Storm Water Modeling and its Utility for Predicting Impacts on Santa Monica Bay

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University of California, Los Angeles

Outline

- **Santa Monica Bay**
  - Facts and Data Sources
  - Statistics
  - Land Use
  - Data Sources
- **Spreadsheet Model**
  - Parameters
  - Calibration
  - Predictions
- **SWMM Model**
  - Network
  - Calibration
- **Some Simple Solutions**
  - Sorbents
  - Simple Screens
  - Boardovers
- **Current Research**
  - Knowledge Based Tools
  - Molecular Markers
- **Final Remarks**

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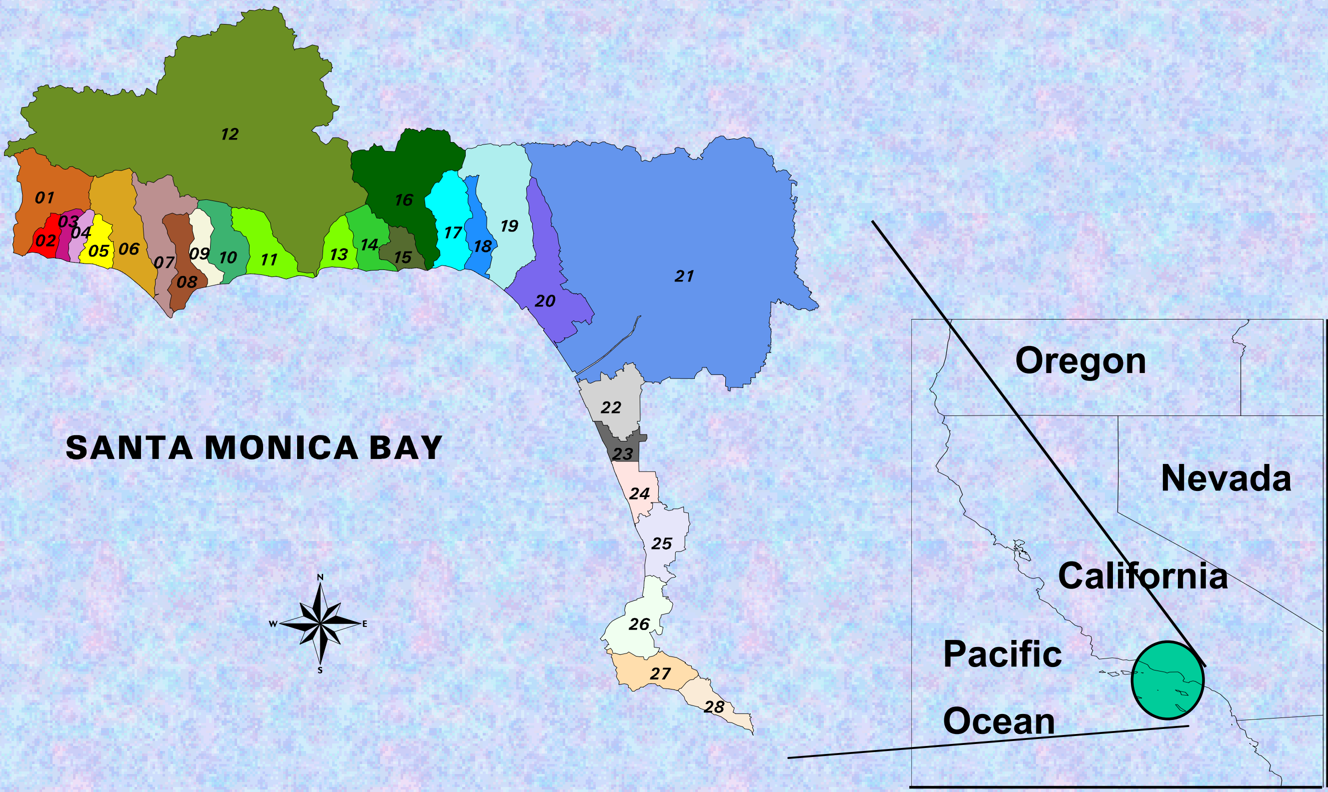
Santa Monica Bay



