Legislative ID#: 110095

Demonstration of Hydrologic, Thermal and Physical-Chemical Modification by an Infrastructure-Constrained "Biodetention" Systems Loaded by Runoff from an Impervious Retail Development Roadway in Florida

Proposal from Univ. of Florida, Environmental Engineering Sciences (UF)

20 July 2010 REV: 25 April 2011 REV: 23 May 2011

UF Investigator:	J. Sansalone, PhD, PE
Budget Total:	$85,837

PROJECT OBJECTIVES

The primary project goal is to implement and demonstrate the attenuation of an infrastructure-constrained "biodetention" system designed to modify influent runoff hydrology, chemistry, thermal and particulate loads from an impervious access roadway. The function of this roadway is to provide ingress/egress for a proposed retail development in Gainesville, Florida. The proposed retail development and roadway traffic (and therefore pollutant loadings) are representative of similar land use and loading conditions in Florida. Of the existing in-situ infrastructure-constrained "biodetention" systems, UF will demonstrate the role of one of the proposed systems; loaded by an asphalt paved roadway catchments approximately ¼ acre. All construction/all equipment to provide demonstration tasks/all installation/all repair expenses will be carried out by others. To achieve the demonstration goal, a number of objectives will be carried out by UF. These objectives are:

1. Design of an in-situ sampling system to allow event-based representative influent and effluent auto sampling for the in-situ infrastructure-constrained "biodetention" system at a proposed retail center roadway at NE 19th Terrace " in Gainesville, Florida. This system will be constructed and installed by others under the supervision of the UF project team with design and implementation requirements provided by the UF project team to ensure representative demonstration of the role of the system.
2. Design of event-based monitoring of hydrologic (rainfall and runoff), and event-based TN, TP, and PM (particulate matter, as TSS) for the in-situ infrastructure-constrained "biodetention" system at the retail center roadway in Gainesville, Florida. This system has been constructed and installed by others under the supervision of the UF project team with design and implementation requirements provided by the UF project team to ensure representative demonstration of the role of the system. The monitoring system will include water budget and bypass monitoring design and implementation.
3. Demonstrate the role of traffic with respect to pollutant loads. Traffic, GIS, land use, topographic data will be collected by City of Gainesville for the roadway area from the end of construction throughout the demonstration phase. The UF project team will provide recommendations to the City of Gainesville to demonstrate the influence of average daily traffic (ADT), previous dry hours (pdh) and vehicles during storm (VDS) (*4*, *6*, *7*)
4. Demonstrate the role of the in-situ infrastructure-constrained "biodetention" system loaded by roadway runoff from NE 19th Street in Gainesville, Florida for a period of one year, as representative of an initial annual load reduction. Demonstration will be initiated once the system vegetation has been established. 12 events will be analyzed based on event-based concentrations; for example, a common index has been the event-mean concentration (EMC) for each "biodetention" system by UF. For the demonstration, an event is defined by a

minimum of 0.1 inch of rainfall, and 24 previous dry hours. These demonstration requirements of an event are similar to demonstration protocols around the USA (for example, TARP or WASHDOE)

5. The UF project team will utilize demonstration results to propose a longer-term demonstration for the role of such systems over multiple years, illustrating the divergent behavior of maturing vegetation bio-attenuation and "biodetention media" (soil) breakthrough. This will become the basis of a follow-on long term demonstration proposal.

IDENTIFICATION OF THE PROBLEM

Hydrologic Effects of Conventional Impervious Pavement in Built Environs: In most built environs, the degree of imperviousness can be greater than 60%. Deleterious impacts on the hydrologic, physical, chemical and thermal rainfall-runoff relationships in the built environs are significantly related to the constructed impervious surfaces, such as pavements, roofs, and modified or compacted/densified soils, created as components of the built environs. Modification of these rainfall-runoff relationships can be quantified using the degree of imperviousness in the built environs. As little as 10% imperviousness has been cited as the threshold for measurable degradation of urban/suburban stream health (*1*), and data from small urban watersheds indicate an approximately linear relationship between volume-based runoff coefficients and imperviousness (*1*). These indices directly quantify the degree of hydrologic modification and indirectly quantify the delivery of anthropogenic constituent mass generated/transported in the built environs. Conventional pavements are the most common examples of impervious surfaces in the urban environment, causing, in part, a significant depletion of surficial groundwater supply and increase in flooding.

