HUMBERTO AVILA,
M.Sc. W.R, M.Sc. E.E, Ph.D. Candidate

Academic Background:
- Ph.D. Candidate in Water Resources Engineering, The University of Alabama, Currently
- Candidate for Master in Applied Statistics, The University of Alabama, Currently
- M.Sc. Environmental Eng., The University of Alabama, 2007
- M.Sc. Water Resources Eng., Universidad de los Andes, Colombia, 2003
- Specialization in River and Coastal Eng., Universidad del Norte, Colombia, 2001
- Bachelor in Civil Engineering, Universidad del Norte, Colombia, 2001

On the Black Warrior River, 2007

Experience
- Researcher in several projects related to Urban Water Systems, River Engineering, and Water Resources Management.
- Consultant and Designer of several projects in Colombia.
- Professor of Water Resources Engineering at the Universidad del Norte, Colombia.

Scour in Stormwater Catchbasin Devices – Experimental Results from a Physical Model

Humberto Avila and Robert Pitt
Ph.D. Candidate and Cudworth Professor of Urban Water Systems,
respectively. The Department of Civil, Construction, and
Environmental Engineering, The University of Alabama, Tuscaloosa,
AL 35487 USA

Acknowledgement:
Laith Al-Faqih
Ph.D. Candidate. The Department of Civil, Construction,
and Environmental Engineering, The University of
Alabama, Tuscaloosa, AL 35487 USA

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Introduction

Field observations have shown that the performance of stormwater controls is not always adequate. Under certain conditions, the pre-deposited sediment can be scoured and transported out of the stormwater control device, resulting in discharges of previously removed contaminants.

Understanding the scour phenomenon in catchbasin devices is an actual need when implementing protocols and rules for preventing and managing polluted stormwater runoff, such as being examined by the Wisconsin Department of Natural Resources (WDNR).

A full-scale physical model was built to obtain experimental results of scour of pre-deposited sediment in catchbasin sumps. The scour experiments were conducted at Lake Lurleen State Park, Alabama, near Tuscaloosa.

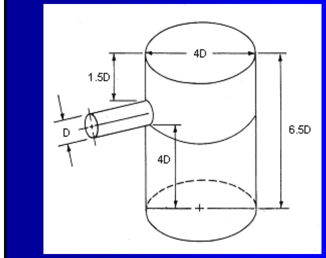
Hydrodynamics (velocity measurements), Turbidity, Total Suspended Solids (TSS), and Particle Size Distributions (PSD) of the scoured material leaving the device were measured and analyzed.

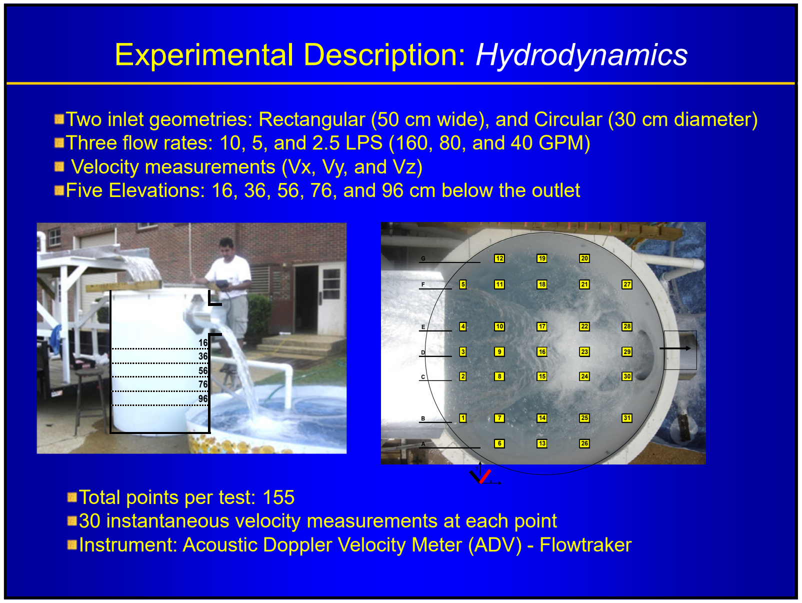
Nature speaks to us through real data. (Humberto Avila)

