Storm Water Monitoring Along Loop 202 and Salt River

Final Report 602

Prepared by:

John Burton
Engineering and Environmental Consultants, Inc. (EEC)
7878 N. 16th Street, Suite 140
Phoenix, AZ85020

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206 South 17th Avenue
Phoenix, AZ 85007
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16. Abstract

A comprehensive research program for the characterization of storm water runoff from an Arizona highway was conducted from January through December 2007. The study area covered a portion of the Loop 202 freeway west of Mesa Drive to a retention basin east of Lindsay Road in Mesa, Arizona. Storm water samples were collected from two storm water detention basins and a discharge point to the Salt River. The study was conducted by manually collecting storm water samples with passive automatic samplers and analyzing them for various roadway constituents. A primary objective of this research effort was to establish baseline values of constituents in ADOT highway runoff, aiding in the evaluation of related best management practices.

A total of 16 storm water samples was collected from the research area between January 2007 and December 2007. The storm water sampling data indicates suspended solids (reported as total suspended solids, or TSS) were present in 14 of the 16 samples collected and zinc (reported as total zinc) was present in 13 out of 16 samples collected. Other heavy metals such as copper, lead, and chromium were occasionally detected. Phosphorous and ammonia were detected only once during this research program. TSS is the most significant pollutant, by mass, found in our nation's waterways, a standing consistent with the outcome of this research. It is important to note that exceedance of an Environmental Protection Agency benchmark does not constitute a storm water violation.

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SI (MODERN METRIC) CONVERSION FACTORS*

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
	AREA			
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
	VOLUME			
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: Volumes greater than 1000L shall be shown in m^3.			
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000lb)	0.907	megagrams (or "metric ton")	mg (or "t")
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C
	ILLUMINATION			
fc	foot candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
	FORCE AND PRESSURE OR STRESS			
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
	AREA			
mm^2	Square millimeters	0.0016	square inches	in^2
m^2	Square meters	10.764	square feet	ft^2
m^2	Square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	Square kilometers	0.386	square miles	mi^2
	VOLUME			
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	Cubic meters	35.315	cubic feet	ft^3
m^3	Cubic meters	1.308	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
mg	megagrams (or "metric ton")	1.102	short tons (2000lb)	T
	TEMPERATURE (exact)			
°C	Celsius temperature	1.8C + 32	Fahrenheit temperature	°F
	ILLUMINATION			
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
	FORCE AND PRESSURE OR STRESS			
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380

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ABBREVIATIONS

ADHS	Arizona Department of Health Services
ADOT	Arizona Department of Transportation
ATRC	Arizona Transportation Research Center
BMP	best management practices
BOD	biological oxygen demand
COD	chemical oxygen demand
CWA	Clean Water Act
EPA	Environmental Protection Agency
ESC	Environmental Science Corporation
NNS	no numerical standard
NPDES	National Pollutant Discharge Elimination System
QA/QC	quality assurance/quality control
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TPH	total petroleum hydrocarbon
TSS	total suspended solids

EXECUTIVE SUMMARY

A comprehensive research program for the characterization of storm water runoff from the Loop 202 freeway in metropolitan Phoenix, Arizona, into two detention basins and the Salt River was completed between January and December of 2007. The study was conducted by manually collecting storm water samples utilizing passive automatic samplers and analyzing them for various roadway constituents. A primary objective of the storm water monitoring was to establish baseline values of constituents in freeway runoff. The data will aid in evaluating the effectiveness of the Arizona Department of Transportation's (ADOT) best management practices (BMPs) for storm water management along portions of the Loop 202.

Sixteen storm water samples were collected from the research area between January and December 2007. The storm water sampling data indicate total suspended solids (TSS) were in excess of the EPA benchmark in 14 of the 16 samples and the benchmark for zinc was exceeded in 13 out of the 16 samples. Other heavy metals such as copper, lead, and chromium were occasionally present. Phosphorous and ammonia were found only once in this research program. Suspended solids (reported as total suspended solids, or TSS) are the most significant pollutant, by mass, found in our nation's waterways. The outcome of this research with regard to the presence of TSS is thus consistent with typical past findings. The high concentration of zinc (reported as total zinc) is likely the result of wear and debris from automobile tires. Other heavy metal concentrations may result from various automobile drippings, fumes, and particulates. It is worth noting that in no instance did exceeding an EPA benchmark constitute a storm water violation.

INTRODUCTION

A comprehensive storm water sampling program was conducted along the Loop 202 freeway in metropolitan Phoenix, Arizona, that involved testing of effluent at the inlets to two detention basins and an outlet into the Salt River, as more fully described in the next chapter and the appendixes. The purpose of this monitoring program was to establish baseline values of constituents in freeway runoff entering each detention basin and the Salt River. The data allows ADOT to evaluate the effectiveness of the Best Management Practices (BMPs) it has implemented along this portion of the Loop 202. The final results of this program will be used to determine whether current BMPs are sufficient to protect surface water quality or whether changes are necessary.

STORM WATER SAMPLING LOCATIONS

The sites for storm water sampling are described in this section. Figure 1 and Figure 2 in Appendix A are maps showing the sampling location sites.

SAMPLE LOCATION AT LINDSAY ROAD AND LOOP 202

The Lindsay Road and Loop 202 sample location was near the northeast corner at the inlet point of the ADOT detention basin south of the 202 and east of Lindsay (Appendix B photos B-1 through B-3). This location was identified as **Basin 1** for sampling purposes and was selected for the following reasons:

- The detention basin is close to the Loop 202 and primarily receives storm water runoff from the freeway.
- There are BMPs in use along the Loop 202 and this section of freeway is within ADOT's Municipal Separate Storm Sewer System (MS4) Phase I National Pollutant Discharge Elimination System (NPDES) permitted area.
- There was safe access to the basin from surface streets and access from the freeway was not required.
- The storm water samplers could be installed at the inlet point of this basin, which is located at the northeast corner.
- An access gate is located near the inlet point, which provided additional security for the samplers.

