromatic hydrocarbons [PAHs], and a number of volatile organic compounds [VOCs]) present a potentially unacceptable risk to ecological receptors that is related to current and/or former releases from IRP sites.

3.3.1 Bousch Creek

A number of sampling events have been conducted in the Bousch Creek system (Table 3-7), which mostly center on the CAL and the Camp Allen Salvage Yard (CASY). There are no known samples from the Lower Reaches of the system, although both surface water and sediment samples have been collected at both ends of the Lower Reach culvert. Samples in Willoughby Bay collected right at the Bousch Creek outfall are included in the Bousch Creek (not the Willoughby Bay) discussion.

Historical Sampling

The first known event for which analytical data are available is the Confirmation Study (CS) conducted by Malcom Pirnie in April 1987. The CS was conducted based upon the results of the 1983 Initial Assessment Study (IAS). The purpose of the IAS was to identify and assess sites posing a potential threat to human health or the environment due to contamination from past hazardous materials handling and operations activities. Eighteen potentially contaminated sites, including the CAL, were identified in the IAS based upon information obtained from historical records, photographs, site inspections, and personnel interviews. The IAS concluded that 6 of the 18 sites (including the CAL) posed sufficient threats to human health or the environment to warrant further evaluation in a CS. Four surface water samples were collected from Bousch Creek during each of four sampling events (December 1983, August 1984, April 1986, and June 1986) for the CS.

An Interim Remedial Investigation (IRI) of the CAL was conducted in 1991. During these IRI studies, sediment and surface water samples were collected at each of 12 locations in Bousch Creek. The data from this event were not validated. Three rounds of data (April, June, and December) were collected during 1992 as part of the RI for the CAL. Sixteen surface water and 34 sediment samples (27 shallow [0 to 6 inches] and 7 deep [6 to 12 inches]) were collected during Rounds 1 and 2, and five sediment samples (all shallow) were collected during Round 3. In August and September 1993, eight surface water, 13 surface (0 to 3 inches) sediment, and eight subsurface (24 to 30 inches) sediment samples were collected along tributaries of Bousch Creek adjacent to the CD Landfill as part of the RI for that site.

Data were collected in February and March 1997 to support a SERA for Bousch Creek, as related to the CAL. Data included 30 surface water samples (collected during low and high tides at each of 15 locations) and 15 shallow (0 to 4 inch) sediment samples. Similarly, data were collected in November 1999 to support the Step 3 BERA for Bousch Creek. Data from this event were limited to sediments and included 25 shallow (0 to 6 inches) and 4 deep (6 to 18 inches) samples. Based upon the results of the Step 3 BERA, Step 4-6 studies were scoped.

These studies were implemented in November-December 2004 and consisted of the collection of five surface water samples, 28 surface sediment samples, five sediment cores (with samples collected at six-inch increments within each two-foot core), and 10 whole-body fish tissue samples.

Sampling locations are shown on Figures 3-8 through 3-10. Results for surface water and surface sediment samples collected at the Willoughby Bay end of the culvert in 1997 are summarized in Tables 3-8 and 3-9, respectively. In surface water, only copper was notably elevated relative to surface water screening values. In sediment, mercury was notably elevated relative to sediment screening values. Results from surface water and surface sediment samples collected in the Upper-Middle Reaches of Bousch Creek nearest the upgradient end of the culvert (Zone 8) are summarized in Tables 3-10 and 3-11, respectively. In surface water, only copper was notably elevated relative to surface water screening values. In sediment, cadmium and PAHs were notably elevated relative to sediment screening values. Results from 2004 fish tissue sampling for the Upper and Upper-Middle portions of the Bousch Creek system are summarized in Table 3-12. No chemical was notably elevated relative to screening values.

Table 3-13 summarizes the results of benthic invertebrate toxicity tests for the Upper and Upper-Middle Reaches of Bousch Creek. Tables 3-14 and 3-15 summarize the results of the BERA for the Upper Reaches of the creek (CH2M HILL, 2006a).

October 2009 Sampling

The approach and methods used to conduct the sediment sampling were outlined in the *Final Lower Reaches of Bousch Creek, Naval Station Norfolk, Norfolk, Virginia, Sampling and Analysis Plan (Field Sampling Plan and Quality Assurance Project Plan)* (CH2M HILL, 2009), hereafter referred to as the SAP. In October 2009, surface sediment samples (0 to 6 inches) were collected with a Ponar dredge and analyzed for target analyte list (TAL) metals, target compound list (TCL) pesticides and PCBs, TCL PAHs, TCL VOCs, TOC, pH, AVS/SEM, and grain size. Water column parameters (conductivity, pH, dissolved oxygen, oxidation-reduction potential [ORP], turbidity, and temperature, as well as water depth and point in the tidal cycle) were measured in the field at each sediment sampling location from three depths within the water column (surface, mid-depth, and bottom). Field measurements of salinity were inadvertently omitted during the October 2009 sampling but measurements were taken in January 2010 during a similar point in the tidal cycle. All sediment data were validated by a third party validator.

Seven surface sediment samples were collected (Figure 3-11), six in Willoughby Bay in the vicinity of the Bousch Creek outfall (Outfall 115) and one at the upper end of the Bousch Creek culvert (Outfall 400, where the Lower Reaches begin). The Willoughby Bay sample locations departed from the locations proposed in the SAP due to the conditions encountered in the field. It was deemed unsafe to attempt sediment collection within the confines of the culvert near Outfall 115. Also, the area in the immediate vicinity of Outfall 115 in Willoughby Bay was covered with a high density of oyster and mussel shells, which made the collection of samples (with either a dredge or corer) very difficult. Thus, sediment samples were collected near the edge of this area, where the lower density of shells allowed a Ponar dredge to be successfully deployed (see Figure 3-11). A member of the Region 3 Biological Technical Assistance Group (BTAG) was present during the sampling and helped

in the selection of the revised sediment sampling locations. The results of the October 2009 sediment sampling are discussed in Section 6. Analytical data are presented in Attachment B.

3.3.2 Sampling in Willoughby Bay

Several investigations including the sampling of sediment, surface water, and aquatic biota have been performed in Willoughby Bay. However, these data are not relevant to this ERA due to the location and/or age of the data. Details on the sampling conducted during these investigations are presented in Attachment A.

3.3.3 LP-20 Area Investigations

A number of investigations have occurred in the LP-20 area. However, none of these data are relevant to this ERA due to the medium sampled, the locations of the samples, and/or the age of the data. Details on the sampling conducted during these investigations are presented in Attachment A.

3.3.4 LP- 20 Plating Shop (Site 23) Investigations

Several investigations have occurred at Site 23 (LP-20 Plating Shop). However, none of these data are relevant to this ERA due to the medium sampled, the locations of the samples, and/or the age of the data. Details on the field activities conducted at the LP-20 Plating Shop are presented in Attachment A.

3.4 Conceptual Model

The conceptual model relates potentially exposed receptor populations with potential source areas based upon physical site characteristics and complete exposure pathways. Important components of the conceptual model are the identification of potential source areas (including non-site-related sources), release mechanisms and transport pathways, exposure media, exposure pathways and routes, and receptor groups. Actual or potential exposures of ecological receptors associated with a source are determined by identifying the most likely, and most important, pathways of contaminant releases and transport. A complete exposure pathway has three components: (1) a source of chemicals that results in a release to the environment; (2) a pathway of chemical transport through an environmental medium; and (3) an exposure or contact point for an ecological receptor. Figures 3-12 and 3-13 illustrate a diagrammatic and graphic conceptual model for Bousch Creek, respectively. Key components of this conceptual model are discussed in the following subsections.

3.4.1 Potential Source Areas/Contaminant Inputs

A number of potential point and non-point sources are present in the watersheds of Bousch Creek and Willoughby Bay. These source areas are discussed in the following subsections.

Outfalls

Twenty-nine outfalls discharge directly to Bousch Creek between its headwaters near the CAL and its confluence with Willoughby Bay. Figure 3-1 shows the locations of the storm water outfalls adjacent to the culvert (i.e., within the Lower Reaches). Most of these outfalls

carry storm water runoff not associated with a regulated industrial activity. Some of these outfalls carry storm water runoff from airfield and vehicle maintenance activities. Only one of the 29 Bousch Creek outfalls (Outfall 408) is associated with industrial drainage. Outfall 408 is permitted under the Virginia Pollution Discharge Elimination System (VPDES) program but monitoring is not required. This outfall is associated with storm water runoff and industrial drainage from the LP area of the facility. Principal activities associated with the LP area included aircraft maintenance hangers (Buildings LP-20 and LP-22), which are now vehicle maintenance facilities, and fuel storage facilities. Contaminated groundwater in this area is being addressed under a Corrective Action Plan (CAP), which includes free product recovery and monitoring, as well as a CERCLA remedy consisting of an air sparging/soil vapor extraction (AS/SVE) system.

Listed Sites

In this ERA, listed sites are defined as sites with recorded releases or sites that have the potential to release hazardous substances as defined by federal and state regulatory programs (CERCLA, Resource Conservation and Recovery Act [RCRA], Aboveground Storage Tank (AST) programs, and Underground Storage Tank [UST] programs) or listed in federal or state databases (LTANKS, SSTS, FIFRA, TSCA, and EPCRA). Table 3-16 lists the type and number of listed sites located within the Bousch Creek Drainage Basin. Locations of these listed sites are shown on Figure 2-1, which were compiled as part of a Watershed Contaminated Source Document conducted in 2003 for Willoughby Bay (CH2M HILL, 2003).

The listed sites associated with the Lower Reaches of Bousch Creek Drainage Basin are presented on Figure 3-1. In addition, Table 3-17 identifies the type of constituents associated with each listed site. The majority of the sites listed have petroleum products as an associated constituent (CH2M HILL, 2003).

The principal source area related to IRP sites in the Lower Reaches of Bousch Creek located adjacent to the 3,900-foot underground culvert is the LP-20 area (Sites 20 and 23). A more detailed description of Sites 20 and 23 (including associated constituents of concern) is provided in Attachment A. As discussed in the Step 7 BERA for the Upper Reaches (CH2M HILL, 2006a), all of the IRP-related sources in the Upper Reaches have been remediated (CAL, CASY, and CD Landfill). Remedial actions to address sediment in portions of the Upper Reaches have also been completed.

Other Water Bodies

As discussed previously, the Lower Reaches of Bousch Creek are tidally influenced through its connection with Willoughby Bay. The water quality of Willoughby Bay is significantly influenced by adjacent waters to which it directly or indirectly connects (the James River, Elizabeth River, and Chesapeake Bay), portions of which are documented to be substantially contaminated (CH2M HILL, 2003). The location of these water bodies in relation to Bousch Creek is shown on Figure 1-1. Activities in Willoughby Bay that have the potential to impact water within the Lower Reaches of Bousch Creek are described below.

Dredging/Waterfront Construction Activities

Possible contaminant release/mobilization can result from dredging or waterfront construction activities within or surrounding Willoughby Bay. These types of activities may

contribute potentially contaminated substances from construction material, equipment emissions, or disturbance of sediments containing contaminants. Dredging activities have the potential to affect water within the Bousch Creek culvert. Permits authorizing activities such as dredging and waterfront construction of breakwaters, terminal groins, and piers are obtained from the U.S. Army Corps of Engineers. The need for analytical testing of the dredged material is determined as part of the permitting process.

Navigation Waterways

There are two navigation channels into Willoughby Bay. The one to the north extends to and from the water in Hampton Roads to the tip of Willoughby Spit. The channel is 10 feet deep at mean low water, 300 feet wide, and 1.5 miles long. The channel to the southwest is about one mile long and extends to and from the water in Hampton Roads to the marina at NSN. Potential contaminant sources include chemicals and waste on ships as well as the materials transported across these waterways.

Boats and Piers

Two marinas are located in Willoughby Bay. A public marina is located in the westernmost portion of Willoughby Spit and the other in the northwestern portion of NSN. Potential contaminant sources include chemicals and wastes carried on boats (fueling and maintenance), as well as creosote from wood preservatives found in pilings (Swihart, 2000). Activities at the public marina that have the potential to pollute the Willoughby Bay water and sediments include high pressure washing, painting, paint stripping, and engine repair.

Other Sources

A potential source of contamination to Willoughby Bay and Bousch Creek is Interstate 64 and 564. I-64, which is a major transportation artery, is located along Willoughby Spit, while I-564 crosses Bousch Creek near the downgradient end of the Lower Reaches (Figure 1-1). Road construction materials, surface water runoff, spills, and vehicle discharges are all possible sources of contamination from these roadways. In addition, contaminants may enter Willoughby Bay and the Bousch Creek system through general atmospheric deposition.

3.4.2 Release Mechanisms and Transport Pathways

A transport pathway describes the mechanisms whereby source-related chemicals, once released, may be transported from a source to an exposure medium, such as sediment, where exposures can occur. These transport pathways are shown on Figures 3-12 and 3-13.

A number of potential release mechanisms associated with both historical and current site operations in the LP-20 area and the Bousch Creek watershed could result in the release and transport of chemical constituents from source areas into the Lower Reaches of Bousch Creek. The potential release mechanisms and transport pathways are:

- Leaching of chemicals from soil and/or waste materials by precipitation and subsequent transport by surface runoff, either overland or via the storm water system, to Bousch Creek. This is the primary historical transport pathway in the Upper Reaches of the creek (e.g., CAL, CASY, and CD Landfill), but is currently a minor pathway in the Lower Reaches based upon the current site configuration (mostly covered by buildings or pavement).

- Leaching of chemicals from soils and/or waste materials by infiltrating precipitation and transport to Bousch Creek via groundwater. This was a historical pathway in the Upper Reaches (particularly for the CAL) and is a current potential pathway in the Lower Reaches for petroleum-related chemicals. Based upon available information for the Lower Reaches, this typically involves the lighter weight petroleum components (such as benzene, toluene, ethylbenzene, xylene [BTEX] and naphthalene), which typically have lower toxicity to aquatic receptors and are not very persistent once discharged to a surface water body. The CAPs in the LP-20 area, particularly the groundwater treatment system, reduce the significance of this pathway in the Lower Reaches of Bousch Creek.
- Leaks and spills from aboveground storage tanks, process equipment, and process areas to surface and subsurface soil, including releases inside former or current buildings that could migrate to the environment through cracks in building floors or leaks from floor drains and associated piping. The CAPs in the LP-20 area, particularly the groundwater treatment system, reduce the significance of this potential pathway in the Lower Reaches of Bousch Creek.
- Leaks to subsurface soil and groundwater from underground storage tanks and associated piping. The CAPs in the LP-20 area, particularly the groundwater treatment system, reduce the significance of this potential pathway in the Lower Reaches of Bousch Creek.
- Spills and leaks associated with the airfield and roads, and transport via surface runoff, either overland or via the storm water system, to Bousch Creek. Recently completed removal actions (sediment excavation) in portions of the creek near the Lower Reach culvert will reduce potential transport and exposures from the PAHs formerly present in these sediments. Although these PAHs are not known to be related to an IRP source area, this removal action was undertaken as part of the same mobilization as the Upper Reach sediment removal action related to the CAL.
- Off-base contaminants transported via storm water runoff from terrestrial areas and via tidal flow through the Willoughby Bay outfall into Bousch Creek. Recently completed removal actions (sediment excavation) in portions of the Upper Reaches will reduce the already low potential for transport via tidal flow from the Upper to the Lower Reaches and Willoughby Bay.
- Contaminants in air from upgradient sources (such as power plants) can be directly deposited onto the surface water and sediments of Bousch Creek and/or Willoughby Bay or first deposited onto surface soil and eventually discharged into Bousch Creek and/or Willoughby Bay through groundwater or surface runoff.
- Uptake by biota from surface soil, sediment, and/or surface water and trophic transfer to upper trophic level receptors. This pathway was important for portions of the Upper Reaches (although risks were acceptable for this pathway) but is generally insignificant in the Lower Reaches.

Once within the Bousch Creek system, contaminants are transported in surface water according to specific hydrodynamic processes, particularly tidal movement. Possible sediment fate and transport processes in the creek are bed load transport or deposition,

sediment burial, and re-suspension of sediment into the water column, although available data suggest relatively little deposition throughout most of the Bousch Creek system due to its low energy nature (small topographic gradient and the attenuating effect of the Lower Reach culvert on tidal flow velocity). Dredging activity is not a significant factor in the Bousch Creek system.

Once contaminants have entered Bousch Creek, fate and transport in the water column is controlled by the residence time and movement of water in the creek (i.e., flushing time and tidal mixing), partitioning of metals and organic compounds to particles, and residence time of suspended particulate matter in the water column. Contaminants bound to particles may settle out and deposit on the creek bottom, where these are subject to re-suspension, bed load transport, or burial. Organic contaminants are subject to various physical, chemical, and biological degradation mechanisms.

Fate and Transport Mechanisms

The physico-chemical properties of source-related compounds are important in terms of the magnitude, speed, and mechanisms of transport, as well as the potential to persist in the various environmental compartments. These properties also strongly influence the uptake, accumulation, and toxicity of the compounds.

The transport and partitioning of chemicals into particular environmental media, and the ultimate fate in those media, can be predicted from key physico-chemical characteristics. The physico-chemical characteristics that are most relevant for exposure modeling include volatility, water solubility, adsorption to solids, octanol-water partitioning, and degradability.

3.4.3 Exposure Media

Exposure media for ecological receptors are typically limited to surface water, surface sediment, and surface soil. Groundwater is generally considered only as a transport medium since there are no ecological exposures to groundwater until it discharges to a water body or surfaces as a seep. Air is not addressed in the ERA because this medium is not likely to result in significant contributions to total exposure at the facility given the nature of the known source areas. Surface soils are not an important exposure medium in the Lower Reaches due to the developed nature of the area and the resulting lack of habitat for most terrestrial receptors. The primary exposure medium in the Lower Reaches is surface water, and to a lesser degree, sediment.

3.4.4 Exposure Pathways and Routes

An exposure pathway links a source with one or more receptors through exposure via one or more media and exposure routes. Exposure, and thus potential risk, can only occur if complete exposure pathways exist. An exposure route describes the specific mechanism(s) by which a receptor is exposed to a chemical present in an environmental medium. Figures 3-12 and 3-13 show the potentially complete exposure pathways, and the exposure routes, to ecological receptors in Bousch Creek.

Terrestrial exposure pathways in the Lower Reaches of Bousch Creek (LP-20 area) are not significant due to the developed (industrial) nature of the area. Land use in this area is expected to remain industrial.

Potentially complete exposure pathways to lower trophic level aquatic receptors (fish and benthic invertebrates) may exist (from direct contact, primarily with surface water) as these organisms pass through the culvert but are expected to be minimal. However, these organisms could be exposed, particularly to sediments, at the points immediately adjacent to the outfalls to the Upper Reaches of Bousch Creek and to Willoughby Bay. Because the entire portion of the Lower Reaches is underground, there are no potential exposure pathways to upper trophic level receptors (such as birds and mammals) other than predatory fish.

3.4.5 Receptors

The Lower Reaches of Bousch Creek consist of a concrete box culvert approximately 3,900 feet in length. The culvert would not support an aquatic population because of its physical nature, although fish are known to pass through the culvert with the tidal cycle and aquatic invertebrates are likely to as well during dispersal. These are the only receptors that are likely to be applicable to this ERA.

3.4.6 Endpoints and Risk Hypotheses

The conclusion of the problem formulation includes the selection of ecological endpoints and risk hypotheses, which are based upon the conceptual model. Two types of endpoints, assessment endpoints and measurement endpoints, are defined as part of the ERA process (USEPA, 1997). An assessment endpoint is an explicit expression of the environmental component or value that is to be protected. A measurement endpoint is a measurable ecological characteristic that is related to the component or value chosen as the assessment endpoint. The considerations for selecting assessment and measurement endpoints are summarized in USEPA (1997) and discussed in detail in Suter (1989, 1990, 1993). Risk hypotheses are testable hypotheses about the relationship among the assessment endpoints and the predicted responses when exposed to contaminants.

Endpoints define ecological attributes that are to be protected (assessment endpoints) and measurable characteristics of those attributes (measurement endpoints) that can be used to gauge the degree of impact that has or may occur. Assessment endpoints most often relate to attributes of biological populations or communities, and are intended to focus the risk assessment on particular components of the ecosystem that could be adversely affected by chemicals attributable to a site (USEPA, 1997). Assessment endpoints contain an entity (e.g., fish population) and an attribute of that entity (e.g., survival rate). Individual assessment endpoints usually encompass a group of species or populations (the receptor) with some common characteristic, such as specific exposure route or contaminant sensitivity, with the receptor then used to represent the assessment endpoint in the risk evaluation.

Assessment and measurement endpoints may involve ecological components from any level of biological organization, from individual organisms to the ecosystem itself. Effects on individual organisms are important for some receptors, such as rare and endangered species; population- and community-level effects are typically more relevant to ecosystems.

Population- and community-level effects are usually difficult to evaluate directly without long-term and extensive study. However, measurement endpoint evaluations at the individual level, such as an evaluation of the effects of chemical exposure on reproduction, can be used to predict effects on an assessment endpoint at the population or community level. In addition, use of criteria values designed to protect the majority of the components of a community (e.g., Ambient Water Quality Criteria for the Protection of Aquatic Life) can be useful in evaluating potential community- and/or population-level effects.

Table 3-18 shows the assessment endpoints, risk hypotheses, and measurement endpoints used in the ERA. Table 3-18 also shows the receptors associated with each endpoint. Fish and aquatic invertebrates are possible assessment endpoints, although potential exposures within the Lower Reaches are expected to be transitory and minimal. Thus, there are no significant exposure points present for these receptors within the Lower Reaches. However, these organisms could be exposed at the points immediately adjacent to the outfalls to the Upper Reaches of Bousch Creek and to Willoughby Bay.

Table 3-1
Habitat Information
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Location	Area / Zone	Date	Tide	Channel Width (m)	Water Depth (m)	Sediment Description	Habitat Description
SD97-14	Bay	3/9/1997	Low/Ebb	--	1.42	Silty clay with intermixed shell fragments; light brown to dark gray	NA
		3/9/1997	High/Flood	--	2.59		
SD97-15	Upper-Middle - 8	3/9/1997	Low	NA	0.03	Silty clay; grading to clean poorly sorted sand; dark gray; no odor	NA
		3/9/1997	High/Flood	NA	0.24		
SD99-15A	Upper-Middle - 8	11/18/1999	Low/Ebb	8.0	0.41	Black organic muck; some fine sand; no odors; no sheens (hard and sandy at bank)	Creek channel unvegetated; banks densely vegetated with woody shrubs, grasses, and Phragmites; rip-rap on north/west banks (at bend)
SD99-15B						Black muck (silt-clay); some fine sand; no odors; no sheens	
SD99-16A	Upper-Middle - 8	11/18/1999	High/Flood	20	0.49	Soft; dark brown to black; silt-clay muck and sand; very slight sulfide odor; no sheen	Creek channel unvegetated; banks steep; banks covered with rip-rap (mostly on west side) and scattered woody/herbaceous vegetation; near I-564; surrounding areas mowed lawn
SD99-16B						Firm; slate gray; clay mixed with small amounts of sand (transition to clay occurs at 6 to 7 inch mark in core); no odor	
SD99-17	Upper-Middle - 8	11/18/1999	High/Flood	20	0.46	Black to brown; silt-clay, sand, detritus (sticks/leaves), and some gravel (likely pieces of rip-rap); strong petroleum odor; oily sheen when sediments disturbed	Creek channel unvegetated; banks steep; banks covered with rip-rap (mostly on west side) and scattered woody/herbaceous vegetation; near I-564 and runway; surrounding areas mowed lawn
SD99-18A	Upper-Middle - 8	11/18/1999	Mid/Ebb	15	0.37	Coarse sand and small amounts of muck; tan to black; slight sulfide odor; no sheen	Creek channel unvegetated; banks densely vegetated with woody shrubs, grasses, and Phragmites
SD99-18B						Coarse sand; tan to dark brown/black; minimal organic matter; no odors	
SD99-25	Upper-Middle - 8	11/18/1999	Mid/Ebb	8.0	0.22	Black muck (silt-clay); some sand; no odors; no sheens	In side channel which enters Bousch Creek from the north; channel unvegetated; banks fairly steep and vegetated with woody shrubs and herbaceous plants; storm water culverts present

Table 3-1
Habitat Information
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Location	Area / Zone	Date	Tide	Channel Width (m)	Water Depth (m)	Sediment Description	Habitat Description
SD04-01	Upper-Middle - 8	11/19/2004	Mid/Ebb	20	0.25 - 1.10	Banks scoured sand; black silty clay in center of channel; sheen observed when sediments disturbed along shoreline	Rip-rap banks with mowed grass
SD04-02	Upper-Middle - 8	11/19/2004	Low/Ebb	18	0.50 - 0.70	Black silt-clay with a trace of sand	Rip-rap banks with mowed grass
SD04-03	Upper-Middle - 8	11/18/2004	Mid/Ebb	13	0.45	Sand with some silt	Rip-rap banks with grass and small shrubs
SD04-03	Upper-Middle - 8	11/19/2004	High/Ebb		2.40		
SD04-19	Upper-Middle - 8	11/18/2004	Low/Ebb	2.5	<0.02	Center channel scoured sand; banks silt with some fine sand, sand below 2 inches	Phragmites and grass/shrubs on banks
SD04-20	Upper-Middle - 8	11/18/2004	Low/Ebb	NA	NA	Center channel scoured sand; banks mostly silt and detritus	Phragmites on banks
SD99-14	Upper-Middle - 7	11/16/1999	High/Ebb	4.5	0.42	Black to brown; organic muck (silt-clay); some sand and silt; strong petroleum odor; heavy oil sheen when sediments disturbed	Side channel off Bousch Creek (from CD Landfill); channel unvegetated; banks dense Phragmites and woody shrubs; surrounding areas mowed (runway)
SD04-04	Upper-Middle - 7	11/17/2004	High	7.0	0.65 - 0.80	NA	Phragmites and Spartina on banks with some small trees and shrubs
SD99-10	Upper-Middle - 6	11/18/1999	Mid/Flood	4.0	<0.01	Firm; black to brown silt with detritus; some iron floc; slight sulfide odor; iron sheen	Side channel off creek; channel unvegetated; banks vegetated with Phragmites and woody shrubs
SD99-11	Upper-Middle - 6	11/18/1988	Low/Flood	8.0	0.26	Soft; black to brown; organic muck (silt-clay) and silt; sulfide odor; slight sheen	Creek channel unvegetated; rip-rap on both banks (at bend); banks sloped and covered with Phragmites, woody shrubs, and brambles
SD99-12A	Upper-Middle - 6	11/18/1999	Low/Ebb	6.0	0.15	Black organic muck (silt-clay); detritus; moderate sulfide odor; no sheens	Side channel off Bousch Creek; channel choked with Phragmites; dense Phragmites along banks; trees and shrubs (south) and mowed grass (north) in surrounding area
SD99-12B						Black organic muck (silt-clay); moderate sulfide odor; no sheens	
SD99-13	Upper-Middle - 6	11/18/1999	Low/Ebb	2.5	0.02	Soft; mixture of muck (silt-clay), sand, and detritus; dark brown; sulfide odor; no sheen	Side channel off Bousch Creek; narrow unvegetated channel; dense Phragmites along banks; trees and shrubs (south) and mowed grass (north) in surrounding area

Table 3-1
Habitat Information
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Location	Area / Zone	Date	Tide	Channel Width (m)	Water Depth (m)	Sediment Description	Habitat Description
SD99-09	Upper-Middle - 6	11/18/1999	No flow	--	<0.01	Firm to hard; layer of organic muck (silt-clay) and detritus atop clay; iron floc/staining; no odors; iron sheen	Side channel off creek where channel loses definition; vegetated with dense Phragmites
SD04-05	Upper-Middle - 6	11/17/2004	Mid/Flood	8.0	0.40 - 1.30	Very dark silty organic muck; no odor	Creek channel unvegetated; rip-rap on both banks (at bend); banks sloped and covered with Phragmites, woody shrubs, and brambles
SD04-A	Upper-Middle - 6	11/17/2004	Mid/Flood	2.5	0.60 - 1.00	Black silt-clay	Phragmites and Spartina on banks with some small trees and shrubs
SD04-B	Upper-Middle - 6	11/18/2004	--	--	0.00	NA	Dense Phragmites
SD04-C	Upper-Middle - 6	11/18/2004	Low/Ebb	0.3	0.15	Clay and silt with some fine sand	Dense phragmites
SD97-01	Upper - 5	3/9/1997	High/Ebb	NA	0.84	Fine organic silty clay with some sand; black-gray; wet; no odor	1 to 2 feet of soft sediment atop concrete
		3/7/1997	Low/Flood	NA	0.15		
SD97-02	Upper - 5	3/7/1997	Low/Ebb	NA	0.18	Fine organic silty clay with abundant 0.5 inch diameter cobbles (rip-rap); black-gray; very wet; no odor	1 to 2 feet of soft sediment atop concrete
		3/8/1997	High/Flood	NA	0.53		
SD99-04	Upper - 5	11/17/1999	Low/Ebb	6.0	0.20	Mix of coarse sand and organic black muck (silt-clay); black to brown; strong sulfide odor; no sheen; trash present (e.g., bottles, a tire) in channel	Unvegetated channel with linear concrete banks
SD99-06	Upper - 5	11/17/1999	Low/Flood	4.5	0.02	Soft organic muck (silt-clay); black to brown; sulfide odor; no sheens	Side channel off Bousch Creek; channel unvegetated; banks dense Phragmites and woody shrubs; small fish abundant in small pools of water remaining from last tidal cycle
SD99-07	Upper - 5	11/17/1999	Low/Slack	6.0	0.50	Mix of coarse sand and organic black muck (silt-clay); detritus (leaves) present on sediment surface; black to brown; strong sulfide odor; slight petroleum odor; no sheen; crab shells present	Unvegetated channel with linear concrete banks; security fence across channel
SD99-08	Upper - 5	11/17/1999	Low/Flood	8.0	0.32	Very soft, black organic muck (silt-clay) with a few streaks of brown-red clay; sulfide odor; no sheens	Channelized reach just past where concrete banks end; banks with scattered rip-rap; Phragmites and woody shrubs above high tide line; apparent storm water outfall pipe enters at opposite bank at channel bend

Table 3-1
Habitat Information
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Location	Area / Zone	Date	Tide	Channel Width (m)	Water Depth (m)	Sediment Description	Habitat Description
SD04-06	Upper - 5	11/16/2004	Low	8.0	1.00	Silt with some clay and a trace of sand; some shells; 0.5" detritus layer	Spartina and Phragmites on rip-rap bank
SD04-07	Upper - 5	11/15/2004	Mid/Flood	6.0	0.40 - 1.20	Very dark silty sand with trace of clay; soft and highly organic; strong petroleum and sulfide odor	Unvegetated channel with linear concrete banks; security fence across channel
SD04-08	Upper - 5	11/30/2004	Mid/Flood	8.25	0.25 - 0.80	Black organic silt-clay with trace of sand; sand increases with depth	Unvegetated channel with linear concrete banks
SD04-08	Upper - 5	11/19/2004	Mid/Ebb		0.15		
SD04-E	Upper - 5	12/1/2004	Mid/Ebb	2.1	0.25	Soft black silt-clay	Banks contain shrubs, Phragmites, and Spartina
SD97-03	Upper - 4	3/7/1997	Low/Ebb	NA	0.03	Fine organic silty clay; black-gray; very wet; no odor	0.5 to 2 feet of soft sediment atop concrete
		3/8/1997	High/Flood	NA	0.51		
SD97-04	Upper - 4	3/8/1997	Low/Ebb	NA	0.15	Silty clay; black/brown; wet; no odor	NA
		3/8/1997	High/Flood	NA	0.48		
SD97-05	Upper - 4	3/8/1997	Low/Ebb	NA	0.08	Silty clay; black/gray/green; wet; no odor	NA
		3/9/1997	High/Flood	NA	0.28		
SD99-02	Upper - 4	11/19/1999	Low/Ebb	4.0	0.01	Sediment soft and mucky; black silty clay; strong sulfide odor	Unvegetated side channel off Bousch Creek in emergent wetland; surrounding vegetation mostly Phragmites with Spartina present closer to Bousch Creek
SD99-03	Upper - 4	11/17/1999	Low/Ebb	6.0	0.10	Sediments very soft and mucky; black to brown; organic with high fine content; strong sulfide odor; no sheens when sediments disturbed	Unvegetated channel on wetland edge; banks vegetated mostly with dense Phragmites
SD99-19	Upper - 4	11/19/1999	Low/Ebb	--	0.00	Firm; wet; dense root mat; dark brown; highly organic silty clay; slight sulfide odor	Phragmites emergent wetland
SD99-20	Upper - 4	11/19/1999	Low/Ebb	--	0.00	Firm; saturated; dense root mat; black, highly organic silty clay with shallow layer of brown silt on top; strong sulfide odor	Spartina alterniflora emergent wetland
SD99-21	Upper - 4	11/19/1999	Low/Ebb	--	0.01	Firm; saturated; dense root mat; black; highly organic silty clay; sulfide odor	Spartina patens emergent wetland with small open pools
SD99-22	Upper - 4	11/19/1999	Low/Ebb	--	0.01	Firm; saturated; dense root mat; black organic silty clay; strong sulfide odor	Phragmites emergent wetland
SD99-23	Upper - 4	11/19/1999	Low/Ebb	--	0.00	Firm; saturated; dark brown to black organic silty clay; moderate sulfide odor	Phragmites emergent wetland

Table 3-1
Habitat Information
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Location	Area / Zone	Date	Tide	Channel Width (m)	Water Depth (m)	Sediment Description	Habitat Description
SD99-24	Upper - 4	11/19/1999	Low/Ebb	0.3	0.00	Firm; saturated; dark brown to black organic silty clay; strong sulfide odor	Small side channel within emergent wetland; channel is unvegetated; Phragmites dominates area furthest from main channel and Spartina dominates closer to main channel
SD04-10	Upper - 4	11/30/2004	Mid/Flood	17	0.25 - 0.75	Black organic silt-clay with a trace of sand	Spartina alterniflora emergent wetland
SD04-11	Upper - 4	11/30/2004	Mid/Flood	4.5	0.25 - 0.50	Black organic silt-clay with trace of sand	Phragmites, some shrubs on east bank; Spartina emergent wetland on west bank
SD04-12	Upper - 4	11/30/2004	Low/Flood	2.5	0.40 - 0.50	Black organic silt-clay with trace of sand	Spartina alterniflora and patens on banks
SD04-13	Upper - 4	11/30/2004	Low	7.5	0.35	Black organic silt-clay with trace of sand	Phragmites and shrubs on banks
SD04-14	Upper - 4	11/30/2004	High/Flood	4.5	0.25 - 0.70	Gray clay with some organic matter	Phragmites emergent wetland
SD04-F	Upper - 4	11/30/2004	Low/Flood	5.0	0.25	Black organic silt-clay	Emergent wetland (Phragmites, Spartina)
SD97-06	Upper - 3	3/5/1997	High/Ebb	NA	0.20	Silty clay with some sand; gray/brown/black with abundant organic material; liquid; no odor	NA
		3/9/1997	Low/Flood	NA	0.10		
SD97-07	Upper - 3	2/26/1997	Low/Ebb	NA	0.30	Organic clay; black; wet; some twigs and organic matter; no odor	NA
		3/8/1997	Low/Flood	NA	0.30		
SD99-01	Upper - 3	11/19/1999	Low/Flood	9.0	0.24	Soft; black; organic muck (silty clay); moderate sulfide odor; no sheen	Channel unvegetated; banks vegetated mostly with woody trees and shrubs; landfill to east, residential area to west
SD04-15	Upper - 3	12/1/2004	Low	7.0	0.20	Black organic silt-clay with trace of sand; detritus (sticks and leaves) on sediment surface	Phragmites with some Spartina on banks; mud flats
SD04-16	Upper - 3	12/2/2004	Mid/Ebb	2.5	0.25	Black silt-clay with trace of sand; center channel scoured sand; sheen on water when sediment disturbed	Phragmites and dense shrubs on banks
SD04-17	Upper - 3	12/2/2004	Low/Flood	3.7	0.25	Channel scoured sand; bank areas black silt-clay with trace of fine sand	Shrubs and small trees on banks
SD04-G	Upper - 3	12/1/2004	Low	3.0	0.25	Black organic silt-clay	Phragmites with some shrubs on banks
SD97-08	Upper - 3A	2/26/1997	No flow	NA	0.10	Clay with some fine sand; very liquid; some twigs and leaves; black-brown; no odor	Concrete bottom (passing under road) with 2 to 3 inches of overlying sediment
		3/8/1997	No flow	NA	0.10		
SD97-09	Upper - 3A	2/26/1997	No flow	NA	0.36	Liquid clay with some fine to coarse sand; black/brown; some twigs; no odor; sand appears to be under clay/sediment	NA
		3/8/1997	No flow	NA	0.36		