Physical Model Description

- The full-scale physical model was based on the geometry of the optimal catchbasin geometry recommended by Larger, *et al* (1977), and tested by Pitt 1979; 1985; and 1993. The diameter of the chamber (4D) was assumed to be 1.20 m, with D= 0.3 m (12 in) being the diameter of the outlet.

- Two different evaluations were performed:
  - ✓Hydrodynamics: Velocity measurements (Vx, Vy, and Vz)
  - ✓Scour: Sediment scour at different elevations and flow rates

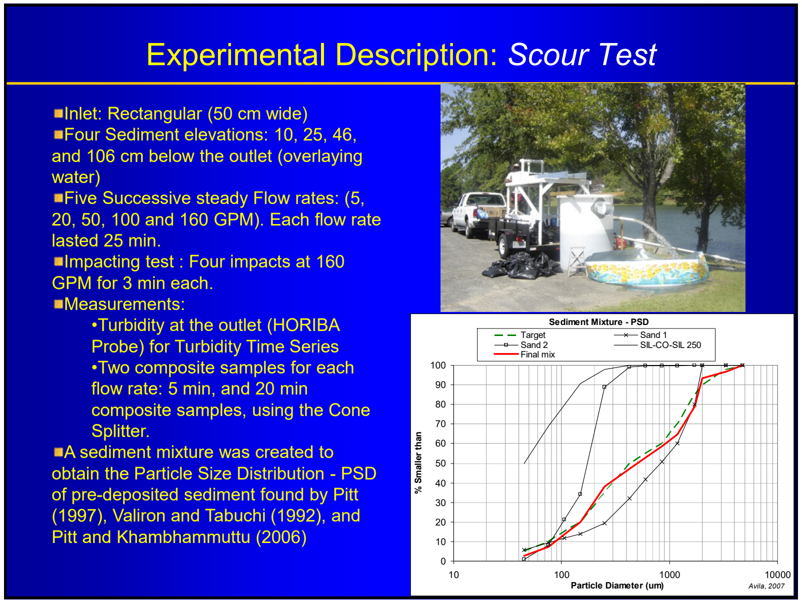




Experimental Description: *Hydrodynamics*

- Two inlet geometries: Rectangular (50 cm wide), and Circular (30 cm diameter)
- Three flow rates: 10, 5, and 2.5 LPS (160, 80, and 40 GPM)
- Velocity measurements (Vx, Vy, and Vz)
- Five Elevations: 16, 36, 56, 76, and 96 cm below the outlet

- Total points per test: 155
- 30 instantaneous velocity measurements at each point
- Instrument: Acoustic Doppler Velocity Meter (ADV) - Flowtraker



Experimental Description: *Scour Test*

- Inlet: Rectangular (50 cm wide)
- Four Sediment elevations: 10, 25, 46, and 106 cm below the outlet (overlaying water)
- Five Successive steady Flow rates: (5, 20, 50, 100 and 160 GPM). Each flow rate lasted 25 min.
- Impacting test : Four impacts at 160 GPM for 3 min each.
- Measurements:
  - Turbidity at the outlet (HORIBA Probe) for Turbidity Time Series
  - Two composite samples for each flow rate: 5 min, and 20 min composite samples, using the Cone Splitter.
- A sediment mixture was created to obtain the Particle Size Distribution - PSD of pre-deposited sediment found by Pitt (1997), Valiron and Tabuchi (1992), and Pitt and Khambhammuttu (2006)

