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Environmental Security Technology Certification Program (ESTCP)

FINAL REPORT
LOW IMPACT TECHNOLOGIES TO REDUCE POLLUTION FROM STORM WATER RUNOFF
SI-200405

by

Gary D. Anguiano
Mark Foreman

September 2008

Environmental Security Technology Certification Program (ESTCP)

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14. ABSTRACT

This project was to validate the performance of a dual media filtration system that removes metals, organic compounds, and sediment found in storm water runoff from DoD industrial sites. Full-scale demonstrations were conducted at the Navy Regional Recycling Center (NRRC) in San Diego, California and the Anniston Army Depot (ANAD) in Anniston, Alabama. The specific performance goal at NRRC was to meet the NPDES storm water permit by passing acute toxicity requirements, and by reducing copper and zinc to less than 63.6 μg/l and 117 μg/l respectively. All of the acute toxicity test requirements were met 100% of the time for the last 5 storm events, after slight modification to the media bed. The average removal efficiencies for the last five storm events of the test period met the permit requirements for aluminum, copper, and lead, and was within 3 percent of the 117 μg/l limit for zinc. The dual media filtration system met the performance goal at ANAD. No sheen, visible oil, floating solids, or visible foam was reported in the dual media storm water filters effluent during throughout the demonstration period.

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ACRONYMS

ACOE	Army Corp of Engineers
ANAD	Anniston Army Depot
ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials
BMP	Best Management Practice
CFS	Cubic Feet per Second
CNRSW	Commander Navy Region Southwest
COTS	Commercial Off the Shelf
CRWQCB	California Regional Water Quality Control Board San Diego Region
DoD	Department of Defense
DRMO	Defense Reutilization and Marketing Office
EBCT	Empty Bed Contact Time
ECAM	Environmental Cost Analysis Methodology
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
ER	Efficiency Ratio
ESTCP	Environmental Security Technology Certification Program
FWPCA	Federal Water Pollution Control Act
GPM	Gallons Per Minute
LSE	Lognormal Statistical Efficiency
MS4	Municipal Separate Storm Sewer Systems
NASSCO	National Steel and Shipbuilding Company
NAVFAC	Naval Facilities Engineering Command
NAVSTA	Naval Station
NAVFAC ESC	Naval Facilities Engineering Service Center
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPV	Net Present Value
NRRC	Naval Regional Recycling Center
RCRA	Resource Conservation and Recovery Act
RDT&E	Research Development Test and Evaluation
SIC	Standard Industrial Classification
SMI	Storm Water Management, Inc
SU	Standard Unit
SWMU	Solid Waste Management Unit
SWPPP	Storm Water Pollution Prevention Plan
TCLP	Toxicity Characteristic Leachate Procedure
TMDL	Total Maximum Daily Loads
TSS	Total Suspended Solids
WET	Waste Extraction Test

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We would like to thank the Army at Anniston Army Depot for allowing us to demonstrate the technology at their site. Appreciation for technical support is extended to Mr. Gary Stokes of the Army Corps of Engineers. We thank Ms. Tracy Williams for spearheading the installation of the system at Anniston. For sampling and troubleshooting, we also thank Mr. Joe Moore.

Thanks to Mr. Richard Kirts and Mr. Mark Foreman of the Naval Facilities Engineering Service Center for their role in design, selection, fabrication and construction.

EXECUTIVE SUMMARY

The Naval Facilities Engineering Service Center (NAVFAC ESC) was funded by the Environmental Security Technology Certification Program to validate the performance of an innovative filtration-adsorption system that removes metals, organic compounds, and sediment found in storm water runoff from Department of Defense industrial sites. Full-scale demonstrations of the technology were conducted at two sites, the first at the Navy Regional Recycling Center (NRRC) located on Naval Station (NAVSTA) San Diego in California, and the second at the Defense Reutilization and Marketing Office (DRMO) located on Anniston Army Depot (ANAD) in Anniston, Alabama.

DoD is under increasing pressure from regulators and local communities to reduce the amount of toxic pollutants being discharged with storm water into harbors, bays, lakes, and streams. Successful completion of this project will provide the DoD with a method of removing toxic contaminants from storm water runoff, thereby avoiding Notices of Violation from regulating agencies and improving public perception of DoD environmental stewardship.

Storm water runoff from DoD industrial sites is not easily treated by current commercial off-the-shelf technology. Most commercial off-the-shelf technologies for storm water treatment are designed for municipal applications such as trash, nutrient, and sediment removal. Also, many storm water treatment technologies require large areas of land for detention basins and similar structures. This type of space requirement is often at a premium at DoD sites, and is especially unavailable at many industrial locations.

The dual media storm water filtration system is inherently simple. It is based on a standard sand filter design used for treating storm water runoff. The original filter medium (sand) is replaced with inexpensive adsorbent materials. The system operates without manual intervention, has no pumps, controls, or other mechanical or electrical components. Annual maintenance consists of removing and replacing top layer of geo-fabric, which strains sediment from storm water runoff as it enters the media bed.

The dual media storm water filtration system offers improved pollutant removal performance and lower capital and operating costs. Commercial off the shelf storm water filter systems tested at NAVFAC ESC (and by other organizations) have been found to have pollutant removal efficiencies of 60% to 70%. The removal efficiency for metals and total suspended solids was greater than 80% for both the NRRC and ANAD demonstrations. Capital cost at NRRC was $27,000 per impervious acre, compared to $57,000 per impervious acre for a well-known commercial off the shelf storm water filter system in the San Diego area.

The limitation of the proposed technology is the susceptibility to plugging of the top layer of the media bed by a thin layer of fine suspended solids in the runoff water. Therefore, the top filter medium (filter fabric and pea gravel) must be annually removed and replaced with clean materials. The maintenance interval will vary by industrial site, and depends on the volume of water processed and the amount of suspended solids removed by the filter bed. Frequent plugging will increase maintenance costs, and can result in bypassing of the system.

The specific performance goal at NRRC was to meet the National Pollution Discharge Elimination System (NPDES) storm water permit by passing acute toxicity requirements, and by reducing copper and zinc to less than 63.6 μg/l and 117 μg/l respectively. The NRRC acute toxicity requirements are to obtain 90% survivability 50% of the time, and 70% survivability 90% of the time.

For the eleven storm events that occurred during the demonstration period (March 2006 to April 2007), the dual media storm water filter system passes the 90% survival requirement 64% of the time, and passes the 70% survival requirement 82% of the time. All of the acute toxicity test requirements were met 100% of the time for the last 5 storm events, after several modifications were made to the configuration of the top fabric layer of the media bed.

The average removal efficiencies (efficiency ratio) for the last five storm events of the demonstration period met the permit requirements for aluminum, copper, and lead, and was within 3 percent of the 117 μg/L limit for zinc.

The specific performance goal at ANAD was to meet Army pollution prevention goals by removing metals, organic compounds, and sediment from storm water runoff. The current NPDES storm water permit for the ANAD demonstration site has no specific discharge limits for metals, total suspended solids, or organic compounds. The general discharge requirement for ANAD states that "The discharge shall have no sheen, and there shall be no discharge of visible oil, floating solids, or visible foam in other than trace amounts".

The effluent sampling results from the ANAD demonstration were inconclusive, mostly due to field changes and instrumentation problems that limited the quantity of valid sampling data available for analysis. However, no sheen, visible oil, floating solids, or visible foam was reported in the dual media storm water filters effluent during sampling procedures conducted throughout the demonstration period. NAVFAC ESC believes that the performance of the system at ANAD removes metals, organic compounds, and total suspended solids in a manner similar to the system installed at NRRC.

For the six storm events that occurred during the ANAD demonstration period, the dual media storm water filter system displayed copper and zinc removal efficiencies ranging from 89% to 99%. Insufficient sampling data was collected to determine the systems effectiveness in removing oil and grease from storm water influent. The limited sampling results for total suspended solids indicated removal efficiencies greater than 90%.

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1.0 INTRODUCTION

1.1 Background

The environmental problem addressed by this demonstration is pollutants in storm water runoff from Department of Defense (DoD) activities. The focus is on metals in storm water runoff from industrial activities. The DoD is under increasing pressure from regulators and local communities to reduce the amount of pollutants being discharged with storm water into harbors, bays, lakes, and streams. Successful completion of this project will provide the DoD with a method of removing toxic contaminants from runoff water, thereby avoiding Notices of Violation (NOVs) from regulating agencies and improving public perception of DoD environmental stewardship.

The technology demonstrated is an innovative filter-adsorption system that removes metals, hydrocarbons, suspended solids, and other pollutants. Filter and adsorbent materials developed at Naval Facilities Engineering Service Center (NAVFAC ESC) have been demonstrated in the laboratory and in small-scale demonstrations to remove toxic metals such as copper, lead, and zinc to below the practicable detection limit. The technology has also been demonstrated to remove organic compounds, such as petroleum hydrocarbons, that are present in low concentrations. It is believed that a conventional sand type storm water filter, with sand being replaced with the improved filter-adsorption media, will provide much more effective pollutant removal at a lower capital and operating cost than commercially available storm water filter systems now on the market.

Military installations must comply with National Pollution Discharge Elimination System (NPDES) storm water permit requirements. Compliance is usually achieved by completing a multi-phase process.

An important step toward meeting NPDES storm water permit requirements is implementation of non-structural best management practices (BMPs) to reduce the amount of pollutants that enter storm water runoff. Non-structural BMPs are usually simple changes in management practices that reduce the potential contamination of storm water runoff. Examples of non-structural BMPs include activities such as regularly sweeping work areas, training employees to properly dispose of wastes, cleaning catch basins, and storing materials under covered areas.

However, implementation of non-structural BMPs alone may not be adequate to assure compliance with discharge requirements. If all applicable non-structural BMPs have been implemented and contaminants in the storm water runoff from the site still exceed the permitted discharge limits, then treatment of the runoff is required. Treatment of storm water runoff to reduce runoff volume or pollutant concentration is termed structural BMPs.

Storm water runoff from DoD industrial operations can be roughly characterized as having elevated metals content, moderate suspended solids and organic content, and low nutrient and bacteria content. The elevated metals content in storm water runoff from DoD industrial sites can be attributed to outdoor metal working processes such as cutting and grinding, storage of metal objects outdoors, and use of metal bearing materials such as corrosion inhibiting and antifouling paints. Organic material can often be attributed to small leaks of motor oil, hydraulic fluid, and antifreeze. Sediment is usually fine particles of soil deposited on the watershed by wind or erosion. Dust created by industrial processes (such as media blasting) is another source of fine particles.

Contaminated sediments from storm water runoff can pose a substantial threat to aquatic life, wildlife, fisheries, and human health. Fish and bottom-dwelling creatures suffer disease, death, reproductive failure, or impaired growth upon exposure to pollutants in the sediment. Trace metals (i.e., copper, mercury, zinc) in the sediments are harmful particularly because they persist in the marine environment and bio-accumulate up the food chain, traveling from marine organisms to fish then to humans.

Storm water runoff from DoD industrial sites is not easily treated by current commercial off-the-shelf (COTS) technology. Most COTS storm water treatment technology is designed for municipal applications such as trash, nutrient, and sediment removal. Also, many storm water treatment technologies require large areas of land for detention basins and similar structures. Space is often at a premium at many DoD sites, especially industrial locations.

1.2 Objectives of the Demonstration

The objective of this demonstration was to validate an innovative filtration-adsorption system to remove metals, organic compounds, and other toxic pollutants in storm water runoff. The demonstrations were performed at the Navy Regional Recycling Center (NRRC), located on Naval Station (NAVSTA) San Diego in California, and at the Anniston Army Depot (ANAD), Anniston, Alabama. The specific site at ANAD is the Defense Reutilization and Marketing Office (DRMO) on the Depot. The DRMO is a tenant activity of ANAD.

Both demonstration sites at NRRC and ANAD are full scale. That is to say, they were designed to treat all of the storm water runoff from the design storm conditions.

The specific objective of the NRRC demonstration was to validate a technology that will permit the Navy to pass a 96-hour bioassay (toxicity) test as required by the California Regional Water Quality Control Board San Diego Region (CRWQCB). To accomplish this objective, it is necessary to remove copper and zinc from the runoff water. National Steel and Shipbuilding Company (NASSCO) data indicates that to pass the toxicity test, copper concentration must be reduced to less than 100 μg/l and zinc concentration must be reduced to less than 300 μg/l. Our demonstration performance goal is to reduce copper to less than 63.6 μg/l and reduce zinc to less than 117 μg/l. Prior to the demonstration, the average copper concentration in storm water runoff from NRRC was 321 μg/l and the average zinc concentration was 1573 μg/l.

The specific objective of the ANAD demonstration was to validate a technology that will permit the Army to meet pollution prevention goals for Army industrial activities. To accomplish this objective, it is necessary to remove metals, organic compounds, and sediment from the runoff water. The current NPDES storm water permit for the ANAD demonstration site has no specific discharge limits for metals, total suspended solids, or organic compounds. The general discharge requirement for ANAD states that "The discharge shall have no sheen, and there shall be no discharge of visible oil, floating solids, or visible foam in other than trace amounts".

It is believed that the technology demonstrated in this project will find use in other applications where toxic metals and organic compounds are present in wastewater. The technology has already been demonstrated to remove zinc from ship's compensating ballast water and is being evaluated as a method of removing pollutants from water collected in dry dock sumps.

The proposed system offers advantages of improved pollutant removal performance and lower capital and operating costs. COTS storm water filter systems have been tested at NAVFAC ESC and other organizations and have been found to have 60 to 70% pollutant removal efficiency. The pollutant removal media developed at NAVFAC ESC have demonstrated removal effectiveness of more than 95% for many metals and more than 80% for petroleum hydrocarbons.

The design of the filtration system is inherently simple. It is based on a standard sand filter designed for treating storm water runoff. The original filter medium (sand) is replaced with special adsorbent materials. Capital cost at NRRC is estimated to equal $27,000 per impervious acre, compared to $57,000 per impervious acre for a well-known COTS storm water filter system. The filter materials developed by NAVFAC ESC are inexpensive: approximately $1 per pound. The system has no pumps, controls, or other mechanical or electrical components. The system operates without manual intervention. Annual maintenance consists of removing and replacing the first inch or so of filter media and top layer of geo-fabric.

1.3 Regulatory Drivers

1.3.1 General Regulations

On November 16, 1990, the U.S Environmental Protection Agency (EPA) issued Federal regulations for storm water discharges (40 CFR Parts 122, 123, and 124). These regulations require specific categories of facilities that discharge storm water associated with industrial activity to obtain a NPDES permit. In addition, facilities are required to implement Best Available Technology Economically Achievable and Best Conventional Pollutant Control Technology to reduce or eliminate industrial storm water pollution. The EPA developed a four-tier permit issuance strategy for storm water discharges associated with industrial activities. These are:

- Tier I, Baseline Permitting – One or more general permits will be developed to initially cover the majority of storm water discharges associated with industrial activity.

- Tier II, Watershed Permitting – Facilities within watersheds shown to be adversely impacted by storm water discharges associated with industrial activity will be targeted for individual or watershed-specific general permits.

- Tier III, Industry-Specific Permitting – Specific industry categories will be targeted for individual or industry-specific general permits.

- Tier IV, Facility-Specific Permitting – A variety of factors will be used to target specific facilities for individual permits.

The regulations allow authorized States to issue General Permits or individual permits to regulate storm water discharges. The General Permit normally requires dischargers to:

A. Eliminate unauthorized non-storm water discharges;

B. Develop and implement a storm water pollution prevention plan (SWPPP); and

C. Perform monitoring of storm water discharges and authorized non-storm water discharges.

Phase I NPDES Storm Water Program

In response to the 1987 Amendments to the Clean Water Act, the EPA developed Phase I of the NPDES Storm Water Program in 1990. The Phase I program addressed sources of storm water runoff that had the greatest potential to negatively impact water quality. Under Phase I, EPA required NPDES permit coverage for storm water discharges from:

- "Medium" and "large" municipal separate storm sewer systems (MS4s) located in incorporated places or counties with populations of 100,000 or more; and

- Eleven categories of industrial activity, one of which is construction activity that disturbs five or more acres of land.

Operators of the facilities, systems, and construction sites regulated under the Phase I NPDES Storm Water Program can obtain permit coverage under an individually tailored NPDES permit (developed for MS4s and some industrial facilities) or a general NPDES permit (used by most operators of industrial facilities and construction sites).

Phase II NPDES Storm Water Program

The Phase II Final Rule, published in the Federal Register on December 8, 1999, requires NPDES permit coverage for storm water discharges from:

- Certain regulated small municipal separate storm sewer systems; and

- Construction activity disturbing between 1 and 5 acres of land (i.e., small construction activities).

In addition to expanding the NPDES Storm Water Program, the Phase II Final Rule revises the "no exposure" exclusion and the temporary exemption for certain industrial facilities under Phase I of the NPDES Storm Water Program.

The Phase I and II Programs together would regulate three types of storm water discharges: industrial activities, construction activities, and MS4s.

Storm Water Discharges from Industrial Activities

Activities that take place at industrial facilities, such as material handling and storage, are often exposed to storm water. The runoff from these activities discharges industrial pollutants into nearby storm sewer systems and water bodies. This may adversely impact water quality.

To limit pollutants in storm water discharges from industrial facilities, the NPDES Phase I Storm Water Program includes an industrial storm water-permitting component. Operators of industrial facilities included in one of the 11 categories of “storm water discharges associated with industrial activity” (40 CFR 122.26 (b)(14)(I)-(xi)) that discharge storm water to a MS4 or directly to waters of the United States require authorization under a NPDES industrial storm water permit. If an industrial facility has a Standard Industrial Classification (SIC) code or meets the narrative description listed in the 11 categories, the facility operator must determine if the facility is eligible for coverage under a general or an individual NPDES industrial storm water permit. In some cases, a facility operator may be eligible for a conditional/temporary exclusion from permitting requirements.

Of the 11 categories of storm water discharges associated with industrial activity, those applicable to DoD are described below:

Category 1: Facilities Subject To Storm Water Effluent Limitations Guidelines, New Source Performance Standards, or Toxic Pollutant Effluent Standards.

Category 4: Hazardous Waste Treatment, Storage, or Disposal Facilities

Category 5: Landfills, Land Application Sites, And Open Dumps Receiving Industrial Wastes

Category 6: Recycling Facilities

Category 8: Transportation Facilities

Category 9: Sewage or Wastewater Treatment Works

Category 10: Construction Activities Including Cleaning, Grading, and Excavation of Areas Over Five Acres

Category 11: Light Industry Where Industrial Materials, Equipment, or Activities are Exposed to Storm Water

The EPA report *Overview of the Storm Water Program* (EPA 833-R-96-008) documents what is required under Federal regulations.

Many installations will also be affected by total maximum daily loads (TMDLs) being established by the EPA and States. TMDL is the amount of a pollutant that a stream, lake, estuary or other water body can accept without violating state water quality standards. Once a TMDL is established, responsibility for reducing pollution is assigned. Thus, military installation's point and non-point sources may be subject to discharge limitations set by TMDLs.

DoD activities must be familiar with their own State and local regulations as well. State or local regulations may be more stringent than Federal regulations.

1.3.2 Site Specific Regulations

1.3.2.1 Navy Regional Recycling Center, San Diego, California

In 2002, the CRWQCB San Diego Region issued an order (Order R9-2002-0169, dated 13 November 2002) setting limits for toxicity in industrial storm water discharges from Navy activities. The water quality objective of the Order states that "All water shall be maintained free from toxic substances in concentrations that are toxic to or produce detrimental physiological responses in human, plant, animal, or aquatic life." The CWA Sec 101(a)(3) declares 'that it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited.' The Order states, "by complying with the industrial storm water discharge specifications for toxicity in this Order, the discharges of industrial storm water will be non-toxic. The receiving waters are not expected to become toxic from the industrial storm water discharge."

The Order designates that industrial storm water discharges from ship repair and maintenance activities at NAVSTA San Diego (including the NRRC) have a *high risk* potential to impact water quality. *High risk areas* are "areas where wastes of pollutants (including abrasive blast grit material, primer, paint, paint ships, solvents, oils, fuels, sludge, detergents, cleaners, hazardous substances, toxic pollutants, non-conventional pollutants, and other substances of water quality significance) are subject to exposure to precipitation and runoff."

The Order requires termination of the first ¼-inch of storm water runoff from *high risk* areas within two years after the adoption of the Order (i.e., by November, 2004). Termination of the first ¼-inch of runoff applies to each storm; not to just the first storms of the storm season. Termination means the water must kept from entering the storm water conveyance system. Termination is interpreted as meaning the first ¼-inch of runoff must be collected in a pond or tank for subsequent disposal as a hazardous waste water. Terminated runoff water may be metered into the sanitary sewer system (with appropriate approvals) if it meets sanitary wastewater pretreatment standards and flow volume limitations. However, copper and zinc concentrations in first flush industrial storm water discharges from NAVSTA San Diego often exceed local sanitary wastewater pretreatment standards. When sanitary wastewater pretreatment standards are exceeded, the sanitary sewer district will not accept the storm water, and the stored runoff must be disposed of by contractor haul-away.

Treatment can be substituted for termination if approved by the CRWQCB. *The technology to be demonstrated must be approved by the CRWQCB as a substitute for termination.*

Effective four years after the adoption of the Order (November 2006), storm water discharges from NAVSTA industrial activities must pass "a 96-hour bioassay (toxicity) test using standard test species, protocols, and undiluted storm water runoff, and not produce less than a 90% survival, 50% of the time, and not less than a 70% survival, 90% of the time."

One indicator of the ability to pass the toxicity test is the concentrations of copper and zinc in the runoff. Therefore, the Order further states, "Whenever the analyses of an industrial storm water discharge from any industrial activity contains a copper concentration of 63.6 μg/l or a zinc concentration of 117 μg/l, the discharger shall perform the following tasks:

a) Modify the SWPPP as necessary to reduce the concentrations of copper and zinc

b) After modifying the SWPPP, sample and analyze the next two storm water runoff events

c) Document the results."

Thus, NAVSTA industrial activities will have to make greater efforts to prevent copper and zinc from entering storm water runoff.

Since industrial activities at NAVSTA have already prepared SWPPPs and implemented applicable non-structural BMPs in a effort to reduce pollution of storm water runoff, structural BMPs are required to reduce the toxicity of the runoff to permitted levels.

1.3.2.2 Anniston Army Depot, Alabama

NPDES Permit number AL0002658, issued by the Alabama Department of Environmental Management, Montgomery, Alabama, regulates storm water runoff at ANAD. The permit is divided into four parts: (1) Discharge Limitation, Conditions, and Requirements, (2) Other Requirements, Responsibilities, and Duties, (3) Other Permit Conditions, and (4) Additional Requirements, Conditions, and Limitations.

Discharge limitations, conditions, and requirements are specified for each storm water discharge point on the Depot. The discharge points nearest the demonstration site are designated DSN005: Storm water from maintenance area and DRMO and DSN059: Storm water for military base operations.

Figure 1 shows these locations in an aerial photograph.

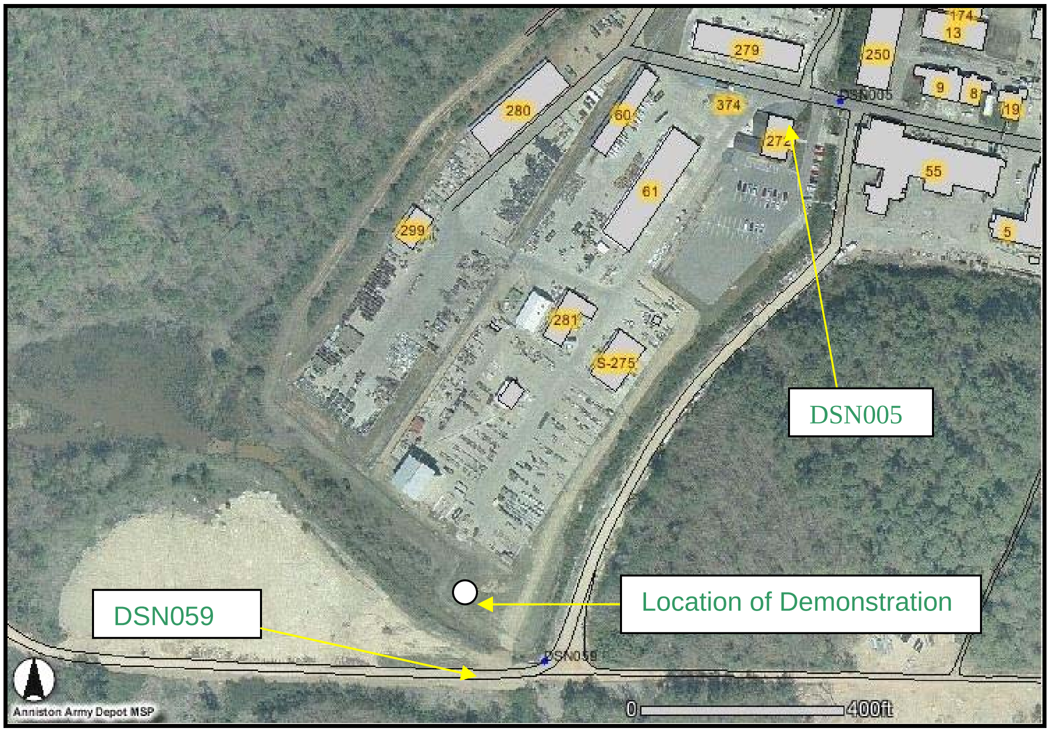

Figure 1. Aerial View of ANAD Demonstration Site with locations of discharge points.

The discharge from site DSN005 must be monitored as specified in Table 1. No specific discharge limits are listed in the permit for DSN005.

Also applicable is the general discharge requirement for <u>DSN059: Storm water from military base operations.</u> No monitoring requirements are imposed for DSN059, but the permit states that, "The discharge shall have no sheen, and there shall be no discharge of visible oil, floating solids, of visible foam in other than trace amounts".

Table 1. Discharge Limitations and Monitoring Requirements for DSN005

Code	Effluent Characteristic	Units	Discharge Limitations	Monitoring Requirements Frequency	Type
50050	Flow	MGD	Monitor	1/6 months	3
00400	PH	s.u.	Monitor	1/6 months	grab
30383	BETX 4*	μg/L	Monitor	1/6 months	grab
34696	Naphthalene	μg/L	Monitor	1/6 months	grab
03582	Oil and grease	mg/L	Monitor	1/6 months	grab
04175	Orthophosphates as P	Mg/L	Monitor	1/6 months	grab
01114	Total recoverable lead	Mg/L	Monitor	1/year	grab
00530	Total suspended solids	Mg/L	Monitor	1/6 months	grab

* BETX is the measured sum of benzene, ethylbenzene, toluene, and xylene.

1.3.2.2.1 Minimum Conditions Applicable to All Alabama Waters

The following minimum conditions are applicable to all Alabama State waters, at all places and at all times, regardless of their uses:

(a) State waters shall be free from substances attributable to sewage, industrial wastes or other wastes that will settle to form bottom deposits which are unsightly, putrescent or interfere directly or indirectly with any classified water use.
(b) State waters shall be free from floating debris, oil, scum, and other floating materials attributable to sewage, industrial wastes or other wastes in amounts sufficient to be unsightly or interfere directly or indirectly with any classified water use.
(c) State waters shall be free from substances attributable to sewage, industrial wastes or other wastes in concentrations or combinations which are toxic or harmful to human, animal or aquatic life to the extent commensurate with the designated usage for such waters.

1.3.2.2.2 Toxic Pollutant Criteria Applicable to Alabama State Waters

The U.S. Environmental Protection Agency has listed certain chemical constituents as toxic pollutants pursuant to Section 307(a)(1) of the Federal Water Pollution Control Act (FWPCA). Concentration of these toxic pollutants in State waters shall not exceed the criteria to the extent commensurate with the designated usage of such waters. The acute aquatic life criteria apply to all waters of the State. The chronic aquatic life criteria apply only to waters classified Outstanding Alabama Water, Public Water Supply, Swimming and Other Whole Body Water Contact Sports, Shellfish Harvesting, Fish and Wildlife, and Limited Warm Water Fishery, as identified in Rule 335-6-11-.02 of the Department's regulations. For the purpose of establishing effluent limitations pursuant to Chapter 335-6-6 of the Department's regulations, the minimum 7-day low flow that occurs once in 10 years (7Q10) shall be the basis for applying the chronic aquatic life criteria, except as noted in Rule 335-6-10-.09(6), and the minimum 1-day low flow that occurs once in 10 years (1Q10) shall be the basis for applying the acute aquatic life criteria; except that where a permit specifies a minimum flow greater than 7Q10, the specified minimum flow may be used as the basis for applying the acute and chronic aquatic life criteria for that permit.

The freshwater and marine aquatic life criteria for certain of the pollutants are dependent on hardness or pH. For these pollutants, the criteria are given by the following equations.

1. Cadmium
(i) freshwater acute aquatic life:conc. (µg/l) = e(1.128[ln(hardness in mg/l as CaCO3)]-3.828)

(ii) freshwater chronic aquatic life: conc. (µg/l) = e(0.7852[ln(hardness in mg/l as CaCO3)]-3.490)

2. Chromium (trivalent)
(i) freshwater acute aquatic life: conc. (µg/l) = e(0.8190[ln(hardness in mg/l as CaCO3)]+3.688)

(ii) freshwater chronic aquatic life: conc. (µg/l) = e(0.8190[ln(hardness in mg/l as CaCO3)]+1.561)

3. Copper
(i) freshwater acute aquatic life: conc. (µg/l) = e(0.9422[ln(hardness in mg/l as CaCO3)]-1.464)

(ii) freshwater chronic aquatic life: conc. (µg/l) = e(0.8545[ln(hardness in mg/l as CaCO3)]-1.465)

4. Lead
(i) freshwater acute aquatic life: conc. (µg/l) = e(1.273[ln(hardness in mg/l as CaCO3)]-1.460)

(ii) freshwater chronic aquatic life: conc. (µg/l) = e(1.273[ln(hardness in mg/l as CaCO3)]-4.705)

5. Nickel
(i) freshwater acute aquatic life: conc. (µg/l) = e(0.8460[ln(hardness in mg/l as CaCO3)]+3.3612)

(ii) freshwater chronic aquatic life: conc. (µg/l) = e(0.8460[ln(hardness in mg/l as CaCO3)]+1.1645)

6. Pentachlorophenol
(i) freshwater acute aquatic life: conc. (µg/l) = e[1.005(pH)-4.830]

(ii) freshwater chronic aquatic life: conc. (µg/l) = e[1.005(pH)-5.290]

7. Silver
(i) freshwater acute aquatic life: conc. (µg/l) = e(1.72[ln(hardness in mg/l as CaCO3)]-6.52)

8. Zinc
(i) freshwater acute aquatic life: conc. (µg/l) = e(0.8473[ln(hardness in mg/l as CaCO3)]+0.8604)

(ii) freshwater chronic aquatic life: conc. (µg/l) = e(0.8473[ln(hardness in mg/l as CaCO3)]+0.7614)

1.4 Stakeholder/End-User Issues

1.4.1 Navy Regional Recycling Center, San Diego, California

The major stakeholder for the demonstration was the Commander Navy Region Southwest (CNRSW). CNRSW holds the discharge permits for all Navy and Marine Corps activities in the San Diego area and is responsible for compliance. Demonstration of a simple, low cost technology that removes toxic metals and other pollutants from storm water runoff provided CNRSW with a technology that can be implemented at a significant number of Navy activities in the San Diego area.

Staff members of CNRSW are the liaison with the CRWQCB San Diego Region. As the liaison, they presented the technical data developed during this demonstration to the board and advocated that the technology be accepted as a substitute for termination of runoff. Also, staff of CNRSW was responsible for any modifications to existing discharge permits that were required for this demonstration effort.

A possible barrier to future implementation of the filter trench storm water treatment technology is the lack of acceptance by regulating bodies. CNRSW will work with the CRWQCB to permit use of the enhanced filter trench technology for treatment of storm water runoff.

The Naval Regional Recycling Center San Diego, the site of the Navy demonstration, is under the command of CNRSW. Interest and support by NRRC staff during the NAVFAC sponsored RDT&E portion of this effort was outstanding.

The stakeholder issues at NRRC can be illustrated by examination of historical data on pollutants in storm water runoff. Table 2 presents the results of several years of analysis of pollutants in NRRC storm water runoff.

Table 2. Chemical Analysis of Runoff Water Collected at Outfall 80, NRRC*

Substance	Average concentration	Minimum concentration	Maximum concentration	Multi-Sector Permit Requirement
Aluminum	1907	69	3660	750
Cadmium	10.3	0.55	34.8	15.9
Chromium	53.8	6.1	170	No value listed
Copper	321.6	37.1	1670	64
Iron	13581	102	89700	No value listed
Lead	417.8	27.1	1580	82
Zinc	1573	168	7830	117
O&G	1.6	0.51	3	15
TSS	273.9	10	1370	100
MBAS	1.85	0.28	6.3	No value listed
pH	6.88	5.9	7.8	6.0 to 9.0

* Units of μg/L except for TSS which is in mg/L and pH which is in standard units.

By providing demonstration results for multiple types of pollutants in storm water runoff, this project addressed the stakeholder concerns regarding toxic storm water runoff from NRRC. Additional implementation sites in San Diego include Naval Air Station North Island, Amphibious Base Coronado, Marine Corps Base Camp Pendleton, Naval Supply Center San Diego, Submarine Base Point Loma, and the Ship Intermediate Maintenance Center San Diego. Each of these activities has multiple storm water outfalls.

Another Navy stakeholder is the Naval Facilities Engineering Command Southwest Division. The Southwest Division designs and constructs real property improvements for the Navy in the San Diego area. As such, the Southwest Division is responsible for specifying, designing, and constructing utility systems such as storm water drainage and treatment systems. The specific interests of the Southwest Division in this demonstration were related to construction methods, space requirements, maintenance requirements, and cost. The Southwest Division storm water program manager supported the effort.

The Navy Public Works Center San Diego is responsible for operation and maintenance of the treatment system following completion of the demonstration.

1.4.2 Anniston Army Depot, Alabama

Although the DRMO demonstration site at ANAD is similar to the NRRC demonstration site (in that both are in the scrap recycling business), the site does present significantly different characteristics in the operations conducted, the contaminants released, and climatic influences on runoff quality. In addition to the segregation and storage of material for resale, demilitarization of equipment is performed at this activity. Wheeled and tracked vehicles, helicopter parts, inert rounds, and all types of miscellaneous equipment are stripped, crushed, and broken as part of the demilitarization and segregation processes. Although the equipment is certified free of hydrocarbons upon receipt, unexpected releases of fuels, oils, and greases frequently occur from parts of equipment that cannot be inspected. These releases of hydrocarbons, as well as the metals released from the scrap breaking operations, can adversely impact the storm water runoff from the DRMO area.

The ANAD permit is currently up for review to incorporate discharges from new facilities in the maintenance areas. It is possible that the history of spills in the DRMO area and the impacts these spills have had on the discharge upstream of DSN059 may result in increased scrutiny of the monitoring requirements for this location. Prior discharges from the DRMO area have resulted in the contamination of the soil between the paved DRMO area and the surface water. As a result of past activities, this area of contaminated soil has been designated as a solid waste management unit (SWMU). Implementation of storm water treatment technology will prevent the continued input of contaminants into this area as well as protect the quality of runoff water discharged into the adjacent stream. DSN059 is also the last monitoring point on the ANAD installation prior to the surface water exiting from the DRMO to private property. These releases, coupled with the establishment of fish hatcheries on private lands downstream of this area, may result in increased regulatory scrutiny of the quality of DRMO runoff water.

ANAD installed a large oil-water separator at the demonstration site to remove oil from the runoff water. The design capacity of the oil-water separator is 3000 gallons per minute; the capacity of the ESTCP demonstration unit is much smaller. Because of the large difference in capacity between the two units, the ESTCP dual-media storm water filtration/adsorption unit is installed in parallel with the oil-water separator. If the runoff flow rate is less than or equal to the design capacity of the ESTCP dual-media storm water filtration/adsorption unit, 500 gallons per minute (GPM), all of the flow will be treated by the ESTCP unit. If the total flow rate is 1500 GPM, then 500 GPM will flow through the ESTCP demonstration unit and 1000 GPM will flow through the oil-water separator.

The Army's Department of Public Works is responsible for operation and maintenance of the treatment system following completion of the demonstration.

2.0 TECHNOLOGY DESCRIPTION

2.1 Technology Development and Application

The combination of a simple low cost storm water treatment technology (sand filters), and engineered materials (adsorbents) specifically selected to remove targeted industrial pollutants makes the demonstrated technology innovative. Sand filters mimic natural sediment traps to trap particles of contaminating materials. Sand filters have been used in the past to treat storm water runoff from shopping center parking lots, residential areas, and other non-industrial applications. The main application has been to remove suspended solids. In the demonstrations, the design has been modified to allow the use of special adsorbent materials to increase the efficiency of removal of metals and organic compounds. Figure 2 presents a sketch of one sand filter design, called the Washington D.C. sand filter. **(**See EPA web site: **http://www.epa.gov/owmitnet/mtb/sandfltr.pdf).**

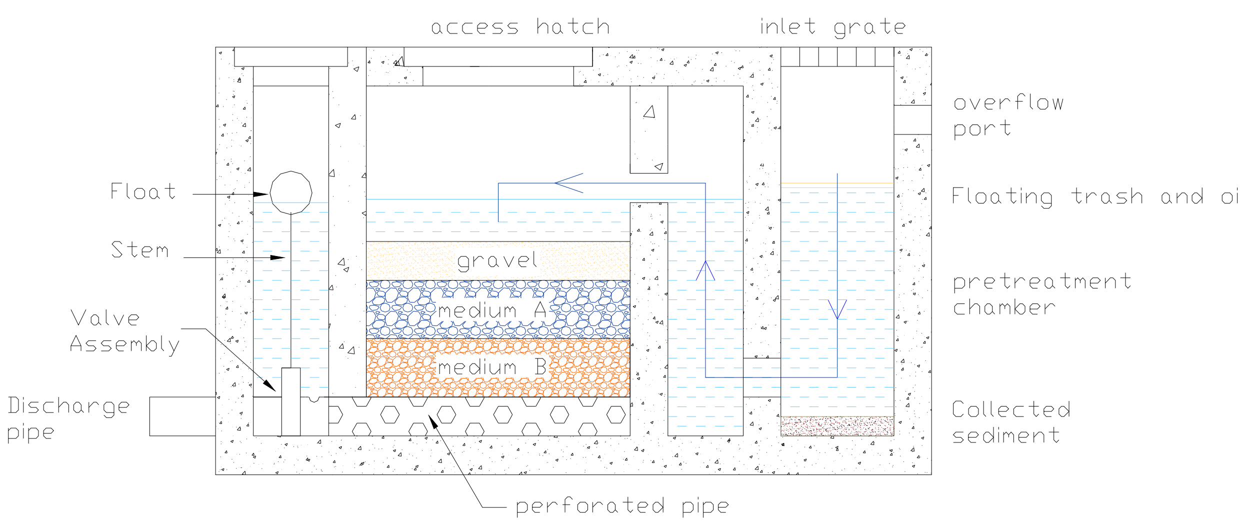

Figure 2. Elevation View of Washington DC Type Sand Filter.

The treated water is collected at the bottom of the bed with an array of perforated pipes, and then conveyed to the discharge channel. A float-controlled valve on the discharge pipe keeps the water level over the media beds constant, regardless of input flow rate. If the water level is constant, water is flowing out of the unit as fast as it flows into the unit. Under these conditions, the velocity of the water through the bed (in ft. per minute) equals Q/A, where Q is the flow rate in units of cubic feet per minute, and A is the cross sectional area of the bed in square feet. The contact time between the water and the filter-adsorption materials, called the empty bed contact time (EBCT), is equal to the bed depth divided by the water velocity through the bed. The filter-adsorption system is designed so that the EBCT will always be 5 minutes per media (10 minutes total EBCT) under the design flow conditions. If the flow rate is less than the design value, the total EBCT will be greater than 10 minutes. At both NRRC and ANAD, the perforated pipe array is surrounded by a bed of washed river stone to the level of the top of the perforated pipes. Next, a layer of filter fabric is laid over the stone, followed by a layer of activated alumina (FS-50), another layer of filter fabric, a layer of bone char, another layer of filter fabric, and topped with a layer of pea gravel.

For both systems, the top of the first layer of media (gravel) will slowly become plugged with very fine sediments and must be cleaned or replaced. Therefore, the top filter medium must be periodically removed and replaced with clean pea gravel.

Analysis has shown that the adsorption media should last for over 40 years before the adsorption capacity is exceeded. However, a 10 year media service life was used in the economic analysis to provide a conservative estimate of life cycle costs for economic comparison.

