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ENGINEERING AND EXPEDITIONARY WARFARE CENTER

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METHODOLOGY FOR IDENTIFYING AND QUANTIFYING METAL POLLUTANT SOURCES IN STORM WATER RUNOFF

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14. ABSTRACT
NAVFAC EXWC has developed a GIS-based methodology to identify and quantify non-point sources of metal pollutants in stormwater runoff. This project was in response to a NESDI need submitted by Naval Base San Diego. The methodology involves conducting a site characterization using a generic questionnairre and importing the data into the Non-point Source Stormwater Management tool. The tool operates within ArcGIS, and it can organize stormwater data (e.g. water quality data, SWPPP, BMPs) as well as predict the significant non-point sources of pollutants on the base. While the tool was used to find non-point sources of copper and zinc, it was designed so that it could be applied to any metal pollutant. The predictive function involves conducting statistical analysis on the site characterization data to determine the statisticaly relevant sources of the pollutants. A multi-linear regression equation is then created that models pollutant loading of the outfalls and drainage areas. This methodology was demonstrated at Naval Base San Diego, Naval Base Ventura County Port Hueneme, Joint Expeditionary Base Little Creek, and Naval Station Pearl Harbor.

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Navy Environmental Sustainability Development to Integration Program

Methodology for Identifying and Quantifying Metal Pollutant Sources in Storm Water Runoff

NESDI Project Number 463

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NESDI FINAL REPORT

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NESDI Program
Final Report

Methodology for Identifying and Quantifying Metal Pollutant Sources in Storm Water Runoff
Project #463

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EXECUTIVE SUMMARY

This project presents a methodology for identifying and quantifying metal pollutants in stormwater runoff in response to a “need” submitted by Naval Base San Diego to the Navy Environmental Sustainability Development to Integration (NESDI) program in January 2010. The base has been exceeding its benchmark values for copper and zinc in stormwater, and capturing and treating the stormwater or diverting the stormwater to a sanitary sewer are not viable options. In addition, visual inspections of the drainage areas have been insufficient in identifying and quantifying the sources. Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) responded to the need by proposing a GIS-based methodology to identify and quantify the non-point sources. This methodology utilizes GIS to assess the source of constituents in stormwater runoff, which has never been accomplished in the Navy. NAVFAC EXWC partnered with Houston Engineering Inc. to develop the methodology and a non-proprietary GIS toolbar with the objective of identifying and quantifying the non-point sources of copper and zinc. The methodology involves site characterization with a personal digital assistant (PDA) and a questionnaire (loaded in the PDA) that was developed by NAVFAC EXWC. The advantage of using the PDA is that it can easily capture data electronically with GPS coordinates. The data from the characterization then feeds into the Non-point Source Stormwater Management tool, which was developed specifically for this project and operates within ArcGIS. While copper and zinc were the pollutants of concern, the tool was designed for any metal pollutants. It includes the prediction function as well as other useful stormwater management functions.

The predictive function involves conducting statistical analysis on the site characterization data to narrow the possible sources of copper and zinc down to four or five. Next a multi-linear regression equation is created to model which drainage areas or outfalls have significant non-point sources of the pollutants. The tool was 70% accurate in identifying sources of copper and 73% accurate for zinc at Naval Base San Diego (NBSD). Demonstrations also took place at Naval Base Ventura County (NBVC) Port Hueneme and Joint Expeditionary Base Little Creek. The linear regression equation created for San Diego was re-used for Naval Base Ventura County, and the performance was poor. The poor performance was attributed to the equation developed for NBSD but used at NBVC. The equation developed was determined to be site-specific; however, a general equation can be developed. To do so, equations need to be developed for multiple bases to determine the commonalities among them. Upon learning that multi-linear regression equations are site-specific, a new equation was created for Joint Expeditionary Base Little Creek, and it did not perform as well as at Naval Base San Diego. The base did not have at least 3 years worth of stormwater quality data throughout the base, so stormwater was collected at 10 locations for three storm events. However, having more stormwater data may improve the quality of the regression equation. The methodology has also been implemented at Naval Station Pearl Harbor to assist the base in identifying non-point sources of copper and zinc. While the methodology for collecting the data was validated, the quality of the predictive function depends on the quality of the site characterization and the availability of existing stormwater data.

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ACRONYMS AND ABBREVIATIONS

BMP	Best Management Practice
DEM	Digital Elevation Model
DoD	Department of Defense
GIS	Geographic Information System
GRC	GeoReadiness Center
GRX	GeoReadiness Exchange
HEI	Houston Engineering Inc.
JEB	Joint Expeditionary Base
NAVFAC ESC	Naval Facilities Engineering Service Center
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NBSD	Naval Base San Diego
NBVC	Naval Base Ventura County
NESDI	Navy Environmental Sustainability Development to Integration
NITC	NAVFAC Information Technology Center
NMCI	Navy/Marine Corp Intranet
NPDES	National Pollutant Discharge Elimination System
NPSSM	Non-point Source Stormwater Management
ROI	Return on Investment
SPAWAR	Space and Naval Warfare Systems Command
SWPPP	Storm Water Pollution Prevention Plan
TICA	Technology Integration and Cost Analysis
TIE	Toxicity Identification Evaluations

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

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1.0 INTRODUCTION

1.1 Background

The National Pollutant Discharge Elimination System (NPDES) permit for Naval Base San Diego (NBSD) includes an acute toxicity effluent standard for industrial storm water discharges that is applied at the end of the pipe. NBSD and other installations have difficulty satisfying this standard. Using Toxicity Identification Evaluations (TIE), copper and zinc were identified as the primary cause of toxicity in the Navy stormwater discharges. These results are not surprising because several other studies in both San Diego and other regions and municipalities of the country show that copper and zinc are major contributors to toxicity in stormwater runoff. To comply with the toxicity standard and benchmark values, an installation can consider collecting and treating storm water runoff or diverting the runoff into the sanitary sewer system, but the cost could exceed millions of dollars. Instead of capturing and treating all stormwater generated on site, the optimal solution is to identify and reduce the significant sources of copper and zinc.

1.2 Regulatory Drivers

The Code of Federal Regulations 40 Part 122.26 states that stormwater discharges associated with industrial activities must have an NPDES permit. The NPDES permit requires an annual acute toxicity test during at least one rain event. The test "shall not produce less than 90% survival, 50% of the time, and not less than 70% survival, 10% of the time, using standard test species and protocol." In addition, at NBSD, copper concentration must not be greater than 63.6 µg/L and zinc concentration must not be greater than 117 µg/L. Note, however, these are only benchmark concentrations and not limits. Also, depending on the region, copper and zinc benchmarks may be less stringent.

1.3 Objective of the Project

The objective of this project was to provide NBSD and other applicable Naval bases a GIS-based methodology and a Non-point Source Stormwater Management (NPSSM) tool to help identify and quantify significant non-point sources of metal pollutants that contribute to benchmark exceedances at stormwater outfalls.

2.0 TECHNOLOGY DESCRIPTION

2.1 Technology Overview

The Non-point Source Stormwater Management tool is an extension in ArcGIS developed by Houston Engineering Inc. (HEI). The extension is non-proprietary and was intended to be used Navy-wide rather than at a particular base. Both the extension and ArcGIS are available to any naval installation. Once the extension is installed and loaded, there is a toolbar with tools relating to water quality and stormwater management (see Figure 1).

(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11)

Figure 1: Non-Point Source Management Toolbar.

The tools include: (1) Import tool, updates database by importing new water quality data, inspections, best management practices (BMPs), SWPPPs, etc. (2) the Water Quality Site tool, used to display the historic water quality data at a selected outfall or catchment; (3) the Observations tool, allows users to view recorded observations at selected outfalls; (4) Water Quality Summary tool, displays the spatial distribution of observed water quality (currently focused on Cu/Zn) across the naval base; (5) the Water Quality Predictive tool, utilizes multi-linear regression methods to predict areas of non-compliance with Cu/Zn standards based on site characteristics and predict quantity of pollutant runoff; (6) Contributing Basins tool, displays the non-point source characteristics (including general physical and source specific information) of the catchment that drains to an outfall; (7) the SWPPP ID tool, views the Storm Water Pollution Prevention Plan (SWPPP) active on base; (8) the Inspection tool, allows stormwater managers to track and manage the stormwater inspections that are required by various stormwater permits; (9) BMP tool, views BMPs implemented at a specific area and BMP description; (10) Settings tool, load appropriate settings per base; (11) Help tool, links to a user manual to provide assistance when needed.

Site characterization data is collected from a generic questionnaire, and the data feeds the NPSSM tool. A data dictionary or the questionnaire can be modified to more accurately characterize a specific base. For example, the data dictionary was modified in July 2013 to reflect the characteristics at Joint Expeditionary Base (JEB) Little Creek. See Figure 2 for an example of the data dictionary.

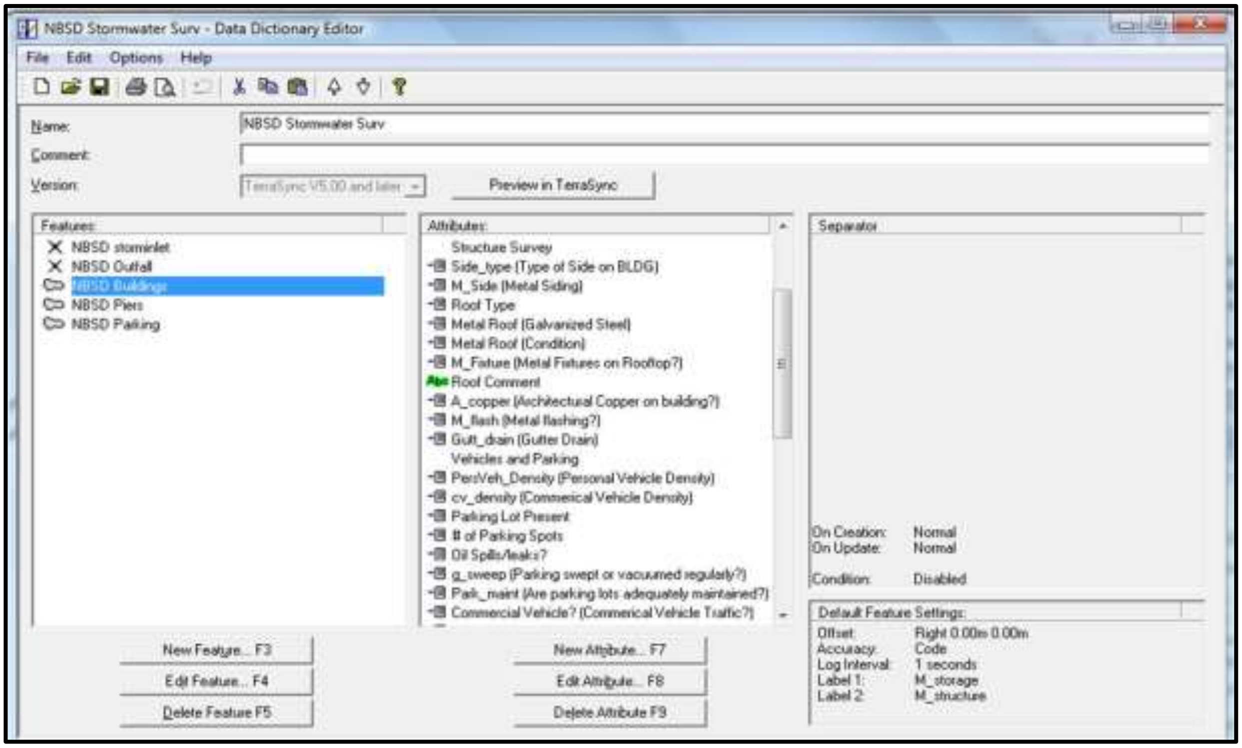

Figure 2: Data Dictionary.