Experimental Description: *Scour Test*

Installation of blocks to set the false bottom

Measuring of depth below the outlet

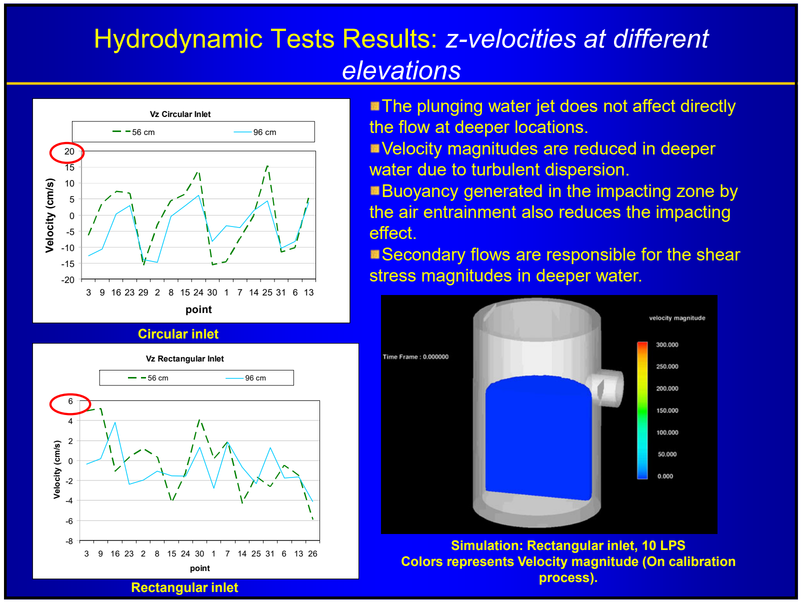
Cone Splitter and Sample Bottles

False bottom sealed on the border

Performing scour test

Sediment bed after test

Leveling of sediment bed: 20 cm thick



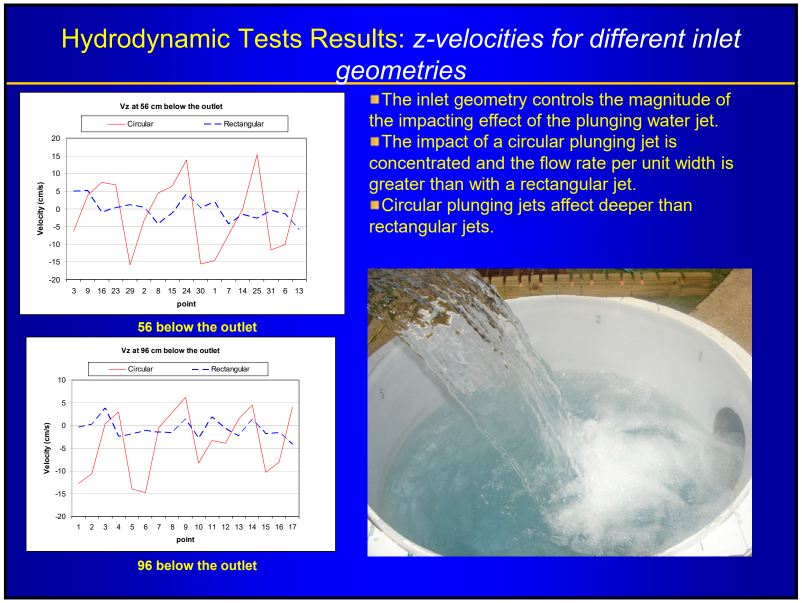
Hydrodynamic Tests Results: *z-velocities at different elevations*

Circular inlet

Rectangular inlet

- The plunging water jet does not affect directly the flow at deeper locations.
- Velocity magnitudes are reduced in deeper water due to turbulent dispersion.
- Buoyancy generated in the impacting zone by the air entrainment also reduces the impacting effect.
- Secondary flows are responsible for the shear stress magnitudes in deeper water.

Simulation: Rectangular inlet, 10 LPS
Colors represents Velocity magnitude (On calibration process).