Table 3-1
Habitat Information
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Location	Area / Zone	Date	Tide	Channel Width (m)	Water Depth (m)	Sediment Description	Habitat Description
SD04-18	Upper - 3A	12/2/2004	Low/Flood	18	1.50	Black organic silt-clay; sulfide odor; leaves on sediment surface; algae present	Impounded area with pool depths >1.5 m; banks contain Phragmites, small trees, and shrubs; snags present
SD04-H	Upper - 3A	12/2/2004	Low/Flood	3.7	0.00	Brown silt-clay	Dense Phragmites
SD97-12	Upper - 2	2/26/1997	No flow	NA	0.43	Sand; black with gray speckles; coarse to fine; wet; some twigs and 0.25 inch diameter cobbles; slight fuel odor	NA
		3/8/1997	No flow	NA	0.43		
SD97-13	Upper - 2	2/25/1997	No flow	NA	0.18	Silty clay; black; very fine; liquid; some roots and organic material; looks like fine black sludge; strong fuel odor; fuel sheen on water	NA
		3/8/1997	No flow	NA	0.18		
SD99-05	Upper - 2	11/17/1999	No flow	--	0.54	Very coarse and sandy; medium to dark brown; no odor; light sheen when sediments disturbed	Pool in ditch bordered by trees, shrubs, Phragmites; surrounding area mowed; adjacent to road 1 m from culvert
SD04-09	Upper - 2	12/2/2004	Mid/Ebb	2.5	0.08	Black organic silt-clay, leaves; center channel scoured sand	Phragmites with some shrubs and rice cut grass
SD04-D	Upper - 2	12/1/2004	Mid/Flood	2.1	0.20	Black silt-clay; algae on sediment surface	Shrubs on banks

See Figures 3-8 through 3-10 for sample locations
NA - Not Available

Table 3-2
Water Column Parameter Measurements
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Sample	Area / Zone	Depth	Date	Tide	Tidal Effect	Hardness (mg/L)	Total Suspended Solids (mg/L)	Total Dissolved Solids (mg/L)	Temperature (^{o}C)	pH	Conductivity (uS/cm)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (MV)	Turbidity (NTU)
SW-97-14L	Bay	Surface	3/9/1997	Low/Ebb	Yes	NA	NA	NA	11.3	7.50	24,520	15.0	11.0	NA	NA
SW-97-14H			3/9/1997	High/Flood	Yes	NA	NA	NA	9.40	7.35	24,620	14.9	10.5	NA	NA
SD09-01	Bay	Surface	10/8/2009	--	Yes	NA	NA	NA	19.5	5.83	29,700	15.0[a]	5.90	172	26.6
		Middle	10/8/2009	--	Yes	NA	NA	NA	19.1	8.16	29,900	NA	7.07	163	25.9
		Bottom	10/8/2009	--	Yes	NA	NA	NA	18.7	8.30	29,900	NA	7.40	160	34.6
SD09-02	Bay	Surface	10/8/2009	--	Yes	NA	NA	NA	19.4	8.41	29,800	NA	6.80	167	48.6
		Middle	10/8/2009	--	Yes	NA	NA	NA	18.9	8.49	29,800	NA	7.26	166	51.8
		Bottom	10/8/2009	--	Yes	NA	NA	NA	18.9	8.12	27,700	NA	6.82	-204	0
SD09-03	Bay	Surface	10/8/2009	--	Yes	NA	NA	NA	23.1	8.18	28,200	NA	5.05	12	0
		Middle	10/8/2009	--	Yes	NA	NA	NA	20.2	8.33	28,400	NA	5.87	15	0
		Bottom	10/8/2009	--	Yes	NA	NA	NA	19.4	8.30	29,400	NA	6.08	-74	0
SD09-04	Bay	Surface	10/8/2009	--	Yes	NA	NA	NA	20.1	8.38	29,700	NA	5.87	61	63.3
		Middle	10/8/2009	--	Yes	NA	NA	NA	19.3	8.41	30,000	NA	6.08	61	84.2
		Bottom	10/8/2009	--	Yes	NA	NA	NA	19.2	8.23	29,600	NA	6.01	-178	0
SD09-05	Bay	Surface	10/8/2009	--	Yes	NA	NA	NA	19.7	8.25	29,700	11.0[a]	5.28	31	85.3
		Middle	10/8/2009	--	Yes	NA	NA	NA	19.1	8.29	30,000	NA	5.25	32	96
		Bottom	10/8/2009	--	Yes	NA	NA	NA	19.1	8.15	29,600	NA	5.35	-170	0
SD09-06	Bay	Surface	10/8/2009	--	Yes	NA	NA	NA	21.7	7.88	29,100	15.0[a]	4.49	-118	0
		Middle	10/8/2009	--	Yes	NA	NA	NA	19.7	8.29	30,100	NA	5.71	-65	5.75
		Bottom	10/8/2009	--	Yes	NA	NA	NA	19.2	8.35	29,900	NA	6.02	-139	0

Table 3-2
Water Column Parameter Measurements
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Sample	Area / Zone	Depth	Date	Tide	Tidal Effect	Hardness (mg/L)	Total Suspended Solids (mg/L)	Total Dissolved Solids (mg/L)	Temperature (^{o}C)	pH	Conductivity (uS/cm)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (MV)	Turbidity (NTU)
SD09-07	Upper-Middle - 8	Surface	10/8/2009	--	Yes	NA	NA	NA	NA	NA	NA	2.00[a]	NA	NA	NA
		Middle	10/8/2009	--	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Bottom	10/8/2009	--	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SW97-15L	Upper-Middle - 8	Surface	3/9/1997	Low	Yes	NA	NA	NA	13.2	7.65	1,575	0.80	6.25	NA	NA
SW97-15H			3/9/1997	High/Flood	Yes	NA	NA	NA	8.70	6.30	21,110	12.6	8.46	NA	NA
SD99-15	Upper-Middle - 8	Surface	11/18/1999	Low/Ebb	Yes	NA	NA	NA	7.80	6.93	9,800	5.20	8.28	NA	NA
SD99-16	Upper-Middle - 8	Surface	11/18/1999	High/Flood	Yes	NA	NA	NA	11.5	8.19	27,300	17.3	10.2	NA	NA
SD99-17	Upper-Middle - 8	Surface	11/18/1999	High/Flood	Yes	NA	NA	NA	11.6	8.11	30,000	18.3	11.1	NA	NA
SD99-18	Upper-Middle - 8	Surface	11/18/1999	Mid/Ebb	Yes	NA	NA	NA	8.50	6.78	17,800	10.3	7.35	NA	NA
SD99-25	Upper-Middle - 8	Surface	11/18/1999	Mid/Ebb	Yes	NA	NA	NA	9.50	6.90	27,900	17.6	6.80	NA	NA
SD04-01	Upper-Middle - 8	Surface	11/19/2004	Mid/Ebb	Yes	NA	NA	NA	12.2	7.38	24,040	14.6	10.8	26.6	0
		Bottom				NA	NA	NA	12.2	7.48	26,820	16.5	10.3	26.7	0
SD04-02	Upper-Middle - 8	Surface	11/19/2004	Low/Ebb	Yes	NA	NA	NA	12.5	7.86	28,420	17.6	11.4	-20.2	0
		Bottom				NA	NA	NA	12.4	7.88	29,040	18.0	11.5	-11.1	0
SD04-03	Upper-Middle - 8	Surface	11/18/2004	Mid/Ebb	Yes	NA	NA	NA	9.33	7.55	10,560	5.99	10.3	28.7	NA
		Bottom				NA	NA	NA	9.90	8.93	10,590	6.01	8.93	31.1	NA
SD04-03	Upper-Middle - 8	Surface	11/19/2004	High/Ebb	Yes	1,150	2.60	5,180	11.8	7.36	8,631	4.83	9.57	25.6	NA
		Bottom				NA	NA	NA	11.8	7.32	8,629	4.83	9.07	25.6	10.4
SD04-19	Upper-Middle - 8	Surface	11/18/2004	Low/Ebb	Yes	NA	NA	NA	13.5	7.26	2,284	1.18	10.8	0.90	NA
SD04-20	Upper-Middle - 8	Surface	11/18/2004	Low/Ebb	Yes	NA	NA	NA	11.2	7.55	789	0.39	11.6	0.60	54
FI04-01	Upper-Middle - 8	Surface	11/16/2004	Low	Yes	NA	NA	NA	11.7	7.35	9,370	5.28	10.3	20.2	0.4

Table 3-2
Water Column Parameter Measurements
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Sample	Area / Zone	Depth	Date	Tide	Tidal Effect	Hardness (mg/L)	Total Suspended Solids (mg/L)	Total Dissolved Solids (mg/L)	Temperature (^{o}C)	pH	Conductivity (uS/cm)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (MV)	Turbidity (NTU)
SD99-14	Upper-Middle - 7	Surface	11/16/1999	High/Ebb	Yes	NA	NA	NA	12.6	5.78	2,590	15.6	7.38	NA	NA
SD04-04	Upper-Middle - 7	Surface	11/17/2004	High	Yes	NA	NA	NA	12.1	8.25	28,240	17.4	3.55	42.5	NA
		Bottom				NA	NA	NA	12.1	8.31	28,170	17.4	4.48	43.1	NA
FI04-02	Upper-Middle - 6-8	Surface	11/16/2004	Low	Yes	NA	NA	NA	11.4	7.81	26,670	16.3	10.0	100	4.0
SD99-09	Upper-Middle - 6	No water	11/18/1999	No flow	Minimal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD99-10	Upper-Middle - 6	No water	11/18/1999	Mid/Flood	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD99-11	Upper-Middle - 6	Surface	11/18/1988	Low/Flood	Yes	NA	NA	NA	10.5	6.59	2,750	1.30	8.80	NA	NA
SD99-12	Upper-Middle - 6	--	11/18/1999	Low/Ebb	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD99-13	Upper-Middle - 6	--	11/18/1999	Low/Ebb	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD04-05	Upper-Middle - 6	Surface	11/17/2004	Mid/Flood	Yes	NA	NA	NA	12.1	8.35	28,970	17.9	14.5	49.3	NA
		Bottom				NA	NA	NA	12.2	8.35	28,910	17.9	11.2	50.8	NA
SD04-A	Upper-Middle - 6	Surface	11/17/2004	Mid/Flood	Yes	NA	NA	NA	12.3	8.28	28,290	17.4	13.6	44.3	NA
		Bottom				NA	NA	NA	12.4	8.28	28,290	17.5	13.5	45.4	NA
SD04-B	Upper-Middle - 6	No water	11/18/2004	--	No	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD04-C	Upper-Middle - 6	Surface	11/18/2004	Low/Ebb	Yes	NA	NA	NA	9.13	7.26	6,220	3.40	8.27	17.5	NA
FI04-03	Upper-Middle - 6	Surface	11/16/2004	Low	Yes	NA	NA	NA	9.41	7.44	8,469	4.68	8.94	78.5	9.4

Table 3-2
Water Column Parameter Measurements
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Sample	Area / Zone	Depth	Date	Tide	Tidal Effect	Hardness (mg/L)	Total Suspended Solids (mg/L)	Total Dissolved Solids (mg/L)	Temperature (^{o}C)	pH	Conductivity (uS/cm)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (MV)	Turbidity (NTU)
SW97-01L	Upper - 5	Surface	3/9/1997	High/Ebb	Yes	NA	NA	NA	11.2	7.18	22,610	13.7	12.6	NA	NA
SW97-01H			3/7/1997	Low/Flood	Yes	NA	NA	NA	16.2	6.20	2,270	1.10	11.0	NA	NA
SW97-02L	Upper - 5	Surface	3/7/1997	Low/Ebb	Yes	NA	NA	NA	16.3	7.00	1,976	1.00	11.4	NA	NA
SW97-02H			3/8/1997	High/Flood	Yes	NA	NA	NA	8.20	6.50	2,932	1.50	3.60	NA	NA
SD99-04	Upper - 5	Surface	11/17/1999	Low/Ebb	Yes	NA	NA	NA	9.80	5.70	1,410	0.70	7.10	NA	NA
SD99-06	Upper - 5	--	11/17/1999	Low/Flood	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD99-07	Upper - 5	Surface	11/17/1999	Low/Slack	Yes	NA	NA	NA	9.70	6.31	3,460	1.70	10.6	NA	NA
SD99-08	Upper - 5	Surface	11/17/1999	Low/Flood	Yes	NA	NA	NA	9.40	6.85	3,940	1.90	9.13	NA	NA
SD04-06	Upper - 5	Surface	11/16/2004	Low	Yes	NA	NA	NA	12.0	8.27	29,540	18.3	11.4	61.5	NA
		Bottom				NA	NA	NA	12.0	8.27	29,550	18.3	11.7	62.3	NA
SD04-06	Upper - 5	Surface	11/19/2004	Mid/Ebb	Yes	1,040	5.00	3,540	13.0	7.21	5,828	3.19	11.5	25.7	1.2
SD04-07	Upper - 5	Surface	11/15/2004	Mid/Flood	Yes	NA	NA	NA	11.6	8.19	27,990	17.2	11.6	176	0
		Bottom				NA	NA	NA	11.7	8.18	28,020	17.3	11.4	167	0
SD04-08	Upper - 5	Surface	11/30/2004	Mid/Flood	Yes	NA	NA	NA	12.8	7.14	13,470	7.91	5.54	-61.1	0
		Bottom				NA	NA	NA	12.6	7.14	29,740	18.4	4.12	-60.9	0
SD04-08	Upper - 5	Surface	11/19/2004	Mid/Ebb	Yes	616	1.40	3,080	13.6	7.31	5,062	2.74	11.0	11.4	1.6
SD04-08 (Dup)	Upper - 5	Surface	11/19/2004	Mid/Ebb	Yes	652	20.80	2,250	NA	NA	NA	NA	NA	NA	NA
SD04-E	Upper - 5	Surface	12/1/2004	Mid/Ebb	Yes	NA	NA	NA	13.7	7.85	4,710	2.54	NA	97.9	27.9
SD04-E	Upper - 5	Surface	12/2/2004	Low/Ebb	Yes	NA	NA	NA	6.40	7.38	2,804	1.46	14.9	-70.7	12.2
FI04-04	Upper - 5	Surface	11/16/2004	Low	Yes	NA	NA	NA	12.1	8.22	29,530	18.3	11.8	53.7	6.9

Table 3-2
Water Column Parameter Measurements
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Sample	Area / Zone	Depth	Date	Tide	Tidal Effect	Hardness (mg/L)	Total Suspended Solids (mg/L)	Total Dissolved Solids (mg/L)	Temperature (^{o}C)	pH	Conductivity (uS/cm)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (MV)	Turbidity (NTU)
SW97-03L	Upper - 4	Surface	3/7/1997	Low/Ebb	Yes	NA	NA	NA	17.9	6.91	1,200	0.60	13.0	NA	NA
SW97-03H			3/8/1997	High/Flood	Yes	NA	NA	NA	8.60	6.16	3,021	1.50	7.15	NA	NA
SW97-04L	Upper - 4	Surface	3/8/1997	Low/Ebb	Yes	NA	NA	NA	15.7	7.29	452	0.50	6.80	NA	NA
SW97-04H			3/8/1997	High/Flood	Yes	NA	NA	NA	8.60	6.19	2,362	1.20	6.90	NA	NA
SW97-05L	Upper - 4	Surface	3/8/1997	Low/Ebb	Yes	NA	NA	NA	15.8	7.26	1,425	0.70	9.88	NA	NA
SW97-05H			3/9/1997	High/Flood	Yes	NA	NA	NA	8.50	6.32	3,910	2.00	4.45	NA	NA
SD99-02	Upper - 4	--	11/19/1999	Low/Ebb	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD99-03	Upper - 4	Surface	11/17/1999	Low/Ebb	Yes	NA	NA	NA	7.40	6.28	5,310	2.60	8.48	NA	NA
SD99-19	Upper - 4	No water	11/19/1999	Low/Ebb	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD99-20	Upper - 4	No water	11/19/1999	Low/Ebb	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD99-21	Upper - 4	--	11/19/1999	Low/Ebb	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD99-22	Upper - 4	--	11/19/1999	Low/Ebb	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD99-23	Upper - 4	No water	11/19/1999	Low/Ebb	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD99-24	Upper - 4	No water	11/19/1999	Low/Ebb	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD04-10	Upper - 4	Surface	11/30/2004	Mid/Flood	Yes	NA	NA	NA	12.7	7.15	10,270	7.36	4.43	-62.1	0
		Bottom				NA	NA	NA	12.9	7.17	28,980	17.8	3.08	-62.8	0
SD04-11	Upper - 4	Surface	11/30/2004	Mid/Flood	Yes	NA	NA	NA	11.2	7.16	6,549	3.55	6.79	-62.3	0
		Bottom				NA	NA	NA	11.5	7.17	9,864	5.60	3.42	NA	0
SD04-12	Upper - 4	Surface	11/30/2004	Low/Flood	Yes	NA	NA	NA	10.7	7.10	3,845	2.04	6.32	-54.2	25.3
SD04-13	Upper - 4	Surface	11/30/2004	Low	Yes	NA	NA	NA	9.85	6.97	3,723	1.98	8.89	-47.7	41.0
SD04-14	Upper - 4	Surface	11/30/2004	High/Flood	Yes	NA	NA	NA	11.2	7.19	4,865	2.62	5.57	-63.3	1.2
		Bottom				NA	NA	NA	12.7	7.21	26,160	16.1	3.52	-64.8	44.2
SD04-14	Upper - 4	Surface	11/19/2004	Mid/Ebb	Yes	637	1.40	2,660	13.9	7.34	3,466	1.84	12.9	52.0	NA
SD04-F	Upper - 4	Surface	11/30/2004	Low/Flood	Yes	NA	NA	NA	9.55	7.06	4,619	2.46	8.02	-51.8	59.1
FI04-05	Upper - 4	Surface	11/17/2004	Low/Ebb	Yes	NA	NA	NA	10.7	7.10	3,845	2.04	6.32	-54.2	25.3
FI04-06	Upper - 4	Surface	11/17/2004	Low/Ebb	Yes	NA	NA	NA	9.85	6.97	3,723	1.98	8.89	-47.7	41.0
FI04-08	Upper - 4	Surface	11/17/2004	Low/Ebb	Yes	NA	NA	NA	11.2	7.16	6,549	3.55	6.79	-62.3	0

Table 3-2
Water Column Parameter Measurements
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Sample	Area / Zone	Depth	Date	Tide	Tidal Effect	Hardness (mg/L)	Total Suspended Solids (mg/L)	Total Dissolved Solids (mg/L)	Temperature (^{o}C)	pH	Conductivity (uS/cm)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (MV)	Turbidity (NTU)
SW97-06L	Upper - 3	Surface	3/5/1997	High/Ebb	Yes	NA	NA	NA	10.3	6.50	1,812	4.99	1.00	NA	NA
SW97-06H			3/9/1997	Low/Flood	Yes	NA	NA	NA	5.80	6.15	988	0.70	8.02	NA	NA
SW97-07L	Upper - 3	Surface	2/26/1997	Low/Ebb	Yes	NA	NA	NA	13.7	6.17	766	0.40	9.50	NA	NA
SW97-07H			3/8/1997	Low/Flood	Yes	NA	NA	NA	11.0	6.83	1,817	0.80	7.50	NA	NA
SD99-01	Upper - 3	Surface	11/19/1999	Low/Flood	Yes	NA	NA	NA	18.0	6.50	552	0.20	10.5	NA	NA
SD04-15	Upper - 3	Surface	12/1/2004	Low	Yes	NA	NA	NA	14.0	7.78	1,436	0.72	NA	-94.6	1.8
SD04-15	Upper - 3	Surface	12/2/2004	Low/Ebb	Yes	NA	NA	NA	14.0	7.56	643	0.32	8.42	-84.4	60.0
SD04-16	Upper - 3	Surface	12/2/2004	Mid/Ebb	Yes	NA	NA	NA	14.2	7.38	623	0.32	8.74	-73.7	2.8
SD04-17	Upper - 3	Surface	12/2/2004	Low/Flood	Yes	NA	NA	NA	16.2	6.87	525	0.25	6.67	-59.5	37.8
FI04-09	Upper - 3	Surface	11/17/2004	Mid/Flood	Yes	NA	NA	NA	14.2	7.38	623	0.32	8.74	-73.7	2.8
SD04-G	Upper - 3	Surface	12/1/2004	Low	Yes	NA	NA	NA	14.2	7.59	640	0.31	7.55	-86.0	52.0
FI04-10	Upper - 3/3A	Surface	11/17/2004	Mid/Flood	Yes	NA	NA	NA	16.2	6.87	525	0.25	6.67	-59.5	37.8
SW97-08L	Upper - 3A	Surface	2/26/1997	No flow	Minimal	NA	NA	NA	12.2	6.99	814	0.40	8.50	NA	NA
SW97-08H			3/8/1997	No flow	Minimal	NA	NA	NA	11.7	6.48	725	0.40	8.45	NA	NA
SW97-09L	Upper - 3A	Surface	2/26/1997	No flow	Minimal	NA	NA	NA	12.6	6.12	570	0.30	8.50	NA	NA
SW97-09H			3/8/1997	No flow	Minimal	NA	NA	NA	12.2	6.39	539	0.30	8.80	NA	NA
SD04-18	Upper - 3A	Surface	12/2/2004	Low/Flood	Minimal	NA	NA	NA	13.0	6.73	150	0.07	2.28	-53.0	0.3
		Bottom				NA	NA	NA	11.0	6.72	160	0.08	5.30	-52.5	21.5
SD04-18	Upper - 3A	Surface	11/19/2004	Mid/Flood	Minimal	68.4	10.4	92.0	15.2	7.36	2.00	0.00	8.82	-20.9	2.9
SD04-H	Upper - 3A	No water	12/2/2004	Low/Flood	Minimal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SW97-12L	Upper - 2	Surface	2/26/1997	No flow	Minimal	NA	NA	NA	11.1	6.05	973	0.50	7.00	NA	NA
SW97-12H			3/8/1997	No flow	Minimal	NA	NA	NA	12.3	6.16	550	0.30	4.50	NA	NA
SW97-13L	Upper - 2	Surface	2/25/1997	No flow	Minimal	NA	NA	NA	11.0	6.86	898	0.40	8.20	NA	NA
SW97-13H			3/8/1997	No flow	Minimal	NA	NA	NA	11.0	6.30	880	0.40	7.43	NA	NA
SD99-05	Upper - 2	Surface	11/17/1999	No flow	Minimal	NA	NA	NA	14.6	5.40	443	0.10	2.22	NA	NA
SD04-09	Upper - 2	Surface	12/2/2004	Mid/Ebb	Minimal	NA	NA	NA	12.1	7.12	178	0.08	9.64	56.4	0
SD04-D	Upper - 2	Surface	12/1/2004	Mid/Flood	Minimal	NA	NA	NA	16.1	7.89	727	0.36	NA	-101	0
SD04-D	Upper - 2	Surface	12/2/2004	Low/Ebb	Minimal	NA	NA	NA	14.1	7.50	1,097	0.55	12.4	-78.0	NA
FI04-07	Upper - 2	Surface	11/16/2004	Low	Minimal	NA	NA	NA	12.3	7.50	NA	NA	8.68	3.10	235

See Figures 3-8 through 3-11 for sample locations
NA - Not Available
a - Salinity was not collected in October 2009 but supplemental readings were collected in January 2010 during a similar point in the tidal cycle

Table 3-3
Physical Sediment Parameter Measurements
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Location	Area / Zone	Depth (inches)	Date	Total Organic Carbon (percent)	pH	SEM/AVS Ratio	Grain Size (percent)						
							Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay
SD97-14	Bay	0 - 6	3/9/1997	4.40	NA	NA	0.0	91.2		6.5	1.6	0.7	
SD09-01	Bay	0 - 6	10/8/2009	2.40	8.20	0.02	0.4		1.8	4.8	19.4	73.6	
SD09-02	Bay	0 - 6	10/8/2009	3.30	8.30	0.03	0.0		0.8	3.2	19.3	76.7	
SD09-02 (Dup)	Bay	0 - 6	10/8/2009	3.90	8.40	0.02	NA		NA	NA	NA	NA	
SD09-03	Bay	0 - 6	10/8/2009	3.90	8.50	0.03	0.0		1.1	2.2	7.9	88.8	
SD09-04	Bay	0 - 6	10/8/2009	4.50	8.30	0.04	0.5		0.4	1.5	6.1	91.5	
SD09-05	Bay	0 - 6	10/8/2009	4.20	8.40	0.02	2.5		1.2	2.6	10.7	83.0	
SD09-06	Bay	0 - 6	10/8/2009	4.20	8.40	0.03	0.0		0.4	0.5	2.7	96.4	
SD09-07	Upper-Middle - 8	0 - 6	10/8/2009	0.06	7.80	--[1]	1.1		0.7	23.4	56.7	18.1	
SD97-15	Upper-Middle - 8	0 - 6	3/9/1997	NA	NA	NA	0.0	15.7		63.5	17.9	2.9	
SD99-15A	Upper-Middle - 8	0 - 6	11/18/1999	1.44	7.08	NA	NA	NA	NA	NA	NA	NA	NA
SD99-15B	Upper-Middle - 8	6 - 18	11/18/1999	0.41	6.92	NA	NA	NA	NA	NA	NA	NA	NA
SD99-16A	Upper-Middle - 8	0 - 6	11/18/1999	0.18	7.77	NA	NA	NA	NA	NA	NA	NA	NA
SD99-16B	Upper-Middle - 8	6 - 18	11/18/1999	0.51	8.13	NA	NA	NA	NA	NA	NA	NA	NA
SD99-17	Upper-Middle - 8	0 - 6	11/18/1999	0.61	7.21	NA	NA	NA	NA	NA	NA	NA	NA
SD99-18A	Upper-Middle - 8	0 - 6	11/18/1999	0.65	7.06	NA	NA	NA	NA	NA	NA	NA	NA
SD99-18B	Upper-Middle - 8	6 - 18	11/18/1999	0.22	6.98	NA	NA	NA	NA	NA	NA	NA	NA
SD99-18B (Dup)	Upper-Middle - 8	6 - 18	11/18/1999	0.31	7.11	NA	NA	NA	NA	NA	NA	NA	NA
SD99-25	Upper-Middle - 8	0 - 6	11/18/1988	0.51	7.36	NA	NA	NA	NA	NA	NA	NA	NA
SD04-01	Upper-Middle - 8	0 - 6	11/19/2004	2.23	7.65	0.32	0.0	1.7	2.2	19.7	44.9	5.7	25.8
SD04-02	Upper-Middle - 8	0 - 6	11/19/2004	6.91	7.00	0.06	0.0	0.0	0.7	13.0	40.4	12.5	33.4
SD04-03	Upper-Middle - 8	0 - 6	11/18/2004	1.31	7.68	0.05	0.0	2.2	2.7	49.4	34.6	2.1	9.0
SD04-19	Upper-Middle - 8	0 - 6	11/18/2004	4.23	7.39	0.91	0.0	0.4	1.0	28.6	31.2	21.9	16.9
SD04-20	Upper-Middle - 8	0 - 6	11/18/2004	5.47	7.20	0.42	0.0	0.0	0.2	12.7	15.0	35.5	36.6
SD04-20 (Dup)	Upper-Middle - 8	0 - 6	11/18/2004	9.33	7.24	0.41	NA	NA	NA	NA	NA	NA	NA
SD99-14	Upper-Middle - 7	0 - 6	11/16/1999	1.22	7.39	NA	NA	NA	NA	NA	NA	NA	NA
SD04-04	Upper-Middle - 7	0 - 6	11/17/2004	4.63	7.72	0.06	0.0	0.1	1.7	28.9	37.3	10.1	21.9
SD99-09	Upper-Middle - 6	0 - 6	11/18/1999	2.59	6.86	NA	NA	NA	NA	NA	NA	NA	NA
SD99-10	Upper-Middle - 6	0 - 6	11/18/1999	1.33	7.45	NA	NA	NA	NA	NA	NA	NA	NA

Table 3-3
Physical Sediment Parameter Measurements
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Location	Area / Zone	Depth (inches)	Date	Total Organic Carbon (percent)	pH	SEM/AVS Ratio	Grain Size (percent)						
							Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay
SD99-11	Upper-Middle - 6	0 - 6	11/18/1999	2.02	7.35	NA	NA	NA	NA	NA	NA	NA	NA
SD99-12A	Upper-Middle - 6	0 - 6	11/18/1999	3.69	7.27	NA	NA	NA	NA	NA	NA	NA	NA
SD99-12B	Upper-Middle - 6	6 - 18	11/18/1999	1.80	7.08	NA	NA	NA	NA	NA	NA	NA	NA
SD99-13	Upper-Middle - 6	0 - 6	11/18/1999	0.63	7.02	NA	NA	NA	NA	NA	NA	NA	NA
SD99-13 (Dup)	Upper-Middle - 6	0 - 6	11/18/1999	0.97	7.05	NA	NA	NA	NA	NA	NA	NA	NA
SD04-05	Upper-Middle - 6	0 - 6	11/17/2004	9.95	7.68	0.13	0.0	0.0	0.0	3.7	14.1	49.3	32.9
SD04-A	Upper-Middle - 6	0 - 6	11/17/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD04-B	Upper-Middle - 6	0 - 6	11/18/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD04-C	Upper-Middle - 6	0 - 6	11/18/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD97-01	Upper - 5	0 - 6	3/7/1997	19.0	NA	NA	0.0	88.1		8.4	2.5	1.0	
SD97-02	Upper - 5	0 - 6	3/7/1997	7.36	NA	NA	0.0	45.9		44.9	8.1	1.1	
SD99-04	Upper - 5	0 - 6	11/17/1999	1.14	7.85	NA	NA	NA	NA	NA	NA	NA	NA
SD99-06	Upper - 5	0 - 6	11/17/1999	2.75	7.68	NA	NA	NA	NA	NA	NA	NA	NA
SD99-07	Upper - 5	0 - 6	11/17/1999	2.24	8.05	NA	NA	NA	NA	NA	NA	NA	NA
SD99-07 (Dup)	Upper - 5	0 - 6	11/17/1999	4.48	8.19	NA	NA	NA	NA	NA	NA	NA	NA
SD99-08	Upper - 5	0 - 6	11/17/1999	4.96	7.92	NA	NA	NA	NA	NA	NA	NA	NA
SD04-06	Upper - 5	0 - 6	11/16/2004	5.92	7.81	0.05	0.0	0.0	1.4	8.8	12.3	58.2	19.3
SD04-06 (Dup)	Upper - 5	0 - 6	11/16/2004	6.57	7.89	0.10	NA	NA	NA	NA	NA	NA	NA
SD04-06	Upper - 5	6 - 12	11/16/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD04-06	Upper - 5	12 - 18	11/16/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD04-06	Upper - 5	18 - 24	11/16/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD04-07	Upper - 5	0 - 6	11/15/2004	5.80	8.15	0.20	0.0	0.0	0.2	2.4	11.5	62.9	23.0
SD04-08	Upper - 5	0 - 6	11/30/2004	4.67	7.51	0.05	0.0	0.0	0.7	31.6	27.7	18.4	21.6
SD04-08	Upper - 5	6 - 12	11/30/2004	0.85	6.82	NA	NA	NA	NA	NA	NA	NA	NA
SD04-08	Upper - 5	12 - 18	11/30/2004	7.89	7.03	NA	NA	NA	NA	NA	NA	NA	NA
SD04-08	Upper - 5	18 - 24	11/30/2004	3.94	7.28	NA	NA	NA	NA	NA	NA	NA	NA
SD04-E	Upper - 5	0 - 6	12/1/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD97-03	Upper - 4	0 - 6	3/7/1997	17.1	NA	NA	0.0	90.1		6.8	2.4	0.7	
SD97-04	Upper - 4	0 - 6	3/8/1997	12.0	NA	NA	0.0	91.2		6.5	1.6	0.7	