The primary function of the NPSSM tool is the predictive function. The function is based off a multi-linear regression equation developed to model a pollutant e.g. one was developed for copper and another for zinc. The equation includes explanatory variables that each represent a significant source of the pollutant as identified by statistical analysis such as building material, parking lot, industrial activity etc. The statistical analysis involves taking all the potential sources of the pollutant identified in the site characterization and narrowing down the possible sources to the most statistically relevant ones. In other words, with statistical analysis, the results are material or sources that have a pattern of appearing in areas that have high concentration of the pollutants of concern, and an equation that simulates the elevated concentration in the drainage basins and outfalls. In the equation, each coefficient represents the "weight" of the variable relative to each other.

The statistical process includes removing doubles, normalizing the variables per drainage area (so the size of the basin does not influence the "weight" of the variables) and creating an equation that is statistically relevant. Statistical relevance and accuracy are measured by the R^2 value, p-value, F-value and t-test. The R^2 value shows how well the regression equation reproduces the observed values; the p-value is the probability of rejecting the null hypothesis (the lower the p-value, the more the null hypothesis can be rejected); F-values over 4 are statistically significant; and the t-test is a test to gauge if the coefficient of the variables are statistically different form zero. The null-hypothesis is a default position that no relationship exists. The purpose of finding these different values is to develop an equation that is statistically significant and relevant.

The methodology in capturing the data is as important as the tool. The iterative methodology is further discussed in the following section.

2.1.1 Methodology

The background and field data are required for the NPSSM tool to function. While the field data needs periodic updates, the background data is collected only once to develop a baseline:

Process supporting collection of background data:

1. Compile historical stormwater quality data for the pollutants of concern.

2. Compile all existing GIS data particularly roads, buildings, parking lots, fences, outfalls and delineated drainage basins.

3. Develop a Digital Elevation Model (DEM) for the base. A DEM is a 3-D representation of terrain surfaces based on elevation data. The DEM helps project how water will flow on the site. The DEM would be used to delineate the base into drainage basins. (This step may be skipped if the base has already delineated its drainage basin in GIS).

4. Collect Stormwater Pollution Prevention Plan, Observations, BMPs, Inspections.

Process for collection of field data:

1. Conduct a site characterization with a personal digital assistant (PDA) that utilizes the data dictionary developed by the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC).

2. Import the GIS data collected from the site characterization, water quality data and all relevant GIS layers into ArcGIS.

3. Load linear regression equation.

4. The model will generate a qualitative visual of the base showing different degrees of hotspots for the pollutants of concern. Hotspots are areas on the site with elevated concentrations of pollutants that may contribute to outfall non-compliance. The degrees range from light yellow (lowest concern) to brown (moderate concern) to dark brown (high concern).

5. Implement appropriate BMPs in the hotspots that are color-coded dark brown.

6. Determine whether the outfall is in compliance after next sampling event.

7. If in compliance, then the process is completed. If not, return to step 1.

2.2 Technology Development

The NPSSM tool and the data dictionary are the only parts of this methodology that were developed. Development of the tool began after the site characterization data of Naval Base San Diego was sent to the HEI. Prior to receiving the site characterization data, NAVFAC EXWC (then NAVFAC Engineering Service Center (ESC)) provided the contractor with preliminary data such as the delineated drainage basins, historical stormwater quality data of copper and zinc, and GIS layers of buildings, piers, parking lots and stormwater inlets. In addition, the contractor visited Naval Base San Diego from 12-13 January 2012 to gain a better understanding of the base layout, industrial activities, and to speak with personnel on the base. From the site visit, HEI concluded that stormwater management tools (in addition to the pollutant predictive source tracking tool) would be very beneficial to the end user.

Upon completing the site characterization in early March 2012 by NAVFAC ESC, HEI used the data to begin developing the model. The contractor completed the tool on 26-September 2012. Also, the data dictionary was undergoing optimizations from January-March 2012 and again in July 2013 when a site characterization was conducted at JEB Little Creek. A generic data dictionary has been developed, but some components may need to be revised to reflect a specific site.

In 2013, NAVFAC EXWC partnered with HEI again to refine the predictive function of the toolbar, troubleshoot and train NAVFAC EXWC personnel on developing the regression equation. The results from the NBSD demonstration site were good; however, NAVFAC EXWC believed the multi-linear regression equation powering the predictive function was specific to NBSD. To make one equation for the entire Navy, additional sites need to be characterized and additional multi-linear regression equations need to be developed. The purpose of the demonstration at JEB Little Creek was to develop another multi-linear regression equation and compare the equation with the one from NBSD. (The second equation was very different from the first).

Other tasks accomplished included troubleshooting the tool and training. When the toolbar was implemented at Naval Base Ventura County, Port Hueneme, many software bugs were encountered, but they have been fixed. The same issues did not occur at JEB Little Creek. Also, NAVFAC EXWC received training from HEI on how to conduct the statistical analysis to create the multi-linear regression so NAVFAC EXWC could create the equations for future locations.

2.3 Advantages and Limitations of the Technology

This project takes a qualitative approach rather than a quantitative one. Since the GIS infrastructure is already established Navy-wide and most bases have their buildings, parking lots, storm inlets etc. on GIS, characterizing the site is less labor intensive than using the current technology. The PDA device used in this project streamlines data collection by collecting all data digitally, and the data collection questionnaire loaded on the PDA is in the form of dropdown menus. Collecting data per parking lot, building etc. takes on average 30 seconds, and data collected are stored on one data file. After collecting the data, it can easily and quickly be transferred from the PDA onto a computer. Once the collected data is imported into the NPSSM tool, the results can be downloaded onto the user's computer. The data from this approach can also be uploaded onto the CITRIX server where any Department of Defense (DoD) personnel with a CITRIX account may readily access the data from around the world. Currently, this process is not in place but the capability is available. Also, the

NPSSM tool developed for this project can be used Navy-wide and even DoD-wide i.e. it was not designed to be used only at Naval Base San Diego.

Another advantage for this technology and methodology is that the tool is non-proprietary and therefore would not have that added annual expense. Although the initial capital investments may include the PDA and GIS software, these types of equipment are not limited to this project and can be used in Public Works.

Lastly, the NPSSM tool includes tools for data management. Stormwater managers can easily look at the performance of an outfall by plotting the pollutant concentration levels over time. In addition, the toolbar organizes the outfall related data (e.g. inspections and observations) in one location so they can be pulled up easily too.

3.0 PERFORMANCE OBJECTIVES

The performance criteria used to evaluate this technology include quantitative and qualitative parameters (See Table 1).

Table 1: Performance Objectives.

Performance Objective	Metric	Data Requirements	Success Criteria
Quantitative Performance Objectives			
Accuracy in identifying sources	% correct	Data analysis for point source identification	>80% success rate
Accuracy in quantifying sources		Data analysis of known metal loadings	
Qualitative Performance Objectives			
Efficient Resource Allocation	Varies	-Affordable by installation -Using existing resources/infrastructure -Non-proprietary model -Reduction in labor hours	Minimal new resources expended (e.g. new infrastructure, software, equipment)
Ease of use	Time used for training	Feedback from users on intuitive usability and operations	Minimal training and administrative burden
Reliability	Number of technical difficulties	Minimal downtime of technology	Minimal downtime/repair reported

4.0 FACILITY/SITE DESCRIPTION

Naval Base San Diego at 32nd street was selected as the original demonstration site for this project. The base sought assistance through the Navy Environmental Sustainability Development to Integration (NESDI) program for assistance in finding significant sources of copper and zinc. The installation had difficulties meeting its industrial stormwater benchmarks for copper and zinc on the "wet" side of the base. Potential sources include activity from vehicle traffic, commercial equipment, scrap metal lay downs and steam plants. Due to the vast range in activities (from commercial to industrial as well as transient lay downs) and different building/fence materials, there are different degrees of copper and zinc loadings on the installation. The activities on the base are a mix of commercial and industrial.

Because of the success in the first demonstration site, the NPSSM tool was demonstrated at Naval Base Ventura County (NBVC) Port Hueneme. The purpose of a second demonstration was to evaluate how well the multi-linear regression equation (developed for NBSD) worked at another installation without modifying the regression equation. This site was selected because it is comparable to NBSD, has similar climate and is easily accessible to NAVFAC EXWC employees without costing additional project dollars. Activities ranged from vehicle traffic to commercial equipment to forklifts to scrap metal and scrap wood lay downs. NBVC Port Hueneme is also known to temporarily store new vehicles from automotive manufacturers in its parking lots.

During the NESDI In-Progress Review November 2012, the discussion was raised about demonstrating the tool in a different environmental setting. Joint Expeditionary Base Little Creek was then selected to be the third demonstration site. The purpose for this demonstration was to determine how well the tool performs in a climate with greater rainfall. Also, as this tool becomes further implemented and new equations are developed, a general regression for the Navy may be created. JEB Little Creek is comparable to the industrial activities found at NBSD (e.g. recycling plant, scrap yard, lay downs, forklifts and heavy vehicles). However, this site differs from the others because of the lay downs of caissons with zinc anodes and the hotter, more humid weather with more frequent rain storms. The site itself does not have a consistent problem with copper or zinc compared to NBSD. The reason may because precipitation is more significant than at NBSD or at NBVC.

5.0 TEST DESIGN

5.1 Conceptual Test Design

This project has both quantitative and qualitative performance objectives used to evaluate the performance of this methodology and tool. The objectives include accurately quantifying and identifying the non-point sources of pollutants, efficient resource allocation, ease of use and reliability. To evaluate the NPSSM tool's ability to accurately quantify the pollutants (at least 80% accurate), the predicted quantified copper and zinc concentrations at the outfalls were compared with the actual results. The assumption is that all the stormwater generated at a drainage basin drains to only one outfall. Therefore, the pollutants originating in a drainage basin can be quantified at the outfall. The percent accuracy of the tool can be calculated from this comparison.

To identify the sources of pollutants, there are two different ways: by drainage basin or by material. Stormwater managers can easily determine which drainage basins are problematic by generating a layer that color codes the drainage basin based on pollutant concentration (See Appendix D); the darker the basin, the more polluted it is. The tool can also list out the problematic material. To evaluate the accuracy of identifying the sources by drainage basin, the predicted pollutant concentration in the drainage basin is compared to the actual. The accuracy of identifying the problematic material cannot be quantifiably verified. The list of problematic material provides a qualitative picture of where the significant non-point sources may come from.

Qualitative objectives include efficient use of resources, ease of use, and reliability. The objective to efficiently use resources is met if all existing resources are used and costs to procure equipment are reasonable. The ease of use is determined after replicating the process to setup the NPSSM tool in ArcGIS, importing the data and using ArcGIS and the tool. Reliability of the software is determined after using the tool and observing the number of incidences of bugs and software "crashes". If the tool has many bugs, then the tool would not be reliable.