2.1.1 Navy Regional Recycling Center, San Diego, California

Storm water runoff enters the filters at NRRC through porous curbs, which act as a coarse sediment filter/trap, and then through fiberglass grating, which sit directly above the filter media. On top of the fiberglass grating are rubber mats that protect the filter media from airborne sediment deposit. Runoff flows to the top of the treatment system at NRRC and ponds in the parking lot until it flows through the system. Figure 3 shows the overall design and construction of the system at NRRC. The porous curb filter/trap was modified at a later date to improve sediment and trash removal while maintaining design flow to the system

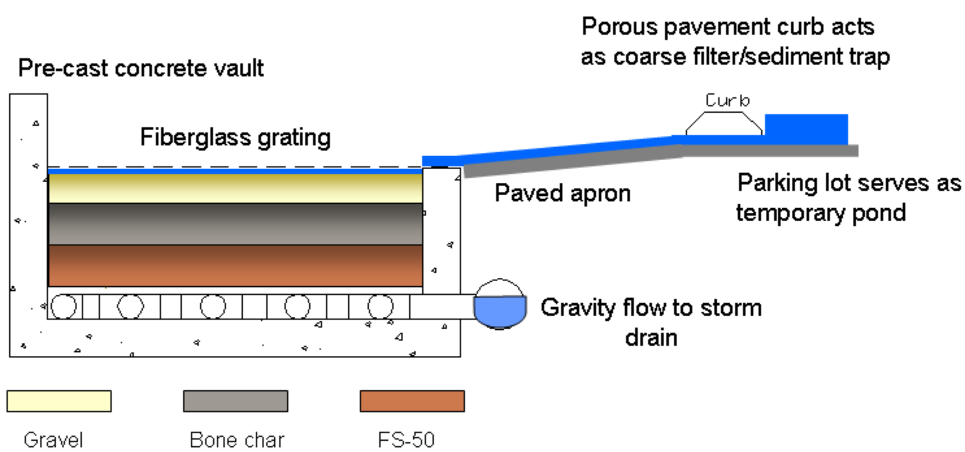

Figure 3. Concept as Designed and Built at NRRC.

2.1.2 Anniston Army Depot, Alabama

Figure 4 shows the concept design at ANAD. The system designed and installed at ANAD utilizes a trash vault and a pretreatment chamber to prevent clogging from trash and sediment. The pretreatment chamber is sized to provide sufficient residence time to allow the larger particles in the runoff to settle to the bottom of the chamber. The pretreatment chamber is also designed so that oil and floating debris are trapped on one side of the chamber. The pretreated water then flows over a weir and onto the filter-adsorption bed. Flow in excess of the design condition would normally be discharged through a port in the end of the first pretreatment chamber and flow to the storm drain system untreated. In this installation, excess flow is diverted to an oil-water separator. The accumulated sediment at the bottom of the pretreatment chamber and trash vault must be periodically removed.

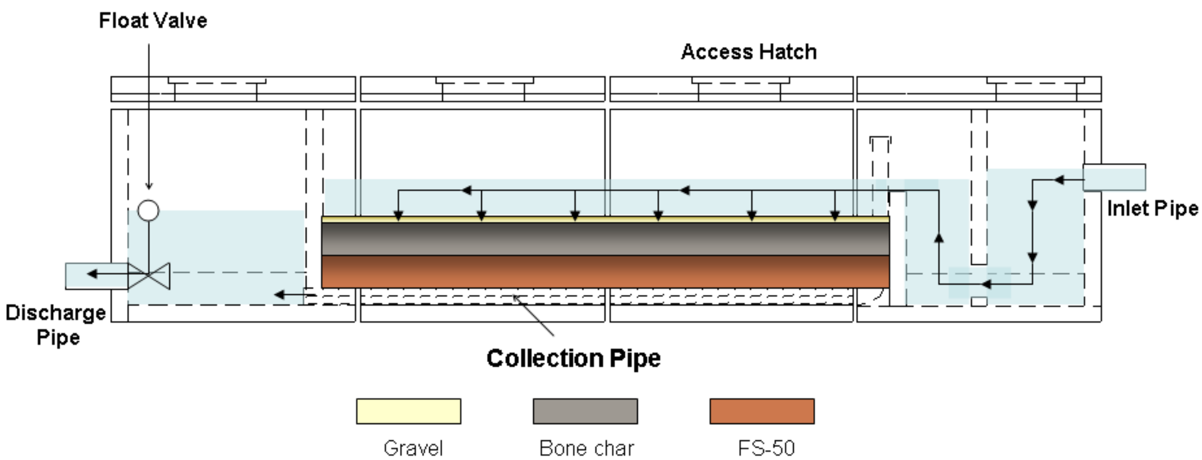

Figure 4. Concept as Designed and Built at ANAD.

2.2 Previous Testing of the Technology

There are three basic designs of sand filters: slow sand filters, rapid sand filters, and re-circulating sand filters. Slow sand filters have been used for over 100 years to remove fine suspended solids from potable water sources and for polishing treatment plant effluent. A slow sand filter has a filtration rate of about 2 GPM/ft^2. Rapid sand filters have filtration rates 2 to 5 five times higher than a slow sand filter. The higher filtration rate reduces filter cost and size, but produces a poorer quality filtrate. A re-circulating sand filter pumps the effluent through the filter several times to increase the quality of the filtrate.

Sand filters are widely used to treat storm water runoff. The Austin sand filter, for example, is a widely used design (See EPA web site: http://www.epa.gov/owmitnet/mtb/sandfltr.pdf).

The system demonstrated for this project is a multi-media rapid sand filter. Multi-media sand filters, i.e., sand filters combining sand and other media, have been previously evaluated for treating storm water runoff. In the past, the media usually consisted of sand and activated carbon (to remove organic material) or sand and peat moss (to remove metal ions). The problems with these systems are that activated carbon is expensive and short lived and that peat moss rapidly decomposes.

For this demonstration, a combination of bone char and surface modified activated alumina has been evaluated as the filter media. These materials are shown as medium A and medium B in Figure 2. These materials were selected based on bench scale testing (see Section 3.5). The media are minerals or have mineral-like physical properties. Samples of the media have been immersed in water for over one year and show no signs of swelling, decomposition, dissolving, or other change in physical properties that would affect the performance of the system.

2.3 Factors Affecting Cost and Performance

2.3.1 Cost

There are several factors affecting the cost of treating storm water runoff with a multi-media rapid sand filter: design cost, construction cost, and maintenance cost. For this project, we used standard sand filter housing to contain the media that will treat storm water runoff. The filter housing is made in pre-cast concrete sections in a factory and is trucked to the job site. Oldcastle Precast, Inc. is one supplier of sectional pre-cast concrete sand filters for storm water runoff.

The cost of the pre-cast filter media container for NRRC, including shipping, was approximately $33,000. The filter system required approximately $19,300 worth of media. Installation labor cost at NRRC San Diego was approximately the same as the materials, or about $43,000. The annual maintenance cost at NRRC was $1,700 per year, which included the cost of replacing the pea gravel and geofabric.

The cost of the pre-cast filter media container for ANAD, including shipping, was approximately $45,500. The filter system required approximately $40,800 worth of media. Installation labor cost at ANAD was approximately $41,250. The higher cost at ANAD for the pre-cast filter media container and the media was due to the larger design size at ANAD. The system at ANAD was designed for a maximum treatment rate of 500 GPM while the system at NRRC was designed for a maximum rate of 275 GPM.

Annual maintenance of the filter is required. The maintenance interval will depend on the volume of water processed and the amount of suspended solids removed by the filter bed. The filter used at ANAD has an integral dual-pretreatment chamber that should capture a large portion of the sediment load. As the top of the filter accumulates fine particles, the resistance to flow increases. As the flow resistance increases, the water level on the top of the filter will rise. The rising water level generates more pressure to force water through the filter, but eventually the water will rise to a level where it bypasses the filter system. Before this happens, the accumulated layer of particles on the top of the filter must be removed. For this demonstration, the filter can be cleaned by removing the thin layer of material from the top layer of media. For the system in ANAD, the accumulated sludge and debris in the pretreatment chambers will have to be removed occasionally.

Another method of cleaning the filter is backwashing. The backwash process forces clean water upward through the filter, lifting the particles off the media and carrying them into a chamber where they can be later removed. Backwashing requires additional capital expenditures for valves, pipes, and controls, may result in media loss, and generates a significant volume of contaminated water that must be disposed. Backwashing was not used in this demonstration.

2.3.2 Performance

The factors that affect the performance of this technology include: the filter media used, hydraulic conductivity of the filter media, and the adsorption capacity of the media.

2.3.2.1 Filter Media

A combination of bone char and surface modified activated alumina was selected as the media for use in this demonstration. These materials were selected based on bench scale testing, and the combinations of these two media were found to be more effective than any single medium or other combinations of media.

The activated alumina used is Alcan Chemical Corporation's FS-50 product. FS-50 is an activated alumina coated with ferrous oxide, ferrous hydroxide, and ferrous sulfide. FS-50 has the appearance of small rust colored flakes. FS-50 does not appear to adsorb or retain a significant amount of water.

Bone char is a black, granular solid obtained by calcinating cattle bones. Through the calcinating process, crushed bone is cooked in an oxygen deficient atmosphere, leaving carbon and tri-calcium phosphate as the residue. Bone char is used to adsorb heavy metals, fluorides, and iron. It has a low total surface area, but for adsorption of certain compounds, bone char outperforms activated carbon products. The action of bone char in removing organic molecules from water may be similar to that of activated carbon, but this hypothesis has not been investigated.

The media are minerals or have mineral-like physical properties. Samples of the media were immersed in water for over 6 months and displayed no signs of swelling, decomposition, dissolving, or other change in physical properties that would affect the performance of the system.

2.3.2.2 Hydraulic Conductivity

NAVFAC ESC measured the hydraulic conductivity of the media. Hydraulic conductivity (also called porosity) is a measure of the resistance of a column of material to the passage of water. The higher the value of the hydraulic conductivity, the easier water passes through the media. Knowledge of hydraulic conductivity is needed to determine the required availability of hydraulic head for a known depth of media bed. The results are summarized in Table 3.

Table 3. Results of Hydraulic Conductivity Tests

Medium	Hydraulic conductivity, ft/hr
FS-50 Activated alumina (28x48 mesh)	19 - 20
FS-50 Activated alumina (14x28 mesh)	30.2 - 33.4
Bone Char (8x30 mesh)	342 - 650
Washed ASTM C-33 concrete sand	6.0 - 7. 2

Note: (28x48 mesh FS-50 is used at NRRC and ANAD)

Hydraulic gradient is determined by measuring the head loss across a model bed of the same depth as the actual installation.

The overall hydraulic conductivity of the bed is equal to

$$K_b = L/(l_1/k_1 + l_2/k_2 + \ldots + l_n/k_n),$$

Where L = total bed depth
l_i = depth of layer i
k_i = hydraulic conductivity of layer i .

Minimum bed thickness equals minimum required contact time (minutes) multiplied by the flow velocity through the bed. Flow velocity through the bed is equal to K_b times the hydraulic gradient across the bed.

In engineering practice, water may flow through these materials faster than desired. Therefore, a modulating valve at the discharge of the system may be required to control the velocity of water through the bed. Velocity through the bed equals flow rate divided by bed cross sectional area (when the discharge flow is controlled so that the water level remains constant).

As sediment is filtered in the first few inches of the media, the hydraulic resistance of the bed will increase. At some point, the top layer of media will have to be removed and replaced with new media.

2.3.2.3 Adsorption Capacity

Additional testing was performed to determine the adsorption capacity of the preferred media. Adsorption capacity is the amount of the target metal species that can be adsorbed onto the media. Adsorption capacity is expressed in milligrams of metal per gram of media. Table 4 presents adsorption capacity results for tests with copper, lead, and zinc.

Table 4. Results of Adsorption Capacity Test

	Iron Coated Activated Alumina	Bone Char
	mg metal/g media	mg metal/g media
copper	3.96	6.29
lead	0.74	2.22
zinc	3.58	6.18

The media bed removes most of the metals through mechanical filtration. Only metal ions and very small particles are removed by adsorption.

The life of the adsorption media can be estimated as follows. Let [Cu] be the concentration of total copper in the water. Then the rate of copper removal by adsorption equals:

([Cu in] * 0.43 – [Cu out]) * flow rate = mass of copper ion removed per unit time.

The factor 0.43 is the percent of copper in ionic form that was observed for NRRC runoff.

The amount of ionic copper the adsorption bed can retain is equal to the weight of the media multiplied by the copper adsorption capacity:

Total adsorption capacity = weight of media multiplied by the unit copper adsorption capacity.

Dividing the total adsorption capacity by the removal rate gives the bed life.

For example, using [Cu in] = 764 μg/l, [Cu out] = 50 μg/l, and a flow rate of 1,040 l/min (275 gpm) gives a copper removal rate of 0.290 grams per minute.

The total adsorption capacity is equal to the weight of media (Let's say a system has 17,500 pounds, or 7.94 million grams of FS-50) multiplied by the unit copper adsorption capacity (3.96 mg/g) = 31,442 grams of copper.

The total bed life of a system using 17,500 pounds of FS-50, based on copper adsorption, is therefore 31,442 grams of copper/0.290 grams of copper per minute = 108,420 minutes ≅ 1,807 hours of operation. 1,807 hours of operation is equal to 602 storms of 3 hours duration. If there are about 15 storms of 3 hours duration per year, the bed can be expected to last 602/15 = about 40 years based on copper adsorption.

2.4 Advantages and Limitations of the Technology

The advantages of the technology are increased contaminant removal performance and lower implementation cost (compared to COTS technology). To establish a baseline for comparison of performance and cost, a storm water treatment technology manufactured by Storm Water Management, Inc. (SMI) of Portland, Oregon, was leased and tested. Testing was done both in the laboratory and under field conditions.

The limitation of the proposed technology is its potential susceptibility to plugging of the media bed by fine suspended solids in the runoff water. Frequent plugging will require frequent removal and replacement of the top layer of media bed. This will increase maintenance costs. Pretreatment devices such as centrifugal separators can remove a large portion of the suspended solids, but extensive pretreatment increases the size and cost of the total treatment system as well as maintenance costs.

2.4.1 SMI System Performance

The COTS storm water filter system made by SMI was tested at NAVFAC ESC, at the manufacturer's laboratory (using water samples shipped to SMI by the Navy), and in the field. Figure 5 shows the SMI unit used to conduct field testing at the NRRC, San Diego. The field test unit collected performance data from three storms. The large black object in the photo is a four-filter SMI treatment system. The flow rate for the unit is 15 gallons per minute. The filter medium is a pelletized mixture of leaf compost and peat moss called Metal Rx ®. Filter life depends on contaminant concentration. Typically filters are replaced annually, whether or not the filter is completely expended.

Figure 5. NAVFAC ESC's Storm Water Test Stand Installed at NRRC.

Table 5 presents SMI Metal Rx test results for the storm water test stand installed at NRRC.

Table 5. SMI Metal Rx Test Results

	Copper			Zinc		
Laboratory	[C] in, μg/l	[C] out, μg/l	% reduction	[C] in, μg/l	[C] out, μg/l	% reduction
SMI	866	349	60	1190	185	84
NAVFAC ESC	840	310	63	430	170	60
NRRC Storm #1	240	85	65	380	120	68
NRRC Storm #2	212	90	58	410	100	76

NRRC Storm #3	502	229	54	980	200	80

The results show a 60% reduction in influent copper concentration and a 70% reduction in influent zinc concentration, generally independent of the magnitude of metal concentration in the influent. The two test results that show high zinc removal correspond to high zinc concentration in the influent. It is believed that the runoff water for these tests contained an unusually high amount of larger zinc particles, and that in these tests the SMI technology was removing most of the zinc by mechanical straining rather than adsorption.

2.4.2 SMI System Cost

The SMI filters referred to in Table 5 costs $115 each, plus shipping. A SMI storm water treatment system installed at the National Steel and Shipbuilding Company (NASSCO), San Diego, CA (Hart Crowser, Inc. 2002) was designed to treat the runoff from 9.25 impervious acres. The system contains 165 filters. The NASSCO system cost $530,000 to construct, and an estimated $41,000 per year to maintain. This is equivalent to a capital cost of about $57,000 per acre and a maintenance cost of $17 per 1000 gallons of runoff treated.

3.0 DEMONSTRATION DESIGN

3.1 Performance Objectives

Table 6 lists the performance objectives for the demonstration at NRRC.

Table 6. Performance Objectives for NRRC San Diego

Type of Performance Objective	Primary Performance Criteria	Performance Objectives (Metric) Targeted
Quantitative	Reliably pass the CRWQCB toxicity test for storm water runoff	Pass the 96 hour, continuous flow, acute toxicity test using undiluted storm water runoff with a 90% survival rate 50% of the time, and not less than 70% survival rate 90% of the time
	Reduce copper in storm water runoff	Reduce the concentration of copper in the storm water treatment system effluent to less than 63.4 μg/l
	Reduce zinc in storm water runoff	Reduce the concentration of zinc in the storm water treatment system effluent to less than 117 μg/l
	Reduce lead in storm water runoff	Reduce the concentration of lead in the storm water treatment system effluent to less than 82 μg/l
	Reduce aluminum in storm water runoff	Reduce the concentration of aluminum in the storm water treatment system effluent to less than 750 μg/l
	Reduce TSS in storm water runoff	Reduce the concentration of total suspended solids in the storm water treatment system effluent to less than 100 mg/l
Qualitative	Lower capital costs	Less than $50,000 per acre of drainage
	Lower annual O&M costs	Less than $15 per 1,000 gallons of water treated.
	Versatility	The process should be applicable to other industrial sites where runoff water exceeds discharge standards
	Reliability	The process is inherently simple, and requires no electrical or mechanical power. It is inherently reliable.

Table 7 lists the performance objectives for the demonstration at ANAD.

Table 7. Performance Objectives for ANAD Alabama

Type of Performance Objective	**Primary Performance Criteria**	**Performance Objectives (Metric) Targeted**
Quantitative	Effluent complies with current NPDES permit.	The permit states that "The discharge shall have no sheen, and there shall be no discharge of visible oil, floating solids, or visible foam in other than trace amounts.
Qualitative	Lower capital costs	Less than $50,000 acre of drainage
	Lower annual O&M costs	Less than $15 per 1,000 gallons of water treated.
	Versatility	The process should be applicable to other industrial sites where runoff water exceeds discharge standards
	Reliability	The process is inherently simple, and requires no electrical or mechanical power. It is inherently reliable.

The quantitative performance objectives were set so that their accomplishment would result in compliance with the NRRC multi-sector discharge permit and ANAD pollution prevention goals. The qualitative performance objectives were established to compare capital and maintenance costs associated with the operations of the dual media filtration system and a demonstrated COTS technology

3.2 Selecting Test Sites/Facilities

3.2.1 Navy Regional Recycling Center, San Diego, California

The test site selected for the Navy demonstration was the NRRC, located on NAVSTA in San Diego, CA. NRRC was selected as the site for the demonstration due to high metals concentrations in their storm water runoff, and has served as the host site for field tests of COTS storm water treatment technology. In addition, NRRC has a comparative abundance of space available to accommodate a full-scale demonstration. NRRC staff members were also very cooperative and helpful during past field tests at the site.

Figure 6 displays a map of the NRRC location in San Diego.

Figure 6. NRRC Location Map.

Section 1.3.2.1 of this report provides additional details for the NRRC demonstration site.

3.2.2 Anniston Army Depot, Alabama

The test site selected for the demonstration was the DRMO at ANAD. Figure 7 shows the location of ANAD in northeastern Alabama.

The site characteristics and contaminants of concern at DRMO differ from those being addressed at the NRRC. Although the discharge requirements at DRMO are not as restrictive as those at the NRRC, the impacts from spills at the ANAD DRMO can potentially impact facility operations. The ANAD DRMO site is also representative of the issues present at most of the Army sites at which the runoff treatment technology would be applicable. Although discharge limitations and monitoring requirements may be more restrictive at other Army sites, the performance information gathered at the ANAD DRMO demonstration site are applicable to other Army sites and useful in supporting the transfer of the technology to the Army.

The DRMO site has a comparative abundance of space available to accommodate a demonstration and its attendant infrastructure. ANAD staff is very receptive to the idea of a storm water treatment demonstration at their facility.

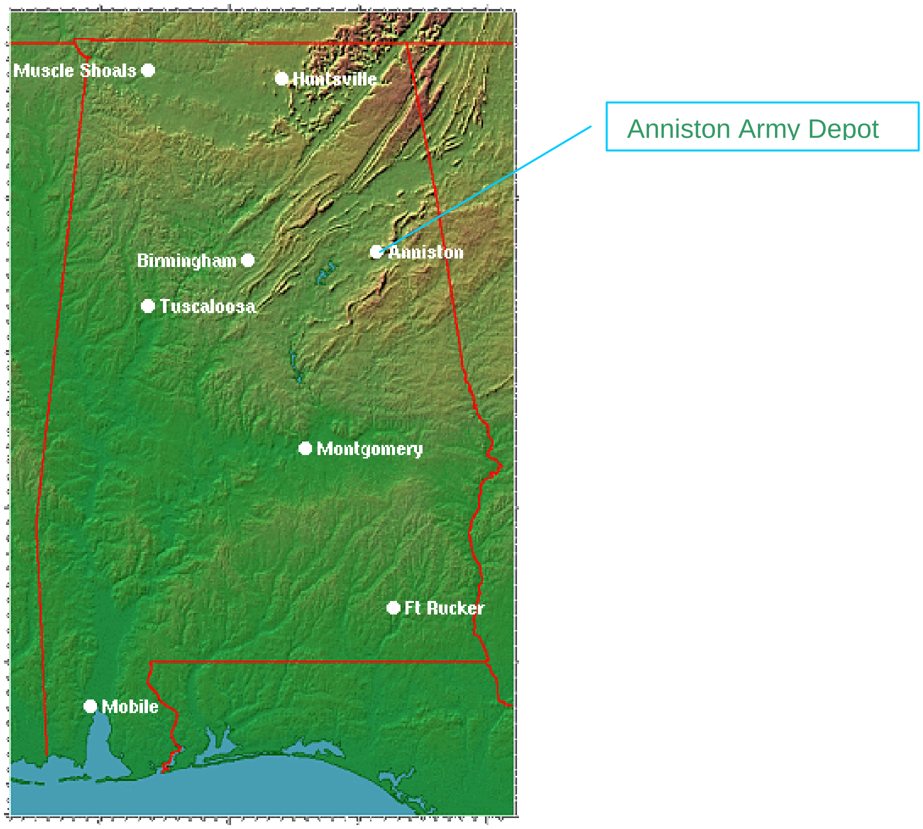

Figure 7. Site Location Map,

3.3 Test Site/Facility Characteristics/History

3.3.1 Navy Regional Recycling Center, San Diego, California

The NRRC accepts used and scrap materials such as metals, paper, cardboard, and plastic for recycling and resale. NRRC is one of several Navy Regional Recycling Centers. Figure 8 shows some of the metal separation activities at NRRC.

Figure 8. Activities at NRRC San Diego.

NAVFAC ESC personnel land surveyed the NRRC site. The resulting contour map is presented in Figure 9. The results of a land survey were used to estimate of the paved drainage area. Our estimate of the drainage area is 3.55 acres. The numbers on the contour map are relative elevations. The red colored boxes mark the locations of storm drain inlets.

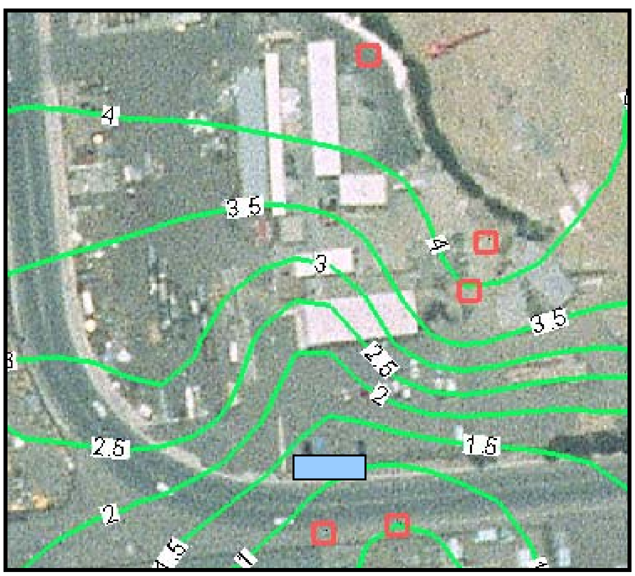

Figure 9. Survey Results for NRRC.

The contour map clearly shows how much of the storm water runoff flows across the work areas and parking lot to the low point in the parking lot, bypassing the storm water drain system. This location was chosen as the site for storm water treatment demonstrations. Figure 9 shows the location of the filter trench as indicated by a blue rectangle. Figure 10 shows a close-up view of the site prior to construction.

Figure 10. Site of Storm Water Treatment Demonstration.

Figure 11 presents rainfall data from Navy Base Coronado, located in San Diego, California. Figure 11 shows that storms of less than 0.5 inches (in 24 hours) provide over 90 percent of all rain. Fewer than 5% of storms deliver more than an inch of rain.

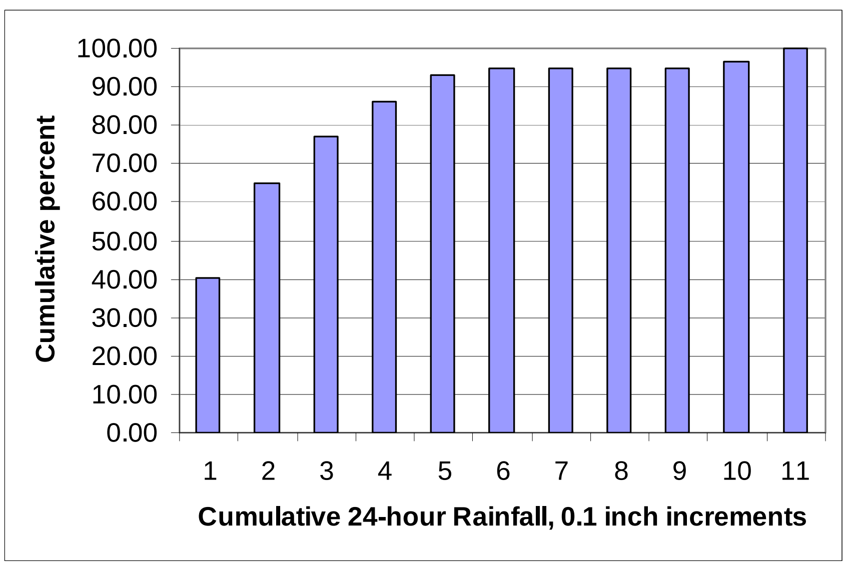

Figure 11. Cumulative Rainfall Data for San Diego.

Good design practice recommends using the 6 month-24 hour storm data as the design basis for determining storm water treatment system capacity. If 6 month data are not available, then it is recommended that one third of the 2-year rainfall value be used (NOAA Web Site). The National Oceanic and Atmospheric Administration (NOAA) Atlas of Weather Data gives the 2-year average rainfall total for San Diego as 1.69 inches in 24 hours. Thus, one possible value for the design storm is 0.33* 1.69 = 0.56 inches of rain over 24 hours. NAVFAC ESC Technical Report TR-2256-ENV (Richard Kirts, Mark Foreman, Gary Anguiano, Nov 2004) presents 10 years of weather statistics for Camp Pendleton, California. The Camp Pendleton weather statistics provided more detailed rainfall information than was available for the San Diego area, and the information served as a useful point of comparison. The data show that the average storm in January is 0.56 inches and the average storm in February is 0.58 inches.   Based on these data, 0.56 inches of rain over 24 hours was selected as the design storm.

The next issue addressed was the average storm duration. NAVFAC ESC Technical Report TR-2256-ENV shows that the average total hours of rainfall in January was 11 hours and in February was 11.5 hours. The average number of storms for January, February, and March was 3.5. Dividing the average total hours of rainfall (11) by the average number of storm events (3.5) gave an average storm duration of 3.14 hours. Appendix B of National Soil Conservation Service (NSCS) Report TR-55 (Urban Hydrology for Small Watershed, 1986) states that southern California has a "type I" rainfall distribution. Figure B-1 of TR-55 indicates that the mean duration for type I rainfall is about 3 hours. Therefore, 3 hours was selected for the mean storm duration.

The NRRC site was assumed to have an impervious cover. The slope of the watershed was calculated from the land survey data.

The above data were input into the EPA Storm Water Management Model computer code. Computer modeling of storm water runoff at NRRC indicates that the maximum expected flow was 0.55 cubic feet per second (265 gallons per minute) and the event mean flow was expected to be 0.092 CFS (44 gpm). Total runoff volume per storm was expected to be 5600 cubic feet (41,900 gallons).

3.3.2 Anniston Army Depot, Alabama

ANAD's primary mission is refurbishment of artillery, wheeled vehicles, and tracked vehicles. ANAD is also site of a chemical weapons storage facility. The ANAD activity selected to host the demonstration is the DRMO. The DRMO accepts used and excess materials from military activities throughout Alabama and the southeast. The materials are processed to prevent reuse as military hardware (demilitarized), then sorted and packaged for sale, as shown in Figure 12.

Army personnel have land surveyed the site. Figure 13 presents the resulting contour map. The contour interval is 5 feet. The results of a land survey were used to estimate of the paved drainage area. The estimated drainage area is 1.9 acres.

Figure 12. Activities at DRMO, ANAD.

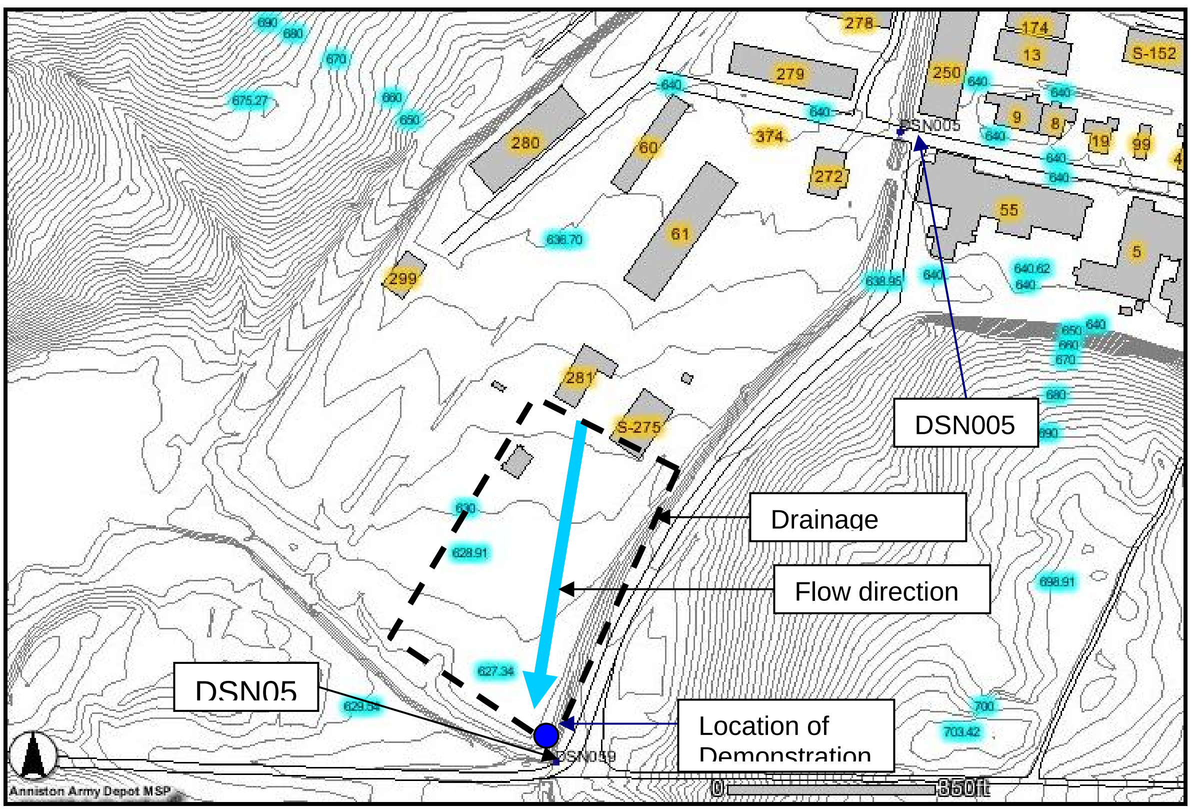

Figure 13. Survey Results for ANAD.

The contour map clearly shows how the storm water runoff flows across the work areas to the low point in the southwest corner of the paved area. The elevation drops by about 6 feet over a distance of 400 feet, for a slope of 1.5 percent. This location was chosen as the site for storm water treatment demonstrations. The location of the filter trench is indicated in Figure 13 as a circle. Figure 14 presents a photograph of the specific site (grass space in background) prior to construction.

Figure 14. Site of Storm Water Treatment Demonstration at ANAD.

The area of the DRMO site is approximately 400 ft by 200 ft, or 1.9 acres. This area is the paved work area south of building S-275 and east of the railroad spur. The DRMO site was assumed to have an impervious cover.

Figure 15 presents data on rainfall at the Anniston Municipal Airport for the years 2000 through 2004. The data are from the National Weather Service web site (www.nws.noaa.gov). Analysis of the data in Figure 15 gives a maximum average daily precipitation of about 1.55 inches.

NOAA weather data indicates that Anniston averages about 50 inches of rain each year.

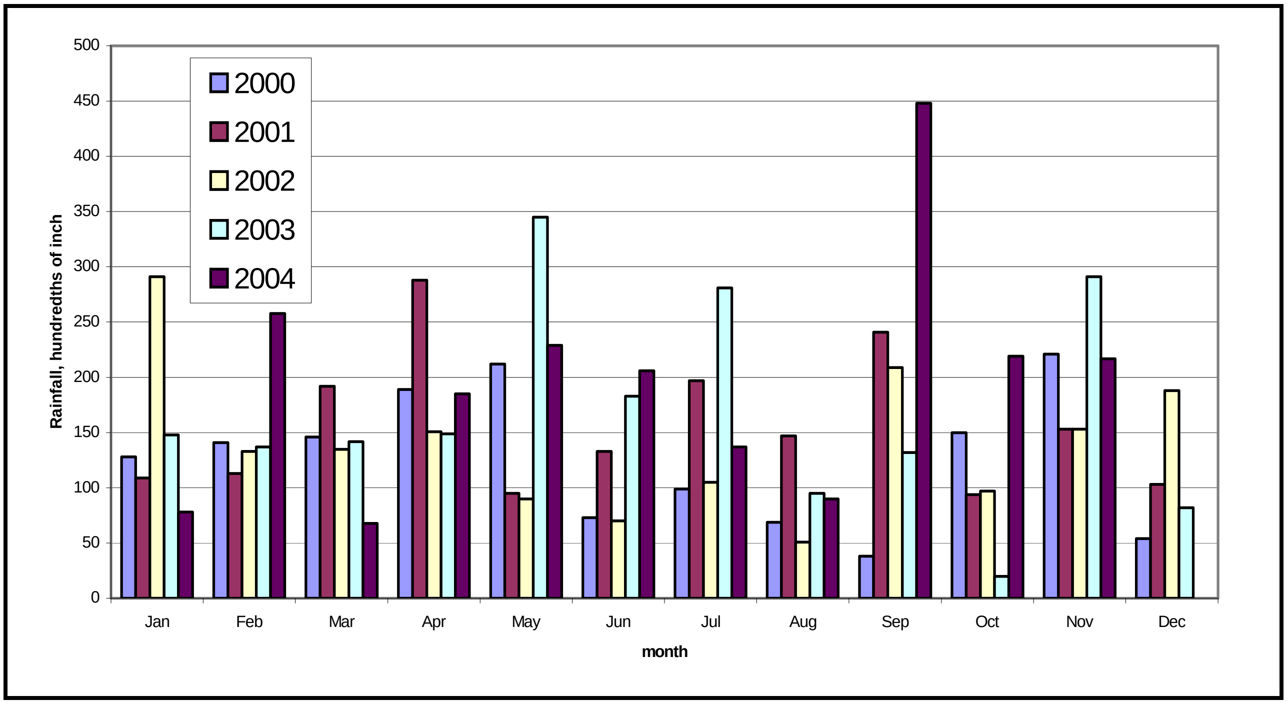

Figure 15. Average Max Daily Precipitation in Anniston, Alabama.

"Urban Hydrology for Small Watersheds", TR-55, shows the 2-year, 24-hour peak rainfall for Anniston is a little less than 4 inches in 24 hours (Figure 16).

Rainfall is seldom distributed evenly over a 24-hour period, and assuming it does leads to low values of runoff rate. Therefore, an estimate was required for the average duration of a storm. Average storm duration was obtained by determining the rainfall standard type for Anniston, then examining the rainfall time distribution for that type of rainfall.

Figure 17 from TR-55 shows that Anniston, Alabama is on the border between a Type II and Type III rainfall distribution. Type III rainfall is shorter duration, more intense rainfall produced by storms generated over the ocean.

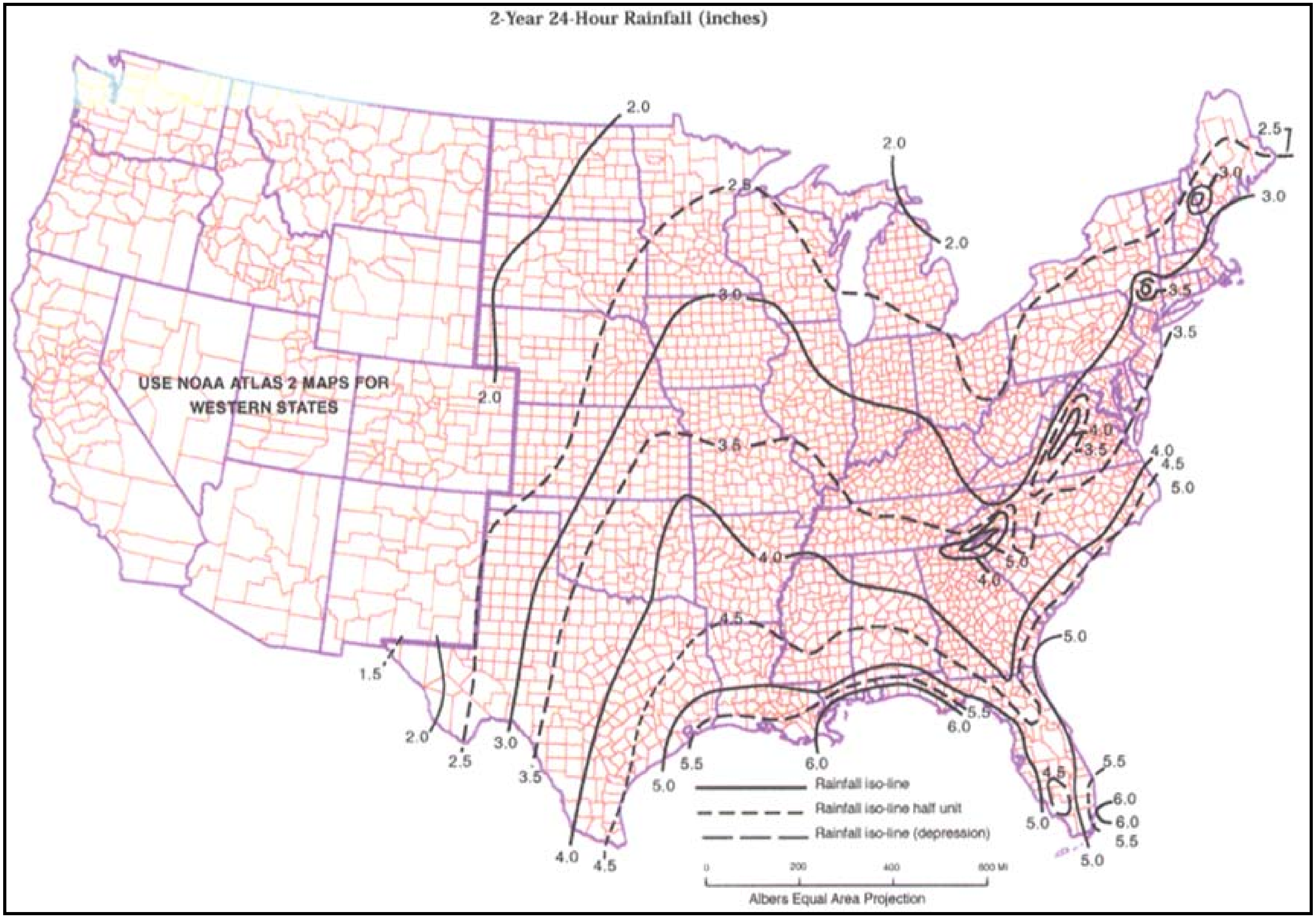

Figure 16. 2-Year, 24-Hour Rainfall Contours.