Table 3-3
Physical Sediment Parameter Measurements
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Location	Area / Zone	Depth (inches)	Date	Total Organic Carbon (percent)	pH	SEM/AVS Ratio	Grain Size (percent)						
							Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay
SD97-05	Upper - 4	0 - 6	3/8/1997	12.6	NA	NA	0.0	91.9		6.2	1.7	0.3	
SD99-02	Upper - 4	0 - 6	11/19/1999	2.20	7.80	NA	NA	NA	NA	NA	NA	NA	NA
SD99-03	Upper - 4	0 - 6	11/17/1999	3.93	7.28	NA	NA	NA	NA	NA	NA	NA	NA
SD99-19	Upper - 4	0 - 6	11/19/1999	6.36	6.92	NA	NA	NA	NA	NA	NA	NA	NA
SD99-20	Upper - 4	0 - 6	11/19/1999	6.02	7.22	NA	NA	NA	NA	NA	NA	NA	NA
SD99-21	Upper - 4	0 - 6	11/19/1999	4.56	7.02	NA	NA	NA	NA	NA	NA	NA	NA
SD99-22	Upper - 4	0 - 6	11/19/1999	3.48	6.98	NA	NA	NA	NA	NA	NA	NA	NA
SD99-23	Upper - 4	0 - 6	11/19/1999	6.21	6.93	NA	NA	NA	NA	NA	NA	NA	NA
SD99-24	Upper - 4	0 - 6	11/19/1999	3.95	7.19	NA	NA	NA	NA	NA	NA	NA	NA
SD04-10	Upper - 4	0 - 6	11/30/2004	9.45	7.16	0.24	0.0	0.0	2.2	5.1	16.5	47.3	28.9
SD04-10	Upper - 4	6 - 12	11/30/2004	10.8	7.05	NA	NA	NA	NA	NA	NA	NA	NA
SD04-10	Upper - 4	12 - 18	11/30/2004	11.0	6.79	NA	NA	NA	NA	NA	NA	NA	NA
SD04-10	Upper - 4	18 - 24	11/30/2004	11.9	6.89	NA	NA	NA	NA	NA	NA	NA	NA
SD04-11	Upper - 4	0 - 6	11/30/2004	8.35	7.54	0.21	0.0	0.0	1.6	24.8	22.1	20.0	31.5
SD04-12	Upper - 4	0 - 6	11/30/2004	4.93	7.56	0.14	0.0	0.0	0.0	15.0	13.6	34.6	36.8
SD04-13	Upper - 4	0 - 6	11/30/2004	5.21	6.91	1.19	0.0	0.2	1.9	11.9	30.8	22.1	33.1
SD04-14	Upper - 4	0 - 6	11/30/2004	4.33	7.33	1.88	0.0	0.0	0.0	1.1	1.9	32.8	64.2
SD04-14	Upper - 4	6 - 12	11/30/2004	3.33	7.72	NA	NA	NA	NA	NA	NA	NA	NA
SD04-14	Upper - 4	12 - 18	11/30/2004	3.60	7.88	NA	NA	NA	NA	NA	NA	NA	NA
SD04-14	Upper - 4	18 - 24	11/30/2004	3.47	7.96	NA	NA	NA	NA	NA	NA	NA	NA
SD04-F	Upper - 4	0 - 6	11/30/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD97-06	Upper - 3	0 - 6	3/5/1997	2.33	NA	NA	0.0	62.2		23.5	12.1	2.3	
SD97-07	Upper - 3	0 - 6	2/26/1997	3.05	NA	NA	0.0	76.8		14.8	7.3	1.2	
SD99-01	Upper - 3	0 - 6	11/19/1999	1.87	7.59	NA	NA	NA	NA	NA	NA	NA	NA
SD04-15	Upper - 3	0 - 6	12/1/2004	7.79	7.72	0.10	0.0	0.0	0.5	3.8	9.6	49.0	37.1
SD04-16	Upper - 3	0 - 6	12/2/2004	6.43	7.29	0.02	0.0	0.0	2.0	8.5	20.9	39.7	28.9
SD04-17	Upper - 3	0 - 6	12/2/2004	6.10	7.29	0.03	0.0	0.0	0.5	5.2	57.1	21.7	15.5
SD04-G	Upper - 3	0 - 6	12/1/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD97-08	Upper - 3A	0 - 6	2/26/1997	2.55	NA	NA	0.0	34.2		32.5	28.8	4.6	

Table 3-3
Physical Sediment Parameter Measurements
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Location	Area / Zone	Depth (inches)	Date	Total Organic Carbon (percent)	pH	SEM/AVS Ratio	Grain Size (percent)						
							Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay
SD97-09	Upper - 3A	0 - 6	2/26/1997	1.89	NA	NA	0.0	4.7		62.1	28.0	5.2	
SD04-18	Upper - 3A	0 - 6	12/2/2004	8.75	6.57	0.54	0.0	0.0	1.3	7.7	38.3	29.2	23.5
SD04-H	Upper - 3A	0 - 6	12/2/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SD97-12	Upper - 2	0 - 6	2/26/1997	1.52	NA	NA	0.0	13.0		69.2	17.0	0.9	
SD97-13	Upper - 2	0 - 6	2/25/1997	2.41	NA	NA	0.0	19.3		54.1	19.7	7.0	
SD99-05	Upper - 2	0 - 6	11/17/1999	0.09	7.13	NA	NA	NA	NA	NA	NA	NA	NA
SD04-09	Upper - 2	0 - 6	12/2/2004	13.7	7.08	0.18	0.0	0.1	1.2	8.7	13.9	32.7	43.4
SD04-D	Upper - 2	0 - 6	12/1/2004	NA	7.19	NA	NA	NA	NA	NA	NA	NA	NA
SD04-D	Upper - 2	6 - 12	12/1/2004	7.79	6.78	NA	NA	NA	NA	NA	NA	NA	NA
SD04-D	Upper - 2	12 - 18	12/1/2004	NA	6.83	NA	NA	NA	NA	NA	NA	NA	NA
SD04-D	Upper - 2	18 - 24	12/1/2004	NA	7.00	NA	NA	NA	NA	NA	NA	NA	NA

See Figures 3-8 through 3-11 for sample locations
NA - Not Available
1 - AVS not detected in this sample

Table 3-4
Fish Species Observed During Fall 2004 Studies
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Reach	Area / Zone	Method	Common Name	Scientific Name	Total Length (mm)	Weight (grams)	Total Count	Count per Trap
1	Upper-Middle - 8	Minnow Traps[1]	Mummichog	*Fundulus heteroclitus*	38 - 76	10 - 30	140	46.7
			Sheepshead minnow	*Cyprinodon variegatus*	NA - NA	NA - NA	1	0.33
1	Upper-Middle - 8	Gill Net	Spot	*Leiostomus xanthurus*	120 - 122	30 - 40	2	--
			Striped mullet	*Mugil cephalus*	198 - 201	90 - 100	2	--
2	Upper-Middle - 6-8	Minnow Traps	Mummichog	*Fundulus heteroclitus*	38 - 108	5 - 25	254	84.7
			Striped killifish	*Fundulus maialis*	108 - 108	30 - 30	1	0.33
2	Upper-Middle - 6-8	Seine	Grass shrimp	*Palaemonetes pugio*	NA - NA	NA - NA	4	--
			Blue crab	*Callinectes sapidus*	NA - NA	NA - NA	5	--
			Snail	--	NA - NA	NA - NA	1	--
			Mummichog	*Fundulus heteroclitus*	NA - NA	NA - NA	1	--
3	Upper-Middle - 6	Minnow Traps	Mummichog	*Fundulus heteroclitus*	NA - NA	NA - NA	28	9.33
			Sheepshead minnow	*Cyprinodon variegatus*	25 - 50	5 - 10	3	1.00
3	Upper-Middle - 6	Gill Net	Striped mullet	*Mugil cephalus*	200 - 230	115 - 150	20	--
			White perch	*Morone americanus*	206 - 216	100 - 120	2	--
4	Upper - 5	Minnow Traps	Mummichog	*Fundulus heteroclitus*	NA - NA	NA - NA	45	15.0
5	Upper - 4	Minnow Traps	Mummichog	*Fundulus heteroclitus*	50 - 100	5 - 25	79	26.3
5	Upper - 4	Seine	Grass shrimp	*Palaemonetes pugio*	NA - NA	NA - NA	40	--
			Jellyfish	--	NA - NA	NA - NA	2	--
			Mummichog	*Fundulus heteroclitus*	NA - NA	NA - NA	1	--
			Blue crab	*Callinectes sapidus*	NA - NA	NA - NA	3	--
6	Upper - 4	Minnow Traps[2]	Mummichog	*Fundulus heteroclitus*	44 - 70	10 - 20	61	30.5
			Sheepshead minnow	*Cyprinodon variegatus*	38 - 38	5 - 5	2	1.00
8	Upper - 4	Minnow Traps	Mummichog	*Fundulus heteroclitus*	50 - 95	10 - 30	66	22.0
8	Upper - 4	Gill Net	Striped mullet	*Mugil cephalus*	NA - NA	NA - NA	16	--

Table 3-4
Fish Species Observed During Fall 2004 Studies
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Reach	Area / Zone	Method	Common Name	Scientific Name	Total Length (mm)	Weight (grams)	Total Count	Count per Trap
8	Upper - 4	Seine	Grass shrimp	*Palaemonetes pugio*	NA - NA	NA - NA	10	--
			Blue crab	*Callinectes sapidus*	NA - NA	NA - NA	15	--
			Darter	--	NA - NA	NA - NA	1	--
			Silverside	*Menidia spp.*	NA - NA	NA - NA	2	--
			Mummichog	*Fundulus heteroclitus*	NA - NA	NA - NA	2	--
9	Upper - 3	Minnow Traps	Mummichog	*Fundulus heteroclitus*	NA - NA	NA - NA	66	22.0
			Sheepshead minnow	*Cyprinodon variegatus*	25 - 38	15 - 15	4	1.33
			Crayfish	--	38 - 38	10 - 10	1	0.33
10	Upper - 3/3A	Minnow Traps	Mummichog	*Fundulus heteroclitus*	NA - NA	NA - NA	48	16.0
			Sheepshead minnow	*Cyprinodon variegatus*	50 - 50	20 - 20	1	0.33
7	Upper - 2	Minnow Traps	Mummichog	*Fundulus heteroclitus*	50 - 100	10 - 30	138	46.0
			Sheepshead minnow	*Cyprinodon variegatus*	38 - 38	15 - 20	2	0.67

NA - Not Available
[1] Three traps per reach
[2] One trap was lost; counts are based upon only two traps

Table 3-5
Benthic Invertebrate Sampling Results - Fall 2004
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Group	Species	Pollution sensitivity	SD04-01	SD04-02	SD04-03	SD04-04	SD04-05	SD04-06	SD04-07	SD04-08	SD04-09	SD04-10	SD04-11	SD04-12	SD04-13	SD04-14	SD04-15	SD04-16	SD04-17	SD04-18	SD04-19	SD04-20	Total
Bivalvia	Macoma balthica	PS	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bivalvia	Spharium spp.	7.7	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	0	0	0	48
Crustacea	Corophium lacustre	--	43	0	10	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	2	0	59
Crustacea	Gammarus daiberi	--	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	3
Crustacea	Leptocheirus plumulosus	PI	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Diptera	Ceratopogon spp.	6.4*	0	0	0	0	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	4
Diptera	Chironomus spp.	PI; 9.8	0	0	2	2	15	3	26	3	0	2	8	42	10	8	20	0	0	1	57	0	199
Diptera	Dolichopodidae spp.	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Diptera	Tanypus spp.	PI; 9.6	0	0	0	0	0	0	0	0	0	0	0	19	3	2	11	4	0	0	0	0	39
Hirundinea	Hirudinea spp.	8.2*	9	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Oligochaeta	Dero spp.	10	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	0	4
Oligochaeta	Ilyodrilus templetoni	9.4	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	9
Oligochaeta	Immature Tubificidae w/o capiliform chaetae	PI; 8.55*	0	0	0	0	0	692	0	144	0	87	189	0	0	0	0	0	0	0	30	30	1,172
Oligochaeta	Limnodrilus claparedianus	PI; 9.78*	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Oligochaeta	Limnodrilus hoffmeisteri	PI; 9.8*	0	0	0	0	0	0	12	7	202	3	11	24	0	27	126	94	400	0	0	0	906
Oligochaeta	Lumbriculus variegatus	--	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Oligochaeta	Paranais littoralis	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	30	43
Oligochaeta	Pristinella osborni	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	4
Oligochaeta	Tubificoides heterochaetous	PI	0	0	0	0	0	0	131	44	0	2	10	0	0	3	0	0	0	0	0	0	190
Oligochaeta	Tubificoides spp. Group 1	PI	15	30	8	3	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	74
Polychaeta	Capitella capitata	PI	18	4	4	13	3	0	0	0	0	0	0	0	0	0	0	0	0	0	24	1	67
Polychaeta	Heteromastus filiformis	--	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Polychaeta	Laonereis culveri	--	73	39	84	142	383	80	53	38	0	17	8	11	0	2	7	0	0	0	130	2	1,069
Polychaeta	Marenzelleria viridis	PS	0	1	6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	8
Polychaeta	Mediomastus ambiseta	PS	0	0	1	0	0	0	0	0	0	2	2	0	0	0	1	0	0	0	2	0	8
Polychaeta	Neanthes succinea	PI	9	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
Polychaeta	Polydora cornuta	PI	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Polychaeta	Streblospio benedicti	PI	8	8	6	6	3	0	2	0	0	1	0	2	0	0	0	0	0	0	0	0	36
	Total Organisms		178	85	127	168	423	776	227	239	266	115	228	98	13	42	165	98	401	4	261	64	3,978
	Number of Taxa		10	7	11	7	6	4	7	7	6	8	6	5	2	5	5	2	2	2	9	5	
	Percent Dominant Taxa		41.0	45.9	66.1	84.5	90.5	89.2	57.7	60.3	75.9	75.7	82.9	42.9	76.9	64.3	76.4	95.9	99.8	75.0	49.8	46.9	
	Percent Oligochaeta		8.43	35.3	6.30	1.79	4.26	89.2	63.0	81.6	80.8	80.0	92.1	24.5	0.00	71.4	76.4	95.9	100	75.0	16.5	93.8	
	Percent Polychaeta		61.8	63.5	81.1	95.8	92.0	10.3	24.2	16.3	0.00	17.4	4.39	13.3	0.00	4.76	4.85	0.00	0.00	0.00	59.8	4.69	

Notes:
Pollution sensitivity rankings:
PI - Pollution Indicative (relatively stress tolerant, short lived taxa; based on correlations of taxa with sediment contaminants and dissolved oxygen)
PS - Pollution Sensitive (large deep dwelling and long lived taxa; based on correlations of taxa with sediment contaminants and dissolved oxygen)
Numeric (Lenat) scores range from 1 to 10 with 10 the most pollution tolerant. Lenat scores with * are averages from similar taxa
Not all taxa have available ratings

Table 3-6
Fall 2004 Benthic Invertebrate Sampling Results - Summary By Area
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

	Lower Reaches			Upper-Middle Reaches (n = 7)			Upper Reaches - Non-Wetland (n = 8)			Upper Reaches - Wetland (n=5)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Total Organisms	No data			64	423	187	4	776	272	13	228	99
Number of Taxa	No data			5	11	8	2	7	4	2	8	5
Percent Dominant Taxa	No data			41.0	90.5	60.7	57.7	100	78.8	42.9	82.9	68.5
Percent Oligochaeta	No data			1.79	93.8	23.8	63.0	100	82.7	0.00	92.1	53.6
Percent Polychaeta	No data			4.69	95.8	65.5	0.00	24.2	6.96	0.00	17.4	7.96

Table 3-7
Summary of Analytical Data Collected in Bousch Creek
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Event	Site	Date	Medium (number of samples)				Area
			Surface Water	Surface Sediment	Subsurface Sediment	Fish Tissue	
Confirmation Study	CAL	December 1983	4	--	--	--	Upper Reaches
Confirmation Study	CAL	August 1984	4	--	--	--	Upper Reaches
Confirmation Study	CAL	April 1986	4	--	--	--	Upper Reaches
Confirmation Study	CAL	June 1986	4	--	--	--	Upper Reaches
Interim Remedial Investigation	CAL	1991	12	12	--	--	Upper Reaches
Remedial Investigation	CAL	April 1992	16	27	7	--	Upper Reaches
Remedial Investigation	CAL	June 1992	16	27	7	--	Upper Reaches
Remedial Investigation	CAL	December 1992	--	5	--	--	Upper Reaches
Remedial Investigation	CD Landill	August/September 1993	8	13	8	--	Upper-Middle Reaches
SERA	CAL/CASY	February/March 1997	28	14	--	--	Upper Reaches Upper-Middle Reaches
SERA	CAL	February/March 1997	2	1	--	--	Willoughby Bay
Step 3 BERA	CAL	November 1999	--	25	4	--	Upper Reaches Upper-Middle Reaches
Step 7 BERA	CAL	November 2004	5	28	15	10	Upper Reaches Upper-Middle Reaches
This ERA	Lower Reaches	October 2009	0	1	0	0	Upper-Middle Reaches
This ERA	Lower Reaches	October 2009	0	6	0	0	Willoughby Bay

Excludes data collected from CASY during spatially-restricted studies

Table 3-8
Summary Statistics for Detected Constituents - Surface Water - Bay (1997)
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Reporting Limit Range	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Concentration	Arithmetic Mean[1]	Standard Deviation of Mean
Inorganics (UG/L)						
Aluminum	6.00 - 6.00	2 / 2	419	NNB-BCM-SW97-14H	290	183
Arsenic	4.00 - 4.00	2 / 2	8.80	NNB-BCM-SW97-14H	7.80	1.41
Barium	1.00 - 1.00	2 / 2	28.5	NNB-BCM-SW97-14L	23.8	6.65
Calcium	48.0 - 48.0	2 / 2	151,000	NNB-BCM-SW97-14H	146,000	7,071
Chromium	2.00 - 2.00	1 / 2	2.10	NNB-BCM-SW97-14H	1.55	0.78
Cobalt	1.00 - 1.00	2 / 2	1.80	NNB-BCM-SW97-14L	1.55	0.35
Copper	2.00 - 2.00	2 / 2	25.9	NNB-BCM-SW97-14H	25.9	0.0
Iron	18.0 - 18.0	2 / 2	830	NNB-BCM-SW97-14H	723	151
Lead	2.00 - 2.00	1 / 2	3.40	NNB-BCM-SW97-14L	2.20	1.70
Magnesium	51.0 - 51.0	2 / 2	395,000	NNB-BCM-SW97-14H	364,000	43,841
Manganese	1.00 - 1.00	2 / 2	59.2	NNB-BCM-SW97-14L	36.7	31.8
Nickel	3.00 - 3.00	2 / 2	10.0	NNB-BCM-SW97-14L	7.70	3.25
Potassium	47.0 - 47.0	2 / 2	263,000	NNB-BCM-SW97-14H	244,000	26,870
Sodium	100 - 100	2 / 2	3,960,000	NNB-BCM-SW97-14H	3,730,000	325,269
Vanadium	1.00 - 1.00	2 / 2	2.40	NNB-BCM-SW97-14H	2.25	0.21
Zinc	2.00 - 2.00	2 / 2	13.1	NNB-BCM-SW97-14L	12.4	0.99
Dissolved Metals (UG/L)						
Aluminum	6.00 - 6.00	1 / 2	66.2	NNB-BCM-SW97-14L	34.6	44.7
Barium	1.00 - 1.00	2 / 2	20.8	NNB-BCM-SW97-14L	15.1	8.13
Calcium	48.0 - 48.0	2 / 2	170,000	NNB-BCM-SW97-14H	141,500	40,305
Cobalt	1.00 - 1.00	2 / 2	1.10	NNB-BCM-SW97-14H	1.10	0.0
Copper	2.00 - 2.00	2 / 2	49.8	NNB-BCM-SW97-14L	38.0	16.7
Iron	18.0 - 18.0	2 / 2	148	NNB-BCM-SW97-14L	138	14.8
Lead	2.00 - 2.00	1 / 2	2.70	NNB-BCM-SW97-14L	1.85	1.20
Magnesium	51.0 - 51.0	2 / 2	446,000	NNB-BCM-SW97-14H	359,000	123,037
Manganese	1.00 - 1.00	2 / 2	43.8	NNB-BCM-SW97-14L	23.7	28.4
Nickel	3.00 - 3.00	1 / 2	3.60	NNB-BCM-SW97-14L	2.55	1.48
Potassium	47.0 - 47.0	2 / 2	323,000	NNB-BCM-SW97-14H	245,500	109,602

1 - One-half of the reporting limit was used for non-detected samples when calculating the mean

Table 3-8
Summary Statistics for Detected Constituents - Surface Water - Bay (1997)
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Reporting Limit Range	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Concentration	Arithmetic Mean[1]	Standard Deviation of Mean
Sodium	100 - 100	2 / 2	4,840,000	NNB-BCM-SW97-14H	3,815,000	1,449,569
Zinc	2.00 - 2.00	1 / 2	14.7	NNB-BCM-SW97-14L	7.85	9.69
Pesticide/Polychlorinated Biphenyls (UG/L)						
No detections						
Semivolatile Organic Compounds (UG/L)						
Hexachlorobutadiene	2.00 - 2.00	1 / 2	2.00	NNB-BCM-SW97-14L	1.50	0.71
Volatile Organic Compounds (UG/L)						
Acetone	2.00 - 2.00	2 / 2	2.00	NNB-BCM-SW97-14H	2.00	0.0
Methylene chloride	2.00 - 2.00	1 / 2	0.60	NNB-BCM-SW97-14L	0.80	0.28
cis-1,2-Dichloroethene	1.00 - 1.00	1 / 2	0.60	NNB-BCM-SW97-14L	0.55	0.071

1 - One-half of the reporting limit was used for non-detected samples when calculating the mean

Table 3-9
Summary Statistics for Detected Constituents - Sediment - Bay (1997)
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Reporting Limit Range	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Concentration
Inorganics (MG/KG)				
Aluminum	0.44 - 0.44	1 / 1	7,620	NNB-BCM-SD97-14
Antimony	0.30 - 0.30	1 / 1	0.35	NNB-BCM-SD97-14
Arsenic	0.30 - 0.30	1 / 1	9.80	NNB-BCM-SD97-14
Barium	0.074 - 0.074	1 / 1	56.7	NNB-BCM-SD97-14
Beryllium	0.074 - 0.074	1 / 1	0.76	NNB-BCM-SD97-14
Cadmium	0.074 - 0.074	1 / 1	3.50	NNB-BCM-SD97-14
Calcium	3.50 - 3.50	1 / 1	75,500	NNB-BCM-SD97-14
Chromium	0.15 - 0.15	1 / 1	37.3	NNB-BCM-SD97-14
Cobalt	0.074 - 0.074	1 / 1	5.40	NNB-BCM-SD97-14
Copper	0.15 - 0.15	1 / 1	40.7	NNB-BCM-SD97-14
Iron	1.30 - 1.30	1 / 1	15,200	NNB-BCM-SD97-14
Lead	0.15 - 0.15	1 / 1	138	NNB-BCM-SD97-14
Magnesium	3.80 - 3.80	1 / 1	3,300	NNB-BCM-SD97-14
Manganese	0.074 - 0.074	1 / 1	205	NNB-BCM-SD97-14
Mercury	0.18 - 0.18	1 / 1	4.60	NNB-BCM-SD97-14
Nickel	0.22 - 0.22	1 / 1	25.2	NNB-BCM-SD97-14
Potassium	3.50 - 3.50	1 / 1	1,990	NNB-BCM-SD97-14
Silver	0.15 - 0.15	1 / 1	0.73	NNB-BCM-SD97-14
Sodium	5.00 - 5.00	1 / 1	5,890	NNB-BCM-SD97-14
Vanadium	0.074 - 0.074	1 / 1	26.3	NNB-BCM-SD97-14
Zinc	0.15 - 0.15	1 / 1	128	NNB-BCM-SD97-14
Pesticide/Polychlorinated Biphenyls (UG/KG)				
4,4'-DDD	3.34 - 3.34	1 / 1	8.50	NNB-BCM-SD97-14
Aldrin	1.67 - 1.67	1 / 1	1.50	NNB-BCM-SD97-14
Semivolatile Organic Compounds (UG/KG)				
4-Methylphenol	25.0 - 25.0	1 / 1	63.0	NNB-BCM-SD97-14
Acenaphthene	27.0 - 27.0	1 / 1	80.0	NNB-BCM-SD97-14
Anthracene	28.0 - 28.0	1 / 1	140	NNB-BCM-SD97-14
Benzo(a)anthracene	24.0 - 24.0	1 / 1	510	NNB-BCM-SD97-14
Benzo(a)pyrene	32.0 - 32.0	1 / 1	590	NNB-BCM-SD97-14
Benzo(b)fluoranthene	18.0 - 18.0	1 / 1	940	NNB-BCM-SD97-14
Benzo(g,h,i)perylene	23.0 - 23.0	1 / 1	230	NNB-BCM-SD97-14
Benzo(k)fluoranthene	32.0 - 32.0	1 / 1	560	NNB-BCM-SD97-14
Carbazole	170 - 170	1 / 1	320	NNB-BCM-SD97-14
Chrysene	26.0 - 26.0	1 / 1	680	NNB-BCM-SD97-14
Di-n-octylphthalate	52.0 - 52.0	1 / 1	52.0	NNB-BCM-SD97-14
Dibenz(a,h)anthracene	51.0 - 51.0	1 / 1	51.0	NNB-BCM-SD97-14
Dibenzofuran	26.0 - 26.0	1 / 1	67.0	NNB-BCM-SD97-14
Fluoranthene	27.0 - 27.0	1 / 1	860	NNB-BCM-SD97-14
Fluorene	26.0 - 26.0	1 / 1	98.0	NNB-BCM-SD97-14
Indeno(1,2,3-cd)pyrene	27.0 - 27.0	1 / 1	220	NNB-BCM-SD97-14
Naphthalene	26.0 - 26.0	1 / 1	39.0	NNB-BCM-SD97-14

Table 3-9
Summary Statistics for Detected Constituents - Sediment - Bay (1997)
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Reporting Limit Range	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Concentration
Phenanthrene	30.0 - 30.0	1 / 1	480	NNB-BCM-SD97-14
Pyrene	32.0 - 32.0	1 / 1	960	NNB-BCM-SD97-14
bis(2-Ethylhexyl)phthalate	26.0 - 26.0	1 / 1	91.0	NNB-BCM-SD97-14
Volatile Organic Compounds (UG/KG)				
Acetone	8.00 - 8.00	1 / 1	300	NNB-BCM-SD97-14
Methylene chloride	10.0 - 10.0	1 / 1	27.0	NNB-BCM-SD97-14
Other Parameters (MG/KG)				
Total organic carbon (TOC)	-- - --	1 / 1	44,000	NNB-BCM-SD97-14

Table 3-10
Summary Statistics for Detected Constituents - Surface Water - Bousch Creek Zone 8 (1997/2004)
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Range of Non-Detect Values	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Detected Concentration	Arithmetic Mean[1]	Standard Deviation of Mean
Inorganics (UG/L)						
Aluminum	148 - 148	2 / 3	5,800	NNB-BCM-SW97-15L	2,025	3,270
Arsenic	3.30 - 4.00	1 / 3	16.5	NNB-BCM-SW97-15L	6.72	8.47
Barium	-- - --	3 / 3	147	NNB-BCM-SW97-15L	72.1	64.9
Beryllium	0.86 - 1.00	1 / 3	1.70	NNB-BCM-SW97-15L	0.88	0.71
Cadmium	0.30 - 1.00	1 / 3	2.50	NNB-BCM-SW97-15L	1.05	1.27
Calcium	-- - --	3 / 3	139,000	NNB-BCM-SW97-15H	115,667	21,385
Chromium	1.50 - 2.00	1 / 3	14.2	NNB-BCM-SW97-15L	5.32	7.69
Cobalt	1.20 - 1.20	2 / 3	5.90	NNB-BCM-SW97-15L	2.70	2.82
Copper	1.90 - 1.90	2 / 3	64.9	NNB-BCM-SW97-15L	29.0	32.7
Iron	-- - --	3 / 3	17,600	NNB-BCM-SW97-15L	6,282	9,803
Lead	1.70 - 1.70	2 / 3	127	NNB-BCM-SW97-15L	43.9	72.0
Magnesium	-- - --	3 / 3	335,000	NNB-BCM-SW97-15H	181,433	151,399
Manganese	-- - --	3 / 3	339	NNB-BCM-SW97-15L	168	152
Mercury	0.10 - 0.20	1 / 3	1.30	NNB-BCM-SW97-15L	0.48	0.71
Nickel	1.50 - 1.50	2 / 3	36.1	NNB-BCM-SW97-15L	14.4	19.0
Potassium	-- - --	3 / 3	220,000	NNB-BCM-SW97-15H	103,047	107,041
Sodium	-- - --	3 / 3	3,250,000	NNB-BCM-SW97-15H	1,655,200	1,587,255
Vanadium	1.40 - 1.40	2 / 3	107	NNB-BCM-SW97-15L	36.5	61.1
Zinc	-- - --	3 / 3	572	NNB-BCM-SW97-15L	201	321
Dissolved Metals (UG/L)						
Aluminum	132 - 132	2 / 3	111	NNB-BCM-SW97-15L	75.0	32.4
Barium	-- - --	3 / 3	59.5	NNB-BCM-SW97-15L	42.3	14.9
Calcium	-- - --	3 / 3	137,000	NNB-BCM-SW97-15H	110,367	28,623
Chromium	0.88 - 2.00	1 / 3	2.60	NNB-BCM-SW97-15L	1.35	1.12
Cobalt	0.86 - 1.00	1 / 3	1.10	NNB-BCM-SW97-15H	0.68	0.37
Copper	0.94 - 0.94	2 / 3	44.9	NNB-BCM-SW97-15L	24.8	22.5
Iron	13.6 - 13.6	2 / 3	312	NNB-BCM-SW97-15H	196	165

1 - One-half of the reporting limit was used for non-detected samples when calculating the mean

Table 3-10
Summary Statistics for Detected Constituents - Surface Water - Bousch Creek Zone 8 (1997/2004)
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Range of Non-Detect Values	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Detected Concentration	Arithmetic Mean[1]	Standard Deviation of Mean
Lead	1.70 - 1.70	2 / 3	3.10	NNB-BCM-SW97-15H	2.35	1.30
Magnesium	-- - --	3 / 3	337,000	NNB-BCM-SW97-15H	183,033	152,960
Manganese	-- - --	3 / 3	170	NNB-BCM-SW97-15L	110	64.2
Nickel	1.80 - 3.00	1 / 3	3.90	NNB-BCM-SW97-15L	2.10	1.59
Potassium	-- - --	3 / 3	230,000	NNB-BCM-SW97-15H	106,110	113,023
Sodium	-- - --	3 / 3	3,540,000	NNB-BCM-SW97-15H	1,719,533	1,737,670
Vanadium	0.50 - 0.50	2 / 3	1.40	NNB-BCM-SW97-15L	0.98	0.64
Zinc	1.20 - 1.20	2 / 3	28.0	NNB-BCM-SW97-15H	15.7	13.9
Pesticide/Polychlorinated Biphenyls (UG/L)						
No detections						
Semivolatile Organic Compounds (UG/L)						
No detections						
Volatile Organic Compounds (UG/L)						
Acetone	-- - --	2 / 2	2.00	NNB-BCM-SW97-15H	2.00	0.0
Methylene chloride	-- - --	2 / 2	2.00	NNB-BCM-SW97-15H	1.50	0.71
Other Parameters (MG/L)						
Hardness	-- - --	1 / 1	1,150	BC-SW04-03	1,150	--
Total dissolved solids (TDS)	-- - --	1 / 1	5,180	BC-SW04-03	5,180	--
Total suspended solids (TSS)	-- - --	1 / 1	2.60	BC-SW04-03	2.60	--

1 - One-half of the reporting limit was used for non-detected samples when calculating the mean

Table 3-11
Summary Statistics for Detected Constituents - Sediment - Bousch Creek Zone 8 (1997 - 2004)
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Range of Non-Detect Values	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Detected Concentration	Arithmetic Mean[1]	Standard Deviation of Mean
Inorganics (MG/KG)						
Aluminum	-- - --	11 / 11	18,300	BC-SD04-20	5,946	4,764
Antimony	0.66 - 1.90	1 / 11	0.42	NNB-BCM-SD97-15	0.55	0.18
Arsenic	-- - --	11 / 11	29.3	BC-SD04-20	11.8	8.13
Barium	-- - --	11 / 11	54.4	BC-SD04-20	26.5	14.8
Beryllium	0.54 - 1.50	5 / 11	10.9	NNB-BCM-SD99-15A	2.35	3.57
Cadmium	0.77 - 1.10	9 / 11	12.9	BC-SD04-02	3.15	3.96
Calcium	-- - --	11 / 11	6,030	BC-SD04-03	2,391	1,531
Chromium	-- - --	11 / 11	315	NNB-BCM-SD99-15A	82.0	108
Cobalt	1.30 - 1.30	10 / 11	12.1	BC-SD04-20	3.66	3.18
Copper	-- - --	11 / 11	55.1	BC-SD04-20	31.1	16.6
Iron	-- - --	11 / 11	41,300	BC-SD04-20	14,158	10,577
Lead	-- - --	11 / 11	111	BC-SD04-02	56.4	32.1
Magnesium	-- - --	11 / 11	4,550	BC-SD04-20	1,825	1,122
Manganese	-- - --	11 / 11	212	BC-SD04-20	79.3	55.9
Mercury	0.040 - 0.42	3 / 11	0.15	NNB-BCM-SD99-17	0.085	0.056
Nickel	-- - --	11 / 11	56.4	BC-SD04-02	17.8	17.3
Potassium	-- - --	11 / 11	3,440	BC-SD04-20	1,020	894
Selenium	0.83 - 2.40	4 / 11	1.80	NNB-BCM-SD99-15A	0.82	0.44
Silver	0.46 - 0.83	6 / 11	4.20	BC-SD04-02	0.97	1.18
Sodium	-- - --	11 / 11	5,820	BC-SD04-20	2,246	1,690
Vanadium	-- - --	11 / 11	84.5	BC-SD04-20	29.7	22.2
Zinc	-- - --	11 / 11	343	BC-SD04-20	135	96.1
Pesticide/Polychlorinated Biphenyls (UG/KG)						
4,4'-DDD	3.30 - 11.0	9 / 11	12.0	BC-SD04-02	3.52	3.40
4,4'-DDE	3.30 - 3.30	10 / 11	21.0	BC-SD04-19	5.22	6.09
4,4'-DDT	3.30 - 11.0	5 / 11	2.80	NNB-BCM-SD99-17	2.35	1.34
Aroclor-1260	33.0 - 110	2 / 11	55.0	BC-SD04-02	29.4	13.3

1 - One-half of the reporting limit was used for non-detected samples when calculating the mean

Table 3-11
Summary Statistics for Detected Constituents - Sediment - Bousch Creek Zone 8 (1997 - 2004)
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Range of Non-Detect Values	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Detected Concentration	Arithmetic Mean[1]	Standard Deviation of Mean
Dieldrin	3.30 - 6.30	1 / 11	2.80	BC-SD04-20	2.45	0.42
Endosulfan sulfate	3.30 - 11.0	1 / 11	2.70	BC-SD04-01	2.69	1.02
Endrin aldehyde	3.30 - 11.0	1 / 11	2.00	BC-SD04-01	2.62	1.04
alpha-Chlordane	1.70 - 2.80	2 / 11	12.0	BC-SD04-19	2.62	3.46
gamma-Chlordane	1.70 - 5.90	4 / 11	2.80	BC-SD04-02	1.48	0.74
Semivolatile Organic Compounds (UG/KG)						
2-Methylnaphthalene	49.0 - 480	1 / 6	94.0	NNB-BCM-SD99-15A	171	90.4
4-Methylphenol	49.0 - 480	1 / 6	73.0	NNB-BCM-SD99-15A	168	94.3
Acenaphthene	54.0 - 1,100	1 / 11	130	BC-SD04-02	244	128
Acenaphthylene	57.0 - 1,100	1 / 11	270	BC-SD04-01	257	122
Anthracene	55.0 - 1,100	3 / 11	540	BC-SD04-01	255	165
Benzo(a)anthracene	48.0 - 1,100	7 / 11	3,000	BC-SD04-01	465	857
Benzo(a)pyrene	64.0 - 1,100	5 / 11	1,700	BC-SD04-01	363	462
Benzo(b)fluoranthene	36.0 - 1,100	9 / 11	4,100	BC-SD04-01	578	1,185
Benzo(g,h,i)perylene	46.0 - 1,100	5 / 11	740	BC-SD04-01	242	215
Benzo(k)fluoranthene	64.0 - 1,100	6 / 11	3,300	BC-SD04-01	499	940
Chrysene	51.0 - 480	8 / 11	5,400	BC-SD04-01	689	1,570
Di-n-butylphthalate	62.0 - 540	2 / 6	83.0	NNB-BCM-SD99-16A	152	109
Dibenz(a,h)anthracene	51.0 - 1,100	2 / 11	480	BC-SD04-01	257	153
Dibenzofuran	52.0 - 480	1 / 6	75.0	NNB-BCM-SD99-15A	169	93.4
Diethylphthalate	54.0 - 480	1 / 6	260	NNB-BCM-SD99-15A	200	86.3
Fluoranthene	53.0 - 53.0	10 / 11	13,000	BC-SD04-01	1,529	3,840
Indeno(1,2,3-cd)pyrene	54.0 - 1,100	4 / 11	1,300	BC-SD04-01	324	350
Naphthalene	52.0 - 1,100	1 / 11	74.0	NNB-BCM-SD99-15A	239	134
Phenanthrene	59.0 - 1,100	7 / 11	530	BC-SD04-01	240	185
Pyrene	64.0 - 64.0	10 / 11	10,000	BC-SD04-01	1,170	2,947
bis(2-Ethylhexyl)phthalate	-- - --	6 / 6	1,100	NNB-BCM-SD99-18A	542	391