SAMPLE LOCATION AT GILBERT ROAD AND LOOP 202

The Gilbert Road and Loop 202 sample location is near the north side at the inlet point of the ADOT detention basin (Appendix B photos B-4 and B-5). This location was identified as **Basin 2** for sampling purposes and was selected for the following reasons:

- The detention basin is close to the Loop 202 and primarily receives storm runoff from the freeway.
- This detention basin is within a quarter-mile of the Lindsay Road detention basin and would provide data for comparison between each basin.
- There are BMPs in use along the Loop 202 and this section of freeway is within ADOT's Phase I NPDES-permitted area.
- There was safe access to the basin from surface streets and access from the freeway was not required.
- The storm water samplers could be installed at the inlet point of this basin, which is located at the northeast corner.
- An access gate is located near the inlet point, which provided additional security for the samplers.

SAMPLE LOCATION AT SALT RIVER AND LOOP 202

The Salt River and Loop 202 sampling location is located approximately 500 feet northwest of ADOT's pump station near Mesa Drive and the Salt River (Appendix B photos B-6 through B-9). This location was identified as **Salt River** for sampling purposes and was selected for the following reasons:

- It would provide ADOT with data concerning discharge into waters of the United States.
- The two detention basins being sampled discharge to this location at the Salt River.
- There was safe access to the basin from surface streets and access from the freeway was not required.
- An access gate is located near the pump station, which provided additional security for the samplers.

STORM WATER LITERATURE

A literature review was conducted that included literature from the Transportation Research Information Services (TRIS) database at http://ntl.bts.gov/tris, and the Research In Progress database located at http://rip.trb.org/search. No literature of direct relevance was found for Arizona concerning storm water. However, several relevant studies conducted outside Arizona concerning storm water in relation to highway and urban runoff were identified. The studies discussed below were found to be relevant to this research because they are associated with highway runoff or with vegetative slopes adjacent to freeways.

STORM WATER RUNOFF FROM NORTH CAROLINA HIGHWAYS

Sampling and Testing of Stormwater Runoff from North Carolina Highways, conducted for the North Carolina Department of Transportation (Wu and Allan 2001) — This research pertains to a comprehensive monitoring program for characterization of North Carolina highway runoff. Ten monitoring sites distributed in various regions were included in the study. Contributing drainage areas ranged from 0.15 to 13.26 acres. Roadway imperviousness ranged from 22% to 100% and traffic volumes ranged from 9,400 to 78,800 vehicles/day in both directions. Rainfall-runoff data and composite storm water samples were obtained from 237 storm events. The effectiveness of vegetative BMPs was assessed by comparing pollutant exports from three groups of paired monitoring sites. A database was established for estimation of seasonal and annual pollutant loads and event-mean concentrations. The study was part of the North Carolina Department of Transportation's compliance with NPDES requirements.

STORM WATER RUNOFF FROM CALIFORNIA HIGHWAYS

Storm Water Monitoring & Data Management: Discharge Characterization Study Report, conducted by the California Department of Transportation (2003) — This study focuses on a water quality monitoring project designed to evaluate the removal of storm water contaminants by existing vegetated slopes adjacent to freeways. The main objective was to determine whether standard roadway design requirements resulted in buffer strips that resulted in stormwater treatment equivalent to those buffer strips specifically engineered for water quality improvement. The runoff through existing vegetated slopes at four locations in northern and southern California was studied; variables such as length, slope, vegetation density, and hydraulic loading were investigated in relation to water quality. Concrete channels were constructed for capturing highway runoff after it passed through existing buffer strips of varying widths at each location. The quantity and quality of the runoff discharged from the buffer strips was compared to that observed at the edge of the pavement. The performance of each vegetated shoulder was evaluated, looking for changes in concentration of constituents typically found in highway runoff as well as the load reduction caused by infiltration of storm water into these areas.

TRACE ELEMENTS IN HIGHWAY AND URBAN RUNOFF

A Synopsis of Technical Issues for Monitoring Trace Elements in Highway and Urban Runoff, conducted by the U.S. Geological Survey (Breault and Granato 2000) — This

research project studied trace elements, described by the authors as “regulated for aquatic life protection, are a primary concern in highway- and urban-runoff studies because stormwater runoff may transport these constituents from the land surface to receiving waters (p.1).” Concentrations in these waters may exceed natural ranges, with unfavorable outcomes.

DATA COLLECTION PLAN

SAMPLE COLLECTION METHOD

Storm water samples were collected manually in accordance with ADOT's *Storm Water Monitoring Guidance Manual for Municipal Separate Storm Sewer System (MS4) Activities* (ADOT 2005). Samples were collected from the first flush, which is within the first 30 minutes of a storm event (storm event is described as at least 0.1 inch of rainfall within 24 hours). To assist with first flush sampling, the research team used the Nalgene® Stormwater Sampler. These samplers are placed at the sample collection point prior to a storm event. Water flows through the collection funnel and into a sample bottle. When the bottle is full, a floating ball valve seals off the sample collection port. When the sample is retrieved, the collection funnel is removed and replaced with a leak-proof cap and the sample is taken to the laboratory. This sample collection method allows flexibility in collecting a first flush sample and for personnel safety during sample acquisition. Additionally, the sample bottles were inspected bi-weekly once they had been placed in the appropriate locations. This was to ensure they were not contaminated or tampered with during the wet periods.

Storm Event Monitoring

Storm events were monitored by reviewing data on the Flood Control District of Maricopa County rainfall information Web site. This Web site is located at http://156.42.96.39/xrainmaps.html and provides real time data. Sampling personnel traveled to the research area when storm water sensors indicated that a qualifying storm event had occurred. If storm events occurred during the evening, sampling personnel traveled to the research area the next morning to retrieve the sample bottles.

Sample Collection Protocol

This storm water sampling study employed clean sampling techniques to minimize potential sources of sampling contamination. Sampling personnel adhered to the following rules while collecting water samples:

- Do not eat, drink, or smoke during sample collection.
- Never sample near a running vehicle.
- Do not park vehicles in the immediate sample collection area.
- Always wear clean, powder-free, nitrile gloves when handling sample containers and lids.
- Never touch the inside surface of a sample container or lid, even with gloved hands.
- Never allow the inner surface of a sample container lid to be in contact with any material other than the sample water.
- If manual sample collection is done, do not overfill sample containers as preservative may be lost.
- Do not allow any object or material (including rain drops) to fall into or make contact with the collected water sample.
- Replace and tighten sample container lids immediately after sample collection.