The control used for the prediction baseline was the empirical sampling data. The samples were grab samples taken at the outfalls per Naval Base San Diego's NPDES permit. To determine the accuracy of the model, the predictive data was compared to the sampling data.

5.2 Design and Layout of Technology Components

5.2.1 Geographic Information System

GIS technology and geospatial information are used to map Navy shore assets and display relationships in a visual format, providing situational awareness and actionable information required to support quick and informed decisions. GIS is a system and database designed to capture, store, manage, analyze and present data with a geospatial reference. Geospatial data includes information such as description of buildings, types of inlets, industrial activities and descriptions of vehicle traffic etc. with associated coordinates.

This project employed a GIS approach to track significant non-point sources of copper and zinc for the following reasons:

- NAVFAC has an existing GIS infrastructure
- Good visual display of results
- The future of data management associated with maps is GIS
- Model is non-proprietary
- Streamlines process in annual stormwater inspection
- Low maintenance
- The developed GIS-model would be applicable Navy-wide
- GIS data may be uploaded onto the Navy's GIS server and Navy installations around the world may access the data

The framework of this project is based on GIS data: a GIS-based map with outfalls and stormwater inlets shown as points, and buildings, parking lots and industrial areas are shown as polygons. Each point and polygon (i.e. feature) have information (i.e. attributes) stored in it that describes the feature in addition to the coordinates. Information is collected on the field by a PDA that allows the user to complete a questionnaire or data dictionary. The data dictionary developed for this project has questions about the buildings, parking lots, laydown areas and industrial activities. Answers to the questions are integrated with the associated featured (i.e. parking lot, building etc.). For a complete table of the data dictionary, see Appendix B.

A key feature of this approach is that the resulting Non-point Source Stormwater Management tool is not designed to be used at a specific installation but may be applied Navy-wide. Also, because most bases already have their base mapped in GIS, they do not have to create a new GIS infrastructure.

5.2.2 Non-point Source Stormwater Management Tool

See Section 2 for an overview of all the functions in the NPSSM tool. Although the tool has many functions to manage stormwater data, the main function for this project is the Water Quality Predictive tool. The Water Quality Predictive tool takes a statistical approach to determine the sources of pollutants. Using the PDA, potential sources of pollutants are characterized and recorded. Next, a statistical analysis is conducted to narrow all the potential sources to only those that are statistically relevant i.e. only sources that repeatedly occur in areas of high pollutant concentrations are filtered. Next, a multi-linear regression equation is established in the tool. The tool will use the multi-linear regression equation to generate a new GIS layer displaying predicted problematic drainage basins that should be inspected. It can also display the predicted median concentration of pollutant leached from these drainage basins. Also, the tool can identify the significant non-point sources and quantify the sources that need to be addressed.

5.2.3 Personal Digital Assistant

A PDA is a type of small, portable handheld device commonly used in the public works sector within and outside the DoD. Some PDAs have the ability to capture information with the associated geo-spatial coordinates. For this project, the PDA must be able to load the data dictionary and export its data into GIS. The different models available depend largely on the accuracy of the device in determining the correct coordinates and other features e.g. an integrated camera, faster processor, and ease of use. The PDA had two purposes in this project: to collect information about the site that pertains to sources of copper and zinc along with the associated coordinates and to demonstrate the use of the PDA as a streamlined method for performing annual stormwater BMP assessments at the installation level.

5.2.4 GeoReadiness Center

Although GIS data in the Navy is housed at the NAVFAC Information Technology Center (NITC) in Port Hueneme, California, the data is managed by the GeoReadiness Center (GRC) in the region where the GIS data was collected (e.g. the GRC in San Diego manages the GIS data in Southwest region). The data is accessible via the web by anyone authorized by that region's GRC. Interested personnel simply need to setup a CITRIX account by contacting the region's GRC and receive permission to view the GIS data. CITRIX is a non-DoD organization who stores the GIS data on their servers where personnel may access the data via the web. While NITC houses GIS data for the Navy, CITRIX houses GIS data for access by personnel. Due to high demand on the server by Navy personnel, information on the CITRIX server is static i.e. no programs or models may run off the server, but new information is updated by the GRC regularly. The GeoReadiness Exchange (GRX) is the interface on the web where users view the data. GRX is a basic tool with the function of only viewing the data. To obtain existing GIS data to use in the tool, the GRC was contacted. GIS data cannot be downloaded from the GRX.

5.3 Operational Testing

5.3.1 Site Characterization Naval Base San Diego

A site survey was conducted at Naval Base San Diego 32nd Street (NBSD) from 21-24 February 2012 and 5-7 March 2012. NBSD is divided into two sides ("wet" and "dry") separated by Harbor Drive. Piers, industrial activities, training, and administrative buildings are located on the "wet" side while schools and residential housing are located on the "dry" side. Because most of the industrial activities and problems are on the "wet" side and due to time constraints, only the "wet" side was inspected and characterized.

The survey comprised two NAVFAC-ESC employees using two PDAs. Both devices were programmed with identical data dictionaries for recording data. As mentioned in the above section, the data dictionary was in the format of drop-down menus to streamline the data collection process. Relevant information not included in the drop-down menu was documented in the comments section. See Appendices B for details on the types of data collected.

During the site visits, all buildings, storm drains, parking lots, traffic densities and industrial areas were inspected. The purpose was to capture information that may indicate a high contributor of copper and zinc (e.g. building material, traffic flow, nearby industrial activities, existing metal fixtures, etc).

The site characterization included visiting every building, industrial area and parking lot, completing the pertinent data dictionary loaded on the PDA for the particular object being characterized, and updating the GIS data if needed. Because NBSD already has parking lots and buildings incorporated onto GIS, no additional work was required to create the GIS infrastructure. (Additional work to create industrial areas in GIS was required).

Following the site visit, the data was exported from the PDA onto a non-NMCI laptop for post-processing. Post-processing improves the accuracy of the coordinates from 20 feet down to as small as 4 inches. Upon rechecking the data for quality control, the GIS data was sent to HEI to develop the NPSSM tool.

5.3.1.1 NPSSM Tool Development

Houston Engineering Inc. was a partner in this project who helped develop the non-proprietary tool to predict non-point source pollutant sources. The tool had to be available to any Navy base for use, yet be able to identify specific sources per base. HEI also developed stormwater data management functions in addition to the source tracking function.

5.3.1.2 Water Quality Prediction Validation

See Section 6.0 for the validation of the Water Quality Predictive tool.

5.3.2 Site Characterization Naval Base Ventura County Port Hueneme

After demonstrating the NPSSM tool at NBSD, NAVFAC EXWC demonstrated the project locally at NBVC Port Hueneme. The purpose of the second demonstration was to evaluate the performance objectives at a different location. While the tool worked at NBSD, it was uncertain if the same equation would predict accurately at a similar base. From January to February 2013, NAVFAC EXWC characterized the base using the same PDA devices and a slightly modified data dictionary. The methodology of conducting the site characterization was the same as the one at NBSD. Prior to the site characterization, the existing GIS and water quality data were retrieved from the GRC and Public Works respectively. Because the GRC does not already have drainage basins delineated in GIS, one was modeled based on elevation. After completing the characterization, the GIS data and layers were setup to run the prediction and water quality assessment functions. However, there were errors in running the tool, but the errors were debugged at a later time.

5.3.3 Site Characterization Joint Expeditionary Base Little Creek

NAVFAC EXWC demonstrated the NPSSM tool at a third site (JEB Little Creek) to evaluate its performance because of its different climate and activities on the base. NAVFAC EXWC partnered with HEI again to develop the regression equation, troubleshoot the tool and train NAVFAC EXWC on how to create the regression equation. The main focus of this phase of the project was to create and evaluate a new linear regression equation at a new base. The NPSSM tool was originally created to be used Navy-wide and not specifically at one location. Thus far, the equation only works at NBSD; however, the goal is to create a general linear regression equation for the Navy. In July 2013, two NAVFAC EXWC personnel went to JEB Little Creek for the site characterization. The protocol was similar to that at NBSD. However, one of the lessons learned was to use cars to travel throughout the base than by foot. This increased the efficiency significantly.

Before collecting the data, a general tour of the base was conducted to get a better picture of the types of activities on the base. The entire site characterization took two weeks.

5.3.3.1 NPSSM Linear Regression Equation Development

During the kick-off meeting before the site visit, HEI noted that there was not enough historical water quality data to properly create a linear regression equation. NAVFAC EXWC communicated with NAVFAC Mid-LANT and told them the situation. NAVFAC EXWC used the base’s existing lab contract to collect and analyze additional samples. Funds were sent to NAVFAC Mid-LANT to collect additional water quality samples. Stormwater samples were collected at 10 outfalls over three storm events. The lab analyzed the samples for dissolved copper and zinc, and the results were sent to NAVFAC EXWC and HEI.

6.0 PERFORMANCE ASSESSMENT

6.1 Quantitative Objectives

6.1.1 Naval Base San Diego

Quantitative objectives included accurately identifying and quantifying non-point sources of copper and zinc. The success criteria are 80% accurate for both identifying and quantifying the non-point sources. The model is able to predict the concentrations of the pollutants at the outfall from the sources within its drainage basin. The assumption was that all the rainfall on a designated drainage basin flows to one outfall, and the pollutants at the outfall come from sources originating only from the designated drainage basin (i.e. the stormwater does not cross drainage basins). To determine the accuracy of predicting the cumulative pollutant concentration flowing from a particular drainage basin, the predicted pollutant concentration at the outfall was compared to the actual concentration at the outfall. The accuracy of identifying the sources by drainage basins could not be quantified. The results were presented to the base to verify the predicted sources.

On 8-Nov 2012, NAVFAC EXWC met with the staff at NBSD to receive feedback on the tool as well as to validate the model. They agreed with the findings. The accuracy of quantifying the sources of copper and zinc was determined to be 70% and 73% respectively. Appendix B displays predicted and actual pollutant concentrations as bar graphs, and Appendix C compares predicted and actual pollutant concentration values.

The accuracy of predicting and quantifying the sources of copper and zinc fell short of the success criteria by 7-10% for zinc and copper. The accuracy of the tool heavily depends on the quality of site characterization data. The better the data would lead to more accurate predictions. The data collected at Naval Base San Diego had good data but fell short in collecting data of industrial activities in finer detail and temporary lay downs for construction. Temporary lay downs are locations where construction workers put their equipment, scrap metal, etc. during construction. Temporary lay downs were not accurately documented and therefore were not included in the modeling. Additional demonstration sites with different environments (e.g. North West and East Coast) may provide additional insight on how the model can be improved and the limitations of the model. See Appendix D-F for graphical and tabular results.

The regression equation for zinc was determined to be:

$$Zn = 36.2 + 2339*X_1 + 2014.2X_2 + 547.5X_3$$

The table explaining the variables is seen in Table 2.

Table 2: Description of Zinc Regression Equation at NBSD.

Variable	Description
X_1	CMU Siding
X_2	Road Area
X_3	Industrial Activities

The variables in Table 2 show the material/area that the tool deemed to be significant in contributing to zinc. However, the accuracy cannot be quantified. Instead, it provides a qualitative illustration on where the significant non-point sources can be. For example, the tool identified concrete masonry units (CMU), industrial activities and roads as potential sources of zinc. It is clear that CMU does not leach out zinc. The more appropriate interpretation is that building material, industrial activities (in general) and traffic (e.g. zinc in brake dust) are major contributors.