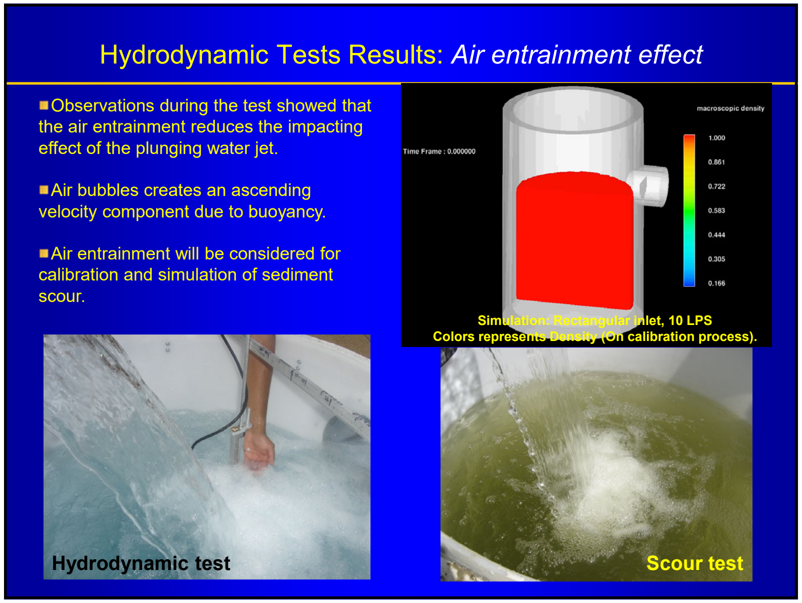


Hydrodynamic Tests Results: *z-velocities for different inlet geometries*

- The inlet geometry controls the magnitude of the impacting effect of the plunging water jet.
- The impact of a circular plunging jet is concentrated and the flow rate per unit width is greater than with a rectangular jet.
- Circular plunging jets affect deeper than rectangular jets.

56 below the outlet

96 below the outlet



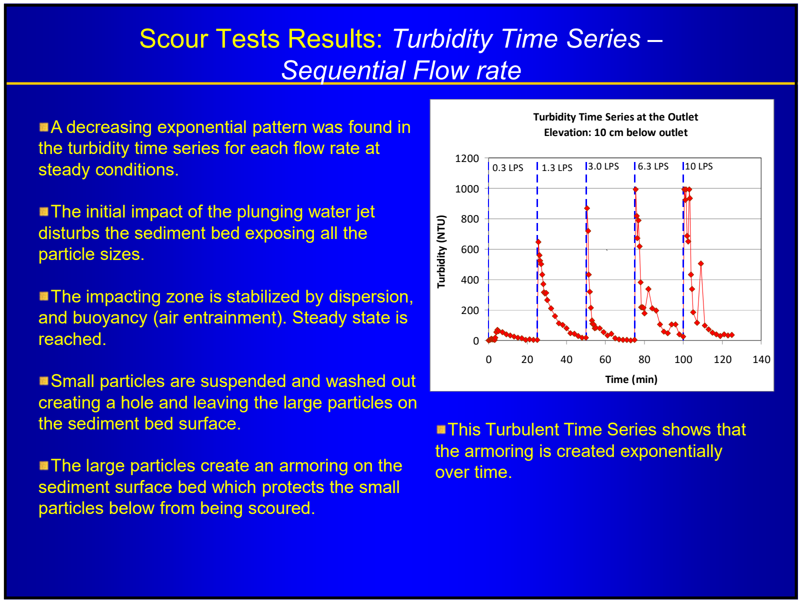
Hydrodynamic Tests Results: *Air entrainment effect*

- Observations during the test showed that the air entrainment reduces the impacting effect of the plunging water jet.
- Air bubbles creates an ascending velocity component due to buoyancy.
- Air entrainment will be considered for calibration and simulation of sediment scour.