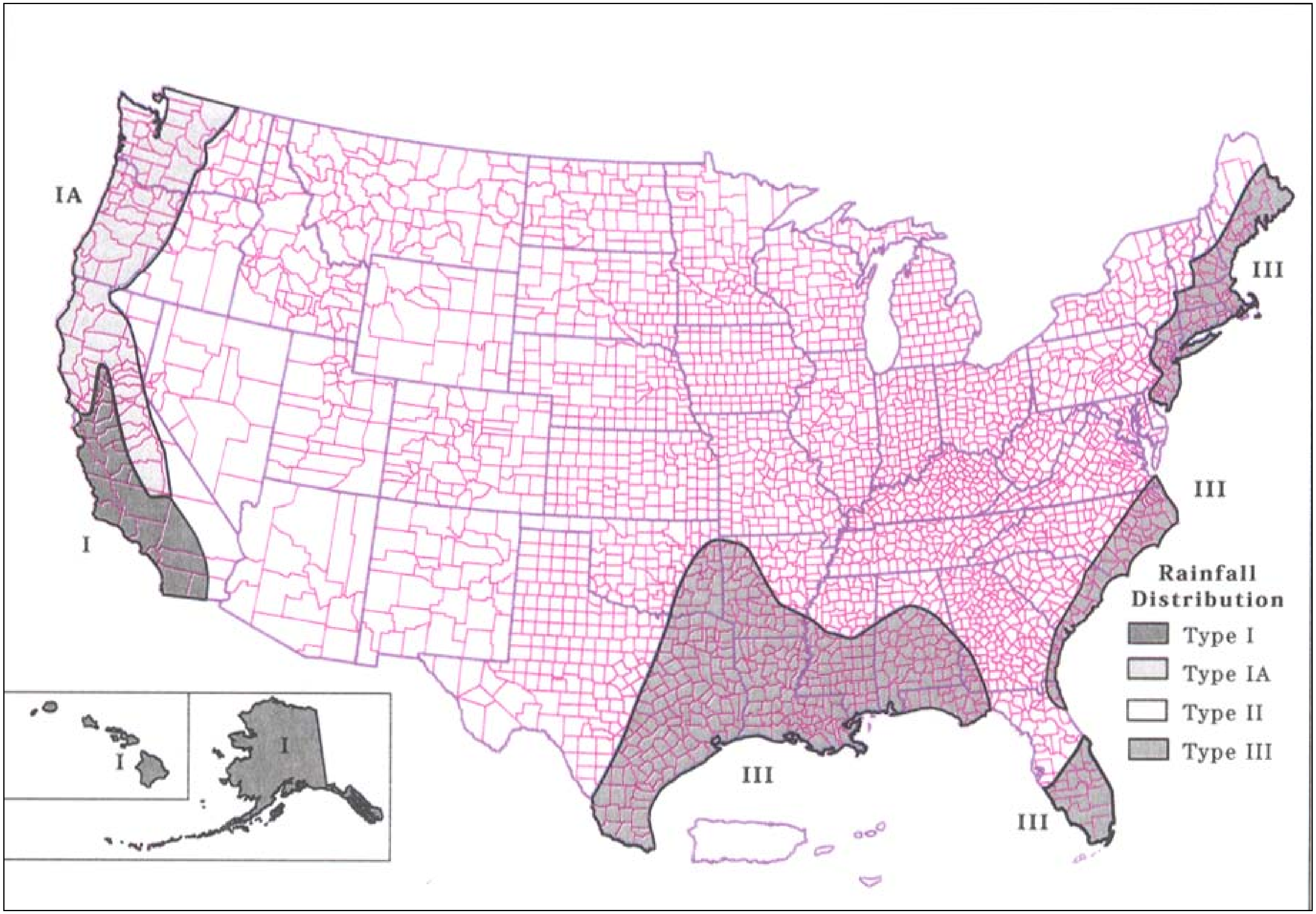

Figure 17. Rainfall Distributions.

Figure 18 shows that for a Type III rainfall distribution, 80% of the rain falls over a period of 6 hours.

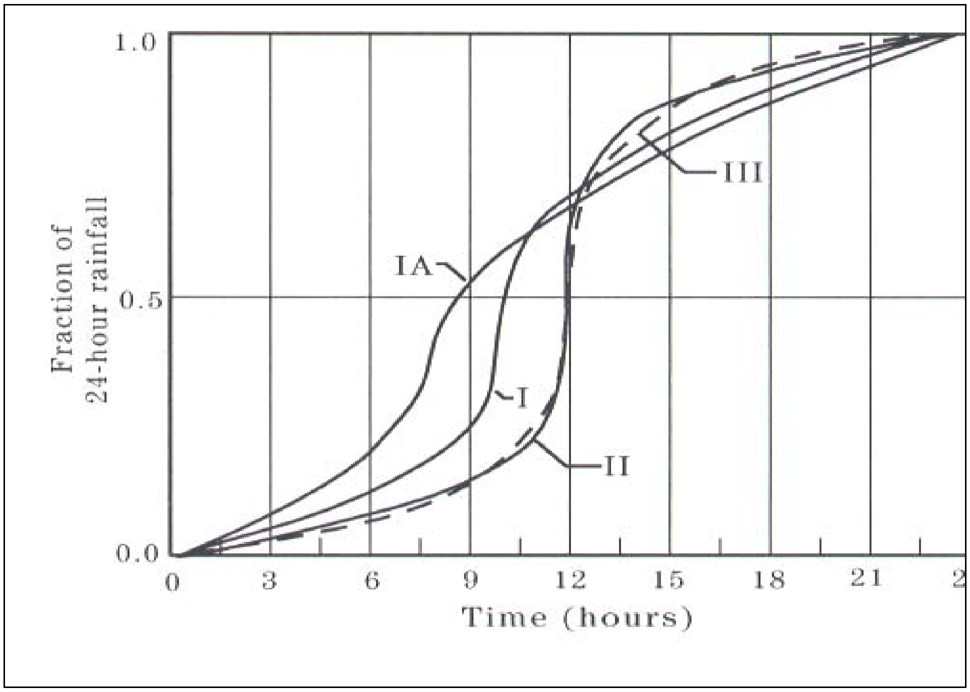

Figure 18. 24-Hour Rain Distribution.

A storm condition of four inches of rain over a period of 6 hours was selected as the design condition.

The above data were input into the EPA Storm Water Management Model computer code. Figure 19 shows the EPA model results.

Table 8 presents computer modeling results of the DRMO watershed for several rainfall amounts.

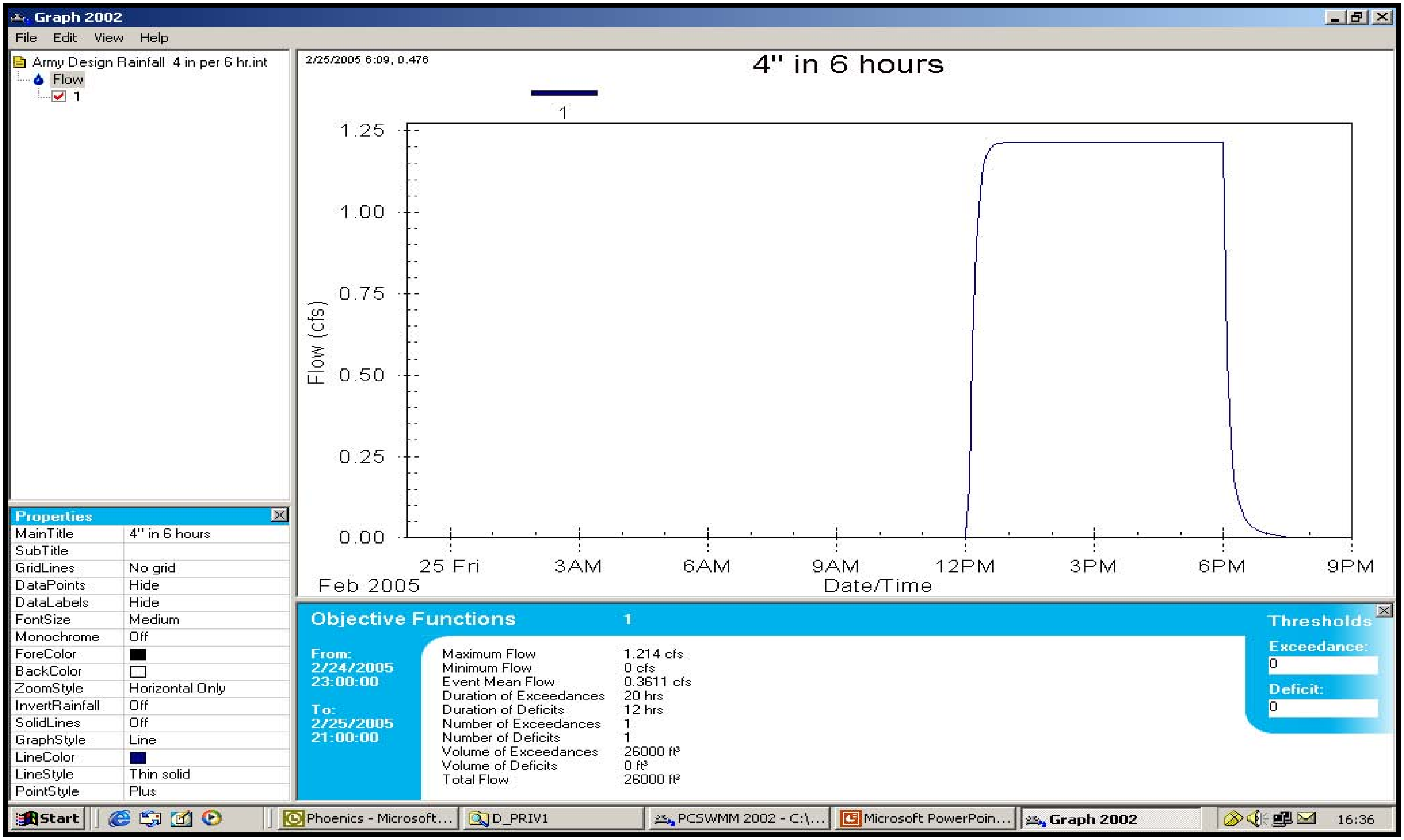

Figure 19. Hydrograph for Runoff from ANAD DRMO Demonstration Site.

Table 8. Runoff Data for Several Precipitation Rates

Time Interval, Years	Precipitation, inches	Peak flow, CFS	Total flow, cubic feet	Probability of occurrence in any 1 year	Probability x Peak Flow
0.5	1*	0.288	6031	1	0.228
1	2*	0.607	13000	1	0.607
2	4	1.214	26000	0.5	0.607
5	5	1.525	32720	0.2	0.305
10	6	1.836	39540	0.1	0.184
25	7	2.122	46170	0.04	0.085
50	7.5	2.303	49530	0.02	0.046
100	8	2.448	52890	0.01	0.024

* Estimated. All other precipitation data are the NOAA web site.

System capital cost is proportional to required capacity or to flow rate, depending on treatment system type. If design system capacity is multiplied by the probability that the capacity will be required (i.e., the probability that the precipitation rate will actually occur in any particular year), a measure of the probability that the system capacity will actually be used in any single year is obtained. This is the last column in Table 8. Table 8 indicates that the appropriate size for the system at ANAD is between 0.6 and 1.2 cubic feet per second (CFS), as these two flow rates have the highest probable usage of system capacity. A system designed for the 100-year storm would be about 2.5 larger and cost proportionately more. However, full system capacity for a system designed for the 100-year storm would be rarely used. A system designed for the 6-month storm would be too small and would overflow about two thirds of the time.

The storm water treatment system design point for ANAD was selected to be 1 CFS, (about 500 GPM). The total flow per design storm is 19,500 cubic feet or 146,000 gallons.

3.4 Present Operations

3.4.1 Regional Recycling Center, San Diego, California

Prior to the installation of the dual media storm water treatment system, the NRRC has had no provisions for either capturing the first ¼-inch of storm water runoff or treating any portion of the storm water runoff. All of the storm drains at NRRC connect to a single drain that can be accessed from a vault known as Outfall 80. Regulations require sampling the storm water runoff from NRRC at Outfall 80 within 1 hour of the first storm event of the storm season and during any two subsequent storms of the season.

3.4.2 Anniston Army Depot, Alabama

Prior to the installation of the ESTCP dual media storm water filtration unit, ANAD had no treatment system in place, but was in the process of installing an oil-water separator to remove the oil in the runoff from the proposed demonstration site. Figure 20 shows the ESTCP demonstration unit installed parallel with the oil-water separator. When ANAD installed the oil-water separator, they installed an inlet basin where the inlet basin would split the influent flow into two streams. In this application, if the flow rate is 500 gallons per minute or less the flow is directed to the ESTCP demonstration unit. If the flow exceeds 500 GPM, the flow in excess of 500 GPM is directed to the oil-water separator.

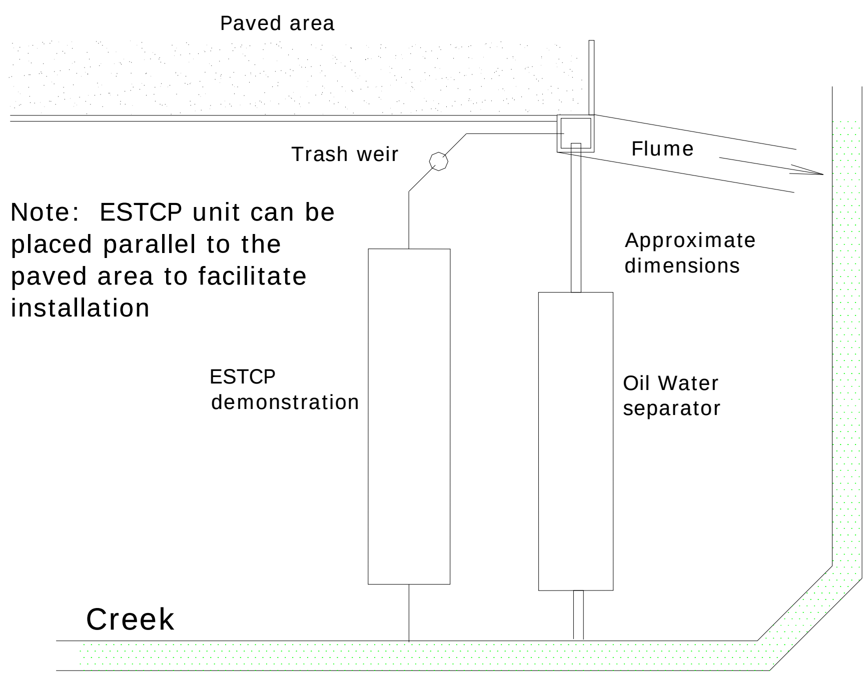

Figure 20. Installation Configuration at ANAD.

3.5 Pre-Demonstration Testing and Analysis

3.5.1 Laboratory Tests of Different Adsorption Media

NAVFAC ESC tested 24 different individual filtration and adsorption media for effectiveness at removing pollutants from storm water runoff. The Navy Pollution Prevention Ashore Program sponsored the project. Runoff from NRRC San Diego was pumped through six columns containing filter and adsorption media. One column was filled with inert filter media (washed sand) so that metals removal by filtration could be differentiated from metals removal by filtration and adsorption. NAVFAC ESC determined that the most effective pollutant removal is obtained through two different combinations: (1) a layer of bone char over a layer of iron coated activated alumina; and (2) a layer of bone char, a layer of activated alumina, and a layer of manganese greensand. A U. S. patent (Patent No. US 7,025,887 B1) has been obtained on the application of these combinations of media for removing contaminants from wastewater streams. The media used at NRRC San Diego and ANAD Alabama was a combination of a layer of bone char over a layer of iron coated activated alumina call FS-50. Complete details of this study can be found in NAVFAC ESC Technical Report, TR-2256-ENV.

3.5.2 Laboratory Interference Tests

NAVFAC ESC conducted laboratory tests to determine if high levels of iron or aluminum will interfere with the adsorption of copper or zinc through the ESTCP dual media storm water filtration unit. In most industrial complexes, the contaminants of concern would be copper and zinc due to their toxicities. To conduct this test, NAVFAC ESC ran test water samples spiked with metal ions through a column packed with filter media. This test utilized a 2-inch diameter clear plastic cylinder approximately 22 inches tall. Flow was adjusted so that the test water running through the filter media, consisting of 10 inches of bone char over 10 inches of FS-50, had an empty bed contact time of 10 minutes. Three samples of the test water were taken prior to running the test water through the filter media. A sample of the test water was taken on the discharge end of the packed filter column every ten minutes for one hour for a total of six samples.

Six tests were conducted to determine if iron and/or aluminum interfered with copper and zinc adsorption. The results of the interference tests are presented in Table 9.

Table 9. Test Results for NAVFAC ESC Filter-Adsorption Media

	Percent Removed											
	Zinc Removal						Copper Removal					
	Test #1 Zn Only		Test #2 Zn & Fe		Test #3 Zn & Al		Test #4 Cu Only		Test #5 Cu & Fe		Test #6 Cu & Al	
Lowest	77.4		88.9		82.1		95.6		85.4		94.4	
	88.1		91.8		84.5		96.0		91.8		95.9	
	88.1		93.0		89.0		96.6		96.8		96.6	
	92.6		93.0		89.7		98.0		97.8		98.3	
	92.6		94.2		90.2		98.4		98.0		99.3	
Highest	94.7		95.5		91.6		99.4		98.7		99.4	
Average	88.9		92.7		87.8		97.3		94.8		97.3	
	Zn		Zn	Fe	Zn	Al	Cu		Cu	Fe	Cu	Al
Initial Conc in ppb	243		243	287	83.7	347	500		500	203	763	350

Test #1 ran water spiked with zinc only through the test column. Test #2 ran water spiked with zinc and iron. Test #3 ran water spiked with zinc and aluminum. Test #4 ran water spiked with copper only. Test #5 ran water spiked with copper and iron. Test #6 ran water spiked with copper and aluminum.

The test water metal ion concentrations were set to roughly correlate to dissolved metals concentration expected at NRRC. Applying the analysis of variance (ANOVA) statistical analysis test using Microsoft Excel to calculate the p-value for the hypothesis that iron and zinc do not interfere in the adsorption of zinc or copper, NAVFAC ESC has concluded that iron and aluminum has minimal if any interference with the adsorption of copper and zinc onto the media at the concentrations expected in the field. The p-value for zinc removal was calculated as 0.16 and for copper removal was calculated as 0.33. The hypothesis would have been rejected if the p-value was lower than 0.05.

3.5.3 Scale Model, Navy Regional Recycling Center, San Diego, California

Table 2 shows storm water contaminant concentrations collected at Outfall 80 prior to the installation of the full scale ESTCP demonstration unit. The untreated storm water runoff exceeds permit requirements for aluminum, copper, lead, zinc, and total suspended solids (TSS).

Figure 21 shows a 1/20th scale model of the full scale demonstration unit tested at NRRC. Table 10 shows 1/20th scale model test results.

The design flow rate of the 1/20th scale model was 15 gallons per minute. The model was approximately 6 ft in length, 4 ft in height, and 2 feet in depth and made of marine grade plywood. The model had clear plastic view ports that will allow observation of hydraulic performance. The model was tested in the field at NRRC. Runoff water for the tests was generated by conducting artificial "rain events" using water from fire hydrants. As seen in Table 10, the scale model brought the storm water contaminant concentrations to well below the permit limit at NRRC.

Figure 21. Model of Filter-Adsorption System Undergoing Field Testing.

Table 10. Typical Field Test Results for NAVFAC ESC Filter-Adsorption Media

Parameter	Method	Influent	Effluent	Permit Limit at NRRC	Units
Aluminum	EPA 200.7	330-860	ND-100	750	µg/L
Cadmium	EPA 200.7	ND-12	ND	15.9	µg/L
Chromium	EPA 200.7	ND-18	ND	20	µg/L
Copper	EPA 200.7	1900-4700	ND-21	64	µg/L
Iron	EPA 200.7	3000-8200	ND-170	1000	µg/L
Lead	EPA 200.7	150-360	ND	82	µg/L
Zinc	EPA 200.7	680-1700	ND-41	117	µg/L

Figures 22 and 23 (Hart Crowser, Inc. 2002) indicate that there is a high probability of passing the 96hr-50%LC toxicity test (as required for NRRC San Diego) if the concentration of copper is less than 100 µg/l and the concentration of zinc is less than 300 µg/l. The brine shrimp *Mysidopsis bahia* was the test species in these tests.

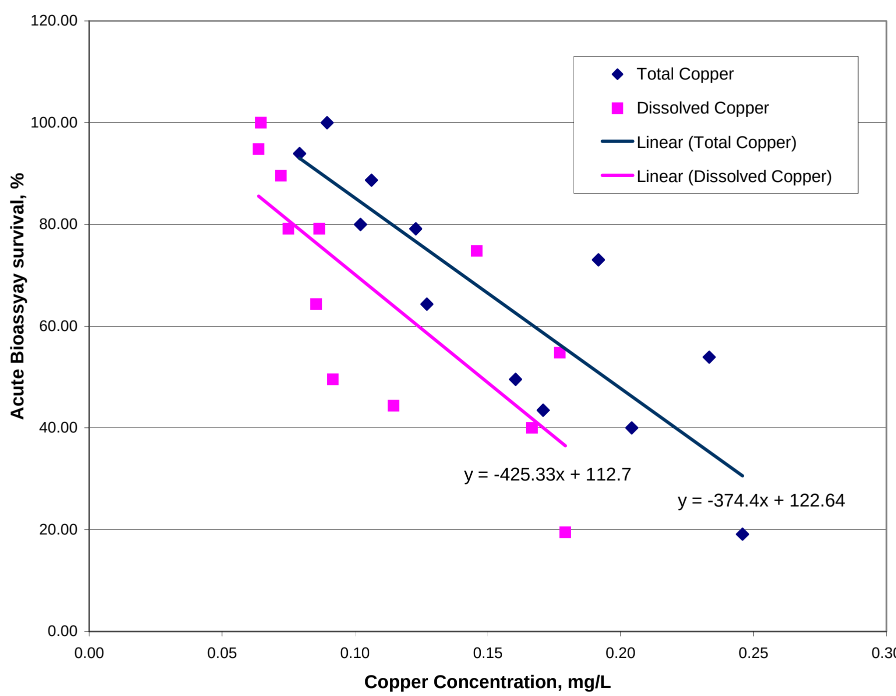

Figure 22. Percent Survival as a Function of Copper Concentration.

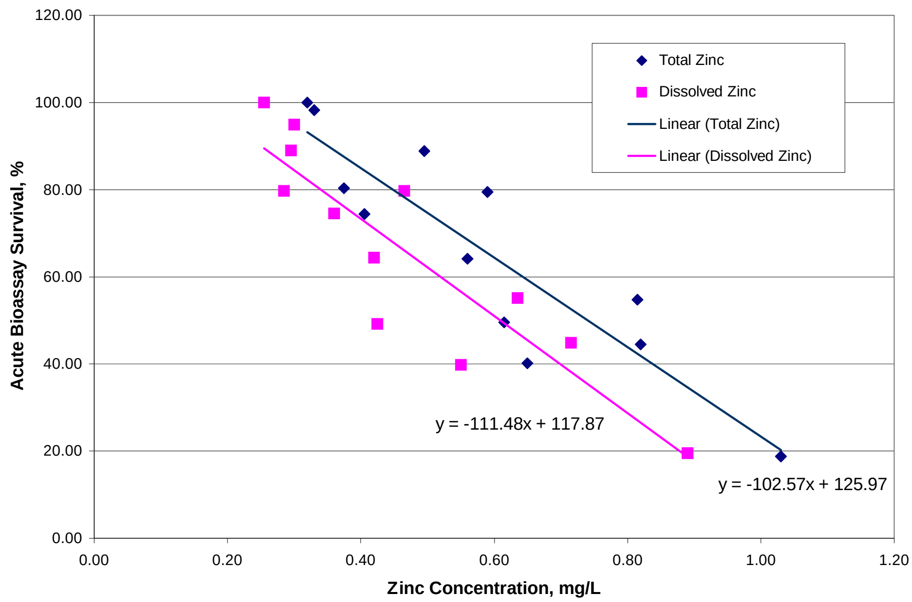

Figure 23. Percent Survival as a Function of Zinc Concentration.

Therefore, we are confident that the media developed at NAVFAC ESC permits NRRC San Diego to pass the required toxicity tests under the most severe influent conditions.

3.5.4 Scale Model, Anniston Army Depot, Alabama

To better characterize the treatment needs at ANAD, two 5-gallon samples of storm water runoff were collected and shipped to NAVFAC ESC for chemical characterization and process testing.

The water samples were mixed together then passed through a model of the treatment system bed. Figure 24 shows the model treatment system. Because only a small sample of storm water runoff was available from ANAD, the amount of characterization and process testing was limited.

Table 11 presents the test results. These results indicate that the ESTCP demonstration dual media technology will treat ANAD's storm water to below benchmark values. These results have not been published.

Figure 24. NAVFAC ESC Adsorption Test Apparatus.

Table 11. Results of Treatability Testing of ANAD Storm Water Runoff

Pollutant	Concentration		Units
	Influent	Effluent	
	July 2005	July 2005	
Antimony	BQL	BQL	µg/L
Arsenic	BQL	BQL	µg/L
Barium	142*	BQL	µg/L
Beryllium	BQL	BQL	µg/L
Cadmium	74*	BQL	µg/L
Chromium	22*	BQL	µg/L
Copper	191*	31*	µg/L
Cobalt	33*	BQL	µg/L
Lead	201*	BQL	µg/L
Mercury	BQL	BQL	µg/L
Molybdenum	BQL	BQL	µg/L
Nickel	16*	BQL	µg/L
Selenium	BQL	BQL	µg/L
Silver	22*	5*	µg/L
Thallium	BQL	BQL	µg/L
Vanadium	16*	BQL	µg/L
Zinc	550*	BQL	µg/L
TSS	300	BQL	mg/L
TDS	68	59	mg/L
Conductance	NT	NT	µS/cm
PH	7.2	7	s.u.
Hardness	68	57	mg/L as CaCO3
BOD	NT	NT	mg/L
COD	NT	NT	mg/L
TOC	BQL	BQL	mg/L
Oil & Grease	9	BQL	mg/L
TPH	1	BQL	mg/L
Benzene, Toluene, Ethylene, Xylene, MTBE	BQL	BQL	mg/L
TKN	NT	NT	mg/L
Total Phosphorous	BQL	BQL	mg/L

***** Average value from two samples
NT - Not Tested

3.6 Testing and Evaluation Plan

3.6.1 Demonstration Set-Up and Start-Up

3.6.1.1 Regional Recycling Center, San Diego, California

A full scale demonstration program has taken place in the field at NRRC. In preparation for the testing program, NAVFAC ESC, in consultation with the Navy Public Works Department conducted the following: re-surveyed the site to determine precise elevations and distances; determined and marked the location of any underground utilities; verified the locations of the nearest existing storm water vault and drainpipe; collected and analyzed soil samples for purposes of excavation; and verified the depth of the water table. No utilities had to be relocated to accommodate the filter trench.

A detailed design and installation plan for NRRC was submitted for review. Following review by the Navy Public Works and Southwest Division of NAVFAC, a contract for procurement and installation of the filter was awarded. The system components consist of pre-cast concrete sand filter units, accessories such as inlet grating and access hatches, and filtration/adsorption media. Installation required excavation, placement and sealing of the pre-cast sections, connection of the discharge to the storm drain system, back-filling of soil, and removal of excess soil and construction debris.

NAVFAC ESC installed the monitoring equipment consisting of automatic water sampling systems, flow meters and flow totalizers, a data logging system, and a recording rain gauge.

The main safety issues addressed were work in open trenches and work in enclosed, and possibly oxygen deficient, environments such as the concrete filter housings. The unused filter media are non-hazardous.

3.6.1.2 Anniston Army Depot, Alabama

A full scale demonstration program has taken place in the field at ANAD. The preparations for ANAD are the same as those for NRRC. A detailed design and installation plan for ANAD was submitted for review. Following review by the Army Corps of Engineers (ACOE), an existing contract with the ACOE was used for the installation of the filter. The system components consist of pre-cast concrete sand filter units, accessories such as the trash vault, and filtration/adsorption media. Installation required excavation, placement and sealing of the pre-cast sections, connection of the discharge to the storm drain system, back-filling of soil, and removal of excess soil and construction debris.

The ACOE had installed a deeper inlet basin than what NAVFAC ESC had expected, resulting in the dual media storm water filtration unit sitting deeper into the ground than originally designed. NAVFAC ESC determined that the hydraulics of the dual media filter system were only slightly compromised, and proceeded with the demonstration.

No utilities had to be relocated to accommodate the treatment system.

The main safety issues addressed were work in open trenches and work in enclosed, and possibly oxygen deficient environments such as the concrete filter housings. The filter media are non-hazardous.

3.6.2 Period of Operation

3.6.2.1 Regional Recycling Center, San Diego, California

Testing began on January 2006, after completion of construction and acceptance of the installation by Navy contracting personnel. Because almost all of the rain in San Diego falls between the months of November and April, operation was intermittent and occurred mostly during the winter months. .

The instrumentation at NRRC captured data from fifteen rain events during the period January 2006 to April 2007. Only eleven of the fifteen rain events were used to assess the performance of system due to malfunctions with the Campbell Scientific data logger, and American Sigma refrigerated auto samplers during the first four rain events. Data from the first four rain events at NRRC were considered unreliable.

3.6.2.2 Anniston Army Depot, Alabama

Testing began at ANAD in October 2006, and concluded in June 2007. As Figure 15 shows, Anniston Alabama typically gets rain year round, though they underwent a 4 month drought prior to August 2006.

3.6.3 Amount/Treatment Rate of Materials to be Treated

3.6.3.1 Navy Regional Recycling Center, San Diego, California

The treatment system installed at NRRC was designed to treat storm water runoff at a maximum rate of 265 gallons per minute. The total anticipated runoff per storm was 41,900 gallons. It is estimated that, on average, 983,200 gallons of storm water runoff would be treated annually (based on historic average annual rainfall in San Diego of 10.2 inches).

The total rainfall occurring during the demonstration period was well below the average annual rainfall in San Diego. The actual volume of runoff filtered by the storm water treatment system during the demonstration period was 107,787 gallons from total rainfall of 4.4 inches. This averages to approximately 9800 gallons per rain event. Appendix C provides additional information on total rainfall, real time flow rate, and total volume of runoff that was treated per storm event.

3.6.3.2 Anniston Army Depot, Alabama

The treatment system installed at ANAD was designed to treat storm water runoff at a maximum rate of 500 GPM. The total anticipated runoff per design storm was 19,500 cubic feet or 146,000 gallons. Assuming there are 30 average storms per year and the average daily precipitation is 1.55 inches, it is estimated that approximately 320,700 cubic feet (2,400,000 gallons) of storm water runoff would be treated annually. This system has been installed parallel to an oil-water separator. If the storm water runoff rate exceeds 500 GPM, the catch basin was designed to divert the runoff over 500 GPM to the oil-water separator. The oil-water separator has a design maximum flow rate of 3000 GPM.

The actual volume of runoff that was treated at ANAD is unavailable due to a malfunction of the Greyline Instruments area-velocity flow meter with data logger. The only available flow data is from a 13 February 07 storm event, where 9,200 gallons of storm water was treated by the system, and that flow rates were as great as 200 gpm.

3.6.4 Residuals Handling

The technology to be demonstrated by this project will generate residual wastes that require disposal. There are two sources of wastes: (1) the sediment and other debris that must be periodically removed from the filter trench system; and (2) the spent filter media.

Future toxicity characteristic leachate procedure (TCLP) and other appropriate tests should be performed on all sludge and sediments to determine if they meet land disposal regulations. TCLP results for sediment and gravel sampled from the top layer of the dual media filter system during the demonstration period indicate that the solid waste can likely be disposed of as non-hazardous.

The spent or exhausted adsorption media must also be tested to see if it passes the TCLP test. It is expected that the spent media requiring replacement upon reaching the end of its lifespan will likely have to be disposed of as hazardous waste. Core samples should be taken through the depth of the media bed before it is removed. The core sample should be divided into uniform increments for testing. This will allow development of contaminant concentration profiles through the bed. This knowledge could result in improved bed designs.

3.6.5 Operating Parameters for the Technology

The storm water treatment system demonstrated is inherently simple and requires no operator intervention. The system runs intermittently, depending on the amount and frequency of rainfall. All storm water will flow strictly through gravitation. The only moving parts in the system are float valves which require no operator intervention.

3.6.6 Experimental Design

Data Analysis: There are 6 methods of calculating the effectiveness of a storm water BMP:

- Efficiency ratio
- Summation of loads
- Regression of loads
- Mean concentration
- Efficiency of individual storms
- Reference watershed before/after studies

Each of these methods has characteristics that may bias the results. We used the efficiency ratio (ER) method, and applied the method to each storm event.

The efficiency ratio is defined in terms of the average event mean concentration (EMC) of pollutants over some finite time period.

ER = 1 – (average outlet EMC)/(average inlet EMC)

Where

$$EMC = \frac{\Sigma(Q_i * C_i)}{\Sigma Q_i}$$, summed over n

where,

Q_i = flow volume during period i
C_i = average concentration of pollutant associated with period i
n = total number of measurements taken during rain event.

Over a storm season, the average EMC can be calculated as

$$\text{Seasonal average EMC} = \frac{\sum EMC_j}{m}$$

where m = total number of storm events measured.

The EMCs can be normalized for statistical purposes by the transformation:

$$\text{Mean of the Log EMCs} = \frac{\sum Log(EMC_j)}{m}$$

Section 4.3, Data Analysis, Interpretation and Evaluation, presents tabulated ER results for the dual media storm water filter system at NRRC.

In addition to a method for calculating effectiveness, a method is required to determine if the differences in inflow and outflow water quality measures are statistically significant. The recommended method was the Lognormal Statistical Efficiency (LSE). The LSE method fully describes the statistical distribution of the water quality upstream and downstream of the BMP and determines if differences in water quality are statistically significant.

Only 11 rainfall events at NRRC (and 6 at ANAD) produced sufficient precipitation to generate storm water runoff during the respective demonstration periods. Thus, it is unlikely that there was sufficient data on system performance to produce a valid statistical analysis.

The system was a fixed, static configuration. The only process variable that could be modified was the type of filter-adsorption media.

3.6.6.1 Navy Regional Recycling Center, San Diego, California

The filter trench at NRRC was equipped with two American Sigma refrigerated auto samplers. One of the American Sigma auto samplers collected samples of the process influent, and the other American Sigma auto sampler collected samples of the process effluent. Each auto sampler was equipped with a 24-1 liter sample container carousel. Each sample container was filled after a certain time interval had passed. The first four sample containers for each Sigma sampler were composited together as a “first-flush” sample. The rest of the sample bottles (the number of samples will vary with the duration of the storm) were analyzed independently. A third auto sampler was used to collect samples for toxicity testing of the process effluent.

All samples were transported to the Navy Environmental Chemistry Laboratory at NAS North Island for chemical analysis. The Navy Environmental Chemistry Laboratory has contracts with EPA certified laboratories for analytical tests. Laboratory analysis was performed to determine metals concentrations and other parameters. Table 12 provides a list of parameters that were sampled.

A flow rate meter (with flow totalizer) was connected to the outlet of the treatment system. This flow meter was connected to an automatic data logging system. This allowed determination of the flow profiles for each storm as well and the minimum, mean, and peak flow rates. The totalizer also permitted computation of the runoff processed.

A weather station was located on site to record the precipitation during the demonstration period. The weather station was connected to the data logger.

The data logging system was a battery powered Campbell Scientific Inc. Model 45X unit that was used on the storm water technology test stand.

These instruments allowed us to correlate system performance with flow rate and provide the additional data needed to support investigations of any performance problems that may occur.

The system was a fixed, static configuration. The only process variable that could be modified was the type of filter/adsorption media. For this demonstration, the media used was a combination of bone char over activated alumina (FS-50).

3.6.6.2 Anniston Army Depot, Alabama

The filter trench at ANAD was equipped with two, dual mode Global Water autosamplers. Each sampler was capable of collecting both a grab sample and a composite sample. One autosampler collected influent samples, and the other sampler collected effluent samples. Figure 25 shows the enclosure containing the autosamplers, battery box, and flow rate meter.

In a grab sample, the sample pump ran continuously until the sample bottle was full. The grab sample is more representative of a "first flush" sample. The first portion of runoff from a storm (first flush) tends to contain higher concentrations of pollutants than samples taken later. As such, it is more representative of the maximum pollutant loading.

A composite sample is a sample collected intermittently during operation. For example, to gather a composite sample the sampler might collect 100 milliliters of runoff water every 30 minutes until the sample bottle is full. A composite sample is a time average of samples of runoff water and is representative of time-averaged pollutant concentrations.

Figure 25. Dual Mode Storm Water Autosampler.

One composite sample and one grab sample of influent, and one composite sample and one grab sample of effluent (a total of 4 samples) were collected for each storm event. All samples were transported to Test America for chemical analysis. Table 12 lists the parameters and methods for analysis.

A flow rate meter (with flow totalizer) that contains a 50,000-point data logger with RS232 output was connected to the inlet of the treatment system. This will allowed the determination of flow profiles for each storm as well and the minimum, mean, and peak flow rates.

The instrument used was a AVFM area-velocity flow meter made by Greyline Instruments, Inc. The flow rate meter used a submerged ultrasonic sensor to continuously measure both the velocity and the level in an open channel.

These instruments allowed us to correlate system performance with flow rate and provide the additional data needed to support investigations of any performance problems that may occur.

Precipitation was not measured at this installation. Precipitation data was obtained from Anniston Municipal Airport.

A minimum inter-event period of 72 hours from a previously measurable storm event was selected for ANAD. This inter-event period provides adequate time for the deposition of particles on the watershed, and allowed the solar panels enough time to recharge the 12VDC batteries that powered the instrumentation.

The system was a fixed, static configuration. The only process variable that could be modified was the type of filter/adsorption media. For this demonstration, the media used was a combination of bone char over activated alumina (FS-50).

Based on historical data, every month produced several storms of sufficient precipitation to generate storm water runoff at ANAD. It was planned to sample one storm a month and/or "significant" storms. A significant storm was a storm that occurred after an extended dry period, or a storm that occurred after there has been an oil spill or other mishap at the DRMO.

3.6.7 Demobilization

For both NRRC and ANAD, following completion of the demonstrations, the storm water treatment systems were be turned over to the Navy Public Works Center San Diego and ANAD for operation and maintenance. There are no plans to remove and dispose either of the trench filter systems. If the host sites does not want to utilize the treatment system for any future reason, the filter trench(es) can be disconnected from the storm drain system, filled with soil, and the inlet sealed. Both systems are below grade, will not create un-usable land area conditions, and present no specific hazards.

3.7 Selection of Analytical/Testing Methods

USEPA or ASTM standard analytical methods have been used to evaluate the effectiveness of the dual storm water runoff treatment system. Table 12 shows the test methods utilized for each parameter at NRRC and ANAD.

Table 12. Analysis and Test Methods

	NRRC	Method	ANAD	Method
Hardness			✓	SM2340
Toxicity	✓	*		
pH	✓	EPA150.1	✓	EPA150.1
Total Suspended Solids	✓	EPA2540D	✓	EPA160.2
Total Dissolved Solids	✓	EPA2540C	✓	EPA160.1
Specific Conductivity	✓	SM2510B	✓	SM2510B
Total Organic Carbon (TOC)	✓	SM5310B		
Chemical Oxygen Demand (COD)	✓	EPA410.4	✓	EPA410.4
Biochemical Oxygen Demand (BOD)	✓	SM5210B	✓	EPA405.1
Surfactants – Methyl Blue Active Substance (MBAS)	✓	SM5540C	✓	EPA377.1
Nitrogen (Total)			✓	SM4500N
Ammonia	✓	EPA350.2		
Total Kjeldahl Nitrogen (TKN)	✓	EPA351.3		
Nitrite	✓	EPA300.0		
Nitrate	✓	EPA300.0		
Phosphorus (Total)	✓	EPA365.2	✓	EPA365.4
Total Recoverable Petroleum Hydrocarbon (TRPH)	✓	EPA418.1		
Oil and Grease	✓	EPA1664	✓	EPA1664
Benzene, Toluene, Ethylbenzene, Xylene (BTEX)			✓	EPA602
Naphtha			✓	EPA602
Total Petroleum Hydrocarbon – Diesel Range			✓	EPA SW846 8015B
Metals				
Aluminum	✓	EPA200.8		
Antimony			✓	EPA200.7
Arsenic	✓	EPA200.8	✓	EPA200.7
Barium			✓	EPA200.7
Beryllium			✓	EPA200.7
Cadmium	✓	EPA200.8	✓	EPA200.7
Chromium	✓	EPA200.8	✓	EPA200.7
Cobalt			✓	EPA200.7
Copper	✓	EPA200.8	✓	EPA200.7
Iron	✓	EPA200.8		
Lead	✓	EPA200.8	✓	EPA200.7
Mercury			✓	EPA245.1
Molybdenum			✓	EPA200.7
Nickel	✓	EPA200.8	✓	EPA200.7
Selenium	✓	EPA200.8	✓	EPA200.7
Silver	✓	EPA200.8	✓	EPA200.7
Thallium			✓	EPA200.7
Titanium	✓	EPA200.8		
Vanadium			✓	EPA200.7
Zinc	✓	EPA200.8	✓	EPA200.7

*EPA/821/R-02/012, 2002
SM-Standard Methods

For the demonstration project at NRRC, the primary goal of the demonstration was to show that the storm water runoff treatment system complies with the CRWQCB Order R9-2002-0169 Section B, Paragraph 4 which states: "Effective 4 years after the adoption of the Order (November 2006), storm water discharges from NAVSTA industrial activities must pass a 96-hour bioassay (toxicity) test using standard test species, protocols, and undiluted storm water runoff, and not produce less than a 90% survival, 50% of the time, and not less than a 70% survival, 90% of the time."

To demonstrate compliance with the Order, several 5-liter polypropylene containers of process effluent were collected from each storm event. These samples were transported to an environmental testing laboratory where they were used (undiluted) for toxicity testing. The test organism was requested by the CRWQCB. The brine shrimp *Mysidopsis bahia* has been used in the past for storm water toxicity tests in San Diego (Hart Crowser, Inc 2002).