The regression equation for copper was determined to be:

$$Cu = 47.72 + 669.3X_1 – 645.5X_2 + 1025.1X_3 -372.7X_4 +439.5X_5$$

The table explaining the variables is seen in Table 3.

Table 3: Description of Copper Regression Equation at NBSD.

Variable	Description
X_1	Scrap Metal Storage in Industrial Areas
X_2	Industrial Areas
X_3	Covered Industrial Areas
X_4	Cables in Industrial Areas
X_5	Scrap Wood Storage in Industrial Areas

For copper sources, the tool identified scrap metal storage in industrial areas, covered industrial areas and scrap wood storage in industrial activities as significant contributors. The other two variables (industrial areas and cables in industrial areas) had negative coefficient. This does not mean that copper was mitigated, but that there were areas that were double counted. The characterization of industrial areas needs to be better separated so features are not counted twice.

While the coefficients of the variables are numerical, the values themselves provide no quantitative insight. They show the "importance" or weight of the variable compared to the other variables. Because interpreting these results requires further insight and analysis, the list of material or activities that contribute to pollutants is qualitative in nature.

6.1.2 Naval Base Ventura County Port Hueneme

At NBVC Port Hueneme, the NPSSM toolbar was not able to accurately identify and quantify the sources of copper and zinc. A regression equation was not developed for this base, but the equation for NBSD was re-used based on the assumption that the industrial activities were similar to those at NBSD. The part of the tool to identify the drainage basins of concern was analyzed for its accuracy by comparing the predicted polluted drainage basins to the actual polluted drainage basins. Only the southern drainage basin was accurately identified as an area of concern while the other basins were either over or under predicted. With regards to quantifying the sources, the tool significantly over predicted the concentration of the pollutants per outfall. The primary reason for the lack of accuracy would be a faulty regression equation. The linear regression equation has varying weights or emphasis to each variable (i.e. pollutant source). The weights in this example were too high; therefore, the tool over-predicted the concentrations by three to four orders of magnitude. It is expected that a new regression has to be generated for this base to improve its prediction accuracy. See Appendix D results displayed on a map of the base. A graph and table were not generated comparing the predicted concentrations versus the actual concentrations because the results were significantly different.

6.1.3 JEB Little Creek

At JEB Little Creek, a new regression equation was developed specifically for this installation. The accuracy in identifying drainage basins of concern for zinc and copper was 59% and 42% respectively. The percentage was derived by comparing the predicted pollutant concentration in the basins to the actual. The same accuracy applies to quantifying the pollutant concentrations in the outfall.

The equations developed for zinc and copper differed drastically from the equations at NBSD. For zinc, the equation was:

$$Zn = 31.0 - 398.8X_1 + 715.5X_2 + 725.5X_3$$

See Table 4 for the explanation of the variables.

Table 4: Description of Zinc Regression Equation at JEB Little Creek.

Variable	Description
X_1	Scrap metal storage in industrial areas
X_2	Industrial laydown areas
X_3	Dry-dock

The variables (X_1-X_3) refer to the significant material sources of zinc. X_1 has a negative coefficient value, and it is interpreted that scrap metal storage acts as a buffer. These areas do not remove zinc, but it displaces areas that could have been used for laydown, which does contribute zinc. Buffers were not accounted for in the equation at NBSD, but they are statistically relevant. Also, it was observed that the dry-dock is a major contributed to zinc and enhances the regression equation. However, it is a singular event i.e. it is located in only one drainage basin. This variable is only used if the dry-dock is located in that drainage basin. The dry-dock variable was used because it significantly improved the quality of the regression equation. A single event variable was also not used in the equation at NBSD.

The equation for copper was:

$Cu = 4.0 – 114.6X_1 + 25.5X_2 + 36.5X_3$.

See Table 5 Table 5: Description of Copper Regression Equation at JEB Little Creekfor the explanation of the variables.

Table 5: Description of Copper Regression Equation at JEB Little Creek.

Variable	Description
X_1	Wetland area
X_2	Metal equipment storage by buildings
X_3	Dry-dock

Again, a buffer variable exists. This time, wetland area was identified as a feature that displaces space for other contributing sources. At NBSD, there was no forestry or natural landscapes (e.g. lakes) that could act as a buffer. For future implantation of this technology at different locations, the landscape will be taken into account in developing the equation. The dry-dock is also seen as a singular event that greatly contributes to metal. Because JEB Little Creek does not have an issue in exceeding its copper benchmarks, and the dry-dock is a major contributor, the dry-dock could not be left out of the equation. The value of the coefficient is applied only in one drainage basin. The accuracy at this site did not meet the quantitative performance objectives and performed much poorer than at NBSD. The reason may be because there was significantly less stormwater quality data available at JEB Little Creek than at NBSD. The predictive function does follow the overall trend i.e. it predicts higher pollutant concentration in some outfalls and lower in others, which matches the actual concentration. Although the NPSSM tool did not perform well, there were lessons learned that added value to the project.

6.2 Qualitative Objectives

The qualitative objectives include efficient resource allocation, ease of use and reliability. The tool is non-proprietary and was developed to be used Navy-wide. The infrastructure of the database is GIS, and bases already have existing GIS infrastructure and have access to GIS software. In addition, many bases already have PDAs they can use to collect data, or they have a GIS contract in which contractors can collect GIS information of the base. Resources need to be allocated to collect specific

GIS information of the base only. And, the data needs to be updated at least once a year. The PDA is a reliable and easy to use for conducting site characterization. The tool was reliable to use for Naval Base San Diego, but it had errors when it was used at Naval Base Ventura County. The tool has been optimized and all known bugs have been resolved.

A problematic area would be the ease of use of the tool. Although running the various functions incorporated in the tool is very simple, setting up the tool and inputting the data into ArcGIS may be confusing for first-time users or for users unfamiliar with ArcGIS. Storm water managers may have to request assistance from their GIS personnel or from NAVFAC EXWC for setting up the tool. Also, as of this report, the statistical analysis for the predictive modeling must be conducted per site to create a linear regression equation. Currently, a comprehensive linear regression equation has not been developed. Performing statistical analysis on the data collected from the site characterization is time consuming and complex. NAVFAC EXWC has received training on the process, but local installations would not have this capability. The best approach for local installations to generate the linear regression equations is to reach back to NAVFAC EXWC for support.

The NPSSM tool succeeds in efficiently using existing resources and in its reliability, but it is not easy to use. For bases that would like to utilize this tool, they would not have to expend funds to acquire the tool or procure new equipment. However, they may need assistance in setting up the tool and to generate the linear regression equation for its site.

7.0 COST ASSESSMENT

7.1 Cost Model

A Technology Integration and Cost Analysis (TICA) report from the NESDI website is not included in this report. The reason is because the TICA report calculated a negative return on investment (ROI). This value is not surprising because this methodology is not replacing existing technology but in fact enhancing it. Major benefits are not cost savings, but time saved in locating the sources of pollutants and functions of the tool that helps with generating annual reports (e.g. water quality graphs and water quality data overlay on a base map). If necessary, the user would make a one-time investment in ordering the PDA and associated software. Other major costs include the labor for compiling existing GIS data, characterizing the site and conducting the statistical analysis. Intangible benefits include regulatory compliance and a streamlined process to conduct stormwater inspections that reduces administrative burden. This methodology helps the user identify significant sources of pollutants. Once identified, the user would implement the appropriate BMPs to mitigate the pollutant loading.

The cost estimate presented in Section 7.3 can be applied at many bases. However, the cost of characterizing a site depends on the installation location (which affects travel and per diem costs) and the size of the base (which affects the duration of the characterization). An assumption is made on the location and area size.

7.2 Cost Drivers

Because the Navy has an established GIS infrastructure via the GRC, a license agreement with ESRI, and many Public Works Departments already own some type of PDA device, the capital investment cost for implementing this tool has been reduced to a minimum. However, major costs would fall under labor. Stormwater personnel would need to know how to setup the toolbar in ArcGIS, conduct a site characterization, and create a multi-linear regression equation to predict non-point sources of pollutants. Conducting a site characterization would take at least 2 weeks with two personnel. Not every installation has the resources to conduct an extensive site characterization, so a contract may have to be established. After the characterization, the data needs to be analyzed so a multi-linear regression may be created. The data analysis and regression equation may take another 4 weeks of time for a qualified person to complete. Someone would need to know how to properly conduct the statistical analysis and have the time and funds to complete the work. The site characterization is one time only, unless major changes (e.g. buildings, parking lots, etc.) are built. An update to the characterization is as needed. Whenever the site characteristics change, then the multi-linear regression equation would need to be re-calculated as well.

7.3 Cost Analysis and Comparison

The current practice in finding significant non-point sources of pollutants on an installation is that the stormwater managers have a general idea on where the most significant sources are. There is no scientific standard in the Navy in finding the pollutant sources; just intuition.

This methodology is an additional tool that stormwater managers can use to facilitate the identification of significant pollutant sources that lead to non-compliance at the outfalls, and it can streamline stormwater inspections and generating graphs for reports. Replacing the current approach of identifying these sources is not the intent of this project. There are six separate costs when using this tool, depending on available resources and data: initial capital investment, existing data collection (GIS and historical water quality), additional stormwater data collection (optional), drainage basin delineation (optional), site characterization and data analysis. The initial investment is for acquiring any equipment the installation does not have e.g. PDA with GIS capabilities. If users currently do not own PDAs, they would spend at least $5,000 to acquire the device. Currently, there is a license agreement between ESRI and the Navy, so acquiring ArcGIS software will not be an issue. However, users will still need to acquire the applicable software for the PDA, which allows the user to upload and download data from the device. The software is NMCI certified; however, users will need to purchase their own licenses.

Next, existing GIS and historical water quality data need to be collected. GIS data and a comprehensive stormwater dataset are necessary components to run the toolbar and for an accurate prediction model. Most installations already have existing GIS data for their installations, particularly buildings, parking lots, utilities and natural grassy areas e.g. wetlands Not all installations have an extensive amount of recent stormwater data for the pollutants of concern. A minimum of 3 storm events and 10 different sampling points throughout the base is needed. More stormwater data would lead to a more accurate prediction model. Labor costs for collecting the data and importing them into the toolbar is approximately $3,000.

If there is not enough stormwater data, then additional stormwater needs to be collected and analyzed. By utilizing an existing lab contract, executing this task would be expedited and at minimal costs. Typically, this task would cost $15,000-$20,000, which includes the collection and analysis of 3 storm events with 10 sampling points.

Another required data is delineated drainage basins in GIS format. The toolbar needs this data for it to run properly. Most installations already have their drainage basins delineated in GIS format. For those that do not have their drainage basins delineated, the task can easily be accomplished using existing GIS extensions within ArcGIS. For an experienced GIS user, this task will cost $7,000 in labor.

Site characterization involves using the PDA and the developed data dictionary to “inventory” potential sources of the pollutants on-site. A data dictionary is a questionnaire loaded onto the PDA. The user would answer questions concerning buildings, parking lots, industrial areas and laydown areas. Typically, conducting the site characterization requires two people to quickly and efficiently cover the entire installation. The duration of the site characterization depends on how large the installation is. Based on the previous demonstrations, the cost of conducting a site characterization is estimated to $12,000 per square mile. This cost covers labor and travel cost. Note, the assumption was that the location is within the continental United States and the base size is about 3.5 square miles.

