

Springwoods Subdivision Study Final Report

Prepared in cooperation with the Harris County Flood Control District
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Environmental Institute of Houston
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Springwoods Subdivision Study Final Report



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TABLE OF CONTENTS

EXECUTIVE SUMMARY.....	9
INTRODUCTION	11
Problem Statement	11
Background	13
Study Area	13
Land Use and Environment	14
Historical Hydrology in Watershed.....	14
Study Objective	15
METHODS	16
Site Selection and Description	16
Sampling Schedule	16
Sampling Methods.....	19
Precipitation.....	19
Stormwater samplers	19
Grab Samples and Flow.....	22
Game Cameras and Site Photographs.....	22
Sampling Protocol	22
Data Analysis	24
RESULTS	24
Precipitation.....	24
Sampling Schedule	25
Stormwater and Grab Samples	26
Nitrogen	28
Orthophosphate.....	28
Suspended Solids and Turbidity	28
Bacteria.....	36
Oil and Grease	36
Heavy Metals	38
Site Photographs and Progression of Construction.....	41
Game Cameras	68
DISCUSSION	72

LITERATURE CITED 74

APPENDIX 1: CALIBRATION DATA 76

APPENDIX 2: FIELD DATA 77

APPENDIX 3: PHOTOGRAPHIC RECORD 78

APPENDIX 4: WEATHER CONDITION SUMMARY 79

APPENDIX 5: GOOGLE EARTH INTERACTIVE MAP 80

LIST OF FIGURES

FIGURE 1. SPRINGWOODS DEVELOPMENT SITE LOCATION RELATIVE TO HOUSTON AND SPRING CREEK HIGHLIGHTING MAJOR LANDMARKS AND MAJOR ROADS.....	12
FIGURE 2. SPRINGWOODS SUBDIVISION DEVELOPMENT AREA OUTLINED (RED), FILED SURVEY SITES, AND SPRING CREEK: J100-00-00.	13
FIGURE 3. SPRING CREEK WATERSHED HUC CODE 12040102 (SOURCE: EPA SURF YOUR WATERSHED.	14
FIGURE 4. ANNUAL FREQUENCY OF DAILY HIGH FLOW PULSES RECORDED AT THE USGS 08068500 SPRING CREEK GAGE BASED ON IHA SOFTWARE ANALYSIS.....	15
FIGURE 5. UPSTREAM (LEFT) AND DOWNSTREAM (RIGHT) VIEW OF SITE 1 STORMWATER SAMPLING LOCATION.	17
FIGURE 6. UPSTREAM (LEFT) AND DOWNSTREAM (RIGHT) VIEW OF SITE 2 STORMWATER SAMPLING LOCATION.	17
FIGURE 7 TIME LAPSE GOOGLE EARTH™ IMAGERY SHOWING PRESENCE OF PRE-DEVELOPMENT CLEARING DURING THE EARLY PHASES OF THIS STUDY.	18
FIGURE 8. NALGENE STORMWATER FIRST FLUSH SAMPLER USED DURING THE STUDY.....	19
FIGURE 9. DEPLOYMENT OF THE STORMWATER SAMPLER USED DURING THIS STUDY.....	20
FIGURE 10. RETRIEVAL OF STORMWATER SAMPLE AT SITE 2.	21
FIGURE 11. ILLUSTRATION OF BOXPLOT USED TO ANALYZE DISTRIBUTION OF DATA.....	24
FIGURE 12. RECORDED 24 HOUR PRECIPITATION AT THE HCFCD 1050 RAIN GAGE CO-LOCATED AT THE USGS 08068500 SITE ON SPRING CREEK AND I-45..	25
FIGURE 13. AMMONIA NITROGEN LEVELS IN RUNOFF DURING RAINFALL EVENTS.	29
FIGURE 14. NITRATE AND NITRITE NITROGEN LEVELS IN RUNOFF DURING RAINFALL EVENTS.	29
FIGURE 15. BOXPLOT OF AMMONIA NITROGEN LEVELS MEASURED AT EACH SITE AND TYPE OF SAMPLE OVER ALL SAMPLING PERIODS OF THE STUDY.....	30
FIGURE 16. BOXPLOT OF NITRATE + NITRITE NITROGEN LEVELS MEASURED AT EACH SITE AND TYPE OF SAMPLE OVER ALL SAMPLING PERIODS OF THE STUDY.....	30
FIGURE 17. RELATIONSHIP BETWEEN PRECIPITATION AND AMMONIA NITROGEN RUNOFF LEVELS AT EACH SITE BY COLLECTION METHOD.	31
FIGURE 18. RELATIONSHIP BETWEEN PRECIPITATION AND COMBINED NITRATE NITRITE NITROGEN RUNOFF LEVELS AT EACH SITE BY COLLECTION METHOD.	31
FIGURE 19. ORTHOPHOSPHATE LEVELS IN RUNOFF DURING RAINFALL EVENTS.	32
FIGURE 20. BOXPLOT OF ORTHOPHOSPHORUS LEVELS MEASURED AT EACH SITE AND TYPE OF SAMPLE OVER ALL SAMPLING PERIODS OF THE STUDY.....	32
FIGURE 21. RELATIONSHIP BETWEEN PRECIPITATION AND ORTHOPHOSPHORUS LEVELS IN RUNOFF AT EACH SITE BY COLLECTION METHOD.	33
FIGURE 22. TOTAL SUSPENDED SOLID LEVELS IN RUNOFF DURING RAINFALL EVENTS.	33
FIGURE 23. TURBIDITY LEVELS IN RUNOFF DURING RAINFALL EVENTS.	34
FIGURE 24. BOXPLOT OF TOTAL SUSPENDED SOLIDS (TSS) LEVELS MEASURED AT EACH SITE AND TYPE OF SAMPLE OVER ALL SAMPLING PERIODS OF THE STUDY.	34
FIGURE 25. BOXPLOT OF TURBIDITY (NTU) LEVELS MEASURED AT EACH SITE AND TYPE OF SAMPLE OVER ALL SAMPLING PERIODS OF THE STUDY.....	35

FIGURE 26. RELATIONSHIP BETWEEN PRECIPITATION AND TOTAL SUSPENDED SOLIDS (TSS) LEVELS IN RUNOFF AT EACH SITE BY COLLECTION METHOD.....35

FIGURE 27. RELATIONSHIP BETWEEN PRECIPITATION AND TURBIDITY (NTU) LEVELS IN RUNOFF AT EACH SITE BY COLLECTION METHOD.....36

FIGURE 28. *E. COLI* LEVELS IN RUNOFF DURING RAINFALL EVENTS.37

FIGURE 29. RELATIONSHIP BETWEEN PRECIPITATION AND *E. COLI* (MPN/100 mL) LEVELS IN RUNOFF AT EACH SITE....37

FIGURE 30. OIL AND GREASE LEVELS IN RUNOFF DURING RAINFALL EVENTS.38

FIGURE 31. MERCURY LEVELS FOR RAINFALL EVENTS.39

FIGURE 32. CADMIUM LEVELS FOR RAINFALL EVENTS.39

FIGURE 33. ZINC AND LEAD LEVELS FOR RAINFALL EVENTS.40

FIGURE 34. PHOTOGRAPH OF SITE 1, TAKEN ON 10/8/10 BEFORE DEPLOYMENT OF STORMWATER SAMPLER42

FIGURE 35. PHOTOGRAPH OF SITE 2, TAKEN ON 10/8/10 IMMEDIATELY AFTER DEPLOYMENT OF STORMWATER SAMPLER FACING UPSTREAM42

FIGURE 36. PHOTOGRAPH OF SITE 1, TAKEN DURING WET WEATHER EVENT 1 ON 11/2/10, LOOKING DOWNSTREAM AT STORMWATER SAMPLER AND GAGE..43

FIGURE 37. PHOTOGRAPH OF SITE 1, TAKEN DURING WET WEATHER EVENT 1 ON 11/2/10, LOOKING DOWNSTREAM AT STORMWATER SAMPLER AND GAGE.43

FIGURE 38. PHOTOGRAPH OF SITE 1, TAKEN DURING EVENT 1 ON 11/2/10, LOOKING UPSTREAM FROM STORMWATER SAMPLER AND GAGE..44

FIGURE 39. PHOTOGRAPH OF SITE 2, TAKEN DURING EVENT 2 ON 11/2/10, LOOKING DOWNSTREAM FROM STORMWATER SAMPLER AND GAGE.44

FIGURE 40. PHOTOGRAPH OF SITE 1, TAKEN DURING 1/14/11, LOOKING DOWNSTREAM TOWARD FLOOD AREA CONTAINING STORMWATER SAMPLER AND GAGE 5 DAYS AFTER SIGNIFICANT RAIN45

FIGURE 41. PHOTOGRAPH OF SITE 1, TAKEN ON 1/28/11, DEPICTING HCFCD PERSONNEL DIGGING UP STORMWATER SAMPLER TO MOVE IT DOWNSTREAM46

FIGURE 42. PHOTOGRAPH OF SITE 1, TAKEN ON 1/28/11, DEPICTING DOWNSTREAM VIEW OF NEW SITE LOCATION FROM MID-CHANNEL, UPSTREAM46

FIGURE 43. PHOTOGRAPH OF SITE 1, TAKEN ON 2/8/11, DEPICTING STORMWATER SAMPLER AND GAUGE POSTS FROM RIGHT BANK.....47

FIGURE 44. PHOTOGRAPH OF SITE 1, TAKEN ON 2/8/11, DEPICTING STORMWATER SAMPLER WITH SEDIMENT CAKED ON SAMPLER TUBE TOP47

FIGURE 45. PHOTOGRAPH OF SITE 1, TAKEN ON 2/8/11, DEPICTING STORMWATER SAMPLER BOTTLE COMPLETELY FILLED AFTER A NON-QUALIFYING RAIN EVENT.48

FIGURE 46. PHOTOGRAPH OF NEW CLEARLY AREA ALONG ROAD ADJACENT TO SITE 1, TAKEN ON 3/7/1149

FIGURE 47. PHOTOGRAPH OF SITE 1 TAKEN DURING EVENT 2 ON MAY 13, 2011.49

FIGURE 48. PHOTOGRAPH OF SITE 2 TAKEN DURING EVENT 2 ON MAY 13, 2011..50

FIGURE 49. PHOTOGRAPH OF SITE 1 TAKEN DURING EVENT 3 ON JUNE 22, 2011..51

FIGURE 50. PHOTOGRAPH OF SITE 2 TAKEN DURING EVENT 3 ON JUNE 22, 2011..51

FIGURE 51. PHOTOGRAPH OF SITE 2 TAKEN DURING EVENT 3 ON JUNE 22, 2011.52

FIGURE 52. PHOTOGRAPH OF SITE 2 TAKEN DURING EVENT 4 ON JUNE 23, 2011..52

FIGURE 53. PHOTOGRAPH OF CULVERT DRAIN AT UPSTREAM ROAD FROM SITE 1 TAKEN ON AUGUST 18, 2011.....53

FIGURE 54. PHOTOGRAPH OF SITE 1 TAKEN ON AUGUST 18, 2011 SHOWING DEBRIS AND MUD.53

FIGURE 55. PHOTOGRAPH OF SITE 2 TAKEN ON AUGUST 18, 2011 SHOWING STORMWATER SAMPLER AND GAGE IN DRY CREEK.....54

FIGURE 56. PHOTOGRAPH OF SITE 2 TAKEN ON AUGUST 18, 2011 SHOWING STORMWATER SAMPLER BOTTLE COMPLETELY FULL FROM NON-QUALIFYING WET WEATHER EVENT.54

FIGURE 57. PHOTOGRAPH OF SITE 2 TAKEN ON SEPTEMBER 1, 2011 SHOWING CONSTRUCTION ACTIVITY UPSTREAM OF SAMPLER.....55

FIGURE 58. PHOTOGRAPH OF SITE 1 TAKEN ON NOVEMBER 9, 2011 SHOWING STORMWATER SAMPLER AND STAFF GAGE WITH ACCUMULATED DEBRIS55

FIGURE 59. PHOTOGRAPH OF SITE 1 TAKEN ON STORMWATER SAMPLING EVENT 5, SEPTEMBER 19, 2011 SHOWING CONSTRUCTION ACTIVITY UPSTREAM OF SAMPLER.....56

FIGURE 60. PHOTOGRAPH OF SITE 1 TAKEN DURING STORMWATER SAMPLING EVENT 5 ON SEPTEMBER 19, 2011 DEPICTING DITCH UPSTREAM OF SAMPLER FULL OF MUDDY RUNOFF FROM CONSTRUCTION ACTIVITY56

FIGURE 61. PHOTOGRAPH OF SITE 1 TAKEN DURING STORMWATER SAMPLING EVENT 5 ON SEPTEMBER 19, 2011 SHOWING STORMWATER SAMPLER OBSTRUCTED WITH DEBRIS.57

FIGURE 62. PHOTOGRAPH OF SITE 1 TAKEN DURING EVENT 5 ON SEPTEMBER 19, 2011.....57

FIGURE 63. PHOTOGRAPH OF SITE 2 TAKEN ON STORMWATER SAMPLING EVENT 5, SEPTEMBER 19, 2011 SHOWING CONSTRUCTION ACTIVITY UPSTREAM OF SAMPLER.....58

FIGURE 64. PHOTOGRAPH OF SITE 2 TAKEN ON STORMWATER SAMPLING EVENT 5, SEPTEMBER 19, 2011 SHOWING MINIMAL WATER IN DITCH AND MINIMAL AMOUNT OF WATER IN SAMPLER58

FIGURE 65. PHOTOGRAPH OF SIDE VIEW OF NEW CULVERT INSTALLED NEAR UPSTREAM OF SITE 1 TAKEN DURING EVENT 6 ON OCTOBER 10, 2011.....59

FIGURE 66. PHOTOGRAPH OF TOP VIEW OF NEW CULVERT INSTALLED NEAR UPSTREAM OF SITE 1 TAKEN DURING STORMWATER SAMPLING EVENT 6 ON OCTOBER 10, 2011.....59

FIGURE 67. PHOTOGRAPH OF SITE 2 TAKEN DURING EVENT 6 ON OCTOBER 10, 2011. VIEW OF POOLS OF RAIN WATER IN THE CREEK; PHOTO TAKEN FROM RIGHT BANK LOOKING DOWNSTREAM.60

FIGURE 68. PHOTOGRAPH OF SITE 2 TAKEN DURING EVENT 6 ON OCTOBER 10, 2011. VIEW OF THE POOLS OF RAIN WATER DOWNSTREAM OF THE SAMPLER.60

FIGURE 69. PHOTOGRAPH OF SITE 1 STAFF GAGE TAKEN ON NOVEMBER 9, 2011, A DAY AFTER RAINFALL. NO STORMWATER SAMPLER WAS DEPLOYED ON THIS DATE.....61

FIGURE 70. PHOTOGRAPH OF CONSTRUCTION AREA IMMEDIATELY UPSTREAM OF SITE 2 ON NOVEMBER 9, 2011, A DAY AFTER SIGNIFICANT RAINFALL.61

FIGURE 71. PHOTOGRAPH OF SITE 2 ON NOVEMBER 9, 2011, A DAY AFTER RAINFALL.....62

FIGURE 72. PHOTOGRAPH OF COLLECTION BOTTLE FROM STORMWATER SAMPLER BOTTLE AT SITE 2 ON NOVEMBER 9, 2011, A DAY AFTER RAINFALL.62

FIGURE 73. PHOTOGRAPH OF STORMWATER SAMPLER AT SITE 1 DURING SAMPLING EVENT 7 ON NOVEMBER 15, 2011.63

FIGURE 74. PHOTOGRAPH OF STORMWATER SAMPLER AT SITE 1 DURING SAMPLING EVENT 7 ON NOVEMBER 15, 2011..63

FIGURE 75. PHOTOGRAPH OF CONSTRUCTION SITE UPSTREAM OF SITE 2 ON NOVEMBER 15, 2011 DURING EVENT 7. ..64

FIGURE 76. PHOTOGRAPH OF DITCH UPSTREAM OF SITE 2 ON NOVEMBER 15, 2012 DURING SAMPLING EVENT 7. NOTE FOAM IN WATER.....64

FIGURE 77. PHOTOGRAPH OF THE STAFF GAGE AND SAMPLER AT SITE 2 ON NOVEMBER 15, 2012, WITH SAMPLER CAP REMOVED; MORE SEDIMENT DEPOSITED IN THE CREEK FROM THE CONSTRUCTION.65

FIGURE 78. PHOTOGRAPH OF SEDIMENT DEPOSITED ON THE STORMWATER SAMPLER COLLECTOR AT SITE 2 DURING EVENT 7 ON NOVEMBER 15, 2012.....65

FIGURE 79. PHOTOGRAPH OF SITE 1 STORMWATER SAMPLER ON NOVEMBER 29, 2011 JUST PRIOR TO REMOVAL AT END OF STUDY.66

FIGURE 80. PHOTOGRAPH OF AREA UPSTREAM OF SITE 1 STORMWATER SAMPLER ON NOVEMBER 29, 2011.66

FIGURE 81. PHOTOGRAPH OF SITE 2 ON NOVEMBER 29, 2011 ON LAST DAY OF STUDY PRIOR TO STORMWATER SAMPLER REMOVAL.67

FIGURE 82. PHOTOGRAPH OF STORMWATER SAMPLER AT SITE 2 ON NOVEMBER 29, 2011 PRIOR TO STORMWATER SAMPLER REMOVAL ON LAST DAY OF STUDY.67

FIGURE 83. PHOTOGRAPH OF FLYING SHORT-EARED OWL, *ASIO FLAMMEUS* ATTACKING A RABBIT68

FIGURE 84. PHOTOGRAPH OF ARMADILLO. THIS SPECIES WAS ALSO OBSERVED DURING THE DAYTIME.....69

FIGURE 85. PHOTOGRAPH OF BOBCAT. THIS SPECIES WAS ALSO OBSERVED AT NIGHT.....69

FIGURE 86. PHOTOGRAPH OF MALE WHITE TAILED DEER.....70

FIGURE 87. PHOTOGRAPH OF FEMALE WHITE TAILED DEER.70

FIGURE 88. PHOTOGRAPH OF COYOTE. THIS SPECIES WAS ALSO OBSERVED AT NIGHT.....71

FIGURE 89. PHOTOGRAPH OF OPOSSUM.71

FIGURE 90. PHOTOGRAPH OF RACCOONS.....72

LIST OF TABLES

TABLE 1 SAMPLE SITE DESCRIPTIONS AND LOCATIONS FOR SPRINGWOODS SUBDIVISION STUDY.....16

TABLE 2. FIELD PARAMETERS COLLECTED BY EIH PERSONNEL AT EVERY SITE VISIT (WHEN POSSIBLE) AND WATER
QUALITY SAMPLE TYPES WITH SPECIFIED CONTAINERS AND PRESERVATIVES.23

TABLE 3. RANKING OF THREE MONTH PRECIPITATION AMONG HISTORICAL VALUES BASED ON TEXAS STATEWIDE
AVERAGE PRECIPITATION25

TABLE 4. ATTEMPTED WET-WEATHER SAMPLE EVENTS FOR EACH SITE AT SPRINGWOODS SUBDIVISION.26

TABLE 5. FIELD PARAMETERS COLLECTED AFTER EACH RAINFALL EVENT IN SPRINGWOODS SUBDIVISION.27

EXECUTIVE SUMMARY

The population of Harris County is expected to continue to grow resulting in an increase of 2,006,000 individuals by the year 2035 (HGAC 2006). As the human population grows there will be increased demands for housing, roads and commercial development. The resulting increased urbanization will alter stream hydrology and contaminant loads. The term “urban stream syndrome” has been used to describe the consistently observed ecological degradation of streams draining urban land. Symptoms of the urban stream syndrome include a flashier hydrograph, increased sediment loading, elevated concentrations of nutrients and contaminants, altered channel morphology and reduced biotic richness with increased dominance of tolerant species. This is due to the replacement of natural soils and vegetation with impervious surfaces which leads to elevated stormwater runoff containing higher concentrations of contaminants.

