Module 4a: The Role of Street Cleaning in Stormwater Management

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Major Sediment Source Along Highways

Wisconsin Dept. of Natural Resources

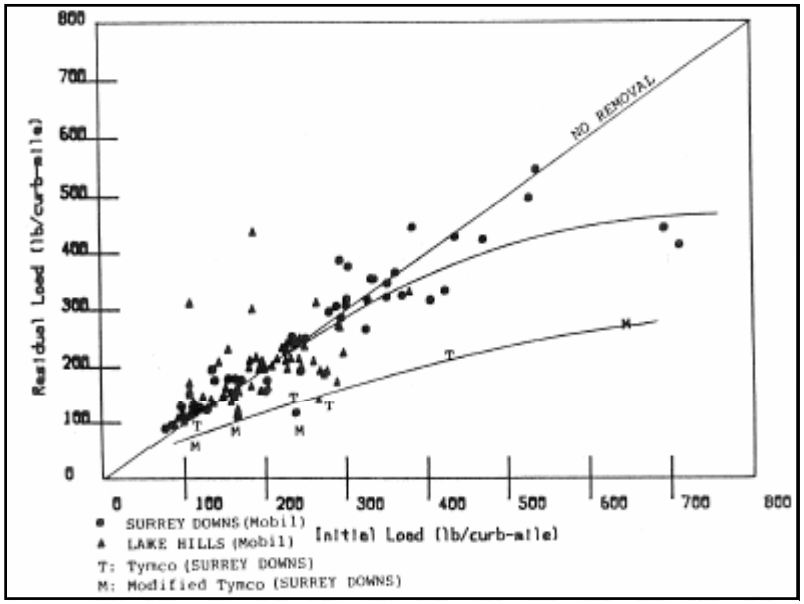
Heavy Street Dirt Loadings after Snowmelt

Roger Bannerman photo

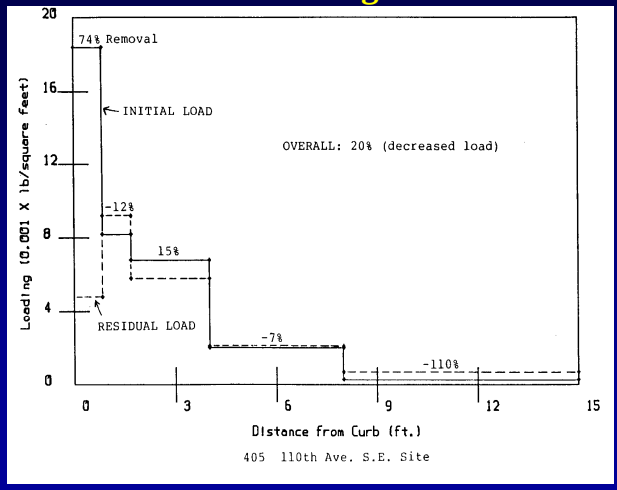
Some Early Street Cleaning Research Projects

- Pitt, R., Demonstration of Nonpoint Pollution Abatement Through Improved Street Cleaning Practices. 1979.
- Bannerman, R. *et. al*, Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee County, WI. 1983.
- Terstriep, M.L., *et. al*, Evaluation of the Effectiveness of Municipal Street Sweeping in the Control of Urban Storm Runoff Pollution. 1983.

Street and catchbasin cleaning, and inlet controls most effective for smaller rains or heavily paved areas.