	NRRC	Method	ANAD	Method
Hardness			✓	SM2340
Toxicity	✓	*		
pH	✓	EPA150.1	✓	EPA150.1
Total Suspended Solids	✓	EPA2540D	✓	EPA160.2
Total Dissolved Solids	✓	EPA2540C	✓	EPA160.1
Specific Conductivity	✓	SM2510B	✓	SM2510B
Total Organic Carbon (TOC)	✓	SM5310B		
Chemical Oxygen Demand (COD)	✓	EPA410.4	✓	EPA410.4
Biochemical Oxygen Demand (BOD)	✓	SM5210B	✓	EPA405.1
Surfactants – Methyl Blue Active Substance (MBAS)	✓	SM5540C	✓	EPA377.1
Nitrogen (Total)			✓	SM4500N
Ammonia	✓	EPA350.2		
Total Kjeldahl Nitrogen (TKN)	✓	EPA351.3		
Nitrite	✓	EPA300.0		
Nitrate	✓	EPA300.0		
Phosphorus (Total)	✓	EPA365.2	✓	EPA365.4
Total Recoverable Petroleum Hydrocarbon (TRPH)	✓	EPA418.1		
Oil and Grease	✓	EPA1664	✓	EPA1664
Benzene, Toluene, Ethylbenzene, Xylene (BTEX)			✓	EPA602
Naphtha			✓	EPA602
Total Petroleum Hydrocarbon – Diesel Range			✓	EPA SW846 8015B
Metals				
Aluminum	✓	EPA200.8		
Antimony			✓	EPA200.7
Arsenic	✓	EPA200.8	✓	EPA200.7
Barium			✓	EPA200.7
Beryllium			✓	EPA200.7
Cadmium	✓	EPA200.8	✓	EPA200.7
Chromium	✓	EPA200.8	✓	EPA200.7
Cobalt			✓	EPA200.7
Copper	✓	EPA200.8	✓	EPA200.7
Iron	✓	EPA200.8		
Lead	✓	EPA200.8	✓	EPA200.7
Mercury			✓	EPA245.1
Molybdenum			✓	EPA200.7
Nickel	✓	EPA200.8	✓	EPA200.7
Selenium	✓	EPA200.8	✓	EPA200.7
Silver	✓	EPA200.8	✓	EPA200.7
Thallium			✓	EPA200.7
Titanium	✓	EPA200.8		
Vanadium			✓	EPA200.7
Zinc	✓	EPA200.8	✓	EPA200.7

*EPA/821/R-02/012, 2002
SM-Standard Methods

The test protocol is EPA 1991 (Acute). Standard Statistical analysis software (such as TOXCALC, Version 5.0) was used by the laboratory for data analysis and presentation of survivability results

3.8 Selection of Analytical/Testing Laboratory

All testing was performed in Government or commercial analytical laboratories that hold EPA certification. The Navy Environmental Chemistry Laboratory at NAS North Island performed analytical testing on NRRC storm water samples.

TestAmerica, certification type DW and certification number 02008, performed analytical testing on ANAD storm water samples. This is the laboratory that ANAD environmental staff regularly uses.

4.0 PERFORMANCE ASSESSMENT

4.1 Performance Criteria

4.1.1 Navy Regional Recycling Center, San Diego, California

The primary goal of the demonstration was passage of the bioassay test. Passage of the bioassay test is a requirement of CRWQCB Order R9-2002-0169. Reducing the copper and zinc concentrations in the runoff water to the levels shown in Table 13 will assure a high probability of passage of the toxicity test.

Table 13. ESTCP Performance Criteria for NRRC

Performance Criteria	Description	Primary or Secondary
Bioassay (toxicity) test	Static or continuous flow bioassay test using undiluted storm water runoff associated with industrial activity shall not produce less than 90% survival 50% of the time and not less than 70% survival 90% of the time using standard test species and protocols	Primary
Hazardous contaminant	Reduce concentration of copper in effluent to less than 64 μg/l, reduce the concentration of zinc in the effluent to less than 117 μg/l, and reduce the concentration of lead in the effluent to less than 83 μg/l.	Primary
Hazardous contaminant	Reduce concentration of aluminum in effluent to less than 750 μg/l, and reduce the concentration of TSS in the effluent to less than 100 mg/l.	Primary
Capital investment	Reduce capital investment to less than $50,000 per acre of drainage	Secondary
O&M costs	Reduce annual O&M costs to less than $15 per 1000 gallons treated.	Secondary
Scale-up Constraints	This is planned as a full-scale demonstration.	Secondary
Factors Affecting Technology Performance	Operating conditions consist of the frequency, intensity, and duration of rainfall and the type and concentration of contaminants in the subsequent runoff. We have no control over these conditions and must accept what occurs.	Secondary
Process waste	Process waste consists of sludge and sediment at the upstream side of the porous concrete and, eventually, spent adsorption media. Wastes will be handled by contract.	Secondary
Ease of use	The process does not require any operators to be routinely present. Data acquisition is automatic.	Secondary
Reliability	The process is inherently simple, has no moving parts, and requires no electrical or mechanical power. It is inherently reliable.	Secondary
Versatility	The process should be applicable to other industrial sites where metal concentration in runoff water exceeds discharge standards	Secondary

4.1.2 Anniston Army Depot, Alabama

Table 14 outlines the demonstration performance criteria for ANAD

Table 14. ESTCP Performance Criteria for ANAD

Performance Criteria	Description	Primary or Secondary
Hazardous contaminant	Effluent complies with current NPDES permit. The permit states that "The discharge shall have no sheen, and there shall be no discharge of visible oil, floating solids, or visible foam in other than trace amounts.	Primary
Capital investment	Reduce capital investment to less than $50,000 per acre of drainage	Secondary
O&M costs	Reduce annual O&M costs to less than $15 per 1000 gallons treated.	Secondary
Scale-up Constraints	This is planned as a full-scale demonstration.	Secondary
Factors Affecting Technology Performance	Operating conditions consist of the frequency, intensity, and duration of rainfall and the type and concentration of contaminants in the subsequent runoff. We have no control over these conditions.	Secondary
Process waste	Process waste consists of sludge and sediment in the pretreatment chambers and, eventually, spent adsorption media. Wastes will be removed by contract.	Secondary
Ease of use	The process does not require any operators to be routinely present. Data acquisition is automatic.	Secondary
Reliability	The process is inherently simple, has no moving parts, and requires no electrical or mechanical power. It is inherently reliable.	Secondary
Versatility	The process should be applicable to other industrial sites where runoff water exceeds discharge standards	Secondary

4.2 Performance Confirmation Methods

The purpose of the demonstration was to obtain information on the effectiveness of a new storm water filter system that is not currently available in the literature. Therefore, the scientific community could measure the overall success of this project in terms of the quality of data acquired and the eventual acceptance of the technology. Table 15 and Table 16 detail the expected performance and the performance confirmation methods for NRRC and ANAD, respectively. See Appendix B for the Data Quality Assurance /Quality Control Plan used for this study which discusses data collection, data format, and data confirmation methods.

Table 15. Expected Performance and Performance Confirmation Methods for NRRC

Performance Criteria	Expected Performance	Performance Confirmation Method	Actual Performance
Primary Performance Criteria			
Bioassay test	Static or continuous flow bioassay test using undiluted storm water shall not produce less than 90% survival 50% of the time, and not less than 70% survival 90% of the time.	EPA/821/R-02/012, 2002 Acute Testing Manual	94% survival 64% of the time, and 70% survival 82% of the time. 100% survival 90% of the time, and 100% survival 70% of the time after media bed modifications.
Hazardous contaminant	Reduce concentration of copper in effluent to less than 64 μg/l, reduce the concentration of zinc in the effluent to less than 117 μg/l, and reduce the concentration of lead in the effluent to less than 83 μg/l.	EPA Standard Methods 200.8	The seasonal EMC for Cu, Zn, and Pb were 95 μg/l, 297 μg/l, and 11 μg/l respectively. The EMC for Cu, Zn, and Pb after media bed modifications were 40 μg/l, 122 μg/l, and 5 μg/l respectively.
Hazardous contaminant	Reduce concentration of aluminum in effluent to less than 750 μg/l, and reduce the concentration of TSS in the effluent to less than 100 mg/l.	EPA Standard Methods 200.8	The seasonal EMC for Al was 377 μg/L. TSS values were all below 100 mg/L.
Secondary Performance Criteria			
Capital investment	Investment less than $50K per acre	Complete and accurate record keeping	Capital investment is $27K per acre.
O&M cost	O&M less than $15/1000 gallons	Complete and accurate record keeping	O&M cost based on estimated annual flow is $1.73/1000 gallons. The O&M cost from the demonstration is $15.77/1000 gallons.
Scale-up Constraints	None	Demonstration Experience	No scale-up constraints.
Factors Affecting Technology Performance	Operating conditions consist of the frequency, intensity, duration of rainfall and the type and concentration of contaminants in the subsequent runoff.	Demonstration Experience	The system was able to filter all rain events occurring during the demonstrations period. The concentrations of targeted contaminants were all reduced.
Process waste	Process waste consists of sludge and sediment at the upstream side of the porous concrete and, the top layer of the media bed. Eventually, spent adsorption media. Wastes will be handled by contract.	Demonstration Experience	Annual maintenance is required to remove sediment from the top layer of the media bed to minimize system plugging. Semi-annual sweeping of the upstream side of the porous curb is required to minimize the amount of sediment reaching the media bed.
Ease of use	The process does not require any operators to be routinely present. Data acquisition is automatic.	Demonstration Experience	The system did not require operators to be present.
Reliability	The process is inherently simple, has no moving parts, and requires no electrical or mechanical power. It is inherently reliable.	Demonstration Experience	The system required no repair.
Versatility	The process should be applicable to other industrial sites where metal concentration in runoff water exceeds discharge standards	Demonstration Experience	The process is applicable to other industrial sites with runoff containing similar influent concentrations.

Table 16. Expected Performance and Performance Confirmation Methods for ANAD

Performance Criteria	Expected Performance	Performance Confirmation Method	Actual Performance
Primary Performance Criteria			
Hazardous contaminant	Effluent complies with current NPDES permit. The permit states that "The discharge shall have no sheen, and there shall be no discharge of visible oil, floating solids, or visible foam in other than trace amounts."	EPA standard analytical methods, and observations made during sampling	No sheen, visible oil, floating solids, or foam was reported during sampling.
Secondary Performance Criteria			
Capital investment	Reduce capital investment to less than $50,000 per acre of drainage	Complete and accurate record keeping	Capital investment is $67K per acre.
O&M cost	Reduce annual O&M costs to less than $15 per 1000 gallons treated.	Complete and accurate record keeping	O&M cost based on estimated annual flow is $1.45/1000 gallons.
Scale-up Constraints	This is planned as a full-scale demonstration.	Demonstration Experience	No scale-up constraints.
Factors Affecting Technology Performance	Operating conditions consist of the frequency, intensity, and duration of rainfall and the type and concentration of contaminants in the subsequent runoff. We have no control over these conditions.	Demonstration Experience	The system was able to filter all rain events occurring during the demonstrations period. The concentrations of targeted contaminants appear to be reduced.
Process waste	Process waste consists of sludge and sediment in the pretreatment chambers and, eventually, spent adsorption media. Wastes will be removed by contract.	Demonstration Experience	Maintenance was not required during the demonstration period. Annual maintenance will likely be required to remove sediment from the pretreatment chambers.
Ease of use	The process does not require any operators to be routinely present. Data acquisition is automatic.	Demonstration Experience	The system does not require operators to be present.
Reliability	The process is inherently simple, has no moving parts, and requires no electrical or mechanical power. It is inherently reliable.	Demonstration Experience	The system required no repair.
Versatility	The process should be applicable to other industrial sites where runoff water exceeds discharge standards	Demonstration Experience	The process is applicable to other industrial sites with runoff containing similar influent concentrations.

4.3 Data Analysis, Interpretation and Evaluation

During their respective demonstration periods, performance data was collected at NRRC and ANAD to access and validate the performance of the dual media storm water filter system. The primary performance criteria identified in Table 13 and Table 14 are discussed in this section as the principal measures of system performance.

4.3.1 Navy Regional Recycling Center, San Diego, California

The instrumentation at NRRC captured data from fifteen rain events during the period January 2006 to April 2007. However, only eleven of the fifteen rain events are used to assess the performance of the dual media storm water filter system. The Campbell Scientific data logger, and American Sigma refrigerated auto samplers malfunctioned during the first four rain events from 10 January 2006 to 13 March 2006, and the resulting data is considered unreliable.

The dual media storm water filter system treated 107,787 gallons of storm water from 4.40 inches of total rainfall during eleven rain events occurring from 28 March 2006 to 20 April 2007. Appendix C contains detailed data for each of the eleven rain events, and also contains performance metrics such as real time system flow rate, total rainfall, and total flow for each storm event of the demonstration period.

Figures 26 and 27 provide examples of the real time performance metrics collected for each storm event.

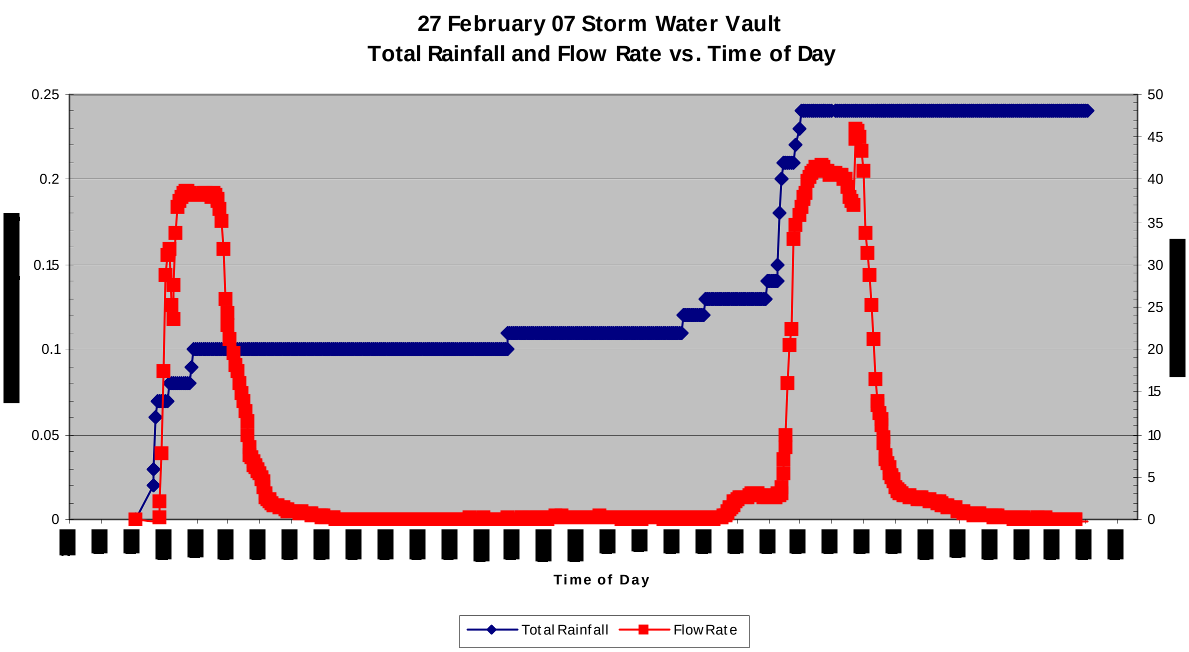

Figure 26. Total Flow vs. Time of Day.

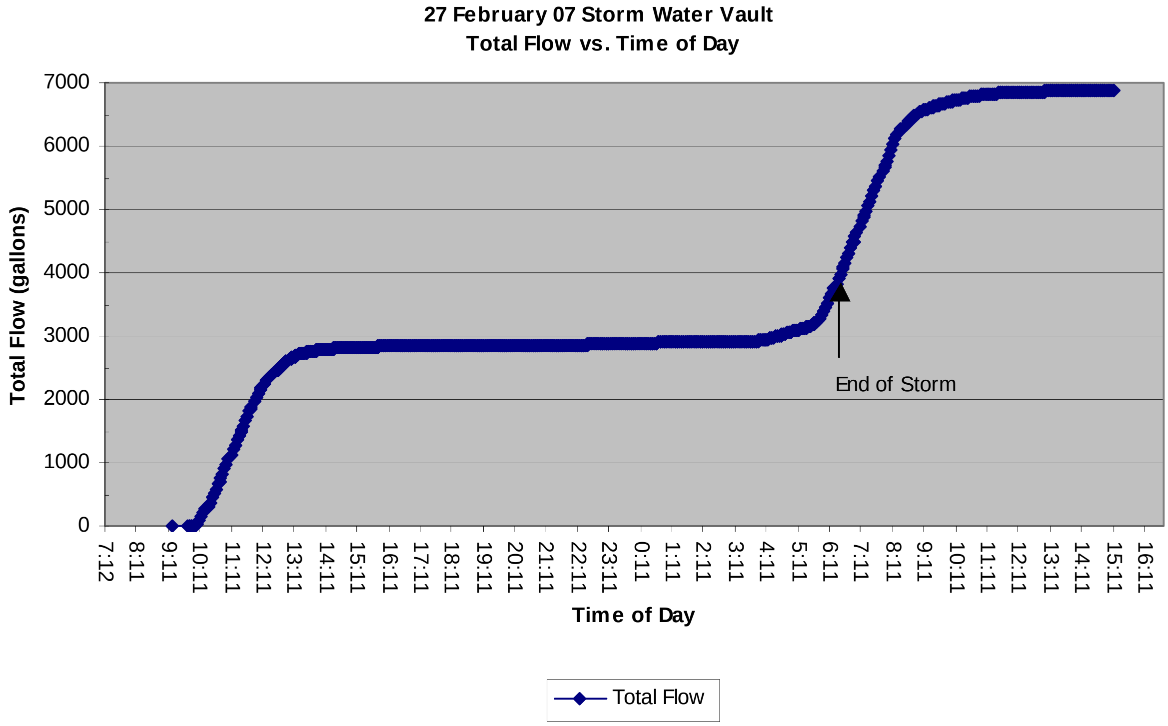

Figure 27. Total Rainfall & Flow Rate vs. Time of Day.

4.3.1.1 Bioassay (Toxicity) Test Results

Table 17 displays acute toxicity test requirements and results for NRRC.

Table 17. Acute Toxicity Results

	Acute Toxicity Test Requirements	
NRRC Requirement	90% Survival 50% of the time	70% survival 90% of the time
All NRRC Results	90% Survival 64% of the time	70% survival 82% of the time
NRRC Results After Design Modification (Last 5 Storm Events)	90% Survival 100% of the time	70% survival 100% of the time

Table 17 shows that the dual media storm water filter system passes the 90% survival requirement 64% of the time. However, the 70% survival requirement is met only 82% of the time. This statistical result is likely due to acute toxicity test results (45% survivability) from the 16 October 2006 storm event, where Nautilus Environmental, the subcontracted bioassay laboratory in San Diego, noted a significant drop in dissolved oxygen levels during the first 24 hours of testing. The Nautilus Environmental test report indicates that the test chambers were aerated after this observation, but it is not clear whether low dissolved oxygen levels or a toxic substance in the sample caused mortality.

Upon further inspection of the Nautilus Environmental test results by NAVFAC ESC, the survival rate for the remaining species after the test chambers were aerated was 70%. Nautilus Environmental considered repeating the test, but there was not enough samples left to conduct the analysis. Had the 70% survival rate *after aeration* of the test chambers been accepted, the 70% survival requirement for the eleven rain events would have been met 91% of the time.

Table 17 also shows that the last five storm events of the demonstration period met both the 90% and 70% acute toxicity test requirements 100% of the time. For the previous storms, it was hypothesized that storm water was bypassing the media bed along the perimeter walls of the vaults (edge effects), resulting in partial treatment of the influent, and non-optimal media bed performance.

Prior to the 16 October 2006 rain event, additional flaps of geofabric were glued to the perimeter walls of the vaults, above an existing sheet of geofabric, to decrease edge effects and redirect the influent to flow through the center of the media bed. The reconfiguration did redirect flow through the center of the media bed, but significantly decreased the porosity of the top fabric layer. Prior to the 18 February 2007 rain event, the top layer of geofabric was replaced with a more porous mesh to reduce the flow restriction through the top fabric layer, and prevent premature clogging of the media bed.

Figure 28 displays both design modifications that were made to the top layer of geofabric. These two modifications significantly improved the performance of the dual media storm water filter for the last 5 storm events of the demonstration period.

Table 18 displays the relationships between total rainfall, rainfall intensity, acute toxicity, first flush (1^{st} hour of rainfall) copper and zinc influent and effluent concentration, and percent removal for each of the eleven storm events at NRRC.

. **Figure 28. Geofabric Reconfiguration.**

With the exception of the 16 October 2006 storm event, survivability was greater then 85% for all the storms events that occurred after the first modification was made to the top geofabric layer of the media bed. After the second modification was made to the top geofabric layer, survivability increased to 97% or greater for each of the last five storm events. The first flush percent removal for both copper and zinc was also greater than 76% during the same storm event period.

The high removal efficiencies for copper and zinc are a direct result of minimizing undesirable edge effects, and redirecting flow through the center of the media bed.

The 45% survivability rate for the 16 October 2006 storm event could very well be attributed to low dissolved oxygen levels in the acute toxicity test chambers, but as Nautilus Environmental states, it is not clear whether low dissolved oxygen levels or a toxic substance in the sample caused mortality.

Table 18. NRRC First Flush Rainfall Data

Date	Total Rainfall (inches)	First Flush Intensity (in/hr)	Survival 100% Concentration (%)	First Flush Influent/Effluent Cu (µg/l)	Cu % Removal	First Flush Influent/Effluent Zn (µg/l)	Zn % Removal
3/28/06	0.35	0.17	95	1170 339	71	1480 343	77
4/14/06	0.16	0.07	85	550 201	63	981 711	28
4/23/06	0.11	0.08	60 [3]	351 228	35	1270 913	28
5/22/06	0.60	0.4	90	987 397	60	2620 1140	57
10/16/06 [1]	0.40	0.06	45 [4]	1070 401	63	4810 1330	72
1/29/07	0.85	0.11	85	488 85	83	1960 277	86
2/18/07 [2]	0.9	0.06	100	307 63	79	1170 180	85
2/22/07	0.2	0.19	100	143 29	80	572 102	82
2/27/07	0.24	0.07	97	356 34	91	1870 167	91
3/22/07	0.06	0.25	100	335 81	76	928 222	76
4/20/07	0.53	0.18	100	342 88	74	1260 251	80

1. Top layer cleaned, and fabric configuration modified prior to this rain event
2. Top layer cleaned, and replaced existing top layer of fabric with more porous mesh prior to this rain event
3. Mortality attributed to insufficient contact time
4. Mortality attributed to low dissolved oxygen levels

Table 18 also displays decreased media bed performance during the smaller, low intensity storm events that occurred prior to modifications being made to the top layer of geofabric. Edge effects are magnified during low intensity storms due to the low runoff flow rates that trickle into the media bed over a long period of time. Optimal contact times between storm water influent and the media bed occur when the vaults are fully flooded.

The dual media storm water filter performance was inconsistent prior to the modifications being made to the top layer of geofabric. Acute toxicity results and first flush removal efficiencies for copper and zinc varied greatly. The inconsistent performance was primarily due to edge effects, which became more prominent as the top layer of geofabric clogged with sediment over time. Influent flowing through the media bed was simply able to take the path(s) of least resistance along the perimeter walls of the vaults, resulting in incomplete treatment.

Figure 29 shows acute toxicity percent survival at NRRC as a function of total copper and total zinc concentrations respectively. First flush effluent concentrations for copper were all below 88 μg/l during the last six storm events of the demonstration period. First flush effluent concentrations for zinc were all below 277 μg/l for the same storm period.

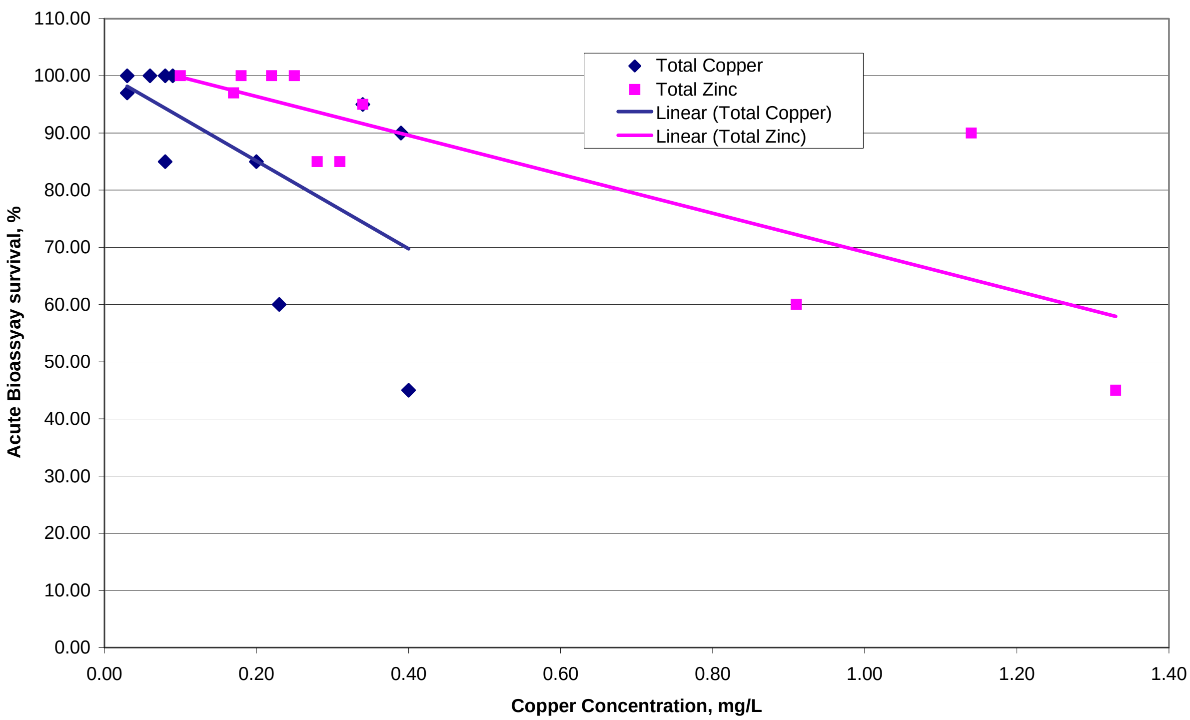

Figure 29. Percent Survival as a Function of Total Copper and Zinc Concentrations.

The results from the last six storm events coincide with the best acute toxicity test results, and reflect the same observations made from the NASSCO results (Figures 22 and 23), which indicate that, copper concentration must be reduced to less than 100 μg/l, and zinc concentration must be reduced to less than 300 μg/l to pass acute toxicity tests at greater than 90% survivability.

4.3.1.2 Hazardous Containment

Hazardous containment is the other primary demonstration criterion that corresponds to bioassay test results. Reducing concentrations of copper, zinc, aluminum, lead, and total suspended solids in storm water runoff to the levels stated in Table 13 assures a high probability of passing acute toxicity requirements.

The NPDES storm water permit at NRRC requires runoff containing less than 64 μg/l copper, 117 μg/l zinc, 83 μg/l lead, 750 μg/l aluminum, and 100 mg/l total suspended solids (TSS) respectively.

Table 19 provides first flush results for copper, zinc, lead, aluminum, and total suspended solids for all NRRC storm events sampled during the demonstration period. Percent removed values appear in parenthesis. Appendix C contains complete first flush data for additional metals, total dissolved solids, specific conductivity, pH, biological oxygen demand, chemical oxygen demand, total organic carbon, etc., for all the NRRC storm events.

The first flush sampling data for copper and zinc do not meet NPDES storm water permit requirements. First flush copper requirements were met for only three of the eleven storm events, and first flush zinc requirements were met for only one of the eleven storm events. However, the four storm events that did meet the requirements (3 for copper, and 1 for zinc) all occurred after modifications were made to the top fabric layer of the media bed. As discussed in the previous section, all acute toxicity test requirements in Table 17 were met for all of the last 5 storm events.

Table 19 also shows that removal efficiencies for copper and zinc range from 74 percent to 91 percent. However, the high influent concentrations routinely obtained for zinc may be too great to meet the low NPDES permit requirements, regardless of the high removal efficiencies.

In lieu of the ESTCP and NASSCO results displayed in Figures 22, 23, and 29 that show percent survival as a function of zinc and copper concentration, the low NPDES storm water permit requirements for copper and zinc that are presently used as an indicator of the ability to pass acute toxicity tests may require some reevaluation.

The first flush sampling data for aluminum met NPDES storm water permit requirements for eight of the eleven storm events, and for all of the last five storm events. First flush sampling data for lead and TSS met NPDES storm water permit requirements for all eleven storm events.

Table 19. NRRC First Flush Sampling Results

Pollutant	NRRC First Flush Results (1)										
	3/28/06 Influent Effluent	**4/14/06** Influent Effluent	**4/23/06** Influent Effluent	**5/22/06** Influent Effluent	**10/16/06** Influent Effluent	**1/29/07** Influent Effluent	**2/18/07** Influent Effluent	**2/22/07** Influent Effluent	**2/27/07** Influent Effluent	**3/18/07** Influent Effluent	**4/20/07** Influent Effluent
Cu (µg/L)	1170 339 (71)	550 201 (63)	351 228 (35)	987 397 (60)	1070 401 (63)	488 85 (83)	307 63 (79)	143 29 (80)	356 34 (91)	335 81 (76)	342 88 (74)
Zn (µg/L)	1480 343 (77)	981 711 (28)	1270 913 (28)	2620 1140 (57)	4810 1330 (72)	1960 277 (86)	1170 180 (85)	572 102 (82)	1870 167 (91)	928 222 (76)	1260 251 (80)
Pb (µg/L)	149 25 (83)	60 16 (73)	43 22 (49)	204 81 (60)	106 37 (65)	73 8 (89)	101 16 (84)	36 3 (92)	93 7 (93)	66 9 (86)	52 12 (77)
Al (µg/L)	5620 750 (87)	2080 1210 (42)	1950 742 (62)	5140 1680 (67)	3260 803 (75)	2280 207 (91)	2200 390 (82)	1020 105 (90)	1820 327 (82)	3180 265 (92)	1210 217 (82)
TSS (mg/L)	54 22 (59)	46 37 (20)	84 35 (58)	253 88 (65)	182 66 (64)	140 ND (86)	300 22 (93)	107 ND (81)	197 ND (90)	152 ND (87)	104 ND (81)

1. Numbers in parenthesis are percent removed

In addition to first flush samples, grab samples were also taken at 20-minute intervals for the duration of each storm event. Figure 30 shows copper concentration over time for the last 6 storm events of the demonstration period. No curve exists for the 18 March 07 storm event because only first flush samples were acquired. The first point of each curve is the first flush value shown for each storm event in Tables 18 and 19. Appendix C shows complete grab sample results for each of the eleven storm events.

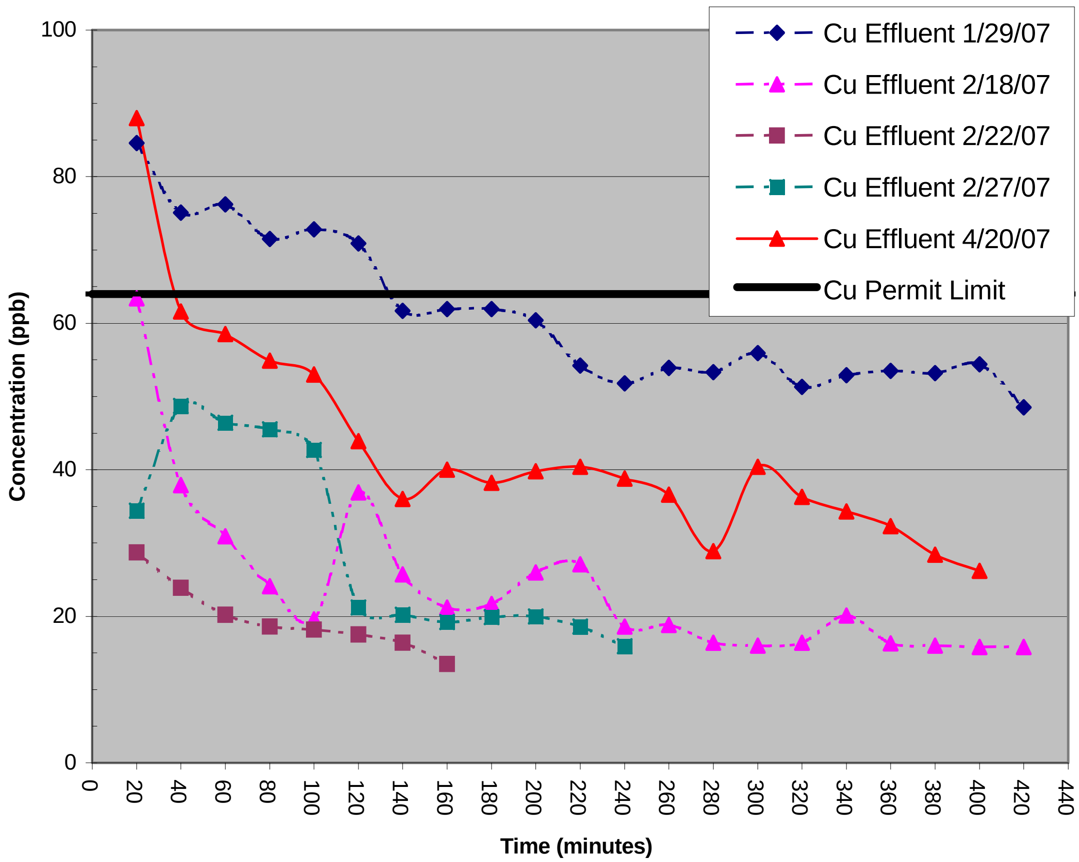

Figure 30. Copper Concentration Over Time.

Figures 30 and 31 display grab sampling data for copper and zinc respectively. The grab effluent samples for copper met the NPDES storm water permit during the last six storm events, and copper concentration generally decreased over time. Copper influent concentrations also generally decrease over time, with the exception of short upward trends that are thought to be related to storm intensity, where greater concentrations of total and dissolved copper are dislodged from the asphalt surface.

Many of the composite grab samples for zinc did not meet NPDES storm water permit requirements. However, the grab effluent samples were all below 250 µg/L, which is below the inferred 300 µg/L threshold for zinc that seems to assure a high probability of passing acute toxicity requirements.

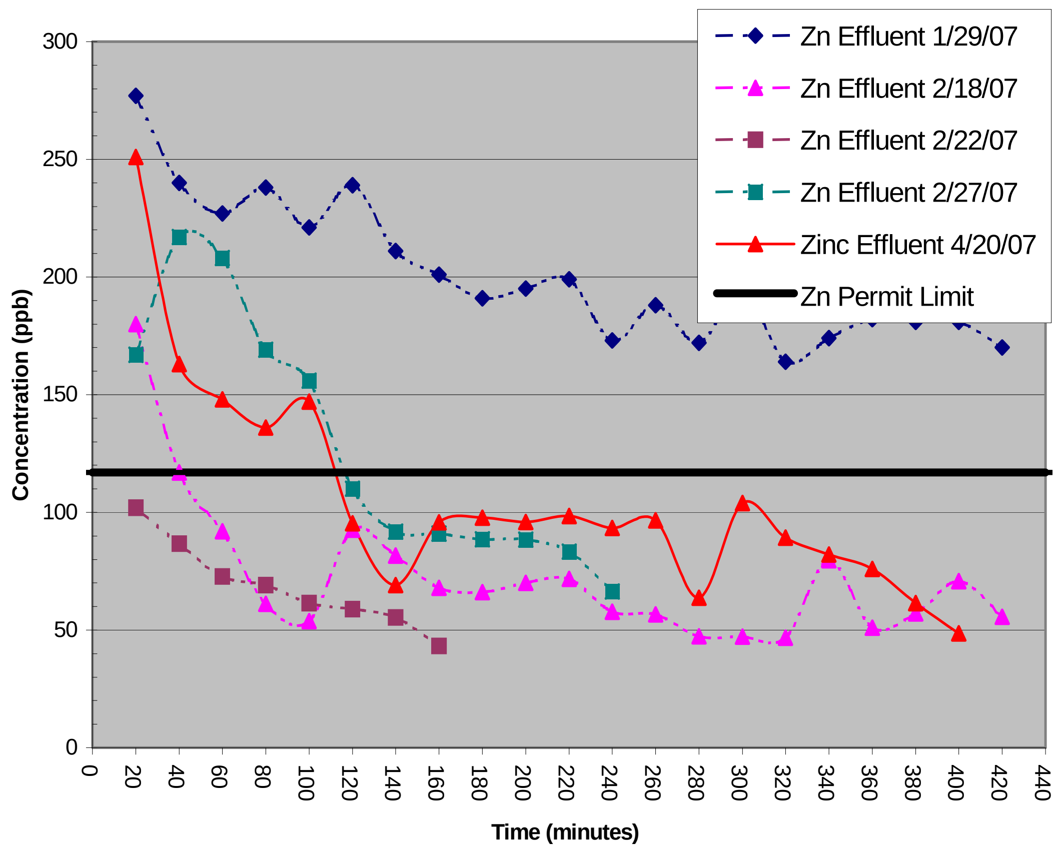

Figure 31. Zinc concentration over time.

4.3.1.3 Efficiency Ratio Method of Data Analysis

Section 3.6.6, Experimental Design, discussed the different methods of calculating the effectiveness of a storm water BMP. The effectiveness of the dual media storm water filter system was evaluated by using the ER method. Table 20 presents ER method results for aluminum, cadmium, copper, iron, lead, nickel, and zinc for the eleven storm events sampled during the demonstration period. ER values appear in parenthesis.

Table 20. NRRC Efficiency Ratio Results

	Influent / Effluent, Average Event Mean Concentration (µg/L) [1]						
Date	**Al**	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**
3/28/2006	1946 / 191	4 / 2	314 / 97	3262 / 290	44 / 7	83 / 24	488 / 184
4/14/2006	1993 / 988	7 / 4	380 / 207	3469 / 1524	50 / 22	73 / 33	799 / 615
4/23/2006	1516 / 907	6 / 6	278 / 189	2401 / 1486	40 / 20	48 / 30	1004 / 767
5/22/2006	1384 / 589	13 / 6	403 / 176	2851 / 1204	69 / 27	39 / 18	1187 / 582
10/16/2006	1650 / 389	10 / 3	435 / 119	2893 / 789	67 / 14	41 / 11	1572 / 313
1/29/2007	959 / 222	15 / 3	230 / 60	1375 / 406	38 / 8	19 / 6	874 / 199
2/18/2007	893 / 141	10 / 1	150 / 24	1229 / 219	43 / 5	11 / 2	561 / 74
2/22/2007	651 / 92	7 / 1	116 / 20	826 / 106	28 / 2	9 / 3	515 / 71
2/27/2007	952 / 220	13 / 2	181 / 29	1242 / 285	51 / 5	14 / 3	865 / 129
3/22/2007	3180 / 265	11 / 3	335 / 81	5350 / 524	66 / 9	29 / 8	928 / 122
4/20/2007	739 / 142	7 / 1	210 / 45	1084 / 208	38 / 5	15/ 3	738 / 113
Seasonal Efficiency Ratio	1442 / 377 (74)	9 / 3 (69)	276 / 95 (65)	2362 / 640 (73)	49 / 11 (77)	35 / 13 (63)	866 / 297 (66)
Last 5 Storm Events Efficiency Ratio	1283 / 172 (87)	10 / 2 (83)	198 / 40 (80)	1946 / 268 (86)	45 / 5 (88)	16 / 4 (75)	721 / 122 (83)

1. ER in parenthesis.

The seasonal average ER did not meet the NRRC NPDES storm water permit requirements for copper and zinc. However, the seasonal average ER for lead and aluminum met the NRRC permit requirements.

The average ER for the last five storm events of the demonstration period met the permit requirements for aluminum, copper, and lead, and was within 3 percent of the 117 μg/L limit for zinc. The improved results for the last 5 storm events are due to the modifications that were made to the top fabric layer of the media bed. All acute toxicity test requirements were met for the last five storm events.

4.3.2 Anniston Army Depot, Alabama

The primary objective of the ANAD demonstration was to validate a technology that can remove metals, organic compounds, and sediment from storm water runoff. Sampling data was captured from six storm events at ANAD during the period October 2006 to April 2007.

Although the DRMO demonstration site is similar to the NRRC demonstration site (in that both are in the scrap recycling business), the site does present significantly different characteristics in regulatory requirements, the operations conducted, the contaminants released, and climatic influences on runoff quality.

The ANAD instrumentation was designed to capture first flush grab and composite samples of storm water influent and effluent, collect real time flow rate data, and totalize the flow. Limited flow data is available from the ANAD demonstration due to a malfunction of the Greyline Instruments area-velocity flow meter with data logger. The only available flow data, from the 13 February 2007 storm event, indicates that 9,200 gallons of storm water was treated by the dual media storm water filter system, and the maximum flow rate was 200 gpm. Appendix C contains sampling results for each of the six rain events from the demonstration period.

The sampling results for effluent metals concentrations and the incomplete data set for TSS and organic compounds make it difficult to validate the performance of the dual media storm water filter system at ANAD. Multiple challenges were encountered during the demonstration period. Unanticipated field modifications, instrumentation failures, and inconsistent sampling regimes limited the amount of data available for analysis and contribute to the uncertainty of the effluent results. However, it is believed that the performance of the system at ANAD removes metals, organic compounds, and TSS in a manner similar to the system installed at NRRC.

Additional details on the challenges associated with the effluent sampling are provided in the following section.

4.3.2.1 Hazardous Containment

The current NPDES permit for ANAD has no specific discharge limits for metals, TSS, or organic compounds found in storm water runoff. The general discharge requirement for ANAD states that "The discharge shall have no sheen, and there shall be no discharge of visible oil, floating solids, or visible foam in other than trace amounts".

Furthermore, the following minimum conditions are applicable to all Alabama State waters, at all places and at all times, regardless of their uses:

(a) State waters shall be free from substances attributable to sewage, industrial wastes or other wastes that will settle to form bottom deposits which are unsightly, putrescent or interfere directly or indirectly with any classified water use.
(b) State waters shall be free from floating debris, oil, scum, and other floating materials attributable to sewage, industrial wastes or other wastes in amounts sufficient to be unsightly or interfere directly or directly with any classified water use.
(c) State waters shall be free from substances attributable to sewage, industrial wastes or other wastes in concentrations or combinations which are toxic or harmful to human, animal or aquatic life to the extent commensurate with the designated usage for such waters.

Table 21 displays first flush grab sample results for copper, lead, zinc, extractable petroleum hydrocarbons (diesel), total suspended solids, and oil & grease for the six storm events sampled during the demonstration period. Percent removed values appear in parenthesis. Appendix C contains complete tabulated first flush data for additional metals, total dissolved solids, specific conductivity, pH, biological oxygen demand, chemical oxygen demand, etc., for all the ANAD storm events.