Simulation: Rectangular inlet, 10 LPS
Colors represents Density (On calibration process).

Hydrodynamic test

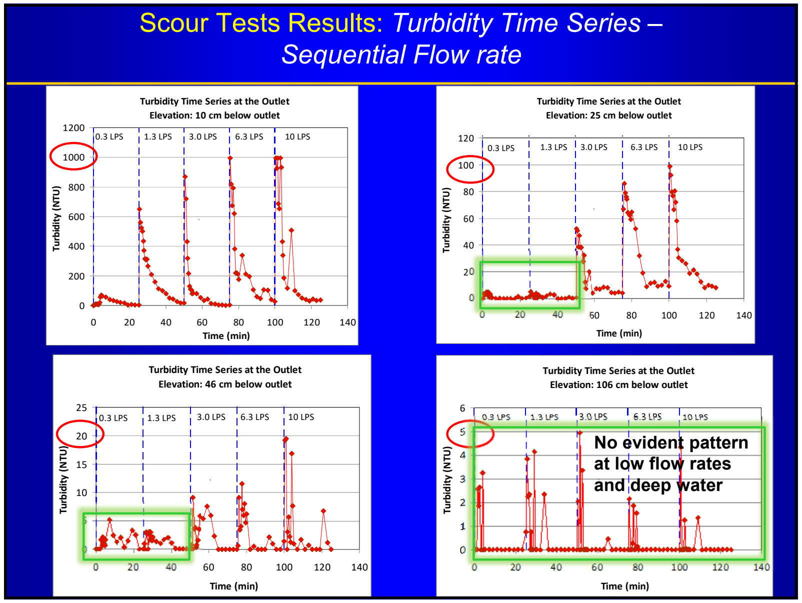
Scour test



Scour Tests Results: *Turbidity Time Series – Sequential Flow rate*

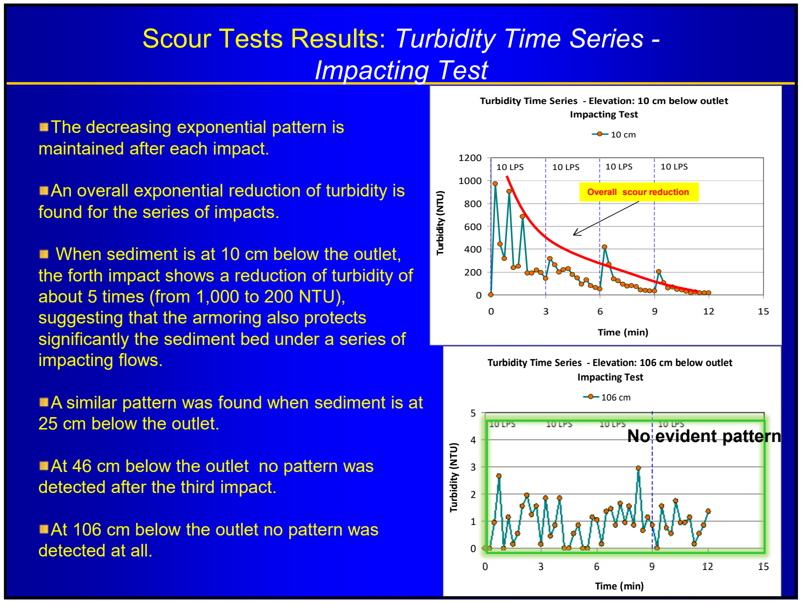
- A decreasing exponential pattern was found in the turbidity time series for each flow rate at steady conditions.
- The initial impact of the plunging water jet disturbs the sediment bed exposing all the particle sizes.
- The impacting zone is stabilized by dispersion, and buoyancy (air entrainment). Steady state is reached.
- Small particles are suspended and washed out creating a hole and leaving the large particles on the sediment bed surface.
- The large particles create an armoring on the sediment surface bed which protects the small particles below from being scoured.