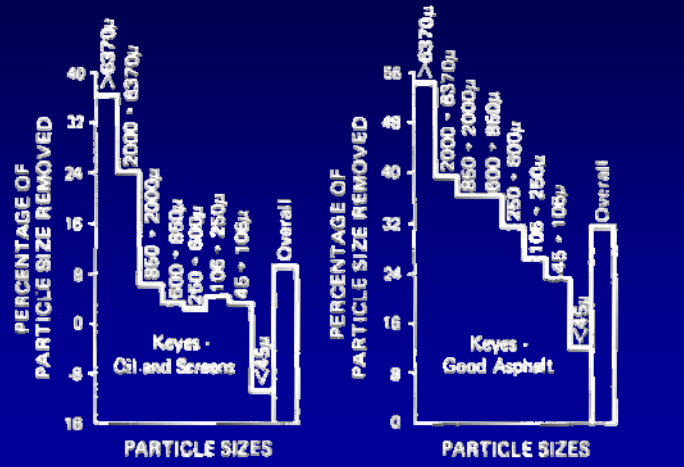


Redistribution of Street Dirt During Street Cleaning



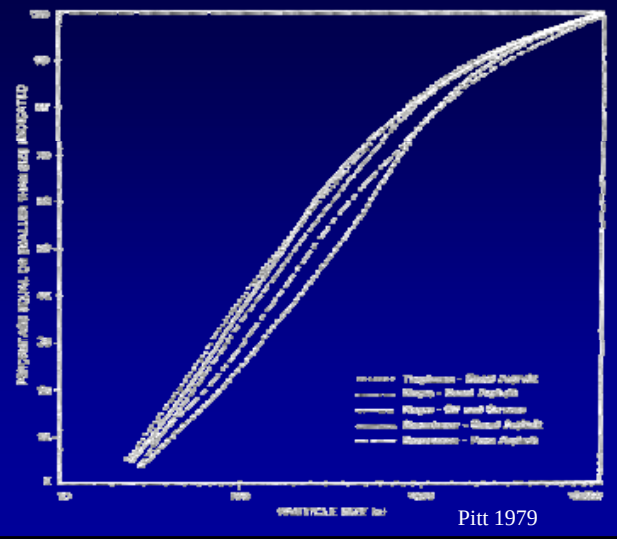
Pitt 1985

Total Solids Removal by Street Cleaning



Pitt 1979

Particle Size Distribution of Street Dirt



Pitt 1979

Street Dirt Chemical Quality (mg/kg)

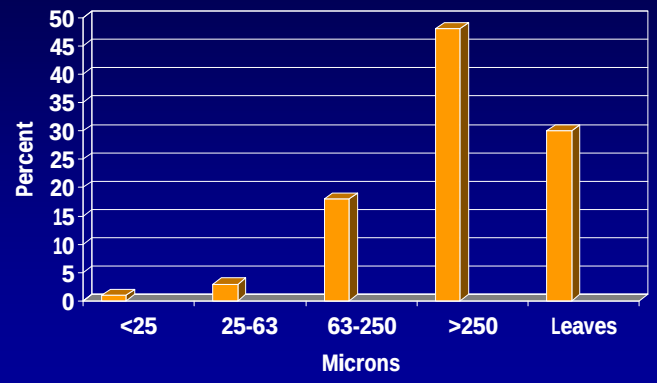
(Milwaukee, WI; San Jose, CA; Bellevue, WA; Toronto, Canada; Reno, NV; Champaign, IL)

Phosphorus (P)	400 – 1500
Total Kjeldahl Nitrogen	290 – 4300
Chemical Oxygen Demand	65,000 – 340,000
Copper (Cu)	110 – 420
Lead (Pb)	530 – 7500
Zinc (Zn)	260 – 1200
Cadmium (Cd)	<3 – 5
Chromium (Cr)	31 – 180

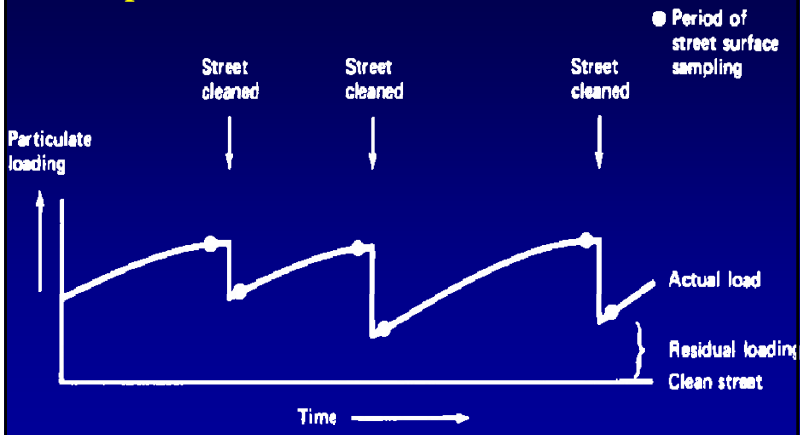
Pitt, Bannerman, and others

Role of Street Cleaning in Leaf and Nutrient Control in Fall?