Sample Preservation
To prolong the stability of the collected samples during transport and storage, chemical preservatives are added to the sample bottles for certain analyses (Table 1). The laboratory provided sample bottles with appropriate preservatives for each analysis requested. All samples were placed on ice immediately after collection.

Sample Filtration
Sample filtration is required when collecting samples for dissolved metals analysis. Filtration for metals was done by the analytical laboratory to reduce the potential for contamination in the field, especially during storm conditions.

Holding Times
The holding time starts when sample collection is complete and is counted until extraction, preparation, and analysis of the sample at the laboratory are complete. In this and similar research projects, specified maximum acceptable holding times for each analytical method are closely watched.

Chain of Custody
The laboratory provided chain-of-custody (COC) forms. They were completed by monitoring personnel for samples submitted to the analytical laboratory. The purpose of COC forms is to keep a record of the sample submittal information and to document the transfer of sample custody. Sample date, sample location, and analyses requested were noted on the COC form. Any special instructions for the laboratory were also noted on the COC form, such as specifications of quality control requirements (e.g., duplicate samples). The COC form was signed by both the person relinquishing the samples and the person receiving the samples every time the samples changed hands, thus documenting the chain of custody. No third party was used to collect, prepare, or deliver samples.

LABORATORY SELECTION

Environmental Science Corporation (ESC) of Mt. Juliet, Tennessee, performs laboratory analysis of the samples. ESC's laboratory, which has been certified by the Arizona Department of Health Services (ADHS #AZ0612), did the analyses of the storm water samples for this project.

ANALYTICAL METHODS

Storm water samples were collected and analyzed in accordance with ADOT's Storm Water Monitoring Guidance Manual for MS4 Activities (ADOT 2005).

Table 1 - Analytical Methods

Parameter	Method No.	Holding Time	Preservation	Reporting Limit
BOD_5	EPA 405.1/SM 5210B	48 hours	4°C	3 mg/L
COD	EPA 410.1/SM 5220D	28 days	4°C and H_2SO_4 to pH<2	10 mg/L
Hardness	EPA 200.7/SM 2340B	6 months	HNO_3 to pH<2	2 mg/L
pH	EPA 150.1	Analyze immediately	None	0.1 std. units
Water Temperature	EPA 170.1/SM 2550B	Analyze immediately	None	0.1 C
Specific Conductance	EPA 120.1/SM 2510B	28 days	4°C	2 μmhos/cm
TDS	EPA 160.1/SM 2540C	7 days	4°C	1 mg/L
TSS	EPA 160.2	7 days	4°C	1 mg/L
Turbidity	EPA 180.1/SM 2130B	48 hours	4°C	0.1 NTU
Color	EPA 110.2/SM 2120	48 hours	4°C	1 units
NO3-N	EPA 300.0/SM 4500	48 hours	4°C	10 mg/L
NO2-N	EPA 300.0/SM 4500	48 hours	4°C	0.1 mg/L
Total Phosphorous	EPA 365.1/SM 4500	28 days	4°C and H_2SO_4 to pH<2	0.03 mg/L
TKN	EPA 351.4	28 days	4°C and H_2SO_4 to pH<2	0.1 mg/L
Ammonia	EPA 350.1/EPA 350.3	28 days	4°C and H_2SO_4 to pH<2	0.03 mg/L
Cadmium	EPA 200.8 [a]	Filter for dissolved fraction and preserve within 48 hours; Holding time is 6 months to analysis	Filter dissolved samples before preservation; 4°C and HNO_3 to pH<2	5 μg/L
Chromium				10 μg/L
Copper				10 μg/L
Lead				30 μg/L
Zinc				10 μg/L
TPH	EPA 418.1W	14 days	4°C and 1:1 H_2SO_4	1 mg/L
Total Phenols	EPA 420.1	28 days	4°C and H_2SO_4 to pH<2	0.1 mg/L
DDE	EPA 608	7 days to extraction; 40 days to analysis	4°C and $Na_2S_2O_3$ if chlorinated to pH 5-9	0.01 μg/L
Surfactants (detergents)	EPA/425.1/SM 5540	48 hours	4°C	0.02 mg/L

QUALITY ASSURANCE/QUALITY CONTROL

The quality assurance/quality control (QA/QC) program ensured that samples collected were of the highest quality and that the laboratory analyzing the samples produced reliable results. The QA/QC procedures implemented for this research project are further described in this section.

Field Preparedness Procedures

Field QA/QC procedures included preparations before sampling events occurred. Sampling equipment, sample bottles, and forms were readied for each monitoring site prior to a monitoring event to ensure that the necessary equipment was ready and available. By preparing for an event ahead of time, the possibility of filling incorrect bottles or mislabeled bottles was avoided. All equipment was readied for the next monitoring event upon return from the previous monitoring event.

Cleanliness

Cleanliness of the sampling equipment is vital to ensuring that contamination is not introduced from a controllable factor. Sample bottles were certified clean by the laboratory to minimize sample contamination. Cleanliness techniques were used when collecting as well as handling the samples.

Sample Collection

The same technician collected the samples at all three locations. This improved data quality by maintaining the same collection procedures for all sampling locations.

Field Records

General information relating to each sampling event was recorded at the monitoring site. This includes such information as sample collection date and time. Other recorded information is listed under 'Physical Observations.' General information included:

- Date
- Time
- Sample technician's name
- Site name
- A general description of site conditions

Data Review and Validation

The data for each sampling event was reviewed and validated. All reports from the contract laboratory were reviewed upon receipt. A review was made of the holding times, proper chain-of-custody procedures, preservation, etc. A data validation sheet was completed for each data set.

DATA MANAGEMENT

Sampling data were organized and each monitoring site's data clearly labeled. Two primary types of data were collected for this research program: (1) analytical water quality data and (2) physical observations.