In an effort to reduce additional impacts from population growth and associated urbanization, new residential communities and municipalities have begun to adopt low impact development (LID) technology. LID is an approach used in land development that manages stormwater as close to its source as possible. Harris County Flood Control District and Harris County Public Infrastructure Department have developed a Low Impact Development & Green Infrastructure Design Criteria for Storm Water Management (http://www.hcfc.org/downloads/manuals/2011-FINAL_LID_GIDC.pdf). Prior to the publication of this guidance document, developers in Harris County were unable to use LID practices for detention credit. LID portions of Springwoods Village, and other proposed developments are operating in Harris County under these guidelines as an evaluations of the usefulness of LID practices within the upper Gulf Coast Region.

Springwoods Village is a new mixed-use community development project covering 1,575 acres in northern Harris County located 30 miles north of downtown Houston and less than 10 miles from George Bush International Airport. Development was scheduled to be conducted in six phases and began in 2011. Low Impact Development (LID) was an integral part of the community development plan used to mitigate runoff and impacts on water quality. In order to better understand and quantify the benefits of LID methods used in the Springwoods Village, it is necessary to take pre-construction, baseline conditions of water quality during wet weather events and compare to conditions during and after construction. The Environmental Institute of Houston at University of Houston – Clear Lake (EIH), partnered with Harris County Flood Control District (HCFC) and Springwoods subdivision developers to obtain data on the effects of LID methods for effluent water quality discharging into nearby Spring Creek (HCFC Unit J100-00-00).

The original scope of the study was to characterize and compare pre-construction and construction stormwater quality at the Springwoods Development Site. The overall objective was to verify the effectiveness of LID methods utilized by Springwoods Development contractors during the construction phase of the project. Due to an advancing construction timeline, pre-construction monitoring did not take place before construction groundbreaking at the site. Stormwater runoff samples, grab samples, and photographic techniques were employed to evaluate the changes in site conditions during construction.

Based on the results of this study EIH was able to characterize the runoff water quality from two sites: site 1 with extensive construction activity and site 2, with minimal activity until later in the project. Evaluation of aerial photography showed that extensive construction activity had already begun by the time EIH began the monitoring project. Therefore it is very difficult to consider data collected during this study as “background” pre-construction data. However, some data collected at site 2, prior to June 2011, suggests that pre-project levels of turbidity and Total Suspended Solids (TSS) were closer to 20 NTU and 40 mg/L respectively. These values were never again observed throughout the study.

Data collected from this study shows that turbidity readings taken on site were elevated in comparison to ambient levels. Almost all of the runoff samples collected during this study exceeded the 75th percentile for historical ambient turbidity levels in Harris County streams. The TSS levels measured during this study appeared to peak during the high rainfall events, and seldom fell below 200 mg/L. This pattern was observed most often at site 1, which was adjacent to more active construction activity. Historical data collected in waterbodies in Harris County suggests that TSS values seldom exceed 100 mg/L, with an overall median value of 21.2 mg/L. Current data collected during this study suggest that erosion of soil and/or road material was occurring at both study sites. Similar trends were observed in other pollutants measured during this study. Orthophosphorus levels were positively correlated with increased precipitation, whereas *E. coli* levels declined, most likely due to increased dilution of runoff water as new precipitation is added to the system.

Due to the late start of this project and failure to establish a firm baseline in terms of documenting pre-construction runoff water quality; EIH recommends that continued monitoring take place at the developed area along with an additional nearby unaltered site containing only native vegetation and soils. If this additional monitoring is conducted for sufficient time it would be possible to assess and compare the quality of runoff from various portions of the new development against control conditions per the original scope of work. Only data from about 1 or 2 stormwater collections made early during the study at site 2 should be considered “baseline” representing pre-construction conditions.

INTRODUCTION

Problem Statement

The population of Harris County is expected to continue to grow by 55% between 2005 and 2035 resulting in an increase of 2,006,000 individuals (HGAC 2006). As the human population grows there will be increased demands for housing, roads and commercial development. The resulting increased urbanization will alter stream hydrology and contaminant loads (Paul and Meyer 2001; Walsh et al. 2005). The term “urban stream syndrome” has been used to describe the consistently observed ecological degradation of streams draining urban land (Walsh et al. 2005). Symptoms of the urban stream syndrome include a flashier hydrograph, increased sediment loading, elevated concentrations of nutrients and contaminants, altered channel morphology and reduced biotic richness with increased dominance of tolerant species. This is due to the replacement of natural soils and vegetation with impervious surfaces which leads to elevated stormwater runoff containing higher concentrations of contaminants (Paul and Meyer 2001).

In an effort to reduce additional impacts from population growth and associated urbanization new residential communities and municipalities have begun to adopt low impact development (LID) technology (EPA 2000; NAHB 2012). LID is an approach used in land development that manages stormwater as close to its source as possible. LID employs principles such as preserving and re-creating natural landscape features, minimizing imperviousness to create functional and aesthetically appealing site drainage that treats stormwater. There are many practices that have been used to support these principles including bioretention facilities, vegetated swales, and permeable pavements. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions (EPA 2000). Harris County Flood Control District, and Harris County Public Infrastructure Department have developed a Low Impact Development & Green Infrastructure Design Criteria for Storm Water Management (http://www.hcfdc.org/downloads/manuals/2011-FINAL_LID_GIDC.pdf). Prior to the publication of this guidance document, developers in Harris County were unable to use LID practices for detention credit. LID portions of Springwoods Village, and other proposed developments are operating in Harris County under these guidelines as an evaluations of the usefulness of LID practices within the upper Gulf Coast Region.

Springwoods Village is a \$10 billion mixed-use, community development project covering 1,575 acres in northern Harris County located 30 miles north of downtown Houston and less than 10 miles from George Bush International Airport (Figure 1). Development was scheduled to be conducted in six phases and began in 2011 (CDC 2012). The overall project site is located adjacent to Spring Creek J100-00-00 (Figure 2). Project development plans included commercial, residential, corporate, and institutional uses as well as programmed open spaces. Low Impact Development (LID) was an integral part of the community development plan used to mitigate runoff and impacts on water quality (CDC 2012). Developers were required to implement LID methods to meet certain water quality and quantity goals. The developer required LID would be supplemented with community LID in some of the public spaces. However, low

impact development requires methods resulting in tangible and evidence-based benefits to better market the concept of LID (CDC 2012).

In order to better understand and quantify the benefits of LID methods used in the Springwoods Village, it is necessary to take pre-project, baseline conditions of water quality during wet weather events and compare to conditions during both before and after construction. The Environmental Institute of Houston at University of Houston – Clear Lake (EIH), has partnered with Harris County Flood Control District (HCFCD) and developers for the Springwoods subdivision to obtain data on the effects of LID methods for effluent water quality leaving the property and discharging into nearby streams.



Figure 1. Springwoods development site location relative to Houston and Spring Creek highlighting major landmarks and major roads.



Figure 2. Springwoods subdivision development area outlined (red), filed survey sites, and Spring Creek: HCFCU Unit Code: J100-00-00.

Background

Study Area

The Springwoods subdivision is located in the Spring Creek watershed. The Spring Creek watershed is classified as HUC Unit 12040102, which includes TCEQ segment 1015, and HCFCU Unit Number J100-00-00 (Figure 3). The watershed extends across the southern area of Montgomery County, Waller and Grimes counties, and extends into northern Harris County. The larger watershed includes about half of Tomball and the Woodlands/I-45 area in southern Montgomery County. It covers approximately 765.88 mi² (source: EPA MyWaters Mapper: http://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=12040102&extraLayers=null). However, other sources including the HGAC GIS maps indicate the surface area of the watershed is only 441-453 mi² (source: HGAC online Water Resources Information Map <http://arcgis02.h-gac.com/wrim/> and HGAC 2011). There are approximately 111 miles of open streams within the watershed, including the primary stream and its tributary channels (HFCFD 2012). The TCEQ designated segment 1008 (From the confluence with the West Fork San Jacinto River in Harris/Montgomery County to the most upstream crossing of FM 1736 in Waller County) is approximately 69 miles long.

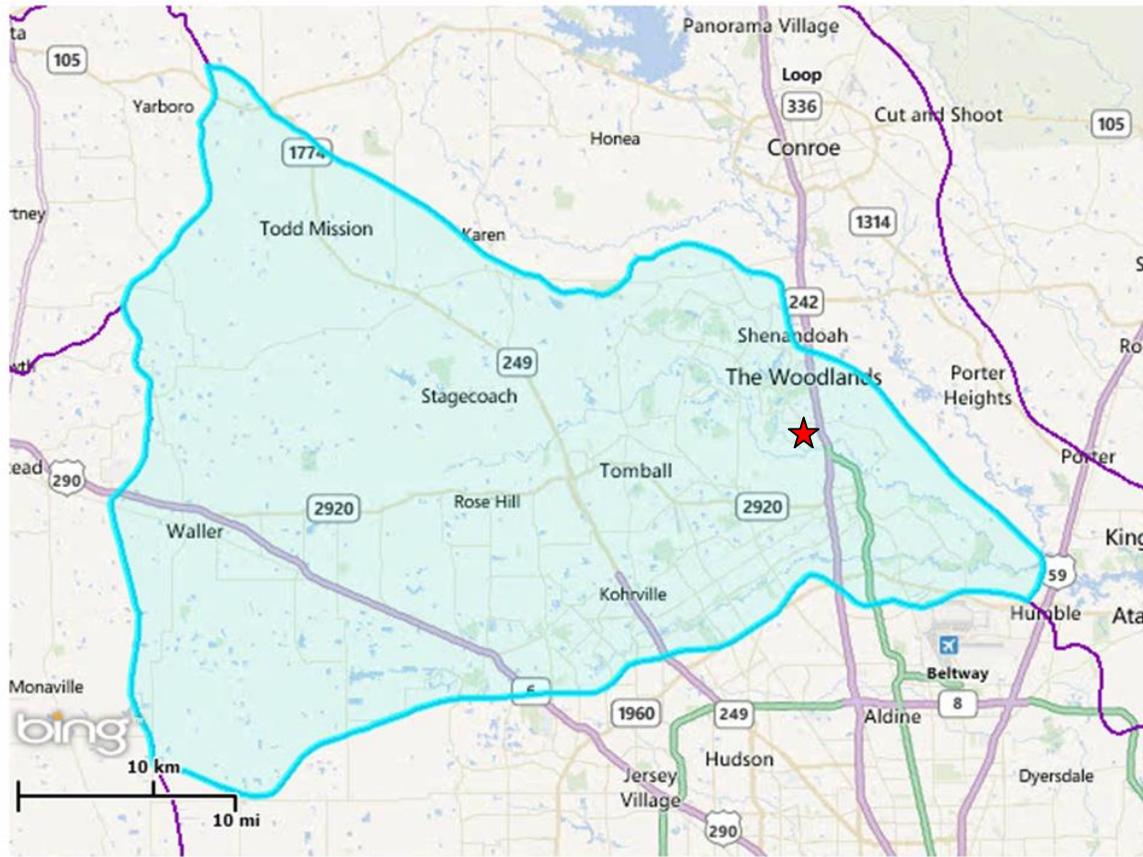


Figure 3. Spring creek watershed HUC Code 12040102 (Source: EPA surf your watershed http://cfpub1.epa.gov/surf/huc.cfm?huc_code=12040102). Location of project site and adjacent USGS gage 08068500 denoted by red star.

Land Use and Environment

Rapid commercial and residential development has occurred in the northeastern and central portions of Spring Creek watershed and will likely continue into the future as the Woodlands, Tomball, and other existing communities expand (HCFCFCD 2012; HGAC 2011). Most of Spring Creek between I-45 to the west and U.S. Highway 59 to the east has been preserved as a greenbelt to minimize flooding risks. The primary land cover west of Tomball is agricultural and cultivated land. Large tracts of forested areas in the middle and northwest portion of the watershed are interspersed by subdivisions. Ranchettes and hobby ranches are also common in that portion of the watershed. On-site sewage facilities are the primary means of waste disposal in those areas. There are numerous county parks along the main channel of Spring Creek in the lower reaches of the watershed. (HCFCFCD 2012).

Historical Hydrology in Watershed

The Spring Creek watershed has undergone considerable development over the last 20 years as the population of Harris and Montgomery County has expanded. In order to assess historical and current hydrology EIH obtained historical stream flow data from the closest gage. The closest USGS gage was identified as 08068500 and is situated within Spring Creek at I-45 bridge in

Montgomery County, Texas. Gage station coordinates are 30°06'37" latitude, -95°26'10" longitude. This gage monitors stream flow from a portion of the watershed with an estimated drainage area of 409 square miles (Source: USGS web site). The HCFCD rain gage 1050 is also co-located at this site. This rain gage was used to monitor precipitation during the study.

In order to evaluate trends in hydrology EIH utilized the Index of Hydrologic Alteration (IHA) to evaluate selected flow regime indices of the stream (Gao et al. 2009; The Nature Conservancy 2009). In particular EIH estimated the number of high flow pulses that occurred annually using the IHA algorithm that classifies high flows as any daily average flow exceeding the 75th percentile of all daily flows recorded during the period of record. The period of record examined was from 1939 through 2011. Based on the IHA algorithm the flow gage records indicate urbanization has steadily increased and affected the rainfall runoff relationship in this watershed (Figure 4). High flow events have increased over time suggesting the stream has become flashier responding quickly to rainfall events.

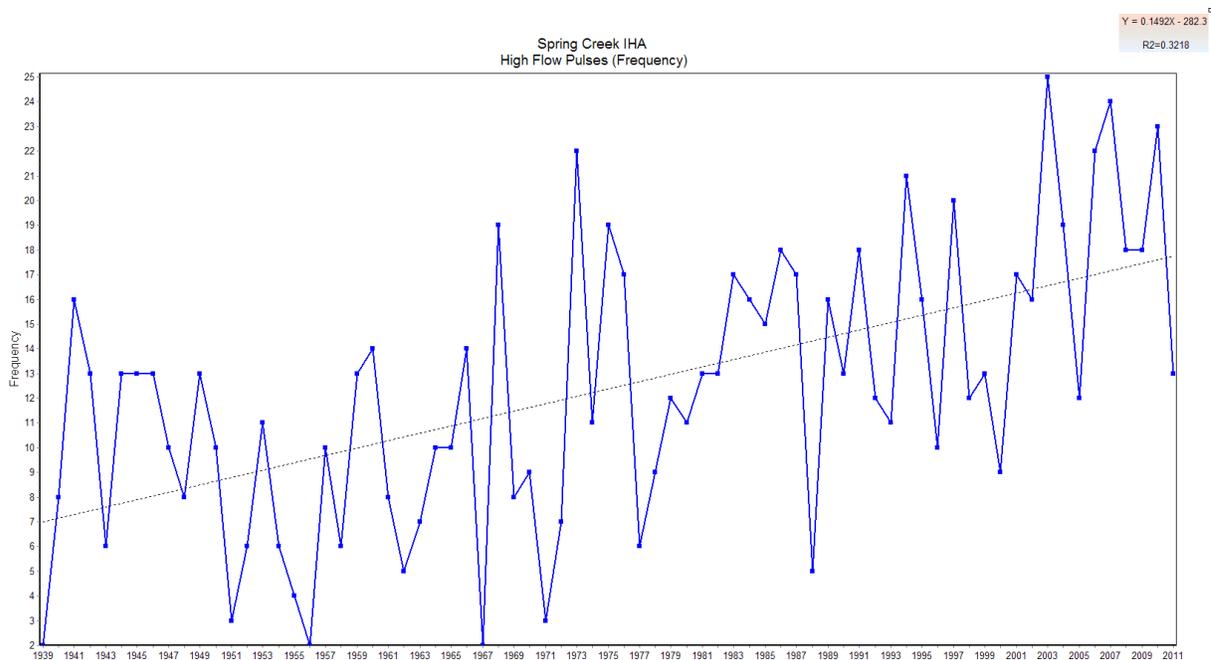


Figure 4. Annual frequency of daily high flow pulses recorded at the USGS 08068500 Spring Creek gage based on IHA software analysis.