- This Turbulent Time Series shows that the armoring is created exponentially over time.



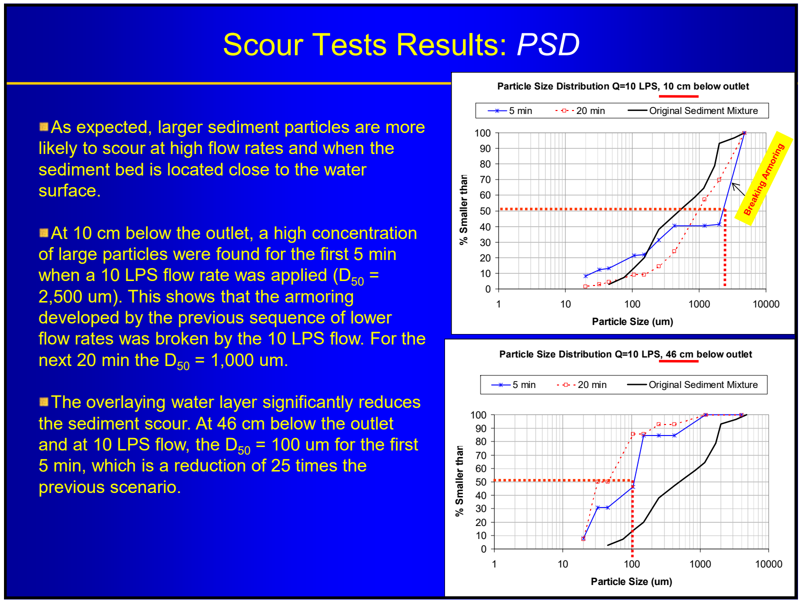
Scour Tests Results: *Turbidity Time Series – Sequential Flow rate*

No evident pattern at low flow rates and deep water



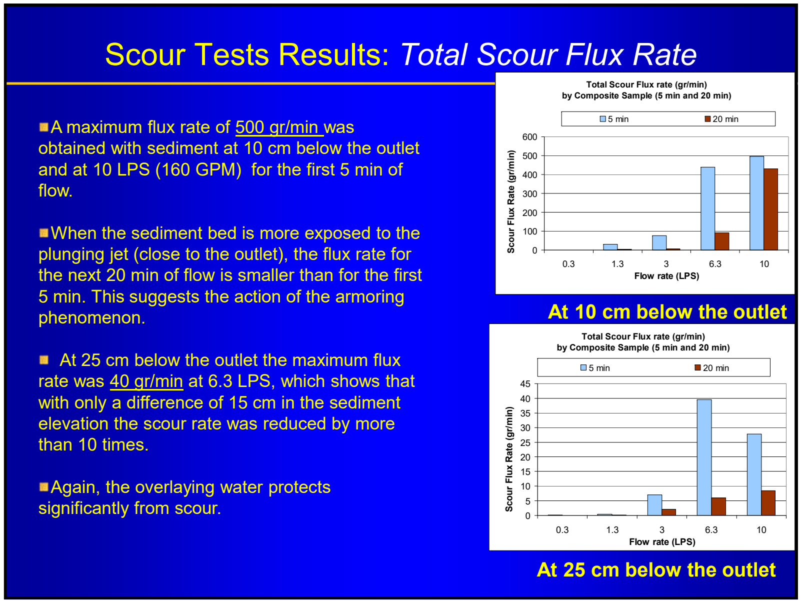
Scour Tests Results: *Turbidity Time Series - Impacting Test*

- The decreasing exponential pattern is maintained after each impact.
- An overall exponential reduction of turbidity is found for the series of impacts.
- When sediment is at 10 cm below the outlet, the forth impact shows a reduction of turbidity of about 5 times (from 1,000 to 200 NTU), suggesting that the armoring also protects significantly the sediment bed under a series of impacting flows.
- A similar pattern was found when sediment is at 25 cm below the outlet.
- At 46 cm below the outlet no pattern was detected after the third impact.
- At 106 cm below the outlet no pattern was detected at all.