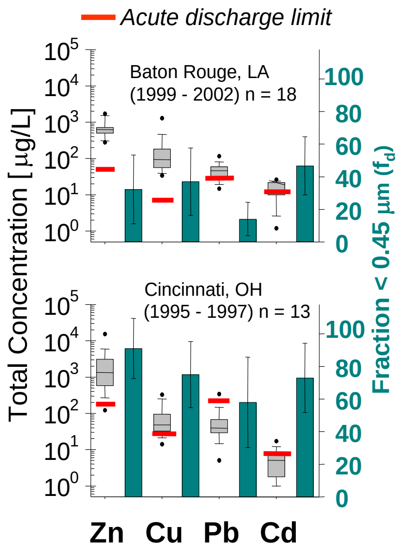
The imperviousness of the constructed surfaces in the built environs modifies many components of the local hydrologic cycle. In the urban environment the construction of impervious surfaces modifies surrounding surficial soils through engineered compaction, and eliminates surficial soil as a significant pervious storage interface between the subsurface and the atmosphere. Impervious surfaces eliminate significant degree of infiltration and depressional-storage abstractions. For anthropogenic and biogenic ecology that depend directly or indirectly on groundwater, expansive impervious areas have a significant impact on reduction in groundwater recharge, depletion of soil moisture and a corresponding increase in runoff. Depressional storage in the urban environment can be reduced by a factor of 5 to 10 depending on the original natural state of the watershed and the degree of imperviousness generated from these constructed surfaces (*2*). The high imperviousness of the built environs significantly reduces evaporation and also evapo-transpiration.

Commensurate with the modification of these hydrologic cycle components and the continued expansion and modification of the built environs are modifications to ambient temperature regimes, known as the heat island effects. In addition, there are hydraulic modifications that result in increased conveyance of runoff, reduced lag times, and increased leaching and transport for soluble and particulate constituents. Compared to the hydrograph from the pre-developed environment, the built environs runoff hydrograph from the same drainage area has the following characteristic modifications: first, a greater peak discharge, second, increased runoff volume and third, a decreased time to peak or lag time. It has been observed that urbanization increases the rate of peak discharge more rapidly than the increased volume generated (*2*).

Impervious Pavement Chemical, Particulate and Temperature Impacts: Rainfall-runoff and snow-snowmelt from impervious constructed surfaces and infrastructure generate and transport significant loads of dissolved, colloidal and suspended particulate matter in a complex heterogeneous mixture that includes metal elements, inorganic and organic compounds (*3, 4*). Metal elements, generated by abrasive and leaching phenomena in the urban environment are not degraded and constitute an important class of acute and chronic contaminants. Rainfall-runoff levels of Zn, Cu, Cd, Pb, Cr, Ni, Hg, as well as nutrients such as N and P, in the built environs are significantly above ambient background levels and, for many land uses, often exceed surface water discharge (*5*). Trace metal data obtained from our previous studies on rainfall-runoff and rainfall in Louisiana and Ohio are summarized in Figure 1. Figure 1 illustrates the significantly different metal partitioning between sites illustrating that a detailed chemical characterization is required as a foundation for site-based design of a successful treatment system With the proper application, defensible data-based design and defensible monitoring, source controls such as new generation pavement cleaners combined multifunctional environmentally-conscious materials can provide a high surface area porous medium for surface complexation, adsorption and chemical precipitation of dissolved, complexed and particulate-bound metals, nitrogen and phosphorus, without chemical leaching and releases between maintenance cycles. Generally the metal and phosphorus loads from the atmosphere are small, as shown for metals in Figure 2.

Rainfall-Runoff Particulate Loads for Pavements:

Since constructed impervious surfaces and drainage systems are designed to provide more rapid conveyance than natural and porous systems, transport of entrained particulate matter can be an order of magnitude greater than particulate transport in the original natural environment (*2*). If particulate transport is not mass limited, higher peak discharges and improved hydraulic characteristics of impervious urban surfaces result in increased entrainment and transport of particulate matter from impervious surfaces (*6, 7*). Because of the widespread generation of anthropogenic particulate matter in the built environs, particulate matter is ubiquitous in rainfall-runoff. Annual loadings of transported particulate matter can be quite significant. For example, on an annual basis for urban transportation land use, approximately 0.2-0.4 dry kg/m^2 of pavement per 1000-mm of rainfall is transported from the impervious pavement area (*4*). This is a significant annual flux of anthropogenic particulates when integrated over the entire impervious built environs.