The last task is the analysis of the data collected from the site characterization. The analysis includes removing erroneous data and data repeats. After filtering the data, statistical analysis will be conducted to create the multi-linear regression equation per pollutant that is used in the toolbar. Non-proprietary software can be used for this purpose e.g. generic spreadsheet software with statistical analysis capabilities. The purpose of the statistical analysis is to link reoccurring high levels of the pollutants of concern to specific features of the base e.g. specific building material, parking lots, traffic density etc. After the linear regression equation is developed, significant sources of the pollutant can be located on the base. The cost of the statistical analysis is $30,000 of labor.

The minimum cost of utilizing this technology is $75,000 assuming 3.5 square miles, the base is within the continental United States and the base does not need additional equipment and data. The current approach is to guess where the potential sources are based on site inspections. This approach complements the current approach by providing a scientific model to corroborate the assumed significant non-point sources. By using this technology, the installation may show the regulators that action is being taken to actively find the significant sources of pollutants.

8.0 CONCLUSIONS, RECOMMENDATIONS AND IMPLEMENTATION ISSUES

8.1 Conclusion and Recommendations

The NPSSM tool and methodology are excellent in incorporating GIS with an installation's stormwater data and in identifying and quantifying non-point sources of metal pollutants. Other benefits include an organized database for stormwater data and a visualization of where the significant non-point sources are. This technology and methodology does require existing GIS and stormwater data. Having the existing data, especially adequate recent stormwater data, would cut the costs and increase the accuracy of the prediction. Also, although site characterization may be time consuming, it is conducted only once and can be updated periodically. To get a better understanding on the accuracy of the prediction function of the tool, the tool needs to be implemented at more bases with adequate stormwater data. The tool had good predictions at NBSD but not at JEB Little Creek because of the lack of stormwater data. Therefore, it is recommended that the tool be implemented at more sites to determine the accuracy.

8.2 Guidance

To facilitate the implementation of this methodology, it is best that the end user compile the following documents:

- Historical Water Quality Data
- Water Quality Standards
- Stormwater Treatment
- Forms
- Inspections
- Observations
- BMPs used
- SWPPP

There must be at least 30 storm water data points collected across the base for the NPSSM prediction tool to function properly. If not, then additional stormwater data needs to be collected. (Note, more stormwater data points would lead to better accuracy in the tool). A template spreadsheet has been created to facilitate importing the stormwater data into the tool. The other documents may be in PDF format. In addition, it is necessary to have GIS data for stormwater outfalls, delineated drainage basins, parking lots and buildings as well as an aerial imagery. The data may then be imported into ArcMap and subsequently into the tool. Tutorials have been written to facilitate usage, and a help guide incorporated in the tool in case any questions arise. Before characterizing the site, a review of the site dictionary is necessary to ensure all relevant characteristics are captured and irrelevant characteristics are removed. After characterizing the site, be sure to import all survey templates (i.e. buildings, parking lots, industrial areas that were surveyed) into a Personal Geodatabase. Having experienced GIS personnel to import all relevant files into ArcMap and load the settings may be necessary.

8.3 Lessons Learned

Some issues that were encountered while conducting the site characterization were merging old and new files together and keeping track of which buildings were characterized. Upon completing a site characterization, different files were created and each file had specific building data. Instead of having multiple files, the files were merged into one, not knowing that sometimes some data was left out. The lesson learned was that the merge function was intended to merge polygons and not data. Therefore, in the future, all the data from the site characterization would be extracted and pasted into its own spreadsheet. Subsequently, the spreadsheet would be imported into ArcMap and the building shape files would cross reference or "join" with the spreadsheet. This process would eliminate the use of merging files.

Another issue was keeping track of which buildings or areas were characterized, especially when multiple people are in the field characterizing. A simple solution would be to "remove" the areas or buildings that were characterized from the shapefile at the end of each day and keep the data in its own spreadsheet. Therefore, only buildings that need to be characterized would appear on the PDA. As the completed buildings or areas are removed, be sure the data is saved in a separate master spreadsheet.

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APPENDIX A
POINTS OF CONTACT

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APPENDIX B
DATA DICTIONARY

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Buildings

Alias	Attribute	Input	Comments
Site Inspection			
Facility Number	FACIL_NO		
Facility Name	FEATNAME		
Survey Date	surv_date		
Photo	photo_d		
Structure Survey			
Building Siding	str_side_m	Metal, Concrete, CMU, Wood, Brick, Combination, Vinyl, Stucco, Fabric, Non	
Metal Siding	str_side_2	Galvanized Steel, Steel, Aluminum, Painted Metal, Unknown	Appears only if Building Siding is "metal"
Roof Material	roof_mat_d	Built Up, Metal Panel, Asphalt, Fabric, Clay, Slate, Wood, Other	
Galvanized Steel Used on Roof?	roof_metal	Yes, No, Painted, Need Info	Appears only if Roof Material is "metal"
Roof Type	roof_typ_d	Flat, Pitched, Combination, Round	
Architectural Copper on Building?	str_copper	Yes, No, N/A	
Grounds			
Ground Type Underneath Gutter	grnd_cover	Pervious, Impervious, Both	
Suspected Activity for Pollution?	ind_act_d	Yes, No	Is there an industrial activity on or next to the parking lot
Industrial Activity Description	ia_desc		Comment on activity and possibility of contaminants of concern
Level of Industrial Activity	ia_level	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Only when there is suspected activity for pollution
Pollution Potential	ia_polpot	High, Medium, Low	Only when there is

			suspected activity for pollution
Scrap Metal Storage On-site?	sm_store	Yes, No	Storing scrap metal increases risk of Cu and Zn
Scrap Metal Covered?	sm_cov	Yes, No	When not covered easier for rainfall to contact metal
Level of Scrap Metal	sm_level	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Only when there is scrap metal on site
Type of Metal	sm_type	Copper, Zinc, Galvanized, Scrap Iron, Misc.	Only when there is scrap metal on site
Pollution Potential	sm_polpot	High, Medium, Low	Only when there is scrap metal on site
Scrap Metal Processing On-site?	sm_use	Yes, No	Does the activity process scrap metal?
Trash Dumpster On-site?	metal_dump	Yes, No	
Scrap Wood Stored on Site?	sw_store	Yes, No	Certain types of treated wood have copper
Industrial Equipment On-site?	indus_eqp	Yes, No	Generators, pumps, other equipment exposed to the elements
Exposed cables on site	cables_d	Yes, No	Cables related to ship power or other operations
Comments	narrative		

Industrial Areas

Alias	Attribute	Input	Comments
Site Inspection			
Survey Date	surv_date		
Recycling Center Present?	recyc_ctr	Yes, No	
Type of Surface	srf_typ_d	Dirt, concrete, gravel, asphalt,mix	Influences runoff
Comments on Site	narrative		230 characters
Photo	photo_d		
Grounds			
Is the Site Covered?	feat_cov	Yes, No	Reduces the risk of contributing to stormwater contamination
Outdoor Industrial Activity?	ind_act_d	Yes, No	Is there any industrial activity?
Industrial Activity Description	ia_desc		Comments on activity
Level of Industrial Activity	ia_level	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Only when there is suspected activity for pollution
Pollution Potential	ia_polpot	High, Medium, Low	Only when there is suspected activity for pollution
Scrap Metal Processing On-site?	sm_use	Yes, No	Does the activity process scrap metal?
Scrap Metal Storage On-site?	sm_store	Yes, No	Storing scrap metal increases risk of Cu and Zn
Cover on Scrap Metal?	sm_cov	Yes, No	When not covered easier for rainfall to contact metal
Level of Scrap Metal	sm_level	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Only when there is scrap metal on site
Type of Metal	sm_type	Copper, Zinc, Galvanized, Scrap Iron, Misc.	Only when there is scrap metal on site
Pollution Potential	sm_polpot	High, Medium, Low	Only when there is scrap metal on site
Metal Dumpster On Site?	metal_dump	Yes, No	Source of metal contamination
Scrap Wood Stored On Site	sw_store	Yes, No	Certain types of treated wood have concentrations of copper
Industrial Equipment On Site?	indus_eqp	Yes, No	
Exposed cables On Site	cables_d	Yes, No	Metal cables related to ship power or other operations

Petroleum Storage or Processing	petro_proc	Yes, No	
Heavy Vehicle Present?	heavy_veh	Yes, No	
Vehicle Maintenance	veh_maint	Yes, No	Does vehicle maintenance occur at this site?
Type of Vehicle	veh_type	Automotive, Ship, Aircraft	When vehicle maintenance present
Vehicle Washing On Site?	veh_wash	Yes, No	Vehicle washing can contribute to contaminant load
Type of Vehicle	veh_type_w	Automotive, Ship, Aircraft	When vehicle washing present
Shipping Container?	iso	Yes, No	
Lay Down?	lay_down	Yes, No	
Lay Down Comments	Lay_down_com		

Parking Lots

Alias	Attribute	Input	Comments
Parking ID	parking_id		
Site Inspection			
Survey Date	surv_date		
Number of Parking Spots	tot_spaces	>50, <50	If known
Status of Paving	paved_d	Paved, not Paved	
Type of Surface	srf_typ_d	Dirt, concrete, gravel, asphalt	Influences runoff
Parking Swept?	park_sweep	Yes, No	
Condition of Parking Lot	park_cnd_d	Good, Fair, Poor	
Comments On Site	narrative		230 characters
Vehicles			
Types of Vehicles	veh_type_d	POV. GOV, Commerical	Commercial means trucks, forklifts, and other utility vehicles
Percent Full	per_park_use_d	<25%, 25%, 50%. >75%	
Oil Spills/Leaks?	petrocat_d	None, Light Significant	
Are Drip Pans Used for Leaks?	drip_petrocat_d	Yes, No	If spills or leaks occur
Traffic Density	den_park_d	Light, Medium, Heavy	Describes the “intensity” of constant traffic flow
Grounds			
Any Outdoor Industrial Activity?	ind_act_d	Yes, No	Is there an industrial activity on or next to the parking lot
Industrial Activity Description	ia_desc		
Level of Industrial Activity	ia_level	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Only when there is suspected activity for pollution
Pollution Potential	ia_polpot	High, Medium, Low	Only when there is suspected activity for pollution
Shipping Container?	iso	Yes, No	
Scrap Metal Processing On Site?	sm_use	Yes, No	Does the activity process scrap metal?
Scrap Metal Storage On Site?	sm_store	Yes, No	Storing scrap metal increases risk of Cu and Zn

Type of Metal	sm_type	Copper, Zinc, Galvanized, Scrap Iron, Misc.	Only when there is scrap metal on site
Cover on Scrap Metal?	sm_cov	Yes, No	When not covered easier for rainfall to contact metal
Pollution Potential	sm_polpot	High, Medium, Low	Only when there is scrap metal on site
Level of Scrap Metal	sm_level	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Only when there is scrap metal on site
Scrap Wood Stored On Site	sw_store	Yes, No	Certain types of treated wood have concentrations of copper
Metal Dumpster On Site?	metal_dump	Yes, No	Source of metal contamination
Metal Dumpster Covered?	metal_dump_cov	Yes, No	When not covered easier for rainfall to contact metal
Industrial Equipment On Site?	indus_eqp	Yes, No	
Heavy Vehicle Present?	heavy_veh	Yes, No	
Vehicle Maintenance On Site?	veh_maint	Yes, No	Does vehicle maintenance occur at this site
Type of Vehicle	veh_type	Automotive, Ship, Aircraft	When vehicle maintenance present
Vehicle Washing On Site?	veh_wash	Yes, No	Vehicle washing can contribute to contaminant load
Type of Vehicle	veh_type_w	Automotive, Ship, Aircraft	When vehicle washing present
Lay Down	lay_down	Yes, No	
Lay Down Comments	lay_down_com		

