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Academic Background:
•Ph.D. Student in Water Resources Engineering at the University of Alabama. Currently working on Computational Fluid Dynamics and Physical Modeling of Hydrodynamic Stormwater Devices.
•M.Sc. Water Resources, 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 Management.
•Consultant and Designer of several projects in Colombia.
•Professor of Water Resources Engineering at the Universidad del Norte, Colombia.

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Factors Affecting Scour of Previously Captured Sediment from Stormwater Catchbasin Sumps

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Introduction

- Sediment-retaining performance in a catchbasin depends on the size and geometry of the device, the flow rate, sediment size, and specific gravity of the sediment.

- Scour phenomenon includes all those parameters previously mentioned, in addition to the depth of the water protection layer and the consolidation of the sediment bed due to aging.

- An experimental design was developed and analyzed with four parameters: flow rate, sediment size, overlying water protection depth, and specific gravity of the sediment. A 2-dimensional Computational Fluid Dynamic (CFD) model was implemented in Fluent 6.2.

- Shear stresses at different sediment depths were also calculated for different flow rates and inlet geometries. These shear stress values were compared to the critical shear stress of different particle sizes.

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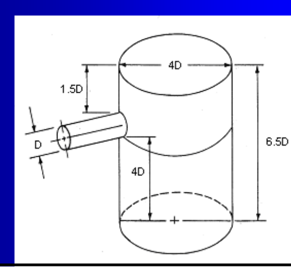
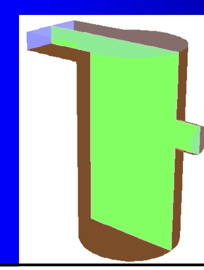
Experimental Design

- The experiments examined the reduction of sediment mass from a catchbasin sump over time under the effect of a submersible-vertical water jet.

- The geometry of the manhole was the same as the optimal manhole 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.

- The initial 2D model examined the longitudinal center-line cross section.





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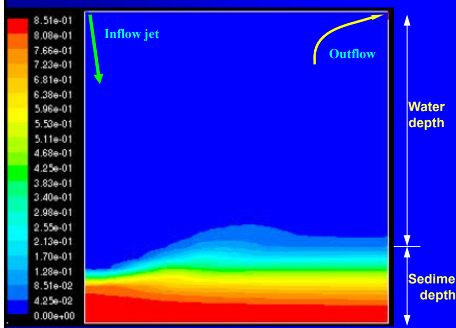
Description of the Model



General representation of a simulation. Inflow, and outflow directions are indicated by arrows. Upper layer of water in blue, and sediment layer in color scale.

- A 2D-Computational Fluid Dynamic Model was implemented in FLUENT 6.2, applying the Eulerian multiphase model, considering a dense fluidized bed.
- The sediment bed was exposed to a continuous flow from a vertical-submergible water jet during a 3600 sec (60 min) period.
- The water jet was modeled to represent gutter flows and an in-line pipe.

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Full Factorial 2^4 Experimental Design

	Factor	Low	High
A	Flow rate (L/s)	1.6	20.8
B	Diameter (µm)	50	500
C	Water Depth (m)	0.2	1.0
D	Specific gravity (g/cc)	1.5	2.5

Treatment	A	B	C	D	AB	AC	AD	BC	BD	CD	ABC	ABD	ACD	BCD	ABCD
I	-	-	-	-	+	+	+	+	+	+	-	-	-	-	+
a	+	-	-	-	-	-	-	+	+	+	+	+	+	-	-
b	-	+	-	-	-	+	+	-	-	+	+	+	-	+	-
ab	+	+	-	-	+	-	-	-	-	+	-	-	+	+	+
c	-	-	+	-	+	-	+	-	+	-	+	-	+	+	-
ac	+	-	+	-	-	+	-	-	+	-	-	+	-	+	+
bc	-	+	+	-	-	-	+	+	-	-	-	+	+	-	+
abc	+	+	-	-	+	-	-	-	-	+	-	-	+	+	+
d	-	-	-	+	+	+	-	+	-	-	-	+	+	+	-
ad	+	-	-	+	-	-	+	+	-	-	+	-	-	+	+
bd	-	+	-	+	-	+	-	-	+	-	+	-	+	-	+
abd	+	+	-	+	+	-	+	-	+	-	-	+	-	-	-
cd	-	-	+	+	+	-	-	-	-	+	+	+	-	-	+
acd	+	-	+	+	-	+	+	-	-	+	-	-	+	-	-
bcd	-	+	+	+	-	-	-	+	+	+	-	-	-	+	-
abcd	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