1 - One-half of the reporting limit was used for non-detected samples when calculating the mean

Table 3-11
Summary Statistics for Detected Constituents - Sediment - Bousch Creek Zone 8 (1997 - 2004)
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Range of Non-Detect Values	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Detected Concentration	Arithmetic Mean[1]	Standard Deviation of Mean
Volatile Organic Compounds (UG/KG)						
Methylene chloride	-- - --	1 / 1	180	NNB-BCM-SD97-15	180	--
Other Parameters						
Total organic carbon (MG/KG)	-- - --	10 / 10	93,300	BC-SD04-20	27,402	31,172
pH	-- - --	10 / 10	7.77	NNB-BCM-SD99-16A	7.34	0.28

1 - One-half of the reporting limit was used for non-detected samples when calculating the mean

Table 3-12
Summary Statistics - 2004 Fish Tissue Samples (Dry-Weight) - Upper and Upper-Middle Reaches
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Range of Non-Detect Values	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Detected Concentration	Arithmetic Mean[1]	Standard Deviation of Mean	95% UCL (Normal Distribution)	Geometric Mean[1]
Metals (MG/KG)								
Arsenic	2.60 - 2.80	6 / 10	5.00	BC-FI04-01	2.56	1.21	3.26	2.31
Cadmium	0.26 - 0.29	0 / 10	--	--	0.14	0.004	0.14	0.14
Chromium	1.40 - 4.80	0 / 10	--	--	1.57	0.49	1.85	1.49
Copper	-- - --	10 / 10	22.6	BC-FI04-02	13.8	4.58	16.5	13.2
Lead	1.50 - 2.60	6 / 10	4.00	BC-FI04-02	2.52	1.28	3.25	2.15
Mercury	0.17 - 0.23	1 / 10	0.19	BC-FI04-04	0.11	0.03	0.13	0.11
Selenium	3.10 - 3.30	2 / 10	4.00	BC-FI04-01	2.03	0.89	2.54	1.90
Zinc	-- - --	10 / 10	243	BC-FI04-02	176	27.2	192	174
Pesticide/Polychlorinated Biphenyls (UG/KG)								
4,4'-DDD	-- - --	10 / 10	260	BC-FI04-09	85.1	74.1	128	64.0
4,4'-DDE	-- - --	10 / 10	480	BC-FI04-09	187	141	268	148
4,4'-DDT	45.0 - 50.0	3 / 10	48.0	BC-FI04-09	27.6	9.12	32.8	26.5
Aldrin	23.0 - 26.0	0 / 10	--	--	12.4	0.58	12.7	12.3
Aroclor-1016	450 - 500	0 / 10	--	--	240	9.13	245	240
Aroclor-1221	910 - 1,000	0 / 10	--	--	486	14.6	494	485
Aroclor-1232	450 - 500	0 / 10	--	--	240	9.13	245	240
Aroclor-1242	450 - 500	0 / 10	--	--	240	9.13	245	240
Aroclor-1248	450 - 500	0 / 10	--	--	240	9.13	245	240
Aroclor-1254	450 - 500	0 / 10	--	--	240	9.13	245	240
Aroclor-1260	450 - 500	0 / 10	--	--	240	9.13	245	240
Dieldrin	-- - --	10 / 10	420	BC-FI04-09	82.2	131	158	37.6
Endosulfan I	23.0 - 26.0	0 / 10	--	--	12.4	0.58	12.7	12.3
Endosulfan II	45.0 - 50.0	0 / 10	--	--	24.0	0.91	24.5	24.0
Endosulfan sulfate	45.0 - 50.0	0 / 10	--	--	24.0	0.91	24.5	24.0
Endrin	45.0 - 50.0	0 / 10	--	--	24.0	0.91	24.5	24.0
Endrin aldehyde	45.0 - 50.0	0 / 10	--	--	24.0	0.91	24.5	24.0
Endrin ketone	50.0 - 50.0	9 / 10	29.0	BC-FI04-07	19.0	5.31	22.1	18.3
Heptachlor	23.0 - 26.0	0 / 10	--	--	12.4	0.58	12.7	12.3

1 - One-half of the reporting limit was used for non-detected samples when calculating the mean

Table 3-12
Summary Statistics - 2004 Fish Tissue Samples (Dry-Weight) - Upper and Upper-Middle Reaches
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Range of Non-Detect Values	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Detected Concentration	Arithmetic Mean[1]	Standard Deviation of Mean	95% UCL (Normal Distribution)	Geometric Mean[1]
Heptachlor epoxide	23.0 - 26.0	3 / 10	27.0	BC-FI04-09	14.3	4.58	16.9	13.8
Methoxychlor	230 - 260	0 / 10	--	--	124	5.80	127	123
Toxaphene	2,300 - 2,600	0 / 10	--	--	1,235	58.0	1269	1234
alpha-BHC	23.0 - 26.0	0 / 10	--	--	12.4	0.58	12.69	12.34
alpha-Chlordane	26.0 - 26.0	9 / 10	180	BC-FI04-09	39.0	56.6	71.8	20.3
beta-BHC	23.0 - 26.0	0 / 10	--	--	12.4	0.58	12.7	12.3
delta-BHC	23.0 - 26.0	0 / 10	--	--	12.4	0.58	12.7	12.3
gamma-BHC (Lindane)	23.0 - 26.0	0 / 10	--	--	12.4	0.58	12.7	12.3
gamma-Chlordane	23.0 - 26.0	4 / 10	34.0	BC-FI04-09	14.2	7.83	18.7	12.7
Other Parameters (Percent)								
Moisture	-- - --	10 / 10	80.0	BC-FI04-01	79.3	0.67	79.7	79.3
Lipids	-- - --	10 / 10	1.80	BC-FI04-09	0.80	0.45	1.06	0.69

1 - One-half of the reporting limit was used for non-detected samples when calculating the mean

Table 3-13
Summary of the 2004 *Leptocheirus plumulosus* 28-Day Toxicity Test Results - Upper and Upper-Middle Reaches
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Area/ Treatment	Sample	Survival					Growth					Reproduction				
		Mean (%)	Statistical Comparisons				Mean Dry Weight (mg)	Statistical Comparisons				Mean Offspring/ Amphipod	Statistical Comparisons			
			Laboratory Control	Reference				Laboratory Control	Reference				Laboratory Control	Reference		
				18	19	20			18	19	20			18	19	20
Control	Laboratory Control	85	--				1.37	--			√	6.49	--			
Reference	BC-SD04-18	51		Not conducted			0.88		Not conducted			1.40	√	Not conducted		
	BC-SD04-19	90		Not conducted			0.91		Not conducted			0.30	√	Not conducted		
	BC-SD04-20	96		Not conducted			2.36		Not conducted			9.37		Not conducted		
Upper-Middle Reaches	BC-SD04-01	0	√	√	√	√	NA	--	--	--	--	NA	--	--	--	--
	BC-SD04-02	39	√		√	√	0.53	√			√	1.30				
	BC-SD04-03	69					0.68	√			√	2.02				√
	BC-SD04-04	87					1.11				√	1.88				√
	BC-SD04-05	95					0.88				√	1.21				√
Upper Reaches	BC-SD04-06	79					0.43	√			√	0.80	√			√
	BC-SD04-07	0	√	√	√	√	NA	--	--	--	--	NA	--	--	--	--
	BC-SD04-08	71					0.80	√			√	0.90	√			√
	BC-SD04-09	40	√		√	√	0.29	√		√	√	0.65	√			√
	BC-SD04-10	2	√	√	√	√	NA	--	--	--	--	NA	--	--	--	--
	BC-SD04-11	67					0.66	√			√	0.80				√
	BC-SD04-12	56				√	0.50	√			√	0.69	√			√
	BC-SD04-13	38	√		√	√	0.45	√			√	0.96				
	BC-SD04-14	64					0.37	√			√	0.35	√			√
	BC-SD04-15	67					0.70	√			√	1.35				√
	BC-SD04-16	100					1.02				√	0.67				√
	BC-SD04-17	76					0.66	√			√	0.56	√			√

"√" indicates a statistically significant decrease in response relative to Laboratory Control or Reference (column headers indicate which comparison is being made)
NA - Not applicable due to low survival

Table 3-14
Risk Characterization Summary Matrix - Baseline ERA for the Upper and Upper-Middle Reaches of Bousch Creek
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Area	Medium-Specific COPCs (Screening Value Comparisons)[1]				Toxicity Tests			Biological Surveys		Bioavailability[1]
	Surface Water	Sediment	Fish Tissue	Food Web	Survival	Growth	Reproduction	Invertebrate	Fish	
Upper Reaches	Al, Fe, Mn	**Metals (12)**	None	None	Control - 4 / 12	Control - 11 / 12	Control - 8 / 12	Limited habitat	Limited habitat	SW - Mn
		PCBs (2)			Ref 18/19 - 4 / 12	Ref 18/19 - 3 / 5	Ref 18/19 - 2 / 12	Low diversity	Low diversity	SD Metals - SD04-13, SD04-14
		Pesticides (9)			Ref 20 - 5 / 12	Ref 20 - 12 / 12	Ref 20 - 11 / 12	High Dominance		SD Organics - None
		SVOCs (3)								
		PAHs (10)								
Upper-Middle Reaches	Al, Mn	Metals (9)	None	None	Control - 2 / 5	Control - 3 / 5	Control - 1 / 5	Limited habitat	Limited habitat	SW - Mn
		PCBs (1)			Ref 18/19 - 2 / 5	Ref 18/19 - 1 / 5	Ref 18/19 - 1 / 5	Low diversity	Low diversity	SD Metals - None
		Pesticides (6)			Ref 20 - 2 / 5	Ref 20 - 5 / 5	Ref 20 - 4 / 5	High Dominance		SD Organics - PAHs (3); SD04-01
		SVOCs (1)								
		PAHs (11)								

[1] Numbers in parentheses (surface water, sediment, and bioavailability) are the number of COPCs; for fish tissue are the frequency of exceedance and the maximum HQ. Bold chemicals are risk drivers (COCs)

Table 3-15
Summary of Chemicals of Concern - Baseline ERA for the Upper and Upper-Middle Reaches of Bousch Creek
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Surface Water		Sediment		Fish Tissue		Food Web	
	Upper Reaches	Upper-Middle Reaches	Upper Reaches	Upper-Middle Reaches	Upper Reaches	Upper-Middle Reaches	Upper Reaches	Upper-Middle Reaches
Metals								
Arsenic			X	x				
Barium			x					
Cadmium			X	X				
Chromium			X					
Copper			X	x				
Lead			X	x				
Mercury			x					
Nickel			x					
Selenium			x	x				
Silver			X					
Zinc			x	x				
Pesticides/PCBs								
4,4'-DDD			x	x				
4,4'-DDE			x	x				
4,4'-DDT			x	x				
alpha-Chlordane				x				
beta-BHC			x					
Aroclor-1254			x					
Aroclor-1260			x	x				
Dieldrin			x					
gamma-Chlordane				x				
Semivolatile Organic Compounds								
PAHs			x	X				

Shaded cells indicate that exposures and risks are likely minimal when bioavailability factors are considered
X - Potential risk drivers
x - Other potential Chemicals of Concern

Table 3-16
Type and Number of Listed Sites Within the Bousch Creek Drainage Area
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Category	Number of Sites
Accumulation Sites	
CERCLA	5 (Sites 1,6,20,22,23)
Non-CERCLA	8 (Sites 7,8; SWMUs 26,29,30,38,39,40)
Hazardous Materials/ Hazardous Wastes/POL Storage	
Flammables in Metal Cabinets/ Storage Facilities	26
Flammables in Drums/ Containers	7
Paint and Paint Related Materials/Waste	16
POLS in Metal Cobinets/Storage Facilities	1
POLs in Drums/Containers/Mobile Tanks	1
Waste Fuel/Used Oil in Drums/Containers	1
Compressed Gas Cylinders/Tanks	18
Batteries	1
Pesticides/Herbicides	2
Aboveground Fuel Storage Tanks	33
Aboveground Fuel Dispensing Tanks	7
Aboveground Waste Fuel/Used Oil/HW Tanks	11
Cooking Oil/Grease Bins/Containers	5
Compressed Gas Cylinders/Tanks	18
Batteries	1
Pesticides/Herbicides	2
Hazardous Waste in Lockers/Sheds	3
Material Storage Areas	
Fueled Equipment/Vehicle Storage	67
Non-fueled Equipment Storage	1
Storage Container/Conex Box	6
Scrap Metal Drumster	16
Recycleable Cardboard/Paper Dumpster	6
Solid Waste Dumpster	64
Portable Toilet	8
Empty Cans/Drums/Tanks	2
Metal Pipe/Misc. Metal storage	12
Misc. Wood/ Lumber Storage	12
Tire Storage	6
Misc. Rubber Storage	3
Plastic Pipe/Misc. Plastic Storage	1
Sand/Aggregate Storage	5
Other Material Storage Areas	5
Materials Loading and Access Areas	
Aircraft/ Vehicle/Equipment Fueling	10
Fuel Transfer	25
Oily Wastewater/Waste Oil Transfer	5
Wastewater Transfer	1
Chemical Transfer	1

Table 3-16
Type and Number of Listed Sites Within the Bousch Creek Drainage Area
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Category	Number of Sites
Exposed Industrial Activity	
Air Transportation with Maintenance	3
Local Trucking with Vehicle Maintenance	1
General Warehousing and Storage	6
Special Warehousing and storage	2
Petroleum Bulk Storage	1
Industrial Truck Repair	3
Other Exposed Industrial Activity	2

Source: VPDES (2000)

Table 3-17
Type and Number of Listed Sites Within the Lower Reaches of the Bousch Creek Drainage Area
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Category	Number of Sites	Specific Sites	Associated Constituents
Accumulation Sites			
CERCLA	2	Sites 20,23	petroleum products, chlorinated solvents
Non-CERCLA	0	NA	NA
Hazardous Materials/ Hazardous Wastes/POL Storage			
Flammables in Metal Cabinets/Storage Facilities	5	U-179, LP-14, V-61, U-46, U-106	alodine waste
Flammables in Drums/Containers	2	U-132, U-46	calibration fluid, waste oil, varsol
Paint and Paint Related Materials/Waste	8	LP-24, U-117, LP-14, LP-12, LP-179, U-132	alodine waste, calibration fluid, waste oil, varsol, paint and paint products, petroleum products
POLs in Metal Cabinets/Storage Facilities	1	LP-54	NA
POLs in Drums/Containers/Mobile Tanks	1	U-46	NA
Aboveground Fuel Storage Tanks	9	LP-209, U-130, V-66, LP-42, LP-39, LP-40, LP-41	petroleum products
Aboveground Fuel Dispensing Tanks	3	U-113, LP-20, LP-16	petroleum products, chlorinated solvents
Aboveground Waste Fuel/Used Oil/HW Tanks	10	LP-21, LP-4, LP-14, U-126, LP-142, LP-19, LP-144	alodine waste, waste oil
Compressed Gas Cyclinders/Tanks	6	U-117, V-61, LP-14, LP-20, U-132, V-147	alodine waste, petroleum products, chlorinated solvents, calibration fluid, waste oil, varsol
Batteries	1	LP-20	petroleum products, chlorinated solvents
HW in Lockers/Sheds	1	V-61	laboratory waste
Material Storage Areas			
Fueled Equipment/Vehicle Storage	32	LP-12, LP-13, LP-14, LP-179, LP-20, LP-24, LP-26, LP-76, LP-FF, U-126, U-129, U-132, U-46, V-61	alodine waste, waste oil, petroleum products, chlorinated solvents, calibration fluid, varsol
Storage Container/Conex Box	2	LP-12, LP-14	alodine waste
Scrap Metal Dumpster	9	U-132, LP-14, U-117, LP-20, V-147, U-115, U-126	alodine waste, calibration fluid, waste oil, varsol, petroluem products, chlorinated solvents
Recylcleable Cardboard/Paper Dumpster	1	V-147	NA
Solid Waste Dumpster	18	LP-13, LP-14, LP-179, LP-20, LP-24, LP-26, LP-76, U-111, U-115, U-117, U-126, U-46, V-147, V-61	alodine waste, petroleum products, chlorinated solvents, calibration fluid, waste oil, varsol
Portable Toilet	5	LP-24, U-46, LP-14, U-132	alodine waste, calibrated fluid, waste oil, varsol

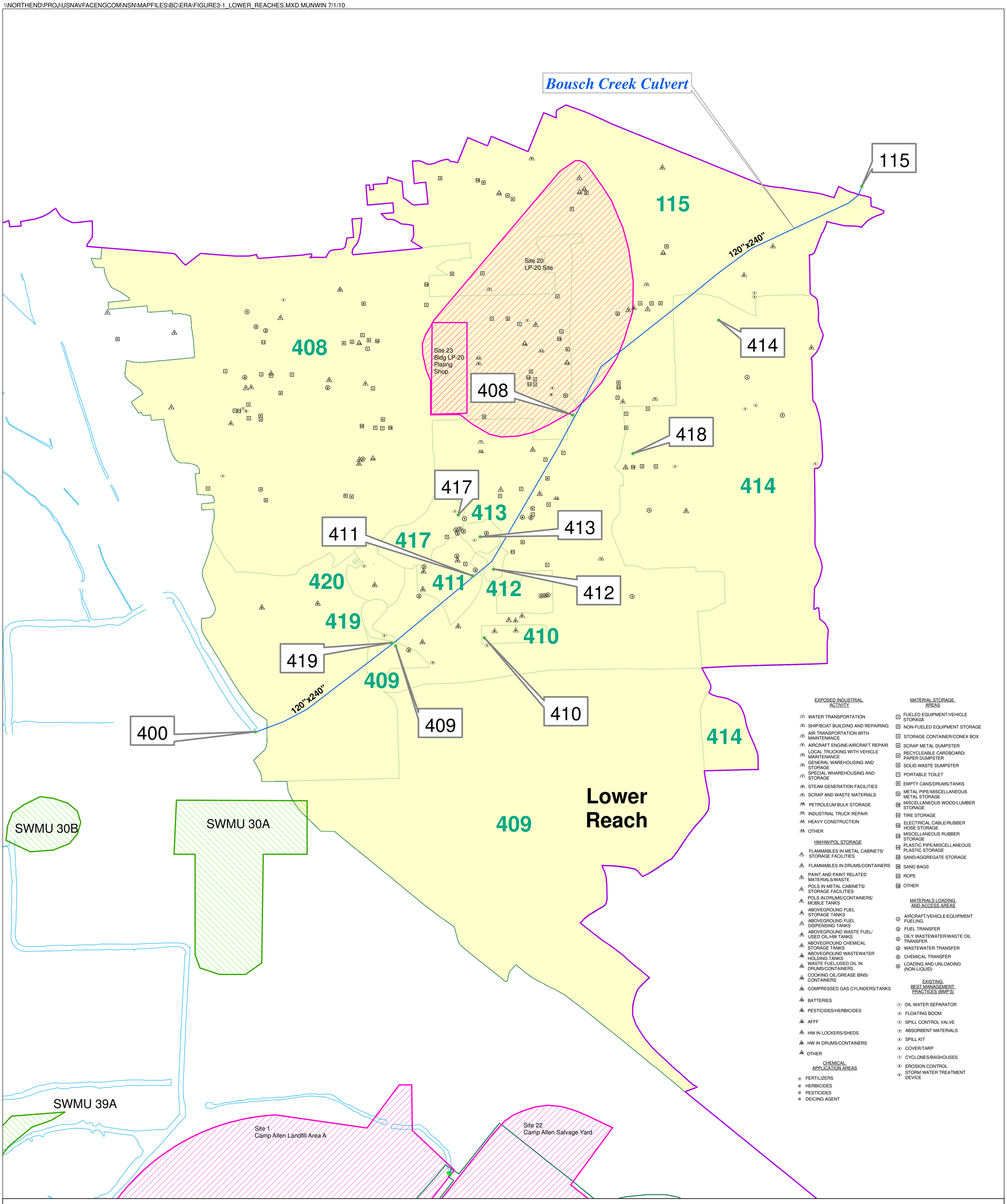
Table 3-17
Type and Number of Listed Sites Within the Lower Reaches of the Bousch Creek Drainage Area
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Metal Pipe/Miscellaneous Metal Storage	2	LP-20, LP-13	petroleum products, chlorinated solvents
Miscellaneous Wood/Lumber Storage	5	LP-12, V-147, LP-26, U-132, LP-20	petroleum products, chlorinated solvents, calibrated fluids, waste oil, varsol
Tire Storage	4	U-124, LP-FF, LP-20, U-126	petroleum products, chlorinated solvents, plastic, rubber
Miscellaneous Rubber Storage	1	LP-13	plastic, rubber, PVC
Sand/Aggregate Storage	1	LP-132	calibrated fluids, waste oil, varsol
Other Material Storage Areas	2	LP-20, U-132	petroleum products, chlorinated solvents, calibration fluid, waste oil, varsol
Materials Loading and Access Areas			
Aircraft/Vehicle Equipment Fueling	6	U-113, LP-125, LP-FF, LP-12, LP-3	petroleum products
Fuel Transfer	15	U-46, U-79B, LP-FF, U-117, U-132	petroleum products, calibration fluids, waste oil, varsol
Oily Wastewater/Waste Oil Transfer	3	LP-FF	waste oil
Wastewater Transfer	1	LP-179	NA
Chemical Transfer	1	LP-179	NA
Exposed Industrial Activity			
Air Transportation and Maintenance	3	NA	NA
Local Trucking with Vehicle Maintenance	1	LP-20	petroleum products, chlorinated solvents
General Warehousing and Storage	1	V-147	NA
Special Warehousing and Storage	2	LP-24, LP-26	NA
Industrial Truck Repair	2	LP-20, LP-22	petroleum products, chlorinated solvents
Other Exposed Industrial Activity	2	LP-24, LP-159	NA

NA - Not Available
Source: VPDES (2000)

Table 3-18
Assessment Endpoints, Risk Hypotheses, and Measurement Endpoints
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Assessment Endpoint		Risk Hypothesis	Measurement Endpoint	Receptor
1	Survival, growth, and reproduction of benthic invertebrate communities	Are site-related chemical concentrations in surface water and sediment sufficient to adversely affect benthic invertebrate communities?	No significant exposure points within the Lower Reaches; possible exposures at either end of the Lower Reach outfall evaluated based upon a comparison of surface sediment concentrations with literature-based screening values and site-specific NOEC values from the Upper Reaches ERA	Benthic invertebrates
2	Survival, growth, and reproduction of fish communities	Are site-related chemical concentrations in surface water and sediment sufficient to adversely affect fish communities?	No significant exposure points within the Lower Reaches; possible exposures at either end of the Lower Reach outfall evaluated based upon a comparison of surface sediment concentrations with literature-based screening values and site-specific NOEC values from the Upper Reaches ERA	Fish



Legend

- Outfalls
- Bousch Creek Culvert
- Site Boundaries
- SWMU Boundaries
- Bousch Creek Watershed
- Lower Reach
- Outfall Subbasins
- Surface Water Features

N
W E
S

0 300 600
Feet

Figure 3-1
Lower Reaches of Bousch Creek Drainage Basin
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, Virginia

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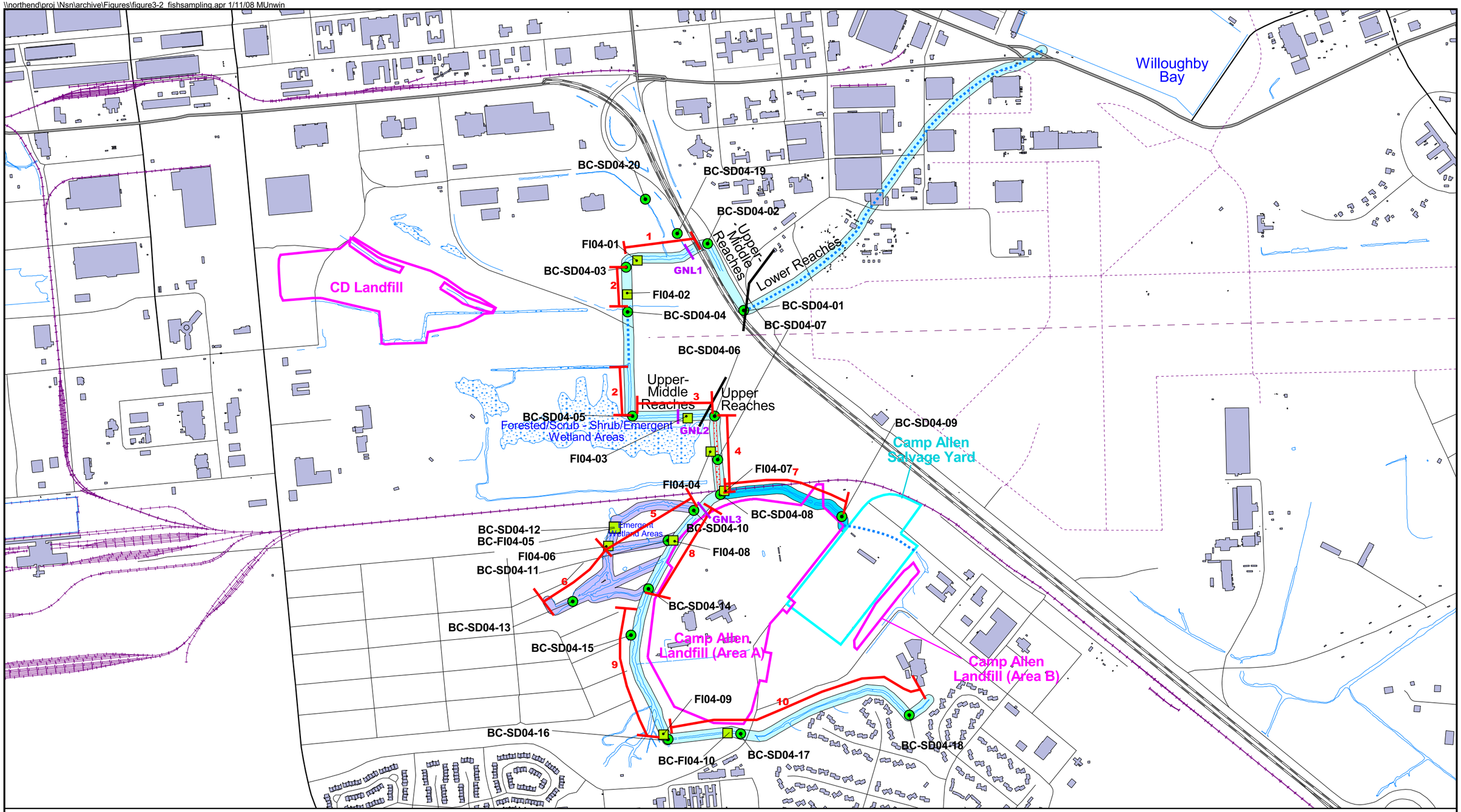

Legend

- 1 Gill Net Locations
- 5 Fish Sampling Locations
- Underground Culvert
- Concrete Lined
- Fish Tissue Sampling Locations
- Benthic Invertebrate Sampling Locations
- Eastern Branch Bousch Creek
- Western Branch Bousch Creek
- Main Branch Bousch Creek

N

0 900 1800 Feet

Figure 3-2
2004 Fish and Benthic Invertebrate Sampling Locations
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, VA

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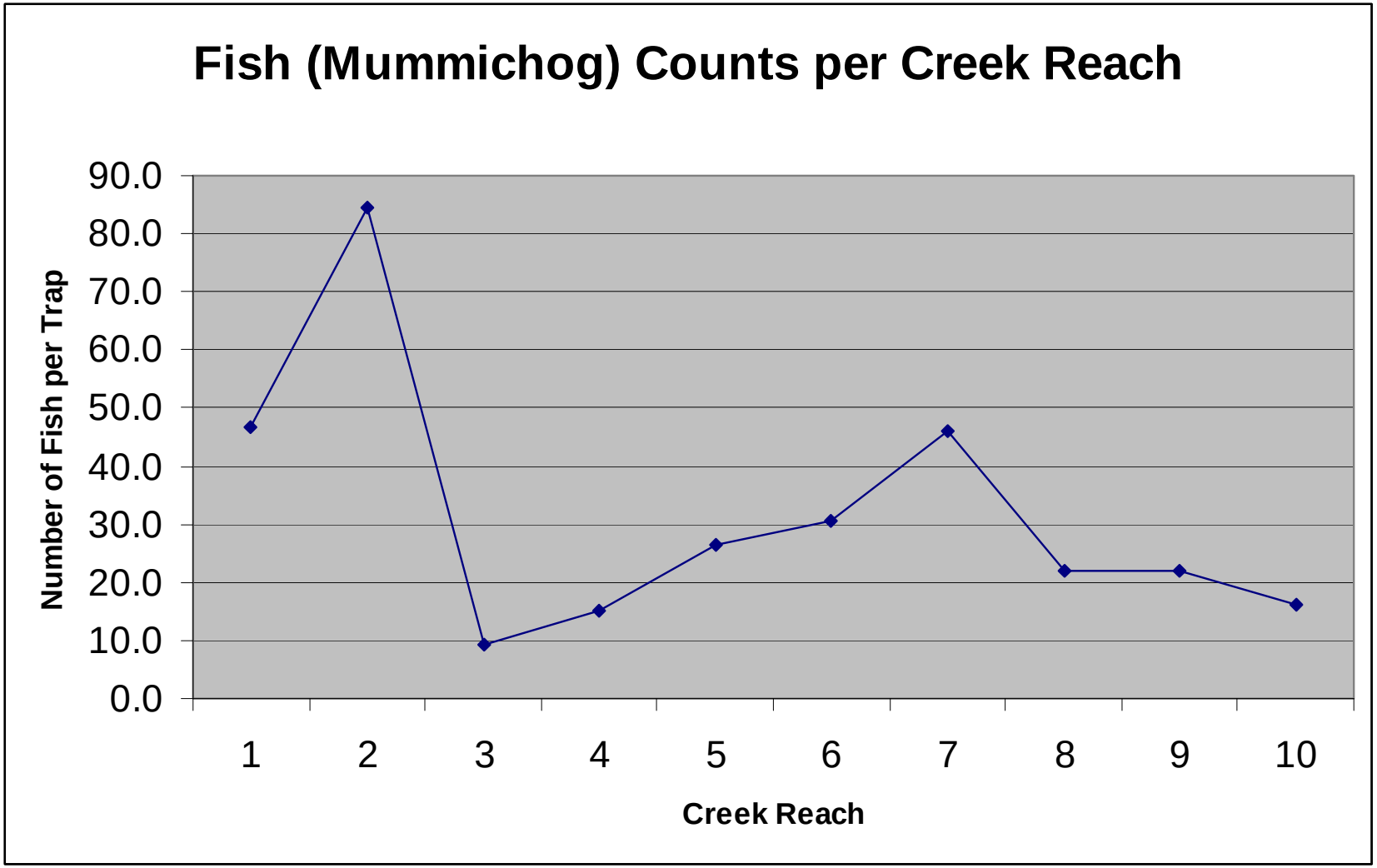

Figure 3-3
Fish (Mummichog) Counts per Creek Reach
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk, Norfolk, Virginia

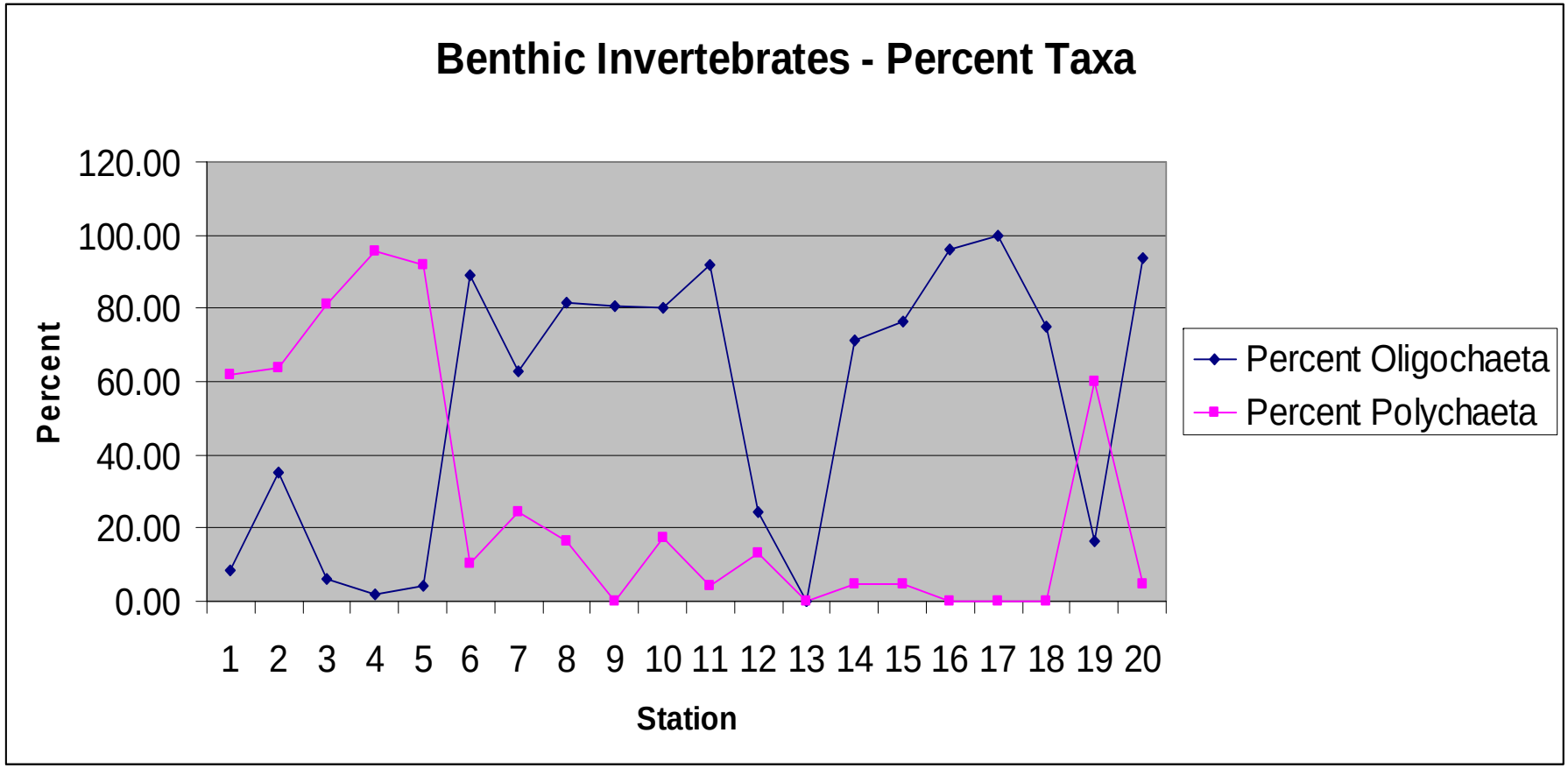

Figure 3-4
Benthic Invertebrates - Percent Dominance of Key Taxa
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk, Norfolk, Virginia