Effluent grab and composite sampling results may be questionable due to the clear well sampling location being submerged by the receiving body of water during periods of heavy rainfall. The outlet of the dual media storm water filtration unit was installed at a depth greater than originally intended as a result of the inlet basin (which feeds both the storm water unit and oil water separator) being installed differently than the initial design. Field engineers determined that the system hydraulics would only be slightly compromised, but did not consider the potential effects on the sampling protocol.

The dual media storm water filtration system displays high removal efficiencies for copper and zinc, ranging from 89 percent to 99 percent. The low removal efficiency for copper during the 16 March 2007 storm event is unknown. The lower removal efficiencies for lead are the result of influent concentrations that are close to the lead detection limit.

Table 22 displays composite sampling results (150 ml sample every 10 minutes) for copper, lead, zinc, extractable petroleum hydrocarbons (diesel), total suspended solids, oil & grease for the six storm events sampled during the demonstration period. Additional composite sampling results are also presented in Appendix C.

Table 21. ANAD First Flush Sampling Results

Pollutant	ANAD First Flush Results (1)					
	10/17/06 Influent Effluent (% Removed)	**11/15/06** Influent Effluent (% Removed)	**1/18/07** Influent Effluent (% Removed)	**2/13/07** Influent Effluent (% Removed)	**3/16/07** Influent Effluent (% Removed)	**4/4/07** Influent Effluent (% Removed)
Copper (mg/L)	0.0384 ND (97)	0.0693 ND (99)	0.0408 ND (98)	0.0625 ND (98)	0.0371 0.0243 (35)	0.0324 ND (97)
Lead (mg/L)	0.0121 ND (59)	0.0514 ND (90)	0.0236 ND (79)	0.0631 0.0061 (90)	0.0427 ND (88)	0.00610 ND (18)
Zinc (mg/L)	0.0973 ND (90)	0.185 ND (95)	0.113 ND (91)	0.318 ND (97)	0.254 ND (96)	0.0931 ND (89)
Diesel (µg/L)	1990 2150	1600 254 (84)	528 178 (66)	4420 597 (86)	NS	2260 505 (78)
TSS (mg/L)	64 5 (92)	NS	NS	360 <5 (99)	NS	NS
Oil & Grease (mg/L)	NS	NS	NS	13 4 (69)	NS	NS

1. NS – No Sample
2. ND – Non-Detectable
3. Yellow − effluent>influent

Table 22. ANAD Composite Sampling Results

Pollutant	ANAD Composite Results (1)					
	10/17/06 Influent Effluent (% Removed)	**11/15/06** Influent Effluent (% Removed)	**1/18/07** Influent Effluent (% Removed)	**2/13/07** Influent Effluent (% Removed)	**3/16/07** Influent Effluent (% Removed)	**4/4/07** Influent Effluent (% Removed)
Copper (mg/L)	0.0363 0.0486	0.0623 ND (98)	0.0222 ND (95)	0.0389 ND (97)	0.0374 ND (97)	0.0382 ND (97)
Lead (mg/L)	0.0096 0.0055 (43)	0.0445 ND (89)	0.00951 ND (47)	0.0331 0.0051 (85)	0.0286 ND (83)	0.00570 ND (8)
Zinc (mg/L)	0.0912 0.134	0.179 ND (94)	0.0724 ND (86)	0.176 ND (94)	0.176 ND (94)	0.0813 ND (88)
Diesel (µg/L)	3740 3030 (19)	1210 175 (86)	284 ND	2590 371 (86)	NS	NS
TSS (mg/L)	NS	NS	NS	160 <5 (97)	NS	NS
Oil & Grease (mg/L)	NS	NS	NS	7 6 (14)	NS	NS

1. NS – No Sample
2. ND – Non-Detectable
3. Yellow − effluent>influent

Sampling personnel were not able to collect sufficient quantities of storm water to run the entire analyses for oils and grease. This was caused by limited storm water available from the low intensity storms events. As a result, oil and grease removal efficiency could not be determined at Anniston. However, no sheen was reported in the influent or effluent by sampling personnel during the demonstration period. Rainbow oil sheen on water is generally accepted to have an oil concentration greater than 15 mg/l. Consequently, no correlation between influent oils and grease concentration and impact on heavy metal removal in the effluent could be made at the Anniston demonstration.

The limited grab and composite sampling results for TSS indicates removal efficiencies greater than 90 percent.

5.0 COST ASSESSMENT

5.1 Cost Reporting

Cost reporting and comparison of the dual media storm water filtration system provides an assessment of the technology cost, and its applicability to DoD installations as pollution prevention and an environmental investment. Implementing any storm water treatment system at military installations involves new capital and operating costs. And like many industrial installations, neither NRRC nor ANAD had storm water treatment systems in place. NRRC was facing the prospect of having to capture and dispose of the first ¼ inch of potentially hazardous storm water runoff from the site, and ANAD was concerned about pollution of nearby water bodies with contaminants and metals from their runoff.

The baseline for cost comparison used in the Environmental Cost Analysis Methodology (ECAM) is the hypothetical installation and implementation of a tank and pump system. This system would require capacity for the first ¼ inch of rainfall on the 3.5 acre NRRC site (approximately 25,000 gallons). An additional comparison is against an installed COTS cartridge filter at a shipyard five miles from the NRRC site, facing the same regulatory pressures and having the same typical rainfall patterns as the NRRC.

As background to understanding what is being compared, flow diagrams are provided for each management scenario including existing condition. Figure 32 shows the process flow diagram for the storm water management practice before the demonstration units were installed at NRRC and ANAD.

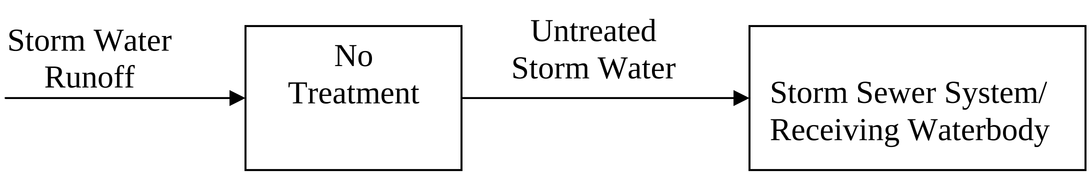

Figure 32. Existing Storm Water Management at NRRC and ANAD.

Figure 33 shows the process flow diagram for what NRRC would have been required prior to the installation of the dual media storm water filtration system.

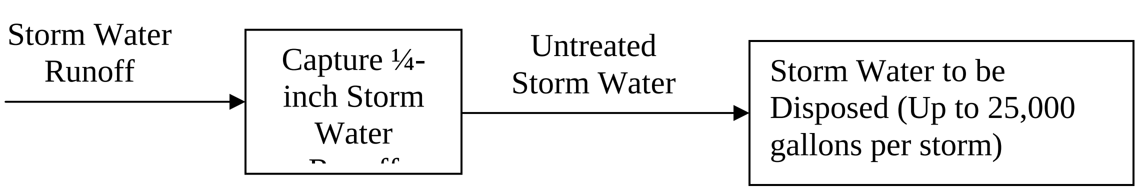

Figure 33. Potential Storm Water Management Requirement at NRRC.

Figure 34 shows the process flow diagram for the storm water management at NRRC after installation of the dual media storm water filtration system.

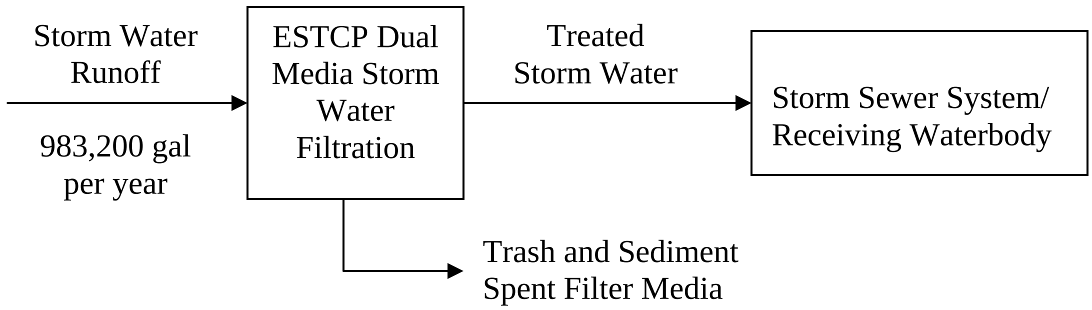

Figure 34. Process Flow Diagram for NRRC with Dual Media Storm Water Filtration System.

Figure 35 shows the process flow diagram for the storm water management at ANAD after installation of NAVFAC ESC's dual media storm water filtration system.

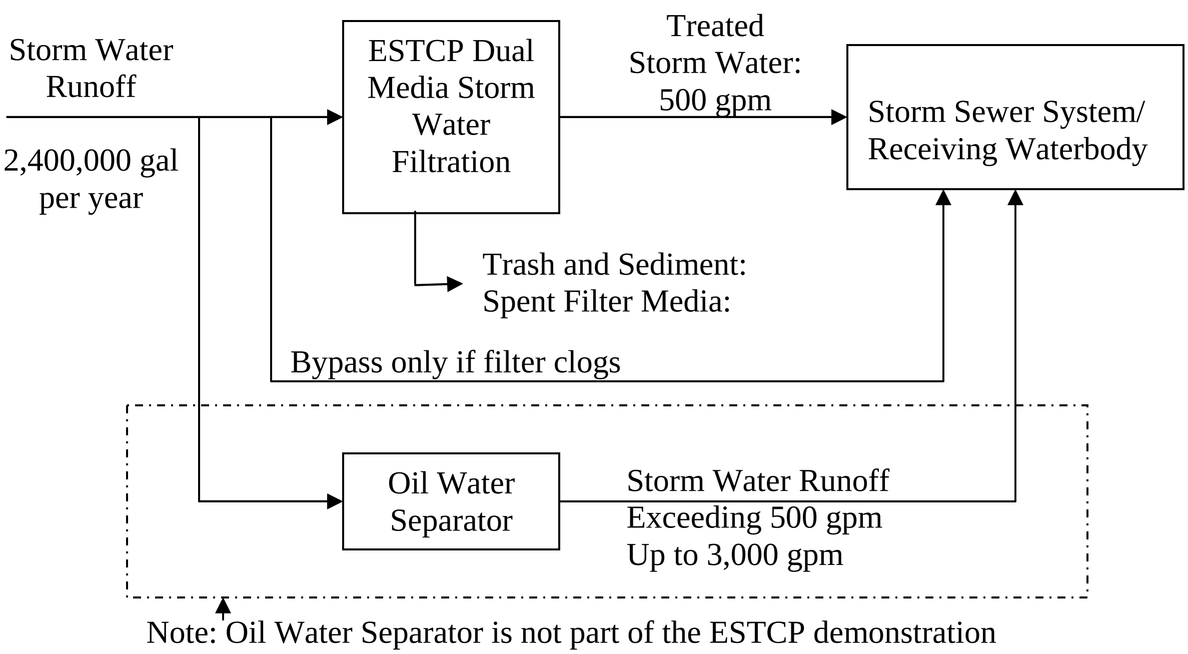

Figure 35. Process Flow Diagram for ANAD with Dual Media Storm Water Filtration System.

Total equipment and material cost for the 3.55 acre NRRC site excluding instrumentation is $52,300. The direct capital costs used in the ECAM analysis of the dual media storm water filtration system include the purchase of pre-cast concrete containment, filter media (FS-50, bone char, coarse gravel, and pea gravel), slotted PVC drain pipes, float valves, and associated minor equipment and material such as pipes, couplings, and grout. The costs of sampling and flow monitoring equipment (flow meter, metering manhole, automatic samplers, and data logger) are not included, since these costs would not be a normal expense for installing a storm water treatment system.

The design investment cost at NRRC is $15,500 and includes the site survey, engineering, and hydraulic analysis.

The installation cost is estimated at $43,000. This cost covers excavation, grading, leveling, compacting, concrete containment placement, media placement, manifold installation, and sewer system connections. This estimating installation costs is considered moderately higher than normal because the implementation site was on an Industrial Remediation (IR) site and the system was installed directly above a high voltage concrete vault due to lack of available space and location/elevation of discharge point. These two conditions are not considered normal site conditions. Actual costs were not de-rated in the ECAM model.

The total annual maintenance cost is approximately $1,700. The major task associated with annual maintenance of the DMFS is the periodical replacement of the top layer of pea gravel (approximately 1.35 tons). Estimations show that the pea gravel requires annual replacement at a cost of $45 per ton. The spent gravel will require hauling (as a non-regulated hazardous waste) and disposal as a solid waste. Hauling is estimated at $1000 per year and disposal at a fee of $41 per ton, which includes the facility disposal fee and taxes. Labor is estimated at $500.

No startup costs or operator training costs were incurred for this system. Once the system was installed, it was ready to operate without human intervention.

Indirect costs may include permit re-application and negotiation, permit fees, monitoring, storm water pollution prevention plan updating, and reporting requirements. However, the additional indirect costs should be minor or none in most cases since these costs would be incurred with or without the storm water filtration technology.

Based on media cost at installation, a one time, conservative media replacement cost of $18,000 for 5.7 tons of media at year 10 is added to the annual operating section. Based on a recent study evaluating the adsorption capacity of the FS-50 media, historic rainfall data, and storm water heavy metal loading profiles, the filter media is predicted to actually last at least 30 years before needing replacement. However, for purposes of this analysis it was de-rated to a 10 year service life. The replacement cost includes an estimate of $5,700 for labor and equipment and disposal fees of $600 per ton for a hazardous waste.

The baseline capital cost on the capture and disposal of the first ¼ inch of storm water runoff by a tank and pump system is $90,000 (materials and installation). The annual operating cost is $37,500. The estimates are based on the RS Means construction cost reference manual for an above ground storage tank system with associated pipes and pumps, an estimated average of

150,000 gallons of storm water captured per year (estimating 6 storm events) for disposal, and $0.03 per pound disposal cost for the captured storm water.

The COTS cartridge system at the nearby shipyard cost a total of $530,000 for a 9.2 acre site, including the costs for validating the technology. Since validation costs were not included in the dual media filtration system analysis, the costs for validating the cartridge system were deducted. The total cost was further reduced proportionally to reflect equivalent watershed areas (9.2 acres to 3.5 acres). The comparable capital cost (materials and installation) used for the cartridge system is approximately $203,000 and the annual operating cost is $14,200.

Table 23 shows the direct and indirect costs that were incurred for NRRC San Diego.

Table 23. Cost Data for NRRC San Diego (Annualized)

Direct Costs				Indirect Costs		Other Costs	
Start-up		Operation					
Activity	$K[1]	Activity	$K	Activity	$K	Activity	$K
Design	1.5			Reporting requirements	See Below	None	None
Media purchase (initial)	1.9	Media replacement	2.7	Monitoring, inc. chemical analysis	See Below		
Equipment purchase	3.4			Test waste streams	0.2		
Installation	4.3			Permit fees	See Below		
		Annual Maintenance (Top layer)	1.7	Document maintenance	See Below		
				Permit / Document Update	4.0		
Total	11.1		4.4		4.2		0
Grand Total	19.7						

[1] Cost are in thousands of U.S. dollars ($K)

Table 24 shows the direct and indirect costs that were incurred for ANAD Alabama.

Table 24. Cost Data for ANAD Alabama (Annualized)

Direct Costs				Indirect Costs		Other Costs	
Start-up		Operation					
Activity	$K[1]	Activity	$K	Activity	$K	Activity	$K
Design	1.5			Reporting requirements	See Below	None	None
Media purchase (Initial)	4.8	Media replacement	$6.1	Monitoring, inc. chemical analysis	See Below		
Equipment purchase	4.5			Test waste streams	0.2		
Installation	4.1			Permit fees	See Below		
		Annual Maintenance (Top layer)	1.2	Document maintenance	See Below		
				Permit / Document Update	See Below		
Total	14.9		7.3		0.2		0
Grand Total	22.4						

[1] Cost are in thousands of U.S. dollars ($K)

No fees are associated with modifying the CRWQCB permit for storm water discharges. Annual fees apply for California NPDES permits, but these fees would have applied with or without the storm water treatment system.

The system at ANAD was installed in the summer of 2006. Media replacement cost is estimated and annualized based on the actual media cost incurred during system installation. It is estimated that the top layer of pea gravel will need to be replaced every five years at a cost of $27 per ton, with 3 tons needed, and a solid waste disposal fee of $34 per ton. An estimate of $6,000 is used for labor and equipment for replacing the pea gravel. We also assumed that the filter media will need to be replaced every 10 years, though it is very likely that the media has the capacity to last longer, possibly up to 30 years. The system uses 13,000 pounds of bone char and 20,000 pounds of FS-50. An estimate of $13,000 is used for labor and equipment for replacing the filter media. The cost of labor is higher for pea gravel and media replacement at ANAD than NRRC due to site specific differences. The system at ANAD is buried underground and will likely require earthwork to remove the lids over the media bed.

5.2 Cost Analysis

The economic analysis performed on the NRRC dual media storm water filtration system was completed using the ESTCP approved Environmental Cost Analysis Methodology (ECAM) cost estimating tool. The majority of the cost analysis is focused on the data from the NRRC site. The NRRC dual media filter system provides a cost benefit over the baseline and the COTS technology. The ECAM analysis indicates the Net Present Value (NPV) of the dual media storm water filtration system at NRRC is $235,762 at 10 years with a discounted payback of 0.65 years. Based on actual adsorption tests, the media should actually last up to 30 years without requiring change out, which provides a higher NPV than reported and a much higher NPV than the baseline.

Cost of procurement and installation of the dual media storm water filtration system at ANAD is approximately the same magnitude as the NRRC despite the doubled design flow rate. Since ANAD does not have specific requirements for rainwater capture nor does the recently installed oil water separator target the same pollutants as the dual media storm water filtration system, a complete ANAD analysis was not done and the oil-water separator was not included in the ECAM comparison analysis.

5.2.1 Cost Comparison

The ECAM analysis indicates that the dual media storm water filtration system has greater cost savings when compared to both the COTS cartridge filters implemented at the nearby shipyard and the theoretical installation of a pump and tank system. While the initial costs for the dual media storm water filtration system are approximately $20,000 more than the baseline, the annual costs are 10 times lower per year making up for the initial investment in less than one year. The initial and annual costs are lower for the dual media storm water filtration system than the COTS alternative. In addition, the NPV of the dual media storm water filtration unit at NRRC is $235,762 and the Cartridge system is $174,604, based on a 10 year life cycle, a difference of $61,158 over 10 years.

From a standpoint of implementation at other industrial activities, there is other tangible cost benefits not calculated here that can be realized with the dual media storm water filtration system.

- Longer service life in submerged conditions (where the media bed is unable to completely drain and dry between storm events) as compared to compost adsorption media cartridge filters.
- Reduced depth of excavation (as shallow as three feet) when compared to depth requirement needs for COTS cartridge technology.
- Reduced logistics for maintenance, i.e., no air purging system and ambient air pumps required to enter confined space vault as required for cartridge filter vault.
- Reduced human exposure to the media and any heavy metal contaminants since the media can be removed with mechanical suction equipment and/or backhoes.
- Easier containment and clarification of any accidental spills to the storm systems.
- Fewer NOVs and better protection of the environment because of better pollutant removal efficiency.

5.2.2 Cost Basis

The basis for the cost of the dual media storm water filtration system was throughput of water to be treated (i.e., ¼-inch of water captured from NRRC), cost of the equipment installed, cost of the materials purchased, and the anticipated maintenance costs of each system. This was compared to the COTS technology used near NRRC and the hypothetical installation and implementation of a tank and pump system. Given these two scenarios, the economic evaluation was constructed and compared.

5.2.3 Cost Drivers

The cost of the implementing a dual media storm water filtration system is highly variable and are briefly discussed because they will impact the overall cost for activities interested in implementing the technology. Site conditions such as the size of the runoff area, rainfall characteristics (intensity and duration) and pollutant loading will have a dramatic effect on cost on the dual media storm water filtration system or any storm water BMP implementation. Other factors that could affect the cost of the system include runoff coefficient, water table, topography, receiving water/sewer elevation, and runoff contaminant characteristics. An area with a larger drainage basin size would require a larger system. Areas that tend to have more intense rainfall will also require a larger system or the addition of a holding tank to accommodate the additional water. The topography of the drainage basin as well as the receiving water/sewer elevation would influence whether a pump is needed or not. The runoff contaminant characteristics would influence the frequency required for cleaning the top layer of pea gravel as well as the frequency of changing out the media. Other factors include location of the site with regards to proximity to landfill disposal sites and shipping distance for from media distribution points. Local wages and construction cost will impact final cost.

6.0 IMPLEMENTATION ISSUES

6.1 Environmental Checklist

6.1.1 Navy Regional Recycling Center, San Diego, California

Storm water discharges are regulated under the CWA through the NPDES permitting program. The Office of the Commander Naval Region Southwest worked with the CRWQCB, San Diego Region, to get a modification to the existing storm water NPDES permit to allow the installation of the storm water dual media filter system. The modification is entitled, "Addendum No. 1 to Order No. R9-2002-0169, NPDES Permit No. CA0109169."

Federal law governing the proper management of hazardous and non-hazardous solid waste is the Resource Conservation and Recovery Act (RCRA). Federal regulations related to hazardous waste can be found in 40 CFR Part 261. California regulations can be found in the California Code of Regulations, Title 22 Chapters 11 and 12.

NRRC should follow California regulations for determining hazardous waste given that California regulations are presently more stringent than federal regulations. Solid waste generated by the storm water dual media filter system, such as spent media and trapped sediment, should be tested using the Waste Extraction Test (WET) procedure each time the system is maintained to ensure that it cannot be characterized as a hazardous waste.

Demonstration period WET results for sediment and gravel that were sampled from the top layer of the dual media filter system during annual maintenance indicate that the solid waste can likely be disposed of as non-hazardous. Test results from the bone char and activated alumina showed that the heavy metal content hadn't reached a concentration level that would require testing as a hazardous waste. However, spent media requiring replacement upon reaching the end of its lifespan will likely have to be disposed of as hazardous waste and should be budgeted accordingly.

6.1.2 Anniston Army Depot, Alabama

The Directorate of Risk Management at ANAD has determined that a new NPDES permit or a permit modification was not required to install the demonstration storm water treatment system. This is because the permit governing the discharge from the demonstration site requires only that the discharge be monitored and not meet specific discharge limits.

Alabama regulations related to hazardous waste generally follow the Federal regulations and can be found in Alabama Department of Environmental Management Administrative Code Chapter 335-14-2.

6.2 Other Regulatory Issues

6.2.1 Navy Regional Recycling Center, San Diego, California

Another regulatory issue is the amount of metals that enter San Diego Bay if the storm water runoff is "terminated" as compared to if the storm water runoff is treated. CNRSW expects that the reduced amount of contaminants that enter San Diego Bay when the runoff is treated as compared to when only the first ¼-inch is "terminated" to a be significant factor in convincing regulators to approve this technology for widespread use.

The amount of water that CRWQCB Order R9-2002-0169 requires to be "terminated" will be 43,560 sq ft/acre x 0.25 inch/12 x 7.48 gal/cu ft = 6,788 gallons per acre per storm for each storm. Assume that all storms of greater than ¼-inch of rainfall (15 storms total) produce at least ¼-inch of runoff, i.e., all rainfall runs off. For the 3.55 acres of paved area at the NRRC, this amounts to 24,100 gallons of water that will have to be collected and either 1) stored for haul away to a disposal site or 2) slowly released into the sanitary sewer system (if permitted). A total of 24,100 gallons/storm x 15 storms/ year = 361,500 gallons/year must be "terminated".

Historically, the average annual rainfall in San Diego is 10.2 inches. Thus, 43,560 sq ft/acre x 10.2/12 x 7.48 gal/cu ft x 3.55 acres = 983,200 gallons runs off the NRRC site. Thus, only 37% of the rainfall will be terminated under the CRWQCB ¼-inch rule. In years when the size or number of storms exceed the historical average, the proportion of runoff terminated will be lower than 37%. By comparison, if a treatment system is installed, more than 90% of the water will always be treated.

6.2.2 Anniston Army Depot, Alabama

There are no other regulatory issues associated with the Anniston Army Depot.

6.3 End-User Issues

The end users of this project are DoD industrial activities that generate storm water runoff that contains toxic metals, TSS, and some organic compounds. These industrial activities include shipyards, ship repair facilities, recycling centers, storage yards, and certain metal working and painting shops.

Potential end users in the San Diego area include the Naval Station San Diego, Naval Air Station North Island, Amphibious Base Coronado, Marine Corps Base Camp Pendleton, Naval Supply Center San Diego, Submarine Base Point Loma, and the Ship Intermediate Maintenance Center San Diego. Each of these activities has multiple storm water outfalls.

The primary stakeholder issues related to the technology are regulator acceptance, permitting requirements, and maintenance requirements.

Commander Navy Region Southwest (CNRSW) is an example of a major stakeholder in California. CNRSW holds the discharge permits for all Navy and Marine Corps activities in the

San Diego area and is responsible for compliance. CNRSW needs to work closely with the CRWQCB to permit use of the dual media filter system. Based on the success of the dual filter media system at NRRC, CNRSW is currently designing a second system at the nearby Defense Reutilization Management Organization that has a similar storm water issue.

The dual media storm water filter system is a combination of commercially available components that are customized to meet site-specific end user requirements. The system could eventually be made available in modular units that treat a specific volume of storm water. The technology is scalable in a 1:1 ratio. If the runoff volume at a site is double that at NRRC, the size of the treatment system will double; if the runoff volume is half, the size of the treatment is will be halved.

NAVFAC ESC is currently working with TechLink, a partnership intermediary sponsored by the DoD and NASA, to license the technology to commercial vendors. There should be no technical or economic impediments to technology transfer or commercialization.

NAVFAC ESC will also coordinate with the Army Installation Management Command and Army Center for the Application of Sustainable Innovations, hosted at the Army Engineering Research and Development Center's Construction Engineering Research Laboratory to facilitate the transfer of the technology within DoD. The technology transfer process with the Army will begin by providing the demonstration results to the aforementioned organizations.

The findings of this demonstration will be incorporated into the Navy Unified Facilities Criteria: *Low Impact Development Manual (draft)*, November 2002, prepared by the Naval Facilities Engineering Command, and similar Army Corps of Engineers documents. The results of the demonstration will be added to the Navy *Storm Water BMP Decision Support System* web site, and presented at the annual DoD Pollution Prevention Conference, the biennial Navy and Marine Corps Water Quality Manager's Conference, and similar Army venues (See we blink: https://www.denix.osd.mil/portal/page/portal/denix/publications/source/Navy/Currents/2006/Winter/Win06_Technology_Tips.pdf).

7.0 REFERENCES

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Richard Kirts, Mark Foreman, Gary Anguiano, Nov 2004. *Removal of Toxic Metals from Storm Water Runoff at Naval Installations*-NAVFAC ESC Technical Report TR-2256-ENV

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https://www.denix.osd.mil/portal/page/portal/denix/publications/source/Navy/Currents/2006/Winter/Win06_Technology_Tips.pdf

(EPA web site: http://www.epa.gov/owmitnet/mtb/sandfltr.pdf **).**

8.0 POINTS OF CONTACT

Table 25 lists the points of contact that participated in the demonstration.

Table 25. Points of Contact

Point Of Contact Name	Organization Name Address	Phone/Fax/Email	Role in Project
Gary Anguiano P.E.	NAVFAC ESC 1100 23RD Avenue Port Hueneme, CA. 93043	(805) 982-1302 (voice) (805) 982-4832 (fax) gary.anguiano@navy.mil	NAVFAC ESC Principal Investigator
Mark Foreman	NAVFAC ESC 1100 23RD Avenue Port Hueneme, CA. 93043	(805) 982-1334 (voice) (805) 982-4832 (fax) mark.foreman@navy.mil	NAVFAC ESC Mechanical Engineer
Gene Fabian	U.S. Army Aberdeen Test Center CSTE-DTC-AT-SL-F 400 Colleran Road APG, MD. 21005-5059	(410) 278-7421 (voice) (410) 278-1589(fax) gene.fabian@atc.army.mil	Technology transfer specialist and QA officer
Neil Weinstein P. E.	Low Impact Development Center, Inc. 5010 Sunnyside Avenue, Suite 200Beltsville, MD 20705	(301) 982-5559 (voice) nweinstein@lowimpactdevelopment.org	Consultant and deputy QA officer
Ronald Levy	Anniston Army Depot 6 Frankfort Ave (AMAST-AN-RKR) Anniston, AL 36264-4199	(256) 235-4804 (voice) Ron.Levy@us.army.mil	ANAD representative
Charlie Ketcham	Navy Region, Southwest Mainside Complex 4790 Cummings Road, San Diego, CA 92136-5610	(619) 556-5149 (voice) (619) 556-9018 (fax) Charles.Ketcham@navy.mil	NRRC representative
Rob Chichester	CNRSW Environmental Department (Code N45) San Diego, CA 92132-0058	(619) 532-2611 (voice) Rob.chichester@navy.mil	NRRC Regulatory Review
Tracy Williams	Anniston Army Depot 7 Frankfort Ave (AMAST-AN-RKR) Anniston, AL 36201-4199	(256) 235-7947 (voice) tracy.lynne.Williams@us.army.mil	ANAD Environmental Oversight
Marti Elder	TechLink Licensing & SBIR 2611 Westridge Dr. Bozeman, MT 59715	(406) 586-7621 (voice and fax) www.martielder.com	Technology Transfer

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APPENDIX A

Analytical Methods Supporting the Experimental Design

The test methods utilized for each parameter at NRRC and ANAD are shown in Table 12 of Section 3.7 of this document. USEPA or Standard Methods (SM) were used to evaluate the effectiveness of the dual storm water runoff treatment system.

All testing was performed in Government or commercial analytical laboratories that hold EPA certification. The Navy Environmental Chemistry Laboratory at NAS North Island performed analytical testing on NRRC storm water samples.

TestAmerica, certification type DW and certification number 02008, performed analytical testing on ANAD storm water samples.

Section 7, References, provides citations for the USEPA and SM that were used for the demonstration.

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APPENDIX B

Data Quality Assurance/Quality Control Plan

Purpose and Scope of the Plan

The purpose of the Quality Assurance (QA) plan was to ensure that the data collected during this demonstration project is of sufficient quality to fulfill the project objectives. This was accomplished by adhering to a Standard Operating Procedure (SOP) for control of the sampling process, performing audits, ensuring sampling personnel are adequately trained and that sufficient laboratory checks are performed (i.e., blanks, duplicates and spikes).

Quality Assurance Responsibilities

The primary responsibility for Quality Assurance belongs to each project performer. However, Mr. Gene Fabian acted as the project's Quality Assurance Officer. An NAVFAC ESC senior engineer, not directly involved in the project, will provided peer review of the final report. Mr. Neil Weinstein of Low Impact Development Inc. acted as backup quality assurance officer.

Data Quality Parameters

Parameters that generally influence data quality for storm water runoff sampling include sampling methodology, (collection method, and equipment operations), laboratory clean sampling procedure, accuracy of lab instrumentation, and competence of the performing technicians (field and lab). Since the primary pollutants of concern, copper and zinc, were measured in the part per billion levels, (limits of 50 ppb and 100 ppb respectively) it is imperative that sufficient efforts were made to prevent contamination of the sampling equipment during setup, transport and testing. A standard operating procedure (SOP) was established and approved at the onset of the demonstration to clearly outline sampling methodology, equipment cleanup, instrument calibration, and shipping. Once the SOP was established, adherence to clean sampling was performed throughout collection, shipping and testing with deviations noted in logbooks. Sampling for this storm water BMP demonstration consisted of capturing influent and effluent grab/composite samples for a minimum of three storm water events during the rainy season. To the extent practical, one of these rain events was the “first flush” of the rainy season and measured within 30 minutes of significant precipitation.

To maintain data quality objective, the same sampling technicians performed equipment calibration, decontamination/cleanup of sampling equipment, setup and sampling. Automated sampling equipment was purged with de-ionized water. A single EPA approved laboratory was used for all testing. Constant checks as to the precision, accuracy, repeatability, completeness and consistency of the laboratory and field sampling was performed. This was accomplished by lab analysis of duplicates, spiked samples and field blanks (to insure cleanliness of the sampling container, and preservative purity).

The types of samples that were utilized during the study include various authentic samples and quality control (QC) samples. The QC samples used include blanks, splits, composites, duplicates and spikes (fortified with an analyte or surrogate of interest). The general use of these sample types is discussed below.

Laboratory blank samples were used to detect systematic analytical problems during analysis. A laboratory blank is a “clean” sample, which is produced in the laboratory. Typically, laboratory blanks are composed of de-ionized water or uncontaminated soils.

A split sample is one sample that is divided equally into two or more sample containers and then analyzed separately. Split samples are used to measure analytical precision. Often the sample preparation process or the method of analysis for one analyte is destructive or modifies the sample with respect to a different analyte. Sample splits were then used to conduct different analyses on the same representative sample. Additionally, a split sample may be handled as a blind sample for analysis by the laboratory.

A composite sample is a single sample combined or composited from a number of smaller samples. Composite samples are useful for cases in which the sample preparation or analysis requires large sample amounts.

Duplicate samples are differentiated from split samples in that duplicate samples are obtained when two samples are taken from the same site, at the same time, using the same method, and independently analyzed in the same manner. These types of samples are representative of the same environmental condition. Duplicates can be used to detect the variability in the treatment, testing, and analysis.

Matrix spike (MS) samples are environmental samples to which known concentrations of compounds are added. The added compounds are chemically similar to the analyte group but not expected to occur in the environmental samples (typical for organic compounds and known as surrogates), or are known components of target analytes (typical for metals analyses). The spiked samples are then processed through the entire analytical procedure, and percent recovery of the spike is calculated. Recovery of the matrix spike analytes is used to monitor for unusual matrix effects or gross sample processing errors.

Matrix spike duplicate (MSD) samples are a second aliquot of an environmental MS sample. The samples are spiked with identical concentrations of target analytes and then processed through normal sample preparation and analysis procedures. MSD samples are used to document the precision and bias of a method in the sample matrix.

Sample Labeling, Custody and Shipping

Written procedures for sample tracking and custody were followed. In brief, custody was relinquished to the Laboratory Sample Custodian. Upon receipt, the Sample Custodian examined the samples, verified that the sample-specific information is recorded on the custody form agrees with the sample label, verified that sample integrity is uncompromised, logged the samples into the Sample Log System, and signed the custody form. Unique laboratory IDs were assigned to each sample. Any discrepancies between sample labels were be documented on the custody forms and the principal investigator was notified immediately. All samples released to laboratory personnel for analysis were accompanied by sample transfer documentation.

Representativeness

Representativeness is the degree to which data represent a characteristic of a population. The representativeness of the data was addressed primarily in the experimental design, through the selection of appropriate samples and analytical procedures. It was also be ensured by the proper collection, handling, storage of samples, and analysis within the specified holding times so that the material analyzed reflects the material collected as much as possible.

Sample representativeness were maintained in the laboratory through appropriate handling, storage, and clean techniques, which minimized contamination.

Documentation associated with laboratory analyses included sample receipt and log-in records, sample processing logs, sample preparation records, sample tracking records, analytical instrument printouts, and equipment logs. Details of laboratory documentation were included in the analytical written records. Initially, all data was recorded either (1) electronically onto computer storage media from laboratory systems or (2) manually into laboratory notebooks or on established data forms. All notes were written in ink. Corrections to hand-entered data were initialed, dated, and justified. Completed forms, laboratory notebooks, or other forms of hand-entered data were signed and dated by the individual entering the data. It was the responsibility of the laboratory manager and principal investigators to ensure that all data entries and hand calculations were verified. Laboratory records of sample preparation were maintained in sample batch books. In addition to these documentation requirements, sample logs associated with field and laboratory custody and tracking were maintained in project files.

Completeness

Completeness is defined as the amount of data collected as compared to the amount that is needed to make valid decisions. The completeness of the study was evaluated by reconciling the chain-of-custody forms received by the laboratory with the list of samples analyzed. One hundred percent of the samples that are received intact were analyzed for target parameters. All samples were analyzed for the parameters discussed below. If any samples are missed, then the principle investigators evaluated the affect the missing data had on evaluating the objectives and took appropriate action.

Comparability

Comparability is the measure of the confidence with which one data set can be compared to another. Comparability is addressed through the use of established laboratory methods (e.g., U.S. Environmental Protection Agency; California Environmental Protection Agency; American Society for Testing and Materials; American Public Health Association). All deviations from written protocols or established laboratory methods were documented and described in the data report.

Accuracy

Accuracy is the agreement between an observed value and an accepted value. Analytical accuracy was evaluated based on the recoveries of analytes from MS samples, and the recovery of surrogate internal standards used for organic analyses.

The quality control samples, their frequency, and acceptance criteria are listed in table below. All corrective actions were documented. Acceptance of out-of-range QC results must be justified in writing and approved by the Principle Investigators. There are no established criteria for acceptance of out-of-range QC. The principle investigators reviewed the cause of any out-

TABLE OF DATA QUALITY OBJECTIVES FOR STUDY

Variable	QC Sample Type or Measurement Procedure	Frequency of Use	Data Quality Objective
Analytical Chemistry			
Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES)	Method Blank Duplicate Sample Matrix Spike Matrix Spike Duplicate Calibration (Target Compounds)	1 per analytical batch 1 per analytical batch 1 per analytical batch 1 per analytical batch 1 per analytical batch	< PQL[1] RPD[2] <30% Recovery 50 - 150% RPD <30% r^2[3] $\geq$ 0.995
Total Suspended Solids (TSS)	Method Blank Duplicate Sample SRM[4] LRM[5]	1 per analytical batch 1 per analytical batch 1 per analytical batch 1 per analytical batch	< PQL RPD <30% RPD <30% RPD <30%
Oil and Grease (O&G)	Method Blank Duplicate Sample	1 per analytical batch 1 per analytical batch	< PQL RPD <30%

[1]Practical Quantitation Limit - 5 times the minimum detection limit (MDL) listed in SW846 method.
[2]RPD - Relative percent difference.
[3]r^2 - Coefficient of determination.
[4]SRM - Standard reference material.
[5]LRM - Laboratory reference material.

of-range QC data and evaluate data acceptability for supporting the evaluation of objectives on a case-by-case basis. Any QC deviations and corrective actions will be summarized in the case narrative supplied with each batch of analytical data.

Precision

Precision is defined as the degree of reproducibility among individual measurements of the same property, obtained under similar conditions. Measure of analytical precision was determined by the analysis of laboratory-prepared MSD samples. Analytical precision for laboratory analyses was determined using the concentrations of duplicate samples (e.g., MS/MSD samples) with percent differences between duplicate analyses serving as a measure of precision.

Sensitivity

Sensitivity is the capability of the methodology or instrumentation to discriminate among measurement responses for quantitative differences or a parameter of interest. Method detection limits (MDLs), defined by the EPA in 40 CFR 136, Appendix B, *Definition and Procedure for Determination of the Method Detection Limit* have been determined for the target analytes of interest for this project. In cases where MDLs are not available, practical quantitation limits (PQLs), defined as the concentration of an analyte in a sample equivalent to the analytical instrument lowest calibration standard, have been determined.

Calibration Procedures, Quality Control Checks, and Corrective Action

All field and laboratory equipment/instruments were calibrated as required by standard methods outlined by the manufacturer. If there are discrepancies in the data, instruments will be calibrated more frequently. Instruments will undergo initial calibration and require 0.90 correlations. Continuing calibration requires an acceptance criterion of ±10% of the true result. The final Technical Report will include a description of methods, observations and results. In addition, data anomalies will be included and discussed.

The quality control checks incorporated in the analysis of samples included such quality control samples as blanks, reagent blanks, duplicate samples, matrix spike and matrix spike duplicate samples. The EPA Methods prescribe the specific quality control measures to be used and frequency of those quality control samples for all analytical methods to be used. Descriptive statistics such as the mean, variance, and standard deviation were used to describe and evaluate the results of sample analysis. Analytical precision was evaluated using the concentrations of duplicate samples and/or MS/MSD to calculate the RPD between replicate analyses.

As often as possible, the need for corrective action was identified by technical staff during the course of their work or through QAU audits. Each individual performing laboratory or data processing activities was responsible for notifying the appropriate supervisory personnel of circumstances that could affect data quality or integrity.

Technical problems in the laboratory, such as sample loss, improper instrument calibration, or out-of-compliance QC results, were first addressed by the laboratory staff and managers.

Significant technical issues were brought to the attention of the Program Manager. Issues that affect the cost, schedule, or performance of the project were reported to the Program Manager. Subsequently, the Project Manager was responsible for evaluating the overall impact of these issues on the project and implementing the necessary corrective actions.

Deficiencies identified through QAU audits were brought to the attention of the Program Manager. Implementing corrective actions was the responsibility of the Program Manager.

Demonstration Procedures

The demonstration consisted of performing grab and composite samples taken before and after the dual media infiltration trench using automatic storm water sampling devices (SS201 Global Water Storm water Sampler). Trash and Sediment control was placed upstream of influent sampling equipment to prevent blockage of the sampler inlets. Three distinct storm water events were captured. Samples were drawn for each storm event (natural and/or artificial rain event) using a configuration approved by CRWQCB. Trained field technicians insured sampling containers are properly labeled, maintained and preserved. Upon collection, a chain of custody form was filled, signed and delivered to the laboratory with the preserved samples. Samples were delivered directly to the EPA certified laboratory for testing of total copper and zinc metals using EPA Method 200.7 (or equivalent) within 48 hours of each storm event. Samples were collected, stored, packaged and preserved as dictated by approved laboratory. Since pollutant loading varies with time, a lag time was accessed to capture influent/effluent samples at prescribed timed interval.