Size Distribution of Total P in Street Dirt

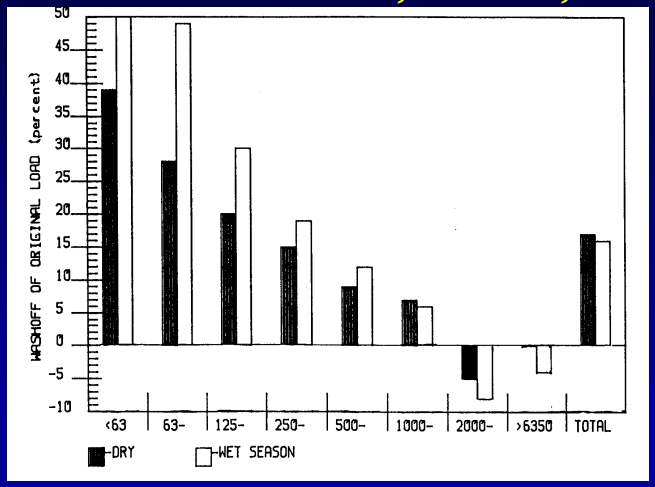


Sawtooth Pattern Associated with Deposition and Removal of Particulates



Pitt 1979

Washoff of Street Dirt, Bellevue, WA



Pitt 1985

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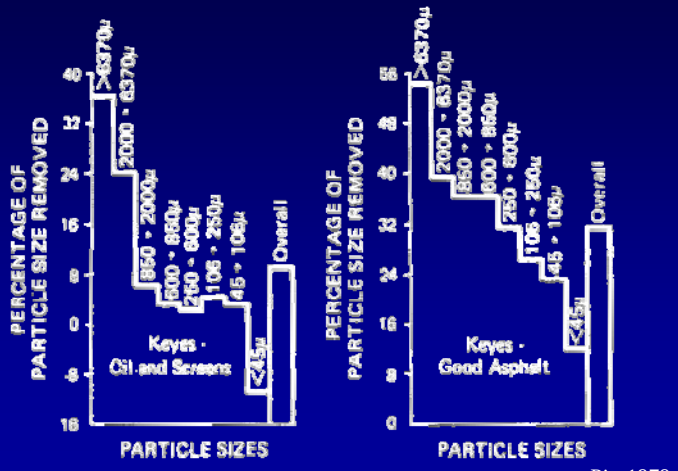
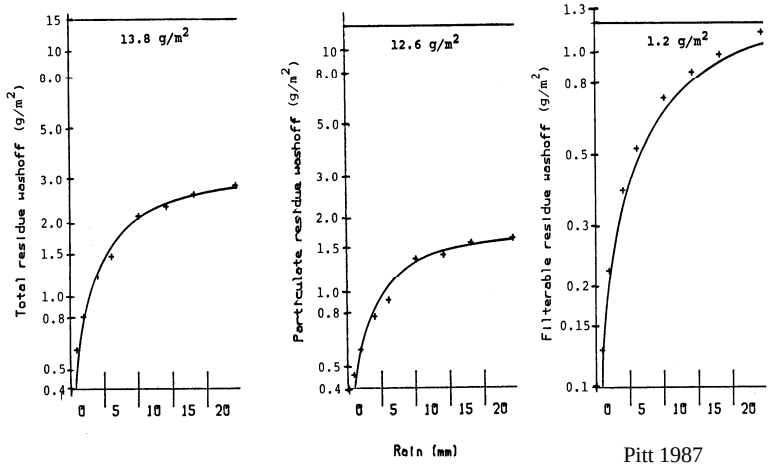


Pitt 1979

Washoff Plots for Heavy Rain Intensities, Dirty Streets, and Rough Pavement Textures



Pitt 1987

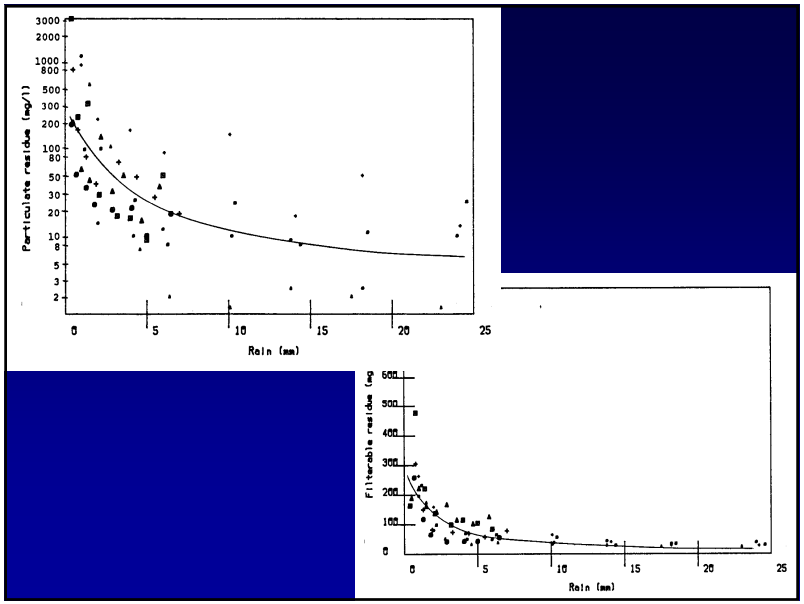
Ratio of Available SS to Total SS Street Dirt Loadings