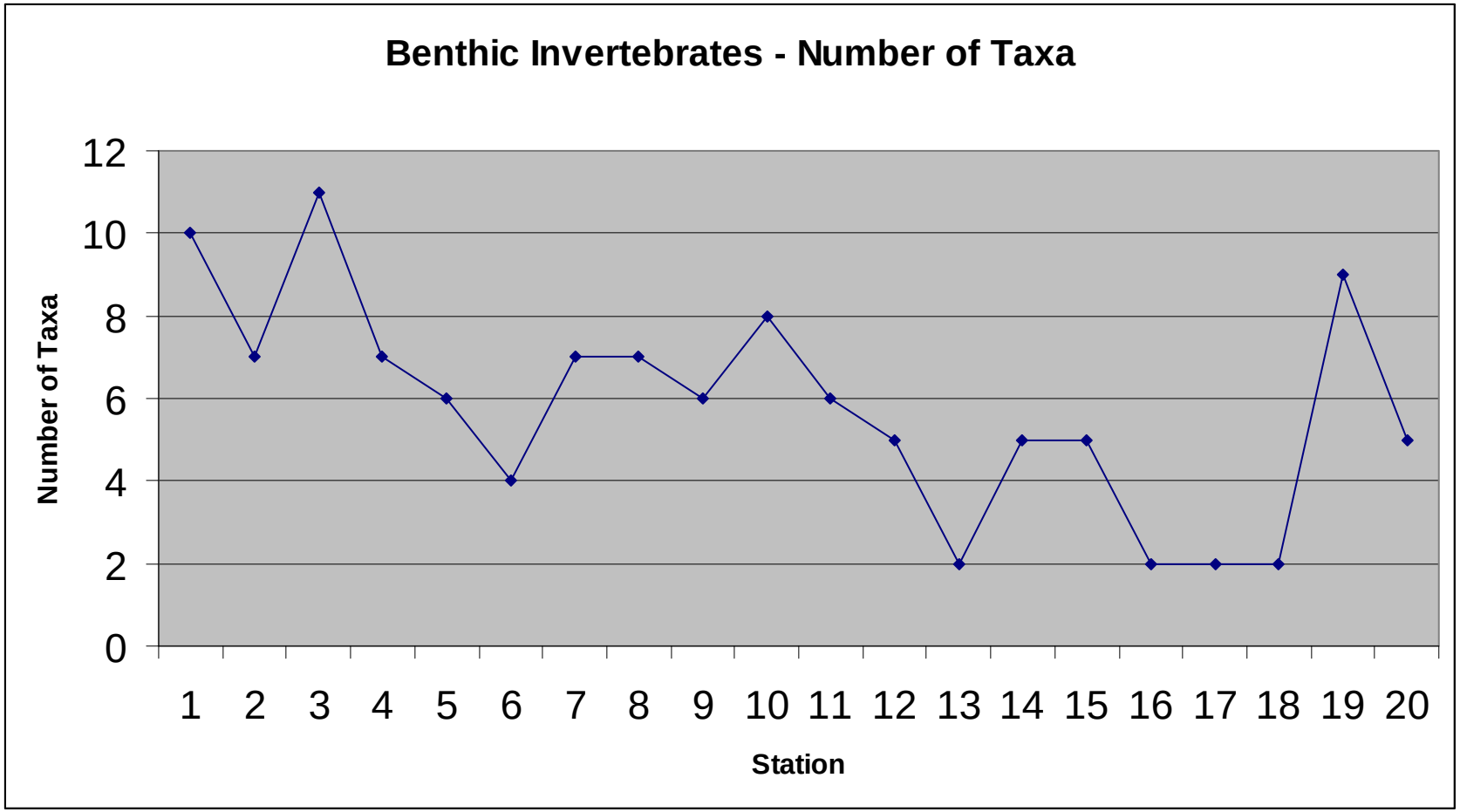

Figure 3-5
Benthic Invertebrates - Number of Taxa per Station
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk, Norfolk, Virginia

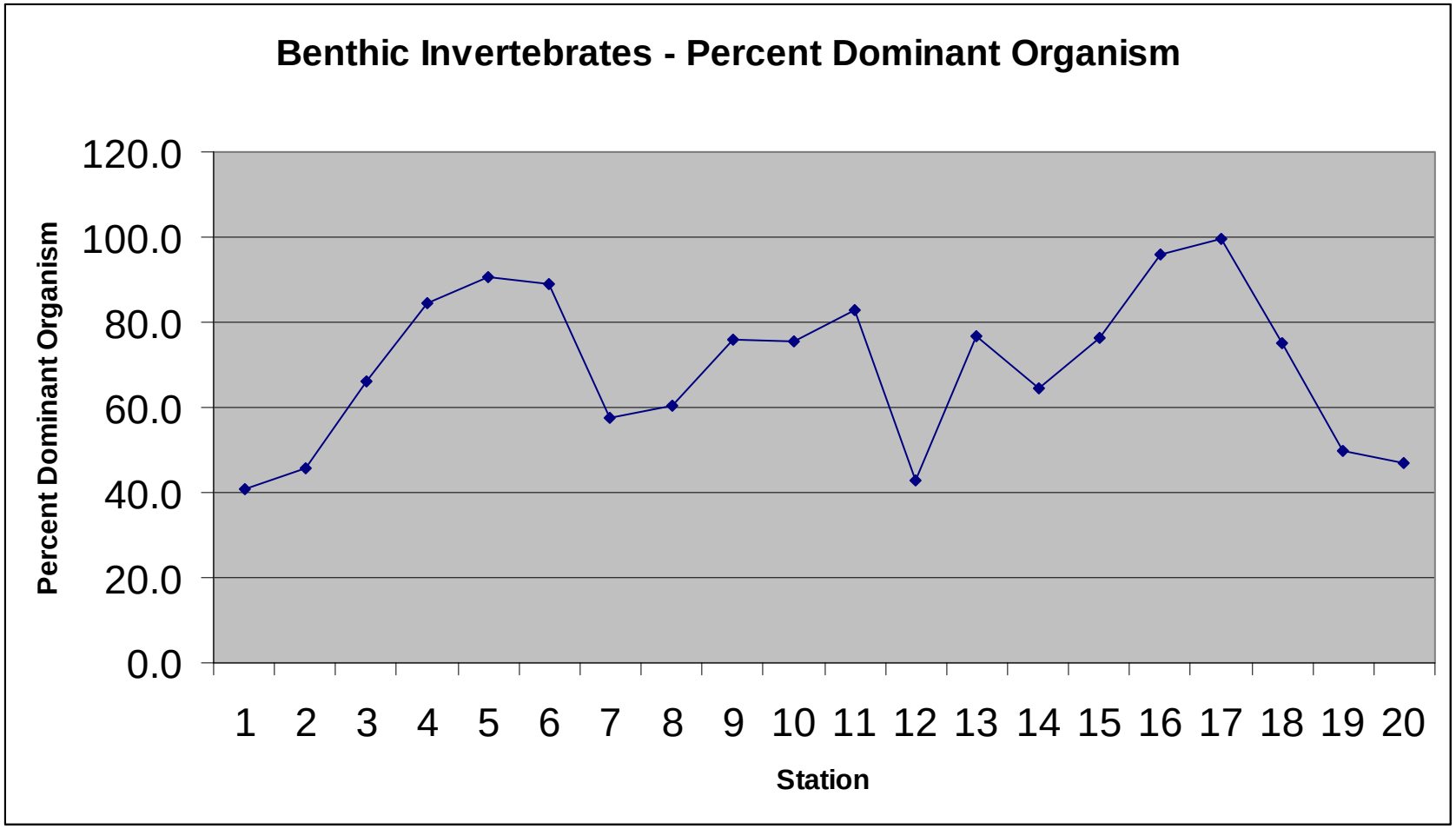

Figure 3-6
Benthic Invertebrates - Percent Dominant Organism
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk, Norfolk, Virginia

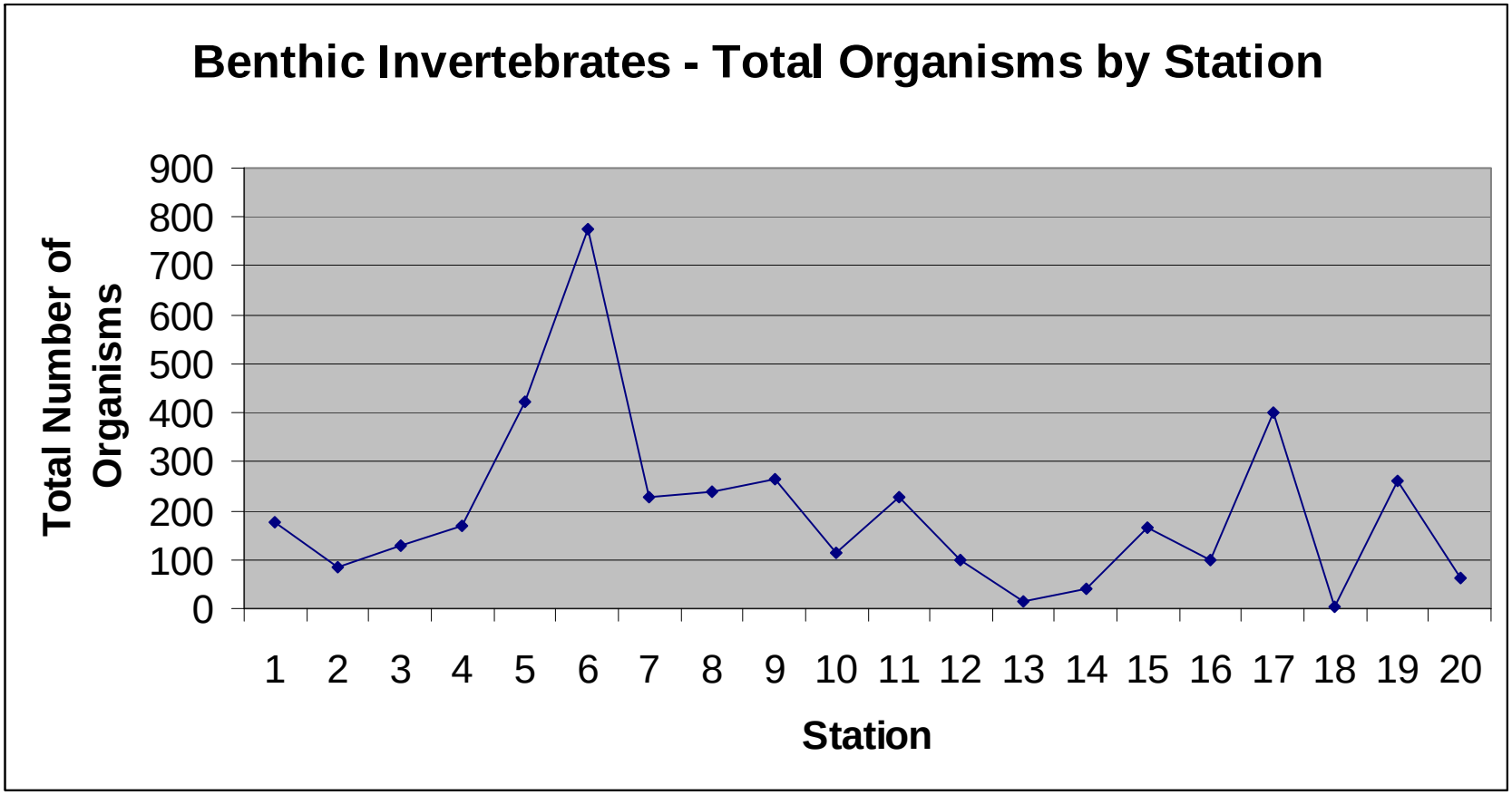

Figure 3-7
Benthic Invertebrates - Total Organisms by Station
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk, Norfolk, Virginia

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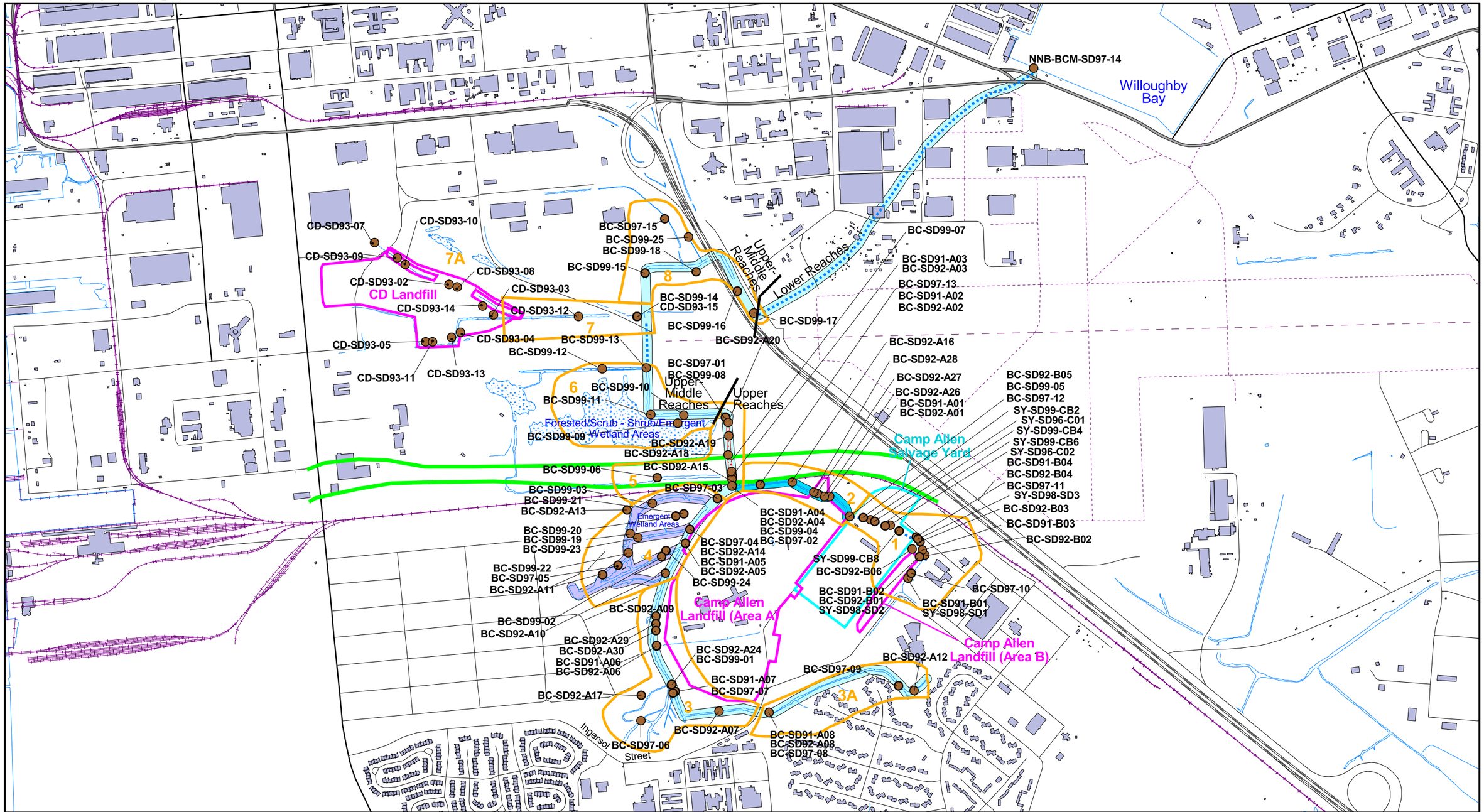

Legend

- Sediment Sampling Locations
- Proposed I-564 Corridor (Approximate)
- Underground Culvert
- Concrete Lined
- Zones
- Eastern Branch Bousch Creek
- Western Branch Bousch Creek
- Main Branch Bousch Creek

N

0 1000 2000 Feet

Figure 3-8
Previous Sediment Sampling Locations
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, Virginia

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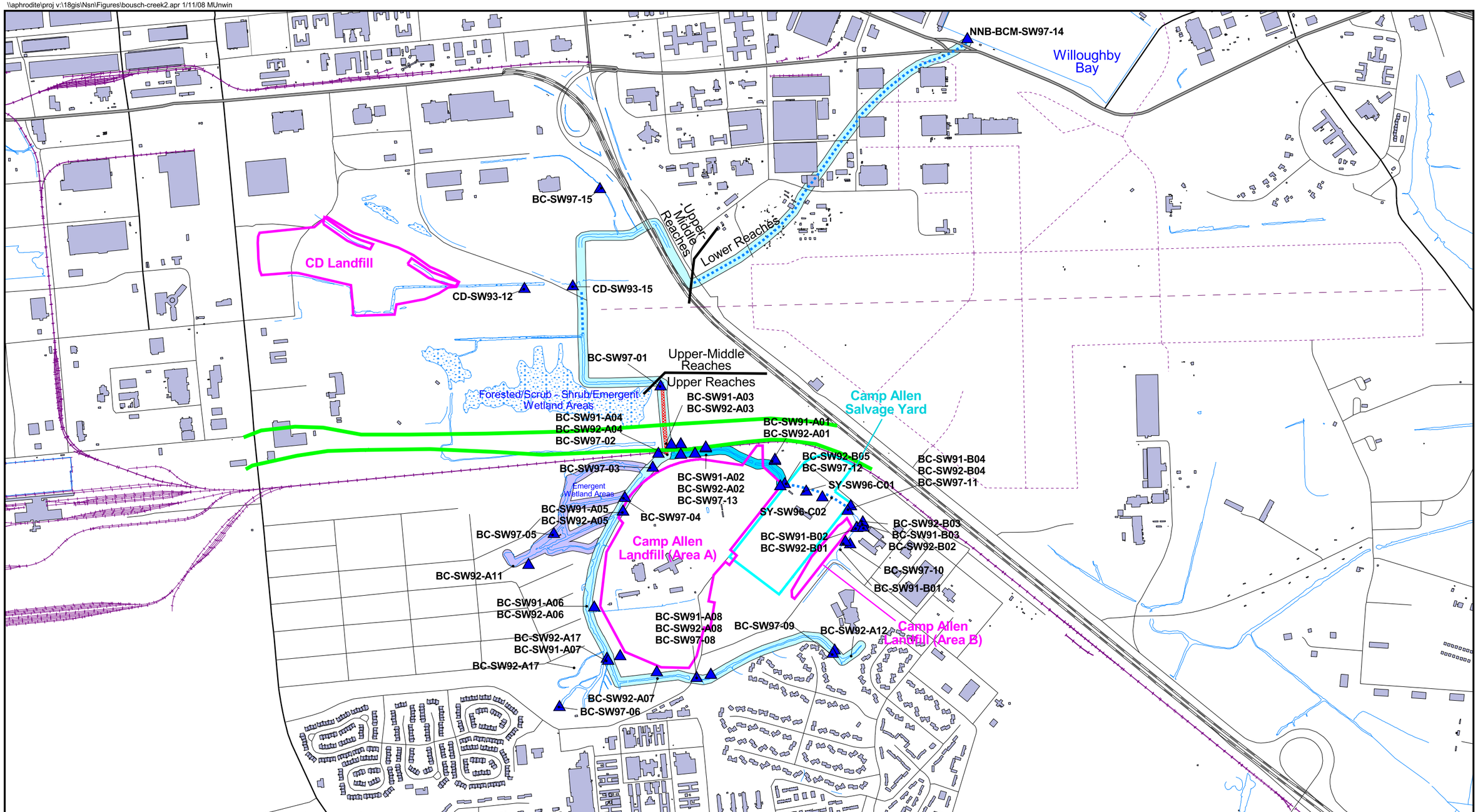

Legend

- Surface Water Sample Locations
- Proposed I-564 Corridor (Approximate)
- Underground Culvert
- Concrete Lined
- Eastern Branch Bousch Creek
- Western Branch Bousch Creek
- Main Branch Bousch Creek

N

0 1000 2000 Feet

Figure 3-9
Previous Surface Water Sampling Locations
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, Virginia

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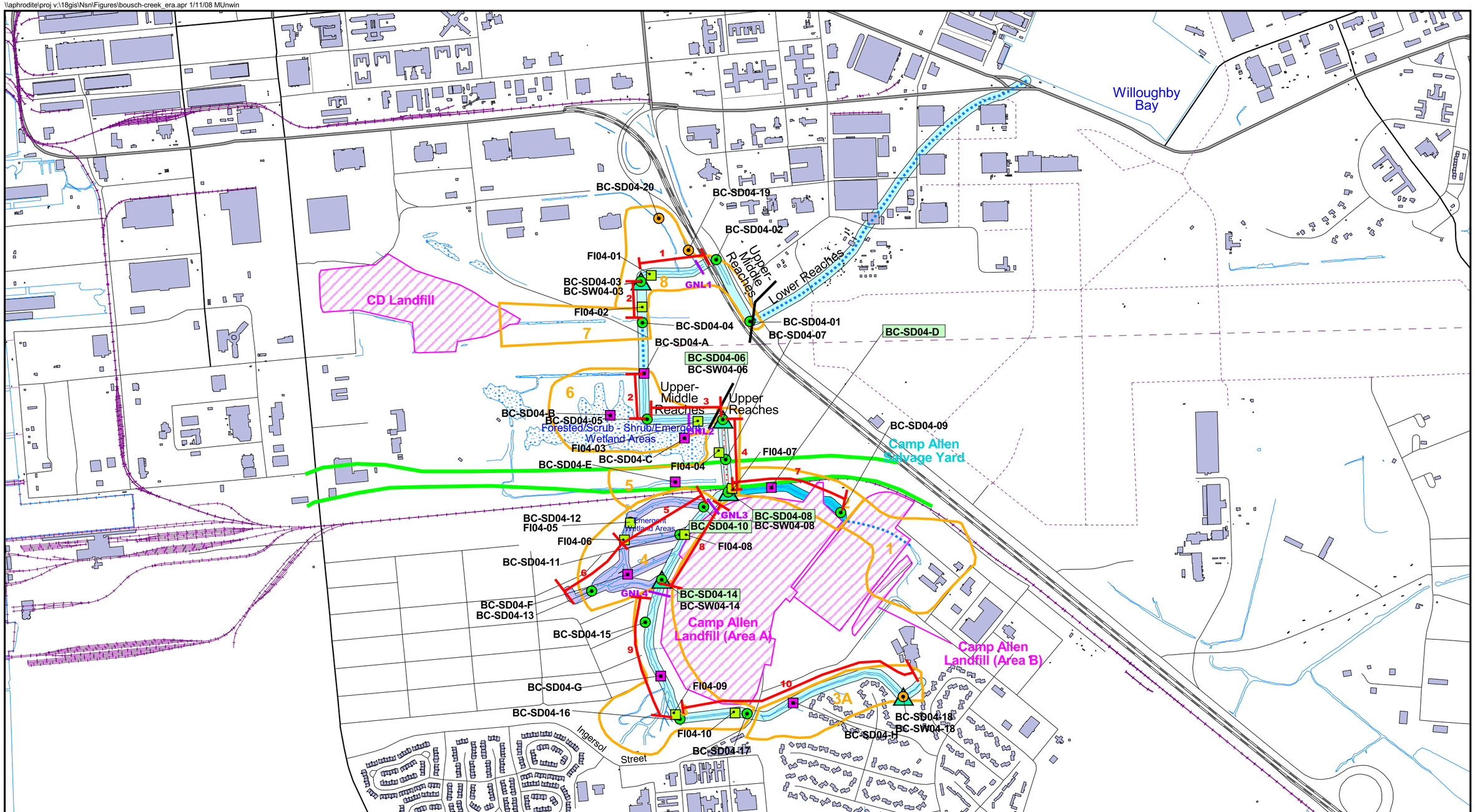

Legend

- General Areas Where Remedial Actions Are On-going or Have Been Completed
- Proposed I-564 Corridor (Approximate)
- Underground Culvert
- Zones
- Concrete Lined
- Gill Net Locations
- Fish Sample Locations
- Fish Tissue Sampling Location
- Primary Sediment/Benthic Invertebrate Sampling Location
- Secondary Sediment/Benthic Invertebrate Sampling Location
- Potential Reference Sediment/Benthic Invertebrate Sampling Location
- Eastern Branch Bousch Creek
- Western Branch Bousch Creek
- Main Branch Bousch Creek
- Surface Water Sampling Location
- Sediment Core Sampling Location

N

0 1000 2000 Feet

Figure 3-10
2004 Sampling Locations
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, Virginia

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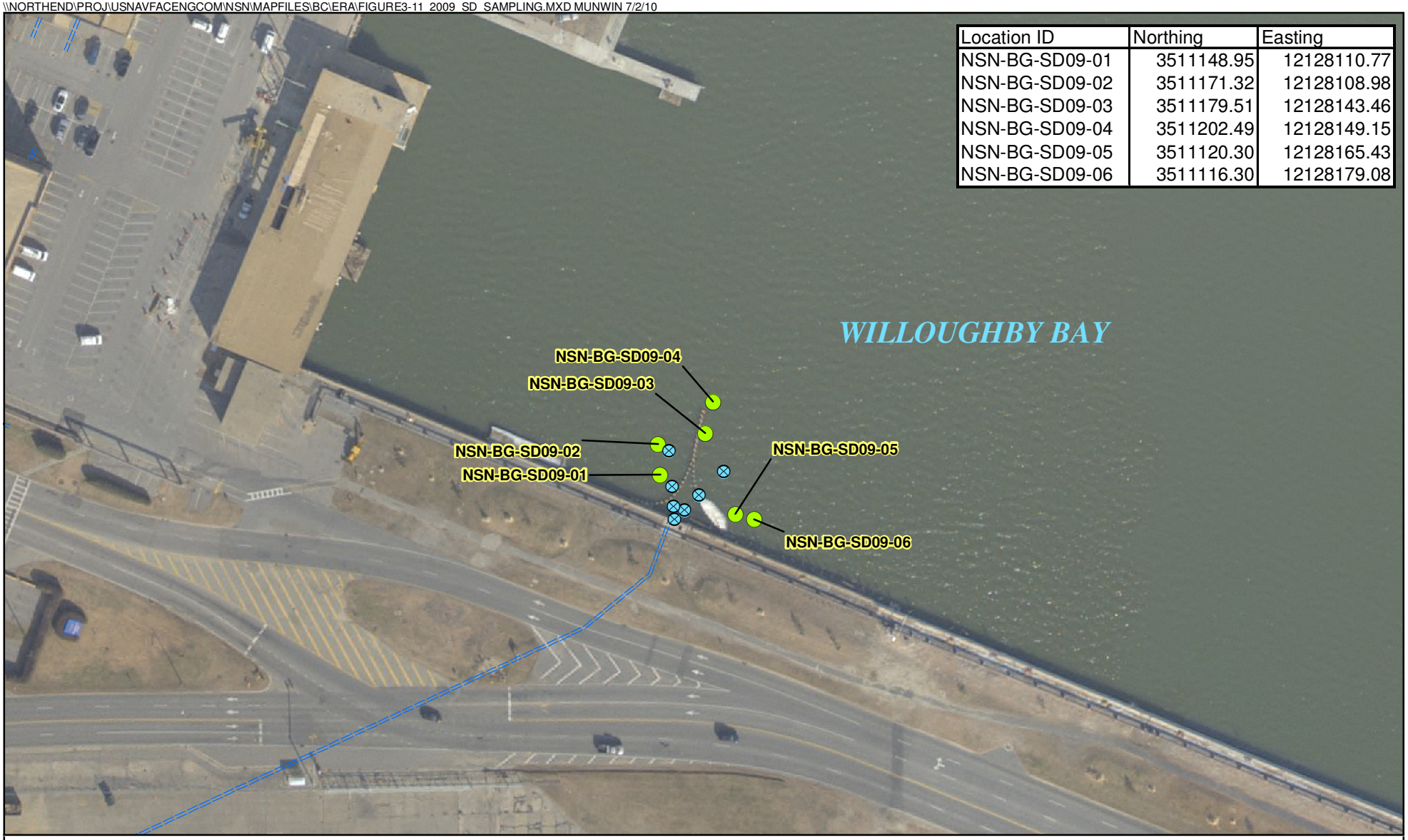


Location ID	Northing	Easting
NSN-BG-SD09-01	3511148.95	12128110.77
NSN-BG-SD09-02	3511171.32	12128108.98
NSN-BG-SD09-03	3511179.51	12128143.46
NSN-BG-SD09-04	3511202.49	12128149.15
NSN-BG-SD09-05	3511120.30	12128165.43
NSN-BG-SD09-06	3511116.30	12128179.08

Legend

- Sample Locations
- Originally Proposed Sampling Locations
- Bousch Creek Culvert

Sample NSN-BG-SD09-07 (not shown) is located at the upper (opposite) end of the Bousch Creek culvert.

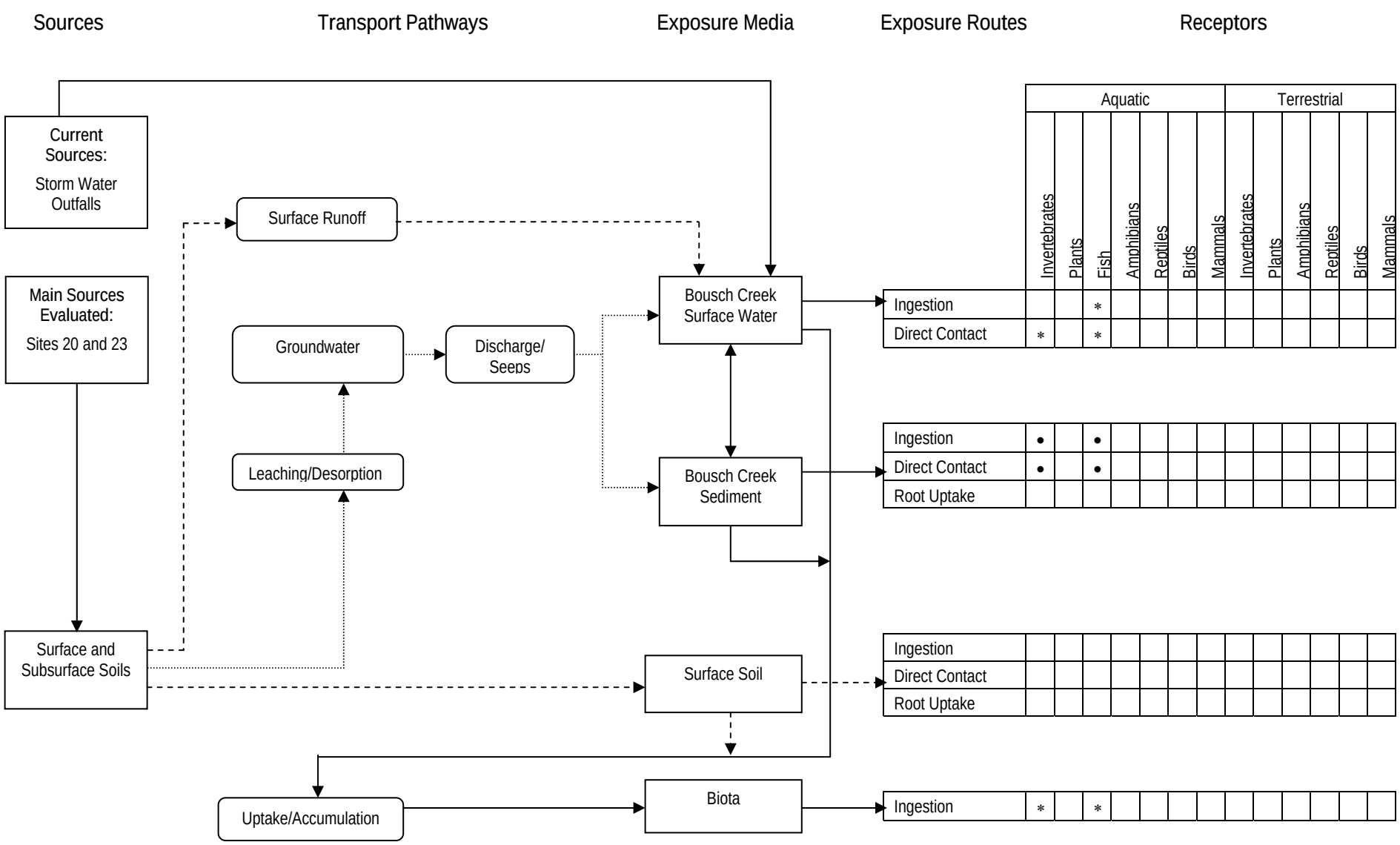
Sample locations based on the perimeter of the oyster/shell bed at the outfall which prohibited sample collection at the planned locations.