ISO 14001

NAVFAC ESC, the principle organization responsible for this demonstration, is not ISO 14001 certified.

Data Format

ICP data was acquired and reduced by the performing analytical laboratory. ICP data was acquired on hardcopy reports and the data entered manually into a PC. All data files were transferred electronically to a PC so that the data can be incorporated into an electronic file for final quantification and tabular results presentation. The data reduction and reporting included the following:

- MDLs were applied on a sample specific basis and qualified.
- Concentrations of the target compounds were presented on dry and wet weight basis. Analytes that were not detected were reported as less than the established MDL.
- Results of procedural blank analyses. Samples may be blank corrected at the discretion of the principal investigator if a consistent, but low-level of background was noted. If data are blank corrected, both the original and the blank corrected data were reported. If data are blank, corrected justification were provided.
- Amounts expected and recovered, and percent recoveries, for MS and MSD samples. Comparisons between the MS and the MSD samples were reported as RPD.

- Results of replicate analyses. Results of analyses of LRM, SRMs, certified values, and the RPD between the results and the certified values.

Test data was acquired both electronically and on paper.

Data Storage and Archiving Procedure

The Principal Investigator (PI) maintained all correspondence, documentation, raw data, and records generated as a result of this demonstration project at NAVFAC ESC for a period of one year after projection completion. The information was collected in its originally generated form (i.e., paper or electronic). The ESTCP Final Report, in paper and electronic versions, will be maintained by the NAVFAC ESC Technical Information Center. The POC for the Technical Information Center is Bryan Thompson at (805) 982-1124.

Documentation associated with laboratory analyses includes sample receipt and log-in records, sample processing logs, sample preparation records, analytical instrument printouts, and equipment logs. Initially, all data was recorded either (1) electronically onto computer storage media from laboratory systems or (2) manually into laboratory notebooks or onto established data forms. All notes were written in ink. Corrections to hand-entered data were initialed, dated, and justified. Completed forms, laboratory notebooks, or other forms of hand-entered data were be signed and dated by the individual entering the data. It was the responsibility of the laboratory managers to ensure that all data entries and hand calculations were verified. Laboratory records of sample preparation were maintained in sample batch books. In addition to these documentation procedures, sample logs associated with field and laboratory custody and tracking were maintained in custody files. Manually recorded data from subcontractor laboratories was entered by the subcontractor into PC-based spreadsheets and submitted.

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APPENDIX C

NRRC and ANAD Field Data

NRRC Real Time Rainfall, Flowrate, and Total Flow

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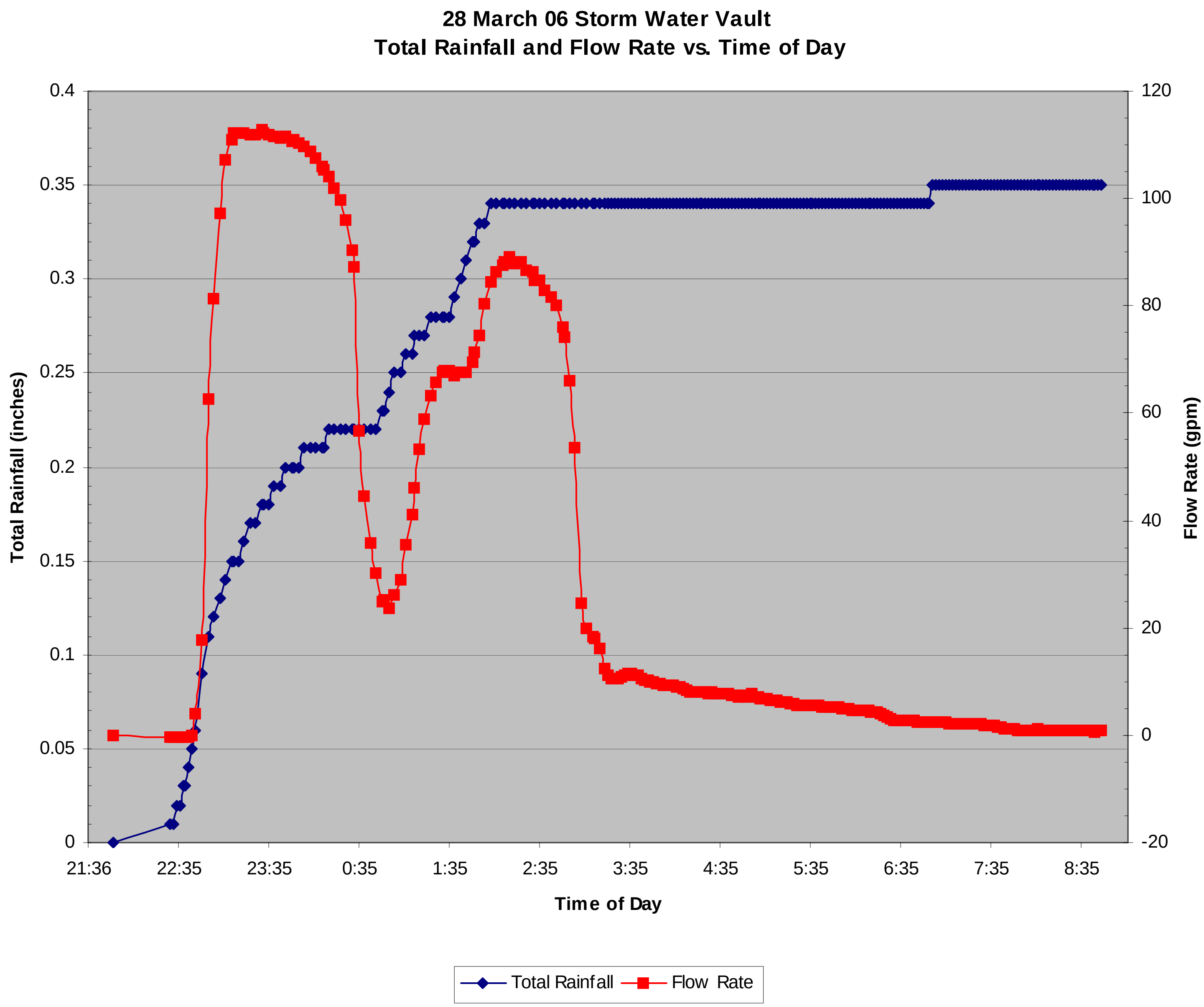
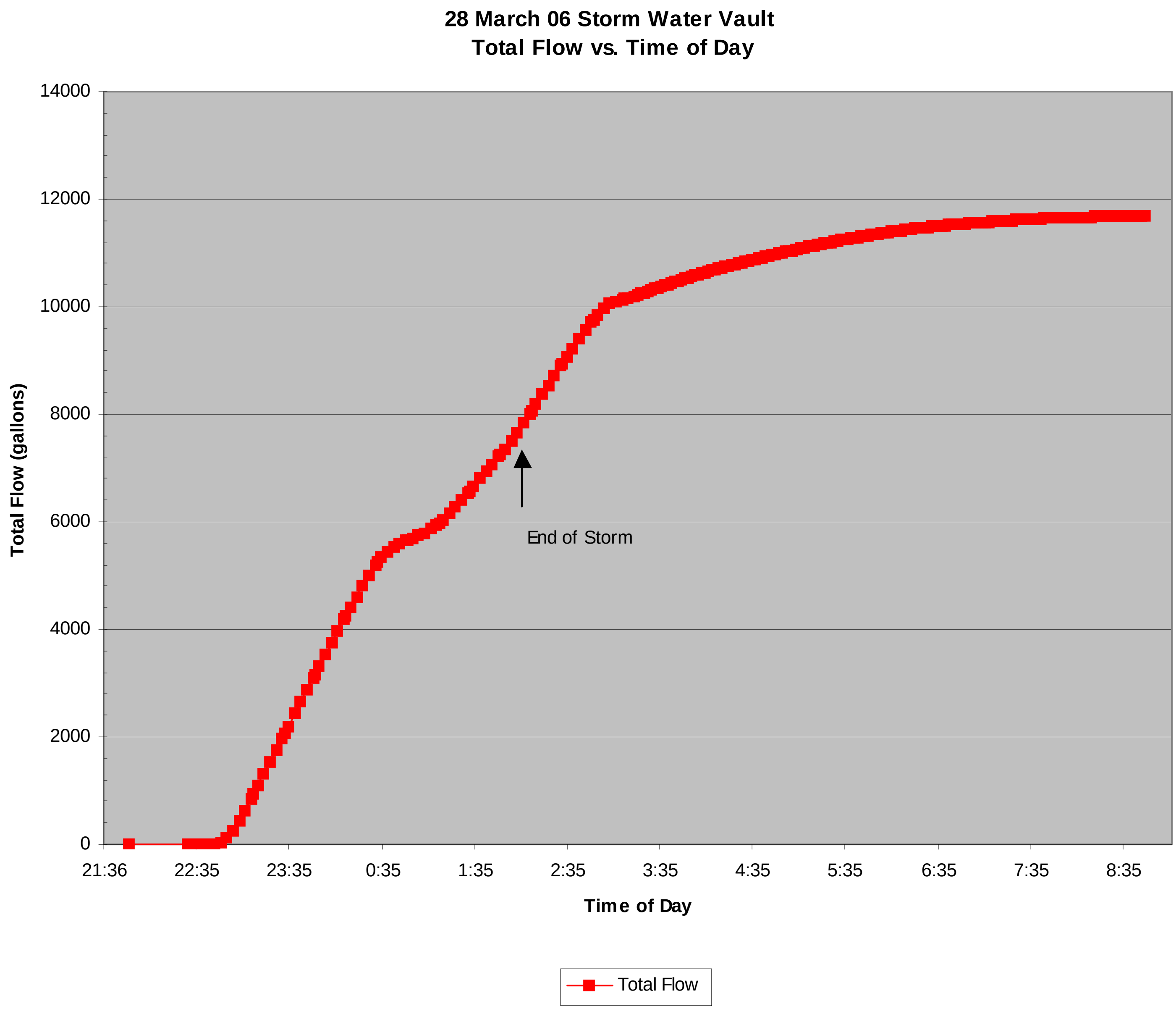
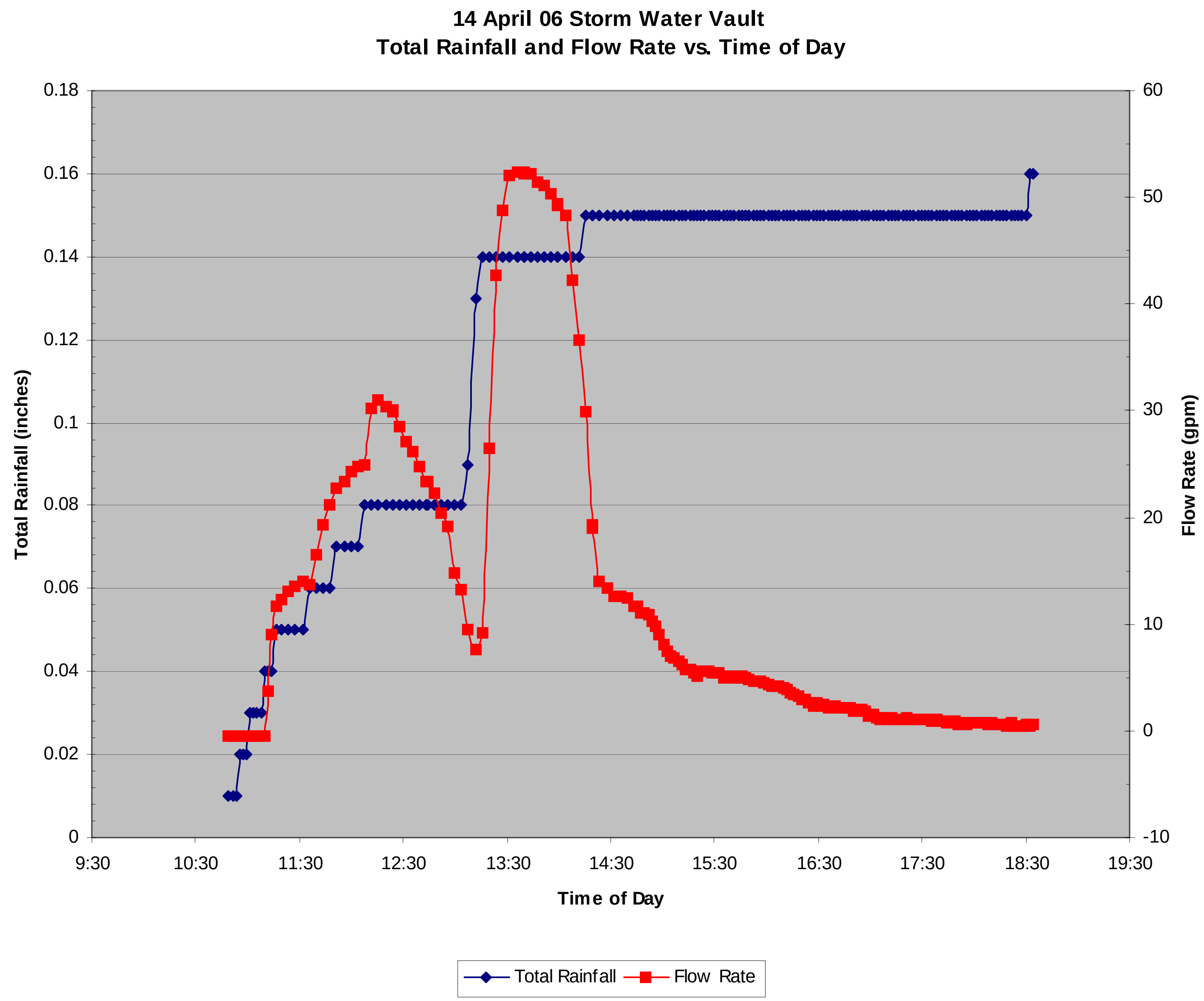
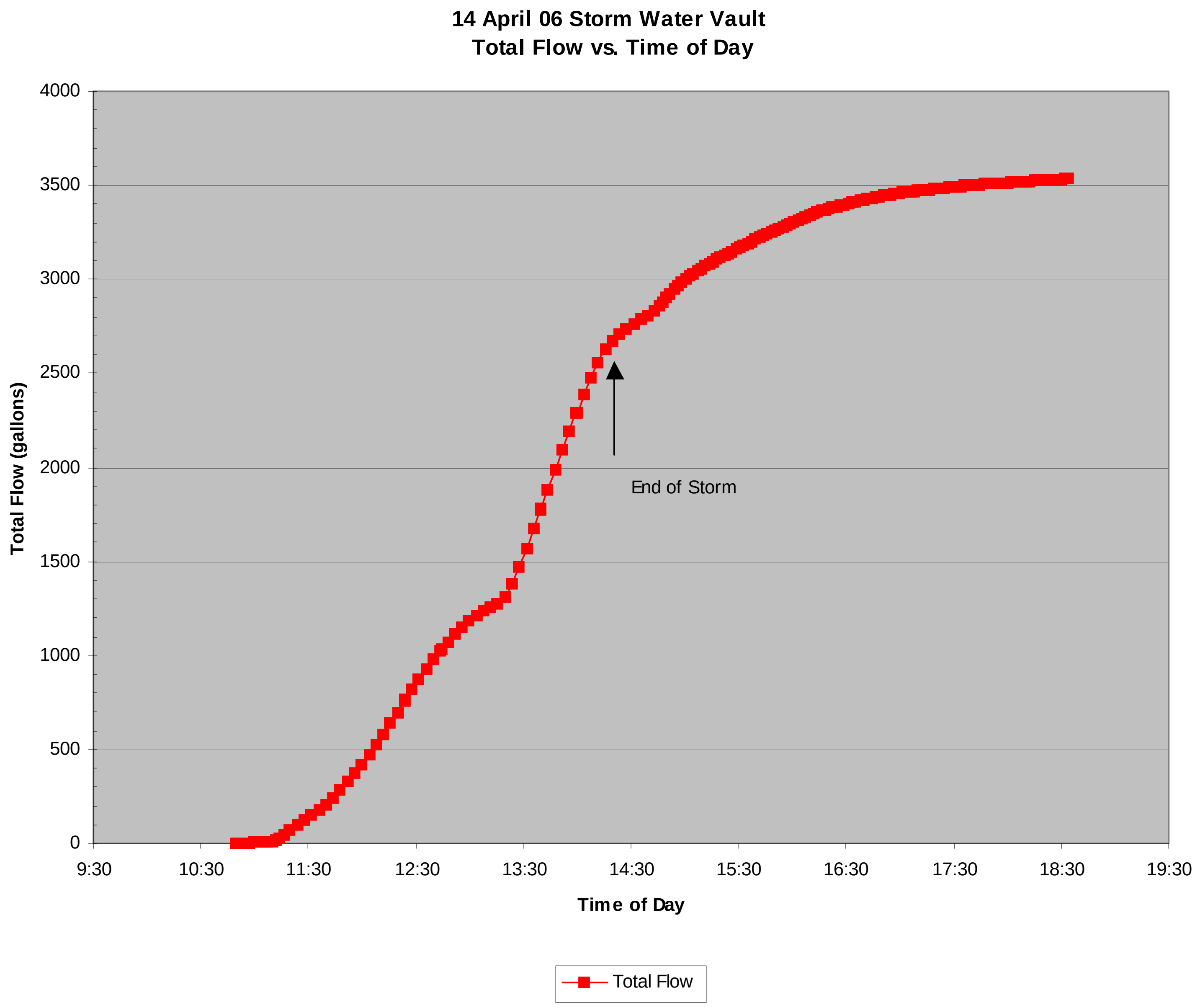


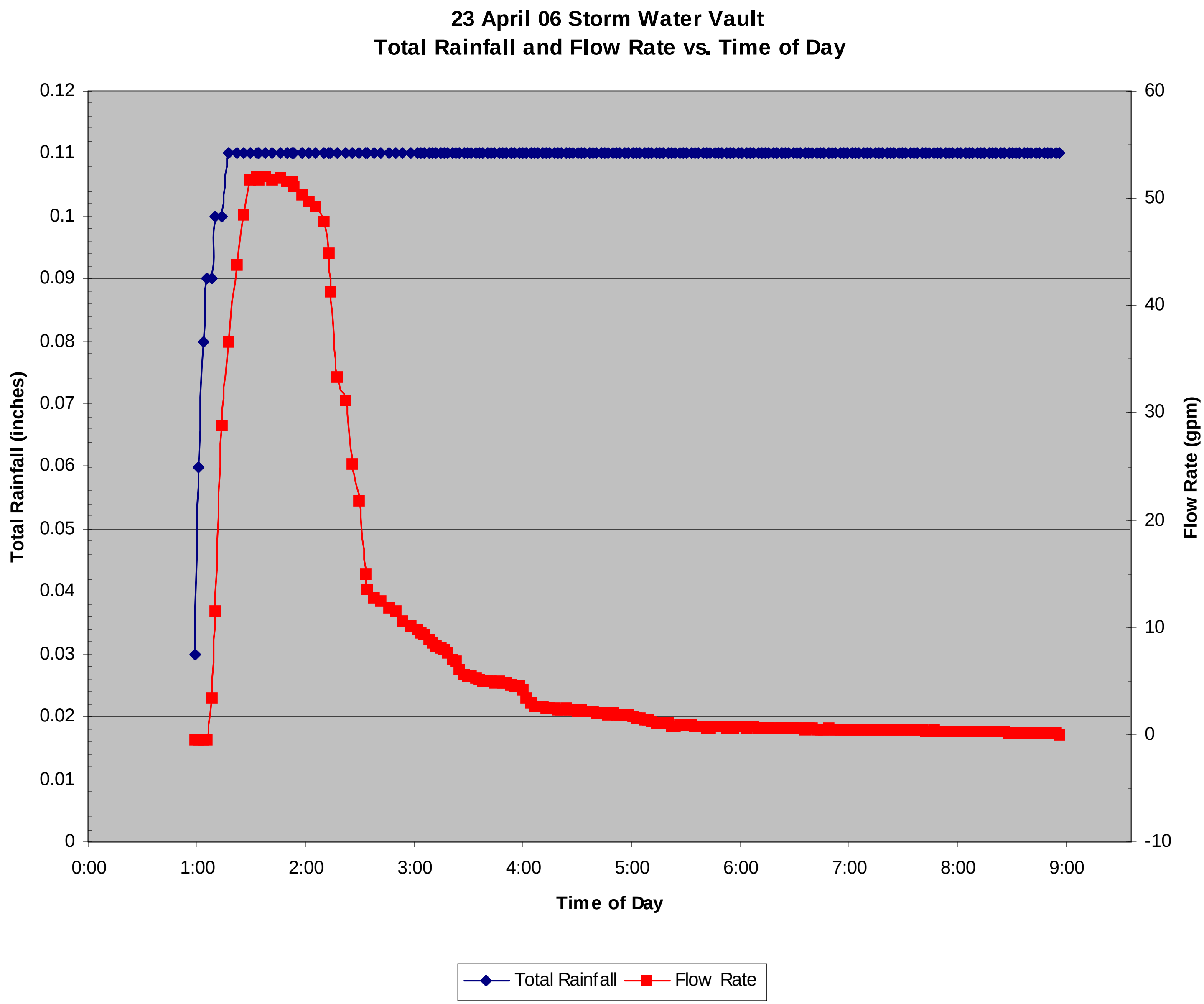
28 March 06 Storm Water Vault
Total Rainfall and Flow Rate vs. Time of Day
Total Rainfall (inches)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Flow Rate (gpm)
120
100
80
60
40
20
0
-20
21:36
22:35
23:35
0:35
1:35
2:35
3:35
4:35
5:35
6:35
7:35
8:35
Time of Day
Total Rainfall
Flow Rate



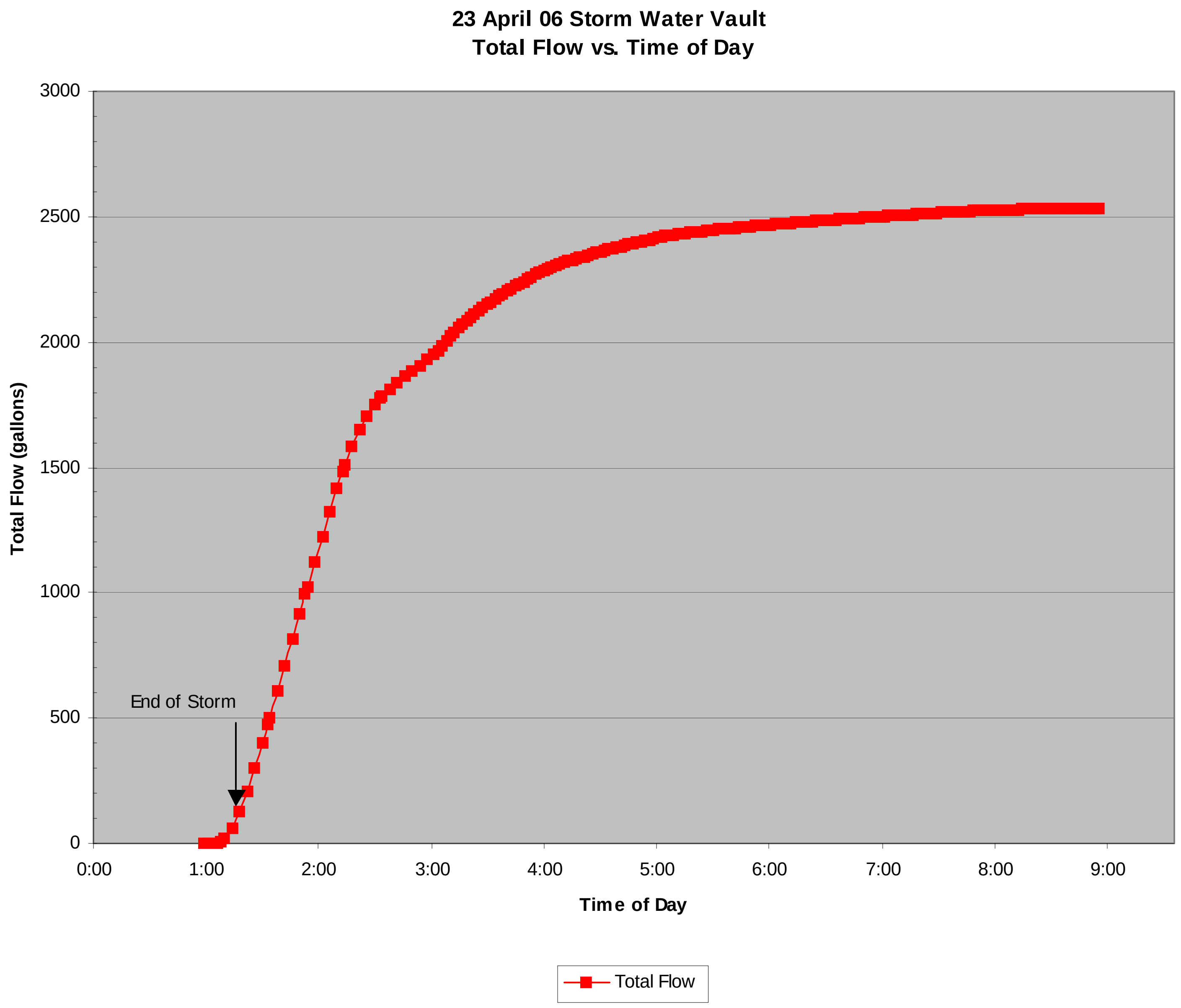
28 March 06 Storm Water Vault
Total Flow vs. Time of Day
14000
12000
10000
8000
6000
4000
2000
0
Total Flow (gallons)
21:36
22:35
23:35
0:35
1:35
2:35
3:35
4:35
5:35
6:35
7:35
8:35
Time of Day
End of Storm
Total Flow


14 April 06 Storm Water Vault
Total Rainfall and Flow Rate vs. Time of Day
Total Rainfall (inches)
Flow Rate (gpm)
Time of Day
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
60
50
40
30
20
10
0
-10
9:30
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
19:30
Total Rainfall
Flow Rate

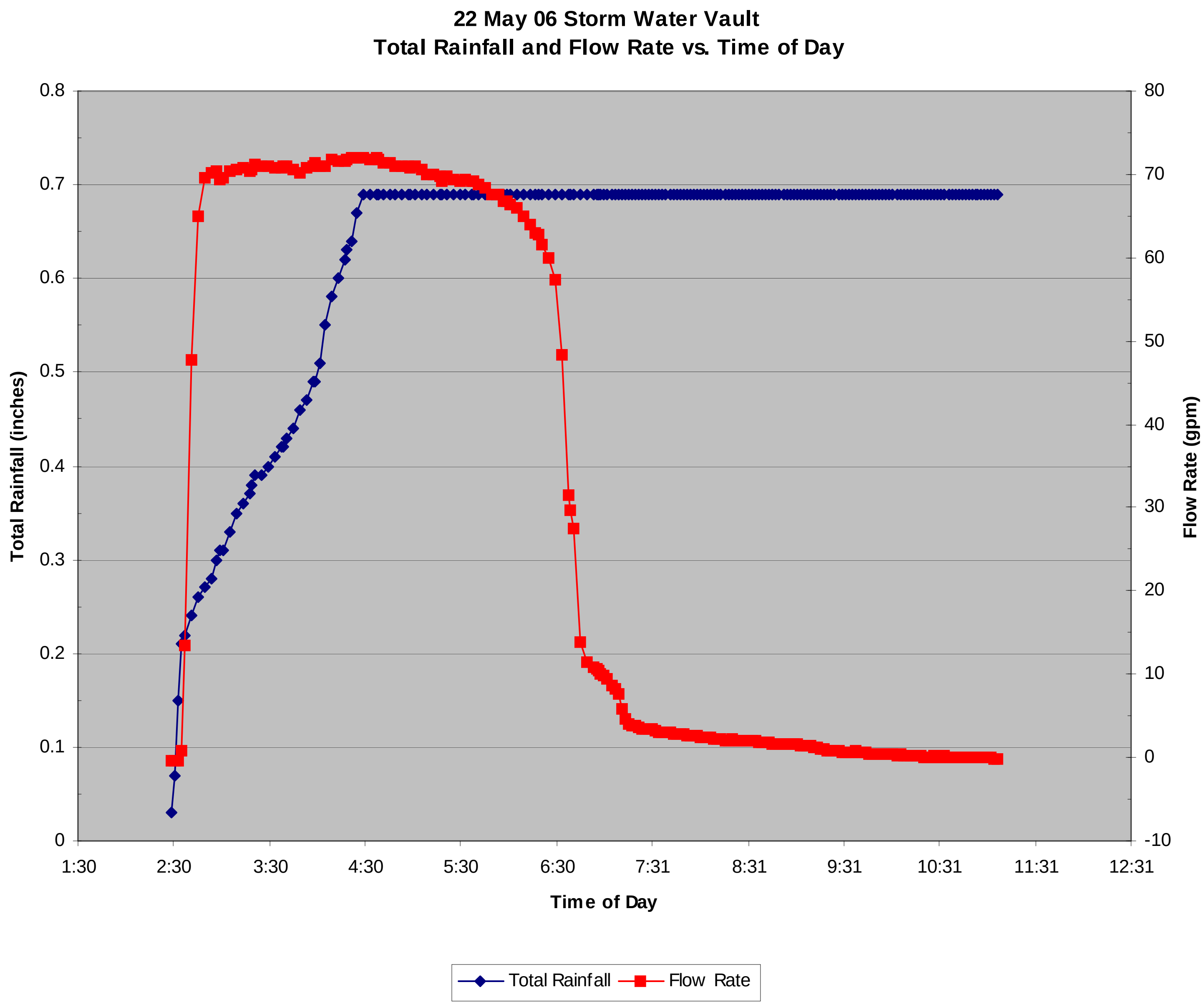

14 April 06 Storm Water Vault
Total Flow vs. Time of Day
Total Flow (gallons)
4000
3500
3000
2500
2000
1500
1000
500
0
9:30
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
19:30
Time of Day
End of Storm
Total Flow

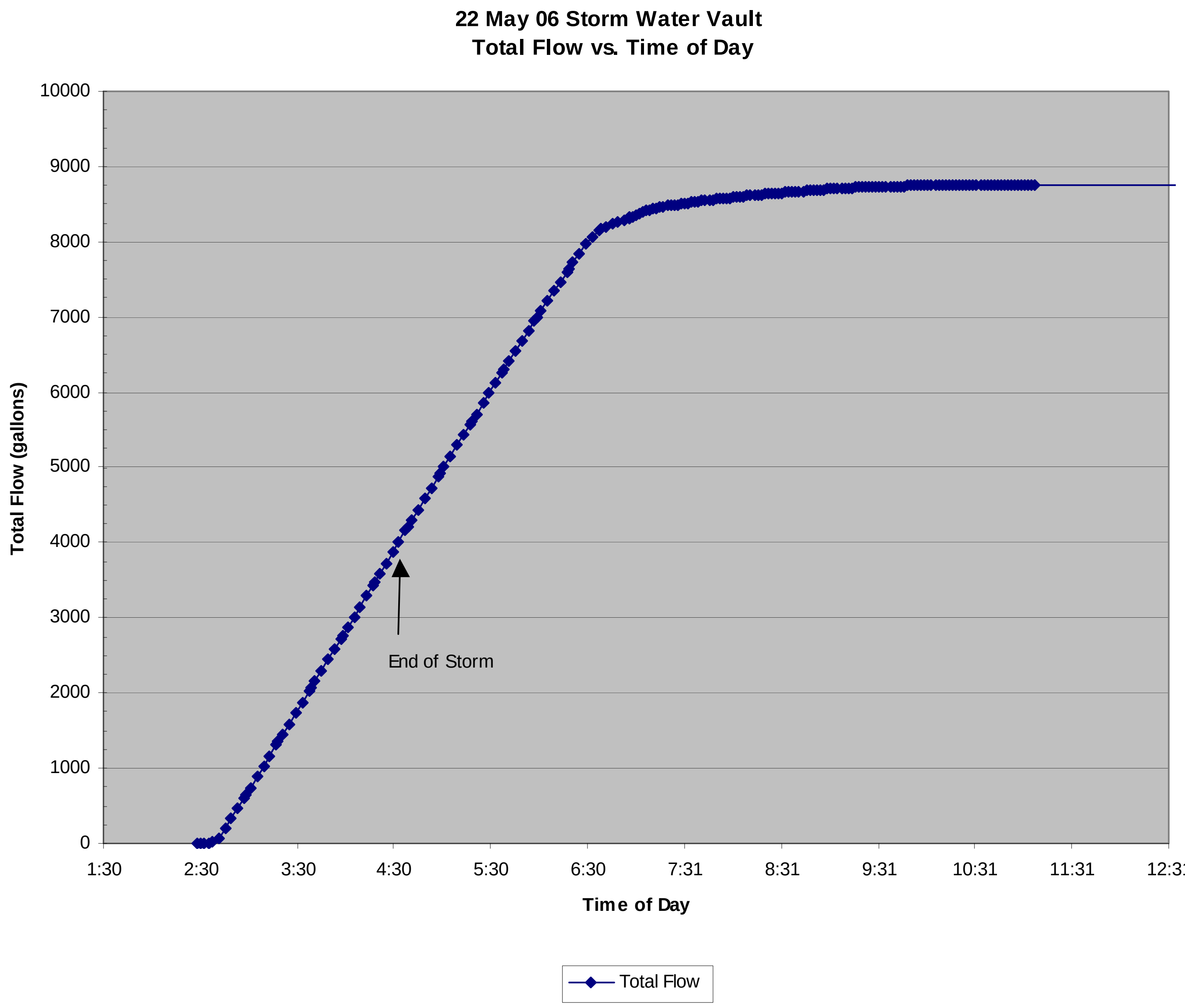


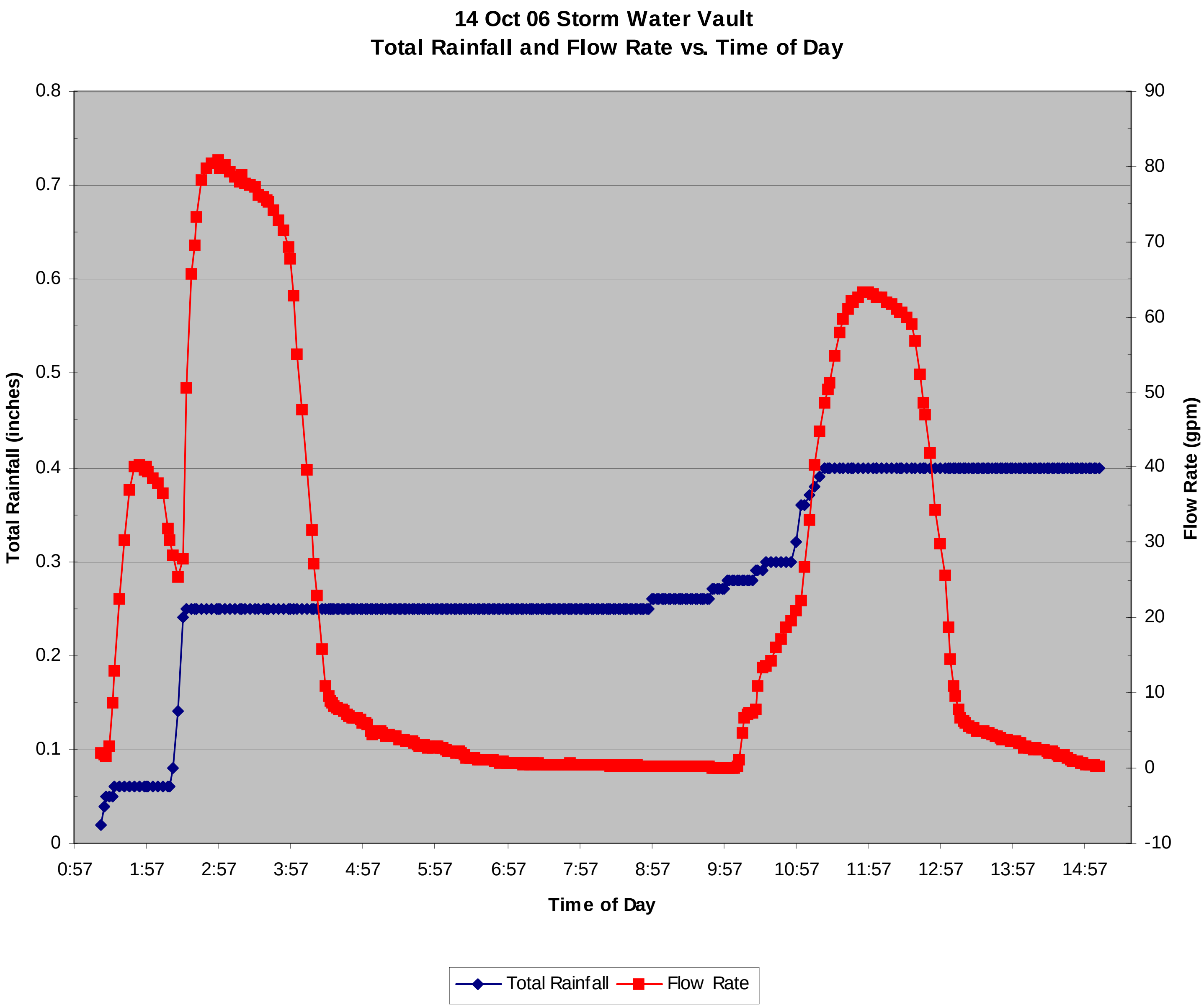
23 April 06 Storm Water Vault
Total Rainfall and Flow Rate vs. Time of Day
Total Rainfall (inches)
Flow Rate (gpm)
Time of Day
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
60
50
40
30
20
10
0
-10
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
Total Rainfall
Flow Rate



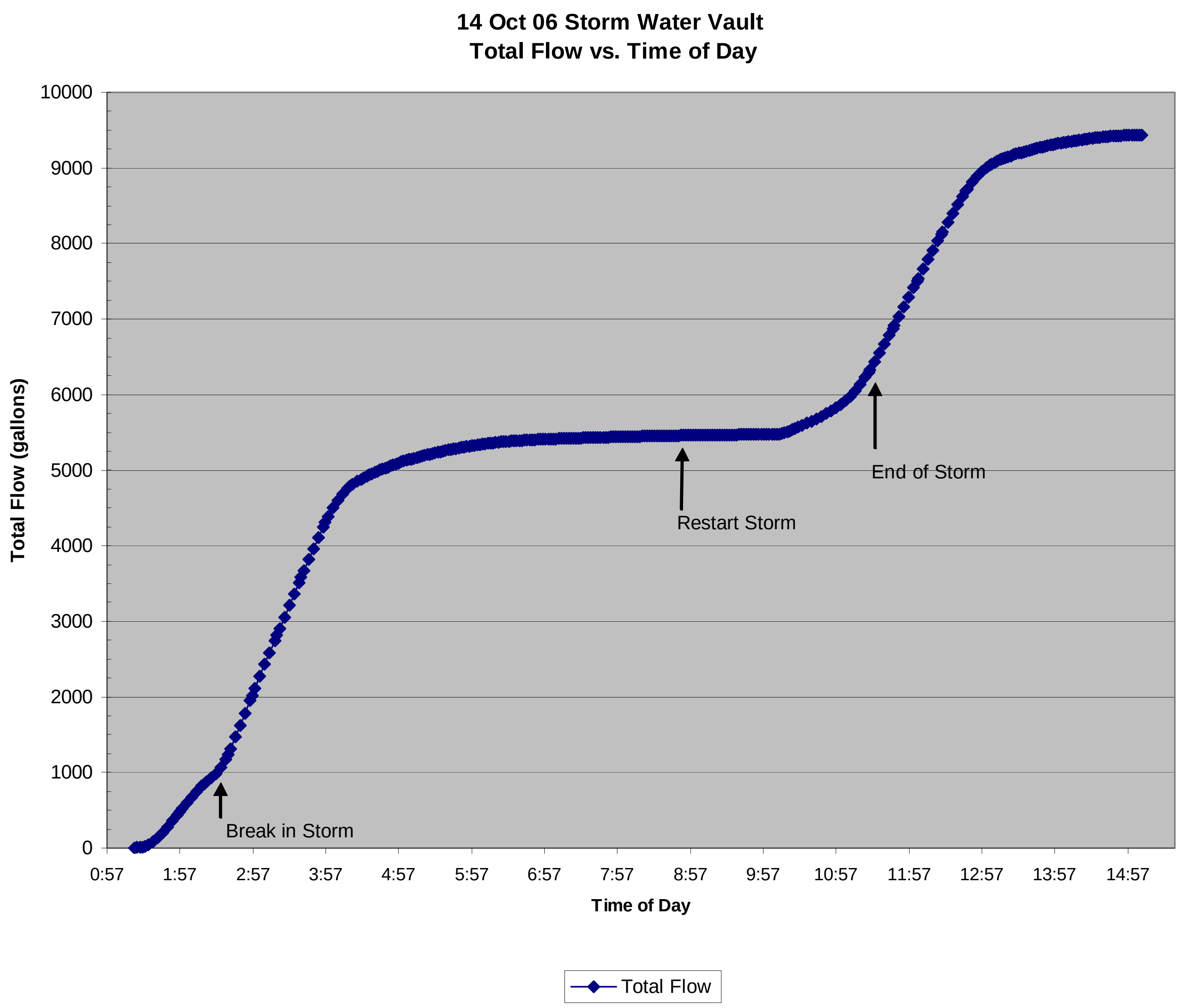
23 April 06 Storm Water Vault
Total Flow vs. Time of Day
Total Flow (gallons)
3000
2500
2000
1500
1000
500
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
Time of Day
End of Storm
Total Flow