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APPENDIX C
Screenshots of the Tool in ArcGIS

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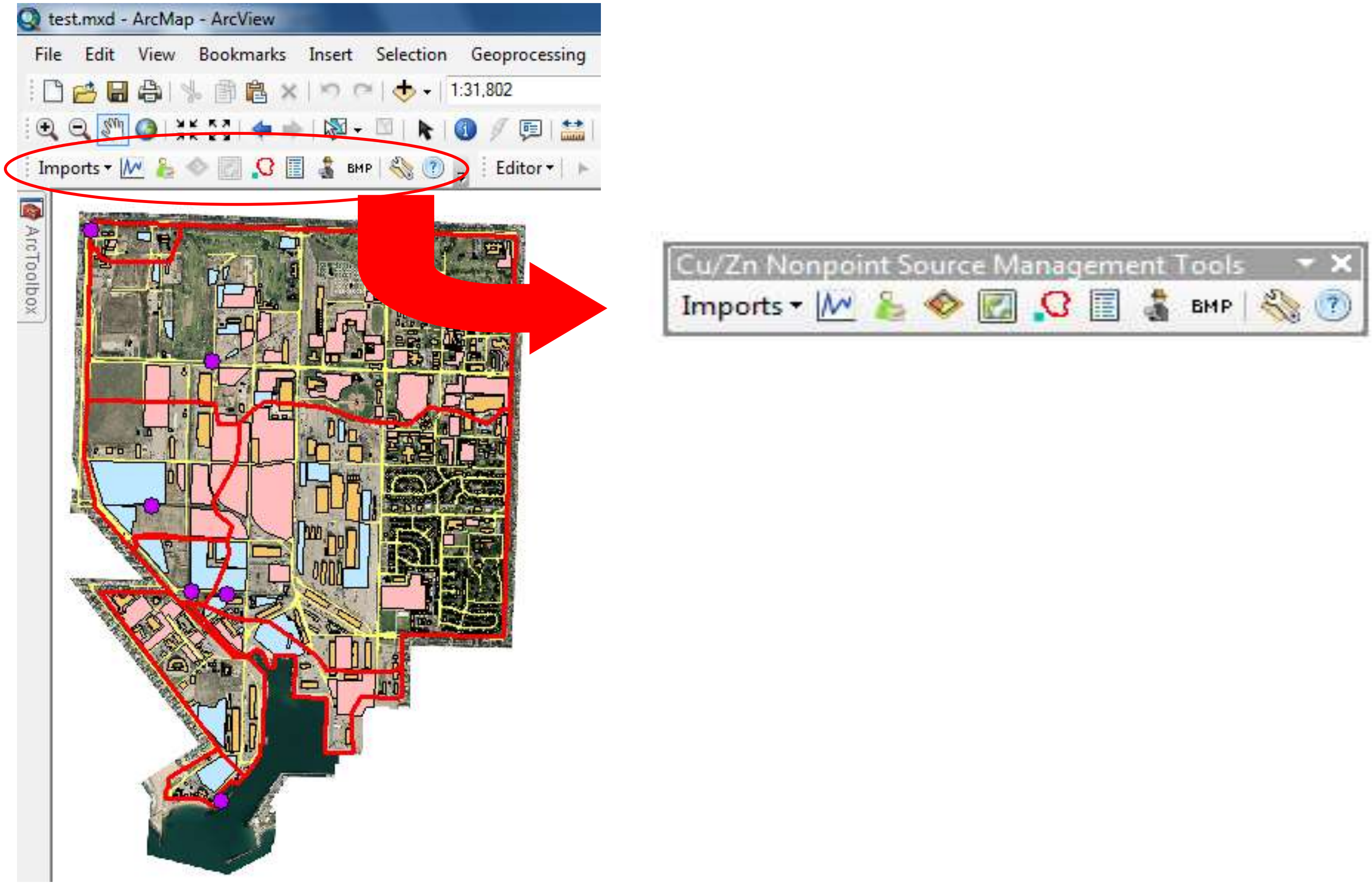
test.mxd - ArcMap - ArcView
File
Edit
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BMP

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APPENDIX D
PREDICTED V. ACTUAL
POLLUTANT CONCENTRATION DISTRIBUTION

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Figure 3: Predicted Copper Distribution at NBSD.

Figure 4: Actual Copper Distribution at NBSD.

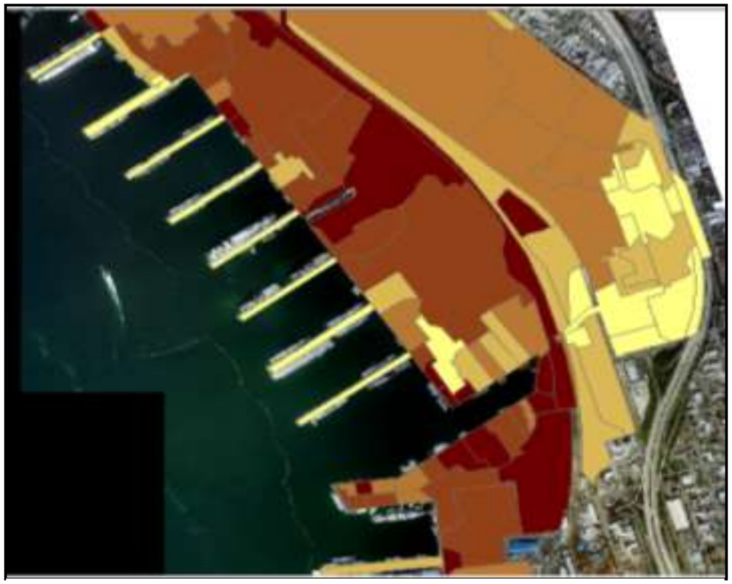

Figure 5: Predicted Zinc Distribution at NBSD.

Figure 6: Actual Zinc Distribution at NBSD.

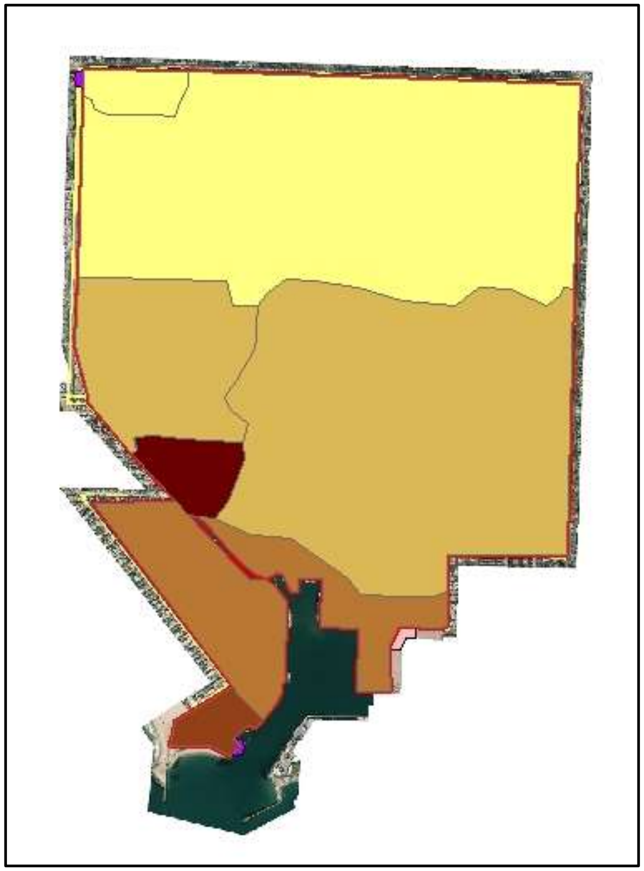

Figure 7: Predicted Copper Distribution at NBVC Port Hueneme.

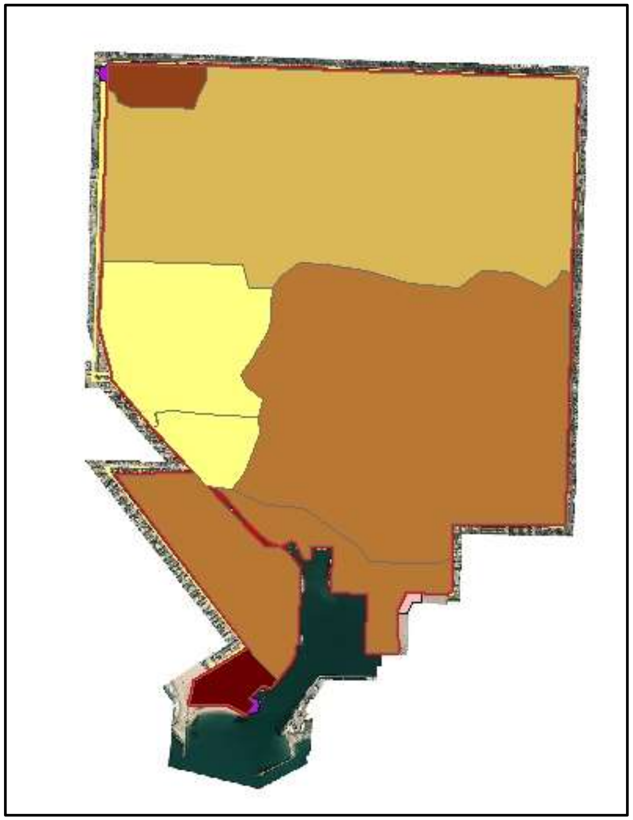

Figure 8: Actual Copper Distribution at NBVC Port Hueneme.

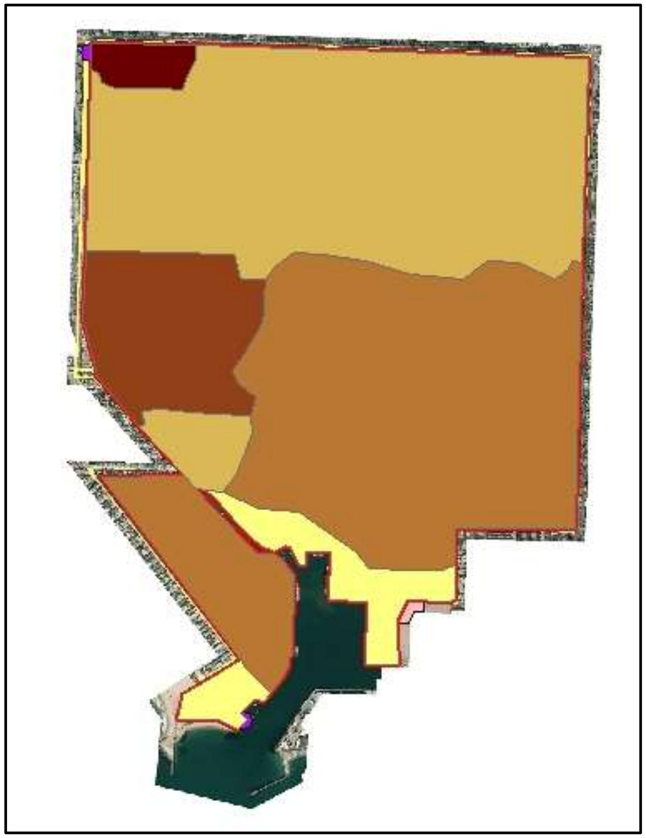

Figure 10: Predicted Zinc Distribution at NBVC Port Hueneme.