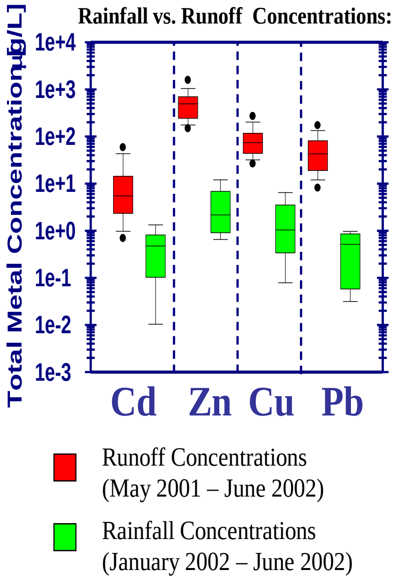
Chemistry/Hydrology – Baton Rouge:

	µ	Range	Unit
SSC	272	32 - 519	mg/L
DOC	99	66 - 138	mg/L
COD	351	82 - 1101	mg/L
pH	7.2	6.5 - 8.1	S.U.
Alkalinity	37.7	8 - 107	mg CaCO$_3$/L
Hardness	39	30 - 43.3	
Rainfall	1266	968 -1583	mm

Chemistry/Hydrology – Cincinnati:

SSC	134	29 - 259	mg/L
DOC	10	2 - 25	mg/L
COD	230	115 - 332	mg/L
pH	6.8	6.0 - 8.0	S.U.
Alkalinity	39	7.8 - 130	mg CaCO$_3$/L
Hardness	64	18 - 171	
Rainfall	1161	1019 - 1357	mm

FIGURE 1 Comparison of dissolved and particulate metals in runoff to acute discharge criteria for impervious pavement sites in two separate built environ (both catchments are fully paved and impervious)



Baton Rouge Rainfall Quality:

Parameter	µ	Range	Unit
TDS	9.4	2.0 – 16.0	mg/L
COD	0.01	0.0 – 0.4	mg/L
pH	4.3	3.3 – 5.7	S.U.
Alkalinity	0.7	0.0 – 5.0	mg/L CaCO$_3$
Hardness	0.7	0.05 – 3.0	
Redox	543	134 – 655	+mV
Turbidity	2.7	1.1 – 3.9	NTU
Conductivity	19.8	3.9 – 28.5	µS/cm
Temperature	21.6	17.5 – 24.8	°C
Event Rain	13.6	1.0 – 41.4	mm

Catchment #1: Located at experimental site, free of obstructions

Catchment #2: Located 5-miles from site in quiescent park-like setting

FIGURE 2 Comparison of rainfall and runoff metal concentrations for paved catchment in Baton Rouge (*3, 11*)

Even when only considering arterial and interstate land use pavement for a given built environs (this pavement area constitutes approximately 10 to 15 percent of a typical urban area), the annual fluxes can be very large. Previous studies provide insight with respect to the magnitude of particulate matter loadings. From urban interstate and major arterial pavement alone, annual metal, suspended solids, chemical oxygen demand (COD) loadings and rainfall-runoff flows have been shown to equal or exceed annual loadings and flows from all untreated domestic wastewater for a given urban area (*4, 8*).

With respect to transport and separation of this particulate matter by a properly engineered permeable matrix, knowledge of the influent particle size gradation (PSD) and the matrix pore properties and media properties is critical. The PSD varies as a function of location in the watershed. As shown in Figure 3, dry deposition (DD) on conventional pavement systems in built environs is relatively coarse with a D_{50m} of 331 μm. The PSD reaching the upper end of the drainage appurtenances of most paved catchments is still relatively coarse with a D_{50m} of 99 μm for the q_{up} flow (*4*). As flow moves downstream to the watershed outlet the PSD becomes significantly finer with a D_{50m} of 23 μm, and finally after one hour of settling finally reduces the D_{50m} to 14 μm. Each of these distributions can be successfully modeled as illustrated in Figure 3. PSDs between the upper end pavement drainage PSD (q_{up}) and the lower end pavement drainage (q_{down}) represent the typical PSD that load a biodetention system and therefore the media properties and pore size distribution of the system must be developed to select the particle separation mechanisms(*6*, *9*, *10*). In addition, the fraction of the PSD gradation remaining on the pavement is either available for leaching, abrasion and transport for the next runoff event, or is material that can be treated through regular pavement cleaning with a high efficiency pavement cleaner (as opposed to conventional pavement sweepers that tend to move particles around and have lower recovery efficiencies).