$$I = 0.08 \pm 0.04$$
$$T = -0.08 \pm 0.05$$

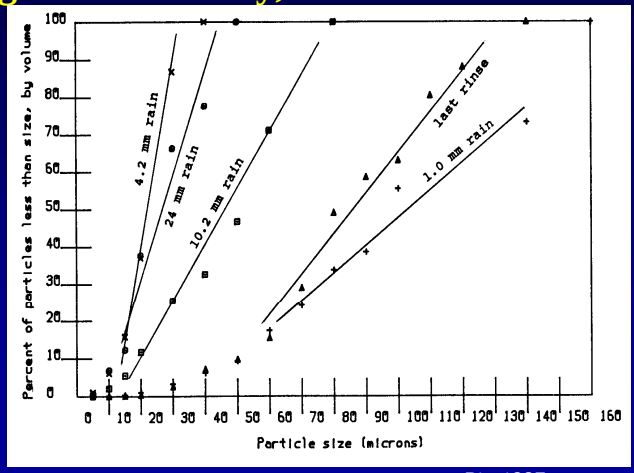
$$\hat{Y} = 0.097 + 0.04(I) - 0.04(T)$$

I+T+ (high and rough) :	$\hat{Y} = 0.10$
I+T- (high and smooth):	$\hat{Y} = 0.18$
I-T+ (low and rough) :	$\hat{Y} = 0.02$
I-T- (low and smooth) :	$\hat{Y} = 0.10$

Pitt 1987

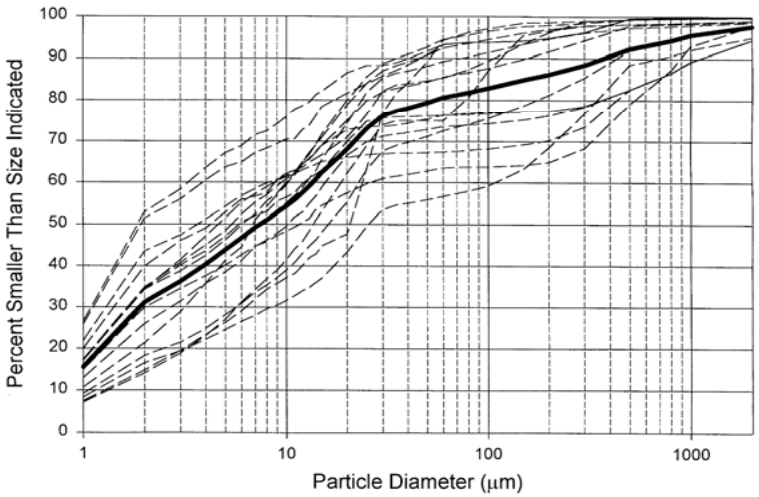


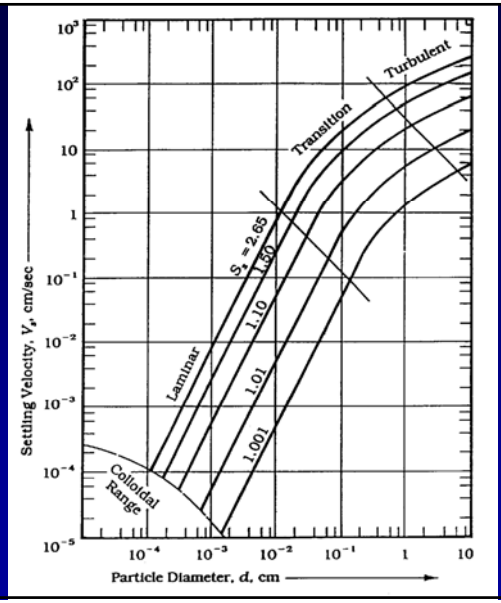
Particle Size Distributions during Washoff Tests (high rain intensity, clean and smooth streets)