Study Objective

The original scope of the study was to characterize and compare pre-development and construction Stormwater quality at the Springwoods Development Site. Due to an advancing construction timeline, pre-development monitoring did not take place before construction groundbreaking at the site. Stormwater runoff samples, grab samples, and photographic techniques were employed to evaluate the changes in site conditions during construction.

METHODS

Site Selection and Description

Two sites (Table 1) were selected for stormwater quality monitoring through the combined effort of EIH personnel, HCFCFCD technical staff, and the Springwoods Development contractors based on two criteria: 1) the sites had to be accessible in wet conditions and 2) the sites would represent stormwater runoff from two of the major drainage corridors located on the property.

Table 1 Sample site descriptions and locations for Springwoods Subdivision study.

Site #	Site Description	Latitude	Longitude
1	At border of PTO East Lake Zone, under main road and receives drainage from Corridor 1	30.10431	-95.44065
2	At border of West Detention zone; receives drainage from Corridor 4; minimal development present.	30.09630	-95.45340

Site 1 (Figure 2) was located downstream from drainage corridor 1 and downstream of the main entrance road crossing as it enters the PTO East Lake zone (Figure 2 and Figure 5). This site was the first to see pre-development construction effects of land clearing and road-building throughout the course of this study. Due to its proximity to the main entrance road, much of the land around Site 1 also experienced heavier vehicular traffic than Site 2 throughout the course of the study. Site 2 was located downstream of drainage corridor 4 and downstream of a previously cleared power-line corridor, immediately within the West Detention zone (Figure 2 and Figure 6). Until later in the sampling period, this site received minimal construction influences such as forest clearing, and vehicular traffic. During the study, EIH personnel had to adjust the exact locations of the samplers at both sites. At site 1 (moved on 1/28/2011), the sampler had to be moved slightly due to prolonged water retention at the site. Early efforts at site 2, yielded insufficient runoff water sample volumes, so EIH adjusted the sampler location (moved on 11/8/2010) to a depression slightly downstream of the initial site. EIH initially thought that the insufficient sample volumes collected at Site 2 was due to the upstream catchment being too small. However, EIH discovered that this was primarily due to soil runoff characteristics since it appeared that at least 1 inch of rainfall within 24 hours was required at site 2 to generate sufficient runoff to fill the collector, whereas only ~0.4 inch of rainfall within 24 hours was required at site 1. Therefore, a significant rainfall event at site 1 was generally not of sufficient magnitude to be ranked as a significant event at site 2.

Sampling Schedule

Sampling began in November 2010 and continued through November 2011. GoogleEarth™ time-lapse imagery from 2008 to 2010 shows evidence of pre-development clearing in the sample area and large scale habitat alteration by early 2011 (Figure 7). While the original objectives of project included documentation of pre-construction stormwater quality to determine baseline levels for comparison of non-affected and LID affected runoff, due to initial lack of wet weather events and the construction schedule, most samples were collected after initial construction had already begun.



Figure 5. Upstream (left) and downstream (right) view of site 1 stormwater sampling location.



Figure 6. Upstream (left) and downstream (right) view of site 2 stormwater sampling location.

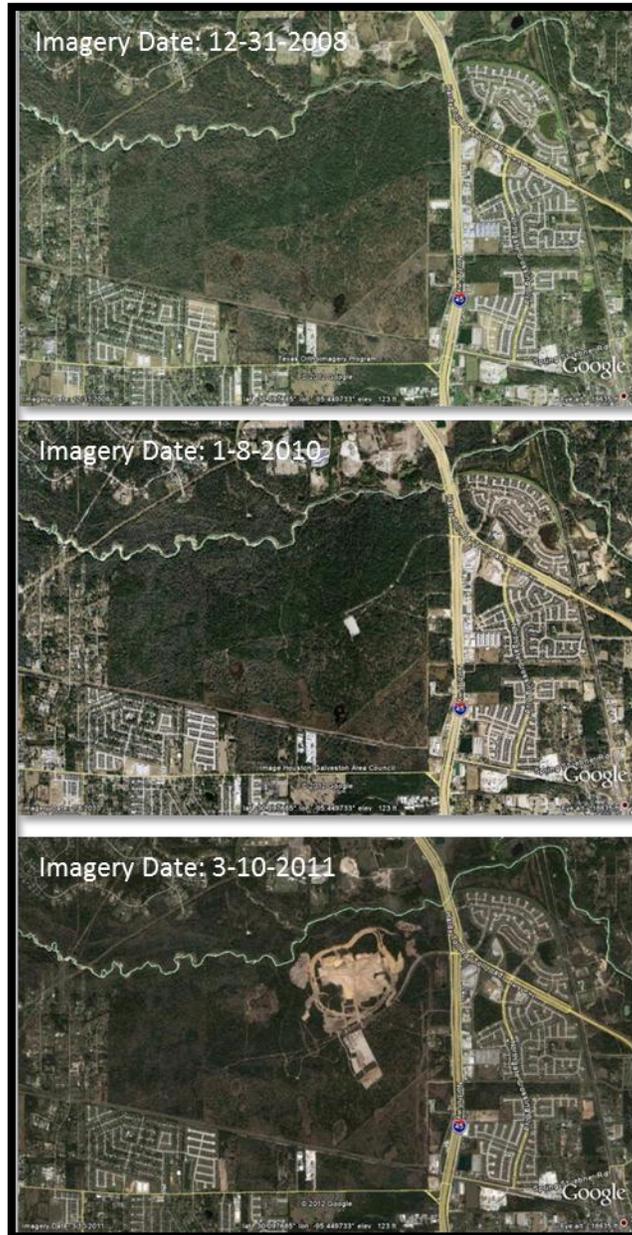


Figure 7 Time lapse GoogleEarth™ imagery showing presence of pre-development clearing during the early phases of this study.

Sampling Methods

Precipitation

Daily precipitation was monitored at the site using data from the HCFCD 1050 rain gage co-located with the USGS 08068500 site at Spring Creek and I-45. Data from this site was also used by the project team to determine whether to initiate a wet weather sampling event after a significant rainfall event. A significant rainfall event was designated as $> 0.4''$ of rainfall within 24 hours preceded by 72 hours of dry conditions. This data was correlated with game camera photographs to determine times of peak flow through each site.

Stormwater samplers

Single grab first flush stormwater samplers (manufactured by Nalgene®), were deployed at each site before and after every significant rainfall event to evaluate changes in stormwater quality from runoff during the course of construction at the Springwoods Subdivision (Figure 8, Figure 9 and Figure 10). The sampler bottle is mounted within a black sample bottle container. The sample bottle container includes a coarse screen and is usually deployed within a similar diameter pit, within 1 inch of the bottom of the stream. The stormwater sampler collects one full liter of water in the un-refrigerated container. The unit is designed to remain sealed until a critical depth (1-2") of runoff is present at the site and will not collect water until this critical depth occurs. Upon filling, the sample bottle is also designed to self-seal to prevent cross-contamination with additional surface water that may be present after initial first flush runoff conditions occur. Samples collected by the stormwater sampler were tested for standard water quality measures including nitrogen, orthophosphate, suspended solids, and turbidity. Originally, the objective of this study included monitoring of pre-construction and construction stormwater quality. Due to an initial lack of significant wet weather events and rapid progression in the construction schedule, most samples were collected after initial construction had already begun.

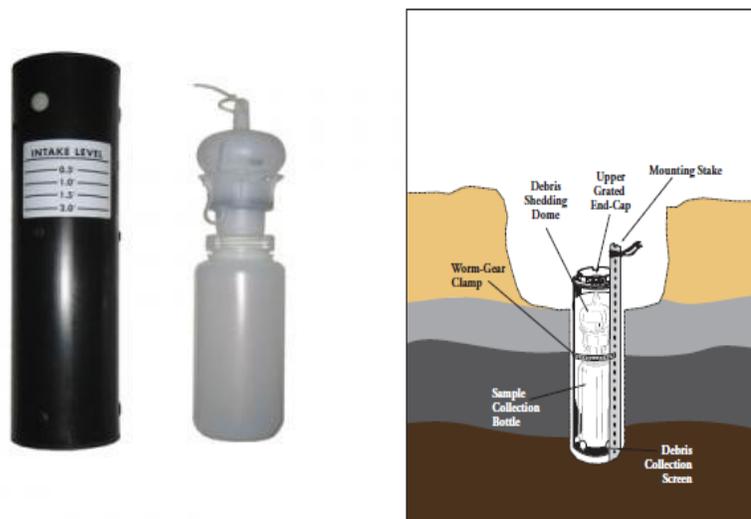


Figure 8. Nalgene stormwater first flush sampler used during the study.



Figure 9. Deployment of the stormwater sampler used during this study.



Figure 10. Retrieval of stormwater sample at Site 2.

Grab Samples and Flow

Rainfall in the Springwoods Subdivision area was monitored closely and after a significant event was detected, EIH field team personnel attempted to arrive at the project site as quickly as possible, generally within 6 hours of initial rainfall. Grab samples were collected at each sampling site (when standing water was present) and analyzed for water quality (similarly to the stormwater samples) to evaluate changes during the course of construction for the Springwoods Subdivision. Grab samples were also analyzed for *E. coli* bacteria, oil/grease, and selected heavy metals. Flow was taken at each sample site when moving water was observed. While the original objective of this study included monitoring of pre-construction and construction water quality, most samples were collected after initial construction had already begun.

Game Cameras and Site Photographs

Game cameras were installed at each sampling site and programmed to take a photograph of the installed staff gage and sampler every hour. The purpose of these game cameras was twofold: 1) to illustrate when the first flush of runoff occurred after a significant rainfall event and 2) to represent the flow type each site experienced at peak flow times. Game cameras were also programmed for motion activation, thus recording wildlife frequenting these areas of the Springwoods Subdivision. Only photographs documenting site conditions during the rain event are provided in the report, although all photographs are provided as an electronic supplement (Appendix 3).

During each site visit, EIH personnel also took photographs to document conditions of the sampling areas at the time of sample collection. Any major changes in Springwoods Subdivision site construction were also photographed (i.e. creation of roads, development of areas, clearing of trees, etc.) to document progress in development.

Sampling Protocol

To determine 24-hour rainfall prior to sampling, rainfall data were downloaded from the Harris County Flood Control District Flood Warning System website at site 1050 (J100 Spring Creek at I-45). After a significant rainfall event (designated as > 0.4 inches of rainfall within 24 hours preceded by 72 hours of dry conditions), an EIH field team was mobilized to the Springwoods Subdivision area. Prior to arrival, management and security at the development area were contacted as specified in the safety and access protocol established by Springwoods Subdivision developers. Upon arrival, the EIH field team: retrieved stormwater sample bottles, collected grab samples (if water was still present at the site); measured flow; recorded current site conditions; photographed the site area; and distributed stormwater samples into specified containers for delivery to the Eastex lab for analysis (see Table 2 for specific parameters evaluated). If conditions allowed, during each site visit, stormwater samplers were replaced with clean units and redeployed. Memory cards within the game cameras were replaced, battery life was checked (and batteries replaced if necessary), and photographs were downloaded back at EIH offices.

Table 2. Field parameters collected by EIH personnel at every site visit (when possible) and water quality sample types with specified containers and preservatives.

Activity	Parameter	Bottle	Preservative	
Field Data Collection	Amount of Rainfall (in) – HCFCD Gage 1050			
	Sample site gage depth (ft)			
	Runoff flow (cfs)			
	Water Temperature (C)			
	Specific Conductance (µS)			
	Dissolved Oxygen (%sat)			
	Dissolved Oxygen (mg/L)			
	pH			
Stormwater Sampler (Water)	Ammonia, NH ₃ (mg/L)	500 mL	Ice, H ₂ SO ₄	
	Nitrate + Nitrite, NO ₂ + NO ₃ (mg/L)			
	Ortho-Phosphorus (OP) (mg/L)	500 mL	Ice	
	Total Suspended Solids, (TSS) (mg/L)			
	Turbidity (NTU)	100 mL	Ice	
Grab Sample (Water)	Ammonia, NH ₃ (mg/L)	500 mL	Ice, H ₂ SO ₄	
	Nitrate + Nitrite, NO ₂ + NO ₃ (mg/L)			
	Ortho-Phosphorus (OP) (mg/L)	500 mL	Ice	
	Total Suspended Solids, (TSS) (mg/L)			
		Turbidity (NTU)	100 mL	Ice
		<i>E. coli</i> (MPN/100mL)	100 mL	Ice, Na ₂ S ₂ O ₃
		Oil/Grease (mg/L)	1 L Amber	Ice, H ₂ SO ₄
		Mercury, Hg (mg/L)		
		Cadmium, Cd (mg/L)		
		Zinc, Zn (mg/L)		
	Lead, Pb (mg/L)			

Additional water quality variables were measured at each site, when possible, using a YSI 600XLM® multi-parameter sonde (Table 2). When flowing water was present at each site, instantaneous flow values were obtained using a SonTek Acoustic Doppler Velocimeter® (ADV) flow meter. All methods used during water quality sampling followed protocol outlined in the TCEQ Surface Water Quality Monitoring manual (Texas Commission on Environmental Quality 2008a).

Data Analysis

Several methods were used to analyze the data collected during this study. Raw data collected during the study was tabulated and/or plotted using bar graphs. Values below the detection limit were assigned a value of ½ the detection limit to facilitate data analysis. In addition, EIH also utilized box plots to facilitate comparison of the median value and distribution of the data between sites and sampling methods (Figure 11). A non-parametric Kruskal-Wallis one way ANOVA was used to test for significant differences between site and collection type (grab or stormwater sampler) combinations or “site-type” (i.e. site 1-grab; site 1 sampler; site 2 grab; site 2 sampler). Data was analyzed using the Minitab® 16.1 statistical software package. Data were also compared to TCEQ water quality numerical criteria or screening levels also reported in HGAC (2011). It should be noted that these criteria are for ambient water quality in receiving streams and not for effluent standards for stormwater.

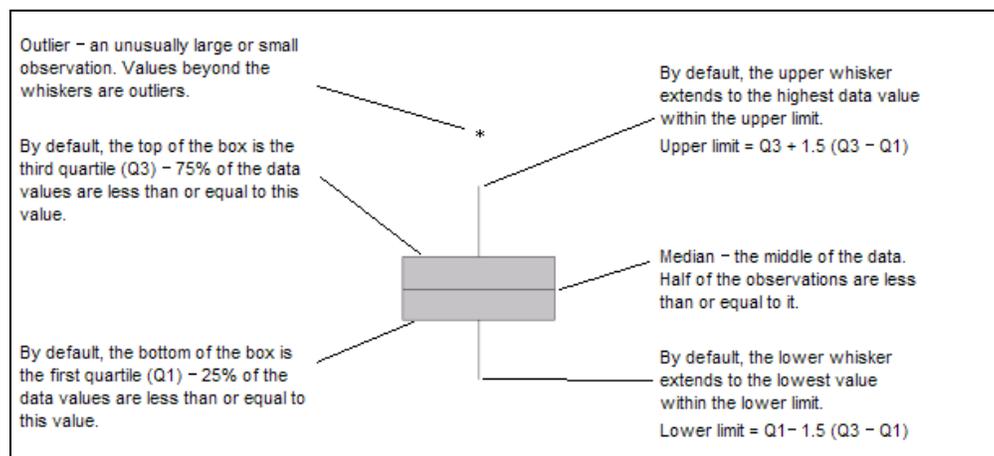


Figure 11. Illustration of boxplot used to analyze distribution of data.

RESULTS

Precipitation

During the study the nearby HCFCD 1050 gage documented precipitation throughout the study period (Figure 12). A total of 19 possible qualifying events (>0.4 inches of rain within 24 hours following 72 hours of no rainfall) occurred during the period of 11/1/2010 through 11/15/11. EIH targeted precipitation events occurring during weekdays only due to sample holding time and lab availability. The highest 24 hour precipitation events (1.56 – 3.00 inches) occurred in July 2011. The qualifying sampling events ranged between 0.4 and 3.0 inches within a 24 hour period (Figure 12).