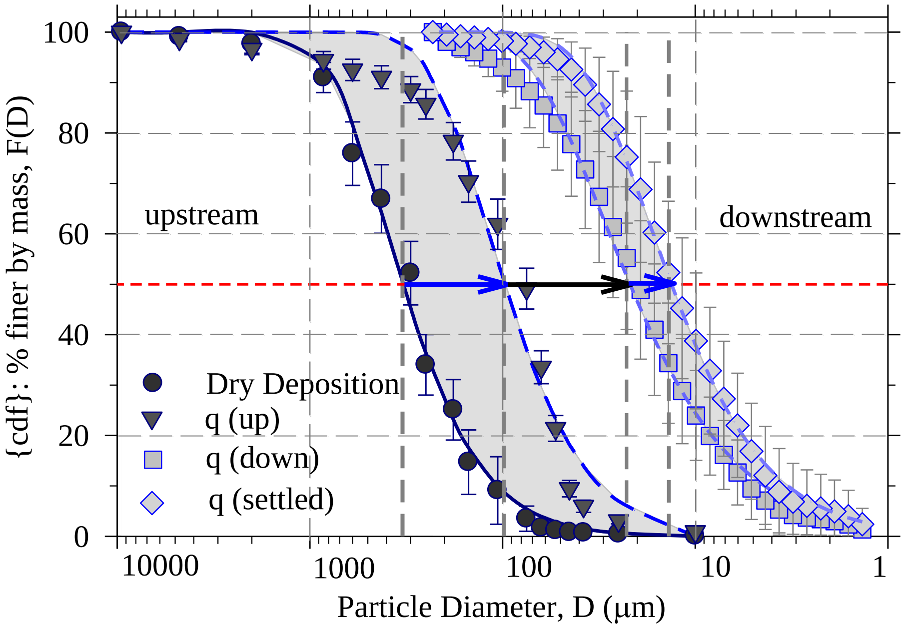


FIGURE 3 Illustration of PSD modification for particulate matter on source area pavement catchments.

Dry deposition particulate matter generated by tire-pavement interaction is modified by runoff as runoff flows downstream across the pavement surface. These modifications are further altered by unit operations such as settling or filtration as a function of the unit operation and the location of the point of treatment in the catchment. This type of information is critical for the success or failure of biodetention combined with pavement cleaning.

Partitioning interaction between metal elements and particulates for pavements:
Metal elements, phosphorus and entrained particulates in rainfall-runoff interact. These interactions result in partitioning that is a function of time, and solid-phase distribution that is a function of particulate properties and transport phenomena at the pavement surface. An example of temporal partitioning, speciation and gradation-based distribution of metal elements in rainfall-runoff (identified in Figure 1) and entrained particulate matter in rainfall-runoff (identified in Figure 3) is illustrated in Figure 4 for Cu (*3, 11*). Copper and zinc are of particular interest for these pavement systems where significant braking and turning activity occur. In addition, metals such as zinc predominately speciate to a divalent form and zinc species are more mobile than other metals identified in urban runoff (3, 20, 21). In addition, while copper binds to organic matter, the temporal oxidation of organic matter also results in the release of copper. Divalent copper is particularly inhibitory or toxic to microbiological systems and in poorly-buffered urban pavement systems, for example from asphalt pavement, divalent copper or copper associated with DOM leached from asphalt can predominate over carbonate species of copper. Implications from these results suggest that multifunctional environmentally-conscious material systems and pavement cleaning must provide a permeable and reactive high surface area medium for mass transfer of dissolved, complexed and particulate-bound metals as well as phosphorus and nutrient species. Partitioning kinetics between dissolved (f_d) and particulate fractions (f_p) approach equilibrium in less than 12 hours. This partitioning which can be as low as 1 hour is a significant challenge to whether automated sampling practices are representative in these monitoring applications. Parallel speciation and distribution phenomena can also be shown for phosphorus, but for brevity these results are not shown herein. Therefore, while automated data-logging of hydrology and on-line water quality will be utilized for the Gainesville site, all influent and effluent sampling will be discrete manual sampling throughout each storm examined.