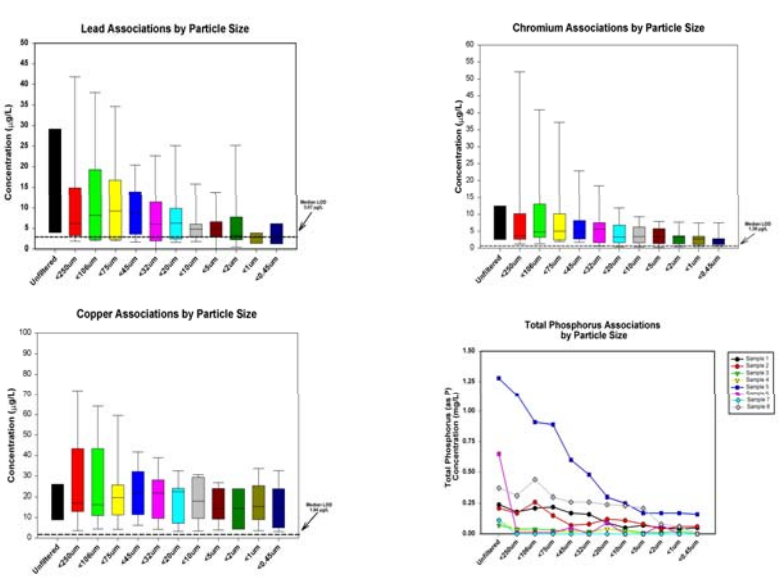
Pitt 1987

Measured Particle Sizes, Including Bed Load Component, at Monroe St. Detention Pond, Madison, WI