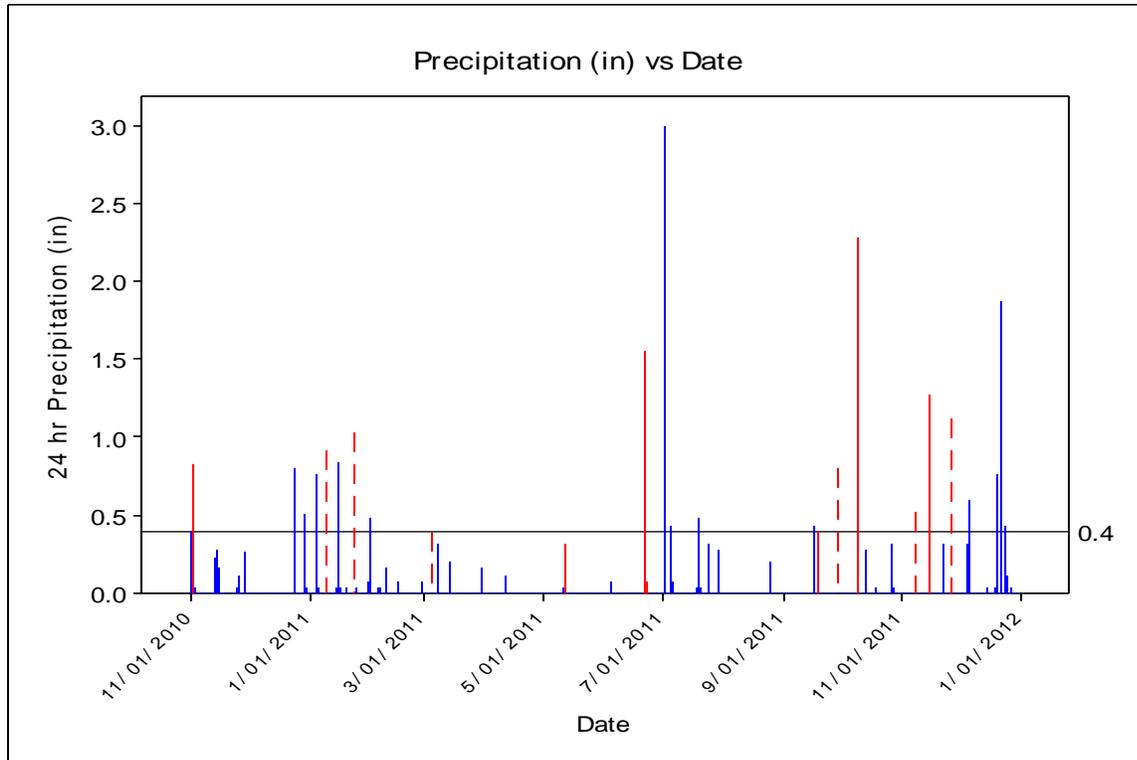


Figure 12. Recorded 24 hour precipitation at the HCFCF 1050 rain gage co-located at the USGS 08068500 site on Spring Creek and I-45. Red lines denote dates when sampling was conducted at the site. Dashed red lines denotes dates when unsuccessful sampling attempts were made on that date or afterwards. The horizontal reference line is the 0.4 inch decision level for sampling when combined with 72 previous hours of dry weather.

Sampling Schedule

Storm-water sampling proved difficult in 2011 due to severe drought conditions experienced in the southern region of the US and Texas (Nielsen-Gamon 2011). Twelve-month average rainfall was the driest on record across much of western, central, and southern Texas, and many stations received less than 25% of their normal 12-month precipitation. The statewide average precipitation was generally the driest period on record (Table 3). The statewide drought index value has surpassed all previous values, and it has been at least forty years since anything close to the severity of the present drought has been experienced across Texas.

Table 3. Ranking of three month precipitation among historical values based on Texas statewide average precipitation (Source: Nielsen-Gamon 2011).

<i>Months</i>	<i>Precipitation Amount (in)</i>	<i>Ranking</i>
November 2010 – April 2011	5.20	2 nd driest
February – July 2011	5.15	Record driest
March – August 2011	5.14	Record driest
April – September 2011	5.93	Record driest

Stormwater samplers were deployed first on October 8, 2010. Based on available resources and observed precipitation at the HCFCF 1050 rain gage, EIH personnel successfully collected

samples during 7 out of a total of 19 independent qualifying (minimum rainfall met and 72 hour antecedent dry period) wet weather events from November 1, 2010 to November 15, 2011 (Table 4). A total of an additional 6 unsuccessful (unable to obtain sufficient volume of runoff samples) attempts were made. Due to differences in the physical characteristics of each site, it was discovered that the actual criteria for a wet-weather event that would generate measurable runoff differed by site. Runoff at site 1 occurred more quickly in response to smaller amounts (0.4 inches) of rainfall while site 2 experienced significant (enough to fill the stormwater sample bottle) runoff only after greater amounts (1 inch) of rainfall had occurred. This resulted in only two events where sufficient runoff volumes occurred and grab samples and stormwater samples were collected at both sites on the same date (Table 4).

Table 4. Attempted wet-weather sample events for each site at Springwoods subdivision.

Site #	Sample Date	Wet Weather Event No. ^{a,b}	Rainfall (in) ^c	Sample Collected	
				Grab	Stormwater
1	11/2/2010	1	1.220	X	X
	5/13/2011	2	0.32		X
	6/22/2011	3	1.48	X	X
	6/23/2011	4	0.08		
	9/19/2011	5	0.4	X	X
	10/10/2011	6	2.16		
	11/15/2011	7	1.28	X	X
2	11/2/2010	1	1.220		X
	5/13/2011	2	0.32		
	6/22/2011	3	1.48	X	X
	6/23/2011	4	0.08	X	X
	9/19/2011	5	0.40		
	10/10/2011	6	2.16	X	X
	11/15/2011	7	1.28	X	X

^a Note although counted as two sampling events, the 6/22 and 6/23 events sampled the same rainstorm runoff.

^b Site visits were also made on the following dates (site 1 – 1/14/11, 1/28/11, 2/8/11, 3/7/11, 8/18/11, 11/9/11, 11/29/11) (site 2 – 12/3/10, 8/18/11, 9/1/11, 11/9/11, 11/29/11). During six dates (1/14, 1/28, 3/7, 9/29, 11/8 and 11/26) samplers were redeployed, or attempts were made to collect stormwater samples from that date or earlier unsuccessfully.

^c Cumulative rainfall for 24-hours prior to sampling event. Source: HCFCF Rain Gage 1050.

Stormwater and Grab Samples

Gauge depth, flow and sonde readings taken at each site including water temperature, conductivity, salinity, dissolved oxygen, and pH are reported (Table 5). During the study EIH field personnel seldom observed flowing water at the time of stormwater sample retrieval because of lack of standing water or moving water. This was most evident at site 2. Highest flow was measured at site 1. The higher amounts of runoff at site 1 may be due to a higher proportion of the catchment being under construction, resulting in a higher runoff amounts during rain events. Ambient measurements of water temperature, specific conductance, dissolved oxygen, and pH were within normal ranges encountered in surface water and precipitation.

Table 5. Field parameters collected after each rainfall event in Springwoods Subdivision.

Wet Weather Event #	Site	Gauge Depth (ft)	Flow (cfs)	Water Temperature (°C)	Specific Conductance (µS)	DO (% sat)	DO (mg/L)	pH
1	1	0.55	0.0530	18.98	261	77.7	7.03	7.79
	2	0.00	0.0000	Dry	Dry	Dry	Dry	Dry
2	1	0.00	0.0000	Dry	Dry	Dry	Dry	Dry
	2	0.00	0.0000	Dry	Dry	Dry	Dry	Dry
3	1	1.50	2.8972	24.15	205	89.6	7.53	9.53
	2	0.00	Pools Only	22.54 ^a	141 ^a	89.0 ^a	7.66 ^a	6.87 ^a
4	1	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled
	2	0.00	Pools Only	26.63 ^a	109 ^a	19.5 ^a	1.42 ^a	6.00 ^a
5	1	0.50	0.6740	24.03	364	84.7	7.02	7.77
	2	0.00	0.0000	Dry	Dry	Dry	Dry	Dry
6	1	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled
	2	0.00	Pooled	21.80 ^a	183 ^a	83.8 ^a	7.35 ^a	6.49 ^a
7	1	0.79	0.5528	21.02	272	89.1	7.80	9.85
	2	0.00	<0.0100 ^b	20.80 ^a	59 ^a	96.5 ^a	8.45 ^a	6.95 ^a

Nitrogen

Results of water quality monitoring were tabulated by sampling event, sample type and site. Individual nitrogen (ammonia-nitrogen and nitrates + nitrite nitrogen) measurement results are presented in Figure 13 and Figure 14. In order to evaluate the distribution of selected measured variables box plots were utilized to describe the data. Both of these nutrients overlap considerably between sites and sample types (Figure 15 and Figure 16). Median levels of ammonia nitrogen varied between 0.08 and 0.8 mg/L (Figure 15). In contrast, median combined nitrate and nitrite nitrogen varied little ranging 0.7 to 1.0 mg/L (Figure 16). EIH was unable to detect a difference in ammonia nitrogen or combined nitrate nitrite nitrogen between sites or collection methods at the $\alpha = 0.05$ level using the Kruskal-Wallis ANOVA. EIH did not observe a linear relationship between precipitation and either ammonia nitrogen or combined nitrate nitrite nitrogen and precipitation levels at each site (Figure 17 and Figure 18). Seven out of the 17 samples (41.2%) collected exceeded the ambient stream screening criteria of 0.33 mg/L ammonia-nitrogen (HGAC 2011). None of the samples exceeded the ambient screening criteria of 1.95 mg/L nitrate-nitrogen (HGAC 2011). Elevated ammonia-nitrogen levels can be caused by many natural processes and man-made sources including application of fertilizer in the watershed (Chapman and Kimstach 1996). At high pH levels and water temperature a larger percentage of ammonia-nitrogen is in the more toxic un-ionized form (Boyd 1990).

Orthophosphate

Individual orthophosphorus measurement results are presented in Figure 19. Site 2 had slightly higher median levels of orthophosphorus (Figure 20). Median levels of orthophosphorus varied between 0.1 and 1.2 mg/L (Figure 20). However, EIH was unable to detect any significant ($p < 0.01$) difference in orthophosphorus levels between site type groups using the Kruskal-Wallis ANOVA. EIH did observe a significant positive linear relationship between precipitation and orthophosphorus levels in runoff at each site (Figure 21). However the r^2 values were below 50%. Six out of the 18 samples (33.3%) collected exceeded the ambient stream screening criteria of 0.37 mg/L orthophosphorus (HGAC 2011). The source of this phosphorus is unknown, since to our knowledge there is no agricultural use of fertilizers in the contributing drainage.

Suspended Solids and Turbidity

Individual total suspended solids (TSS) and turbidity measurement results are presented in Figure 22 and Figure 23. In order to evaluate the distribution of selected measured variables box plots were utilized to describe the data. Both of these variables exhibited considerable variation between sites and sample dates. Median levels of TSS varied between 468 and 1070 mg/L (Figure 24). In contrast, median turbidity (NTU) varied little ranging 134.2 to 503.5 NTU, although the range of data was considerable (Figure 25). EIH was unable to detect a difference in TSS or turbidity between site type levels at the $\alpha = 0.05$ level using the Kruskal-Wallis ANOVA. EIH did not observe a significant linear relationship between precipitation and either TSS or turbidity, although at rain amounts greater than 1.0 inches, levels of both variables appear to be elevated (Figure 26 and Figure 27). It did appear that turbidity levels increased over time with highest levels occurring near the end of the study in November 15, 2012 at site 2 (Figure 26 and Figure 27). This pattern is consistent with observed construction activity at site 1 and then later at site 2 near the end of the study. This included road construction, forest clearing, and placement of culverts.

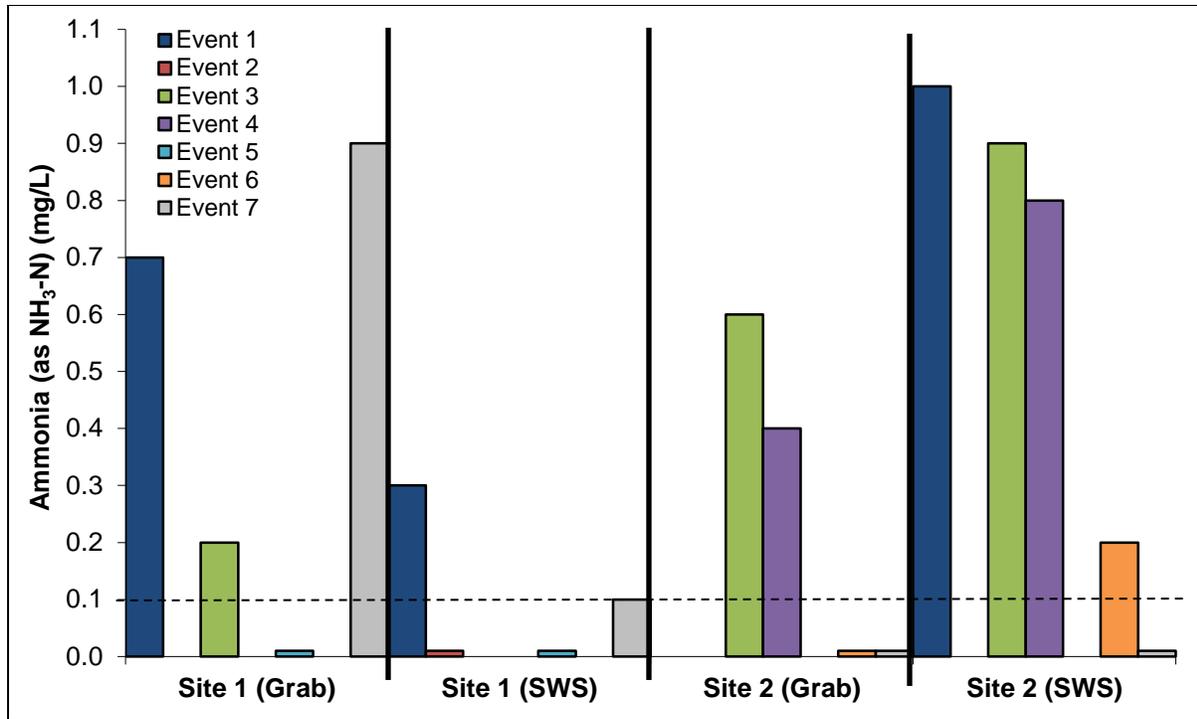


Figure 13. Ammonia nitrogen levels in runoff during rainfall events. Dashed line represents detection limit for this test (<0.01 mg/L); values below this line indicate presence at levels below the detection limit. Grab = grab samples; SWS = stormwater sampler.

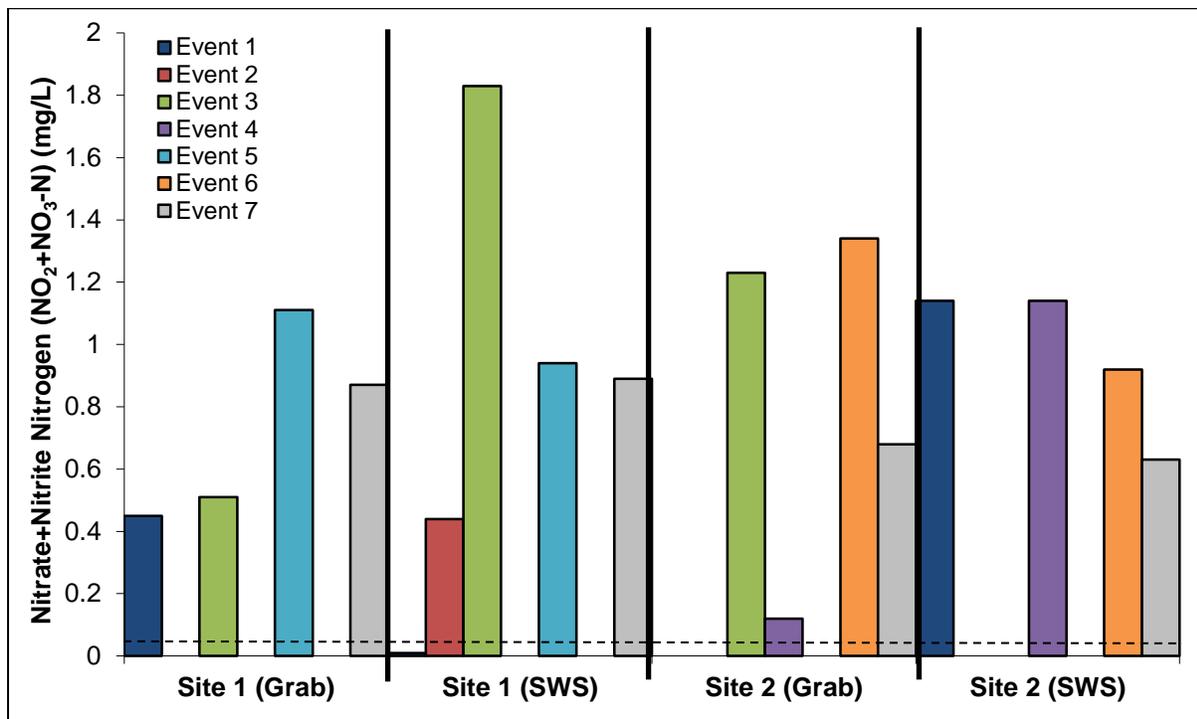


Figure 14. Nitrate and nitrite nitrogen levels in runoff during rainfall events. Dashed line represents detection limit for this test (<0.04 mg/L); values below this line indicate presence at levels below the detection limit. Grab = grab samples; SWS = stormwater sampler.