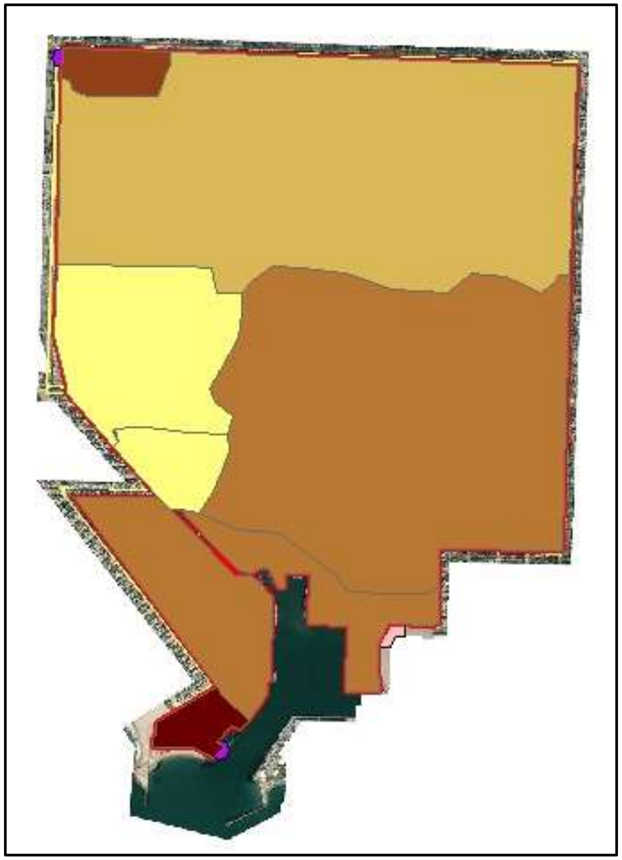

Figure 9: Actual Zinc Distribution at NBVC Port Hueneme.

Figure 11: Predicted Copper Distribution at JEB Little Creek.

Figure 12: Actual Median Copper Concentrations at Outfalls from Respective Drainage Basins (white is zero value while darker colors have higher values).

Figure 13: Predicted Zinc Distribution at JEB Little Creek.

Figure 14: Actual Median Zinc Concentrations at Outfalls from Respective Drainage Basins (white is zero value while darker colors have higher values).

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APPENDIX E
PREDICTED VS. ACTUAL POLLUTANT CONCENTRATION GRAPHS

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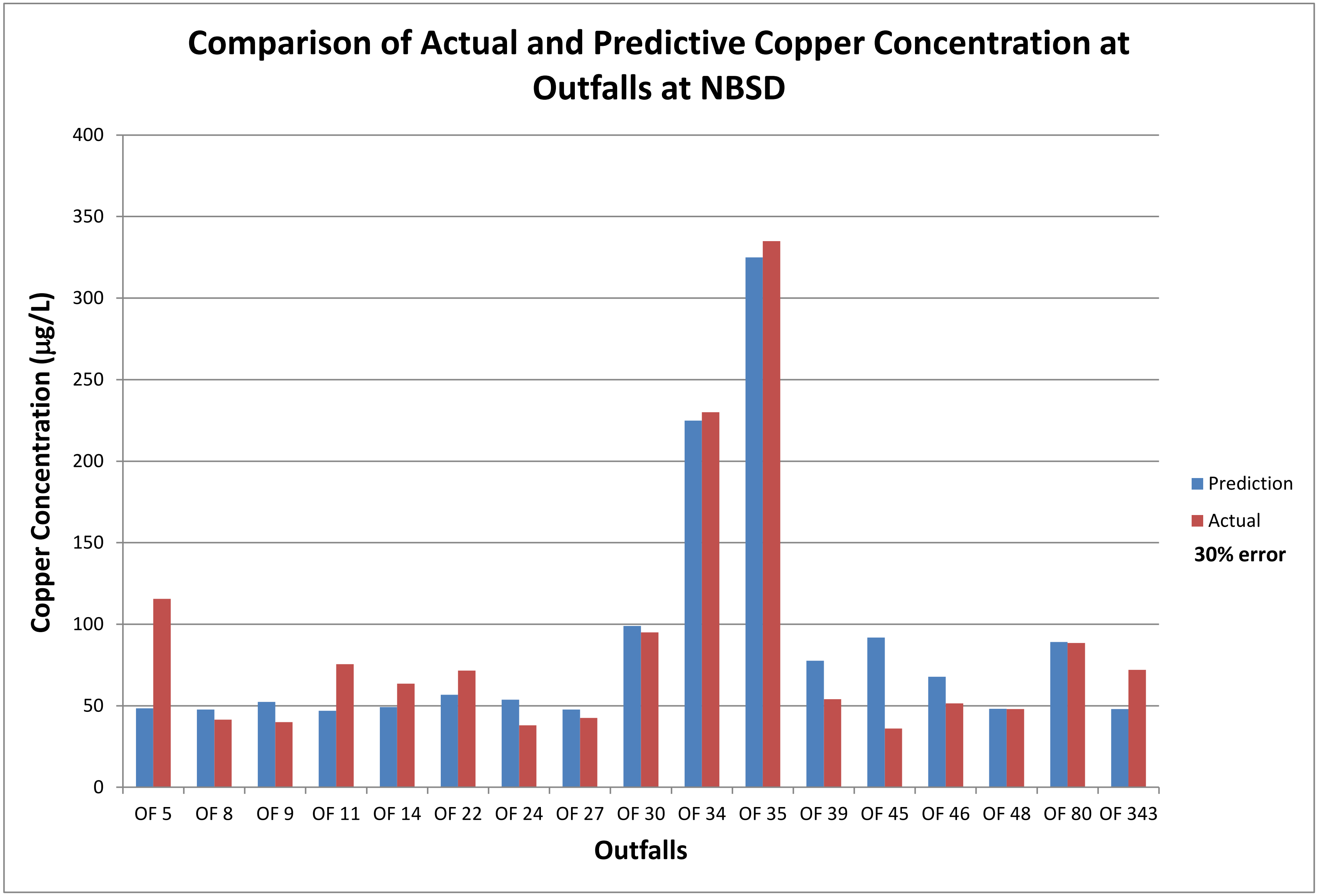
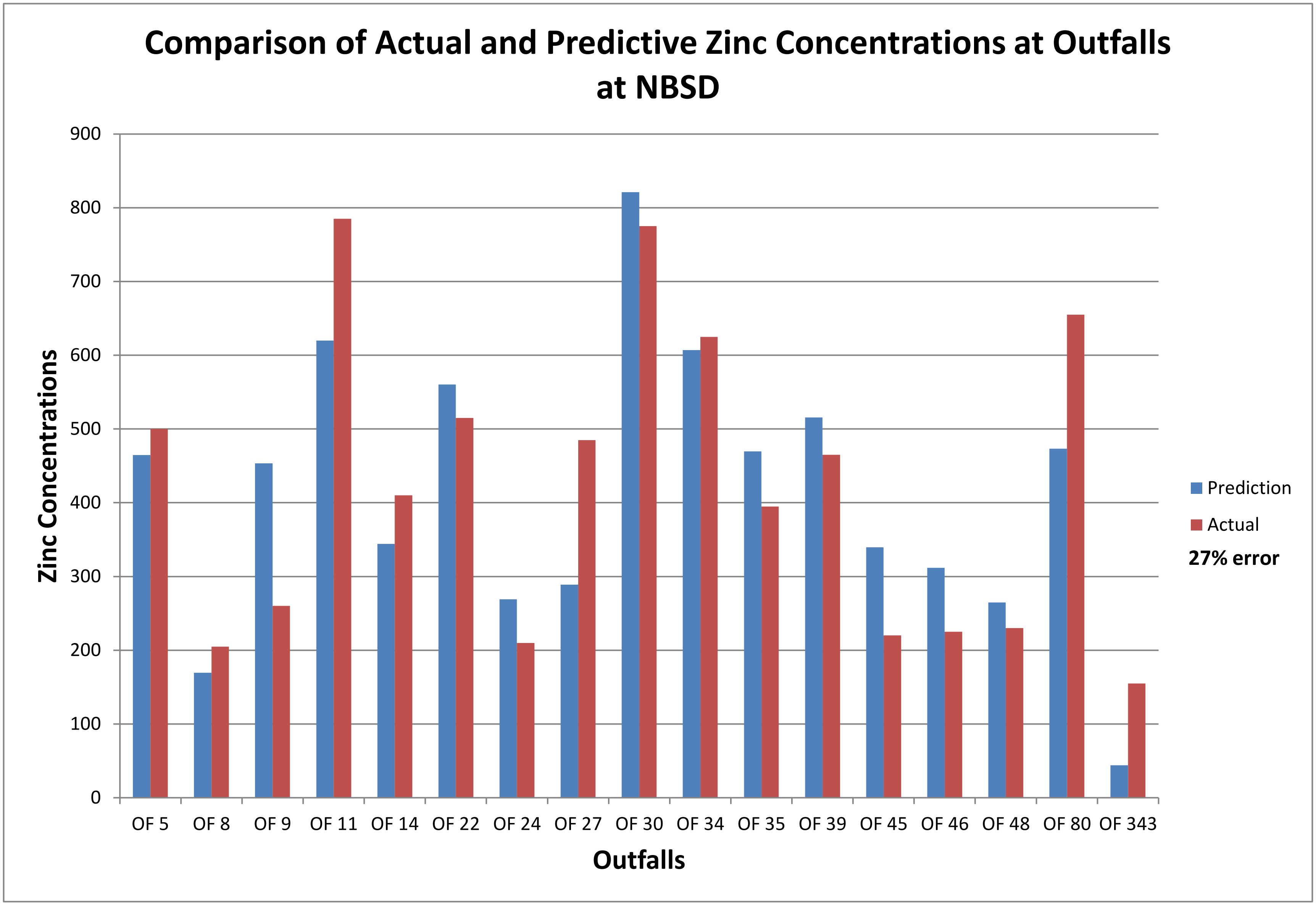
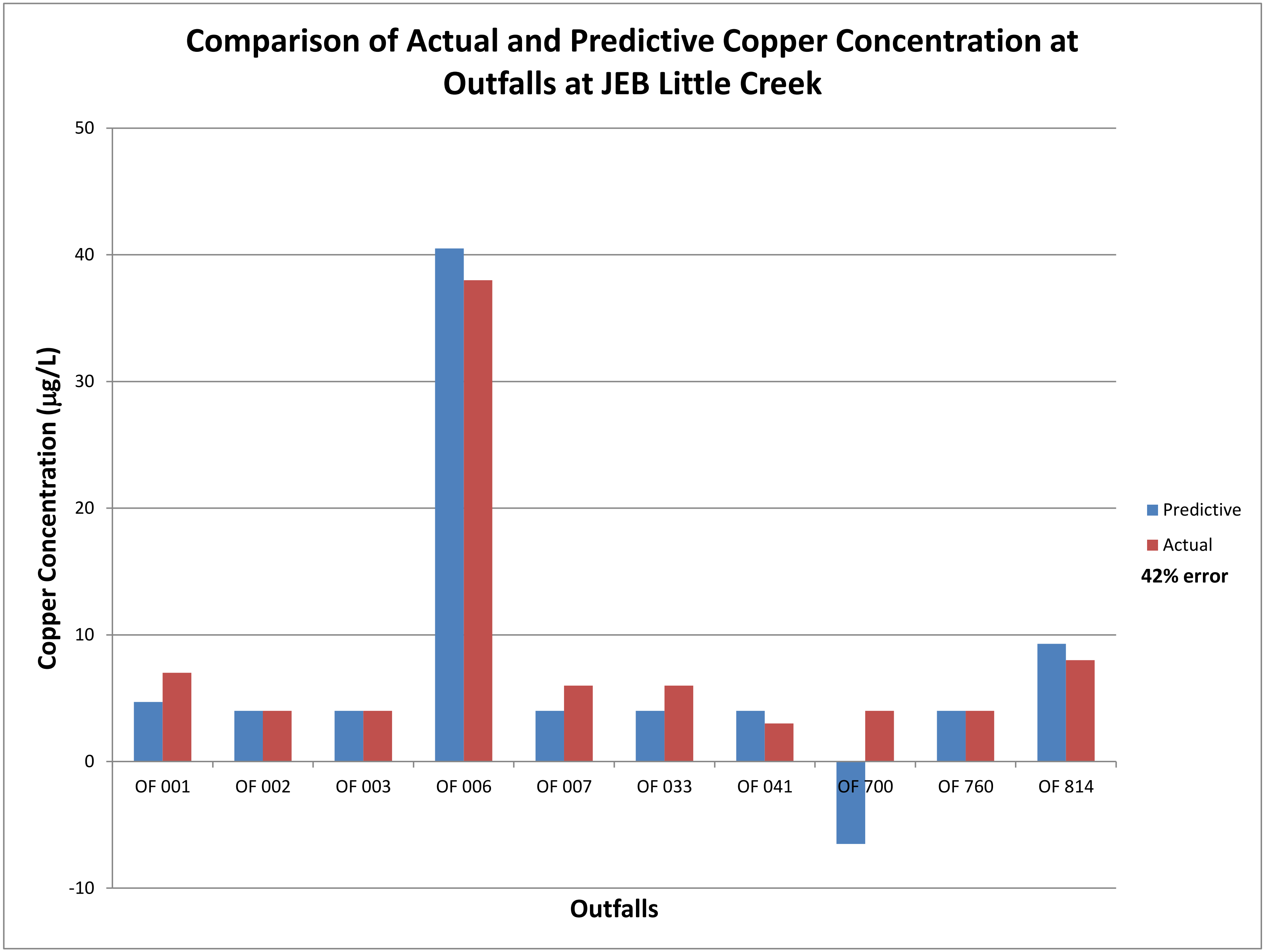
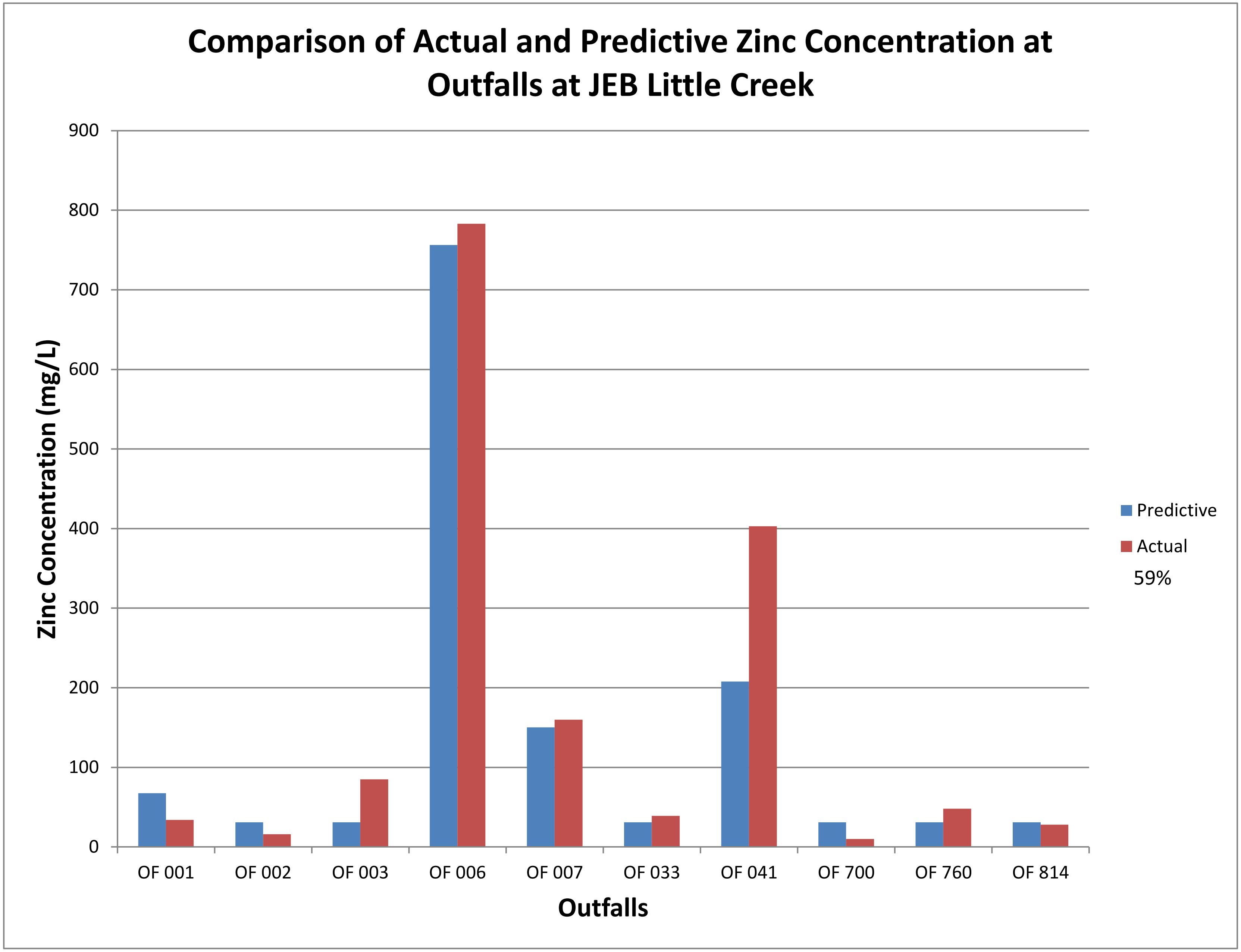