Available Data

- **Land Use:** 1993 SCAG
- **Drainage:** Catchment and Basin Coverages from Los Angeles Public Works, DEM
- **Rainfall:** Los Angeles Airport Gage
- **Monitoring Data:** 43,015 Data Points of 47 Monitoring Locations
- **Pollutant Concentrations:** Local monitoring data, NURP, Calibrations

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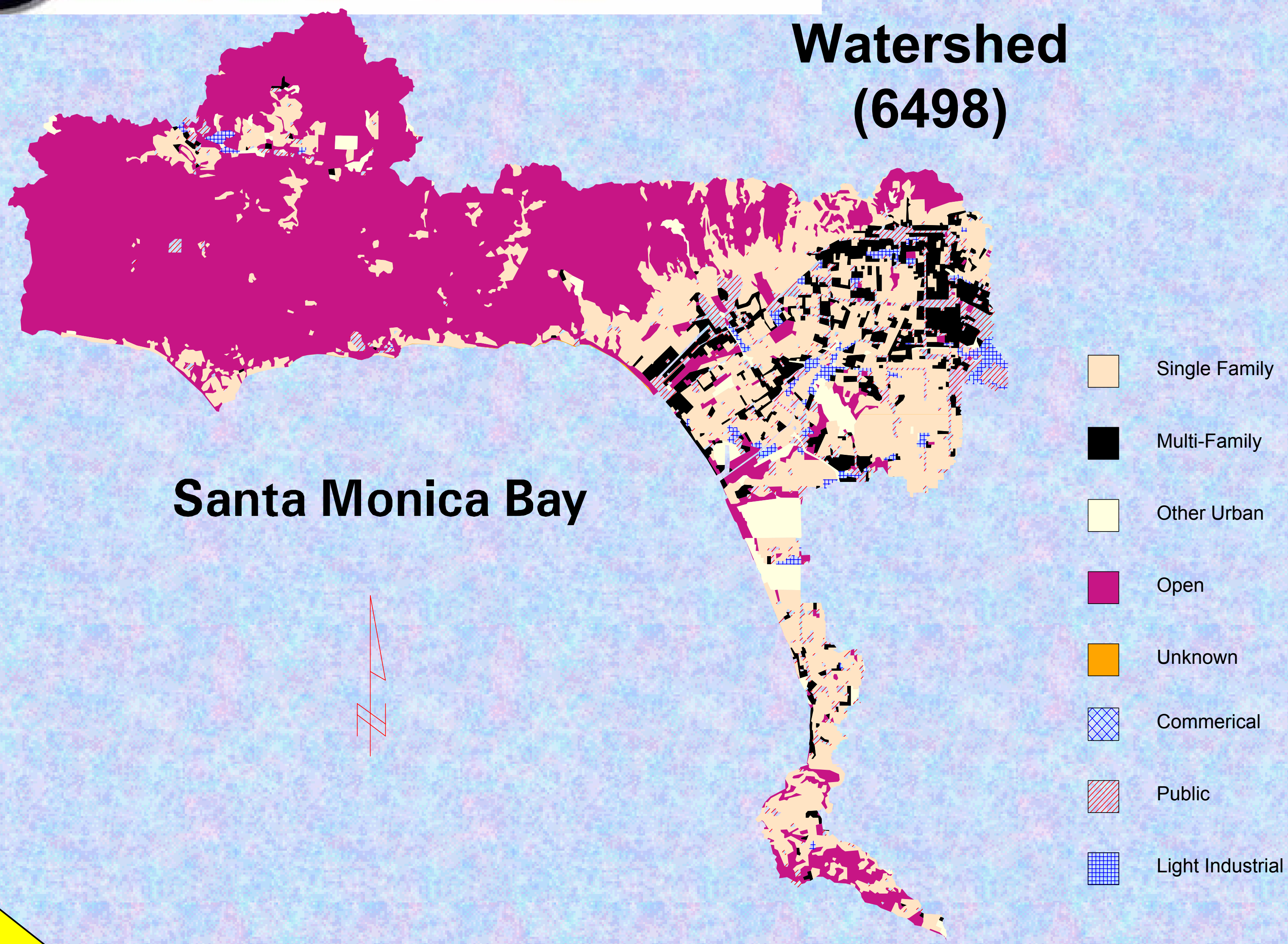
Land Use Pattern in SMB Watershed (6498)