22 May 06 Storm Water Vault
Total Rainfall and Flow Rate vs. Time of Day
Total Rainfall (inches)
Flow Rate (gpm)
Time of Day
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
80
70
60
50
40
30
20
10
0
-10
1:30
2:30
3:30
4:30
5:30
6:30
7:31
8:31
9:31
10:31
11:31
12:31
Total Rainfall
Flow Rate

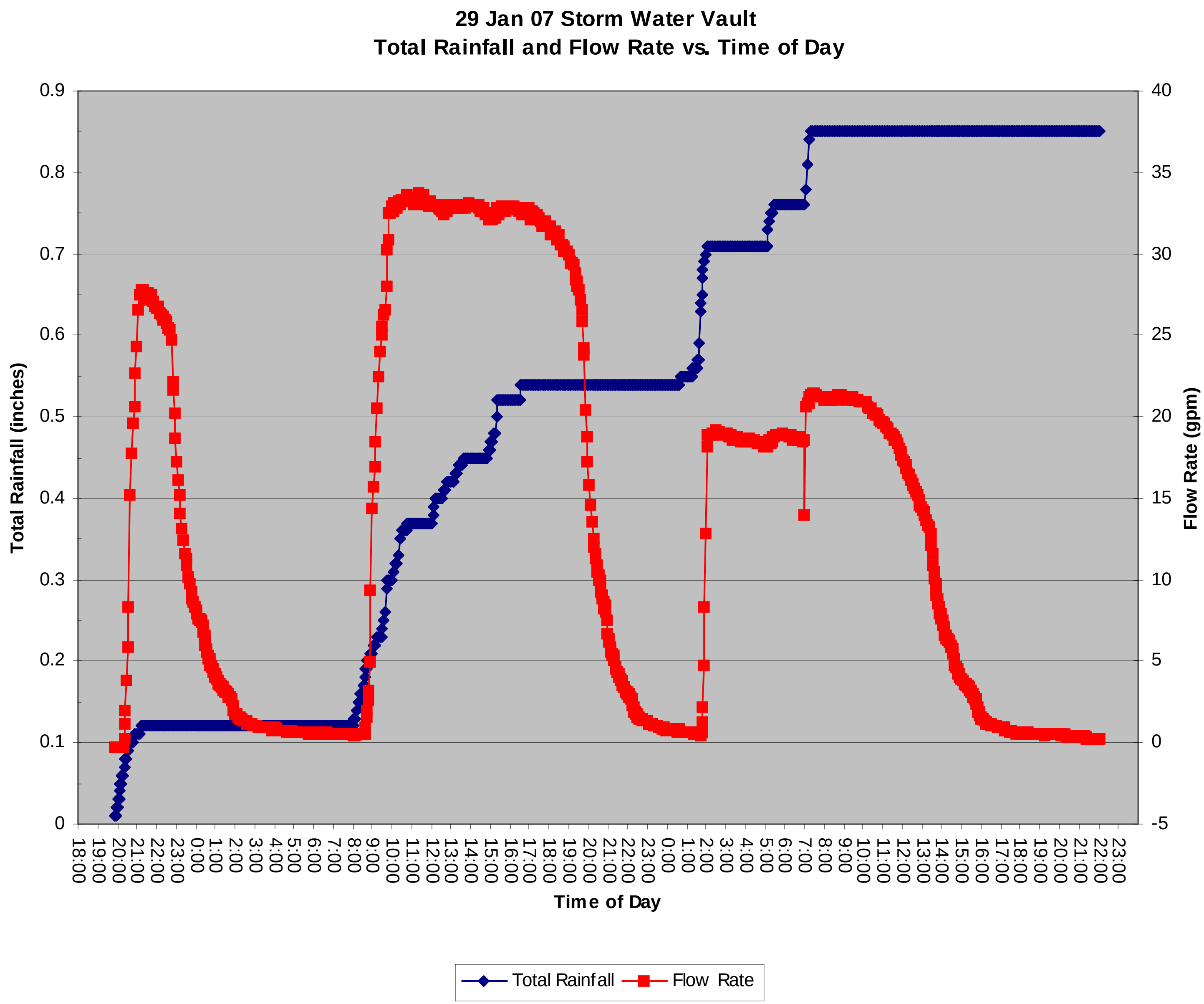

22 May 06 Storm Water Vault
Total Flow vs. Time of Day
Total Flow (gallons)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1:30
2:30
3:30
4:30
5:30
6:30
7:31
8:31
9:31
10:31
11:31
12:31
Time of Day
End of Storm
Total Flow



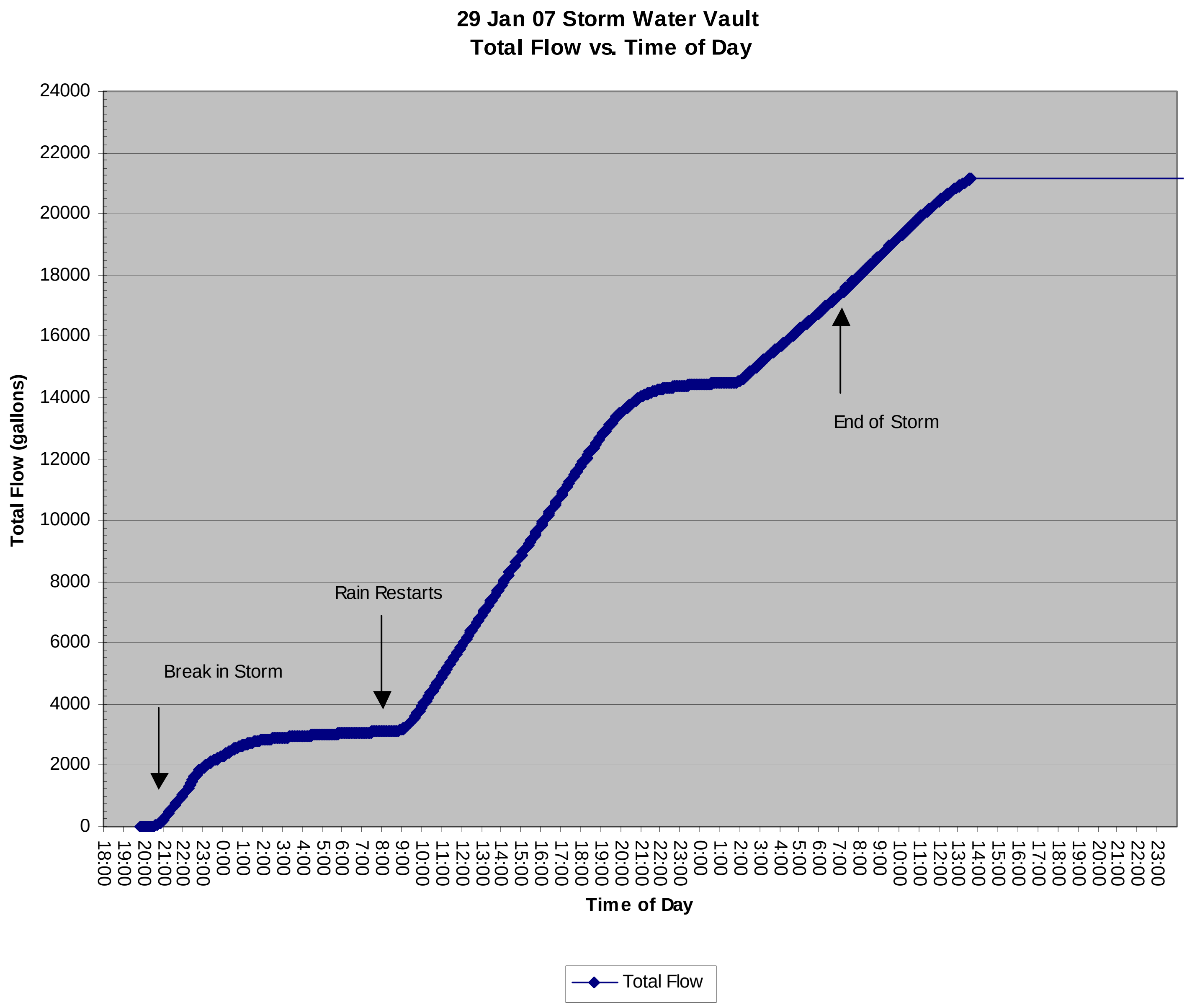
14 Oct 06 Storm Water Vault
Total Rainfall and Flow Rate vs. Time of Day
Total Rainfall (inches)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Flow Rate (gpm)
90
80
70
60
50
40
30
20
10
0
-10
0:57
1:57
2:57
3:57
4:57
5:57
6:57
7:57
8:57
9:57
10:57
11:57
12:57
13:57
14:57
Time of Day
Total Rainfall
Flow Rate

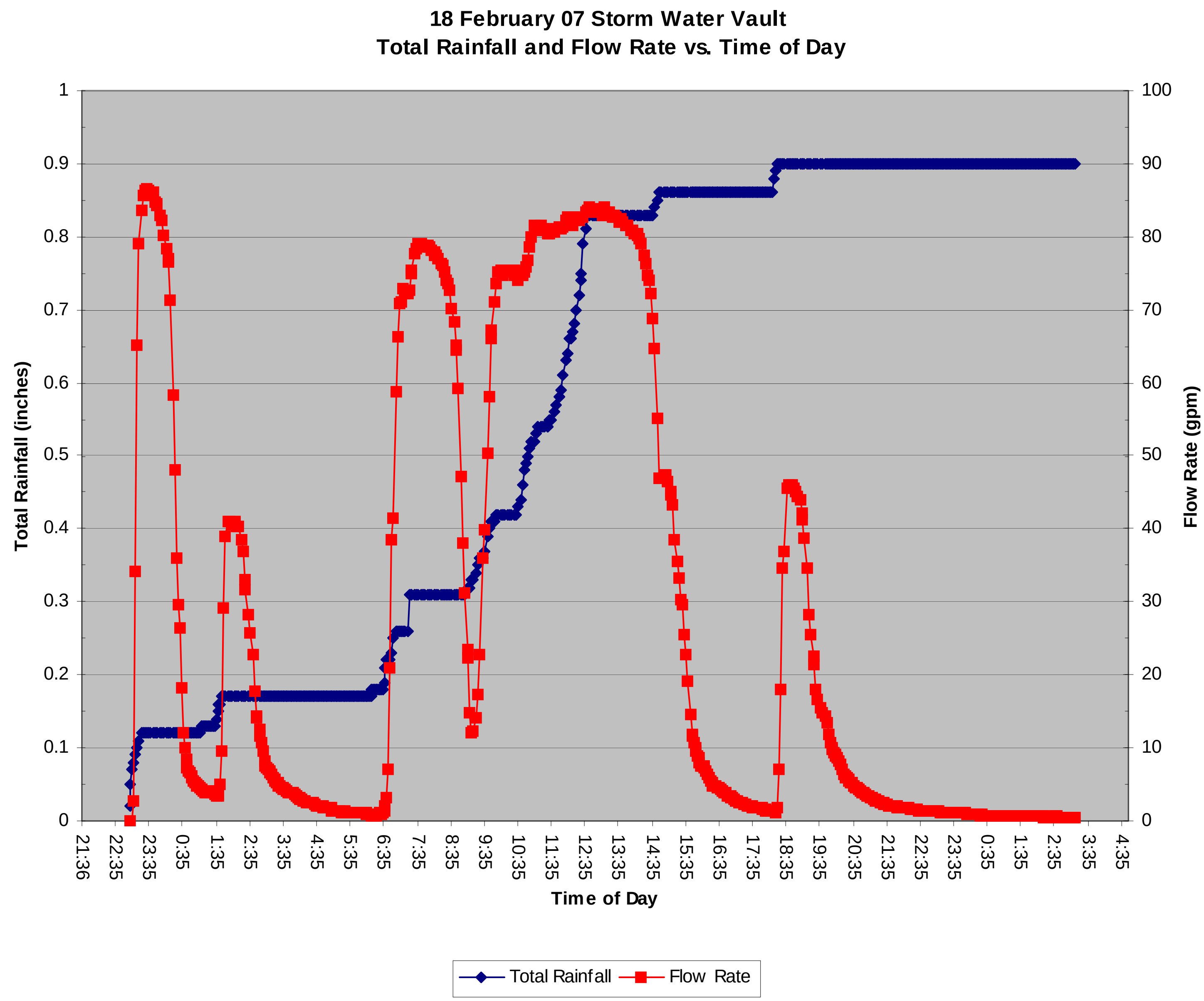


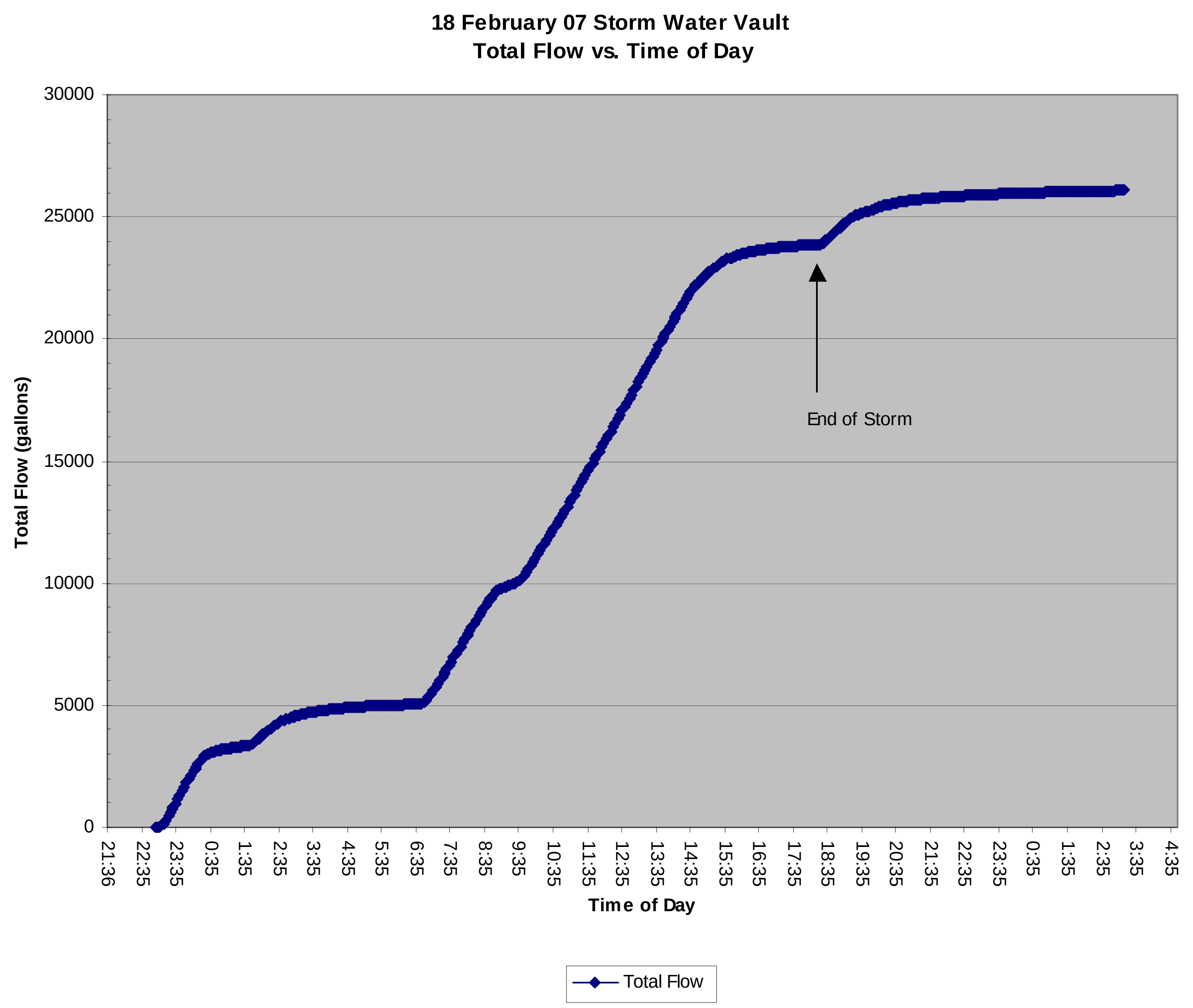
14 Oct 06 Storm Water Vault
Total Flow vs. Time of Day
Total Flow (gallons)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Time of Day
0:57
1:57
2:57
3:57
4:57
5:57
6:57
7:57
8:57
9:57
10:57
11:57
12:57
13:57
14:57
Break in Storm
Restart Storm
End of Storm
Total Flow



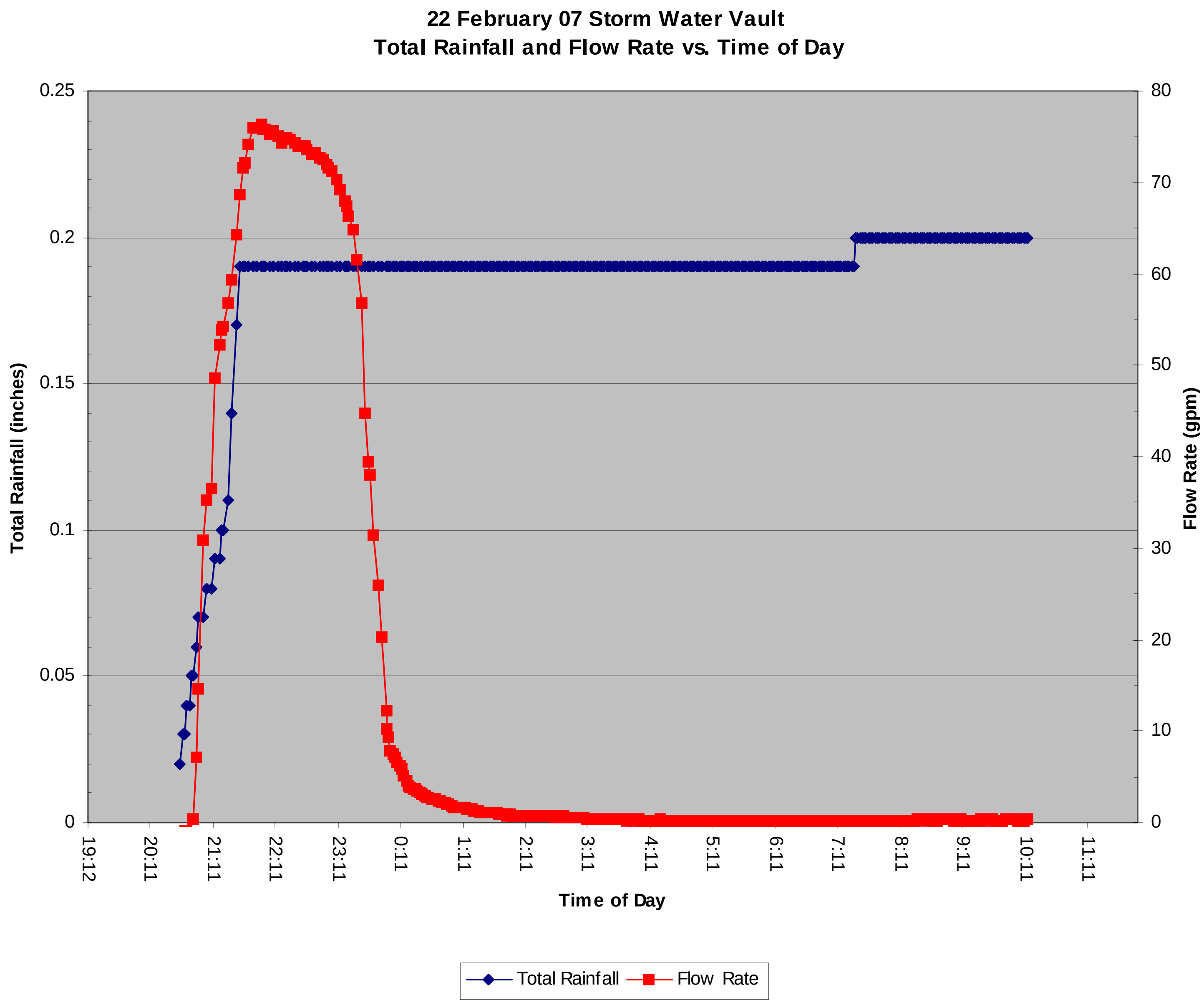
29 Jan 07 Storm Water Vault
Total Rainfall and Flow Rate vs. Time of Day
Total Rainfall (inches)
Flow Rate (gpm)
Time of Day
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
40
35
30
25
20
15
10
5
0
-5
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Total Rainfall
Flow Rate


29 Jan 07 Storm Water Vault
Total Flow vs. Time of Day
Total Flow (gallons)
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Break in Storm
Rain Restarts
End of Storm
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day
Total Flow

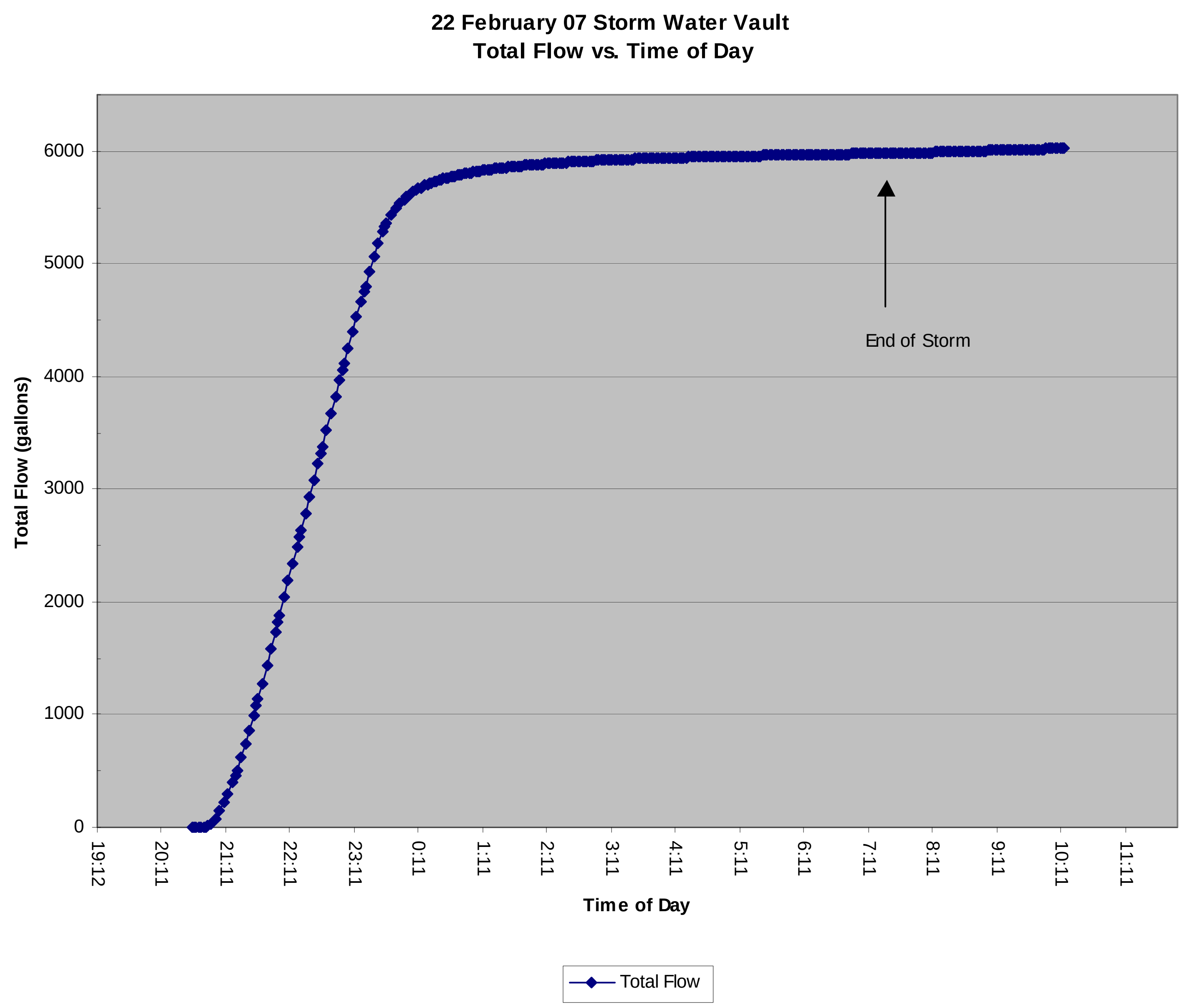

18 February 07 Storm Water Vault
Total Rainfall and Flow Rate vs. Time of Day
Total Rainfall (inches)
Flow Rate (gpm)
Time of Day
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50
60
70
80
90
100
21:36
22:35
23:35
0:35
1:35
2:35
3:35
4:35
5:35
6:35
7:35
8:35
9:35
10:35
11:35
12:35
13:35
14:35
15:35
16:35
17:35
18:35
19:35
20:35
21:35
22:35
23:35
0:35
1:35
2:35
3:35
4:35
Total Rainfall
Flow Rate



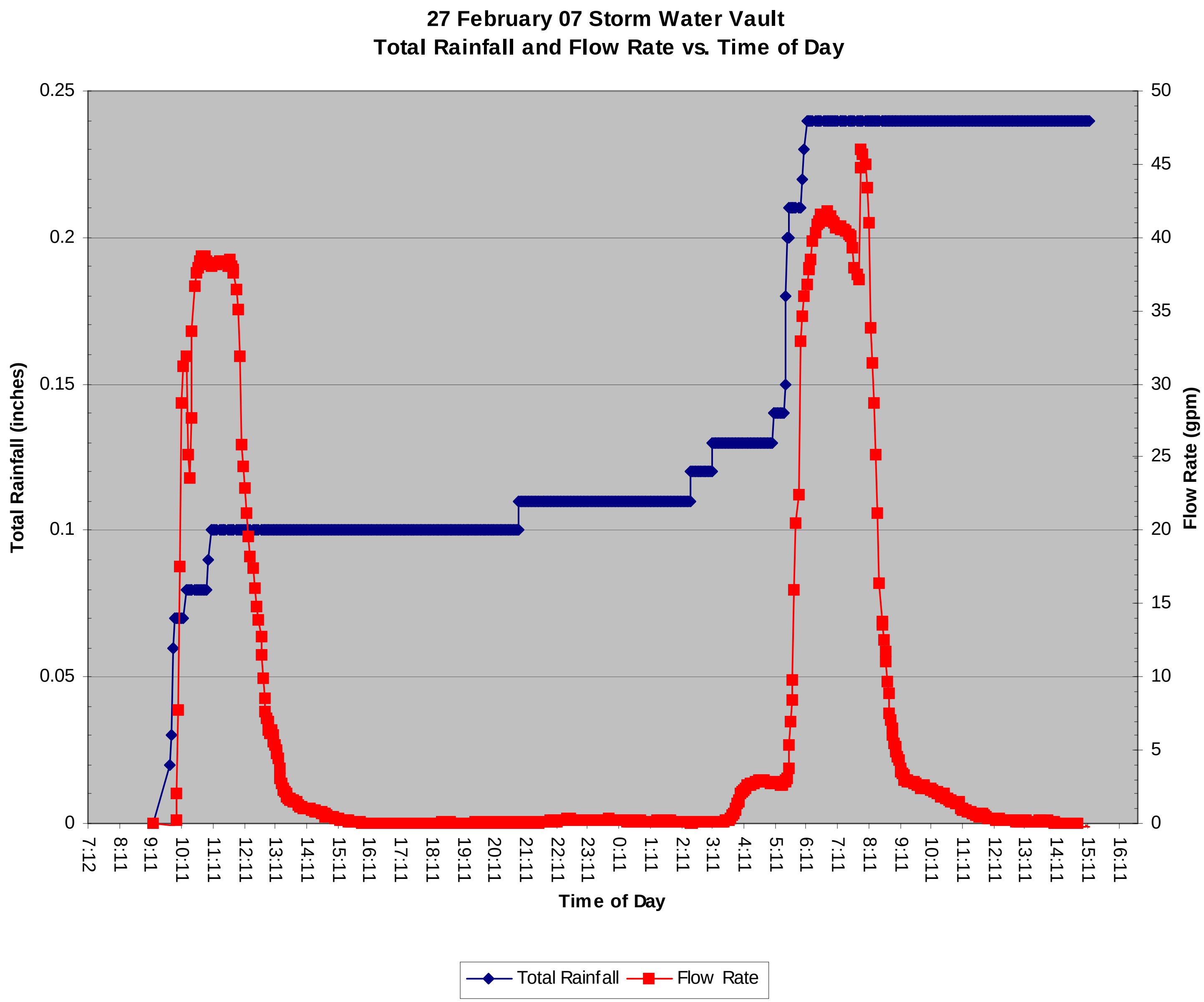
18 February 07 Storm Water Vault
Total Flow vs. Time of Day
30000
25000
20000
15000
10000
5000
0
Total Flow (gallons)
End of Storm
21:36
22:35
23:35
0:35
1:35
2:35
3:35
4:35
5:35
6:35
7:35
8:35
9:35
10:35
11:35
12:35
13:35
14:35
15:35
16:35
17:35
18:35
19:35
20:35
21:35
22:35
23:35
0:35
1:35
2:35
3:35
4:35
Time of Day
Total Flow



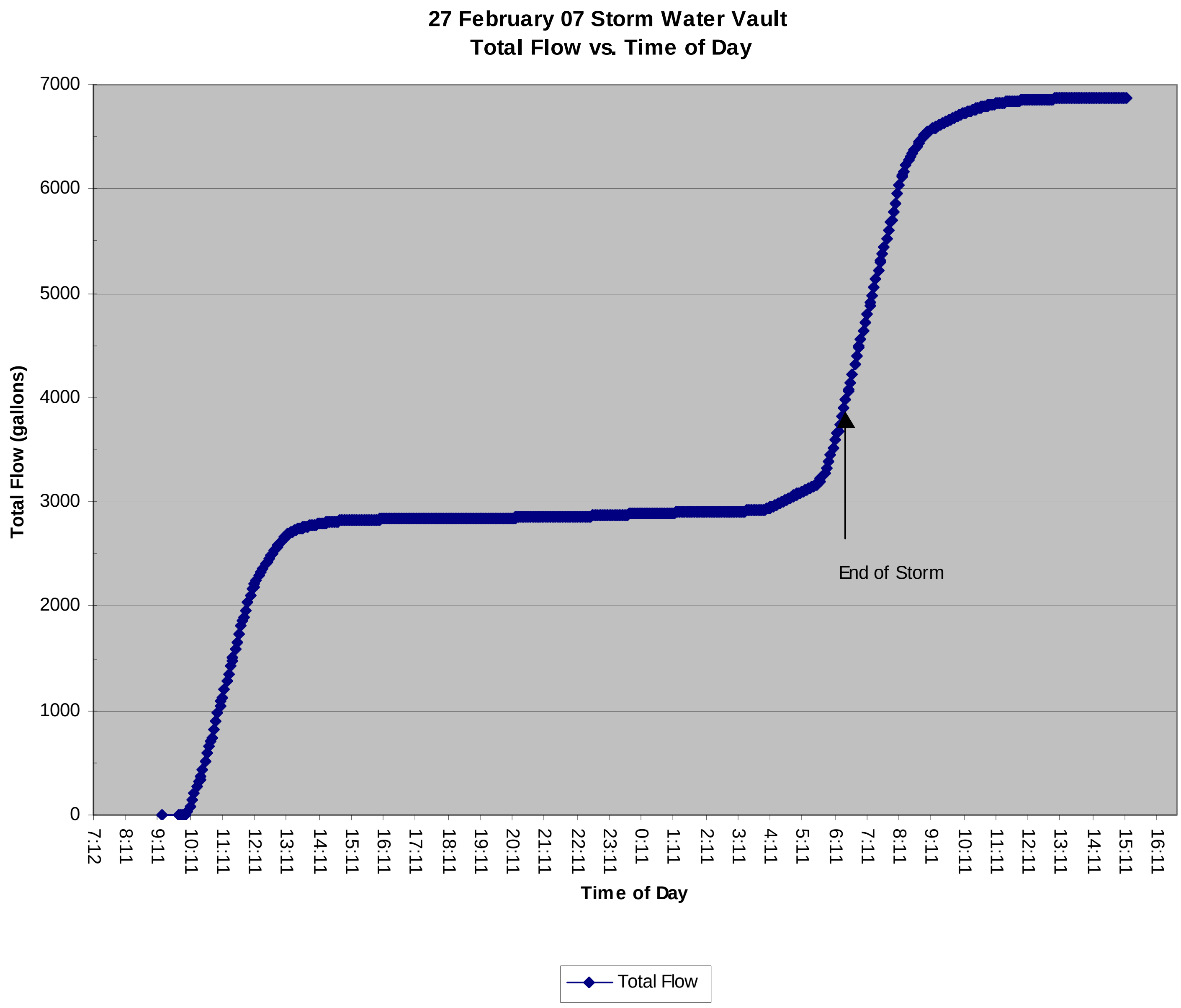
22 February 07 Storm Water Vault
Total Rainfall and Flow Rate vs. Time of Day
Total Rainfall (inches)
0.25
0.2
0.15
0.1
0.05
0
Flow Rate (gpm)
80
70
60
50
40
30
20
10
0
19:12
20:11
21:11
22:11
23:11
0:11
1:11
2:11
3:11
4:11
5:11
6:11
7:11
8:11
9:11
10:11
11:11
Time of Day
Total Rainfall
Flow Rate



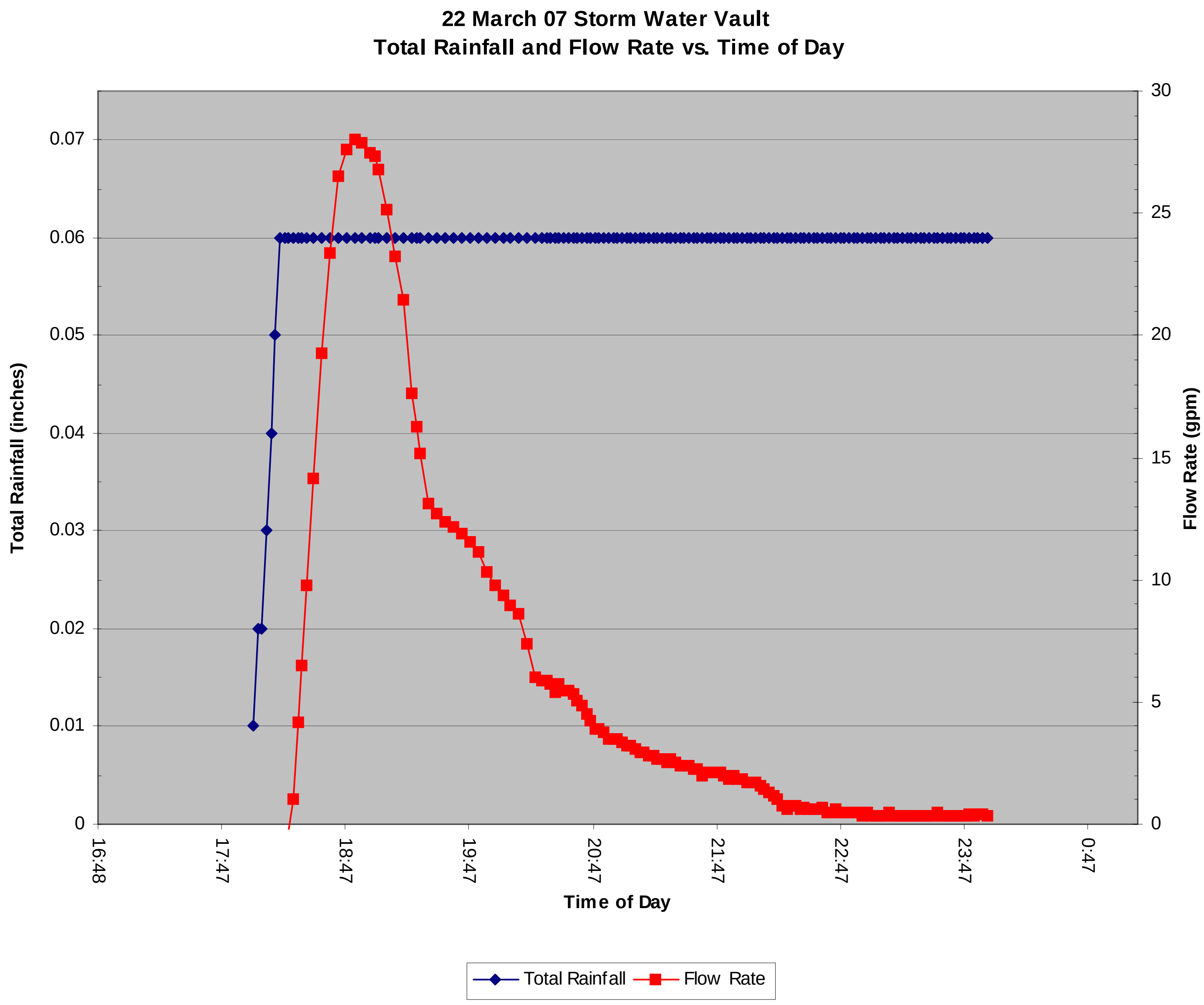
22 February 07 Storm Water Vault
Total Flow vs. Time of Day
Total Flow (gallons)
0
1000
2000
3000
4000
5000
6000
19:12
20:11
21:11
22:11
23:11
0:11
1:11
2:11
3:11
4:11
5:11
6:11
7:11
8:11
9:11
10:11
11:11
Time of Day
End of Storm
Total Flow

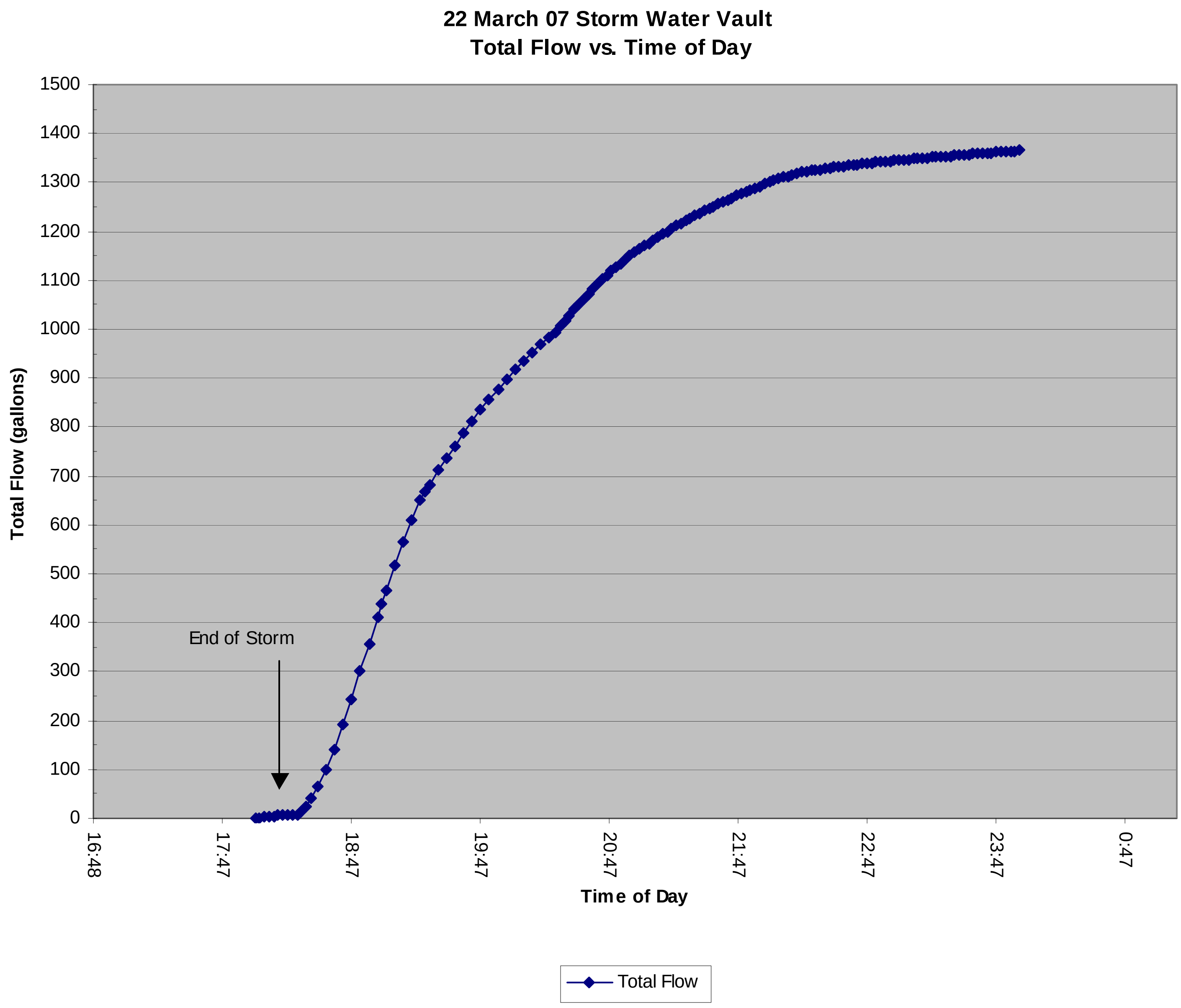


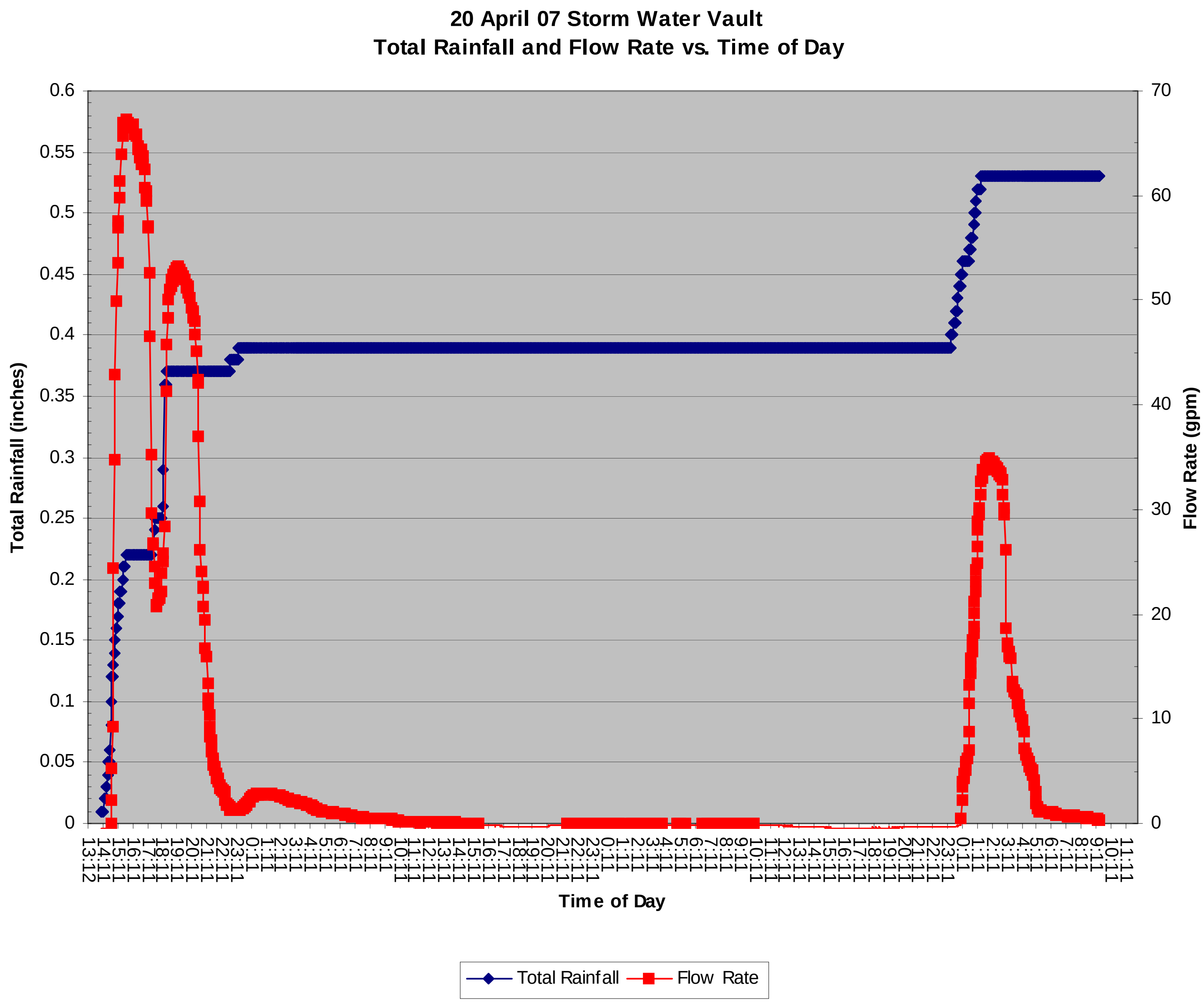
27 February 07 Storm Water Vault
Total Rainfall and Flow Rate vs. Time of Day
Total Rainfall (inches)
Flow Rate (gpm)
Time of Day
0.25
0.2
0.15
0.1
0.05
0
50
45
40
35
30
25
20
15
10
5
0
7:12
8:11
9:11
10:11
11:11
12:11
13:11
14:11
15:11
16:11
17:11
18:11
19:11
20:11
21:11
22:11
23:11
0:11
1:11
2:11
3:11
4:11
5:11
6:11
7:11
8:11
9:11
10:11
11:11
12:11
13:11
14:11
15:11
16:11
Total Rainfall
Flow Rate