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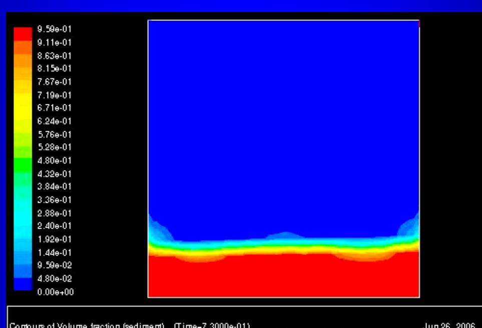
Simulation of case ABC



Simulation of case ABC
flow rate at high (20.8 L/sec)
depth of water at high (1 m)
diameter at high (500 µm)
specific gravity at low (1.5 g/cc)

Colors represent Volume Fraction of Sediment

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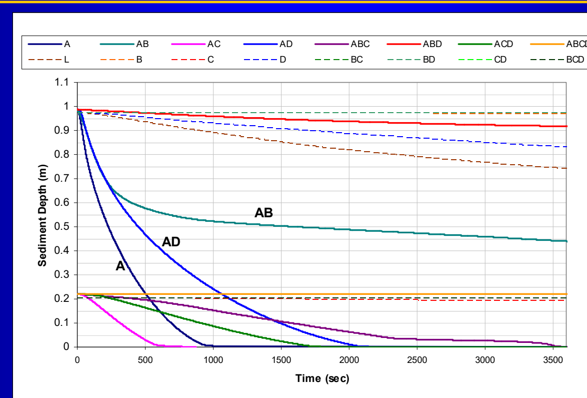
Reduction of sediment depth over time



	High
A	Q (L/s)
B	D (µm)
C	hw (m)
D	SG

Runs A, AD, and AB show how the specific gravity and the diameter affect the response, reducing the loss of sediment over time.
Particle size has more effect on the loss of sediment than specific gravity.

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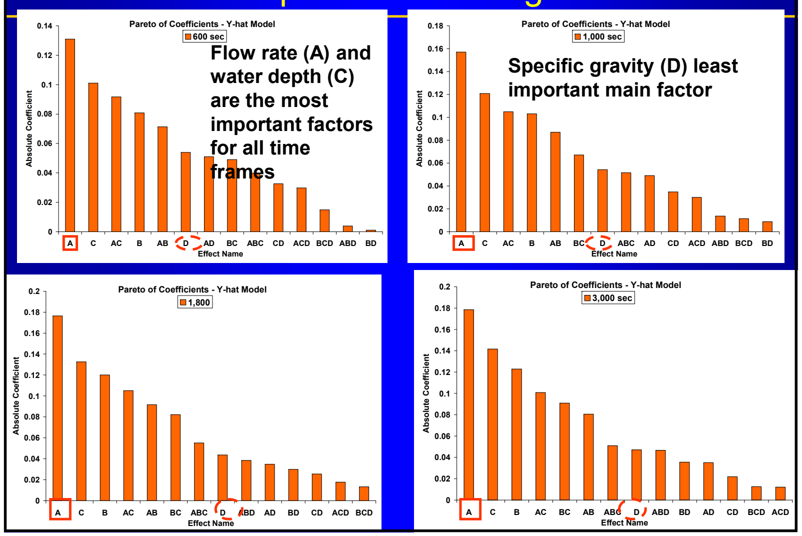
Experimental Design



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Evaluation of Shear Stress: Description of the Model

•Flow rates considered: 2, 5, 10, 20, and 40 L/s (30, 80, 160, 320, and 630 GPM). These flows are high when compared to typical inlet flows for catchbasin inlets, but were selected to correspond to the available earlier laboratory and CFD test results to enable more accurate comparisons.