Analytical Water Quality Data

The analytical water quality data is a direct result of the field measurements taken and the samples collected during a monitoring event. The samples were analyzed for the pollutants listed in Table 1. Data was reported from the contract laboratory in hard copy and an electronic file. Reported measurements included:

- pH
- Air temperature
- Water temperature
- Conductivity

Physical Observations

Physical observations were recorded and retained to supplement the analytical water quality data. Photographs were taken and a site sketch was made. Also recorded in this category were observations such as:

- Estimated discharge
- Vegetative growth
- Oily sheen
- Surface scum
- Deposits
- Odor
- Land use type

STORM WATER SAMPLING

Storm water samples collected and analyzed as part of this research project have been compared to an Environmental Protection Agency (EPA) benchmark level if one was available (not all parameters analyzed have benchmark levels). It is important to note that exceeding a benchmark does not constitute a storm water violation. This section provides a summary of sampling results for the samples collected throughout 2007.

STORM WATER SAMPLE COLLECTION DATES

Sixteen storm water samples were collected from the research areas between January 2007 and December 2007. Due to the differences in rainfall and storm water drainage patterns, each sampling location did not have an equal amount of storm water flow. Therefore, sample collection was not evenly distributed at each location. Table 2 identifies the sample location and the date samples were collected:

Table 2 - Sample Location and Date Sampled

Date Sampled	Sample Location		
	Basin 1	Basin 2	Salt River Site
01-11-07		X	X
02-6-07		X	X
02-22-07		X	X
03-30-07	X	X	X
05-15-07		X	X
07-17-07		X	
07-24-07			X
07-26-07		X	X
12-04-07			X

X – Indicates sample collected at this location and date

The difference between the number of samples collected at Basin 1 and the other sites is due to low storm water flow during storm events. This may be the result of storm water runoff from the Loop 202 flowing through a dirt-lined ditch prior to discharging to Basin 1. It is likely that in many instances storm water soaked into the ground along this path, not reaching Basin 1. The other two sample locations each have concrete-lined channels that directed storm water to the sample locations.

SAMPLE RESULTS FIRST QUARTER 2007

Storm water samples were collected on the following dates: January 11, 2007, February 6, 2007, February 22, 2007, and March 30, 2007. Each sampling event for this first quarter of 2007 is further discussed in this section.

Sampling Results January 11, 2007

Storm water samples were collected on January 11, 2007, from Basin 2 and the Salt River site (Table 3). Storm water flow at Basin 1 was not of an adequate amount to fill the sample bottles and so no analyses were completed. The volumes of storm water collected from Basin 2 and the Salt River site were not enough to perform dissolved metal analyses. The analytical results that are in boldface indicate the sample collected from the Salt River exceeded the EPA benchmarks for total suspended solids (TSS), total copper, and total zinc.

Table 3 - Sample Results January 11, 2007

	Constituent	Sampling Location and Result (mg/L) Basin 1	Basin 2	Salt River	Benchmark mg/L
Conventional	Total Dissolved Solids	--	760	300	NNS
	Total Suspended Solids	--	19	**1100**	100
	Turbidity	--	29	36	NNS
	Specific Conductance	--	1,200 umos/cm	480 umos/cm	NNS
	Hardness	--	350	380	NNS
	BOD	--	<5	8.3	30
	COD	--	32	96	120
	Color	--	62 pcu	68 pcu	NNS
	pH	--	7.46 su	6.95 su	6.0 – 9.0
	Temperature	--	56.9 °F	57.1 °F	NNS
Nutrients	Nitrite	--	<0.10	<0.10	NNS
	Nitrate	--	1.4	0.77	NNS
	Ammonia Nitrogen	--	0.35	<0.10	19.00
	Total Phosphorus	--	0.11	2.0	2.0
	Total Kjeldahl Nitrogen	--	3.3	3.6	NNS
Metals, Total	Cadmium (Cd)	--	<0.005	0.010	0.0159
	Chromium (Cr)	--	<0.01	0.050	NNS
	Copper (Cu)	--	<0.02	**0.094**	0.0636
	Lead (Pb)	--	<0.005	0.056	0.0816
	Zinc (Zn)	--	<0.03	**0.38**	0.117
Metals, Dissolved	Dissolved Cadmium (Cd)	--	--	--	NNS
	Dissolved Chromium (Cr)	--	--	--	NNS
	Dissolved Copper (Cu)	--	--	--	NNS
	Dissolved Lead (Pb)	--	--	--	NNS
	Dissolved Zinc (Zn)	--	--	--	NNS
Other	4,4 – DDE (pesticide)	--	<.0005	<0.0010	NNS
	Total Petroleum Hydrocarbon	--	<5	--	NNS
	Total Phenol	--	<0.04	<0.040	1.0
	Surfactants (detergents)	--	<0.1	<0.10	NNS

-- indicates inadequate volume of water to complete analyses
NNS = no numerical standard

Sampling Results February 6, 2007

Storm water samples were collected on February 6, 2007, from Basin 2 and the Salt River site (See Table 4). Storm water flow at Basin 1 was not of an adequate amount to fill the sample bottles and so no analyses were completed. The volumes of storm water collected from Basin 2 and the Salt River site were inadequate to perform dissolved metal analyses and total petroleum hydrocarbon analyses. The analytical results that are in boldface show samples that exceeded the EPA benchmark for TSS. Total zinc also exceeded the EPA benchmark at the Salt River sampling location.

Table 4 - Sample Results February 6, 2007

	Constituent	Sampling Location and Result (mg/L) Basin 1	Basin 2	Salt River	Benchmark mg/L
Conventional	Total Dissolved Solids	--	420	210	NNS
	Total Suspended Solids	--	**390**	**1800**	100
	Turbidity	--	180	350	NNS
	Specific Conductance	--	800 umos/cm	260 umos/cm	NNS
	Hardness	--	260	160	NNS
	BOD	--	<5.0	<5.0	30
	COD	--	29	49	120
	Color	--	26 pcu	63 pcu	NNS
	pH	--	7.47 su	7.26 su	6.0 – 9.0
	Temperature	--	59.1°F	64.1°F	NNS
Nutrients	Nitrite	--	<0.10	0.10	NNS
	Nitrate	--	1.4	1.7	NNS
	Ammonia Nitrogen	--	<0.10	0.15	19.00
	Total Phosphorus	--	0.22	1	2.0
	Total Kjeldahl Nitrogen	--	0.97	1.6	NNS
Metals, Total	Cadmium (Cd)	--	<0.0050	0.0079	0.0159
	Chromium (Cr)	--	<0.010	0.019	NNS
	Copper (Cu)	--	<0.020	0.058	0.0636
	Lead (Pb)	--	<0.0050	0.027	0.0816
	Zinc (Zn)	--	<0.030	**0.37**	0.117
Metals, Dissolved	Dissolved Cadmium (Cd)	--	--	--	NNS
	Dissolved Chromium (Cr)	--	--	--	NNS
	Dissolved Copper (Cu)	--	--	--	NNS
	Dissolved Lead (Pb)	--	--	--	NNS
	Dissolved Zinc (Zn)	--	--	--	NNS
Other	4,4 – DDE (pesticide)	--	<0.0005	<0.0005	NNS
	Total Petroleum Hydrocarbon	--	--	--	NNS
	Total Phenol	--	<0.040	<0.040	1.0
	Surfactants (detergents)	--	<0.10	<0.5	NNS