Scour Tests Results: *PSD*

- As expected, larger sediment particles are more likely to scour at high flow rates and when the sediment bed is located close to the water surface.
- At 10 cm below the outlet, a high concentration of large particles were found for the first 5 min when a 10 LPS flow rate was applied (D_{50} = 2,500 um). This shows that the armoring developed by the previous sequence of lower flow rates was broken by the 10 LPS flow. For the next 20 min the D_{50} = 1,000 um.
- The overlaying water layer significantly reduces the sediment scour. At 46 cm below the outlet and at 10 LPS flow, the D_{50} = 100 um for the first 5 min, which is a reduction of 25 times the previous scenario.

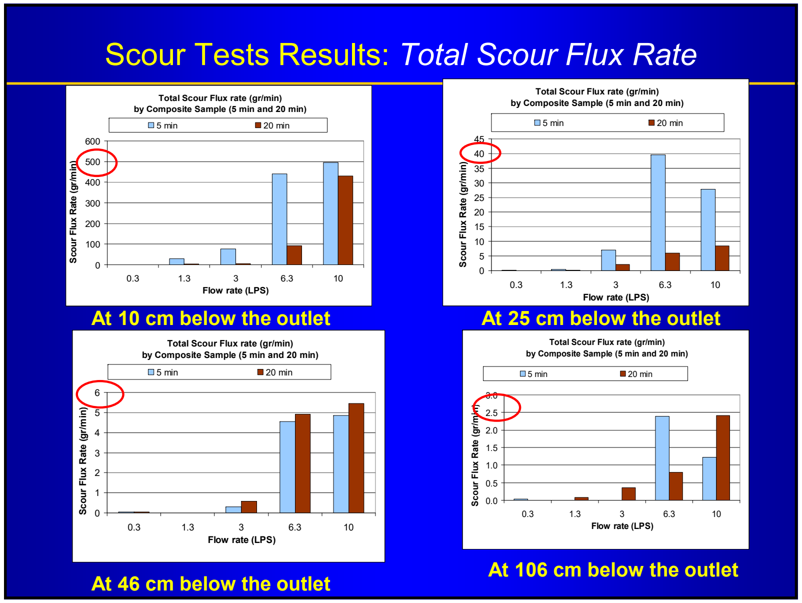


Scour Tests Results: *Total Scour Flux Rate*

- A maximum flux rate of 500 gr/min was obtained with sediment at 10 cm below the outlet and at 10 LPS (160 GPM) for the first 5 min of flow.
- When the sediment bed is more exposed to the plunging jet (close to the outlet), the flux rate for the next 20 min of flow is smaller than for the first 5 min. This suggests the action of the armoring phenomenon.
- At 25 cm below the outlet the maximum flux rate was 40 gr/min at 6.3 LPS, which shows that with only a difference of 15 cm in the sediment elevation the scour rate was reduced by more than 10 times.
- Again, the overlaying water protects significantly from scour.

At 10 cm below the outlet

At 25 cm below the outlet



Scour Tests Results: *Total Scour Flux Rate*

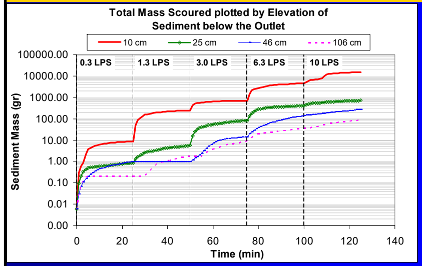
At 10 cm below the outlet

At 25 cm below the outlet

At 46 cm below the outlet

At 106 cm below the outlet

Scour Tests Results: *Scoured Sediment Mass*



Total Mass Scoured plotted by Elevation of Sediment Bed

- An increment in the overlaying water results in a significant reduction of the scoured mass.