Annual Flow Rate Distributaries (GPM/acre pavement), (*1 L/s ≈ 15 GPM*) (Pitt and Khambhammettu 2006)

Location	50^{th} Percentile	70^{th} Percentile	90^{th} Percentile	Maximum flow rate expected during typical rain year
Seattle, WA	16	28	44	60
Portland, ME	31	52	80	130
Milwaukee, WI	35	60	83	210
Phoenix, AZ	38	60	150	190
Atlanta, GA	45	65	160	440

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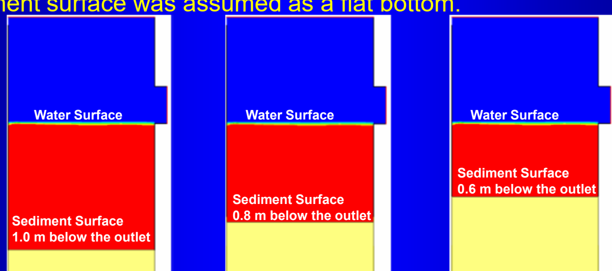
Evaluation of Shear Stress: Description of the Model

- Inlet geometries evaluated during this study: a 0.8 m-wide rectangular inlet (representing typical gutter flows entering the catchbasin) and a 300-mm-pipe inlet (12 inches) (representing in-line sump conditions); the outlet diameter (D) is 300 mm for both cases.
- Elevations of sediment: 1.0, 0.8, and 0.6 m below the outlet. The sediment surface was assumed as a flat bottom.



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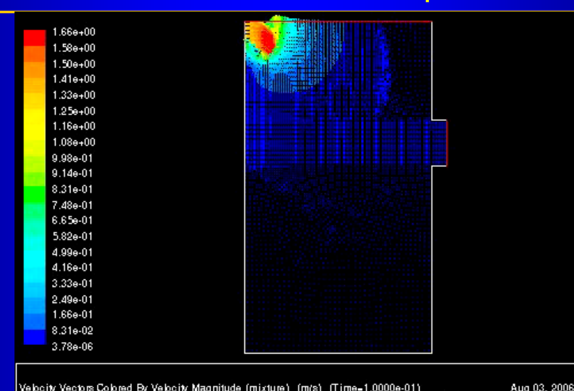
Simulation of Water Impact



Simulation of manhole with circular inlet (300 mm diameter) and 40 L/s flow rate. Colors represent velocity (includes water and air phases).

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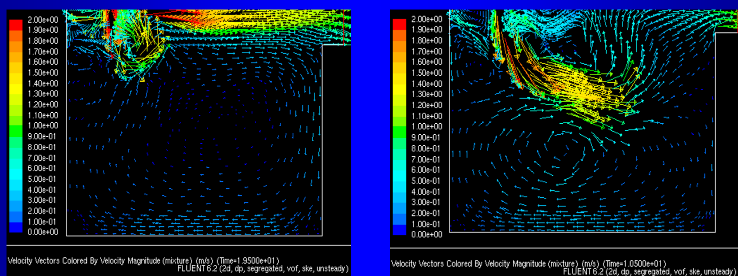
Comparison of Hydrodynamic Effect: *Water Impact*

- The impact force of the waterfall coming from the pipe inlet is considerably higher than when the inlet is rectangular gutter flow.
- In the case of the rectangular inlet (left) the jet (with velocity magnitudes of about 1.2 m/s) only reaches about 0.15 m below the outlet; in contrast, the jet reaches about 0.5 m below the outlet when the inlet is circular.