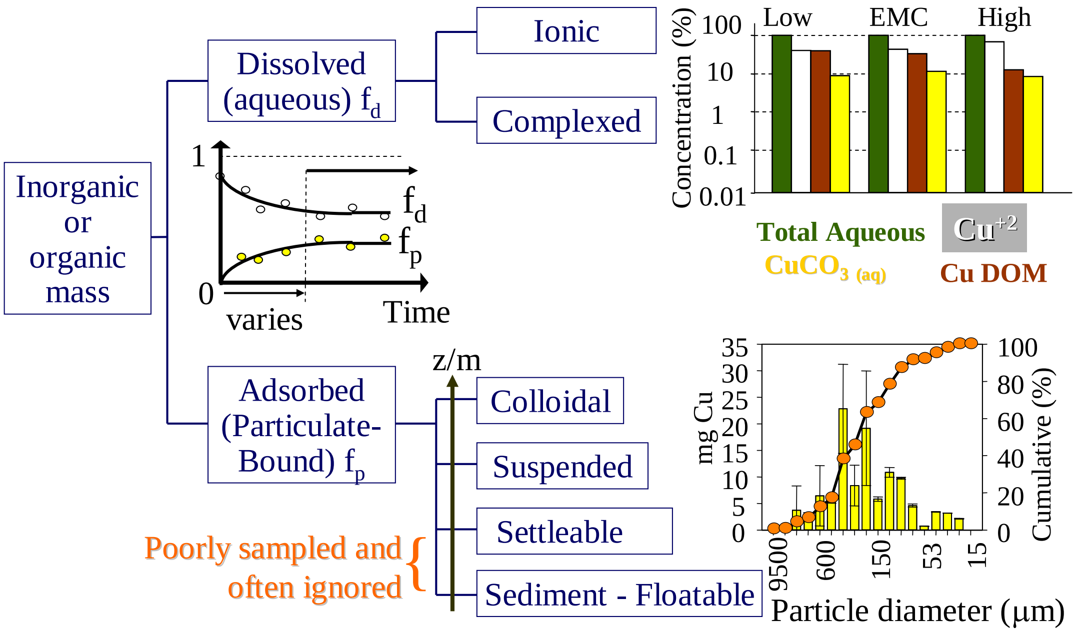


FIGURE 4 Illustration of partitioning and kinetics between particulate matter and aqueous solution in runoff (*3*), as well as an example of the solid phase distribution and aqueous speciation of copper in Baton Rouge rainfall-runoff from an impervious pavement

Temperature modification by impervious pavements:
The built environs have a significant effect on the local and regional climate. Despite the current recognition of climate change, it has been since the late nineteenth century that European scientists were aware from the analyses of weather records that large European cities such as Paris, Berlin, Milano, Vienna and London acted as "heat islands" (*12*). Urban areas modify their heat transfer mechanisms (altering their radiation heat transfer and add sensible heat) to the point that the built environs are warmer than surrounding rural environs. Temperature data from North America indicates that there is approximately a 2°C temperature rise per order of magnitude increase in population, in the population range of 10^3 to 10^7 (*13, 14*). Large metropolitan areas, such as St. Louis, Chicago, Washington D.C. and Cincinnati, are now home to approximately 70% of the North American population. Data taken from Landsberg (*14*) indicates that induced temperature increases in the built environs are greatest during the summer season. The degree of imperviousness plays a significant role in modification of evaporation and temperature in the built environs. Metropolitan areas such as St. Louis, that rapidly developed after the end of the Second World War, with a population of 2.6 million, have precipitation levels in the built environs that over the last 40 years have consistently demonstrated a 5 to 10 cm increase over the surrounding non-urbanized areas (*15*). Intensive field studies of a 6-year duration in St. Louis and 4 years in Chicago demonstrated that urban areas have a significant influence on heavy (> 2.5 cm) convective rainfalls in humid continental climates when the atmosphere was highly unstable (*16*). The localized and regional climate effects of these urban heat islands in North America may likely be irreversible at least within the next century unless we begin to change the construction materials that compose a significant fraction of the soil-atmospheric interface. This fraction is now largely impervious pavement and in many cases relatively heat-absorptive asphalt pavement. Such imperviousness reduces evaporation, infiltration and storage. Materials, methods and systems that restore the in-situ hydrologic cycle such as preserving mature vegetation, soil porosity, utilization of cementitious permeable pavement and planting of context-appropriate trees can collectively make a significant improvement in the hydrologic cycle (although such vegetation requires management for nutrients and biogenic detritus).

IDENTIFICATION OF A POTENTIAL SOLUTION THROUGH BIODETENTION

A biodetention unit is a simple, plant- and soil-based BMP conceived to detain and treat stormwater runoff in developed areas. While the common terminology for such systems is bioretention, the name is a misnomer for systems that function to a large extent as detention for runoff volume and many pollutants in urban roadway runoff. Therefore this proposal identifies the proposed systems in this demonstration project as biodetention. The proposed systems are also confined within pre-cast infrastructure, hence are sub-classified as "infrastructure-constrained". Unit operations and processes that are suggested for such systems include evapotranspiration (ET), soil infiltration, filtration, adsorption, biotransformation, storage and volatilization. The infiltration processes attenuate peak flows, and groundwater recharge is emphasized for natural systems not constrained by infrastructure. Recently, laboratory and pilot-scale biodetention box studies were conducted to monitor pollutant removal in biodetention (*22*). Measured removals of copper, lead, and zinc were typically greater than 95%. Good removal of total phosphorus (approximately 80%), total Kjeldahl nitrogen (50 to 75%), and ammonium (60 to 80%) were also found. Nitrate removal was poor, with indications of some nitrate synthesis in the systems.