-- indicates inadequate volume of water to complete analyses
NNS = no numerical standard

Sampling Results February 22, 2007

Storm water samples were collected on February 22, 2007, from Basin 2 and the Salt River site (See Table 5). Storm water flow at Basin 1 was not of an adequate amount to fill the sample bottles and therefore no analyses were completed. The volume of storm water collected from Basin 2 and the Salt River site was inadequate to perform dissolved metal analyses and total petroleum hydrocarbon analyses. The analytical results that are in boldface indicate samples that exceeded the EPA benchmark for TSS. Total zinc also exceeded the EPA benchmark at the Salt River sampling location.

Table 5 - Sample Results February 22, 2007

	Constituent	Sampling Location and Result (mg/L) Basin 1	Basin 2	Salt River	EPA Benchmark mg/L
Conventional	Total Dissolved Solids	--	190	160	NNS
	Total Suspended Solids	--	**120**	**320**	100
	Turbidity	--	62	160	NNS
	Specific Conductance	--	270 umos/cm	270 umos/cm	NNS
	Hardness	--	92	120	NNS
	BOD	--	5.5	<5	30
	COD	--	69	55	120
	Color	--	60 pcu	43 pcu	NNS
	pH	--	6.85 su	7.76 su	6.0 – 9.0
	Temperature	--	56.1°F	53.2 °F	NNS
Nutrients	Nitrite	--	0.17	<0.10	NNS
	Nitrate	--	2.6	0.54	NNS
	Ammonia Nitrogen	--	0.43	0.36	19.00
	Total Phosphorus	--	0.21	0.90	2.0
	Total Kjeldahl Nitrogen	--	3.1	2.2	NNS
Metals, Total	Cadmium (Cd)	--	<0.0050	<0.0050	0.0159
	Chromium (Cr)	--	<0.010	0.012	NNS
	Copper (Cu)	--	<0.020	0.032	0.0636
	Lead (Pb)	--	0.0064	0.0098	0.0816
	Zinc (Zn)	--	0.071	**0.18**	0.117
Metals, Dissolved	Dissolved Cadmium (Cd)	--	--	--	NNS
	Dissolved Chromium (Cr)	--	--	--	NNS
	Dissolved Copper (Cu)	--	--	--	NNS
	Dissolved Lead (Pb)	--	--	--	NNS
	Dissolved Zinc (Zn)	--	--	--	NNS
Other	4,4 – DDE (pesticide)	--	<0.0025	<0.0025	NNS
	Total Petroleum Hydrocarbon	--	--	--	NNS
	Total Phenol	--	<0.040	<0.040	1.0
	Surfactants (detergents)	--	0.24	0.10	NNS

-- indicates inadequate volume of water to complete analyses

NNS = no numerical standard

Sampling Results March 30, 2007

Storm water samples were collected on March 30, 2007, from Basin 1, Basin 2, and the Salt River site (See Table 6). The volume of storm water collected was inadequate to completely fill the sample bottles and so dissolved metals analyses were not completed. The analytical results that are in boldface indicate that each sampling location exceeded the EPA benchmark for TSS and total zinc.

Table 6 - Sample Results March 30, 2007

	Constituent	Sampling Location and Result (mg/L) Basin 1	Basin 2	Salt River	EPA Benchmark mg/L
Conventional	Total Dissolved Solids	380	660	180	NNS
	Total Suspended Solids	**1,200**	**830**	**2,800**	100
	Turbidity	2,400	45	120	NNS
	Specific Conductance	190	1,300 umos/cm	260 umos/cm	NNS
	Hardness	210	350	150	NNS
	BOD	<5	24	<5	30
	COD	33	72	38	120
	Color	55 pcu	30 pcu	38 pcu	NNS
	pH	7.31 su	7.35 su	7.42 su	6.0 – 9.0
	Temperature	60.9°F	61.3°F	59.3°F	NNS
Nutrients	Nitrite	0.15	5.5	<0.10	NNS
	Nitrate	0.16	24	1.6	NNS
	Ammonia Nitrogen	0.56	**27**	<0.10	19.00
	Total Phosphorus	1.5	1.6	0.88	2.0
	Total Kjeldahl Nitrogen	3.5	57	1.1	NNS
Metals, Total	Cadmium (Cd)	<0.005	<0.005	<0.005	0.0159
	Chromium (Cr)	0.028	0.026	0.016	NNS
	Copper (Cu)	0.033	0.036	0.032	0.0636
	Lead (Pb)	0.025	0.024	0.017	0.0816
	Zinc (Zn)	**0.26**	**0.14**	**0.4**	0.117
Metals, Dissolved	Dissolved Cadmium (Cd)	--	--	--	NNS
	Dissolved Chromium (Cr)	--	--	--	NNS
	Dissolved Copper (Cu)	--	--	--	NNS
	Dissolved Lead (Pb)	--	--	--	NNS
	Dissolved Zinc (Zn)	--	--	--	NNS
Other	4,4 – DDE (pesticide)	<0.0005	<0.0005	<0.0005	NNS
	Total Petroleum Hydrocarbon	<0.10	<0.10	0.43	NNS
	Total Phenol	<0.040	<0.040	<0.040	1.0
	Surfactants (detergents)	<0.10	<0.10	<0.10	NNS

-- indicates inadequate volume of water to complete analyses

NNS = no numerical standard

SAMPLE RESULTS SECOND QUARTER 2007

Storm water samples were collected in the second quarter on May 15, 2007, from Basin 2 and the Salt River site (See Table 7). Storm water flow at Basin 1 was inadequate to fill the sample bottles and so no analyses were completed. The volumes of storm water collected from Basin 2 and the Salt River site were inadequate to perform dissolved metal analyses. The analytical results in boldface indicate samples that exceeded the EPA benchmark for TSS and total zinc. The Salt River sample also exceeded the EPA benchmark for total phosphorus.