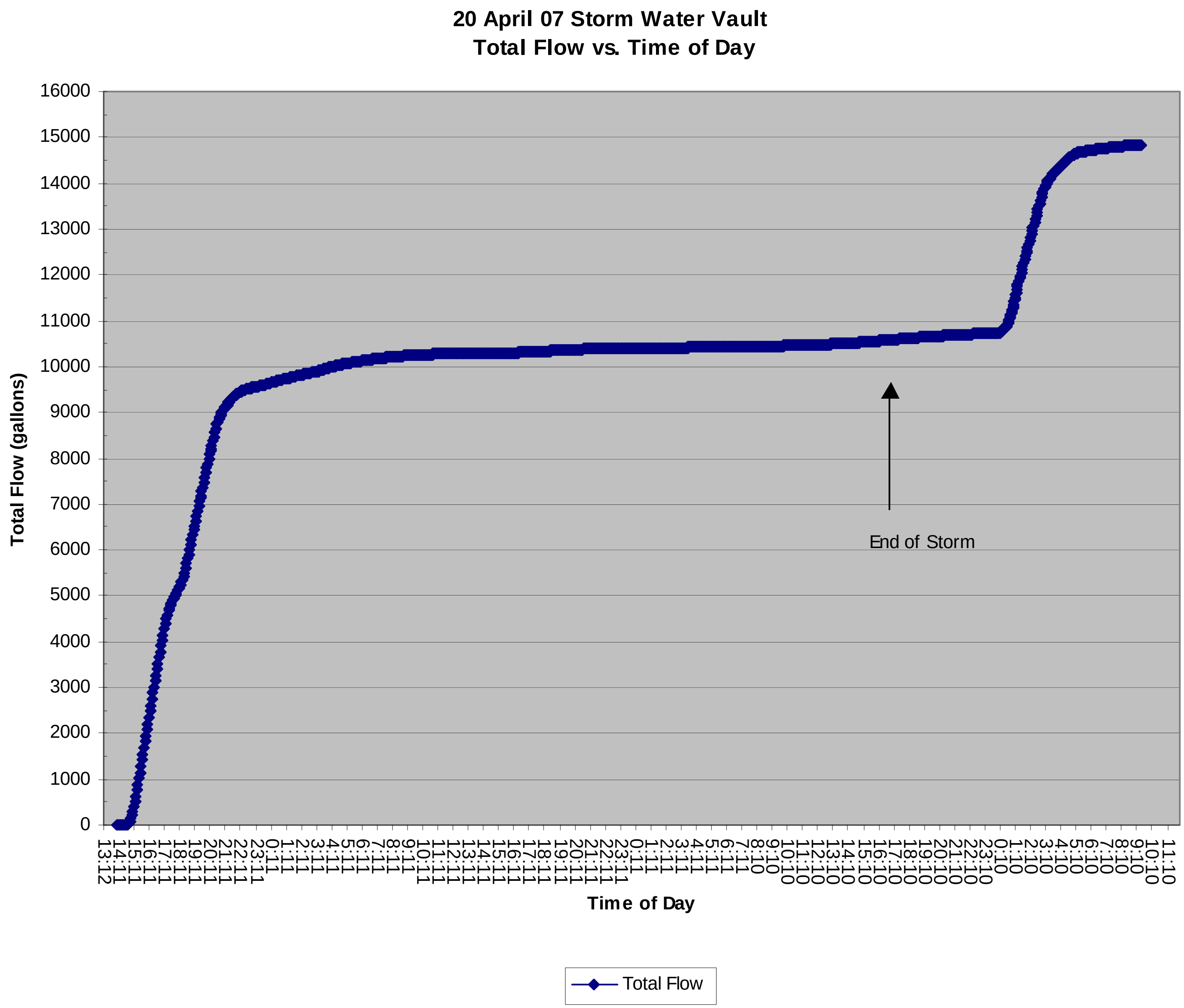


27 February 07 Storm Water Vault
Total Flow vs. Time of Day
Total Flow (gallons)
7000
6000
5000
4000
3000
2000
1000
0
7:12
8:11
9:11
10:11
11:11
12:11
13:11
14:11
15:11
16:11
17:11
18:11
19:11
20:11
21:11
22:11
23:11
0:11
1:11
2:11
3:11
4:11
5:11
6:11
7:11
8:11
9:11
10:11
11:11
12:11
13:11
14:11
15:11
16:11
Time of Day
End of Storm
Total Flow


22 March 07 Storm Water Vault
Total Rainfall and Flow Rate vs. Time of Day
Total Rainfall (inches)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Flow Rate (gpm)
30
25
20
15
10
5
0
16:48
17:47
18:47
19:47
20:47
21:47
22:47
23:47
0:47
Time of Day
Total Rainfall
Flow Rate


22 March 07 Storm Water Vault
Total Flow vs. Time of Day
Total Flow (gallons)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
End of Storm
16:48
17:47
18:47
19:47
20:47
21:47
22:47
23:47
0:47
Time of Day
Total Flow


20 April 07 Storm Water Vault
Total Rainfall and Flow Rate vs. Time of Day
Total Rainfall (inches)
Flow Rate (gpm)
Time of Day
Total Rainfall
Flow Rate



20 April 07 Storm Water Vault
Total Flow vs. Time of Day
Total Flow (gallons)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
End of Storm
Time of Day
Total Flow

NRRC First Flush Sampling Data

Pollutant	NRRC First Flush Results						Units
	Influent			Effluent			
	28 Mar 2006	**14 April 2006**	**23 April 2006**	**28 Mar 2006**	**14 April 2006**	**23 April 2006**	
Aluminum	5620	2080	1950	750	1210	742	µg/L
Arsenic	5.42	3.8	2.14	1.35	2.68	1.21	µg/L
Cadmium	16	8.41	8.67	3.94	3.1	7.68	µg/L
Chromium	26.4	12.3	9.49	5.39	6.0	6.02	µg/L
Copper	1170	550	351	339	201	228	µg/L
Iron	9970	3780	3170	1.38	1720	1280	µg/L
Lead	149	60	42.6	25.1	16.1	22.2	µg/L
Nickel	330	120	58.7	101	26.6	34.6	µg/L
Selenium	ND	ND	ND	ND	ND	ND	µg/L
Silver	1.13	ND	ND	ND	ND	ND	µg/L
Titanium	309	92.6	120	39.6	68.6	38.6	µg/L
Zinc	1480	981	1270	343	711	913	µg/L
TSS	54	46	84	22	37	35	mg/L
TDS	85	205	110	140	170	130	mg/L
Specific Conductivity	127	196	130	237	180	181	umhos/ cm
PH		6.28	6.08		6.68	6.55	s.u.
BOD	14.2	33	16	12	17	14.9	mg/L
COD	125	136	116	130	95.9	89.9	mg/L
TOC	22.1	50.6	30.2	14.3	33.6	24.3	mg/L
MBAS	0.597	0.599	0.498	0.292	0.708	0.508	mg/L
Oil & Grease	7.0		ND	ND		ND	mg/L
TRPH	1.9		ND	ND		ND	mg/L
TKN	0.844	3.5	1.64	0.723	2	1.39	mg/L
Nitrate/Nitrite-N	0.523	1.19	0.885	0.63	0.725	0.846	mg/L
Ammonia (NH3-N)	0.613	1.34	0.284	0.399	0.534	0.201	mg/L
Total Phosphorous	0.463	0.083	0.369	0.249	0.146	0.182	mg/L

Pollutant	NRRC First Flush Results						Units
	Influent			Effluent			
	22 May 2006	**16 Oct 2006**	**29 Jan 2007**	**22 May 2006**	**16 Oct 2006**	**29Jan* 2007**	
Aluminum	5140	3260	2280	1680	803	207	µg/L
Arsenic	5.04	5.03	3.99	1.92	1.41	0.9	µg/L
Cadmium	27.6	29.7	34	12.4	10.6	4.2	µg/L
Chromium	27.4	20.8	13.2	10.6	8.1	2.8	µg/L
Copper	987	1070	488	397	401	84.6	µg/L
Iron	11300	5740	3550	3730	1850	432	µg/L
Lead	204	106	72.6	80.5	37.4	7.9	µg/L
Nickel	121	119	37.3	42.6	40	8.2	µg/L
Selenium	ND	1.77	ND	ND	0.70	ND	µg/L
Silver	1.41	0.77	0.7	ND	ND	ND	µg/L
Titanium	245	163	98.2	72.9	42.9	8	µg/L
Zinc	2620	4810	1960	1140	1330	277	µg/L
TSS	253	182	140	88	66	ND	mg/L
TDS	160	750	280	160	555	380	mg/L
Specific Conductivity	147	660	288	165	641	594	umhos/ cm
PH	6.71	6.36	7.33	7.02	6.83	7.08	s.u.
BOD	52.7	118	86.3	29	102	33.9	mg/L
COD	267	766	271	133	293	106	mg/L
TOC	54	218	70	28.6	95.6	27.2	mg/L
MBAS	0.612	1.78	0.815	0.311	0.93	0.313	mg/L
Oil & Grease	9.4	7.1	7.5	ND	ND	ND	mg/L
TRPH	30	2.46	2.7	16.2	1.52	ND	mg/L
TKN	2.52	13	4.52	1.48	5.65	1.84	mg/L
Nitrate/Nitrite-N	2.38	9.47	2.06/ND	1.7	7.17	1.67/ND	mg/L
Ammonia (NH3-N)	1.16	4.61	1.43	0.7	1.84	1.06	mg/L
Total Phosphorous	0.153	ND	0.150	0.264	ND	0.145	mg/L

Pollutant	NRRC First Flush Results						Units
	Influent			Effluent			
	18 Feb 2007	**22 Feb 2007**	**27 Feb 2007**	**18 Feb 2007**	**22 Feb 2007**	**27 Feb 2007**	
Aluminum	2200	1020	1820	390	105	327	µg/L
Arsenic	2.7	2.36	2.3	0.79	ND	0.7	µg/L
Cadmium	20.7	8.0	30.4	3.4	1.5	2.5	µg/L
Chromium	9.3	4.9	7.5	2.4	1.3	1.6	µg/L
Copper	307	143	356	63.4	28.7	34.4	µg/L
Iron	2960	1220	2390	673	163	464	µg/L
Lead	101	35.7	93	15.7	3.1	7.0	µg/L
Nickel	22.8	12.2	26.1	7.6	3.6	3.6	µg/L
Selenium	ND	ND	2.2	ND	ND	ND	µg/L
Silver	0.5	ND	ND	ND	ND	ND	µg/L
Titanium	39.2	26.6	21.2	17.1	5.1	18.9	µg/L
Zinc	1170	572	1870	180	102	167	µg/L
TSS	300	107	197	22	ND	ND	mg/L
TDS	135	140	150	240	180	125	mg/L
Specific Conductivity	98.7	68.6	187	327	179	181	umhos/ cm
PH	6.87	6.45	6.74	6.77	6.83	6.9	s.u.
BOD	24.3	11	24.9	11.1	6.14	5.71	mg/L
COD	276	168	234	113	46.4	33.6	mg/L
TOC	19.5	12.7	25.3	10.7	9.6	7.44	mg/L
MBAS	0.461	0.30	0.25	0.192	0.160	0.18	mg/L
Oil & Grease	9.24	5.77	14.8	ND	ND	ND	mg/L
TRPH	5.42	2.17	10.3	ND	ND	ND	mg/L
TKN	2.74	1.28	1.84	0.71	0.95	0.64	mg/L
Nitrate/Nitrite-N	1.04/ND	0.56/ND	1.57/ND	1.7/ND	0.79/ND	0.67/ND	mg/L
Ammonia (NH3-N)	1.1	0.42	0.68	0.347	0.19	0.17	mg/L
Total Phosphorous	ND	ND	0.25	0.23	0.168	0.22	mg/L

Pollutant	NRRC First Flush Results						Units
	Influent			Effluent			
	18 Mar 2007	**20 April 2007**		**22Mar 2007**	**20 April 2007**		
Aluminum	3180	1210		265	217		µg/L
Arsenic	4.1	1.9		0.9	0.6		µg/L
Cadmium	11	11.6		2.9	3.2		µg/L
Chromium	12.4	7.3		2.9	2.9		µg/L
Copper	335	342		81.1	88		µg/L
Iron	5350	1830		524	427		µg/L
Lead	65.6	51.8		9.4	12.3		µg/L
Nickel	28.9	23.4		7.6	5.8		µg/L
Selenium	0.5	ND		ND	ND		µg/L
Silver	ND	ND		ND	ND		µg/L
Titanium	164	54.4		14.7	10.4		µg/L
Zinc	928	1260		222	251		µg/L
TSS	152	104		ND	ND		mg/L
TDS	160	255		265	270		mg/L
Specific Conductivity	132	226		360	362		umhos/ cm
PH	6.79	6.81		6.94	7.24		s.u.
BOD	47.3	24.2		18.3	16.7		mg/L
COD	202	184		59.3	83.8		mg/L
TOC	37.2	44.8		18.6	19.3		mg/L
MBAS	0.32	.576		0.32	.25		mg/L
Oil & Grease	6.37	ND		ND	ND		mg/L
TRPH	1.98	2.6		ND	1.38		mg/L
TKN	3.31	2.9		1.37	1.71		mg/L
Nitrate/Nitrite-N	1.93/ND	1.67/ND		2.44/ND	5.41/ND		mg/L
Ammonia (NH3-N)	1.43	2.29		0.5	.41		mg/L
Total Phosphorous	0.19	.225		0.3	.186		mg/L

NRRC Grab Sampling Data

28 March 2006 NRRC Grab Metals Data at 20 Minute Intervals														
Sample I.D.	Influent Pollutant Concentration (µg/L)							Effluent Pollutant Concentration (µg/L)						
	Al	Cd	Cu	Fe	Pb	Ni	Zn	Al	Cd	Cu	Fe	Pb	Ni	Zn
1-4 Comp	5620	16	1170	9970	149	330	1480	750	3.94	339	1380	25.1	101	343
5	924	3.77	281	1610	24	82.9	389	166	2.38	106	205	9.18	25.7	204
6	3880	6.74	513	6450	76	147	763	143	1.86	72	157	7.09	15.9	167
7	1610	2.63	205	2530	29.8	57.5	330	174	1.72	63.1	160	5.84	13.4	165
8	5190	7.55	409	8380	111	69.6	1010	135	1.51	51.8	138	3.98	9.5	149
9	2450	2.76	160	4040	47.1	24.7	420	103	1.52	57.4	120	3.54	10.8	147
10	585	1.77	100	955	13.6	16.5	217	93.4	1.8	67.2	105	3.26	12.4	185
11	520	1.05	61.9	732	9.46	9.98	153	75.4	1.57	50.2	88.9	3.03	8.37	155
12	450	0.78	51.8	668	7.5	8.83	126	71.4	1.58	50.9	116	3.3	8.17	158
13	247	1.43	66.1	318	8.23	10.5	185	68.7	1.35	45.2	105	2.93	8.25	141
14	636	1.46	73.8	1010	14.8	9.31	200	74.7	1.24	40.9	122	2.6	8.34	134
15	508	0.94	58.5	799	10.9	7.43	136	66.4	1.17	52.2	112	2.2	12	110

14 April 2006 NRRC Grab Metals Data at 20 Minute Intervals														
Sample I.D.	Influent Pollutant Concentration (µg/L)							Effluent Pollutant Concentration (µg/L)						
	Al	Cd	Cu	Fe	Pb	Ni	Zn	Al	Cd	Cu	Fe	Pb	Ni	Zn
1-4 Comp	2080	8.41	550	3780	60	120	981	1210	3.07	201	1720	16.1	26.6	711
5	2230	5.62	252	3770	47.2	34	732	953	4.94	250	1670	32.2	50.1	596
6	1150	2.52	142	1760	25.6	18.1	380	365	2.97	124	552	14.3	15.3	354

23 April 2006 NRRC Grab Metals Data at 20 Minute Intervals														
Sample I.D.	**Influent Pollutant Concentration (µg/L)**							**Effluent Pollutant Concentration (µg/L)**						
	Al	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**	**Al**	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**
1-4 Comp	1950	8.67	351	3170	42.6	58.7	1270	742	7.68	228	1280	22.2	34.6	913
5	2540	7.85	336	4120	53.2	60	1150	1000	6.61	214	1740	23.9	36	837
6	842	4.63	216	1250	33.3	36.6	809	945	4.78	159	1470	17.5	24.5	664

22 May 2006 NRRC Grab Metals Data at 20 Minute Intervals														
Sample I.D.	**Influent Pollutant Concentration (µg/L)**							**Effluent Pollutant Concentration (µg/L)**						
	Al	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**	**Al**	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**
1-4 Comp	5140	27.6	987	11300	204	121	2620	1680	12.4	397	3730	80.5	42.6	1140
5	1750	21.7	739	3410	125	65.8	2100	1020	10.2	300	2140	52	30.9	950
6	2000	17.5	568	4750	113	54.8	1640	712	8.1	229	1450	35.3	21.8	777
7	656	14.4	429	1060	68.8	33.7	1360	522	6.7	190	1050	25	19.4	661
8	1080	11.1	345	2340	52.5	29.3	1050	445	6.2	164	931	22.6	15.7	554
9	765	9.9	339	1440	40.7	25.6	927	431	5.7	143	837	19.7	15.6	494
10	731	8.3	221	1360	33.2	20.5	738	430	4.7	124	751	16.5	12.1	435
11	746	7.5	199	1380	31.3	18	656	345	4.3	110	619	14.4	11.7	398
12	668	6.8	183	1230	25.7	17.9	604	294	3.1	89.2	583	10.5	9.3	316
13	540	6.4	169	959	22.6	15.5	588	250	2.8	81.3	465	8.9	10.2	306
14	697	5.1	150	1120	22.1	15	498	241	2.6	81.6	433	8.4	8.1	286
15	2080	8.9	360	4100	83.9	49	1030	359	2.6	84.4	728	11.3	10.5	290

Note the jump at sample 15.

16 October 2006 NRRC Grab Metals Data at 20 Minute Intervals														
Sample I.D.	**Influent Pollutant Concentration (µg/L)**							**Effluent Pollutant Concentration (µg/L)**						
	Al	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**	**Al**	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**
1-4 Comp	3260	29.7	1070	5740	106	119	4810	803	10.6	401	1850	37.4	40	1330
5	3380	11.6	693	5450	57.2	91.4	3120	655	4.4	186	1640	30.5	18.9	501
6	3480	22.3	864	6760	190	73.6	2970	661	3.7	140	1390	29.2	14.1	385
7	1900	12.7	480	3700	97.5	39.8	1640	722	2.9	127	1510	24.4	12.4	332
8	820	10.6	378	1240	61.8	29.1	1360	335	1.9	90	566	10.3	7.25	241
9	1330	7.75	294	2290	53.8	26.8	1090	354	1.6	81.4	587	8.8	6.7	210
10	2090	5.68	256	3610	63.1	25.3	848	297	1.05	53.8	414	6	4.4	143
11	1190	2.97	158	1890	34.7	15.7	589	149	2.3	126	366	6.8	10.3	289
12	898	5.33	342	1550	31	32.6	1020	171	1.9	115	372	6.35	8.7	252
13	1210	6.07	347	1830	38.2	31.9	1070	190	1.75	105	382	6.2	8.6	249
14	844	4.72	267	1380	24.7	24.1	843	204	1.7	107	397	5.9	8.6	228
15	595	2.68	187	898	15.2	18.3	592	200	1.2	80.3	343	4.6	6.8	172
16	353	1.7	150	516	7.5	15.1	430	NS	NS	NS	NS	NS	NS	NS

29 January 2007 NRRC Grab Metals Data at 20 Minute Intervals														
Sample I.D.	**Influent Pollutant Concentration (µg/L)**							**Effluent Pollutant Concentration (µg/L)**						
	Al	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**	**Al**	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**
1-4 Comp	2280	34	488	3550	72.6	37.3	1960	207	4.2	84.6	432	8	8	277
5	1370	22.3	334	2220	35.9	27.4	1330	168	3.6	75.1	376	6.2	7	240
6	1220	19.5	330	1710	46.1	29.1	1280	201	3.3	76.2	410	6.8	7.5	227
7	1120	16.3	297	1500	39.3	25.2	1130	179	3	71.5	353	5.5	7.1	238
8	1160	16	294	1550	37.4	25.2	1190	190	3	72.8	371	6	6.9	221
9	2430	24.8	456	3070	106	34.3	1720	268	3.9	70.9	470	10.5	6.9	239
10	1770	16.7	341	2360	72.4	23.4	1170	261	3.4	61.7	482	9.5	6.4	211
11	976	12.6	213	1290	42.5	16.2	745	289	3.6	61.9	524	10.3	6.3	201
12	756	12.5	187	1120	34	15	676	294	3.6	61.9	535	10.6	6.3	191
13	905	13.1	186	1200	35.7	15.6	678	247	3.7	60.4	451	10	6.5	195
14	797	13.5	192	1260	34.9	17.9	687	233	3.5	54.2	446	8.5	6.1	199
15	845	13.9	196	1200	33.5	15.3	729	203	3.4	51.8	387	8	5.5	173
16	532	13.2	179	827	28	14.4	685	222	3.5	53.9	422	8.2	5.6	188
17	791	14	192	1280	31.3	15.2	689	226	3.2	53.3	412	8.2	5.5	172
18	469	12.3	165	670	23.7	12.8	629	236	3.4	55.9	410	8	5.8	195
19	651	11.9	172	998	29.8	13.8	664	178	3.1	51.3	344	6.5	5.3	164
20	494	11.6	161	739	23	13	625	182	3.2	52.9	339	6.4	5.6	174
21	626	11.1	157	966	24.6	13.8	608	198	3.1	53.5	366	7.4	5.7	182
22	463	10.1	132	729	19.9	11.8	556	242	3.1	53.2	296	7.1	5.7	181
23	398	8.8	122	521	14.2	11.1	503	212	3.1	54.4	367	7.4	5.7	181
24	528	10.1	143	777	21.1	12.7	585	180	2.7	48.5	314	6.3	5.3	170

18 February 2007 NRRC Grab Metals Data at 20 Minute Intervals														
Sample I.D.	**Influent Pollutant Concentration (µg/L)**							**Effluent Pollutant Concentration (µg/L)**						
	Al	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**	**Al**	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**
1-4 Comp	2200	20.7	307	2960	101	22.8	1170	390	3.4	63.4	673	15.7	7.6	180
5	1270	8.4	171	1840	49.4	14.1	653	192	2	37.9	345	7.8	4.3	117
6	965	5.7	145	1390	39.8	12.5	528	158	1.4	30.9	271	4.6	3.9	92
7	*	*	*	*	*	*	*	121	0.9	24.1	185	4.7	2.2	61.2
8	806	6.2	139	1110	30.2	11.3	473	90.4	0.9	19.6	144	3	1.8	53.8
9	958	7.8	187	1330	45	14.5	643	227	1.4	36.9	427	9.9	4.2	92.6
10	1270	8.2	163	1760	49.3	12.6	606	110	1.5	25.7	218	5.4	3.3	81.6
11	2550	38.8	445	2760	153	26.5	1480	135	1.1	21.2	202	4.7	2	67.9
12	1390	19.3	237	2080	78.7	15.5	887	123	1.2	21.7	194	5.5	1.7	66.1
13	961	7.5	119	1420	36.3	10.1	458	153	1	26	230	6.6	2.8	70.1
14	764	5.6	94.5	1120	28.9	7.8	372	191	1.1	27.1	274	7.2	3.2	71.7
15	1420	19.5	255	1950	79	15.8	973	157	0.7	18.6	203	4.1	1.6	57.7
16	726	8.9	146	1120	34.7	10.8	446	123	0.9	18.8	174	3.7	1.5	56.7
17	637	7.2	117	906	31	8.3	401	93	0.7	16.4	134	3.4	1.6	47.3
18	384	4.1	67.9	524	15.9	6	252	110	0.6	16	137	3.1	1.3	47.2
19	310	4.7	78.4	455	16.1	6.2	311	108	0.6	16.4	138	2.9	1.3	46.7
20	268	4.9	71.8	401	13.9	6.5	311	93.4	0.7	20.1	166	3.5	2.9	79.7
21	343	4.9	82.9	490	18.5	7	334	92.4	0.7	16.3	133	3.3	1.3	51
22	238	4.2	65.1	355	12.4	6	299	109	0.6	16	149	3	1.3	57
23	373	6.6	88.3	556	18.8	7.7	423	93.2	0.7	15.8	124	3	1.4	70.8
24	309	5.6	79.7	490	14.7	6.8	376	111	0.7	15.8	131	2.9	1.4	55.6

* Missing Data

22 February 2007 NRRC Grab Metals Data at 20 Minute Intervals														
Sample I.D.	**Influent Pollutant Concentration (µg/L)**							**Effluent Pollutant Concentration (µg/L)**						
	Al	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**	**Al**	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**
1-4 Comp	1020	8.0	143	1220	35.7	12.2	572	105	1.52	28.7	163	3.1	3.6	102
5	1220	14.9	198	1540	53.4	14.3	927	87.5	1.2	23.9	99.4	1.9	2.8	86.7
6	822	10.8	148	1040	37.8	11.1	721	75	0.9	20.2	89.6	1.8	2.2	72.8
7	520	6.7	108	688	24	8.9	484	89.4	0.8	18.6	97.1	1.9	5.8	69
8	360	3.7	67.4	459	14.1	5.7	298	99.5	0.8	18.2	105	1.9	1.8	61.4
9	284	2.5	58.7	407	12	6.6	257	91.3	0.8	17.5	101	1.7	1.7	58.9
10	311	3.5	69.6	389	16.3	6.4	279	98.9	0.7	16.4	101	1.6	1.6	55.3
11	509	6.8	127	658	30.1	7.8	473	91.9	ND	13.5	88.1	1.4	1.7	43.2

27 February 2007 NRRC Grab Metals Data at 20 Minute Intervals														
Sample I.D.	**Influent Pollutant Concentration (µg/L)**							**Effluent Pollutant Concentration (µg/L)**						
	Al	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**	**Al**	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**
1-4 Comp	1820	30.4	356	2390	92.9	26.1	1870	327	2.5	34.4	464	7.0	3.6	167
5	1310	26.2	289	1780	66.4	21.7	1580	211	3.1	48.7	345	8.8	5.1	217
6	961	17	212	1340	49.6	17.5	1120	197	2.5	46.4	284	8.6	5.3	208
7	827	10	162	1050	49.2	12	725	203	2.2	45.5	325	7.2	4.9	169
8	625	7.4	125	787	24	11.1	580	340	1.9	42.7	414	6.7	3.6	156
9	805	10.8	160	1100	58	13.7	786	161	1.4	21.2	218	3.7	2.2	110
10	1110	12.6	214	1340	67.7	14.7	909	161	1.2	20.2	202	3.4	2.0	91.8
11	1080	9.4	166	1310	52.2	13.3	715	171	1.0	19.2	188	3.3	1.8	90.9
12	734	7.2	133	940	46.6	10.5	583	186	1.1	19.9	219	3.3	1.9	88.5
13	683	5.1	104	866	29	8.7	449	216	0.9	20.0	268	3.3	1.9	88.4
14	672	5.8	105	886	30.1	8.7	448	247	0.7	18.6	253	3.3	1.7	83.4
15	625	5.7	118	985	31.2	8.9	441	284	0.7	15.9	291	3.3	1.3	66.4

22 March 2007 NRRC Grab Metals Data at 20 Minute Intervals														
Sample I.D.	**Influent Pollutant Concentration (µg/L)**							**Effluent Pollutant Concentration (µg/L)**						
	Al	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**	**Al**	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**
1-4 Comp	3180	11	335	5350	65.6	29	928	265	3	81	524	9.4	7.6	222

20 April 2007 NRRC Grab Metals Data at 20 Minute Intervals														
Sample I.D.	**Influent Pollutant Concentration (µg/L)**							**Effluent Pollutant Concentration (µg/L)**						
	Al	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**	**Al**	**Cd**	**Cu**	**Fe**	**Pb**	**Ni**	**Zn**
1-4 Comp	1210	11.6	342	1830	51.8	23.4	1260	217	3.2	88	427	12.3	5.8	251
5	976	9.3	299	1440	44.1	22.3	1100	134	2.1	61.6	211	6.6	4.4	163
6	718	7.6	249	918	34.5	19.7	951	139	1.8	58.5	244	5.5	4.4	148
7	873	6.0	210	1070	31.3	18.3	826	196	1.7	54.9	250	5.2	3.8	136
8	944	7.1	227	1350	36.4	18.8	872	221	1.5	53	305	4.9	3.7	147
9	1050	5.7	200	1490	33.7	16.9	772	241	1.1	43.9	285	3.9	3.4	95.4
10	641	4.0	154	848	22.6	13.5	589	234	0.7	36	262	3.1	2.8	69.1
11	800	7.7	225	1250	36.8	16.7	856	109	1.4	40	163	3.9	3.1	95.8
12	1010	16.7	431	1360	107	22.7	1310	94	1.3	38.2	154	4.3	2.7	97.7
13	539	8.2	214	892	49.2	12.2	717	117	1.3	39.8	178	4.9	2.9	95.9
14	730	9.2	227	1080	54.5	13	783	154	1.3	40.4	201	5.4	2.8	98.4
15	380	7.6	184	559	46	10.6	636	143	1.2	38.8	210	5.2	2.6	93.4
16	440	5.4	152	641	29.9	12.2	516	187	1.0	36.6	193	4.9	2.6	96.6
17	1100	4.6	142	1970	37.4	13.3	467	134	0.7	28.9	186	3.8	2.2	63.7
18	1190	3.9	129	2010	35.6	10.5	433	68.4	1.1	40.4	168	1.7	3.2	104
19	432	4	149	685	18.3	10.2	452	ND	0.9	36.3	101	1.6	2.7	89.2
20	487	4.3	150	724	18.9	10.5	439	ND	0.9	34.3	93.5	1.5	2.5	82.1
21	292	2.7	112	404	10.9	8.6	317	ND	0.7	32.3	89.8	1.4	2.4	76
22	380	3.2	125	532	17.9	8.8	385	60.7	.6	28.4	106	1.4	2.1	61.5
23	214	2.1	95.5	308	9.8	7.4	258	50.6	.6	26.2	72.1	1.3	2	48.6
24	480	6.2	162	706	26.3	12.3	557							

ANAD First Flush Sampling Data

Pollutant	ANAD First Flush Results					
	10/17/06 Influent/Effluent	**11/15/06** Influent/Effluent	**1/18/07** Influent/Effluent	**2/13/07** Influent/Effluent	**3/16/07** Influent/Effluent	**4/4/07** Influent/Effluent
Antimony (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Arsenic (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Barium (mg/L)	0.0153 / ND	0.032 / 0.038	0.0377 / ND	0.0502 / 0.0123	0.0334 / 0.0108	0.0156 / ND
Beryllium (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Cadmium (mg/L)	0.008 / ND	0.0261 / ND	0.0149 / ND	0.0371 / 0.0021	0.0263 / 0.003	0.0222 / ND
Calcium (mg/L)	NS	NS	10.8 / 12.0	12.0 / ND	8.22 / 19.8	7.21 / 14.6
Chromium (mg/L)	0.0069 / ND	0.0198 / ND	0.0103 / ND	0.0391 / ND	0.0115 / ND	0.00630 / ND
Cobalt (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Copper (mg/L)	0.0384 / ND	0.0693 / ND	0.0408 / ND	0.0625 / ND	0.0371 / 0.0243	0.0324 / ND
Lead (mg/L)	0.0121 / ND	0.0514 / ND	0.0236 / ND	0.0631 / 0.0061	0.0427 / ND	0.00610 / ND
Magnesium (mg/L)	NS	NS	2.42 / 4.99	1.97 / 4.32	1.45 / 4.87	ND / 4.92
Molybdenum (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Nickel (mg/L)	ND / ND	0.0113 / ND	ND / ND	0.0189 / ND	ND / ND	0.0110 / ND

Selenium (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Silver (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Thallium (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Vanadium (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Zinc (mg/L)	0.0973 / ND	0.185 / ND	0.113 / ND	0.318 / ND	0.254 / ND	0.0931 / ND
Mercury (mg/L)	ND / ND	0.00021 / ND	ND / ND	ND / ND	ND / 0.00172	0.000210 / ND
Benzene (µg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Ethylbenzene (µg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Naphthalene (µg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Toluene (µg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Xylenes, total (µg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Diesel (µg/L)	1990 / 2150	1600 / 254	528 / 178	4420 / 597	NS	2260 / 505
pH	6.97 / 6.1	NS	6.91 / 6.41	6.27 / 6.52	NS	NS
TSS (mg/L)	64 / 5	NS	NS	360 / <5	NS	NS
TDS (mg/L)	99 / 34	NS	56 / 34	66 / 92	NS	NS
BOD (mg/L)	<5 / 4	NS	NS	20 / 5	NS	NS
COD (mg/L)	34 / 28.9	49.3 / ND	22.3 / ND	57.3 / ND	59.5 / ND	30.3 / 10.6
Phosphorus (mg/L)	0.107 / ND	ND / ND	0.218 / ND	ND / 0.160	0.123 / ND	0.188 / 0.176
MBAS	NS	0.104 / ND	0.0867 / ND	0.609 / 0.110	NS	0.235 / 0.0699

(mg/L)						
Nitrate/Nitrite (mg/L)	NS	ND / 0.484	ND / ND	0.767 / 0.301	0.132 / 0.726	0.177 / ND
Specific Conductance (umhos/cm)	NS	99.6 / 367	123 / 119	108 / 129	73 / 148	79.9 / 156
Total Nitrogen (mg/L)	NS	0.313 / 0.588	0.494 / 0.31	1.87 / 0.781	0.928 / 0.952	0.752 / ND
TKN (mg/L)	NS	0.313 / 0.104	0.494 / 0.31	1.10 / 0.480	0.796 / 0.226	0.752 / ND
Hardness (mg/L)	NS	29.1 / 169	36.9 / 50.5	38.1 / 46	26.5 / 69.5	18 / 56.7
Oil & Grease (mg/L)	NS	NS	NS	13 / 4	NS	NS

Yellow denotes effluent>influent

ANAD Composite Sampling Data

Pollutant	ANAD Composite Results					
	10/17/06 Influent/Effluent	**11/15/06** Influent/Effluent	**1/18/07** Influent/Effluent	**2/13/07** Influent/Effluent	**3/16/07** Influent/Effluent	**4/4/07** Influent/Effluent
Antimony (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Arsenic (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Barium (mg/L)	0.0113 / ND	0.0276 / 0.0117	0.0157 / ND	0.0302 / 0.0301	0.025 / ND	0.0125 / ND
Beryllium (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Cadmium (mg/L)	0.0062 / ND	0.0235 / ND	0.0109 / ND	0.0231 / 0.0015	0.0162 / 0.0012	0.0165 / ND
Calcium (mg/L)	NS	NS	6.51 / 17.7	9.10 / 32	13.1 / 12.3	5.23 / 14.8
Chromium (mg/L)	ND / ND	0.0164 / ND	ND / ND	0.0291 / ND	0.00990 / ND	0.00580 / ND
Cobalt (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Copper (mg/L)	0.0363 / 0.0486	0.0623 / ND	0.0222 / ND	0.0389 / ND	0.0374 / ND	0.0382 / ND
Lead (mg/L)	0.0096 / 0.0055	0.0445 / ND	0.00951 / ND	0.0331 / 0.0051	0.0286 / ND	0.00570 / ND
Magnesium (mg/L)	NS	NS	1.10 / 7.8	1.24 / 13.8	1.17 / 4.95	ND / 5.03
Molybdenum (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Nickel (mg/L)	ND / ND	0.0105 / ND	ND / ND	0.0101 / ND	ND / ND	ND / ND
Selenium	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND

(mg/L)						
Silver (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Thallium (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Vanadium (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Zinc (mg/L)	0.0912 / 0.134	0.179 / ND	0.0724 / ND	0.176 / ND	0.176 / ND	0.0813 / ND
Mercury (mg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	0.000766 / ND
Benzene (µg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Ethylbenzene (µg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Naphthalene (µg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Toluene (µg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Xylenes, total (µg/L)	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND	ND / ND
Diesel (µg/L)	3740 / 3030	1210 / 175	284 / ND	2590 / 371	NS	NS
pH	NS	NS	6.98 / 6.67	5.85 / 7.27	NS	NS
TSS (mg/L)	NS	NS	NS	160 / <5	NS	NS
TDS (mg/L)	NS	NS	24 / 98	38 / 150	NS	NS
BOD (mg/L)	NS	NS	NS	16 / 4	NS	NS
COD (mg/L)	56.6 / 53.8	42.9 / ND	12.4 / ND	47.1 / ND	63 / 14.6	45.2 / 15.6
Phosphorus (mg/L)	ND / ND	ND / ND	ND / ND	0.130 / 0.120	0.154 / 0.126	ND / 0.169
MBAS (mg/L)	NS	0.0877 / ND	0.0739 / ND	0.493 / 0.141	NS	0.230 / ND
Nitrate/Nitrite (mg/L)	NS	ND / 0.2	0.233 / 0.205	0.472 / 0.592	ND / 0.535	ND / ND
Specific	NS	350 / 147	74.3 / 172	89.6 / 275	86.4 / 148	68.3 / 160

Conductance (umhos/cm)						
Total Nitrogen (mg/L)	NS	0.197 / 0.656	0.533 / 0.332	1.10 / 0.724	0.584 / 0.767	0.395 / 0.118
TKN (mg/L)	NS	0.197 / 0.456	0.3 / 0.127	0.626 / 0.132	0.584 / 0.232	0.395 / 0.118
Hardness (mg/L)	NS	26.5 / 52.4	20.8 / 76.3	27.8 / 137	37.5 / 51.1	13.1 / 57.7
Oil & Grease (mg/L)	NS	NS	NS	7 / 6	NS	NS

Yellow denotes effluent>influent