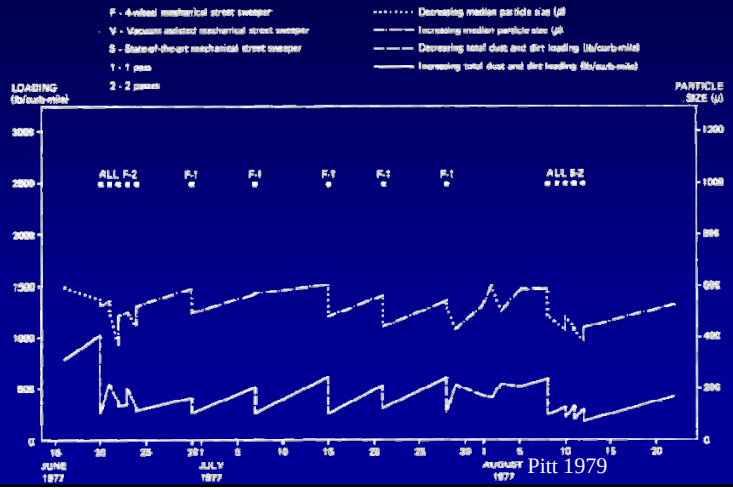




Particle Settling Rates; Stoke's and Newton's Laws

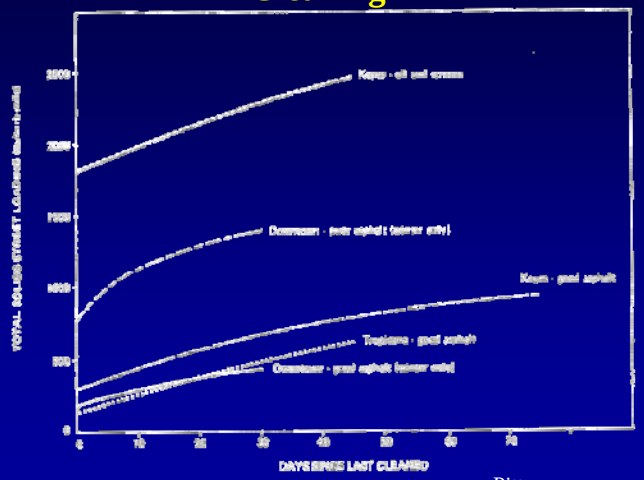


Total Particulate Loading , Keys – Good Asphalt Test Area



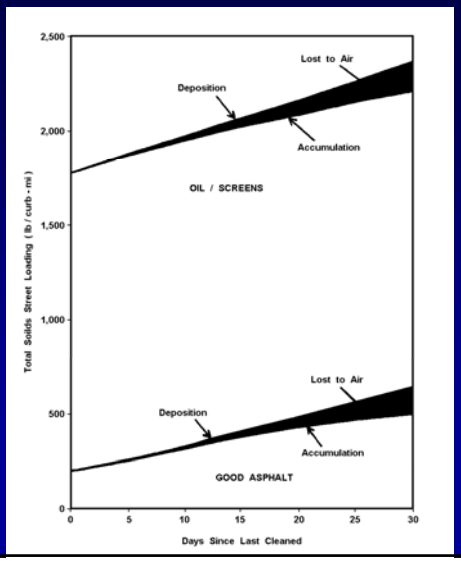
Pitt 1979

Total Solids Accumulation Since Last Cleaning



Pitt

Deposition and Accumulation of Street Dirt

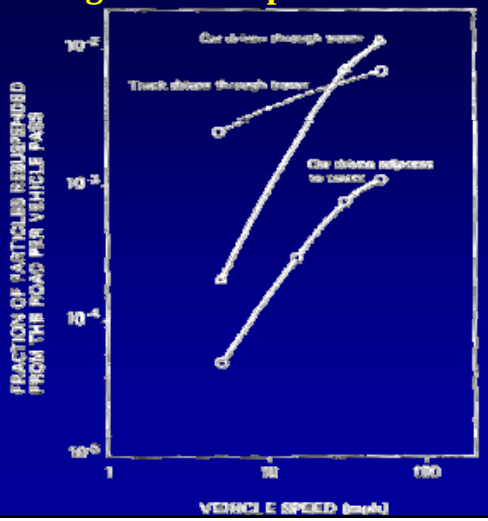


Pitt 1979

Example Deposition and Accumulation Rates (many studies)

	Initial load (g/m)	Depos. Rate (g/m-d)	Days to max. load
Reno, NV, smooth and good condition	80	1	5
San Jose, CA, good condition	35	4	>50
Castro Valley, CA, mod. condition	85	10	70
Ottawa, Ontario, mod. condition, indus.	60	40	>10
Toronto, Ontario, mod. condition, resid.	40	32	>10
Bellevue, WA, smooth, heavy traffic	60	1	30
San Jose, CA, oil and screens overlay	510	6	>50
Ottawa, Ontario, rough	200	20	>10

Particle Resuspension Rates Caused by Vehicle Passage for an Asphalt Road



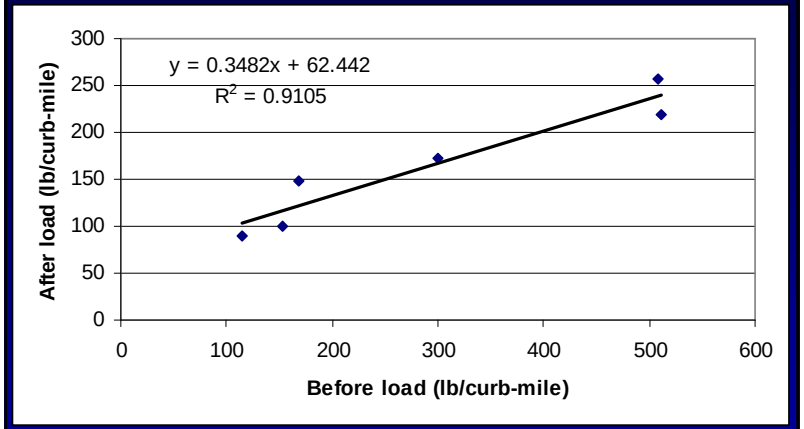
Measured Fugitive Dust Losses from Streets, San Jose, CA

Keyes, good asphalt	6 lb/curb-mi/day	0.33 grams/vehicle-mi
Keyes, oil and screens asphalt	4 lb/curb-mi/day	18 grams/vehicle-mi
Tropicana, good asphalt	6 lb/curb-mi/day	2.5 grams/vehicle-mi