Table 7 - Sample Results May 15, 2007

	Constituent	Sampling Location and Result (mg/L) Basin 1	Basin 2	Salt River	EPA Benchmark mg/L
Conventional	Total Dissolved Solids	--	640	240	NNS
	Total Suspended Solids	--	**700**	**1500**	100
	Turbidity	--	410 ntu	240 ntu	NNS
	Specific Conductance	--	1200	440	NNS
	Hardness	--	330	280	NNS
	BOD	--	<5.0	<5.0	30
	COD	--	35	32	120
	Color	--	60	52	NNS
	pH	--	7.28 su	7.3 2 su	6.0 – 9.0
	Temperature	--	60.2°F	59.7°F	NNS
Nutrients	Nitrite	--	<0.10	<0.10	NNS
	Nitrate	--	2.1	0.12	NNS
	Ammonia Nitrogen	--	<0.10	<0.10	19.00
	Total Phosphorus	--	1.0	**3.9**	2.0
	Total Kjeldahl Nitrogen	--	2.8	10	NNS
Metals, Total	Cadmium (Cd)	--	<0.0050	<0.0050	0.0159
	Chromium (Cr)	--	0.030	0.022	NNS
	Copper (Cu)	--	0.041	0.041	0.0636
	Lead (Pb)	--	0.02	0.02	0.0816
	Zinc (Zn)	--	**0.32**	**0.24**	0.117
Metals, Dissolved	Dissolved Cadmium (Cd)	--	--	--	NNS
	Dissolved Chromium (Cr)	--	--	--	NNS
	Dissolved Copper (Cu)	--	--	--	NNS
	Dissolved Lead (Pb)	--	--	--	NNS
	Dissolved Zinc (Zn)	--	--	--	NNS
Other	4,4 – DDE (pesticide)	--	<0.0050	<0.010	NNS
	Total Petroleum Hydrocarbon	--	0.32	0.29	NNS
	Total Phenol	--	<0.040	<0.040	1.0
	Surfactants (detergents)	--	<0.10	<0.10	NNS

-- indicates inadequate volume of water to complete analyses
NNS = no numerical standard

SAMPLE RESULTS THIRD QUARTER 2007

Storm water samples were collected in the third quarter of 2007 on July 17, 2007, July 24, 2007, and July 26, 2007. Each sampling event for this quarter of 2007 is further discussed in this section.

Sampling Results July 17, 2007

Storm water samples were collected on July 17, 2007, from Basin 2 (See Table 8). Storm water flow at Basin 1 and the Salt River site was inadequate to fill the sample bottles and so no analyses were completed. The analytical results in boldface indicate the sample that exceeded the EPA benchmark for total zinc.

Table 8 Sample Results July 17, 2007

	Constituent	Sampling Location and Result (mg/L) Basin 1	Basin 2	Salt River	EPA Benchmark mg/L
Conventional	Total Dissolved Solids	--	1300	--	NNS
	Total Suspended Solids	--	50	--	100
	Turbidity	--	1.4	--	NNS
	Specific Conductance	--	2200	--	NNS
	Hardness	--	370	--	NNS
	BOD	--	<5.0	--	30
	COD	--	110	--	120
	Color	--	150	--	NNS
	pH	--	6.78	--	6.0 – 9.0
	Temperature	--	100.7	--	NNS
Nutrients	Nitrite	--	<0.10	--	NNS
	Nitrate	--	0.18	--	NNS
	Ammonia Nitrogen	--	4.5	--	19.00
	Phosphorus, Total	--	0.55	--	2.0
	Total Kjeldahl Nitrogen	--	6.4	--	NNS
Metals, Total	Cadmium (Cd)	--	<0.0050	--	0.0159
	Chromium (Cr)	--	<0.010	--	NNS
	Copper (Cu)	--	<0.020	--	0.0636
	Lead (Pb)	--	<0.0050	--	0.0816
	Zinc (Zn)	--	**0.085**	--	0.117
Metals, Dissolved	Dissolved Cadmium (Cd)	--	<0.0050	--	NNS
	Dissolved Chromium (Cr)	--	<0.010	--	NNS
	Dissolved Copper (Cu)	--	0.020	--	NNS
	Dissolved Lead (Pb)	--	<0.0050	--	NNS
	Dissolved Zinc (Zn)	--	0.049	--	NNS
Other	4,4 – DDE (pesticide)	--	<0.00050	--	NNS
	Total Petroleum Hydrocarbon	--	0.44	--	NNS
	Total Phenol	--	<0.040	--	1.0
	Surfactants (detergents)	--	<0.10	--	NNS

-- indicates inadequate volume of water to complete analyses
NNS = no numerical standard

Sampling Results July 24, 2007

Storm water samples were collected on July 24, 2007, from the Salt River site (See Table 9). Storm water flow at Basin 1 and Basin 2 was inadequate to fill the sample bottles and so no analyses were completed. The analytical results in boldface indicate the sample that exceeded the EPA benchmark for TSS, chemical oxygen demand (COD), and zinc.