Comparison of Actual and Predictive Copper Concentration at Outfalls at NBSD
Copper Concentration (µg/L)
0
50
100
150
200
250
300
350
400
OF 5
OF 8
OF 9
OF 11
OF 14
OF 22
OF 24
OF 27
OF 30
OF 34
OF 35
OF 39
OF 45
OF 46
OF 48
OF 80
OF 343
Outfalls
Prediction
Actual
30% error


Comparison of Actual and Predictive Zinc Concentrations at Outfalls at NBSD
Zinc Concentrations
0
100
200
300
400
500
600
700
800
900
OF 5
OF 8
OF 9
OF 11
OF 14
OF 22
OF 24
OF 27
OF 30
OF 34
OF 35
OF 39
OF 45
OF 46
OF 48
OF 80
OF 343
Outfalls
Prediction
Actual
27% error


Comparison of Actual and Predictive Copper Concentration at Outfalls at JEB Little Creek
Copper Concentration (µg/L)
50
40
30
20
10
0
-10
OF 001
OF 002
OF 003
OF 006
OF 007
OF 033
OF 041
OF 700
OF 760
OF 814
Outfalls
Predictive
Actual
42% error


Comparison of Actual and Predictive Zinc Concentration at Outfalls at JEB Little Creek
900
800
700
600
500
400
300
200
100
0
Zinc Concentration (mg/L)
OF 001
OF 002
OF 003
OF 006
OF 007
OF 033
OF 041
OF 700
OF 760
OF 814
Outfalls
Predictive
Actual
59%

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APPENDIX F
PREDICTED VS. ACTUAL POLLUTANT CONCENTRATION VALUES

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Copper Concentration at Naval Base San Diego			
Predicted		Actual	
Outfall	Median Values (μg/L)	Median Values (μg/L)	% Error
OF 5	48.41	115.5	58.09%
OF 8	47.72	41.5	14.99%
OF 9	52.29	40	30.73%
OF 11	46.92	75.5	37.85%
OF 14	49.18	63.5	22.55%
OF 22	56.80	71.5	20.56%
OF 24	53.65	38	41.18%
OF 27	47.72	42.5	12.28%
OF 30	98.95	95	4.16%
OF 34	224.81	230	2.26%
OF 35	324.90	335	3.01%
OF 39	77.61	54	43.72%
OF 45	91.78	36	154.94%
OF 46	67.84	51.5	31.73%
OF 48	48.15	48	0.31%
OF 80	89.06	88.5	0.63%
OF 343	48.04	72	33.28%
		Average % Error	30.13%

Zinc Concentration at Naval Base San Diego			
Prediction		Actual	
Outfall	Median Values (μg/L)	Median Values (μg/L)	% Error
OF 5	464.59	500	7.08%
OF 8	169.45	205	17.34%
OF 9	453.27	260	74.33%
OF 11	619.76	785	21.05%
OF 14	344.28	410	16.03%
OF 22	560.23	515	8.78%
OF 24	268.98	210	28.09%
OF 27	289.00	485	40.41%
OF 30	821.05	775	5.94%
OF 34	607.01	625	2.88%
OF 35	469.69	395	18.91%
OF 39	515.54	465	10.87%
OF 45	339.61	220	54.37%
OF 46	311.80	225	38.58%
OF 48	264.77	230	15.12%
OF 80	473.39	655	27.73%
OF 343	44.00	155	71.61%
		Average % Error	27.01%

Copper Concentration at Joint Expeditionary Base Little Creek			
Prediction		Actual	
Outfalls	Median Values (µg/L)	Median Values (µg/L)	% Error
OF 001	4.7	7	32.9%
OF 002	4	4	0.0%
OF 003	4	4	0.0%
OF 006	40.5	38	6.6%
OF 007	4	6	33.3%
OF 033	4	6	33.3%
OF 041	4	3	33.3%
OF 700	-6.5	4	262.5%
OF 760	4	4	0.0%
OF 814	9.3	8	16.3%
		Average % error	41.8%

Zinc Concentration at Joint Expeditionary Base Little Creek			
Prediction		Actual	
Outfalls	Median Values (µg/L)	Median Values (µg/L)	% Error
OF 001	67.5	34	98.5%
OF 002	31	16	93.8%
OF 003	31	85	63.5%
OF 006	756.5	783	3.4%
OF 007	150.3	160	6.1%
OF 033	31	39	20.5%
OF 041	207.8	403	48.4%
OF 700	31	10	210.0%
OF 760	31	48	35.4%
OF 814	31	28	10.7%
		Average error	59.0%