Pitt 1979

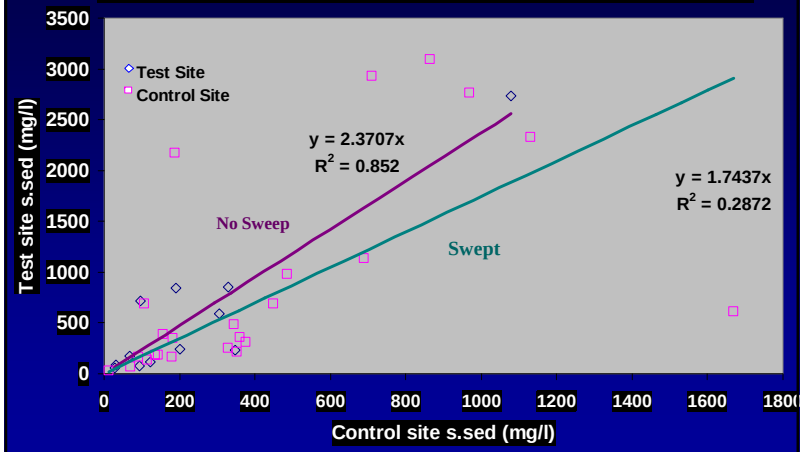
Effects of Parked Cars on Street Cleaning

High-Efficiency Street Cleaner Tests, Milwaukee, WI



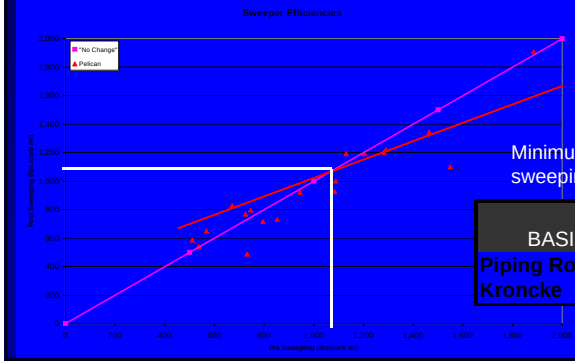
WI DNR and USGS

Comparison of Suspended Sediment at Test and Control Sites for Swept and Unswept Periods



Summary of Current Street Cleaning Tests

SWEEPER	Linear Regression Slope	Linear Regression Efficiency	Robust LTS Regression Slope	Robust LTS Regression Efficiency
Pelican	0.65	35%	0.74	26%
Plastic Bristles	0.91	9%	0.97	4%
Crosswind	0.71	29%	0.77	23%
Whirlwind	0.19	81%	0.22	78%



These are street dirt loadings, not outfall TSS concentrations.

Minimum initial load for which sweeping has a positive effect

BASIN	Initial load (lbs/curb-mile)
Piping Rock	700
Kroncke	38

Conclusions

- Sediment in urban streams is a serious problem.
- Rains only remove a small fraction of the total particulate load from paved surfaces, mostly the smallest particles.
- Street cleaning only removes a small fraction of the street dirt loading, mostly the larger particles.
- The accumulation rate is much less than expected due to residual load.
- Particle size distributions at outfalls are mostly made up of small particles (larger particles that wash off accumulate in sewerage)
- Particle size distributions of source area sheetflows have large particles, but many of these aren't effectively transported to outfalls.
- Most models are out of balance on source area contributions.

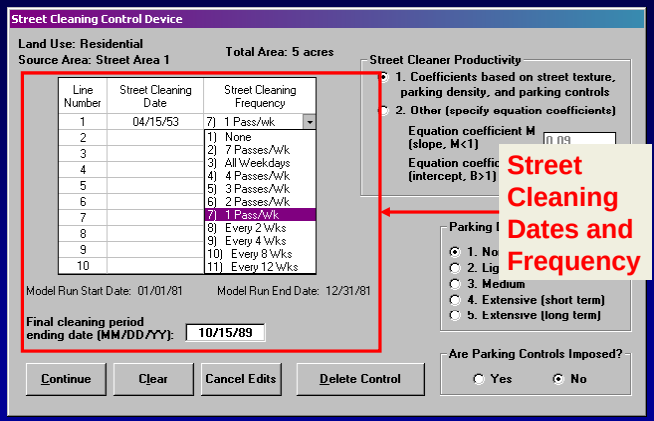
Conclusions (cont.)