Table 9 - Sample Results July 24, 2007

	Constituent	Sampling Location and Result (mg/L) Basin 1	Basin 2	Salt River	EPA Benchmark mg/L
Conventional	Total Dissolved Solids	--	--	680	NNS
	Total Suspended Solids	--	--	**1100**	100
	Turbidity	--	--	540	NNS
	Specific Conductance	--	--	970	NNS
	Hardness	--	--	490	NNS
	BOD	--	--	13	30
	COD	--	--	**130**	120
	Color	--	--	180	NNS
	pH	--	--	6.86	6.0 – 9.0
	Temperature	--	--	84.5	NNS
Nutrients	Nitrite	--	--	<0.10	NNS
	Nitrate	--	--	<0.14	NNS
	Ammonia Nitrogen	--	--	1.8	19.00
	Phosphorus, Total	--	--	0.7	2.0
	Total Kjeldahl Nitrogen	--	--	3.8	NNS
Metals, Total	Cadmium (Cd)	--	--	<0.0050	0.0159
	Chromium (Cr)	--	--	<0.010	NNS
	Copper (Cu)	--	--	<0.020	0.0636
	Lead (Pb)	--	--	0.017	0.0816
	Zinc (Zn)	--	--	**0.7**	0.117
Metals, Dissolved	Dissolved Cadmium (Cd)	--	--	<0.0050	NNS
	Dissolved Chromium (Cr)	--	--	0.031	NNS
	Dissolved Copper (Cu)	--	--	<0.020	NNS
	Dissolved Lead (Pb)	--	--	<0.0050	NNS
	Dissolved Zinc (Zn)	--	--	0.098	NNS
Other	4,4 – DDE (pesticide)	--	--	<0.00050	NNS
	Total Petroleum Hydrocarbon	--	--	1.8	NNS
	Total Phenol	--	--	<0.040	1.0
	Surfactants (detergents)	--	--	<0.1	NNS

-- indicates inadequate volume of water to complete analyses

NNS = no numerical standard

Sampling Results July 26, 2007

Storm water samples were collected on July 26, 2007, from Basin 2 and the Salt River site (See Table 10). Storm water flow at Basin 1 was inadequate to fill the sample bottles, so no analyses were done for that site. The analytical results in boldface indicate samples that exceeded the EPA benchmarks for TSS, COD, phosphorous, copper, lead, and zinc. Basin 2 also exceeded the EPA benchmark for biological oxygen demand (BOD) and chromium.

Table 10 - Sample Results July 26, 2007

	Constituent	Sampling Location and Result (mg/L) Basin 1	Basin 2	Salt River	EPA Benchmark mg/L
Conventional	Total Dissolved Solids	--	400	260	NNS
	Total Suspended Solids	--	**3100**	**2900**	100
	Turbidity	--	3200	1400	NNS
	Specific Conductance	--	570	360	NNS
	Hardness	--	1000	460	NNS
	BOD	--	**53**	16	30
	COD	--	**220**	**130**	120
	Color	--	150	120	NNS
	pH	--	7.03	7.39	6.0 – 9.0
	Temperature	--	87	81.9	NNS
Nutrients	Nitrite	--	<0.10	<0.10	NNS
	Nitrate	--	<0.10	<0.10	NNS
	Ammonia Nitrogen	--	2.9	0.29	19.00
	Phosphorus, Total	--	**2.7**	**4.5**	2.0
	Total Kjeldahl Nitrogen	--	8.9	7	NNS
Metals, Total	Cadmium (Cd)	--	0.0083	<0.0050	0.0159
	Chromium (Cr)	--	**0.26**	0.09	NNS
	Copper (Cu)	--	**0.38**	**0.18**	0.0636
	Lead (Pb)	--	**0.18**	**0.098**	0.0816
	Zinc (Zn)	--	**1.1**	**0.92**	0.117
Metals, Dissolved	Dissolved Cadmium (Cd)	--	<0.0050	<0.0050	NNS
	Dissolved Chromium (Cr)	--	<0.010	<0.010	NNS
	Dissolved Copper (Cu)	--	0.038	0.026	NNS
	Dissolved Lead (Pb)	--	<0.0050	0.0062	NNS
	Dissolved Zinc (Zn)	--	<0.030	<0.030	NNS
Other	4,4 – DDE (pesticide)	--	<0.0050	<0.0050	NNS
	Total Petroleum Hydrocarbon	--	0.98	1.6	NNS
	Total Phenol	--	0.054	<0.040	1.0
	Surfactants (detergents)	--	<0.50	<0.10	NNS

-- indicates inadequate volume of water to complete analyses
NNS = no numerical standard

SAMPLE RESULTS FOURTH QUARTER 2007

Storm water samples were collected on December 4, 2007, from the Salt River site. Storm water flow at Basin 1 and Basin 2 was inadequate to fill the sample bottles and so no analyses were completed for these sites (See Table 11). The volume of storm water collected from the Salt River was inadequate to perform analyses for 4, 4'-DDE (pesticides) and petroleum hydrocarbons. The analytical results in boldface indicate samples that exceeded the EPA benchmarks for TSS, phosphorus, copper, lead, and zinc.

Table 11 - Sample Results December 4, 2007

	Constituent	Sampling Location and Result (mg/L) Basin 1	Basin 2	Salt River	EPA Benchmark mg/L
Conventional	Total Dissolved Solids	--	--	320	NNS
	Total Suspended Solids	--	--	**1800**	100
	Turbidity	--	--	2000	NNS
	Specific Conductance	--	--	480	NNS
	Hardness	--	--	2200	NNS
	BOD	--	--	<5.0	30
	COD	--	--	46	120
	Color	--	--	50	NNS
	pH	--	--	7.3	6.0 – 9.0
	Temperature	--	--	62.4	NNS
Nutrients	Nitrite	--	--	<0.1	NNS
	Nitrate	--	--	0.55	NNS
	Ammonia Nitrogen	--	--	0.22	19.00
	Phosphorus, Total	--	--	**4.3**	2.0
	Total Kjeldahl Nitrogen	--	--	4.4	NNS
Metals, Total	Cadmium (Cd)	--	--	0.0062	0.0159
	Chromium (Cr)	--	--	<0.010	NNS
	Copper (Cu)	--	--	**0.78**	0.0636
	Lead (Pb)	--	--	**0.10**	0.0816
	Zinc (Zn)	--	--	**1.5**	0.117
	Phosphorus, Total	--	--	4.3	NNS
Metals, Dissolved	Dissolved Cadmium (Cd)	--	--	<0.0050	NNS
	Dissolved Chromium (Cr)	--	--	<0.010	NNS
	Dissolved Copper (Cu)	--	--	<0.020	NNS
	Dissolved Lead (Pb)	--	--	<0.0050	NNS
	Dissolved Zinc (Zn)	--	--	<0.030	NNS
Other	4,4 – DDE (pesticide)	--	--	--	NNS
	Total Petroleum Hydrocarbon	--	--	--	1.0
	Total Phenol	--	--	<0.040	NNS
	Surfactants (detergents)	--	--	<0.50	NNS

-- indicates inadequate volume of water to complete analyses
NNS = no numerical standard

CONCLUSION AND RECOMMENDATIONS

A comprehensive research program for the characterization of storm water runoff from the Loop 202 into two detention basins and the Salt River was completed between January and December of 2007. The study was conducted by manually collecting storm water samples with passive automatic samplers and analyzing for various constituents. A primary objective of the storm water monitoring was to establish baseline values of constituents in freeway runoff.