Steady-state velocity vectors ranged between 0 and 2.0 m/s. Flow rate: 20 L/s, Sediment level below the outlet: 0.8 m. Rectangular inlet (left), circular inlet (right).

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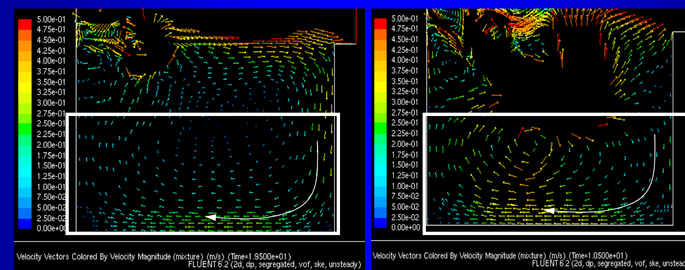
Comparison of Hydrodynamic Effect: *Velocity Field*

- Once steady-state condition is established, a rotational velocity field is developed due to the water flowing toward the outlet; this velocity field reaches the sediment surface or the bottom of the chamber.



Steady-state velocity vectors ranged between 0 and 0.5 m/s. Flow rate: 20 L/s, Sediment level below the outlet: 0.8 m. Rectangular inlet (left), circular inlet (right).

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Initial Motion and Initial Suspension Criteria

- The sediment bed shifting will not necessarily represent migration out of the device because the sediment does not necessarily reach the elevated outlet. Only suspended sediment is assumed to leave the chamber.
- The Cheng-Chiew criterion (1999), which involves both initial motion and initial suspension, was evaluated. This criterion relates the critical shear stress with the probability that sediment with a particular specific gravity, diameter, and settling velocity, becomes bed load or gets suspended.
- This shear stress was compared to initial-motion and initial-suspension critical shear stresses associated with a specific particle size. A total of 30 different scenarios have been evaluated to date.

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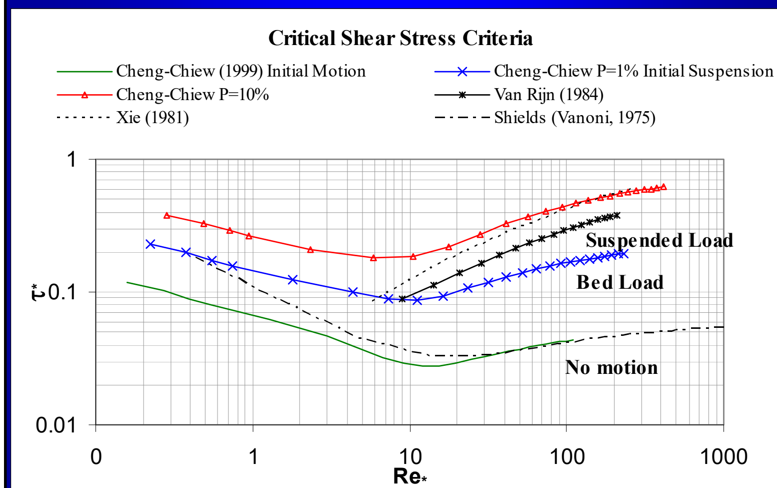
Initial Motion and Initial Suspension Criteria