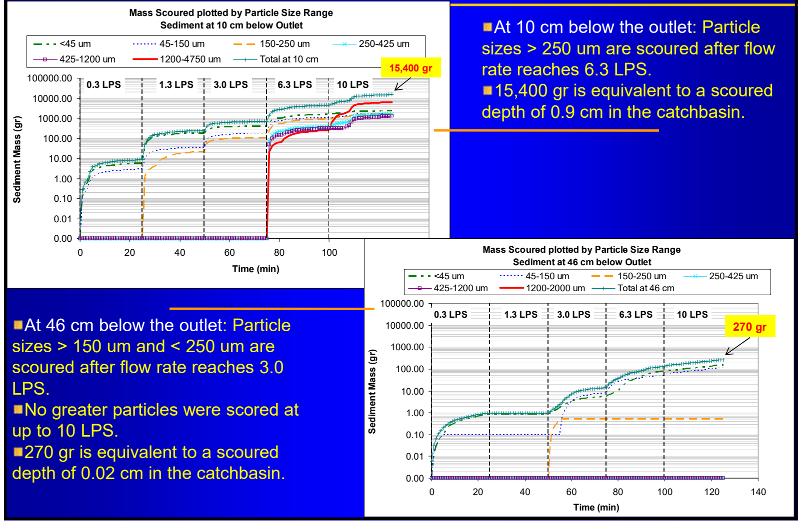
- Sediment particles are more exposed to scour during fluctuation of flow rates.

- For steady state conditions the scour mass is reduced exponentially (for this particular PDS) to a marginal scour rate due to an equilibrium reached by the turbulent flow, air entrainment, the scour hole, and the armoring phenomenon.

- At 10 cm below the outlet the maximum scored mass after 120 min was 15,400 gr with particle size < 4,700 um.

- At 106 cm below the outlet the maximum scoured mass after 120 min was 89 gr with particle size < 45 um.

Scour Tests Results: *Scoured Sediment Mass by Particle Size*



- At 10 cm below the outlet: Particle sizes > 250 um are scoured after flow rate reaches 6.3 LPS.
- 15,400 gr is equivalent to a scoured depth of 0.9 cm in the catchbasin.

- At 46 cm below the outlet: Particle sizes > 150 um and < 250 um are scoured after flow rate reaches 3.0 LPS.
- No greater particles were scored at up to 10 LPS.
- 270 gr is equivalent to a scoured depth of 0.02 cm in the catchbasin.

Conclusions

- The scour potential in a catchbasin sump depends directly on the inlet geometry. Circular inlets are more erosive than rectangular inlets.

- Velocity magnitudes are reduced in deeper water due to turbulent dispersion and buoyancy (air entrainment). Secondary flows are responsible for the shear stress magnitudes in deeper water.

- A decreasing exponential pattern was found in the Turbidity Time Series, which suggest that the scour mass trend to decrease exponentially under steady flow conditions.

- Fluctuating flow rates have more impact on the scour production. However, the decreasing exponential trend is maintained for successive flow rate fluctuations of equal magnitude.

- The overlaying water has a significant reduction of sediment scour. The particle sizes scoured at 10 cm below the outlet (D_{50} = 1,000) is reduced by 25 times if the sediment bed is located at 25 cm below the outlet (D_{50} = 100) .

- The same effect is detected with the flux rate, in which a magnitude of 500 gr/min was found for 10 LPS and sediment at 10 cm below the outlet, while at the same flow rate but at 25 cm below the outlet the flux rate was 40 gr/min.

- The total mass scoured at 10 cm below the outlet was 15,400 gr equivalent to about a depth of 0.9 cm of material, while at 46 cm below the outlet the scoured mass was 270 gr, equivalent to 0.02 cm of material in the catchbasin.

Thank you!

Author’s contact information:
humbertoavila@gmail.com