N W E S

0 50 100 Feet

Figure 3-11
2009 Sediment Sampling Locations
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, Virginia

CH2MHILL



Historical complete pathway
Current complete pathway
Incomplete pathway

FIGURE 3-12
DIAGRAMMATIC CONCEPTUAL MODEL
LOWER REACHES OF BOUSCH CREEK

• - Receptor evaluated quantitatively
* - Receptor evaluated qualitatively

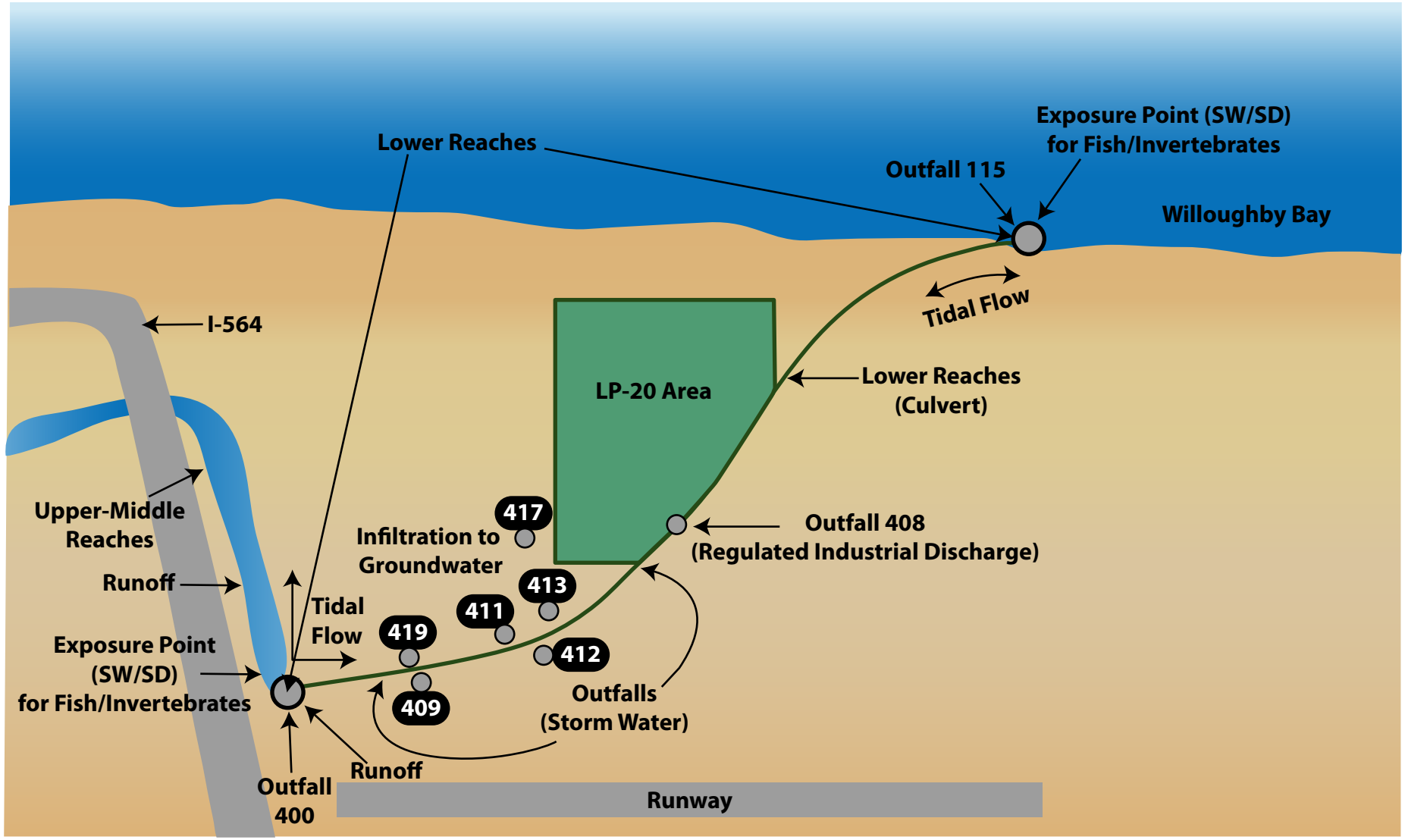


Figure 3-13
Graphic Conceptual Model
Lower Reaches of Bousch Creek ERA
Naval Station Norfolk
Norfolk, Virginia

SECTION 4

Exposure Assessment

The principal activity associated with the exposure assessment is the estimation of chemical concentrations in applicable media, termed exposure point concentrations (EPCs), to which the receptors may be exposed. This is accomplished through the selection of appropriate sets of the available analytical data using a set of criteria (e.g., validation status, sampling date). Once the analytical data sets are selected, EPCs are calculated as a particular point on the distribution of concentrations. At the screening level, the EPC is the maximum detected concentration. At the baseline level, EPCs are typically central tendency estimates (e.g., arithmetic mean).

4.1 Selection Criteria for Analytical Data

Available analytical data (described in Section 3.3.1) were selected for use in the ERA based upon a set of selection criteria that included:

- Data must have been validated by a qualified data validator using acceptable data validation methods to be used quantitatively in the ERA. Rejected (R) values were not used in the ERA. Unqualified data and data qualified as J (estimated), L (biased low), or K (biased high) were treated as detected. Data qualified as U (undetected) or B (blank contamination) were treated as non-detected.
- For samples with duplicate analyses, the higher of the two concentrations was used when both values were detects or when both values were non-detects. In cases where one result was a detection and the other a non-detect, the detected value was used in the assessment.
- For non-detected results, the sample quantitation (reporting) limit (SQL) was used to represent the concentration. When calculating statistics (e.g., arithmetic mean), one-half of the SQL was used for non-detected results. In cases where the SQL was not provided, the method detection limit (MDL) was used.

4.2 Exposure Point Concentrations

EPCs are calculated as a particular point on the distribution of concentrations. At the screening level, the EPC is the maximum detected concentration. At the baseline level, EPCs are typically central tendency estimates (e.g., arithmetic mean), which provide a more representative estimate of potential exposures and risks to receptor populations (the focus of the assessment endpoints). In this ERA, the maximum and arithmetic mean concentrations from the October 2009 sediment samples were evaluated for direct exposures. Individual PAHs were evaluated but PAHs in sediment were also evaluated based upon the sum total concentration of all individual chemicals (one-half of the reporting limit was used for non-detects). Due to the lack of food sources within the culvert, and the small size and

developed (e.g., bulkheaded) nature of the areas at the immediate ends of the Bousch Creek culvert, food web exposures were not modeled.

SECTION 5

Effects Assessment

The effects assessment defines the methods and data used to define an adverse ecological effect. Effects data are available from multiple lines of evidence, which are reflected in the measurement endpoints, and include:

- **Screening Values for Sediment –** October 2009 analytical sediment data are compared to the sediment screening values developed in Section 5.1.
- **Toxicity Testing No Observed Effect Concentration (NOEC) Values –** During the Step 7 ERA for the Upper Reaches, laboratory toxicity tests (bioassays) were conducted using split samples of sediment collected in 2004 throughout the Upper and Upper-Middle Reaches of the Bousch Creek system. Amphipods were the test organism and a total of 20 tests were conducted, three of which were from reference areas. NOEC values developed from these data as part of the Upper Reaches ERA were used in this ERA.
- **Bioavailability Measures** - Additional data were collected to help evaluate chemical-specific bioavailability in sediment.

5.1 Sediment Screening Values

Per the SAP, the following sediment screening values were used in this ERA:

- Literature-based marine screening level concentration (SLC) values (e.g., ER-Ls).
- Literature-based marine equilibrium partitioning (EqP) values for organic constituents, which include a measure of site-specific bioavailability when normalized to the mean site TOC of 3.31 percent.

These values are provided in Table 5-1.

5.2 Toxicity Testing NOEC Values

The sediment NOEC values developed in the ERA for the Upper Reaches of Bousch Creek (CH2M HILL, 2006a), which are based upon benthic invertebrate sediment toxicity tests, were also used in this ERA as outlined in the SAP (Table 5-2). These Upper Reach NOEC values are applicable to this evaluation since the measured salinity in Bay samples ranged from 11 to 15 ppt, which is within the range of salinity (<1 to 18 ppt) from the Upper Reaches and similar to the salinity (10 ppt) to which the sediment toxicity tests were normalized. Since NOEC values are site-specific, they were given higher weight during risk characterization (see Section 6) than the literature-based screening values.

5.3 Bioavailability Measures

Data collected to evaluate the potential chemical-specific bioavailability in surface sediment included TOC, pH, SEM/AVS, and grain size.

Table 5-1
Marine Sediment Screening Values
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	SLC Screening Value			EqP Value			
	Value	Units	Reference	Value	Units	TOC (%)	Reference
Metals							
Aluminum	18,000	mg/kg	Buchman 2008				
Antimony	2.00	mg/kg	Long and Morgan 1990, USEPA 2006				
Arsenic	8.20	mg/kg	Long et al. 1995				
Barium	48.0	mg/kg	Buchman 2008				
Cadmium	1.20	mg/kg	Long et al. 1995				
Chromium	81.0	mg/kg	Long et al. 1995				
Cobalt	10.0	mg/kg	Buchman 2008				
Copper	34.0	mg/kg	Long et al. 1995				
Iron	220,000	mg/kg	Buchman 2008				
Lead	46.7	mg/kg	Long et al. 1995				
Manganese	260	mg/kg	Buchman 2008				
Mercury	0.15	mg/kg	Long et al. 1995				
Nickel	20.9	mg/kg	Long et al. 1995				
Selenium	1.00	mg/kg	Buchman 2008				
Silver	1.00	mg/kg	Long et al. 1995				
Vanadium	57.0	mg/kg	Buchman 2008				
Zinc	150	mg/kg	Long et al. 1995				
Pesticides/PCBs							
4,4'-DDD	2.00	ug/kg	Long and Morgan 1990	32.8	ug/kg	3.31	Table 5-1a
4,4'-DDE	2.20	ug/kg	Long et al. 1995	146	ug/kg	3.31	Table 5-1a
4,4'-DDT	1.58	ug/kg	Long et al. 1995	86.9	ug/kg	3.31	Table 5-1a
alpha-Chlordane	2.26	ug/kg	MacDonald 1994, USEPA 2006	216	ug/kg	3.31	Table 5-1a
Aroclor-1260	48.0	ug/kg	MacDonald et al. 2000	397	ug/kg	3.31	Washington State 1995
Dieldrin	0.715	ug/kg	MacDonald 1994, USEPA 2006	314	ug/kg	3.31	USEPA 1996
Endosulfan I	--	--	--	1.69	ug/kg	3.31	USEPA 2008
Endosulfan II	--	--	--	7.94	ug/kg	3.31	USEPA 2008
Endosulfan sulfate	--	--	--	1.19	ug/kg	3.31	USEPA 2006
Endrin	2.67	ug/kg	CCME 2002, USEPA 2006	11.6	ug/kg	3.31	USEPA 1996
Endrin aldehyde	2.67	ug/kg	Endrin value	11.6	ug/kg	3.31	Endrin value

Table 5-1
Marine Sediment Screening Values
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	SLC Screening Value			EqP Value			
	Value	Units	Reference	Value	Units	TOC (%)	Reference
gamma-BHC (Lindane)	0.32	ug/kg	MacDonald 1994, USEPA 2006	4,502	ug/kg	3.31	USEPA 2006 (for alpha-BHC)
gamma-Chlordane	2.26	ug/kg	MacDonald 1994, USEPA 2006	216	ug/kg	3.31	Table 5-1a
Polycyclic Aromatic Hydrocarbons							
2-Methylnaphthalene	70.0	ug/kg	Long et al. 1995	1,258	ug/kg	3.31	Washington State 1995
Acenaphthene	16.0	ug/kg	Long et al. 1995	3,641	ug/kg	3.31	USEPA 1996
Acenaphthylene	44.0	ug/kg	Long et al. 1995	2,185	ug/kg	3.31	Washington State 1995
Anthracene	85.3	ug/kg	Long et al. 1995	7,282	ug/kg	3.31	Washington State 1995
Benzo(a)anthracene	261	ug/kg	Long et al. 1995	3,641	ug/kg	3.31	Washington State 1995
Benzo(a)pyrene	430	ug/kg	Long et al. 1995	3,277	ug/kg	3.31	Washington State 1995
Benzo(b)fluoranthene	1,800	ug/kg	Buchman 2008	7,613	ug/kg	3.31	Washington State 1995
Benzo(g,h,i)perylene	670	ug/kg	Buchman 2008	1,026	ug/kg	3.31	Washington State 1995
Benzo(k)fluoranthene	1,800	ug/kg	Buchman 2008	7,613	ug/kg	3.31	Washington State 1995
Chrysene	384	ug/kg	Long et al. 1995	3,641	ug/kg	3.31	Washington State 1995
Dibenz(a,h)anthracene	63.4	ug/kg	Long et al. 1995	397	ug/kg	3.31	Washington State 1995
Fluoranthene	600	ug/kg	Long et al. 1995	4,634	ug/kg	3.31	USEPA 1996
Fluorene	19.0	ug/kg	Long et al. 1995	761	ug/kg	3.31	Washington State 1995
Indeno(1,2,3-cd)pyrene	600	ug/kg	Buchman 2008	1,125	ug/kg	3.31	Washington State 1995
Naphthalene	160	ug/kg	Long et al. 1995	3,277	ug/kg	3.31	Washington State 1995
Phenanthrene	240	ug/kg	Long et al. 1995	3,641	ug/kg	3.31	USEPA 1996
Pyrene	665	ug/kg	Long et al. 1995	33,100	ug/kg	3.31	Washington State 1995
PAH (total)	4,022	ug/kg	Long et al. 1995	9,599	ug/kg	3.31	USEPA 2006
Volatile Organic Compounds							
2-Butanone	--	--	--	874	ug/kg	3.31	Table 5-1a
Acetone	--	--	--	10,851	ug/kg	3.31	Table 5-1a
Carbon disulfide	--	--	--	2.82	ug/kg	3.31	Table 5-1a

Table 5-1a
Calculated EqP Sediment Values
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Marine Water Screening Value	Units	Reference	log Kow	Reference	Koc[a]	Total Organic Carbon (%)	Sediment EqP Value[b]	Units
Pesticides									
4,4'-DDD	0.001	ug/L	USEPA 2009	6.10	USEPA 1995	992,156	3.31	32.8	ug/kg
4,4'-DDE	0.001	ug/L	USEPA 2009	6.76	USEPA 1995	4,419,366	3.31	146	ug/kg
4,4'-DDT	0.001	ug/L	USEPA 2009	6.53	USEPA 1995	2,625,851	3.31	86.9	ug/kg
alpha-Chlordane	0.004	ug/L	USEPA 2009	6.32	USEPA 1995	1,632,450	3.31	216	ug/kg
gamma-Chlordane	0.004	ug/L	USEPA 2009	6.32	USEPA 1995	1,632,450	3.31	216	ug/kg
Volatile Organic Compounds									
Acetone	564,000	ug/L	USEPA 2006	-0.24	USEPA 1995	0.58	3.31	10,851	ug/kg
2-Butanone	14,000	ug/L	Suter and Tsao 1996 (Freshwater)	0.28	USEPA 1995	1.89	3.31	874	ug/kg
Carbon disulfide	0.92	ug/L	Suter and Tsao 1996 (Freshwater)	2.00	USEPA 1995	92.5	3.31	2.82	ug/kg

[a] Koc calculated according to equation and method described in USEPA (1996)
[b] Sediment screening value calculated according to equation and method described in USEPA (1996)

Table 5-2
NOECs for Amphipod Bioassay Endpoints - ERA for the Upper Reaches
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Maximum (All Samples)	Survival NOEC	Growth NOEC	Reproduction NOEC
Metals (MG/KG)				
Arsenic	73.1	73.1	38.4	73.1
Barium	124	71.9	70.6	71.9
Cadmium	52.2	11.5	11.3	16.1
Chromium	604	170	168	301
Copper	222	136	112	123
Lead	332	152	139	152
Mercury	1.10	0.68	0.50	0.50
Nickel	59.5	34.9	34.9	56.4
Silver	19.9	4.80	3.70	6.70
Vanadium	98.9	98.9	98.9	98.9
Zinc	738	494	494	462
Organics (UG/KG)				
4,4'-DDE	180	120	120	120
4,4'-DDT	12.0	12.0	12.0	12.0
Aroclor-1260	1,600	200	140	200
Dieldrin	8.60	8.60	7.50	5.30
alpha-Chlordane	25.0	23.0	20.0	20.0
gamma-Chlordane	30.0	23.0	23.0	16.0
Acenaphthene	130	--	--	130
Acenaphthylene	270	--	--	--
Anthracene	540	--	--	190
Benzo(a)anthracene	3,000	470	350	480
Benzo(a)pyrene	1,700	460	380	460
Chrysene	5,400	590	460	590
Dibenz(a,h)anthracene	480	--	--	--
Fluoranthene	13,000	1,100	800	1,900
Phenanthrene	700	240	130	430
Pyrene	10,000	910	810	1,200
PAH, total (detects)	44,360	5,460	4,240	6,350
PAH, total (totals)	45,185	8,760	8,240	8,760

NOEC = Maximum detected concentration in sample that did not have significantly reduced performance as compared to the control

SECTION 6

Risk Characterization

The risk characterization portion of the ERA uses the information generated during the three previous parts of the ERA (problem formulation, exposure assessment, and effects assessment) to estimate potential risks to ecological receptors. In addition to the lines of evidence that were described in Section 5, the following additional factors were considered during the risk characterization:

- **Essential Nutrients.** Calcium, magnesium, potassium, and sodium were excluded from consideration because they are essential macronutrients that are needed in relatively high concentrations for normal metabolism, growth, and reproduction.
- **Chemical Groups.** PAHs in sediment were also evaluated based upon the sum total concentrations of all individual chemicals.

6.1 Comparison With NOEC and Sediment Screening Values

Sediment exposure concentrations are compared with the corresponding screening and NOEC values to derive risk estimates using the hazard quotient (HQ) method. HQs are calculated by dividing the chemical concentration in sediment by the corresponding chemical-specific screening or NOEC value. HQs exceeding one indicate the potential for unacceptable risk since the chemical concentration (exposure) exceeds the screening value (effect). HQs less than or equal to one indicate that unacceptable risks are unlikely.

The sediment sample at the upper end of the Bousch Creek culvert (SD09-07) generally had the lowest concentrations (Attachment B). This area was remediated as part of the Upper Reaches removal action to address non-IRP related PAH sediment contamination and was backfilled with clean fill following sediment excavation. The October 2009 results for this sample indicate that no PAH recontamination has occurred. There were no NOEC or EqP exceedances for sample SD09-07 and only two low magnitude SLC exceedances for pesticides in this sample (Attachment C). This indicates that no significant contaminant transport is occurring from remediated IRP sources in the Upper Reaches or from sources in the Lower Reaches.

Four metals (barium, lead, mercury, and nickel) exceeded the NOEC values based upon maximum concentrations (Table 6-1). The NOEC exceedances for these four metals were of low magnitude (HQs of 1.6 or lower) and none exceeded based upon mean concentrations. SEM/AVS ratios were all well below one for the Bay samples (Table 3-3), suggesting that lead, mercury, and nickel have limited bioavailability (barium is not an AVS metal). Four metals (aluminum, cobalt, manganese, and selenium) without NOEC values exceeded SLC-based screening values (Table 6-1). Maximum HQs were two or less. None of these metals was a primary COC (risk driver) from the Upper Reaches, although selenium was identified as a "secondary" (other) COC. The marine screening value for selenium, however, is based upon limited data. The Region 3 BTAG values for freshwater is 2 mg/kg, which is greater

than the maximum detected concentration (1.70 mg/kg). Beryllium and thallium were each detected in all seven sediment samples but did not have NOEC or SLC values. Neither was a COC from the Upper Reaches or is known to be associated with source areas in the Lower Reaches.

Two pesticides (4,4′-DDT and dieldrin) and Aroclor-1260 exceeded the NOEC values based upon maximum concentrations (Table 6-1). The NOEC exceedances for these three chemicals were of low magnitude (HQs of 1.4 or lower) and none exceeded based upon mean concentrations. In addition, maximum HQs based upon EqP values, which account for bioavailability, were less than one (Table 6-1). Three pesticides (4,4′-DDD, endrin aldehyde, and lindane) without NOEC values exceeded SLC-based screening values but none exceeded based upon EqP values. None of these pesticides was a primary COC (risk driver) from the Upper Reaches (4,4′-DDD was identified as a "secondary" [other] COC). Two pesticides (endosulfan I and endosulfan sulfate) without both NOEC and SLC values exceeded EqP-based screening values. However, neither was a COC from the Upper Reaches or is known to be associated with source areas in the Lower Reaches.

Six individual PAHs and total PAHs exceeded the NOEC values based upon maximum concentrations (Table 6-1). The NOEC exceedance for total PAHs (the COC from the Upper Reaches) was of low magnitude (HQ of 2.6) and the HQ did not exceed one based upon mean concentrations. In addition, maximum HQs based upon EqP values, which account for bioavailability, exceeded one for only two individual PAHs (HQs of 1.17 and 1.24) and for total PAHs (HQ of 2.22); mean HQs were less than one for both PAHs and for total PAHs. The PAH exceedances were driven by a single sample (SD09-01) located in the Bay close to the Bousch Creek outfall. However, there were no exceedances of NOEC, SLC, or EqP values at SD09-02, located about 25 feet bay-ward of SD09-01 (Figure 3-11). There were several exceedances of SLC and NOEC (but not EqP) values at SD09-05 for individual PAHs (and total PAHs based upon SLC, but not NOEC, values). SD09-05 is located in the Bay close to the Bousch Creek outfall but on the opposite side from SD09-01. This pattern suggests that the outfall is the source of these PAHs but the spatial pattern of exceedances suggests that the spatial extent is limited since there were no NOEC, SLC, or EqP exceedances for PAHs at SD09-03 or SD09-04, located about 75 to 100 feet from the outfall, or at SD09-06, located just east (away from the outfall) of SD09-05. Based upon the experience in the Upper Reaches near the upper end of the Bousch Creek culvert, these PAHs are not likely related to any IRP source area in either the Upper or Lower Reaches.

Three VOCs were detected in sediment samples (Table 6-1). Based upon calculated EqP values (NOEC and SLC values were not available), only carbon disulfide had HQs that exceeded one. This chemical, which can be naturally produced in wetland and aquatic environments, was not a COC from the Upper Reaches nor is it known to be associated with source areas in the Lower Reaches.

6.2 Risk Evaluation and Recommendations

According to the decision rules outlined in the SAP (CH2M HILL, 2009), if there are significant exceedances of key evaluation criteria (i.e., NOEC values) for the COCs identified in the ERA for the Upper Reaches of Bousch Creek (a number of metals and pesticides, PCBs, and PAHs) or potentially related to IRP source areas in the Lower Reaches (a number

of VOCs), risks will be indicated. Based upon the results of the risk characterization, namely no exceedances of NOEC values based upon mean concentrations for any of the Upper Reach COCs and no detections of chlorinated VOCs, no unacceptable ecological risks are indicated. Thus, no further investigation or action is recommended for the Lower Reaches of Bousch Creek as related to potential ecological exposures associated with IRP sites.

Table 6-1
Screening Statistics - Surface Sediment - Detected Constituents
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Range of Non-Detect Values	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Detected Concentration	Arithmetic Mean	Standard Deviation of Mean	SLC Screening Value	Frequency of Exceedance	Maximum Hazard Quotient	Mean Hazard Quotient	EqP Screening Value	Frequency of Exceedance	Maximum Hazard Quotient	Mean Hazard Quotient	NOEC	Frequency of Exceedance	Maximum Hazard Quotient	Mean Hazard Quotient	Exceed Max/ Mean SLC?[2]	Exceed Max/ Mean EqP?[2]	Exceed Max/ Mean NOEC?[2]	COC from Upper Reach ERA?[3]
Inorganics (MG/KG)																						
Aluminum	-- - --	7 / 7	37,200	NSN-BG-SD09-06	25,157	11,417	18,000	5 / 7	2.07	1.40	--	-- / --	--	--	NSV	-- / --	NSV	NSV	Y/Y		NSV	
Antimony	0.65 - 2.80	1 / 7	1.30	NSN-BG-SD09-02	0.98	0.44	2.00	0 / 7	0.65	0.49	--	-- / --	--	--	NSV	-- / --	NSV	NSV	N/N		NSV	
Arsenic	-- - --	7 / 7	16.9	NSN-BG-SD09-03	12.9	6.35	8.20	5 / 7	2.06	1.58	--	-- / --	--	--	38.4	0 / 7	0.44	0.34	Y/Y		N/N	X
Barium	-- - --	7 / 7	87.7	NSN-BG-SD09-06	61.6	27.3	48.0	5 / 7	1.83	1.28	--	-- / --	--	--	70.6	5 / 7	1.24	0.87	Y/Y		Y/N	x
Beryllium	-- - --	7 / 7	1.90	NSN-BG-SD09-06	1.27	0.67	NSV	-- / --	NSV	NSV	--	-- / --	--	--	NSV	-- / --	NSV	NSV	NSV		NSV	
Cadmium	-- - --	7 / 7	2.80	NSN-BG-SD09-02	1.59	0.88	1.20	5 / 7	2.33	1.32	--	-- / --	--	--	11.3	0 / 7	0.25	0.14	Y/Y		N/N	X
Calcium [1]	-- - --	7 / 7	23,100	NSN-BG-SD09-02	8,606	7,065	NSV	-- / --	NSV	NSV	--	-- / --	--	--	NSV	-- / --	NSV	NSV	--		--	
Chromium	-- - --	7 / 7	84.0	NSN-BG-SD09-06	59.4	29.6	81.0	1 / 7	1.04	0.73	--	-- / --	--	--	168	0 / 7	0.50	0.35	Y/N		N/N	X
Cobalt	-- - --	7 / 7	11.7	NSN-BG-SD09-06	8.08	4.23	10.0	3 / 7	1.17	0.81	--	-- / --	--	--	NSV	-- / --	NSV	NSV	Y/N		NSV	
Copper	-- - --	7 / 7	62.0	NSN-BG-SD09-05	45.1	22.9	34.0	5 / 7	1.82	1.33	--	-- / --	--	--	112	0 / 7	0.55	0.40	Y/Y		N/N	X
Iron	-- - --	7 / 7	45,800	NSN-BG-SD09-06	32,370	16,300	220,000	0 / 7	0.21	0.15	--	-- / --	--	--	NSV	-- / --	NSV	NSV	N/N		NSV	
Lead	-- - --	7 / 7	197	NSN-BG-SD09-05	72.9	59.4	46.7	5 / 7	4.22	1.56	--	-- / --	--	--	139	1 / 7	1.42	0.52	Y/Y		Y/N	X
Magnesium [1]	-- - --	7 / 7	11,100	NSN-BG-SD09-06	7,600	4,013	NSV	-- / --	NSV	NSV	--	-- / --	--	--	NSV	-- / --	NSV	NSV	--		--	
Manganese	-- - --	7 / 7	395	NSN-BG-SD09-06	268	146	260	5 / 7	1.52	1.03	--	-- / --	--	--	NSV	-- / --	NSV	NSV	Y/Y		NSV	
Mercury	0.040 - 0.040	6 / 7	0.78	NSN-BG-SD09-01	0.30	0.23	0.15	6 / 7	5.20	1.98	--	-- / --	--	--	0.50	1 / 7	1.56	0.59	Y/Y		Y/N	x
Nickel	-- - --	7 / 7	51.4	NSN-BG-SD09-02	29.9	17.5	20.9	5 / 7	2.46	1.43	--	-- / --	--	--	34.9	3 / 7	1.47	0.86	Y/Y		Y/N	x
Potassium [1]	-- - --	7 / 7	6,730	NSN-BG-SD09-06	4,480	2,357	NSV	-- / --	NSV	NSV	--	-- / --	--	--	NSV	-- / --	NSV	NSV	--		--	
Selenium	0.81 - 2.60	5 / 7	1.70	NSN-BG-SD09-04	1.02	0.51	1.00	3 / 7	1.70	1.02	--	-- / --	--	--	NSV	-- / --	NSV	NSV	Y/Y		NSV	x
Silver	1.20 - 1.20	6 / 7	1.50	NSN-BG-SD09-02	1.14	0.39	1.00	5 / 7	1.50	1.14	--	-- / --	--	--	3.70	0 / 7	0.41	0.31	Y/Y		N/N	X
Sodium [1]	-- - --	7 / 7	22,700	NSN-BG-SD09-04	15,449	8,214	NSV	-- / --	NSV	NSV	--	-- / --	--	--	NSV	-- / --	NSV	NSV	--		--	
Thallium	-- - --	7 / 7	1.20	NSN-BG-SD09-02	0.74	0.39	NSV	-- / --	NSV	NSV	--	-- / --	--	--	NSV	-- / --	NSV	NSV	NSV		NSV	
Vanadium	-- - --	7 / 7	90.7	NSN-BG-SD09-06	65.7	30.6	57.0	5 / 7	1.59	1.15	--	-- / --	--	--	98.9	0 / 7	0.92	0.66	Y/Y		N/N	
Zinc	-- - --	7 / 7	313	NSN-BG-SD09-02	218	110	150	5 / 7	2.09	1.45	--	-- / --	--	--	462	0 / 7	0.68	0.47	Y/Y		N/N	x
Pesticide/Polychlorinated Biphenyls (UG/KG)																						
4,4'-DDD	-- - --	7 / 7	16.0	NSN-BG-SD09-02	7.30	4.86	2.00	6 / 7	8.00	3.65	32.8	0 / 7	0.49	0.22	NSV	-- / --	NSV	NSV	Y/Y	N/N	NSV	x
4,4'-DDE	-- - --	7 / 7	7.10	NSN-BG-SD09-02	4.33	2.00	2.20	6 / 7	3.23	1.97	146	0 / 7	0.05	0.03	120	0 / 7	0.06	0.04	Y/Y	N/N	N/N	x
4,4'-DDT	3.90 - 12.0	5 / 7	17.0	NSN-BG-SD09-02	8.01	4.79	1.58	5 / 7	10.8	5.07	86.9	0 / 7	0.20	0.09	12.0	1 / 7	1.42	0.67	Y/Y	N/N	Y/N	x
alpha-Chlordane	2.00 - 6.30	4 / 7	2.00	NSN-BG-SD09-02	2.10	0.79	2.26	0 / 7	0.88	--	216	0 / 7	0.01	--	20.0	0 / 7	0.10	--	N/--	N/--	N/--	x
Aroclor-1260	21.0 - 70.0	1 / 7	180	NSN-BG-SD09-02	47.4	59.4	48.0	1 / 7	3.75	0.99	397	0 / 7	0.45	0.12	140	1 / 7	1.29	0.34	Y/N	N/N	Y/N	x
Dieldrin	4.00 - 12.0	4 / 7	5.90	NSN-BG-SD09-02	3.66	2.12	0.72	4 / 7	8.25	5.12	314	0 / 7	0.02	0.01	5.30	1 / 7	1.11	0.69	Y/Y	N/N	Y/N	x
Endosulfan I	2.00 - 6.30	1 / 7	2.40	NSN-BG-SD09-04	2.34	0.93	NSV	-- / --	NSV	NSV	1.69	1 / 7	1.42	1.38	NSV	-- / --	NSV	NSV	NSV	Y/Y	NSV	
Endosulfan II	3.90 - 13.0	2 / 7	5.80	NSN-BG-SD09-02	4.31	2.22	NSV	-- / --	NSV	NSV	7.94	0 / 7	0.73	0.54	NSV	-- / --	NSV	NSV	NSV	N/N	NSV	
Endosulfan sulfate	3.90 - 13.0	2 / 7	13.0	NSN-BG-SD09-02	6.46	3.28	NSV	-- / --	NSV	NSV	1.19	2 / 7	10.9	5.42	NSV	-- / --	NSV	NSV	NSV	Y/Y	NSV	
Endrin aldehyde	3.90 - 12.0	4 / 7	11.0	NSN-BG-SD09-02	5.64	3.45	2.67	4 / 7	4.12	2.11	11.6	0 / 7	0.95	0.49	NSV	-- / --	NSV	NSV	Y/Y	N/N	NSV	
gamma-BHC (Lindane)	5.50 - 6.60	4 / 7	4.70	NSN-BG-SD09-01	3.01	1.23	0.32	4 / 7	14.7	9.41	4,502	0 / 7	0.001	0.001	NSV	-- / --	NSV	NSV	Y/Y	N/N	NSV	
gamma-Chlordane	5.70 - 6.30	5 / 7	16.0	NSN-BG-SD09-01	4.49	5.15	2.26	4 / 7	7.08	1.98	216	0 / 7	0.07	0.02	16.0	0 / 7	1.00	0.28	Y/Y	N/N	N/N	x
Semivolatile Organic Compounds (UG/KG)																						
2-Methylnaphthalene	24.0 - 80.0	1 / 7	19.0	NSN-BG-SD09-01	30.1	10.5	70.0	0 / 7	0.27	--	1,258	0 / 7	0.02	--	NSV	-- / --	NSV	NSV	N/--	N/--	NSV	
Acenaphthene	24.0 - 80.0	4 / 7	72.0	NSN-BG-SD09-01	27.1	24.1	16.0	1 / 7	4.50	1.70	3,641	0 / 7	0.02	0.01	130	0 / 7	0.55	0.21	Y/Y	N/N	N/N	
Acenaphthylene	23.0 - 74.0	4 / 7	7.20	NSN-BG-SD09-05	12.5	11.1	44.0	0 / 7	0.16	--	2,185	0 / 7	0.003	--	NSV	-- / --	NSV	NSV	N/--	N/--	NSV	
Anthracene	24.0 - 24.0	6 / 7	180	NSN-BG-SD09-01	49.4	59.7	85.3	1 / 7	2.11	0.58	7,282	0 / 7	0.02	0.01	190	0 / 7	0.95	0.26	Y/N	N/N	N/N	
Benzo(a)anthracene	-- - --	7 / 7	2,000	NSN-BG-SD09-01	520	715	261	2 / 7	7.66	1.99	3,641	0 / 7	0.55	0.14	350	2 / 7	5.71	1.49	Y/Y	N/N	Y/Y	
Benzo(a)pyrene	-- - --	7 / 7	1,200	NSN-BG-SD09-01	293	414	430	1 / 7	2.79	0.68	3,277	0 / 7	0.37	0.09	380	1 / 7	3.16	0.77	Y/N	N/N	Y/N	
Benzo(b)fluoranthene	-- - --	7 / 7	2,300	NSN-BG-SD09-01	564	791	1,800	1 / 7	1.28	0.31	7,613	0 / 7	0.30	0.07	NSV	-- / --	NSV	NSV	Y/N	N/N	NSV	
Benzo(g,h,i)perylene	-- - --	7 / 7	670	NSN-BG-SD09-01	161	229	670	0 / 7	1.00	0.24	1,026	0 / 7	0.65	0.16	NSV	-- / --	NSV	NSV	N/N	N/N	NSV	

Table 6-1
Screening Statistics - Surface Sediment - Detected Constituents
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Range of Non-Detect Values	Frequency of Detection	Maximum Concentration Detected	Sample ID of Maximum Detected Concentration	Arithmetic Mean	Standard Deviation of Mean	SLC Screening Value	Frequency of Exceedance	Maximum Hazard Quotient	Mean Hazard Quotient	EqP Screening Value	Frequency of Exceedance	Maximum Hazard Quotient	Mean Hazard Quotient	NOEC	Frequency of Exceedance	Maximum Hazard Quotient	Mean Hazard Quotient	Exceed Max/ Mean SLC?[2]	Exceed Max/ Mean EqP?[2]	Exceed Max/ Mean NOEC?[2]	COC from Upper Reach ERA?[3]
Benzo(k)fluoranthene	-- - --	7 / 7	690	NSN-BG-SD09-01	170	238	1,800	0 / 7	0.38	0.09	7,613	0 / 7	0.09	0.02	NSV	-- / --	NSV	NSV	N/N	N/N	NSV	
Chrysene	-- - --	7 / 7	2,500	NSN-BG-SD09-01	572	882	384	2 / 7	6.51	1.49	3,641	0 / 7	0.69	0.16	460	2 / 7	5.43	1.24	Y/Y	N/N	Y/Y	
Dibenz(a,h)anthracene	24.0 - 24.0	6 / 7	170	NSN-BG-SD09-01	57.4	52.6	63.4	2 / 7	2.68	0.91	397	0 / 7	0.43	0.14	NSV	-- / --	NSV	NSV	Y/N	N/N	NSV	
Fluoranthene	-- - --	7 / 7	5,400	NSN-BG-SD09-01	1,200	1,934	600	2 / 7	9.00	2.00	4,634	1 / 7	1.17	0.26	800	2 / 7	6.75	1.50	Y/Y	Y/N	Y/Y	
Fluorene	24.0 - 80.0	2 / 7	67.0	NSN-BG-SD09-01	34.2	18.4	19.0	1 / 7	3.53	1.80	761	0 / 7	0.09	0.04	NSV	-- / --	NSV	NSV	Y/Y	N/N	NSV	
Indeno(1,2,3-cd)pyrene	-- - --	7 / 7	1,400	NSN-BG-SD09-01	339	477	600	1 / 7	2.33	0.57	1,125	1 / 7	1.24	0.30	NSV	-- / --	NSV	NSV	Y/N	Y/N	NSV	
Naphthalene	24.0 - 80.0	2 / 7	47.0	NSN-BG-SD09-01	30.9	14.0	160	0 / 7	0.29	0.19	3,277	0 / 7	0.014	0.009	NSV	-- / --	NSV	NSV	N/N	N/N	NSV	
PAH (total)	-- - --	7 / 7	21,327	NSN-BG-SD09-01	5,133	7,446	4,022	2 / 7	5.30	1.28	9,599	1 / 7	2.22	0.53	8,240	1 / 7	2.59	0.62	Y/Y	Y/N	Y/N	X
Phenanthrene	-- - --	7 / 7	1,200	NSN-BG-SD09-01	237	429	240	1 / 7	5.00	0.99	3,641	0 / 7	0.33	0.07	130	3 / 7	9.23	1.83	Y/N	N/N	Y/Y	
Pyrene	-- - --	7 / 7	3,400	NSN-BG-SD09-01	841	1,218	665	2 / 7	5.11	1.26	33,100	0 / 7	0.10	0.03	810	2 / 7	4.20	1.04	Y/Y	N/N	Y/Y	
Volatile Organic Compounds (UG/KG)																						
2-Butanone	33.0 - 110	3 / 7	26.0	NSN-BG-SD09-03	30.2	15.7	NSV	-- / --	NSV	NSV	874	0 / 7	0.03	--	NSV	-- / --	NSV	NSV	NSV	N/--	NSV	
Acetone	7.00 - 75.0	3 / 7	140	NSN-BG-SD09-03	67.7	59.9	NSV	-- / --	NSV	NSV	10,851	0 / 7	0.013	0.006	NSV	-- / --	NSV	NSV	NSV	N/N	NSV	
Carbon disulfide	7.00 - 7.00	6 / 7	21.0	NSN-BG-SD09-02	12.9	7.78	NSV	-- / --	NSV	NSV	2.82	5 / 7	7.45	4.58	NSV	-- / --	NSV	NSV	NSV	Y/Y	NSV	

NSV - No Screening Value
Gray shaded cells in the HQ columns indicate HQ > 1
1 - Macronutrient - Not considered to be a COPC
2 - Red shading = HQ > 1 for both maximum and mean; orange shading = HQ < 1 based on maximum but > 1 based on mean; green shading = HQ < 1 for both maximum and mear
3 - X = risk driver; x = other COC; gray shading indicates risks minimal when bioavailability is considered

SECTION 7

Uncertainties

Uncertainties are present in all risk assessments because of the limitations of the available data and the need to make certain assumptions and extrapolations based upon incomplete information. The uncertainties in this ERA are mainly attributable to the following factors:

- **Duplicate Analyses—**When evaluating samples with field duplicates, the value used in the ERA was always the detect when one result was a detect and the duplicate was a non-detect, regardless of whether or not the non-detected value was higher. In these cases, the use of the detect has less uncertainty since it represents an actual measured value (versus an upper limit bound) and the two samples will have identical or similar reporting limits.
- **Sediment Screening Values—**Some of the sediment screening values used in the ERA do not consider site-specific bioavailability to ecological receptors and are typically based upon correlational studies (termed the SLC approach). These factors tend to make the resulting screening values conservative and likely overestimate potential risks but not to the extent that it would unduly impact the conclusions of the ERA since NOEC and EqP values, which do consider bioavailability, were also used in the assessment.
- **Chemical Mixtures—**Information on the ecotoxicological effects of chemical interactions is generally lacking, which required (as is standard for ERAs) that the chemicals be evaluated on a compound-by-compound basis during the comparison to screening values. This could result in an underestimation of risk (if there are additive or synergistic effects among chemicals) or an overestimation of risks (if there are antagonistic effects among chemicals). However, the toxicity test NOEC values do account for the chemical mixtures that are present in sediment samples, minimizing the potential impact of these uncertainties on the conclusions of the ERA.