With respect to nitrate, (*23*) systematically evaluated a reengineered concept of biodetention for nitrate removal via microbial denitrification, Pilot-scale biodetention studies demonstrated the effectiveness of the proposed design, showing nitrate plus nitrite mass removals of up to 80%. These results indicate that engineered biodetention for the removal of nitrogen from stormwater runoff has the potential for application as an urban stormwater treatment practice.

Davis et al. (*24*) using pilot-plant laboratory biodetention systems and two existing biodetention facilities documented their effectiveness at removing lead, copper, and zinc from synthetic stormwater runoff. Removal rates of these metals (based on concentration and total mass) were high for all metals under most conditions, with effluent copper and lead levels in effluent mostly less than *5* µg/L and zinc less than 25 µg/L. In another study done by (*25*), a biodetention test column was set up and experiments proceeded once every week for a total of 12 tests. All 12 tests demonstrated good removal efficiency for TSS, oil/grease, and lead (> 90%). For total phosphorus, the removal efficiency was about 47% for the first test, increasing to 68% by the twelfth test. For ammonium, the system removal efficiency ranged from 2.3% to 23%. Effluent nitrate concentration became higher than the influent concentration during the first 28 days and removal efficiency ranged from 9% to 20% afterward. In other field studies biodetention cells were filled with different fill media types or drainage configuration. The field studies confirmed good annual total nitrogen mass removal rates at two conventionally drained biodetention cells (40% reduction each). Nitrate-nitrogen mass removal rates varied between 75 and 13%, and calculated annual mass removal of zinc, copper, and lead from one cell were 98, 99, and 81%, respectively. All high mass removal rates were mainly due to a substantial decrease in outflow volume.

In other studies, a mulch layer was used as a contaminant trap to remove oil and grease (O&G) from a synthetic runoff during a bench-scale infiltration studies (*26*). Approximately 80 to 95% removal of all contaminants from synthetic runoff was found via sorption and filtration. Subsequently, approximately 90% of the sorbed naphthalene, toluene, oil, and particulate-associated naphthalene were biodegraded within approximately 3, 4, 8, and 2 days after the event, respectively, based on decreases in contaminant concentrations coupled with increases of microbial consortium populations. These results suggest the potential effectiveness of placing a thin layer of mulch on the surface of a biodetention facility for reducing O&G pollution from urban stormwater runoff.

These studies indicate that biodetention represents one potential solution for urban runoff quantity and quality attenuation. This project is intended to demonstrate the role of infrastructure-constrained biodetention loaded by asphalt-paved roadway runoff for an initial loading period of one year.

SCOPE OF DEMONSTRATION WORK (TASK LIST)

The UF project team will carry out the following tasks as part of the demonstration objectives:

1. Work with the design engineer to design and specify configurations for each “biodetention” system utilized in the demonstration tasks. (COMPLETE)
2. Work with the design engineer to design and specify monitoring, sampling, equipment and security needs of each “biodetention” system. (COMPLETE)

3. Work with the design engineer to design and specify redundant access and sampling points for future system modifications and demonstrations. (COMPLETE)
4. Work with the design engineer and general contractor to inspect construction, installation and final connection and operation of the demonstration system. (COMPLETE)
5. Demonstrate event-based system response for a series of 12 discrete rainfall-runoff events over a period of approximately one year for hydrology (rainfall and runoff), TN, TP and PM (as total suspended solids, TSS transport for the in-situ system. In order to demonstrate the biodetention system role:
    a. Influent and effluent EMC data will be collected to characterize influent and effluent loads for TN, TP and PM.
    b. Hydrologic data including rainfall and runoff will also be collected.
    c. TN, TP and PM analyses will be carried out by the UF project team.
    d. Notify City of Gainesville of required system maintenance and repairs as needed; while as characterizing maintenance specifics and repair occurrences.
6. Demonstrate the annual pollutant loading assessments from the NE 19th Terrace roadway and residential area and a long term historical load assessment (10 years) with SWMM (GIS and Survey data by City of Gainesville). Loads include TN, TP, runoff volume and PM.

DELIVERABLES:

1. The investigator will prepare and deliver a report and presentation to GNV summarizing and quantifying the results of these tasks and demonstrating the behavior of the biodetention system. All results and analyses will be detailed in the report as well as conclusions and recommendations.