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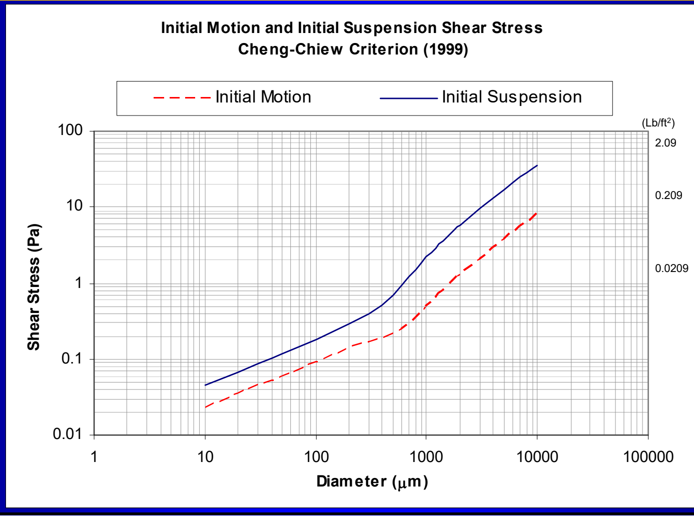
Initial Motion and Initial Suspension Criteria



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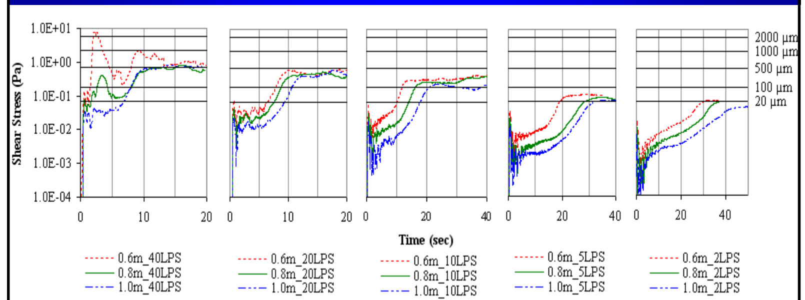
Shear Stress: 0.8 m-wide Rectangular Inlet



Shear stress on the sediment layer at different elevations in a conventional manhole with a rectangular inlet of 0.8-m wide, and initial suspension threshold for different particle sizes. Series of graph classified by flow rate: 40, 20, 10, 5, and 2 LPS

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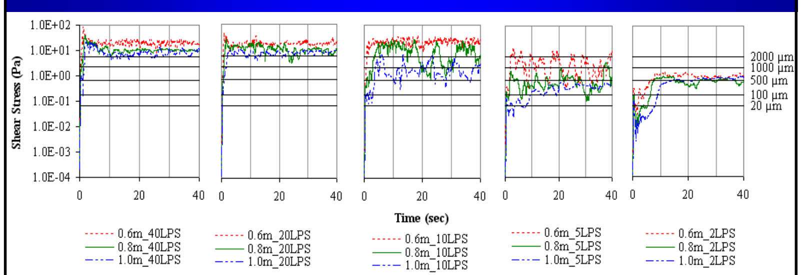
Shear Stress: 300 mm-diameter Pipe Inlet



Shear stress on the sediment layer at different elevations in a conventional manhole with circular inlet of 300-mm diameter, and initial suspension threshold for different particle sizes. Series of graph classified by flow rate: 40, 20, 10, 5, and 2 LPS

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Conclusions (1)

- Flow rate, particle size, water depth, and their interactions are significant factors that affect the scour of sediment in a conventional catchbasin sump.
- The inlet geometry has a significant effect on the scour potential of sediments captured in conventional catchbasin sumps. The impact force will be greater when the waterfall is concentrated in the smaller area associated with a pipe inlet.
- The overlying water layer depth above the sediment has an important function in protecting the sediment layer from scour. High shear stresses caused by the impacting water jet will not easily reach the sediment surface if the water is deep.

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Conclusions (2)

- Flows smaller than 2.0 L/s (30 GPM), typical for stormwater catchbasins, do not expose particles greater than 50 μm to suspension in manholes with rectangular inlets wider than 0.8 m. This suggests that the sediment would not be exposed to scour most of the time.

- CFD modeling to include 3D analyses (using Flow-3D software), and detailed laboratory tests using a full-scale manhole are being used to verify the computational results. Finally, the results will be implemented in the WinSLAMM stormwater model to better consider sediment scour from small hydrodynamic devices.