SECTION 8

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Attachment A
Analytical Data and Potential Source Areas Associated with the Lower Reaches of Bousch Creek, Naval Station Norfolk

ATTACHMENT A

Analytical Data and Potential Source Areas Associated with the Lower Reaches of Bousch Creek, Naval Station Norfolk

A.1 Summary of Available Analytical Data

A number of sampling events have occurred in the LP-20 area and in Willoughby Bay, which is adjacent to the Lower Reaches of Bousch Creek. Site 23 (LP-20 Plating Shop) is located within the boundary of Site 20 (the Building LP-20 Site), therefore, there may be an overlap in analytical data between the two sites.

A.1.1 Sampling in Willoughby Bay

Several investigations, including the sampling of sediment, surface water and aquatic biota, have been performed in Willoughby Bay. However, these data are not relevant to this ERA due to the location and age of the data.

The Agency for Toxic Substances and Disease Registry (ATSDR) issued a public health assessment in Fall 2002 (ATSDR, 2002) that evaluated the past, current, and potential future exposures to contaminants at NSN and adjacent areas. During the assessment, all available sediment, surface water, and aquatic biota samples collected from Willoughby Bay were compiled and reviewed by ATSDR. However, the majority of the samples collected were not validated. ATSDR obtained sampling data from: (1) Baker Environmental, Inc.; (2) Mid-Atlantic Integrated Assessment; (3) USEPA - Chesapeake Bay Program and the Storage and Retrieval database (STORET); and (4) Virginia Department of Environmental Quality - Chesapeake Bay Program and the Water Division General, Water Quality Standards, Department of Shellfish Sanitation.

ATSDR identified 17 sediment sampling events in Willoughby Bay. Most of these samples were collected before 1988 and analyzed for total metals, PAHs, PCBs, and selected pesticides. Several samples were collected from the central portion of the bay just north of NSN. In the mid-1990s, two sediment samples were collected from a lagoon located in Salt Marsh Park adjacent to Willoughby Bay. This lagoon is directly connected to the Bay by a narrow channel.

ATSDR identified 18 surface water samples that were collected in the Bay between 1972 and 1995. Samples were collected from the center of the mouth of Willoughby Bay and locations near the eastern end of IRP Site 13 (Past Industrial Wastewater Outfalls). Some of the samples were analyzed for metals and pesticides. Two of the samples were analyzed for PCBs. In the mid-1990s, three surface water samples were collected from the lagoon located in Salt Marsh Park.

According to ATSDR, between 1971 and 2001, only limited numbers of fish and shellfish samples were collected from the Bay. Prior to 2001, most of the sampling events were focused on oysters, however, spot, blue crab, and hard crab were also collected. Samples were collected from locations near the eastern end of IRP Site 13, near the center of Willoughby Bay, and to the south of the eastern end of Willoughby Spit. In the summer of 2001, Virginia Department of Environmental Quality (VDEQ) collected a variety of seafood species (including crabs, clams, and oysters) from Willoughby Bay and analyzed them for metals.

A.1.2 LP-20 Area Investigations

Eleven separate pre-remedial investigations were carried out between September 1986 and May 1994 in the LP-20 area. The investigations were performed primarily to characterize contamination suspected to originate from the LP Fuel Farm (south of Building LP-20), past industrial activity in the LP-20 area, and USTs in the area. The principal objective of these investigations was to assess the subsurface soils and groundwater in this area for petroleum contamination. The investigation results showed widespread chlorinated solvent (e.g., BTEX and trichloroethene [TCE]) and petroleum contamination in the vicinity of Building LP-20. These investigations included the installation of 95 monitoring wells in the LP-20 area.

Between December 1994 and October 1995, five separate phases of a RI were conducted at Site 20 (Baker Environmental, 1996a):

- Phase I (December 1994) - Three deep monitoring wells were installed to evaluate the subsurface conditions and to verify the existence of the confining layer that separates the water table aquifer and the Yorktown Aquifer in the vicinity of Building LP-20. After the installation, an in-situ groundwater survey was performed to evaluate the vertical and horizontal extent of TCE contamination within the aquifer in the vicinity of Building LP-20.
- Phase II (January 1995) - Two groundwater samples (shallow and deep) were collected and analyzed from 11 new in-situ groundwater sampling locations. In addition, nine wells were installed to confirm horizontal extent of groundwater contamination and provide long-term monitoring to the Columbia Aquifer.
- Phase III (February 1995) - Twelve newly installed monitoring wells and 14 selected existing wells were sampled. In addition, fluid levels from 43 monitoring wells were obtained.
- Phase IV (May 1995) - In-situ hydraulic tests in five of the monitoring wells installed during Phases 1 and 2 and a 48-hour constant rate drawdown test was performed within a test well. One groundwater sample was taken from the test well to perform metals treatability study. In addition, 28 monitoring wells and the Bousch Creek culvert were monitored to evaluate the radius of influence of the test well within the shallow aquifer and the potential impact to the Yorktown Aquifer.

- Phase V (September through October 1995) - Six deep monitoring wells were installed. The six new wells and three existing deep monitoring wells were sampled in addition to obtaining fluid levels from each of the deep wells. The purpose of this investigation was to evaluate the horizontal and vertical extent of groundwater contamination within the Yorktown Aquifer.

Soil and groundwater contamination was attributed to several sources/past activities, including: (1) past storage and distribution systems for a variety of petroleum products such as gasoline, waste oils, and aviation fuels are know to have leaked at various locations; (2) past storage and disposal of chemical solvents used in cleaning, painting, and metal plating operations performed in Building LP-20 area, and (3) accidental releases of waste fluids via breaks in the Industrial Wastewater Sewer (IWS) caused during construction activities in the area. The RI and Baseline Risk Assessment (Baker Environmental, 1996a) provide the complete risk assessment evaluation for Site 20.

None of these data are relevant to this ERA due to the medium sampled, the locations of the samples, and/or the age of the data.

A.1.3 LP- 20 Plating Shop (Site 23) Investigations

Three phases of activities were included in the RCRA Investigation at Site 23 (O'Brien and Gere, 1997). The following is a summary of the RCRA field activities:

- Phase I (February 1996) - The objective of Phase I activities was to delineate the extent of contamination. Phase I was conducted at the former metal plating shop and consisted of the collection of 26 shallow soil borings with the Plating Shop and former process units. Two deep soil samples were collected along the IWS running through the Plating Shop. Eight soil samples were collected from background locations in the vicinity of Building LP-18. Groundwater samples were collected from upgradient and downgradient locations as well as within the Plating Shop. In addition, five concrete floor samples within the Plating Shop and background concrete samples (from areas with little to no industrial activity) were collected.

- Phase II (October 1996) – The objective of the Phase II investigation was to further delineate the areas of subsurface soil contamination where the concentrations of the Phase I sampling locations exceeded risk-based criteria. Thirteen additional borings and 21 additional soil samples were selected to provide further horizontal and vertical delineation of contamination.

- Phase III (December 1997) – The objective of the Phase III investigation was to evaluate the background soil conditions. Three additional background soil samples were collected during this sampling event.

The RCRA Closure Report (O'Brien and Gere, 1997) provides a discussion of the risk assessment evaluation for the Building LP-20 site area.

The Site Investigation for Site 23 focused on the site soils. The site investigation was performed to: (1) further investigate the vertical extent of soil contamination in identified hotspots; (2) determine the nature and extend of soil contamination in the metal plating/ processing pits; (3) delineate soil contamination within the Plating Shop areas outside of the

pits; and (4) provide more complete list analytes compared to the limited analysis conducted in the previous RCRA. Field activities were completed in December 2004 (CH2M HILL, 2006b).

Surface and subsurface soil samples were collected from Site 23, Building LP-20 Plating Shop. Samples were collected in three different areas of the Plating Shop, the hotspots, metal plating/process pits, and outside the process pits. The number of samples and sample placement were designed to fill spatial gaps from previous sampling and delineate soil contamination within the plating shop area outside of the pits.

None of these data are relevant to this ERA due to the medium sampled, the locations of the samples, and/or the age of the data.

A.2 Potential Source Areas/Contaminant Inputs

IRP sites are a type of potential contaminant source to Bousch Creek. Site 23 (LP-20 Plating Shop) and Site 20 (the Building LP-20 Site) are IRP sites located adjacent to the Lower Reaches of Bousch Creek and therefore, included in the evaluation of potential sources areas to the Lower Reaches.

A.2.1 Site 20 - LP-20 Site

Investigations at the site began in 1986 following a release of JP-5 fuel from an underground pipeline. Since 1986, approximately ten separate investigations have been conducted to evaluate the extent of releases from underground fuel pipelines, the industrial wastewater line, and various USTs at the site. These investigations determined that significant amounts of free product, as well as chlorinated solvents, are present. A RI and Feasibility Study summarizing the previous investigation data were completed in 1996 (Baker Environmental, Inc., 1996a; Baker Environmental, Inc., 1996b).

The data generated during the RI indicate that VOCs are the primary contaminants detected in the area. Specifically, chlorinated solvents were detected in the vicinity of LP-20 and LP-26. In addition, petroleum products are present east of Building LP-22 and south of Building LP-179. Concentrations of vinyl chloride, 1,1-dichloroethene, 1,2-dichloroethene, 1,2-dichloroethane, TCE, and benzene were observed in the shallow (Columbia) aquifer. Furthermore, concentrations of vinyl chloride, 1,2-dichloroethene, and TCE were also detected in the deep (Yorktown) aquifer.

As a result of the free product at the site, two product recovery systems were installed south and southeast of Building LP-22. Product Recovery System #1 was constructed in 1986, and Product Recovery System #2 was reportedly constructed sometime between 1988 and 1990. Both systems operated four recovery wells that pumped groundwater and product into oil/water separators (O/WS). The O/WS discharged into Bousch Creek and the free product was collected in an AST. Reportedly, neither system performed as anticipated, and both systems were seldom in operation due to mechanical problems. The systems were shut off in December 1994 and dismantled in 1995.

The Decision Document (Baker Environmental, Inc., 1996c) for the LP-20 Site required that contamination at the site be treated to reduce the threat to human health and the environment. The goal of the remedial action was to treat the contaminant plume in the

shallow aquifer using an air sparging and soil vapor extraction (AS/SVE) system to prevent migration of the plume offsite and into the deep aquifer, and reduce the contaminant concentrations to established cleanup goals. In addition, aquifer use restrictions (for both the shallow and deep aquifer) were mandated to prevent the groundwater from being used for either a potable or non-potable (industrial water) source.

The construction of the treatment system was completed and began operating on April 14, 1998. The shallow aquifer is treated by an AS/SVE system consisting of 31 air injection wells and 21 vapor extraction wells. The system was placed throughout the center and downgradient extent of the contaminant plume. In addition, several monitoring wells were sampled for VOCs in February 1998 to provide baseline water quality data before the remediation system was started (CH2M HILL, 1998).

As a requirement of the Decision Document, the LP-20 site is part of the long-term monitoring (LTM) program at NSN. Monitoring for LP-20 currently consists of an annual sampling of groundwater monitoring wells in the shallow and deep aquifer to track the levels of contaminants at the site and determine if these constituents are migrating offsite or into the deep aquifer. The first round of LTM for groundwater quality at the LP-20 Site was performed in February 1999, after approximately 10 months of system operation (CH2M HILL, 2000). LTM has continued annually with the most recent round of sampling (Round 10) completed in February 2007.

Round 10 of the LTM sampling consisted of 13 monitoring wells analyzed for TCL VOCs. Figure A-1 shows groundwater analytical results for those sampling locations with detections of benzene, 1,1-dichloroethene, 1,2-dichloroethane, total 1,2-dichloroethene, TCE, and vinyl chloride in the past two years of LTM sampling. The analytical results indicate VOC concentrations in eight monitoring wells (MW-2, MW-3, MW-5, MW-6, MW-13, MW-14, MW97-2S, and MW97-2D) either stabilized or decreased from 2006 to 2007. VOC concentrations in two of the monitoring wells (SW-1 and MW97-1S) increased based on comparison to recent LTM data. In addition, some VOC increases in wells SW-1 and MW97-1S resulted in concentrations similar to or greater than the baseline concentrations established at the site prior to installation of the remedial system. Analytical results for detected VOCs during Round 10 of the LTM event are presented in Table A-1. However, VOCs have not been as issue in the surface water or sediment of Bousch Creek for ecological exposures based upon the ERAs that have been conducted to date.

The continuing effectiveness of the existing AS/SVE system will be evaluated by the Remedial Process Optimization Team based upon these trends. Recommendations will be presented to the Tier 1 Partnering Team for consensus.

A.2.2 Site 23 - LP-20 Plating Shop

During a 1989 site visit, representatives of the VDEQ observed violations of the Virginia Hazardous Waste Management Regulations. Violations included hazardous waste stored in generator container accumulation areas in excess of 90 days, hazardous waste stored in tanks without interim status or a permit, and containers not clearly marked as hazardous waste. Violations also included the lack of inspection records and notification of exact locations of all existing accumulation areas.

An enforcement order was effective in December 1990. Under RCRA, the Clean Closure Plan and Contingency Plan were completed in 1993 and approved by VDEQ in September

1994. The Navy requested a modification of the plans to conduct a risk-based closure. Multiple phases of investigation were conducted for partial implementation of the Risk-Based Closure Plan (Versar, Inc., 1997). The investigation included the collection of soil, concrete, and groundwater, and the analysis for VOCs, cyanide, and eight metals. The risk assessment indicated unacceptable industrial risk at 17 soil locations, but no unacceptable risks with exposure to the plating shop concrete floors. Groundwater was recommended to be addressed under a post-closure monitoring program. Final closure was not achieved; however, partial closure including the removal of tanks and most of the piping and either decontamination or disposal as hazardous waste did occur. In September 2000, a revised Clean Closure Plan was submitted to VDEQ. The scope of the revised plan included the removal of the concrete floor and approximately three feet of soil in the plating shop. In addition, the plan included sampling of the remaining soil in the shop area as well as the plating sumps and select locations along the industrial wastewater piping system. Following the sampling activities, the plan called for general cleanup and decontamination of the plating shop, the removal or rerouting of underground utilities beneath the plating shop, and the cleaning of portions of concrete slab that are demolished. Currently, there has been no activity at the plating shop since the submittal of the revised Clean Closure Plan (Versar, 2000a) and the Contingent Closure Plan (Versar, 2000b).

In July 2003, the Navy decided to move the site from the RCRA to the CERCLA program. A Preliminary Assessment/Site Inspection is the first step in evaluating a site under CERCLA, however, in November 2003 the NSN Tier 1 Partnering Team determined that the existing documents completed under the RCRA program could be used. In addition, the NSN Tier 1 Partnering Team jointly scoped additional soil investigation activities. The additional investigation was conducted in December 2004. Results of the investigation indicated there was one VOC and several semi-volatile organic compounds and metals at concentrations exceeding the residential and industrial risk-based concentrations.

In May 2005, the NSN Tier 1 Partnering Team agreed to conduct an interim removal action to address the site soils. A Final Engineering Evaluation and Cost Analysis was submitted in December 2006 that summarized the soil removal action. The construction activities associated with the interim action were initiated in June of 2006.

Table A-1
Summary of Constituents Detected in Groundwater - Site 20 (LP 20 Area) - Round 10
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, Virginia

Chemical	Cleanup Goals	NBS20-MW-13		NBS20-MW-14	NBS20-MW-2	NBS20-MW-3	NBS20-MW-5	NBS20-MW-6	NBS20-MW-8		NBS20-MW97-1D	NBS20-MW97-1S	NBS20-MW97-2D	NBS20-MW97-2S	NBS20-MW99-1S	NBS20-SW-1
		NBS20-MW-13-R10	NBS20-MW-13-P-R10	NBS20-MW-14-R10	NBS20-MW-2-R10	NBS20-MW-3-R10	NBS20-MW-5-R10	NBS20-MW-6-R10	NBS20-MW-8-R10	NBS20-MW-8P-R10	NBS20-MW97-1D-R10	NBS20-MW97-1S-R10	NBS20-MW97-2D-R10	NBS20-MW97-2S-R10	NBS20-MW99-1S-R10	NBS20-SW-1-R10
		02/15/07	02/15/07	02/15/07	02/13/07	02/15/07	02/14/07	02/15/07	02/13/07	02/13/07	02/14/07	02/14/07	02/14/07	02/14/07	02/15/07	02/14/07
Volatile Organic Compounds (UG/L)																
1,1,1-Trichloroethane	--	10 U	10 U	10 U	10 U	4.1 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2-Trichloroethane	--	10 U	10 U	10 U	10 U	3.3 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethane	--	2.2 J	10 U	10 U	8.8 J	380 J	41	2.6 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethene	11	19	16	10 U	47	1,200	170	8.2 J	10 U	10 U	100	39	5.4 J	10 U	10 U	3.2 J
1,2-Dichloroethane	172	10 U	10 U	10 U	10 U	18	2 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acetone	--	10 U	10 U	8.6 J	10 U	10 U	10 U	10 U	10 U	2.7 J	10 U	10 U	10 U	10 U	10 U	10 U
Benzene	19	10 U	10 U	10 U	2.8 J	10 U	12	10 U	2.2 J	2.4 J	3.7 J	2.4 J	3 J	10 U	10 U	10 U
Cyclohexane	--	10 U	10 U	10 U	10 U	10 U	160	10 U	3.8 J	4.3 J	10 U	2.8 J	12	10 U	10 U	10 U
Isopropylbenzene	--	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	4.9 J
Methylcyclohexane	--	10 U	10 U	10 U	10 U	10 U	26	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	--	10 U	10 U	10 U	10 U	5.5 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Toluene	--	10 U	10 U	10 U	3.5 J	3.4 J	2.9 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Trichloroethene	136	340	320	2.4 B	17,000	5,200	870	670	100 J	17 B	24 B	840	8 B	2.3 B	10 U	170
Vinyl chloride	6	64	54	10 U	5,900	360 J	1,100	3.4 J	150 J	120 J	350	220	100	10 U	10 U	150
cis-1,2-Dichloroethene	--	600	580	10 U	28,000	3,700	1,500	150	400	420	1,300	670	180	10 U	10 U	160
trans-1,2-Dichloroethene	--	13	11	10 U	360 J	30	420	15	16	14	230	140	6.1 J	10 U	10 U	13

Notes:
U- Analyte not detected
J- Reported value is estimated
B - Analyte not detected above associated blank
Represents Cleanup Goal Exceedances

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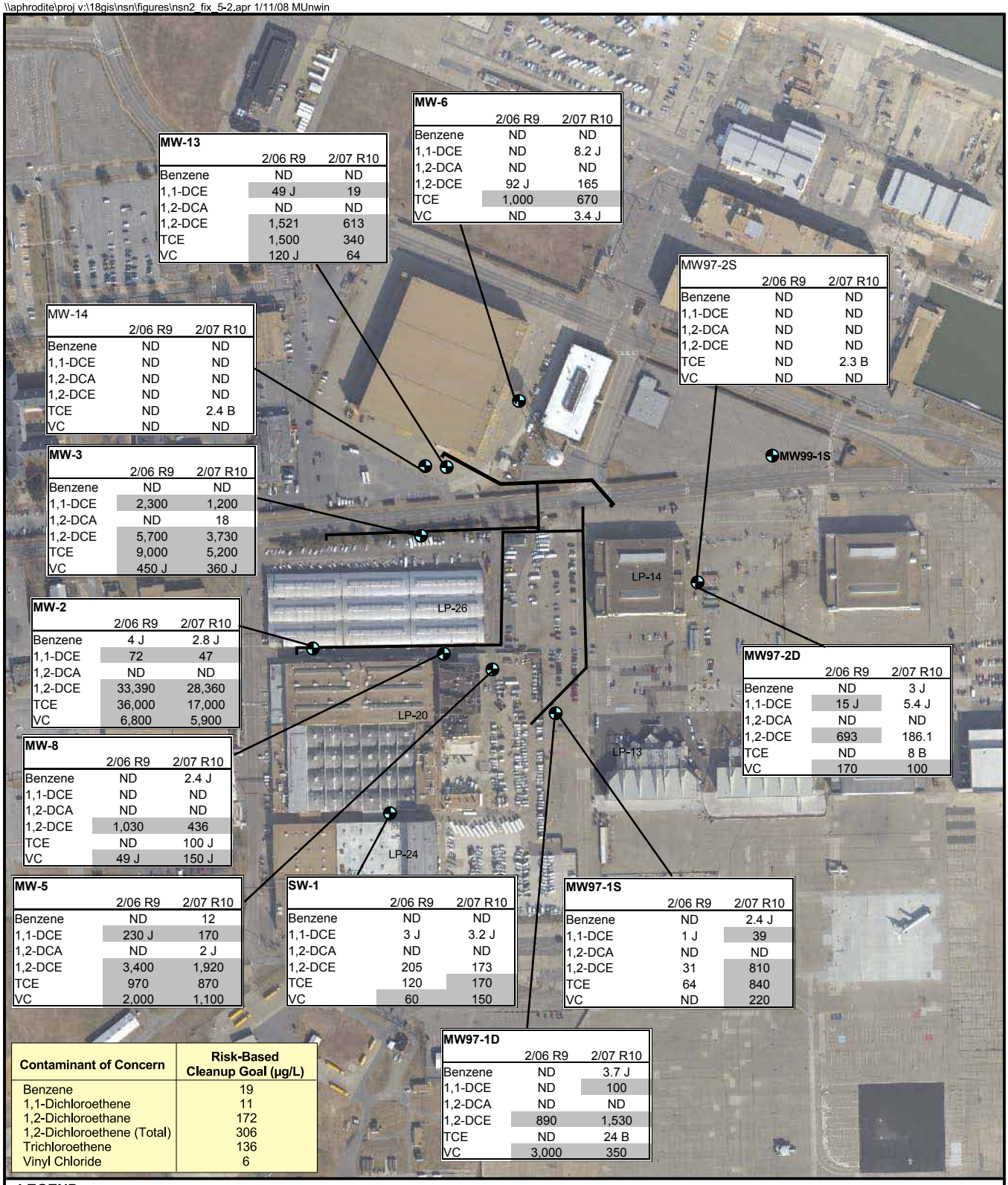

MW-13

	2/06 R9	2/07 R10
Benzene	ND	ND
1,1-DCE	49 J	19
1,2-DCA	ND	ND
1,2-DCE	1,521	613
TCE	1,500	340
VC	120 J	64

MW-6

	2/06 R9	2/07 R10
Benzene	ND	ND
1,1-DCE	ND	8.2 J
1,2-DCA	ND	ND
1,2-DCE	92 J	165
TCE	1,000	670
VC	ND	3.4 J

MW97-2S

	2/06 R9	2/07 R10
Benzene	ND	ND
1,1-DCE	ND	ND
1,2-DCA	ND	ND
1,2-DCE	ND	ND
TCE	ND	2.3 B
VC	ND	ND

MW-14

	2/06 R9	2/07 R10
Benzene	ND	ND
1,1-DCE	ND	ND
1,2-DCA	ND	ND
1,2-DCE	ND	ND
TCE	ND	2.4 B
VC	ND	ND

MW-3

	2/06 R9	2/07 R10
Benzene	ND	ND
1,1-DCE	2,300	1,200
1,2-DCA	ND	18
1,2-DCE	5,700	3,730
TCE	9,000	5,200
VC	450 J	360 J

MW-2

	2/06 R9	2/07 R10
Benzene	4 J	2.8 J
1,1-DCE	72	47
1,2-DCA	ND	ND
1,2-DCE	33,390	28,360
TCE	36,000	17,000
VC	6,800	5,900

MW97-2D

	2/06 R9	2/07 R10
Benzene	ND	3 J
1,1-DCE	15 J	5.4 J
1,2-DCA	ND	ND
1,2-DCE	693	186.1
TCE	ND	8 B
VC	170	100

MW-8

	2/06 R9	2/07 R10
Benzene	ND	2.4 J
1,1-DCE	ND	ND
1,2-DCA	ND	ND
1,2-DCE	1,030	436
TCE	ND	100 J
VC	49 J	150 J

MW-5

	2/06 R9	2/07 R10
Benzene	ND	12
1,1-DCE	230 J	170
1,2-DCA	ND	2 J
1,2-DCE	3,400	1,920
TCE	970	870
VC	2,000	1,100

SW-1

	2/06 R9	2/07 R10
Benzene	ND	ND
1,1-DCE	3 J	3.2 J
1,2-DCA	ND	ND
1,2-DCE	205	173
TCE	120	170
VC	60	150

MW97-1S

	2/06 R9	2/07 R10
Benzene	ND	2.4 J
1,1-DCE	1 J	39
1,2-DCA	ND	ND
1,2-DCE	31	810
TCE	64	840
VC	ND	220

MW97-1D

	2/06 R9	2/07 R10
Benzene	ND	3.7 J
1,1-DCE	ND	100
1,2-DCA	ND	ND
1,2-DCE	890	1,530
TCE	ND	24 B
VC	3,000	350

Contaminant of Concern	Risk-Based Cleanup Goal (µg/L)
Benzene	19
1,1-Dichloroethene	11
1,2-Dichloroethane	172
1,2-Dichloroethene (Total)	306
Trichloroethene	136
Vinyl Chloride	6

LEGEND

Monitoring Well

Approximate Alignments of Air-Sparging and Soil-Vapor Extraction Wells and Piping

1,1-DCE 1,1-Dichloroethene
1,2-DCA 1,2-Dichloroethane
1,2-DCE 1,2-Dichloroethene (Total, includes cis1,2-DCE and trans1,2-DCE)
TCE Trichloroethene
VC Vinyl Chloride
B Analyte not detected above associated blank
J Reported value is estimated
ND Not Detected

Notes:
Units are micrograms per liter (µg/L).
The labels of the monitoring wells that exceed cleanup goals in the most recent round of LTM sampling are in **BOLD.**
The detected concentration values that exceed cleanup goals are highlighted.
This figure only shows the past two years of LTM sampling where there were detections of benzene, 1,1-DCE, 1,2-DCA, 1,2-DCE (total), TCE, and VC.
2/06 R9 indicates the month/year the sample was collected and the LTM sampling round number

Aerial Photography - February 2005

N

0 200 400 Feet

Figure A-1
Volatile Organic Compound Concentrations in Selected Monitoring Wells
2006 through 2007 LTM Analytical Results
Site 20 - LP-20 Site
Naval Station Norfolk
Norfolk, Virginia

CH2MHILL

Attachment B
Analytical Data – October 2009 Sampling

Attachment B
Analytical Data - Surface Sediment - October 2009
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, VA

Chemical	NSN-BG-SD09-01 NSN-BG-SD09-01 10/08/09	NSN-BG-SD09-02 NSN-BG-SD09-02 10/08/09	NSN-BG-SD09-02P NSN-BG-SD09-02P 10/08/09	NSN-BG-SD09-03 NSN-BG-SD09-03 10/08/09	NSN-BG-SD09-04 NSN-BG-SD09-04 10/08/09	NSN-BG-SD09-05 NSN-BG-SD09-05 10/08/09	NSN-BG-SD09-06 NSN-BG-SD09-06 10/08/09	NSN-BG-SD09-07 NSN-BG-SD09-07 10/09/09
Inorganics (MG/KG)								
Aluminum	9,810	25,000	28,100	31,400	29,200	32,200	37,200	8,190
Antimony	0.80 UL	2.20 UL	1.30 L	2.00 UL	2.60 UL	2.30 UL	2.80 UL	0.65 UL
Arsenic	6.50	14.0	16.3	16.9	16.2	16.6	16.7	1.30
Barium	32.7	62.7	71.7	73.8	76.6	75.0	87.7	13.7
Beryllium	0.54	1.30 J	1.40	1.60	1.60 J	1.70	1.90	0.12 J
Cadmium	0.87 J	2.00 J	2.80 J	1.80 J	1.80 J	2.00 J	1.80 J	0.040 J
Calcium	4,930 J	9,650 J	23,100 J	8,500 J	8,820 J	8,660 J	5,910 J	324 J
Chromium	26.4	69.8	69.9	76.6	71.1	79.2	84.0	8.30
Cobalt	3.60	8.90	9.30	10.1	10.0	11.2	11.7	0.64 J
Copper	23.1	53.0	55.3	57.4	55.9	62.0	59.4	2.70
Iron	14,400	34,500	37,500	41,200	41,000	42,700	45,800	3,990
Lead	39.8	73.5	75.4	69.1	61.6	197	60.6	6.70
Magnesium	3,300	8,100	8,780	9,480	9,980	10,000	11,100	563
Manganese	112	272	293	361	366	337	395	14.9
Mercury	0.78	0.23	0.34	0.23	0.20	0.28	0.23	0.040 U
Nickel	13.0	36.6	51.4	32.0	30.0	46.4	34.9	1.90 J
Potassium	1,820 K	4,650 K	5,210 K	5,660 K	5,620 K	5,850 K	6,730 K	467 K
Selenium	0.37 J	0.63 J	1.30 J	2.60 U	1.70 J	0.79 J	1.30 J	0.81 U
Silver	0.57 J	1.20 J	1.50 J	1.40 J	1.30 J	1.20 J	1.40 J	1.20 U
Sodium	6,660	16,900	18,400	18,600	22,700	19,400	21,300	1,080
Thallium	0.60 J	1.20 J	0.98 J	0.79 J	1.20 J	0.78 J	0.57 J	0.070 J
Vanadium	29.0	78.0	78.7	82.5	77.4	86.8	90.7	14.7
Zinc	124 K	254 K	313 K	268 K	264 K	271 K	276 K	9.20 K
Pesticide/Polychlorinated Biphenyls (UG/KG)								
4,4'-DDD	11.0 J	7.50 J	16.0 J	6.60 J	6.60 J	5.20 J	4.80 J	0.92 J
4,4'-DDE	4.20	5.80 J	7.10 J	4.60 J	6.10 J	3.80 J	3.70 L	0.82 J
4,4'-DDT	5.80 J	10.0 U	17.0	11.0 J	7.70 J	6.60 J	12.0 UL	3.90 U
Aldrin	2.10 U	5.30 U	5.70 U	5.50 UL	6.60 U	6.30 U	6.30 UL	2.00 U
alpha-BHC	2.10 U	5.30 U	5.70 U	5.50 UL	6.60 U	6.30 U	6.30 UL	2.00 U
alpha-Chlordane	1.80 J	2.00 J	1.60 J	1.70 L	1.90 J	6.30 U	6.30 UL	2.00 U
Aroclor-1016	22.0 U	56.0 U	60.0 U	58.0 U	70.0 U	67.0 U	66.0 UL	21.0 U
Aroclor-1221	51.0 U	130 U	140 U	140 U	160 U	160 U	150 UL	49.0 U
Aroclor-1232	34.0 U	88.0 U	94.0 U	90.0 U	110 U	100 U	100 UL	33.0 U
Aroclor-1242	22.0 U	56.0 U	60.0 U	58.0 U	70.0 U	67.0 U	66.0 UL	21.0 U
Aroclor-1248	23.0 U	60.0 U	64.0 U	61.0 U	74.0 U	70.0 U	70.0 UL	22.0 U
Aroclor-1254	18.0 U	47.0 U	50.0 U	48.0 U	58.0 U	56.0 U	55.0 UL	18.0 U

Shaded cells indicate detections

Attachment B
Analytical Data - Surface Sediment - October 2009
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, VA