SCHEDULE OF PROJECT ACTIVITIES

Task or Deliverable	Quarter (starting 1 July 2011)							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Task 1 (complete)								
Task 2 (complete)								
Task 3 (complete)								
Task 4 (complete)								
Task 5	▨	▨	▨	▨	▨	▨		
Task 6				▨	▨	▨	▨	
Task 7					▨	▨	▨	
Task 8					▨	▨	▨	
Deliverable 1							▨	▨

PERSONNEL

Dr. John Sansalone will focus on overall project coordination, analysis of results, chemistry and treatment considerations, model development, documentation and presentation of results. He will work with graduate students on model development and analysis of existing results for model calibration and validation, the role of uncertainty, design, and the role of mechanistic hydrologic and chemical/particulate phenomena and results. Researchers will carry out literature reviews, SWMM model setup, inputs, calibration and runs, as well as data collection, analyses and data quality assurance. Results and implications will be summarized by Dr. Sansalone, and the students in the form of scientific report and project meetings. Dr. Sansalone will work with and interface with the City of Gainesville and SJRWMD/FDEP to communicate the results, progress and implications of study results. Dr. Sansalone and researchers will on statistical evaluation of data, rainfall-runoff loading model development and the unit performance across the monitoring campaign. Dr. John Sansalone is a Professor of Engineering in the Department of Environmental Engineering Sciences and a Professional Engineer. With respect to this project he has expertise in rainfall-runoff hydrology, environmental hydrology, and experimental methods in environmental geochemistry, development of unit operations and processes (UOPs) for BMPs loaded by rainfall-runoff, transport, CFD modeling, fate and treatment of particulate matter, nutrients and metals. He has conducted research in the area of rainfall-runoff treatment for the last 10 years and this is one of his primary areas of teaching expertise along with development of BMPs for rainfall-runoff and CSOs.

JOHN J. SANSALONE, Ph.D., P.E.

PROFESSIONAL PREPARATION

Christian Brothers University (Memphis, TN)	B.S.	Civil Engineering	1983
North Carolina State University	M.S.	Civil (Geotechnical) Engineering	1992
University of Cincinnati	Ph.D.	Environmental Engineering	1996

APPOINTMENTS

Aug 2008 -	Professor	Environmental Engineering Sciences, University of Florida
Aug. 2005 – Aug 2008	Associate Professor	Environmental Engineering Sciences, University of Florida
Aug. 2002 – Aug. 2005	Associate Professor	Civil and Environmental Engineering, Louisiana State University
July 1998 – Aug. 2002	Assistant Professor	Civil and Environmental Engineering, Louisiana State University
June 1998, 2004, 2005	Visiting Professor	College of Engineering, University of Calabria, Cozensa, Italy
Jan. 1997 – July 1998	Research Asst. Prof.	Civil and Environmental Engineering, University of Cincinnati

PUBLICATIONS

1. Liu, D., Sansalone, J.J., and Cartledge, F.C., “Overall Rate Kinetics for Adsorption of Rainfall-Runoff Heavy Metals by Composite Oxide-Coated Polymeric Media”, ***J. of Environmental Engineering***, August 2005.
2. Liu, D., Sansalone, J.J., and Cartledge, F.C., “Bench-Scale Comparison of Storm Water Filter Media for Heavy Metal Capacity”, ***J. of Environmental Engineering***, August 2005.
3. Sansalone, J.J., Hird, J. P., Cartledge, F.C., and Tittlebaum, M.E., “Event-based Rainfall-Runoff Water Quality and Quantity Loadings from Elevated Urban Infrastructure Impacted by Transportation”, ***J. of Water Environment Research***, August, 2005.
4. Dean, C.M., Sansalone, J.J., Cartledge, F.K., and Pardue, J.H., “Influence of Hydrology on Storm Water Metal Element Speciation at the Upper End of the Urban Watershed**”, *ASCE J. of Environmental Engineering***, Vol. 131, No. 4, April 2005.
5. Sansalone, J.J and Cristina, C.M., “Gradation-Based Heavy Metal Mass Prediction Utilizing Granulometry of Urban Land Use Snowmelt Particulate Residuals”, ***ASCE J. of Environmental Engineering***, Vol. 130, No. 12, December 2004.
6. Mishra, S.K., Sansalone, J.J., and Singh, V.P., “A Partitioning Analog for Metal Elements in Urban Overland Flow Using the SCS-CN Concept”, ***ASCE J. of Environmental Engineering***, Vol. 130, No. 2, pp. 145-154, 2004.
7. Mishra, S.K., Sansalone, J.J., Glenn, D.W. and Singh, V.P., “PCN-Based Metal Partitioning in Urban Snowmelt, Rainfall-Runoff and River Flow Systems”, ***J. of American Water Resources Association***, Vol. 40, No. 5, October, 2004.
8. Sansalone, J.J. and Glenn, D.W., “Physical and Chemical Characteristics of Urban Roadway Snow Residuals Generated from Traffic Activities”, ***J. of Water, Air and Soil Pollution***, Vol. 148, (1-4), pp. 46-61, August 2003.
9. Mishra, S.K., Sansalone, J.J. and Singh, V.P., “Hysteresis-Based Analysis of Overland Metal Transport”, ***J. of Hydrologic Processes***, 17(8), pp. 1579-1606, 2003.
10. Glenn, D.W. and Sansalone J.J., “Accretion and partitioning of heavy metals associated with urban traffic activities in roadway snow – Part II”, ***ASCE J. of Environmental Engineering***, Vol. 128, No. 2, pp. 167-185, February 2002.