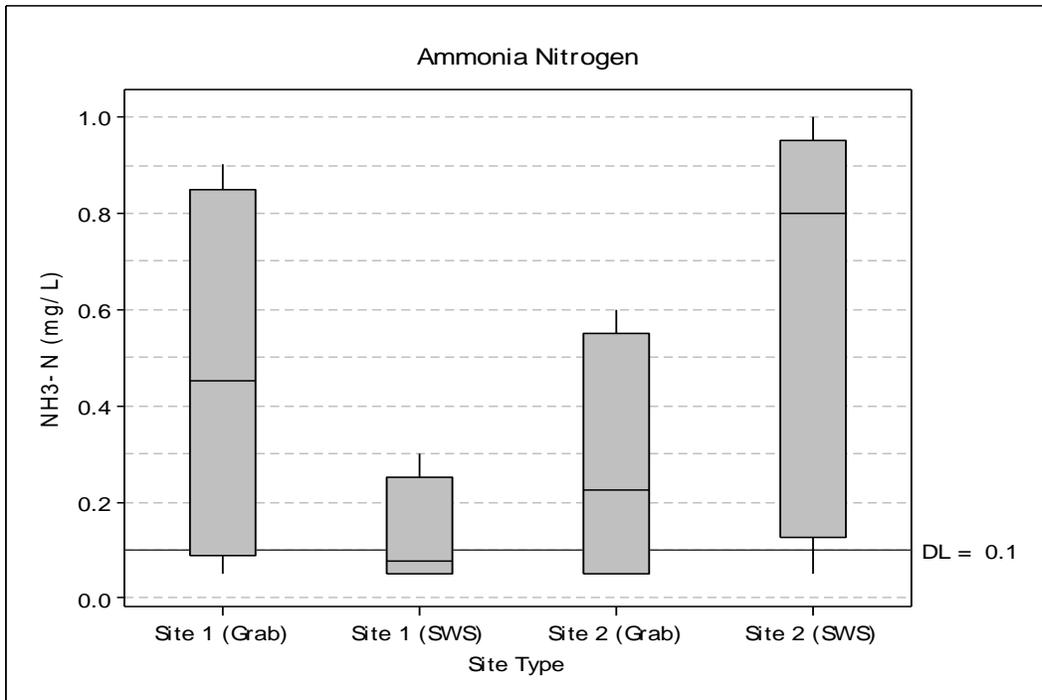


Figure 15. Boxplot of ammonia nitrogen levels measured at each site and type of sample over all sampling periods of the study.

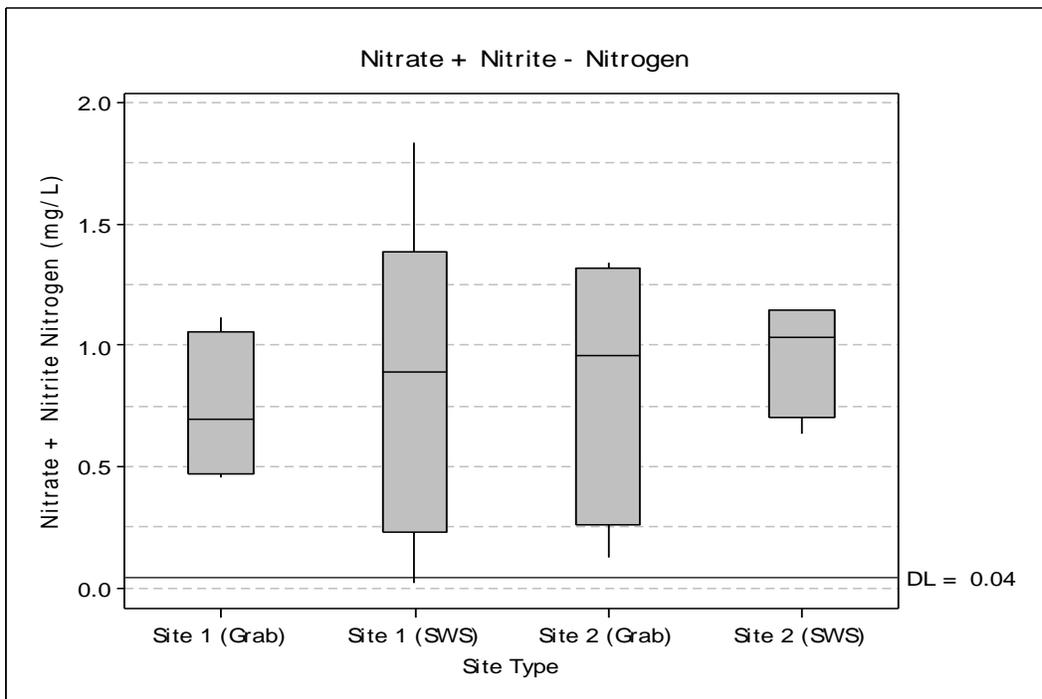


Figure 16. Boxplot of nitrate + nitrite nitrogen levels measured at each site and type of sample over all sampling periods of the study.

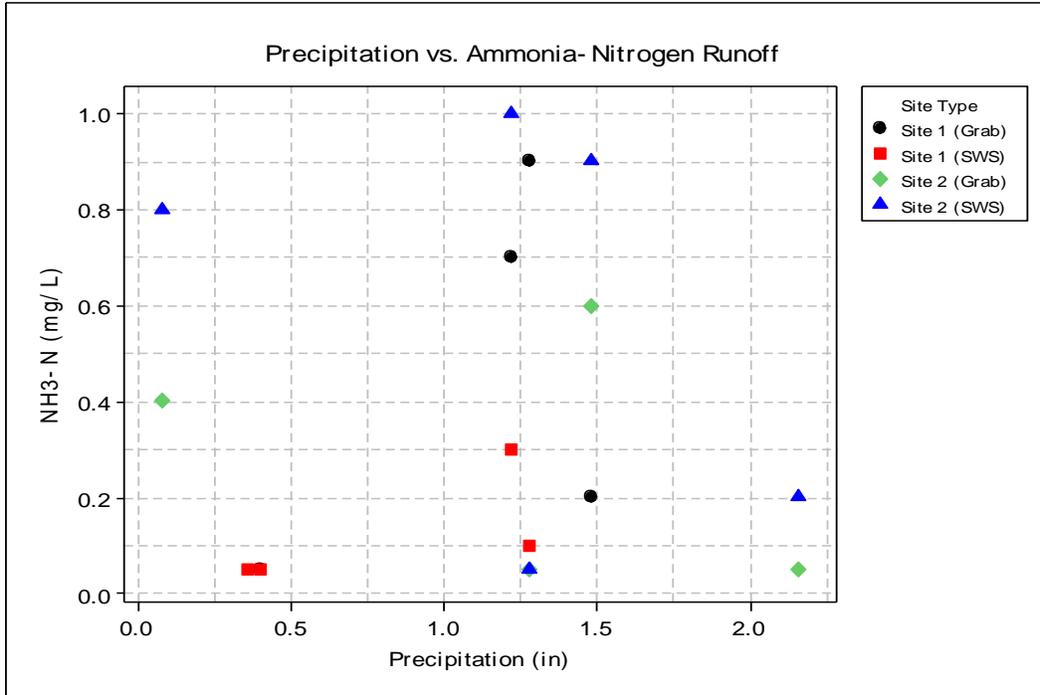


Figure 17. Relationship between precipitation and ammonia nitrogen runoff levels at each site by collection method.

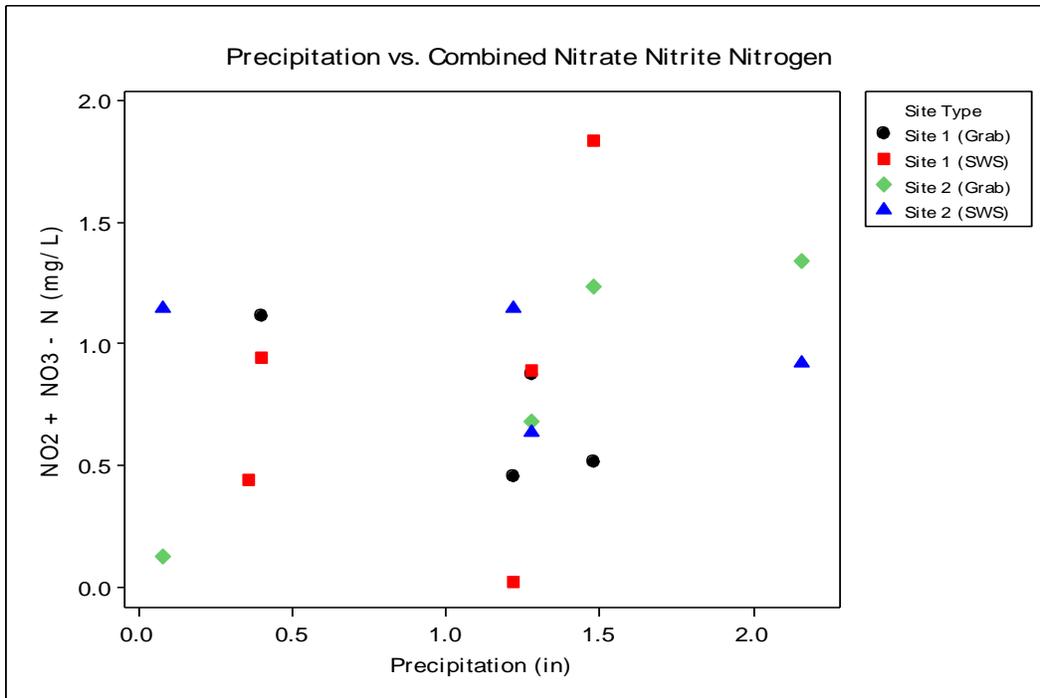


Figure 18. Relationship between precipitation and combined nitrate nitrite nitrogen runoff levels at each site by collection method.

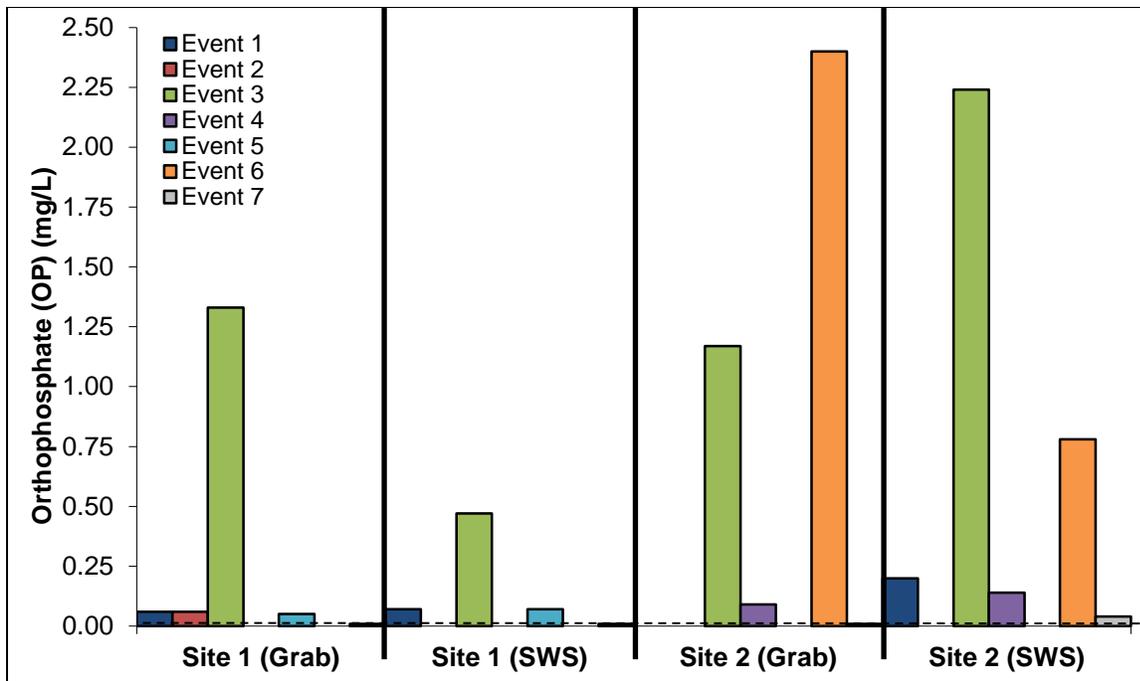


Figure 19. Orthophosphate levels in runoff during rainfall events. Dashed line represents detection limit for this test (<0.02 mg/L); values below this line indicate presence at levels below the detection limit. Grab = grab samples; SWS = stormwater sampler.

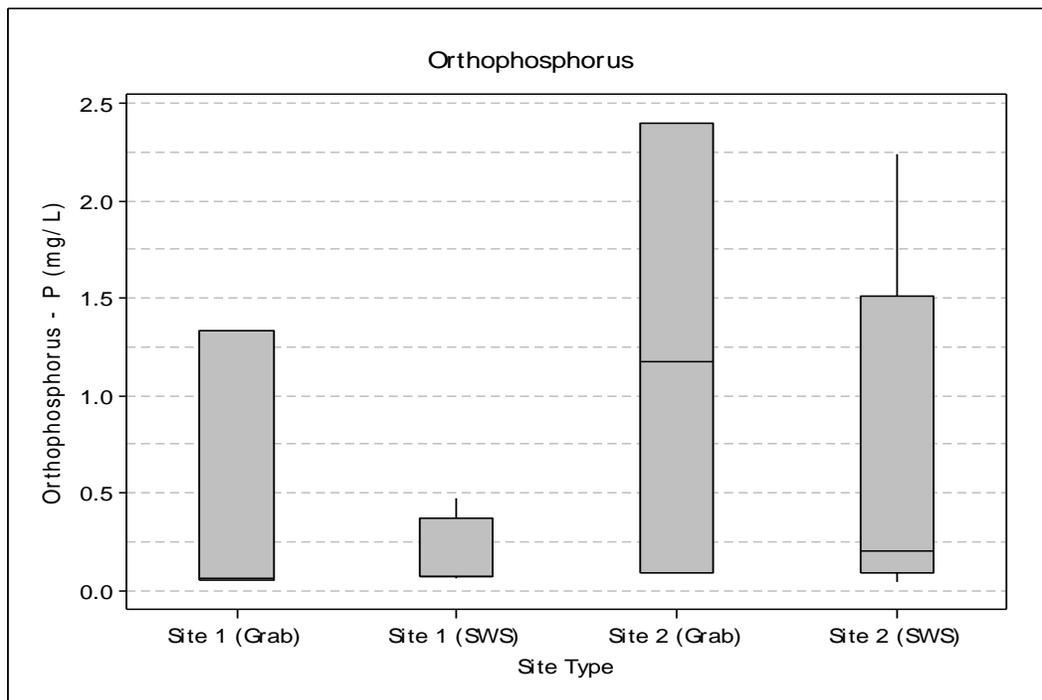


Figure 20. Boxplot of orthophosphorus levels measured at each site and type of sample over all sampling periods of the study.

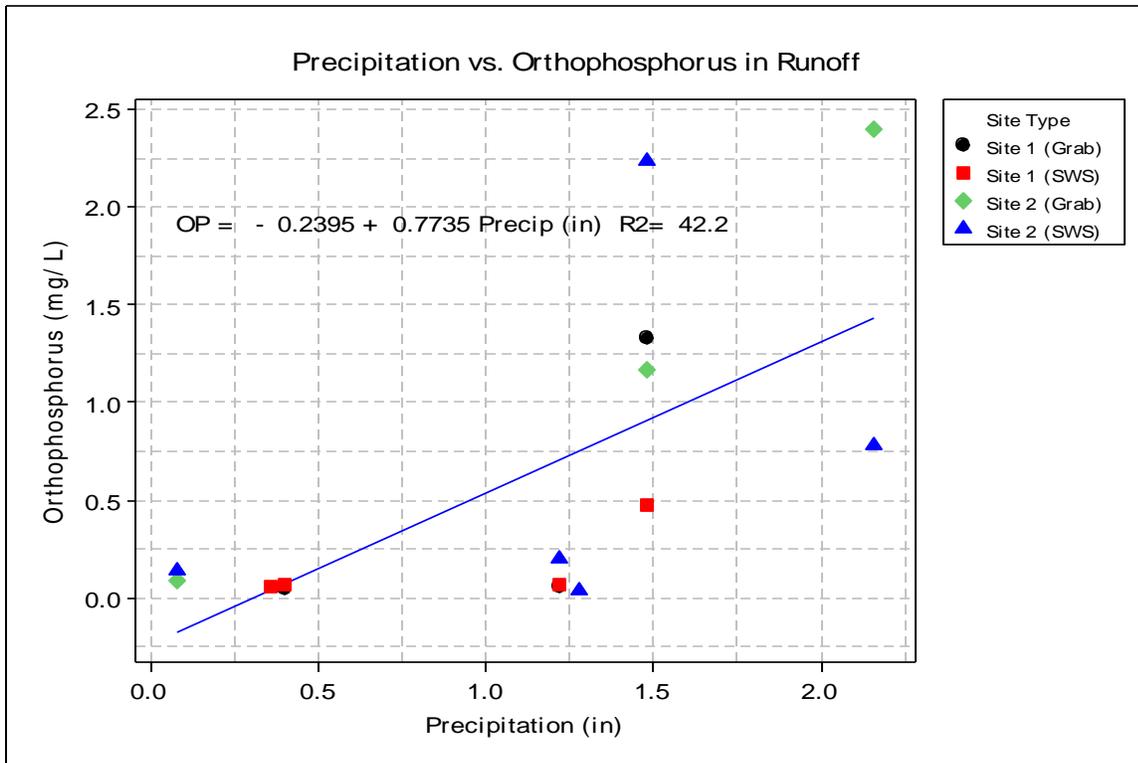


Figure 21. Relationship between precipitation and orthophosphorus levels in runoff at each site by collection method. Slope of regression line was significant at p = 0.009.