Chemical	NSN-BG-SD09-01 NSN-BG-SD09-01 10/08/09	NSN-BG-SD09-02 NSN-BG-SD09-02 10/08/09	NSN-BG-SD09-02P NSN-BG-SD09-02P 10/08/09	NSN-BG-SD09-03 NSN-BG-SD09-03 10/08/09	NSN-BG-SD09-04 NSN-BG-SD09-04 10/08/09	NSN-BG-SD09-05 NSN-BG-SD09-05 10/08/09	NSN-BG-SD09-06 NSN-BG-SD09-06 10/08/09	NSN-BG-SD09-07 NSN-BG-SD09-07 10/09/09
Aroclor-1260	22.0 U	56.0 U	180	58.0 U	70.0 U	67.0 U	66.0 UL	21.0 U
beta-BHC	2.10 U	5.30 U	5.70 U	5.50 UL	6.60 U	6.30 U	6.30 UL	2.00 U
delta-BHC	2.10 U	5.30 U	5.70 U	5.50 UL	6.60 U	6.30 U	6.30 UL	2.00 U
Dieldrin	4.00 U	5.90 J	2.40 J	11.0 UL	2.80 J	2.70 J	12.0 UL	0.72 J
Endosulfan I	2.10 U	5.30 U	5.70 U	5.50 UL	2.40 J	6.30 U	6.30 UL	2.00 U
Endosulfan II	4.00 U	5.80 J	11.0 U	1.90 L	13.0 U	12.0 U	12.0 UL	3.90 U
Endosulfan sulfate	6.30 J	10.0 U	13.0 J	11.0 UL	13.0 U	12.0 U	12.0 UL	3.90 U
Endrin	4.00 U	10.0 U	11.0 U	11.0 UL	13.0 U	12.0 U	12.0 UL	3.90 U
Endrin aldehyde	4.00 U	10.0 U	11.0 J	9.30 J	4.20 J	5.00 J	12.0 UL	3.90 U
Endrin ketone	4.00 U	10.0 U	11.0 U	11.0 UL	13.0 U	12.0 U	12.0 UL	3.90 U
gamma-BHC (Lindane)	4.70	3.90 J	2.40 J	5.50 UL	6.60 U	2.50 J	6.30 UL	0.77 J
gamma-Chlordane	16.0 J	5.30 U	5.70 U	2.90 L	3.30 J	6.30 U	2.50 L	0.70 J
Heptachlor	2.10 U	5.30 U	5.70 U	5.50 UL	6.60 U	6.30 U	6.30 UL	2.00 U
Heptachlor epoxide	2.10 U	5.30 U	5.70 U	5.50 UL	6.60 U	6.30 U	6.30 UL	2.00 U
Methoxychlor	21.0 U	53.0 U	57.0 U	55.0 UL	66.0 U	63.0 U	63.0 UL	20.0 U
Toxaphene	51.0 U	130 U	140 U	140 UL	160 U	160 U	150 UL	49.0 U
Semivolatile Organic Compounds (UG/KG)								
2-Methylnaphthalene	19.0 J	60.0 U	67.0 U	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
Acenaphthene	72.0	16.0 J	14.0 J	5.90 J	80.0 U	7.00 J	74.0 U	24.0 U
Acenaphthylene	23.0 U	60.0 U	6.90 J	5.90 J	6.80 J	7.20 J	74.0 U	24.0 U
Anthracene	180	47.0 J	37.0 J	20.0 J	24.0 J	51.0 J	12.0 J	24.0 U
Benzo(a)anthracene	2,000 J	240 J	220 J	240 J	180 J	900 J	71.0 J	8.60 J
Benzo(a)pyrene	1,200	170	140	140	120	350	63.0 J	8.20 J
Benzo(b)fluoranthene	2,300	300 J	290	270 K	250	670	140	21.0 J
Benzo(g,h,i)perylene	670	100 J	98.0	78.0	77.0 J	150	44.0 J	7.20 J
Benzo(k)fluoranthene	690	97.0	79.0	80.0 L	71.0 J	210	36.0 J	5.10 J
Chrysene	2,500 J	260 K	220 J	230 J	180 J	740 J	86.0 J	7.10 J
Dibenz(a,h)anthracene	170	45.0 J	46.0 J	39.0 J	40.0 J	69.0 J	26.0 J	24.0 U
Fluoranthene	5,400	390	420	400 K	330	1,700	130	19.0 J
Fluorene	67.0	14.0 J	14.0 J	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
Indeno(1,2,3-cd)pyrene	1,400 J	210 J	190 J	170 J	160 J	320 J	96.0 J	18.0 J
Naphthalene	47.0	11.0 J	11.0 J	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
PAH (total)	21,327	2,440	2,289	2,173	1,917	6,844	1,033	196
Phenanthrene	1,200	120	150	65.0 J	58.0 J	160	24.0 J	4.00 J
Pyrene	3,400	360	320	330 K	260	1,400	120	14.0 J
Volatile Organic Compounds (UG/KG)								
1,1,1-Trichloroethane	7.00 U	19.0 U	21.0 U	21.0 U	24.0 U	21.0 U	22.0 U	7.00 U

Shaded cells indicate detections

Attachment B
Analytical Data - Surface Sediment - October 2009
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, VA

Chemical	NSN-BG-SD09-01 NSN-BG-SD09-01 10/08/09	NSN-BG-SD09-02 NSN-BG-SD09-02 10/08/09	NSN-BG-SD09-02P NSN-BG-SD09-02P 10/08/09	NSN-BG-SD09-03 NSN-BG-SD09-03 10/08/09	NSN-BG-SD09-04 NSN-BG-SD09-04 10/08/09	NSN-BG-SD09-05 NSN-BG-SD09-05 10/08/09	NSN-BG-SD09-06 NSN-BG-SD09-06 10/08/09	NSN-BG-SD09-07 NSN-BG-SD09-07 10/09/09
1,1,2,2-Tetrachloroethane	6.00 U	16.0 U	17.0 UJ	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
1,1,2-Trichloro-1,2,2-trifluoroethane(Freon-113)	7.00 U	19.0 U	21.0 U	21.0 U	24.0 U	21.0 U	22.0 U	7.00 U
1,1,2-Trichloroethane	6.00 U	16.0 U	17.0 U	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
1,1-Dichloroethane	7.00 U	19.0 U	21.0 U	21.0 U	24.0 U	21.0 U	22.0 U	7.00 U
1,1-Dichloroethene	6.00 U	16.0 U	17.0 U	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
1,2,4-Trichlorobenzene	6.00 U	16.0 U	17.0 UJ	18.0 UL	20.0 U	17.0 U	19.0 U	6.00 U
1,2-Dibromo-3-chloropropane	8.00 U	22.0 U	24.0 UJ	25.0 U	28.0 U	24.0 U	26.0 U	8.00 U
1,2-Dibromoethane	7.00 U	19.0 U	21.0 U	21.0 UL	24.0 U	21.0 U	22.0 U	7.00 U
1,2-Dichlorobenzene	6.00 U	16.0 U	17.0 UJ	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
1,2-Dichloroethane	6.00 U	16.0 U	17.0 U	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
1,2-Dichloropropane	6.00 U	16.0 U	17.0 U	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
1,3-Dichlorobenzene	6.00 U	16.0 U	17.0 UJ	18.0 UL	20.0 U	17.0 U	19.0 U	6.00 U
1,4-Dichlorobenzene	6.00 U	16.0 U	17.0 UJ	18.0 UL	20.0 U	17.0 U	19.0 U	6.00 U
2-Butanone	34.0 U	19.0 J	22.0 J	26.0 J	25.0 J	100 U	110 U	33.0 U
2-Hexanone	29.0 U	78.0 U	87.0 U	89.0 U	100 U	87.0 U	94.0 U	28.0 U
4-Methyl-2-pentanone	34.0 U	90.0 U	100 U	100 UL	120 U	100 U	110 U	33.0 U
Acetone	16.0 B	110 J	130 J	140 J	120 J	70.0 B	75.0 B	7.00 B
Benzene	6.00 U	16.0 U	17.0 U	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
Bromodichloromethane	6.00 U	16.0 U	17.0 U	18.0 UL	20.0 U	17.0 U	19.0 U	6.00 U
Bromoform	6.00 U	16.0 U	17.0 U	18.0 R	20.0 U	17.0 U	19.0 U	6.00 U
Bromomethane	6.00 U	16.0 U	17.0 U	18.0 UL	20.0 U	17.0 U	19.0 U	6.00 U
Carbon disulfide	0.90 J	11.0 J	21.0	19.0 L	18.0 J	14.0 J	14.0 J	7.00 U
Carbon tetrachloride	6.00 U	16.0 U	17.0 U	18.0 UL	20.0 U	17.0 U	19.0 U	6.00 U
Chlorobenzene	6.00 U	16.0 U	17.0 U	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
Chloroethane	12.0 U	31.0 U	35.0 U	36.0 U	40.0 U	35.0 U	37.0 U	11.0 U
Chloroform	7.00 U	19.0 U	21.0 U	21.0 U	24.0 U	21.0 U	22.0 U	7.00 U
Chloromethane	12.0 U	31.0 U	35.0 U	36.0 U	40.0 U	35.0 U	37.0 U	11.0 U
cis-1,2-Dichloroethene	7.00 U	19.0 U	21.0 U	21.0 U	24.0 U	21.0 U	22.0 U	7.00 U
cis-1,3-Dichloropropene	6.00 U	16.0 U	17.0 U	18.0 R	20.0 U	17.0 U	19.0 U	6.00 U
Cumene	6.00 U	16.0 U	17.0 UJ	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
Cyclohexane	6.00 U	16.0 U	17.0 U	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
Dibromochloromethane	6.00 U	16.0 U	17.0 U	18.0 UL	20.0 U	17.0 U	19.0 U	6.00 U
Dichlorodifluoromethane (Freon-12)	12.0 U	31.0 U	35.0 U	36.0 U	40.0 U	35.0 U	37.0 U	11.0 U
Ethylbenzene	6.00 U	16.0 U	17.0 U	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
m- and p-Xylene	12.0 U	31.0 U	35.0 U	36.0 U	40.0 U	35.0 U	37.0 U	11.0 U
Methyl acetate	16.0 U	44.0 U	49.0 U	50.0 UL	57.0 U	49.0 U	52.0 U	16.0 U
Methylcyclohexane	6.00 U	16.0 U	17.0 U	18.0 UL	20.0 U	17.0 U	19.0 U	6.00 U

Shaded cells indicate detections

Attachment B
Analytical Data - Surface Sediment - October 2009
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, VA

Chemical	NSN-BG-SD09-01 NSN-BG-SD09-01 10/08/09	NSN-BG-SD09-02 NSN-BG-SD09-02 10/08/09	NSN-BG-SD09-02P NSN-BG-SD09-02P 10/08/09	NSN-BG-SD09-03 NSN-BG-SD09-03 10/08/09	NSN-BG-SD09-04 NSN-BG-SD09-04 10/08/09	NSN-BG-SD09-05 NSN-BG-SD09-05 10/08/09	NSN-BG-SD09-06 NSN-BG-SD09-06 10/08/09	NSN-BG-SD09-07 NSN-BG-SD09-07 10/09/09
Methylene chloride	29.0 U	78.0 U	87.0 U	89.0 U	100 U	87.0 U	94.0 U	28.0 U
Methyl-tert-butyl ether (MTBE)	10.0 U	28.0 U	31.0 U	32.0 U	36.0 U	31.0 U	34.0 U	10.0 U
o-Xylene	6.00 U	16.0 U	17.0 U	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
Styrene	6.00 U	16.0 U	17.0 U	18.0 UL	20.0 U	17.0 U	19.0 U	6.00 U
Tetrachloroethene	7.00 U	19.0 U	21.0 U	21.0 U	24.0 U	21.0 U	22.0 U	7.00 U
Toluene	6.00 U	16.0 U	17.0 U	18.0 U	20.0 U	17.0 U	19.0 U	6.00 U
trans-1,2-Dichloroethene	8.00 U	22.0 U	24.0 U	25.0 U	28.0 U	24.0 U	26.0 U	8.00 U
trans-1,3-Dichloropropene	8.00 U	22.0 U	24.0 U	25.0 UL	28.0 U	24.0 U	26.0 U	8.00 U
Trichloroethene	7.00 U	19.0 U	21.0 U	21.0 U	24.0 U	21.0 U	22.0 U	7.00 U
Trichlorofluoromethane(Freon-11)	12.0 U	31.0 U	35.0 U	36.0 U	40.0 U	35.0 U	37.0 U	11.0 U
Vinyl chloride	12.0 U	31.0 U	35.0 U	36.0 U	40.0 U	35.0 U	37.0 U	11.0 U
Xylene, total	17.0 U	47.0 U	52.0 U	53.0 U	61.0 U	52.0 U	56.0 U	17.0 U
AVS/SEM (UMOL/G)								
Acid volatile sulfide	68.0	37.0	100	120	59.0	65.0	24.0	0.12 U
Cadmium	0.0061	0.0052 J	0.0090	0.011	0.0085	0.0066	0.0029 J	2.70E-04 J
Copper	0.16	0.061	0.098	0.30	0.23	0.028 J	0.038	0.015
Lead	0.092	0.086	0.11	0.18	0.13	0.086	0.042	0.013
Mercury	6.40E-05 R	1.60E-04 R	1.80E-04 R	1.80E-04 R	2.00E-04 R	1.80E-04 R	2.00E-04 R	5.90E-05 R
Nickel	0.043	0.044 J	0.052	0.080	0.077	0.027 J	0.018 J	0.0017 J
Silver	5.40E-04 L	5.50E-04 L	6.80E-04 L	0.0018 L	8.50E-04 L	0.010 UL	0.011 UL	0.0033 UL
Zinc	1.13	1.08	1.70	2.84	1.90	1.42	0.73	0.043
Other Parameters								
Solids (Percent)	78.0	30.0	28.0	27.0	24.0	27.0	25.0	82.0
pH	8.20	8.30	8.40	8.50	8.30	8.40	8.40	7.80
Total organic carbon (MG/KG)	24,000	33,000	39,000	39,000	45,000	42,000	42,000	600

Shaded cells indicate detections

Attachment C
Exceedance Tables – October 2009 Sediment Data

Attachment C
Exceedances - Surface Sediment
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, VA

Chemical	SLC Screening Value	NSN-BG-SD09-01 NSN-BG-SD09-01 10/08/09	NSN-BG-SD09-02 NSN-BG-SD09-02 10/08/09	NSN-BG-SD09-02P NSN-BG-SD09-02P 10/08/09	NSN-BG-SD09-03 NSN-BG-SD09-03 10/08/09	NSN-BG-SD09-04 NSN-BG-SD09-04 10/08/09	NSN-BG-SD09-05 NSN-BG-SD09-05 10/08/09	NSN-BG-SD09-06 NSN-BG-SD09-06 10/08/09	NSN-BG-SD09-07 NSN-BG-SD09-07 10/09/09
Inorganics (MG/KG)									
Aluminum	18,000	9,810	25,000	28,100	31,400	29,200	32,200	37,200	8,190
Antimony	2.00	0.80 UL	2.20 UL	1.30 L	2.00 UL	2.60 UL	2.30 UL	2.80 UL	0.65 UL
Arsenic	8.20	6.50	14.0	16.3	16.9	16.2	16.6	16.7	1.30
Barium	48.0	32.7	62.7	71.7	73.8	76.6	75.0	87.7	13.7
Beryllium	--	0.54	1.30 J	1.40	1.60	1.60 J	1.70	1.90	0.12 J
Cadmium	1.20	0.87 J	2.00 J	2.80 J	1.80 J	1.80 J	2.00 J	1.80 J	0.040 J
Calcium	--	4,930 J	9,650 J	23,100 J	8,500 J	8,820 J	8,660 J	5,910 J	324 J
Chromium	81.0	26.4	69.8	69.9	76.6	71.1	79.2	84.0	8.30
Cobalt	10.0	3.60	8.90	9.30	10.1	10.0	11.2	11.7	0.64 J
Copper	34.0	23.1	53.0	55.3	57.4	55.9	62.0	59.4	2.70
Iron	220,000	14,400	34,500	37,500	41,200	41,000	42,700	45,800	3,990
Lead	46.7	39.8	73.5	75.4	69.1	61.6	197	60.6	6.70
Magnesium	--	3,300	8,100	8,780	9,480	9,980	10,000	11,100	563
Manganese	260	112	272	293	361	366	337	395	14.9
Mercury	0.15	0.78	0.23	0.34	0.23	0.20	0.28	0.23	0.040 U
Nickel	20.9	13.0	36.6	51.4	32.0	30.0	46.4	34.9	1.90 J
Potassium	--	1,820 K	4,650 K	5,210 K	5,660 K	5,620 K	5,850 K	6,730 K	467 K
Selenium	1.00	0.37 J	0.63 J	1.30 J	2.60 U	1.70 J	0.79 J	1.30 J	0.81 U
Silver	1.00	0.57 J	1.20 J	1.50 J	1.40 J	1.30 J	1.20 J	1.40 J	1.20 U
Sodium	--	6,660	16,900	18,400	18,600	22,700	19,400	21,300	1,080
Thallium	--	0.60 J	1.20 J	0.98 J	0.79 J	1.20 J	0.78 J	0.57 J	0.070 J
Vanadium	57.0	29.0	78.0	78.7	82.5	77.4	86.8	90.7	14.7
Zinc	150	124 K	254 K	313 K	268 K	264 K	271 K	276 K	9.20 K
Pesticide/Polychlorinated Biphenyls (UG/KG)									
4,4'-DDD	2.00	11.0 J	7.50 J	16.0 J	6.60 J	6.60 J	5.20 J	4.80 J	0.92 J
4,4'-DDE	2.20	4.20	5.80 J	7.10 J	4.60 J	6.10 J	3.80 J	3.70 L	0.82 J
4,4'-DDT	1.58	5.80 J	10.0 U	17.0	11.0 J	7.70 J	6.60 J	12.0 UL	3.90 U
alpha-Chlordane	2.26	1.80 J	2.00 J	1.60 J	1.70 L	1.90 J	6.30 U	6.30 UL	2.00 U
Aroclor-1260	48.0	22.0 U	56.0 U	180	58.0 U	70.0 U	67.0 U	66.0 UL	21.0 U
Dieldrin	0.715	4.00 U	5.90 J	2.40 J	11.0 UL	2.80 J	2.70 J	12.0 UL	0.72 J
Endosulfan I	--	2.10 U	5.30 U	5.70 U	5.50 UL	2.40 J	6.30 U	6.30 UL	2.00 U
Endosulfan II	--	4.00 U	5.80 J	11.0 U	1.90 L	13.0 U	12.0 U	12.0 UL	3.90 U
Endosulfan sulfate	--	6.30 J	10.0 U	13.0 J	11.0 UL	13.0 U	12.0 U	12.0 UL	3.90 U
Endrin aldehyde	2.67	4.00 U	10.0 U	11.0 J	9.30 J	4.20 J	5.00 J	12.0 UL	3.90 U
gamma-BHC (Lindane)	0.32	4.70	3.90 J	2.40 J	5.50 UL	6.60 U	2.50 J	6.30 UL	0.77 J
gamma-Chlordane	2.26	16.0 J	5.30 U	5.70 U	2.90 L	3.30 J	6.30 U	2.50 L	0.70 J
Semivolatile Organic Compounds (UG/KG)									
2-Methylnaphthalene	70.0	19.0 J	60.0 U	67.0 U	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
Acenaphthene	16.0	72.0	16.0 J	14.0 J	5.90 J	80.0 U	7.00 J	74.0 U	24.0 U
Acenaphthylene	44.0	23.0 U	60.0 U	6.90 J	5.90 J	6.80 J	7.20 J	74.0 U	24.0 U

Attachment C
Exceedances - Surface Sediment
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, VA

Chemical	SLC Screening Value	NSN-BG-SD09-01 NSN-BG-SD09-01 10/08/09	NSN-BG-SD09-02 NSN-BG-SD09-02 10/08/09	NSN-BG-SD09-02P NSN-BG-SD09-02P 10/08/09	NSN-BG-SD09-03 NSN-BG-SD09-03 10/08/09	NSN-BG-SD09-04 NSN-BG-SD09-04 10/08/09	NSN-BG-SD09-05 NSN-BG-SD09-05 10/08/09	NSN-BG-SD09-06 NSN-BG-SD09-06 10/08/09	NSN-BG-SD09-07 NSN-BG-SD09-07 10/09/09
Anthracene	85.3	180	47.0 J	37.0 J	20.0 J	24.0 J	51.0 J	12.0 J	24.0 U
Benzo(a)anthracene	261	2,000 J	240 J	220 J	240 J	180 J	900 J	71.0 J	8.60 J
Benzo(a)pyrene	430	1,200	170	140	140	120	350	63.0 J	8.20 J
Benzo(b)fluoranthene	1,800	2,300	300 J	290	270 K	250	670	140	21.0 J
Benzo(g,h,i)perylene	670	670	100 J	98.0	78.0	77.0 J	150	44.0 J	7.20 J
Benzo(k)fluoranthene	1,800	690	97.0	79.0	80.0 L	71.0 J	210	36.0 J	5.10 J
Chrysene	384	2,500 J	260 K	220 J	230 J	180 J	740 J	86.0 J	7.10 J
Dibenz(a,h)anthracene	63.4	170	45.0 J	46.0 J	39.0 J	40.0 J	69.0 J	26.0 J	24.0 U
Fluoranthene	600	5,400	390	420	400 K	330	1,700	130	19.0 J
Fluorene	19.0	67.0	14.0 J	14.0 J	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
Indeno(1,2,3-cd)pyrene	600	1,400 J	210 J	190 J	170 J	160 J	320 J	96.0 J	18.0 J
Naphthalene	160	47.0	11.0 J	11.0 J	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
PAH (total)	4,022	21,327	2,440	2,289	2,173	1,917	6,844	1,033	196
Phenanthrene	240	1,200	120	150	65.0 J	58.0 J	160	24.0 J	4.00 J
Pyrene	665	3,400	360	320	330 K	260	1,400	120	14.0 J
Volatile Organic Compounds (UG/KG)									
2-Butanone	--	34.0 U	19.0 J	22.0 J	26.0 J	25.0 J	100 U	110 U	33.0 U
Acetone	--	16.0 B	110 J	130 J	140 J	120 J	70.0 B	75.0 B	7.00 B
Carbon disulfide	--	0.90 J	11.0 J	21.0	19.0 L	18.0 J	14.0 J	14.0 J	7.00 U

Highlighting indicates exceedance of screening value

Attachment C
Exceedances - Surface Sediment
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, VA

Chemical	EqP Value	NSN-BG-SD09-01 NSN-BG-SD09-01 10/08/09	NSN-BG-SD09-02 NSN-BG-SD09-02 10/08/09	NSN-BG-SD09-02P NSN-BG-SD09-02P 10/08/09	NSN-BG-SD09-03 NSN-BG-SD09-03 10/08/09	NSN-BG-SD09-04 NSN-BG-SD09-04 10/08/09	NSN-BG-SD09-05 NSN-BG-SD09-05 10/08/09	NSN-BG-SD09-06 NSN-BG-SD09-06 10/08/09	NSN-BG-SD09-07 NSN-BG-SD09-07 10/09/09
Pesticide/Polychlorinated Biphenyls (UG/KG)									
4,4'-DDD	32.8	11.0 J	7.50 J	16.0 J	6.60 J	6.60 J	5.20 J	4.80 J	0.92 J
4,4'-DDE	146	4.20	5.80 J	7.10 J	4.60 J	6.10 J	3.80 J	3.70 L	0.82 J
4,4'-DDT	86.9	5.80 J	10.0 U	17.0	11.0 J	7.70 J	6.60 J	12.0 UL	3.90 U
alpha-Chlordane	216	1.80 J	2.00 J	1.60 J	1.70 L	1.90 J	6.30 U	6.30 UL	2.00 U
Aroclor-1260	397	22.0 U	56.0 U	180	58.0 U	70.0 U	67.0 U	66.0 UL	21.0 U
Dieldrin	314	4.00 U	5.90 J	2.40 J	11.0 UL	2.80 J	2.70 J	12.0 UL	0.72 J
Endosulfan I	1.69	2.10 U	5.30 U	5.70 U	5.50 UL	2.40 J	6.30 U	6.30 UL	2.00 U
Endosulfan II	7.94	4.00 U	5.80 J	11.0 U	1.90 L	13.0 U	12.0 U	12.0 UL	3.90 U
Endosulfan sulfate	1.19	6.30 J	10.0 U	13.0 J	11.0 UL	13.0 U	12.0 U	12.0 UL	3.90 U
Endrin aldehyde	11.6	4.00 U	10.0 U	11.0 J	9.30 J	4.20 J	5.00 J	12.0 UL	3.90 U
gamma-BHC (Lindane)	4,502	4.70	3.90 J	2.40 J	5.50 UL	6.60 U	2.50 J	6.30 UL	0.77 J
gamma-Chlordane	216	16.0 J	5.30 U	5.70 U	2.90 L	3.30 J	6.30 U	2.50 L	0.70 J
Semivolatile Organic Compounds (UG/KG)									
2-Methylnaphthalene	1,258	19.0 J	60.0 U	67.0 U	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
Acenaphthene	3,641	72.0	16.0 J	14.0 J	5.90 J	80.0 U	7.00 J	74.0 U	24.0 U
Acenaphthylene	2,185	23.0 U	60.0 U	6.90 J	5.90 J	6.80 J	7.20 J	74.0 U	24.0 U
Anthracene	7,282	180	47.0 J	37.0 J	20.0 J	24.0 J	51.0 J	12.0 J	24.0 U
Benzo(a)anthracene	3,641	2,000 J	240 J	220 J	240 J	180 J	900 J	71.0 J	8.60 J
Benzo(a)pyrene	3,277	1,200	170	140	140	120	350	63.0 J	8.20 J
Benzo(b)fluoranthene	7,613	2,300	300 J	290	270 K	250	670	140	21.0 J
Benzo(g,h,i)perylene	1,026	670	100 J	98.0	78.0	77.0 J	150	44.0 J	7.20 J
Benzo(k)fluoranthene	7,613	690	97.0	79.0	80.0 L	71.0 J	210	36.0 J	5.10 J
Chrysene	3,641	2,500 J	260 K	220 J	230 J	180 J	740 J	86.0 J	7.10 J
Dibenz(a,h)anthracene	397	170	45.0 J	46.0 J	39.0 J	40.0 J	69.0 J	26.0 J	24.0 U
Fluoranthene	4,634	5,400	390	420	400 K	330	1,700	130	19.0 J
Fluorene	761	67.0	14.0 J	14.0 J	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
Indeno(1,2,3-cd)pyrene	1,125	1,400 J	210 J	190 J	170 J	160 J	320 J	96.0 J	18.0 J
Naphthalene	3,277	47.0	11.0 J	11.0 J	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
PAH (total)	9,599	21,327	2,440	2,289	2,173	1,917	6,844	1,033	196
Phenanthrene	3,641	1,200	120	150	65.0 J	58.0 J	160	24.0 J	4.00 J
Pyrene	33,100	3,400	360	320	330 K	260	1,400	120	14.0 J
Volatile Organic Compounds (UG/KG)									
2-Butanone	874	34.0 U	19.0 J	22.0 J	26.0 J	25.0 J	100 U	110 U	33.0 U
Acetone	10,851	16.0 B	110 J	130 J	140 J	120 J	70.0 B	75.0 B	7.00 B
Carbon disulfide	2.82	0.90 J	11.0 J	21.0	19.0 L	18.0 J	14.0 J	14.0 J	7.00 U

Highlighting indicates exceedance of screening value

Attachment C
Exceedances - Surface Sediment
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, VA

Chemical	NOEC Value	NSN-BG-SD09-01 NSN-BG-SD09-01 10/08/09	NSN-BG-SD09-02 NSN-BG-SD09-02 10/08/09	NSN-BG-SD09-02P NSN-BG-SD09-02P 10/08/09	NSN-BG-SD09-03 NSN-BG-SD09-03 10/08/09	NSN-BG-SD09-04 NSN-BG-SD09-04 10/08/09	NSN-BG-SD09-05 NSN-BG-SD09-05 10/08/09	NSN-BG-SD09-06 NSN-BG-SD09-06 10/08/09	NSN-BG-SD09-07 NSN-BG-SD09-07 10/09/09
Inorganics (MG/KG)									
Aluminum	--	9,810	25,000	28,100	31,400	29,200	32,200	37,200	8,190
Antimony	--	0.80 UL	2.20 UL	1.30 L	2.00 UL	2.60 UL	2.30 UL	2.80 UL	0.65 UL
Arsenic	38.4	6.50	14.0	16.3	16.9	16.2	16.6	16.7	1.30
Barium	70.6	32.7	62.7	71.7	73.8	76.6	75.0	87.7	13.7
Beryllium	--	0.54	1.30 J	1.40	1.60	1.60 J	1.70	1.90	0.12 J
Cadmium	11.3	0.87 J	2.00 J	2.80 J	1.80 J	1.80 J	2.00 J	1.80 J	0.040 J
Calcium	--	4,930 J	9,650 J	23,100 J	8,500 J	8,820 J	8,660 J	5,910 J	324 J
Chromium	168	26.4	69.8	69.9	76.6	71.1	79.2	84.0	8.30
Cobalt	--	3.60	8.90	9.30	10.1	10.0	11.2	11.7	0.64 J
Copper	112	23.1	53.0	55.3	57.4	55.9	62.0	59.4	2.70
Iron	--	14,400	34,500	37,500	41,200	41,000	42,700	45,800	3,990
Lead	139	39.8	73.5	75.4	69.1	61.6	197	60.6	6.70
Magnesium	--	3,300	8,100	8,780	9,480	9,980	10,000	11,100	563
Manganese	--	112	272	293	361	366	337	395	14.9
Mercury	0.50	0.78	0.23	0.34	0.23	0.20	0.28	0.23	0.040 U
Nickel	34.9	13.0	36.6	51.4	32.0	30.0	46.4	34.9	1.90 J
Potassium	--	1,820 K	4,650 K	5,210 K	5,660 K	5,620 K	5,850 K	6,730 K	467 K
Selenium	--	0.37 J	0.63 J	1.30 J	2.60 U	1.70 J	0.79 J	1.30 J	0.81 U
Silver	3.70	0.57 J	1.20 J	1.50 J	1.40 J	1.30 J	1.20 J	1.40 J	1.20 U
Sodium	--	6,660	16,900	18,400	18,600	22,700	19,400	21,300	1,080
Thallium	--	0.60 J	1.20 J	0.98 J	0.79 J	1.20 J	0.78 J	0.57 J	0.070 J
Vanadium	98.9	29.0	78.0	78.7	82.5	77.4	86.8	90.7	14.7
Zinc	462	124 K	254 K	313 K	268 K	264 K	271 K	276 K	9.20 K
Pesticide/Polychlorinated Biphenyls (UG/KG)									
4,4'-DDD	--	11.0 J	7.50 J	16.0 J	6.60 J	6.60 J	5.20 J	4.80 J	0.92 J
4,4'-DDE	120	4.20	5.80 J	7.10 J	4.60 J	6.10 J	3.80 J	3.70 L	0.82 J
4,4'-DDT	12.0	5.80 J	10.0 U	17.0	11.0 J	7.70 J	6.60 J	12.0 UL	3.90 U
alpha-Chlordane	20.0	1.80 J	2.00 J	1.60 J	1.70 L	1.90 J	6.30 U	6.30 UL	2.00 U
Aroclor-1260	140	22.0 U	56.0 U	180	58.0 U	70.0 U	67.0 U	66.0 UL	21.0 U
Dieldrin	5.30	4.00 U	5.90 J	2.40 J	11.0 UL	2.80 J	2.70 J	12.0 UL	0.72 J
Endosulfan I	--	2.10 U	5.30 U	5.70 U	5.50 UL	2.40 J	6.30 U	6.30 UL	2.00 U
Endosulfan II	--	4.00 U	5.80 J	11.0 U	1.90 L	13.0 U	12.0 U	12.0 UL	3.90 U
Endosulfan sulfate	--	6.30 J	10.0 U	13.0 J	11.0 UL	13.0 U	12.0 U	12.0 UL	3.90 U
Endrin aldehyde	--	4.00 U	10.0 U	11.0 J	9.30 J	4.20 J	5.00 J	12.0 UL	3.90 U
gamma-BHC (Lindane)	--	4.70	3.90 J	2.40 J	5.50 UL	6.60 U	2.50 J	6.30 UL	0.77 J
gamma-Chlordane	16.0	16.0 J	5.30 U	5.70 U	2.90 L	3.30 J	6.30 U	2.50 L	0.70 J

Attachment C
Exceedances - Surface Sediment
Ecological Risk Assessment - Lower Reaches of Bousch Creek
Naval Station Norfolk, Norfolk, VA

Chemical	NOEC Value	NSN-BG-SD09-01 NSN-BG-SD09-01 10/08/09	NSN-BG-SD09-02 NSN-BG-SD09-02 10/08/09	NSN-BG-SD09-02P NSN-BG-SD09-02P 10/08/09	NSN-BG-SD09-03 NSN-BG-SD09-03 10/08/09	NSN-BG-SD09-04 NSN-BG-SD09-04 10/08/09	NSN-BG-SD09-05 NSN-BG-SD09-05 10/08/09	NSN-BG-SD09-06 NSN-BG-SD09-06 10/08/09	NSN-BG-SD09-07 NSN-BG-SD09-07 10/09/09
Semivolatile Organic Compounds (UG/KG)									
2-Methylnaphthalene	--	19.0 J	60.0 U	67.0 U	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
Acenaphthene	130	72.0	16.0 J	14.0 J	5.90 J	80.0 U	7.00 J	74.0 U	24.0 U
Acenaphthylene	--	23.0 U	60.0 U	6.90 J	5.90 J	6.80 J	7.20 J	74.0 U	24.0 U
Anthracene	190	180	47.0 J	37.0 J	20.0 J	24.0 J	51.0 J	12.0 J	24.0 U
Benzo(a)anthracene	350	2,000 J	240 J	220 J	240 J	180 J	900 J	71.0 J	8.60 J
Benzo(a)pyrene	380	1,200	170	140	140	120	350	63.0 J	8.20 J
Benzo(b)fluoranthene	--	2,300	300 J	290	270 K	250	670	140	21.0 J
Benzo(g,h,i)perylene	--	670	100 J	98.0	78.0	77.0 J	150	44.0 J	7.20 J
Benzo(k)fluoranthene	--	690	97.0	79.0	80.0 L	71.0 J	210	36.0 J	5.10 J
Chrysene	460	2,500 J	260 K	220 J	230 J	180 J	740 J	86.0 J	7.10 J
Dibenz(a,h)anthracene	--	170	45.0 J	46.0 J	39.0 J	40.0 J	69.0 J	26.0 J	24.0 U
Fluoranthene	800	5,400	390	420	400 K	330	1,700	130	19.0 J
Fluorene	--	67.0	14.0 J	14.0 J	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
Indeno(1,2,3-cd)pyrene	--	1,400 J	210 J	190 J	170 J	160 J	320 J	96.0 J	18.0 J
Naphthalene	--	47.0	11.0 J	11.0 J	66.0 U	80.0 U	73.0 U	74.0 U	24.0 U
PAH (total)	8,240	21,327	2,440	2,289	2,173	1,917	6,844	1,033	196
Phenanthrene	130	1,200	120	150	65.0 J	58.0 J	160	24.0 J	4.00 J
Pyrene	810	3,400	360	320	330 K	260	1,400	120	14.0 J
Volatile Organic Compounds (UG/KG)									
2-Butanone	--	34.0 U	19.0 J	22.0 J	26.0 J	25.0 J	100 U	110 U	33.0 U
Acetone	--	16.0 B	110 J	130 J	140 J	120 J	70.0 B	75.0 B	7.00 B
Carbon disulfide	--	0.90 J	11.0 J	21.0	19.0 L	18.0 J	14.0 J	14.0 J	7.00 U

Highlighting indicates exceedance of NOEC