SYNERGISTIC ACTIVITIES

New Curricular Development

1. **Control and Treatment of Urban Storm Water:** (Graduate-Undergraduate) This course develops the knowledge of urban hydrologic processes, water quality aspects of urban storm water, unit operations and processes for storm water treatment and evaluation of treatment alternatives. A primary objective is the understanding of pollutant species and loads in rainfall runoff and snow melt and how this understanding can be used to design unit operations and processes for storm water.
2. **Experimental Methodology in Environmental and Hydrologic Engineering:** (Undergraduate) The course provides students the opportunity to participate, contribute and learn through direct involvement with research involving specific environmental and hydrologic engineering topics, typically as part of current research of particular interest to the student. Students participate in laboratory and field research experience with faculty, students and research associates. Participation includes experimental design, testing, operation, measurements and field methodology.

3. **Unit Operations Laboratory:** (Undergraduate) Course provided students with lab experience that develops understanding of physical, chemical and biological operations and processes commonly utilized in environmental engineering and science. A new laboratory was designed and built. New unit operations and process experiments were designed and fabricated as part of course development.
4. **Geo-Environmental Engineering:** (Undergraduate) Introduction to properties and engineering behavior of soil as a native earth material, an engineering material and an environmental medium subject to flux and transport of liquids and contaminants. Provide an understanding of elementary physical, chemical, biological and hydraulic phenomena as such phenomena influence the engineering behavior of soils. A companion lab was modified to address geo-environmental topics.

B. Committee Service

International

1. Scientific Organizing Committee for the Tenth International Conference of Urban Drainage, (10ICUD) Copenhagen, Denmark (2005).
2. Scientific Organizing Committee for the Third International Conference on New Trends in Water and Environmental Engineering for Safety and Life, Capri, Italy (2005).
3. Secretary, Working Group on Cold Climates, International Association on Water Quality (2003 – present).
4. Storm Water Source Control Management SOCOMA Committee on Urban Water Quality of International Association on Water Quality (1993-present).

International Conference or Symposia Session Chair

1. Session Chair and Session Organizer, "The Nature of Storm Water Particulate Matter", Session at the 9th International IWA/IAHR/ASCE Conference on Urban Drainage (ICUD-2002) in Portland, Oregon, Sept. 2002.
2. Session Chair, "Storm Water Databases and Applications", Session at the 4th International Conference on Innovative Technologies in Urban Storm Drainage in Lyon, France, June 2001.
3. Water Resources and Eco-Systems Management Session, "New Trends in Water and Environmental Engineering for Safety and Life – Eco-Compatible Solutions for Aquatic Environments", International Association for Hydraulic Research Conference, Capri, Italy, July 2000.
4. Underground Water Vulnerability Session, "New Trends in Water and Environmental Engineering for Safety and Life – Eco-Compatible Solutions for Aquatic Environments", International Association for Hydraulic Research Conference, Capri, Italy, July 2000.
5. "Hydraulic and Biological Processing of Infiltration Devices" Session at the 3rd International Conference on Innovative Technologies in Urban Storm Drainage in Lyon, France, 1998.

National

1. Associate Editor for Journal of Environmental Engineering (October 2004 -)
2. University of New Hampshire National Storm Water Center Board (2005 -)
3. Scientific Expert Service to US EPA's Brake Pad Partnership (2004).
4. Member, American Society of Civil Engineering Gross Solids Committee (2004 -).
5. Expert Service to California Storm Water Quality Task Force (2001).
6. Expert Service to Southern California Regional Water Quality Control Board (2001).
7. Expert Service to University of California at Irvine/Davis for Research Project Review and Scientific Report Reviews. (Aug. 2001 – Present)

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