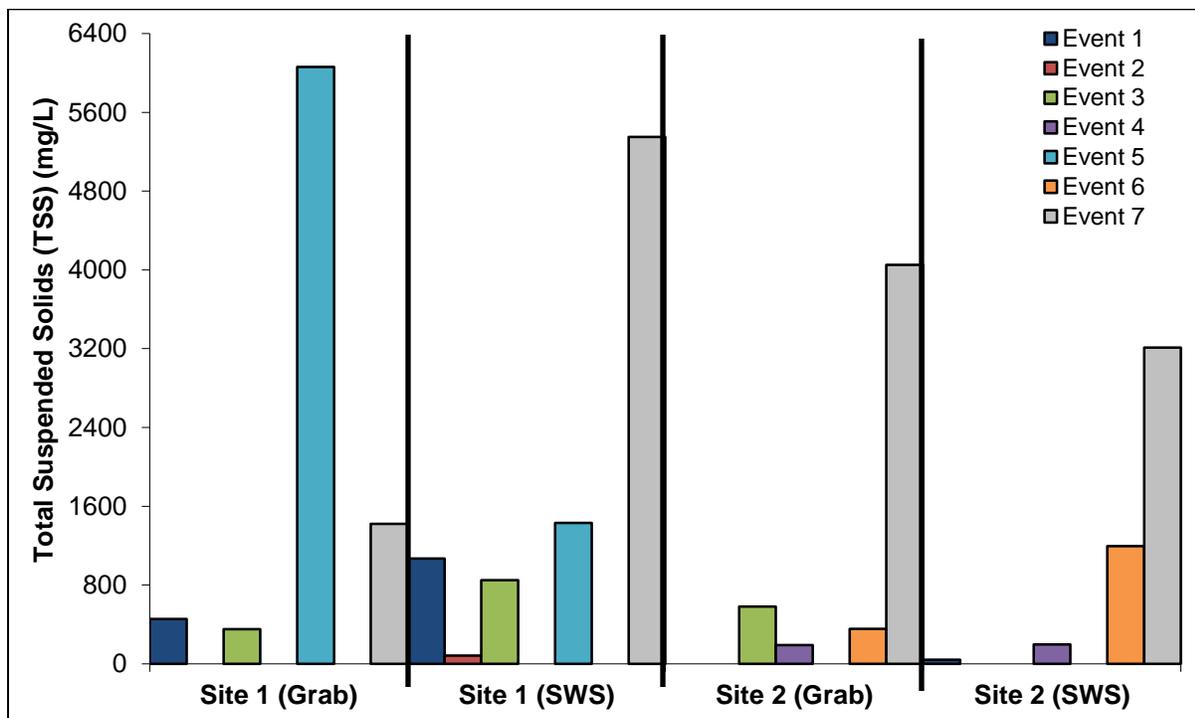


Figure 22. Total suspended solid levels in runoff during rainfall events. Grab = grab samples; SWS = stormwater sampler.

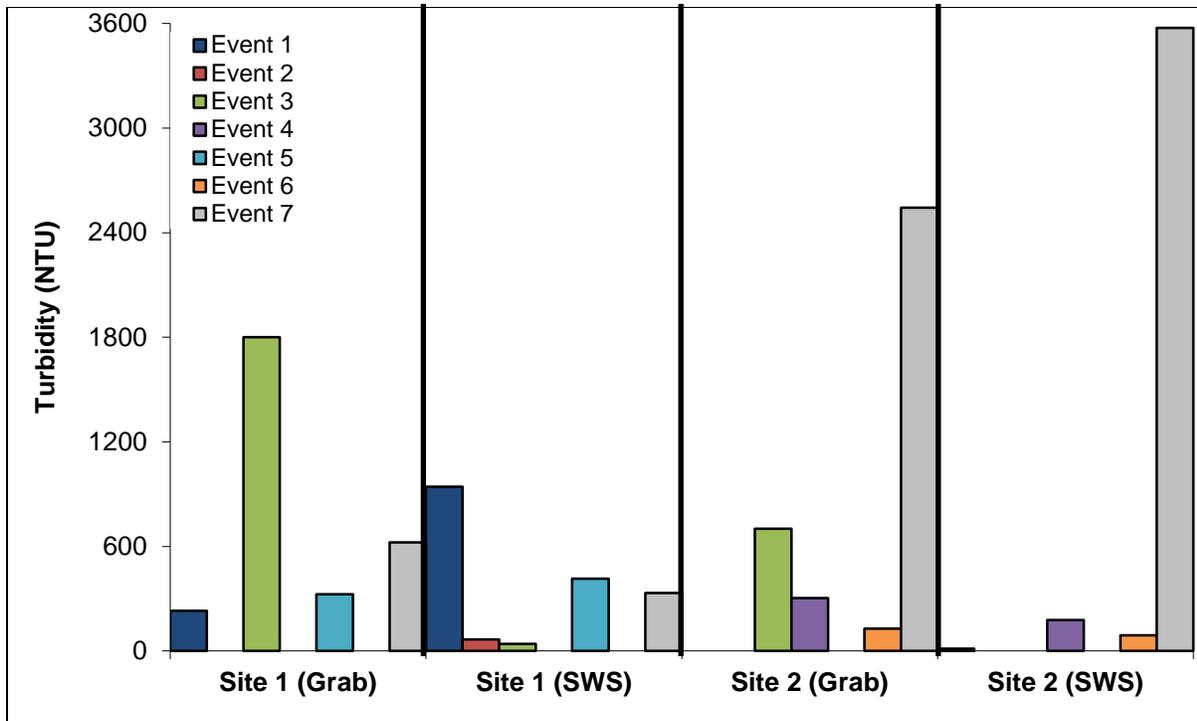


Figure 23. Turbidity levels in runoff during rainfall events. Grab = grab samples; SWS = stormwater sampler.

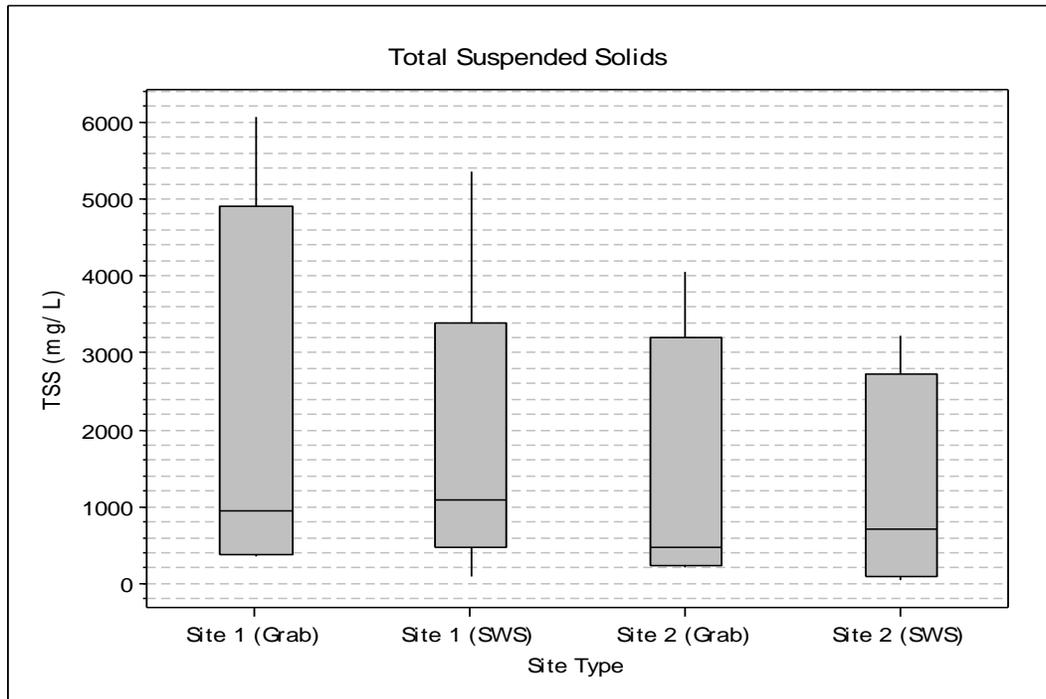


Figure 24. Boxplot of total suspended solids (TSS) levels measured at each site and type of sample over all sampling periods of the study.

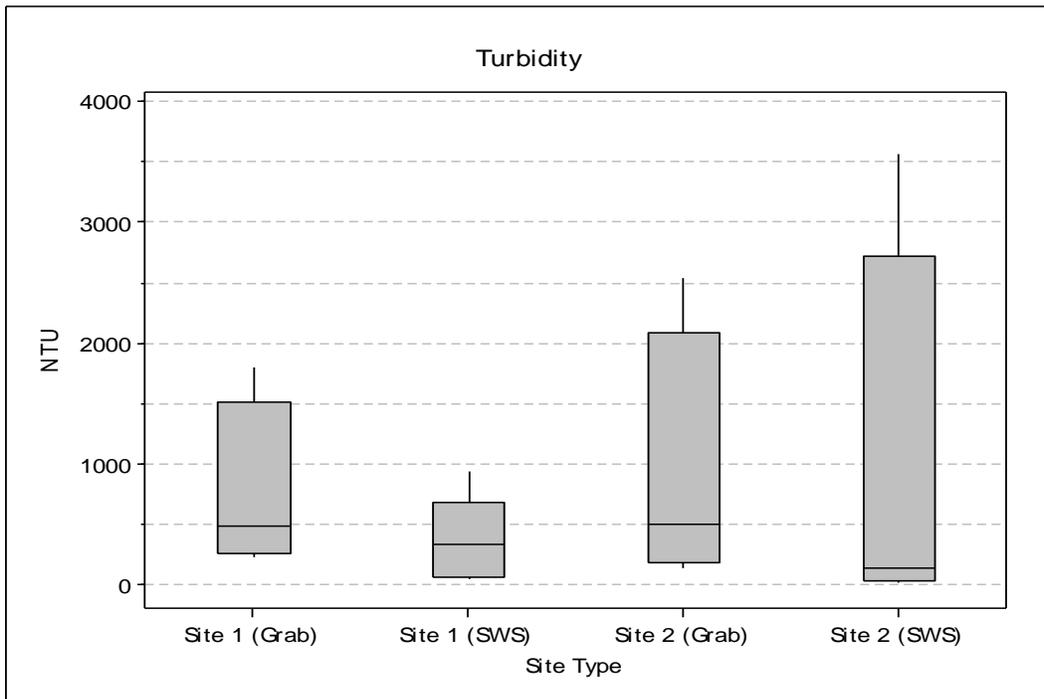


Figure 25. Boxplot of turbidity (NTU) levels measured at each site and type of sample over all sampling periods of the study

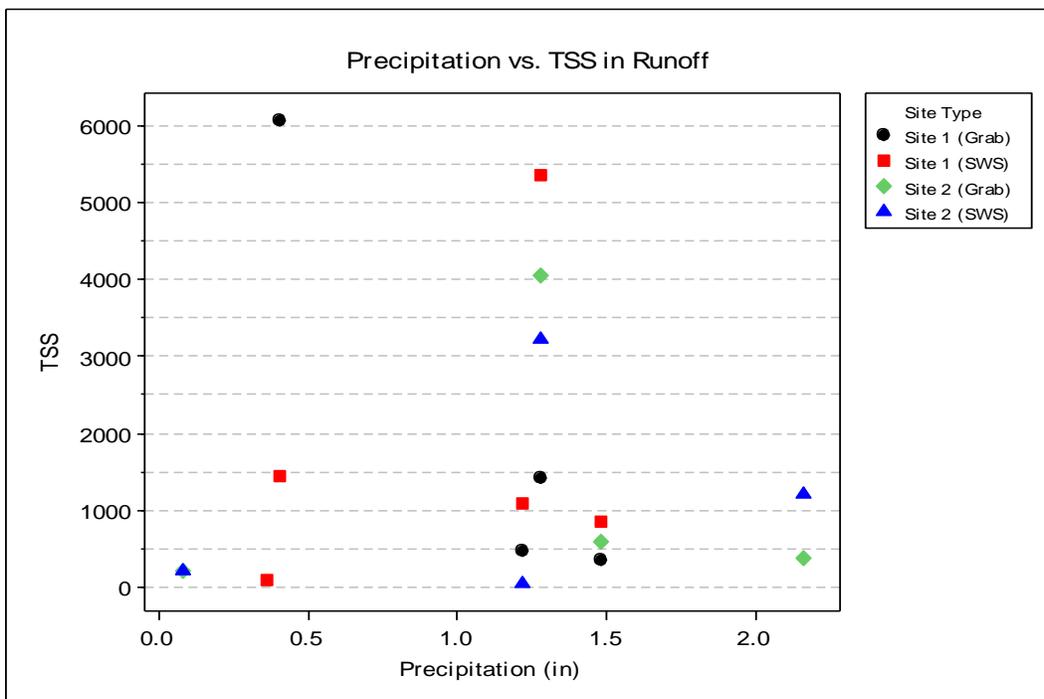


Figure 26. Relationship between precipitation and total suspended solids (TSS) levels in runoff at each site by collection method. There was no significant ($p < 0.01$) linear relationship between variables.

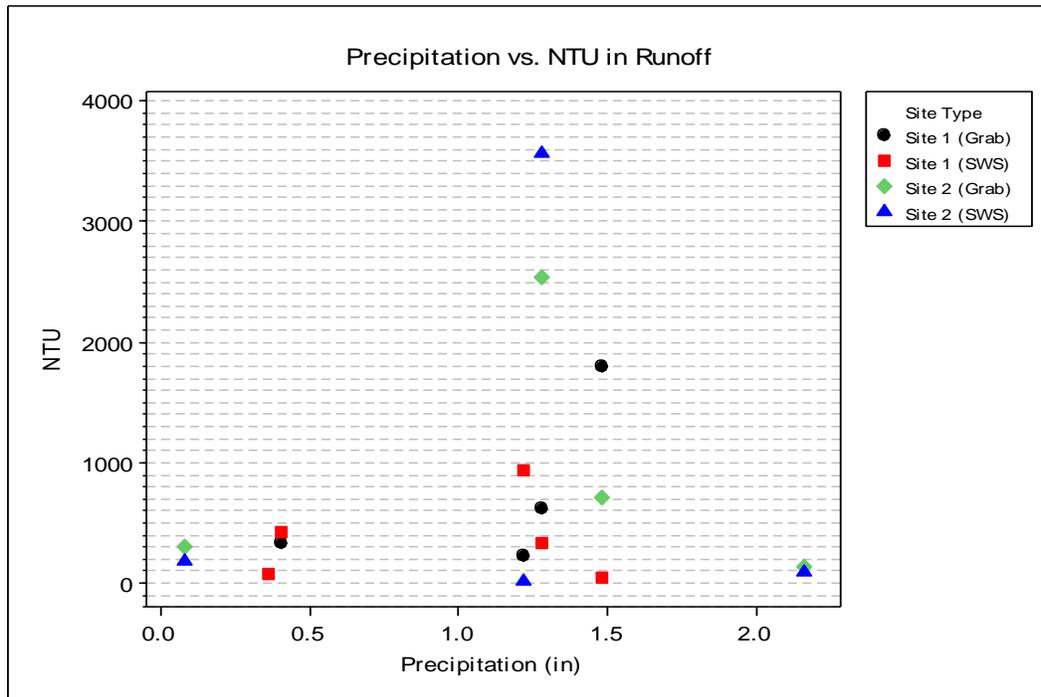


Figure 27. Relationship between precipitation and turbidity (NTU) levels in runoff at each site by collection method. There was no significant ($p < 0.01$) linear relationship between variables.

Bacteria

E. coli levels exhibited considerable variation between sites and sample dates. *E. coli* levels ranged between 135 and 14,101 mpn/100 ml (Figure 28). Seven of the eight samples (87.5%) exceeded the single grab criteria for *E. coli* of 394 mpn/100 ml. Due to the limited sample size EIH did not construct box plots or conduct formal ANOVA analysis. However, the majority of higher values (>1000 mpn/100 ml) were observed at Site 1. A significant linear relationship ($p = 0.05$) between precipitation and *E. coli* levels was observed (Figure 29). This relationship indicates that as the precipitation amount increases, the *E. coli* levels generally decrease.

Oil and Grease

Oil and grease levels were generally low (< 5 mg/L, the detection limit) except for event 4 levels at site 2 when 70.4 mg/L of oil and grease was detected (Figure 30). There is no explanation for the elevated level. Due to the limited sample size EIH did not construct box plots or conduct formal ANOVA analysis. EIH did not observe a significant ($p = 0.07$) linear relationship between precipitation and Oil and Grease levels. There are no listed TCEQ screening criteria for oil and grease in this stream segment (HGAC 2011).