- Water Quality Benefits of Street Cleaning is Limited – Best in Spring
- Role in Aesthetics and Safety
- Performance Effected by Street Load, Particle Size, Street Texture, Method of Operation, & Parking
- More Effective for Particles > 250 micron (which are few in runoff waters)

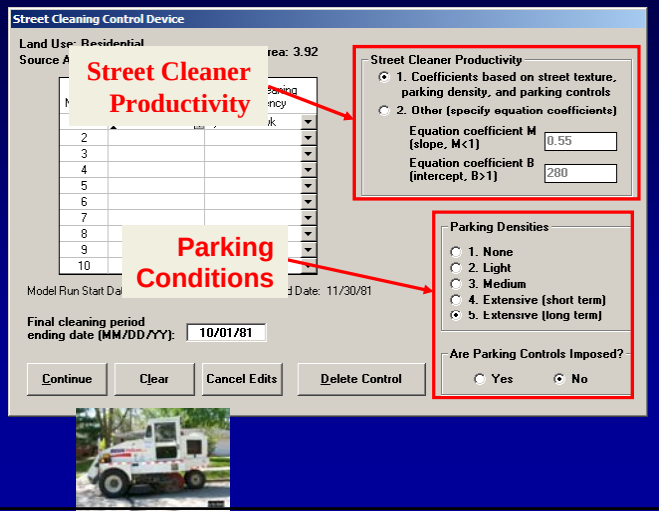
Three Components to Modeling Street Cleaning

- Street Cleaning Dates
- Street Cleaner Productivity
- Parking Conditions

Street Cleaning Data



Street Cleaning Data



Street Cleaning Sensitivity

Street Cleaning Performance Plots

If BeforeEventLoad < B / (1 - M) Then
    AfterEventLoad = BeforeEventLoad
Else
    AfterEventLoad = M * BeforeEventLoad + B
End If

Additional Output

Washoff Details.csv

Street Dirt Removal.csv

Washoff or Street Cleaning.csv

BEGIN STREET CLEANING/WASHOFF LOOP FOR STREET	1								
Event Type	Rain#	St#	Date	JulDate	AccumDur	CurrentLoad	BeforEvntLoad	AftEvntLoad	PartSolYield
Washoff	111	1	03/12/53	436.17	70	1,400.00	1,400.00	1,367.20	81.98
Washoff	112	1	03/14/53	438.46	1.96	1,367.20	1,367.20	1,259.50	269.33
Washoff	113	1	03/20/53	444.96	5.58	1,259.50	1,259.50	1,248.80	26.82
Washoff	114	1	03/21/53	445.88	0.88	1,248.80	1,248.80	1,245.20	8.86
Washoff	115	1	03/22/53	446.79	0.83	1,245.20	1,245.20	1,203.40	104.51
Washoff	116	1	03/25/53	449.13	1.88	1,203.40	1,203.40	1,203.10	0.52
Washoff	117	1	03/30/53	454.79	5.46	1,203.10	1,203.10	1,189.70	33.52
Washoff	118	1	03/31/53	455.5	0.5	1,189.70	1,189.70	1,111.70	194.81
Washoff	119	1	04/01/53	456.67	0.38	1,111.70	1,111.70	1,106.00	14.45
Washoff	120	1	04/03/53	458.21	1.25	1,106.00	1,106.00	1,103.60	5.92
Washoff	121	1	04/08/53	463.67	5.33	1,103.60	1,103.60	1,096.10	18.82
Washoff	122	1	04/09/53	464.58	0.75	1,096.10	1,096.10	1,011.20	212.23
Washoff	123	1	04/14/53	469.92	4.54	1,011.20	1,011.20	936.8	185.88
Street Cleaning	126	1		471.5	0.5	936.8	942.9	664.9	0
Street Cleaning	126	1		478.5	7	664.9	750.3	647.5	0
Washoff	126	1	04/24/53	479.46	0.96	647.5	659.2	610	123.15
Washoff	128	1	04/28/53	483.96	2.92	610	645.5	633.7	29.56
Washoff	129	1	04/30/53	485.21	1.13	633.7	647.4	616	78.64
Washoff	130	1	05/01/53	486.54	0.33	616	620	617.8	5.68
Washoff	131	1	05/02/53	487.46	0.54	617.8	624.4	618.1	15.8
Street Cleaning	133	1		492.5	4.38	618.1	671.4	640.4	0
Street Cleaning	133	1		499.5	7	640.4	725.8	645.3	0
Washoff	133	1	05/17/53	502.46	2.96	645.3	681.4	671.1	25.83
Washoff	134	1	05/21/53	506	3.38	671.1	712.3	699.2	32.62
Street Cleaning	135	1		506.5	0.42	699.2	704.3	643.4	0
Washoff	135	1	05/22/53	507.21	0.71	643.4	652	639	32.63
Washoff	136	1	05/24/53	509.38	2.08	639	664.4	658.7	14.15

Street Dirt Washoff and Removal due to Street Cleaning

Street Dirt Changes Over Time