Sixteen storm water samples were collected. The storm water sampling data indicates TSS exceeded the EPA benchmark in 14 of the 16 samples. TSS (total suspended solids) is the generic name given to represent sediment in storm water runoff and is the most significant pollutant, by mass, found in our nation's waterways.

Zinc exceeded the EPA benchmark in 13 of the 16 samples. The high concentrations of zinc noted in this storm water are likely the result of wear from automobile tires. It is estimated that tires are composed of 1% zinc by weight. One study reviewed as part of this study estimated that in 1999 alone, a nationwide total of about 11,000 tons of zinc was released through tire wear (Councell et al. 2004).

Concentrations of other heavy metals such as copper and lead may come from other automobile debris, such as brake dust, exhaust fumes, and motor oil drippings. It is worth repeating here that in no instance did exceeding an EPA benchmark constitute a storm water violation.

This study is consistent with other studies that have looked at these elements in storm water runoff. It is important to note that storm intensity, storm duration, and antecedent dry periods can all influence differences in concentrations. Data from this study may be used as baseline values of constituents in ADOT highway runoff and assist with development of appropriate BMPs. As mentioned at the beginning of this chapter, TSS is the most significant pollutant, by mass, found in our nation's waterways. It is listed as a conventional pollutant under the federal Clean Water Act (CWA). When these suspended particles settle to the bottoms of water bodies, they are defined as sediments. Consequently, erosion and sediment control and revegetation toward enhanced final stabilization as required by CWA will continue to play a major role in storm water quality protection. The application of landscape ecological design principles by individuals with the relevant technical expertise should be a significant part of every project that impacts the quality of storm water runoff into our nation's rivers and streams.

BIBLIOGRAPHY

Arizona Secretary of State. 2003. *Arizona Administrative Code. Title 18, Chapter 11, Department of Environmental Quality Water Quality Standards*. Phoenix, Ariz.: Arizona Secretary of State.

Arizona Department of Environmental Quality. 2003. *Arizona Pollutant Discharge Elimination System General Permit for Discharge from Small Municipal Separate Storm Sewer Systems (MS4s) to Waters of the U.S., Permit No. AZG2002-002.* Phoenix, Ariz: the Dept.

Arizona Department of Transportation. 2005. *Storm Water Monitoring Guidance Manual for Municipal Separate Storm Sewer System (MS4) Activities.* Phoenix, Ariz.: the Dept.

Arizona Department of Transportation. 2003. *AZPDES Phase II Permit Application, Proposed Modification of Existing Phase I Permit, MS4 Permit #AZS000018*. Phoenix, Ariz.: the Dept.

Breault, Robert F. and Gregory E. Granato. 2000. *A Synopsis of Technical Issues for Monitoring Trace Elements in Highway and Urban Runoff.* Open-file Report 00-422. Northborough, Mass.: United States Geological Survey.

California. Department of Transportation. 2003. *Storm Water Monitoring and Data Management: Discharge Characterization Study Report.* CTSW-RT-03-065.51.42. Sacramento, Calif.: the Dept.

Councell, T.B., K.U. Duckenfield, E.R. Landa, and E. Callender, 2004. "Tire-wear particles as a source of zinc to the environment." *Environ. Sci. Technol.* 38: 4206-4214

Flood Control District of Maricopa County. 1999. *Field Sampling Protocol (Version 4.5).* Phoenix, Ariz.: the District.

Maricopa Association of Governments. 1999. *Regional Transportation Plan.* Phoenix, Ariz.: the Association.

Pima Association of Governments. 1999. *Regional Transportation Plan.* Tucson, Ariz: the Association.

U.S. Environmental Protection Agency. 2000. "Table II – Required Containers, Preservation Techniques, and Holding Times." 40 U.S. Code of Federal Regulations Chapter 1, §136.3. Washington, D.C.: the Agency.

U.S. Environmental Protection Agency. 2000. "Storm Water Discharges." 40 U.S. Code of Federal Regulations Chapter 1, §122.26. Washington, D.C. the Agency.

Wu, Jy S. and Craig J. Allan. 2001. *Sampling and Testing of Stormwater Runoff from North Carolina Highways*. FHWA-NC-2001-002. Raleigh, N. Car.: Center for Transportation and the Environment, North Carolina State University.

APPENDIX A: SITE MAPS

Figure 1. Detention Basin Sampling Locations

Figure 2. Salt River Sampling Location

APPENDIX B: SITE PHOTOGRAPHS

Photo No. B-1

Description: Lindsay Rd. and Loop 202 before sampler installation

View: North

Date: August 29, 2006

Photo No. B-2

Description: Lindsay Rd. and Loop 202 installed storm water samplers

View: North

Date: August 29, 2006

Photo No. B-3

Description: Lindsay Rd. and Loop 202 installed storm water samplers

View: Northwest

Date: August 29, 2006

Photo No. B-4

Description: Gilbert Rd. and Loop 202 before sampler installation

View: North

Date: August 31, 2006

Photo No. B-5

Description: Gilbert Rd. and Loop 202 installed storm water samplers

View: Northwest

Date: August 31, 2006

Photo No. B-6

Description: Salt River site before samplers installed

View: Northwest

Date: September 6, 2006

Photo No. B-7

Description: Salt River site installed storm water samplers

View: Northwest

Date: September 6, 2006

Photo No. B-8

Description: Salt River site before samplers installed

View: South

Date: September 6, 2006

Photo No. B-9

Description: Salt River site installed storm water samplers

View: South

Date: September 6, 2006