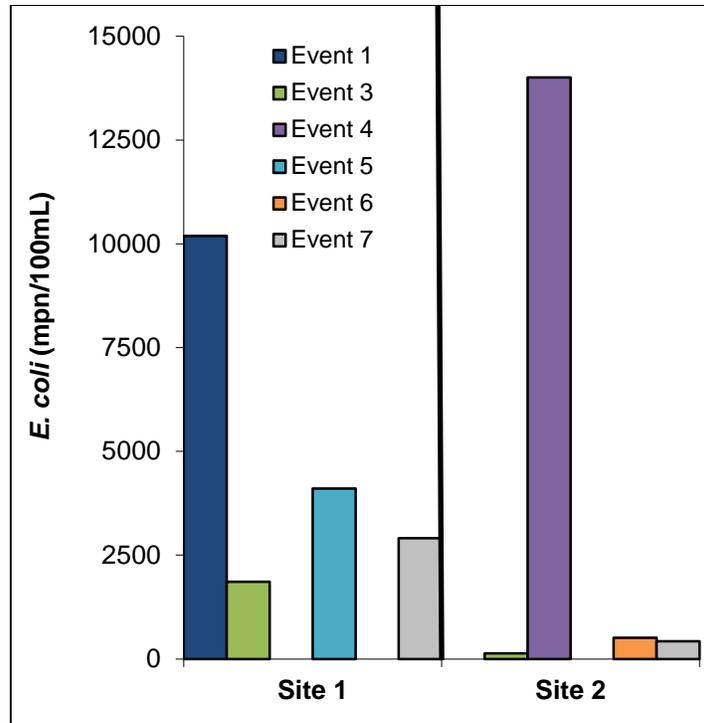


Figure 28. *E. coli* levels in runoff during rainfall events. Data based on grab samples only.

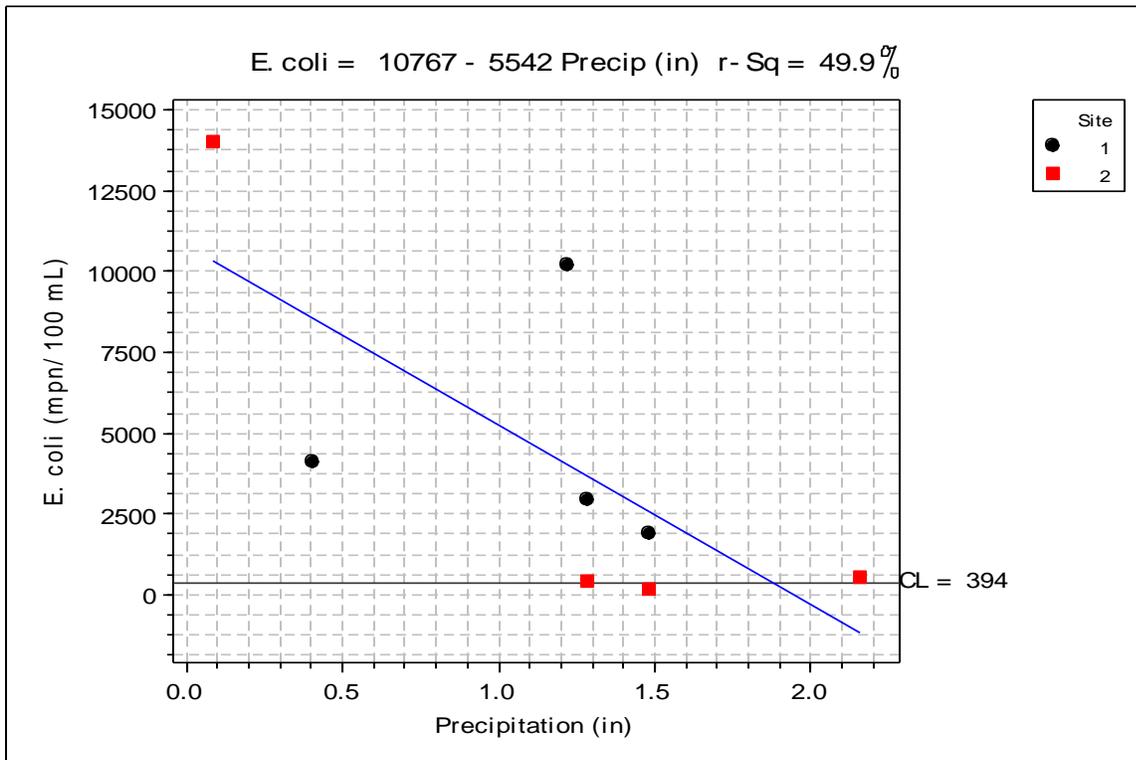


Figure 29. Relationship between precipitation and *E. coli* (mpn/100 mL) levels in runoff at each site. Significant at ($p = 0.05$) linear relationship between variables. CL = TCEQ criteria level.

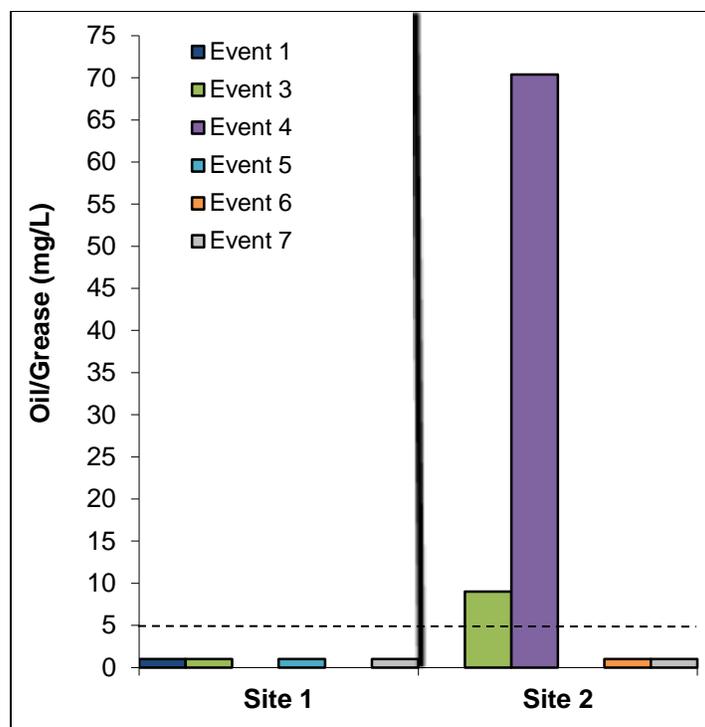


Figure 30. Oil and grease levels in runoff during rainfall events. Dashed line represents detection limit for this test (<5 mg/L); values below this line indicate presence at levels below the detection limit. Grab samples only.

Heavy Metals

Total mercury levels were generally low (< 0.001 mg/L, the detection limit) except for event 5 and 6 levels at sites 1 and 2 respectively when 0.00204 mg/L of mercury was detected (Figure 31). There is no explanation for the elevated level. Due to the limited sample size EIH did not construct box plots or conduct formal ANOVA analysis. EIH did not observe a significant ($p = 0.099$) linear relationship between precipitation and mercury levels. The TCEQ freshwater chronic criterion for protection of aquatic life is 1.3 mg/L (Texas Commission of Environmental Quality. 2008b).

Total cadmium levels were generally low (< 0.0002 mg/L, the detection limit) except for event 6 levels at site 2 when concentrations of 0.003 to 0.004 mg/L of cadmium were detected (Figure 32). There is no explanation for the elevated level. Due to the limited sample size EIH did not construct box plots or conduct formal ANOVA analysis. EIH did not observe a significant ($p = 0.932$) linear relationship between precipitation and total cadmium levels. TCEQ does not have a criterion for total cadmium in water (Texas Commission of Environmental Quality. 2008b). Their criterion is based on dissolved concentration and ambient pH and/or hardness levels.

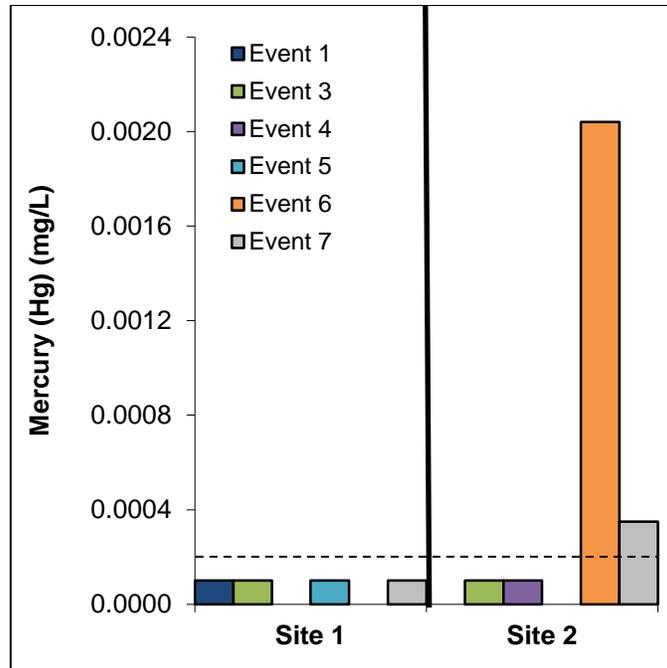


Figure 31. Mercury levels for rainfall events. Dashed line represents detection limit for this test (<0.0002 mg/L); values below this line indicate presence at levels below the detection limit. Grab samples only.

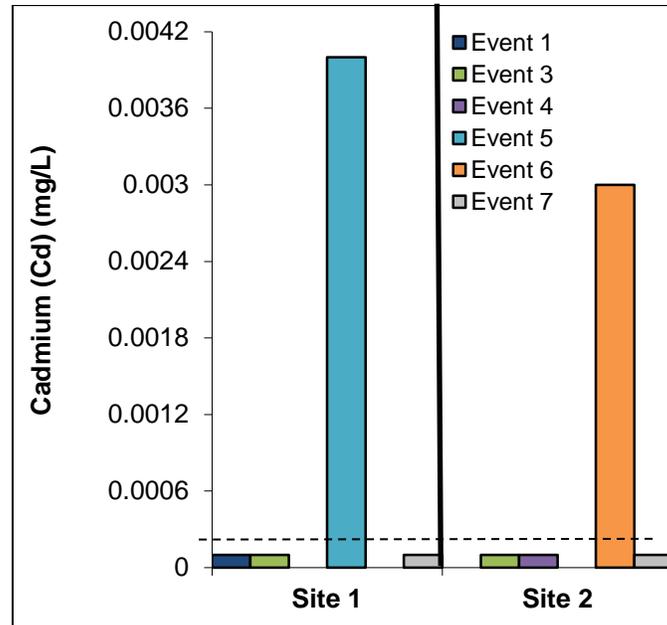


Figure 32. Cadmium levels for rainfall events. Dashed line represents detection limit for this test <0.0001 mg/L); values below this line indicate presence at levels below the detection limit. Grab samples only.

Total zinc levels were highly variable ranging from <0.005 to 0.24 mg/L (Figure 33). There is no explanation for the elevated level. Median values at site 1 were slightly higher (0.11 mg/L) when compared to site 2 (0.05 mg/L). However highest values (0.24 mg/L) were recorded at site 2 during event 6. Due to the limited sample size EIH did not construct box plots or conduct formal ANOVA analysis. EIH did not observe a significant ($p = 0.158$) linear relationship between precipitation and total cadmium levels. TCEQ does not have a state criterion for total cadmium in water (Texas Commission of Environmental Quality, 2008b). The state criterion is based on dissolved concentration and ambient pH and/or hardness levels.

Total lead levels were highly variable ranging from <0.005 to 0.18 mg/L (Figure 33). Median values were lower at site 1 versus 2 (0.03 vs. 0.18 mg/L). Highest values (0.213 mg/L) were recorded at site 2 during event 6. Due to the limited sample size EIH did not construct box plots or conduct formal ANOVA analysis. EIH did not observe a significant ($p = 0.254$) linear relationship between precipitation and total cadmium levels. TCEQ does not have a criterion for total cadmium in water (Texas Commission of Environmental Quality, 2008b). Their criterion is based on dissolved concentration and ambient pH and/or hardness levels.

It should be noted that 3 of the 4 metals monitored (mercury, zinc and lead) exhibited peak levels at site 2 during event 6. EIH is uncertain as to why this may have occurred, but may be due to increased vehicular traffic associated with road construction. It was noted that water samples were collected at site 2 in an instream pool located 9 meters upstream from the gage on that date. This was done because of lack of water at the normal sites located closer to the stormwater sampler and gage.

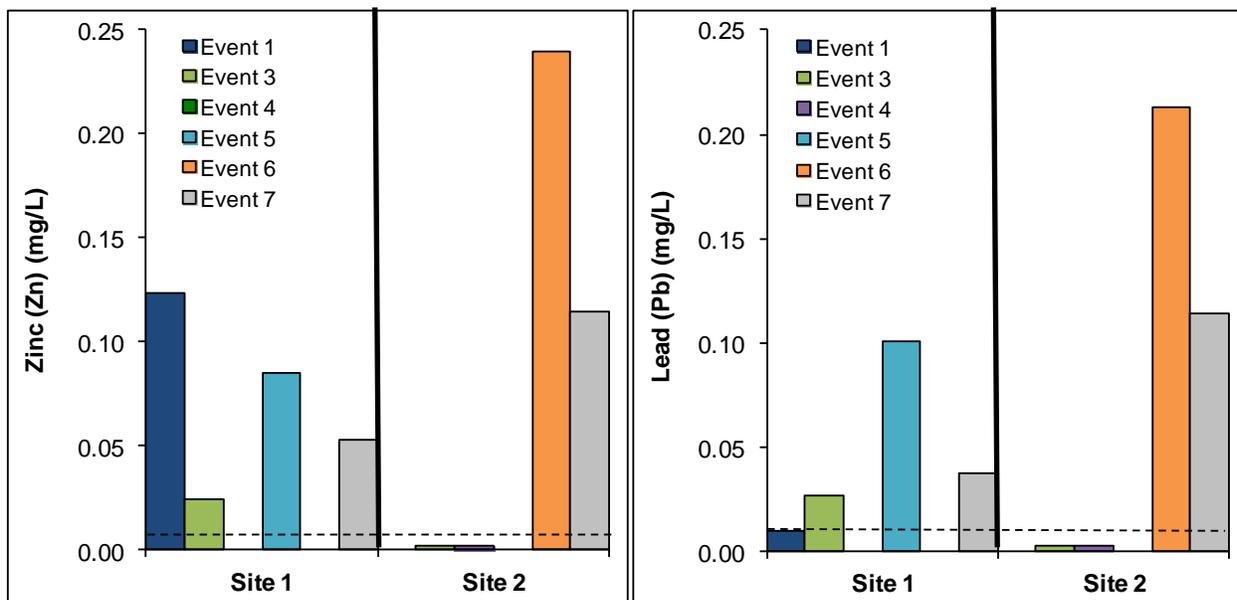


Figure 33. Zinc and lead levels for rainfall events. Dashed line represents detection limit for this test (< 0.01 mg/L); values below this line indicate presence at levels below the detection limit. Grab samples only.

Site Photographs and Progression of Construction

A series of photos were taken during the project using hand held cameras and automated “game” cameras during site visits and on sampling dates depicting site conditions (Figure 34 to Figure 82). As documented earlier, the exact location of the stormwater collector at site 1 was moved on 1/28/11. The collector at site 2 was also moved on 11/8/10. Each series of photographs is grouped by date and sampling location in chronological order. There are other photos that are not presented in this report but are included in the electronic supplement (Appendix 3). The photographic record provides very good documentation of site conditions and associated changes in the contributing watershed including onsite construction activities.

During the early phases of the project, measured runoff flows and suspended solids were generally lower, but gradually increased through time as new development occurred at both sites (Figure 22 and Figure 23, and Figure 53 to Figure 82). This trend was first observed at site 1 and subsequently after June, 2011 at site 2 as well. The ultimate cause of increased sediments and turbidity appears to be increased road construction near each site. The background levels of each monitored pollutant were likely only present near the beginning of the project before road construction activity had begun at each site. In the case of site 1, it appears that construction activity had already affected water quality at the site before sampling started. At site 2, observed turbidity in the field, and associated turbidity measurements increased near the end of the project and were likely associated with the increased road construction that were observed on 11/15/12 (Figure 22 and Figure 23; Figure 76 to Figure 78). The general appearance of the turbid water at both sites was a yellowish clay color.

Similar trends in nutrients and heavy metals and to a lesser extent *E. coli* are probably associated with particulate associated forms of these pollutants. The only pollutant exhibiting a very strong positive relationship with rainfall levels was orthophosphorus. *E. coli* levels appeared to actually decline with increasing rainfall amounts suggesting a dilution effect. This is a likely mechanism since *E. coli* measurements were taken exclusively from grab samples and not first flush samples, which have been shown to typically contain higher amounts of pollutants.

EIH Personnel also collected photographs on various species of wildlife using our automated game cameras. Detailed information on these species is presented in the game camera section. It should be noted that warm-blooded vertebrate wildlife can be a significant source of *E. coli* bacteria when the organisms are in high densities. EIH did not attempt to conduct a study of or estimate the density of the various species observed.

10-8-2010 Initial Stormwater Sampler Deployment



Figure 34. Photograph of site 1, taken on 10/8/10 before deployment of stormwater sampler (Source: hand held camera).



Figure 35. Photograph of site 2, taken on 10/8/10 immediately after deployment of stormwater sampler facing upstream (Source: hand held camera).

Sampling Event 1 November 2, 2010



Figure 36. Photograph of site 1, taken during wet weather event 1 on 11/2/10, looking downstream at stormwater sampler and gage. (Source: automated game camera).



Figure 37. Photograph of site 1, taken during wet weather event 1 on 11/2/10, looking downstream at stormwater sampler and gage. (Source: hand held camera).



Figure 38. Photograph of site 1, taken during event 1 on 11/2/10, looking upstream from stormwater sampler and gage. (Source: hand held camera).



Figure 39. Photograph of site 2, taken during event 2 on 11/2/10, looking downstream from stormwater sampler and gage. (Source: hand held camera).

Site Visit January 14, 2011



Figure 40. Photograph of site 1, taken during 1/14/11, looking downstream toward flood area containing stormwater sampler and gage 5 days after significant rain (Source: hand held camera).

Site Visit January 28, 2011



Figure 41. Photograph of site 1, taken on 1/28/11, depicting HCFCD personnel digging up stormwater sampler to move it downstream (Source: hand held camera). Sampler was buried in mud.



Figure 42. Photograph of site 1, taken on 1/28/11, depicting downstream view of new site location from mid-channel, upstream (Source: hand held camera).

Site Visit February 8, 2011



Figure 43. Photograph of site 1, taken on 2/8/11, depicting stormwater sampler and gauge posts from right bank (Source: hand held camera).



Figure 44. Photograph of site 1, taken on 2/8/11, depicting stormwater sampler with sediment caked on sampler tube top (Source: hand held camera). Sampler checked after non-qualifying rain event.



Figure 45. Photograph of site 1, taken on 2/8/11, depicting stormwater sampler bottle completely filled after a non-qualifying rain event (Source: hand held camera).

Site Visit March 7, 2011



Figure 46. Photograph of new clearly area along road adjacent to site 1, taken on 3/7/11 (Source: hand held camera).

Sampling Event 2, May 13, 2011



Figure 47. Photograph of site 1 taken during event 2 on May 13, 2011. (Source: hand held camera).



**Figure 48. Photograph of site 2 taken during event 2 on May 13, 2011.
(Source: hand held camera).**

Sampling Event 3, June 22, 2011



Figure 49. Photograph of site 1 taken during event 3 on June 22, 2011. (Source: hand held camera).



Figure 50. Photograph of site 2 taken during event 3 on June 22, 2011. (Source: game camera).



Figure 51. Photograph of site 2 taken during event 3 on June 22, 2011. View is upstream from and downstream toward sampler respectively. (Source: hand held camera).

Sampling Event 4, June 23



Figure 52. Photograph of site 2 taken during event 4 on June 23, 2011. (Source: game camera).

Site Visit August 18, 2011

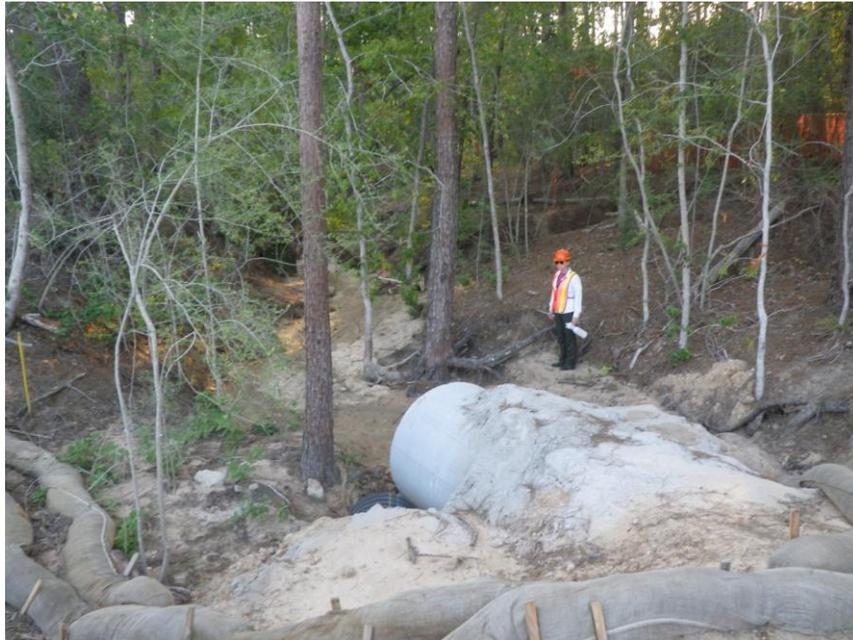


Figure 53. Photograph of culvert drain at upstream road from site 1 taken on August 18, 2011. View downstream toward sampler. (Source: hand held camera).



Figure 54. Photograph of site 1 taken on August 18, 2011 showing debris and mud. (Source: hand held camera).



Figure 55. Photograph of site 2 taken on August 18, 2011 showing stormwater sampler and gage in dry creek (Source: hand held camera).



Figure 56. Photograph of site 2 taken on August 18, 2011 showing stormwater sampler bottle completely full from non-qualifying wet weather event (Source: hand held camera).



Figure 57. Photograph of site 2 taken on September 1, 2011 showing construction activity upstream of sampler (Source: hand held camera).

Site Visit September 9, 2011



Figure 58. Photograph of site 1 taken on November 9, 2011 showing stormwater sampler and staff gage with accumulated debris (Source: hand held camera). No sample bottles deployed prior to this rain event.

Sampling Event 5 September 19, 2011



Figure 59. Photograph of site 1 taken on stormwater sampling event 5, September 19, 2011 showing construction activity upstream of sampler (Source: hand held camera).



Figure 60. Photograph of site 1 taken during stormwater sampling event 5 on September 19, 2011 depicting ditch upstream of sampler full of muddy runoff from construction activity (Source: hand held camera).



Figure 61. Photograph of site 1 taken during stormwater sampling event 5 on September 19, 2011 showing stormwater sampler obstructed with debris (Source: hand held camera).



Figure 62. Photograph of site 1 taken during event 5 on September 19, 2011. (Source: game camera).



Figure 63. Photograph of site 2 taken on stormwater sampling event 5, September 19, 2011 showing construction activity upstream of sampler (Source: hand held camera).



Figure 64. Photograph of site 2 taken on stormwater sampling event 5, September 19, 2011 showing minimal water in ditch and minimal amount of water in sampler (Source: hand held camera). Insufficient water collected for most analyses.

Sampling Event 6 October 10, 2011



Figure 65. Photograph of side view of new culvert installed near upstream of site 1 taken during event 6 on October 10, 2011. (Source: hand held camera).



Figure 66. Photograph of top view of new culvert installed near upstream of site 1 taken during stormwater sampling event 6 on October 10, 2011. (Source: hand held camera).



Figure 67. Photograph of site 2 taken during event 6 on October 10, 2011. View of pools of rain water in the creek; photo taken from right bank looking downstream (Source: hand held camera).



Figure 68. Photograph of site 2 taken during event 6 on October 10, 2011. View of the pools of rain water downstream of the sampler. (Source: hand held camera).

Site Visit November 9, 2011



Figure 69. Photograph of site 1 staff gage taken on November 9, 2011, a day after rainfall. No stormwater sampler was deployed on this date. (Source: hand held camera).



Figure 70. Photograph of construction area immediately upstream of site 2 on November 9, 2011, a day after significant rainfall. (Source: hand held camera).



Figure 71. Photograph of site 2 on November 9, 2011, a day after rainfall. (Source: hand held camera).



Figure 72. Photograph of collection bottle from stormwater sampler bottle at site 2 on November 9, 2011, a day after rainfall. (Source: hand held camera). Note minimal sample volume collected which was not used for analyses.

Sampling Event 7 November 15, 2011



Figure 73. Photograph of stormwater sampler at site 1 during sampling event 7 on November 15, 2011.



Figure 74. Photograph of stormwater sampler at site 1 during sampling event 7 on November 15, 2011. (Source hand held camera). Note sampler cap is full of mud.



Figure 75. Photograph of construction site upstream of site 2 on November 15, 2011 during event 7. (Source: hand held camera).



Figure 76. Photograph of ditch upstream of site 2 on November 15, 2012 during sampling event 7. Note foam in water. (Source hand held camera).



Figure 77. Photograph of the staff gage and sampler at site 2 on November 15, 2012, with sampler cap removed; more sediment deposited in the creek from the construction. Note rain water filled the sampler (Source: hand held camera).



Figure 78. Photograph of sediment deposited on the stormwater sampler collector at site 2 during event 7 on November 15, 2012. Note cap lying on the ground had a frothy film on it. (Source: hand held camera).

Site Visit and Sampler Removal November 29, 2011

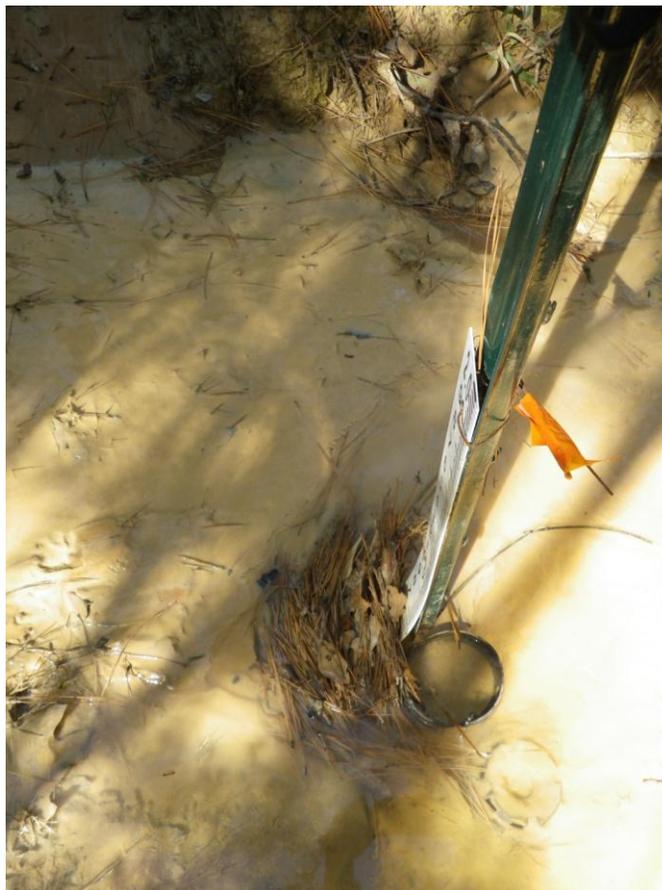


Figure 79. Photograph of site 1 stormwater sampler on November 29, 2011 just prior to removal at end of study. (Source: hand held camera).



Figure 80. Photograph of area upstream of site 1 stormwater sampler on November 29, 2011. (Source: hand held camera).



Figure 81. Photograph of site 2 on November 29, 2011 on last day of study prior to stormwater sampler removal. (Source: hand held camera).



Figure 82. Photograph of stormwater sampler at site 2 on November 29, 2011 prior to stormwater sampler removal on last day of study. (Source: hand held camera). No stormwater sample bottle had been deployed prior to this event.

Game Cameras

Additional selected photographs are provided below from game camera deployment to illustrate and document the local wildlife at the site (Figure 83 - Figure 90). This included owls, white tailed deer, raccoon, armadillo, bobcat, coyote, and opossum. This illustrates that the wooded area within the development site provided habitat that supported numerous mammalian and avian wildlife. The presence of upper level predators such as coyote, bobcat and owls suggest that numerous forage species are present in sufficient numbers to support the resident carnivore's diet.



Figure 83. Photograph of flying short-eared owl, *Asio flammeus* attacking a rabbit.



Figure 84. Photograph of armadillo. This species was also observed during the daytime.



Figure 85. Photograph of bobcat. This species was also observed at night.



Figure 86. Photograph of male white tailed deer.

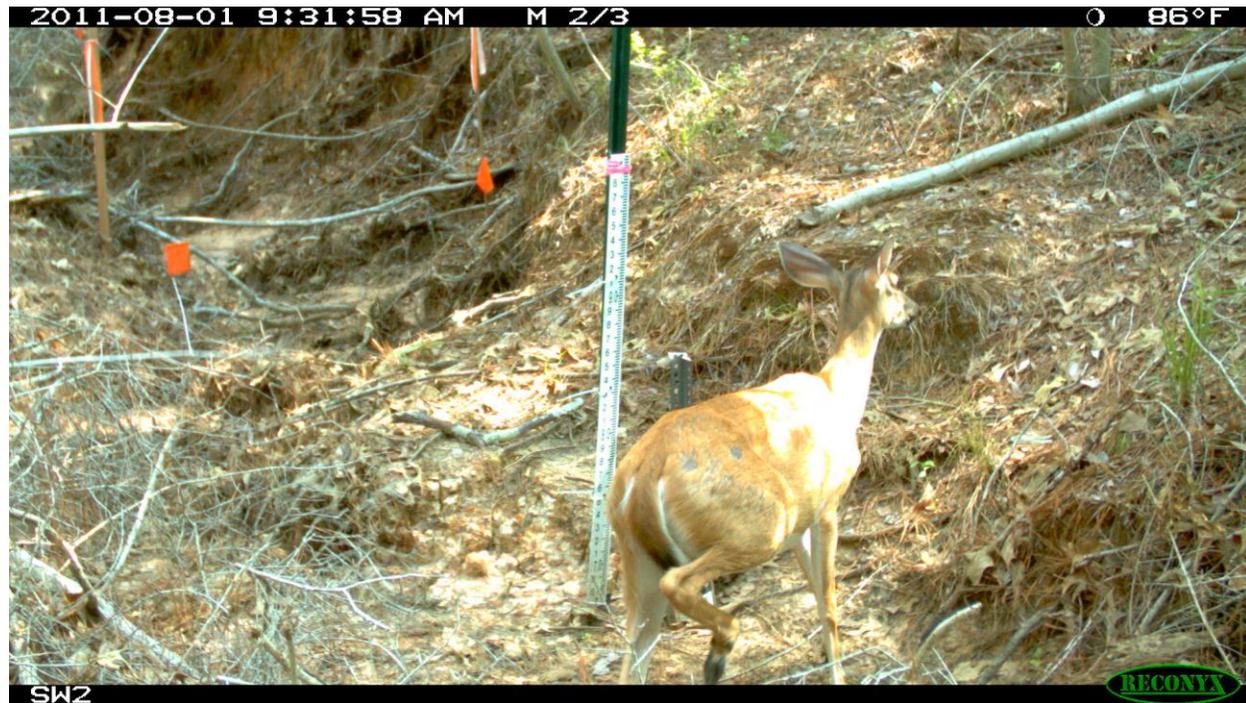


Figure 87. Photograph of female white tailed deer.



Figure 88. Photograph of coyote. This species was also observed at night.



Figure 89. Photograph of opossum.



Figure 90. Photograph of raccoons.

DISCUSSION

Data collected from our study shows that turbidity readings taken on site were elevated in comparison to ambient levels. Historical data collected by EIH for the Clean Rivers Program (CRP) during 2005 to 2011 document the majority of the NTU measurements ranged between 5 and 75 NTU (Guillen et al. 2012). The most frequent measurements ranged between 5 and 20 NTU. Values never exceeded 275 NTU. During April to December 2011 automated monitoring datasondes deployed at 5 sites in Harris County collected a total of 28,783 NTU measurements (Guillen et al. 2012). The 10th, 25th, median, 75th and 95th percentile NTU values based on these data were 7, 13, 26, 60 and 381 respectively, and ranged between 0 and 1,778. In contrast EIH measured 134 to 503 NTUs during the course of this study. This suggests that all of the runoff samples collected during this study exceeded the 75th percentile for ambient turbidity levels.

The TSS levels measured during this study appeared to peak during the high rainfall events, and seldom fell below 200 mg/L (Figure 22, Figure 24 and Figure 26). This pattern was observed most often at site 1, which was adjacent to more active construction activity. In contrast Guillen et al. (2012) found that for waterbodies in Harris County TSS values seldom exceeded 100 mg/L, with an overall median value of 21.2 mg/L. They also found that TSS increased as a percentage of the maximum flow in a stream. These data suggest that erosion of soil and/or road material was occurring at both sites. Based on water quality monitoring data, increased transport of surface sediments was occurring at site 1 and to a lesser extent site 2. This trend probably reflects increased road construction activity.

One of the primary challenges of reducing non-point pollution from runoff associated with construction sites and subsequent residential and industrial facilities is the control of sediments. One of the primary pollutants in runoff is suspended solids including eroded soils. The control of this pollutant is important because many other pollutants including heavy metals, hydrocarbons, and nutrients are often associated with or bonded to particulate matter in water (Lick 2009). Therefore much of the analysis for this study was focused on the results of suspended solids and turbidity monitoring.

The overall objective of this study was to characterize and compare pre-development and construction water quality to later verify the effectiveness of LID methods utilized by Springwoods Development contractors. Stormwater runoff samples, grab samples, and photographic techniques were employed to evaluate the changes in site conditions during construction. Based on the results of this study EIH was able to characterize the runoff quality of their drainage from two sites, site 1 with extensive construction activity and site 2, with minimal activity until later in the project. Evaluation of aerial photography showed that extensive construction activity had already begun by the time EIH started our monitoring project. Therefore it is very difficult to consider data collected during this study as “background” pre-construction data. However, some data collected at site 2, prior to June 2011, suggests that pre-project construction levels of turbidity and TSS were closer to 20 NTU and 40 mg/L respectively. These values were never again observed throughout the study.

EIH recommends that continued stormwater runoff monitoring be conducted due to the late start of this project and failure to document baseline pre-construction runoff water quality conditions. Additional monitoring should incorporate runoff water sampling within the developed project and a nearby undeveloped control site. The control site should be an unaltered site containing only native vegetation and soils. Monitoring should be conducted for at least two years post construction to incorporate seasonal and annual variability in meteorology, hydrology and water quality. During each season several wet weather events should be monitored. This monitoring plan would provide sufficient data to assess and compare the water quality of runoff from various portions of the development project over time against control site baseline conditions, as envisioned in the original scope of work.

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APPENDIX 1: CALIBRATION DATA

Electronic Supplement

APPENDIX 2: FIELD DATA

Electronic Supplement

APPENDIX 3: PHOTOGRAPHIC RECORD

Electronic Supplement

APPENDIX 4: WEATHER CONDITION SUMMARY

Electronic Supplement

APPENDIX 5: GOOGLE EARTH INTERACTIVE MAP

Electronic Supplement