Land Use Characteristics

Land Use Category	Impervious Surface Area [%]	Runoff Coefficient
Single-Family	42	0.39
Multi-Family	68	0.58
Commercial	92	0.74
Public	80	0.66
Light Industrial	91	0.74
Other Urban	80	0.66
Open	0	0.10
Unknown	65	0.56

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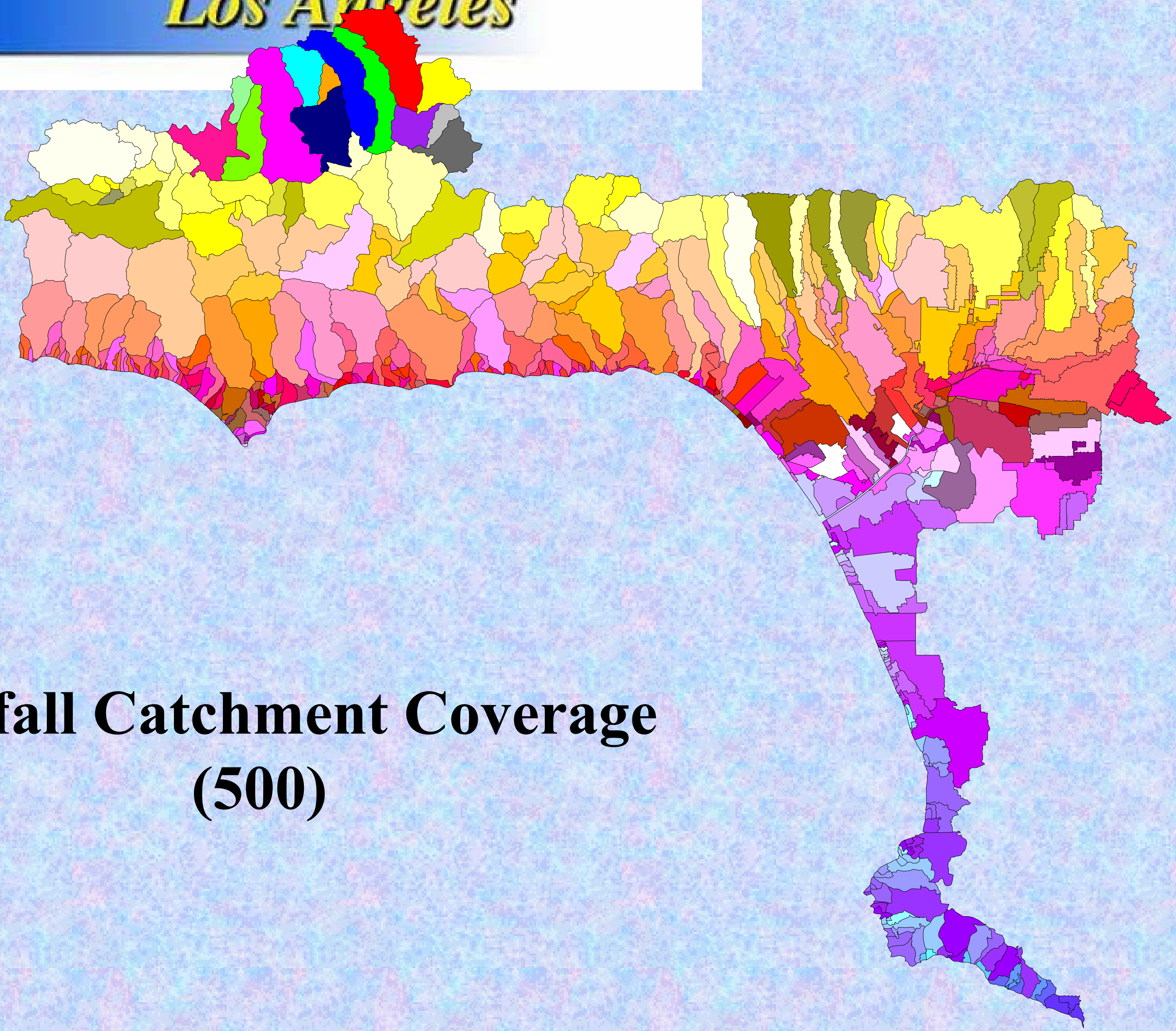

Rainfall Catchment Coverage
(500)

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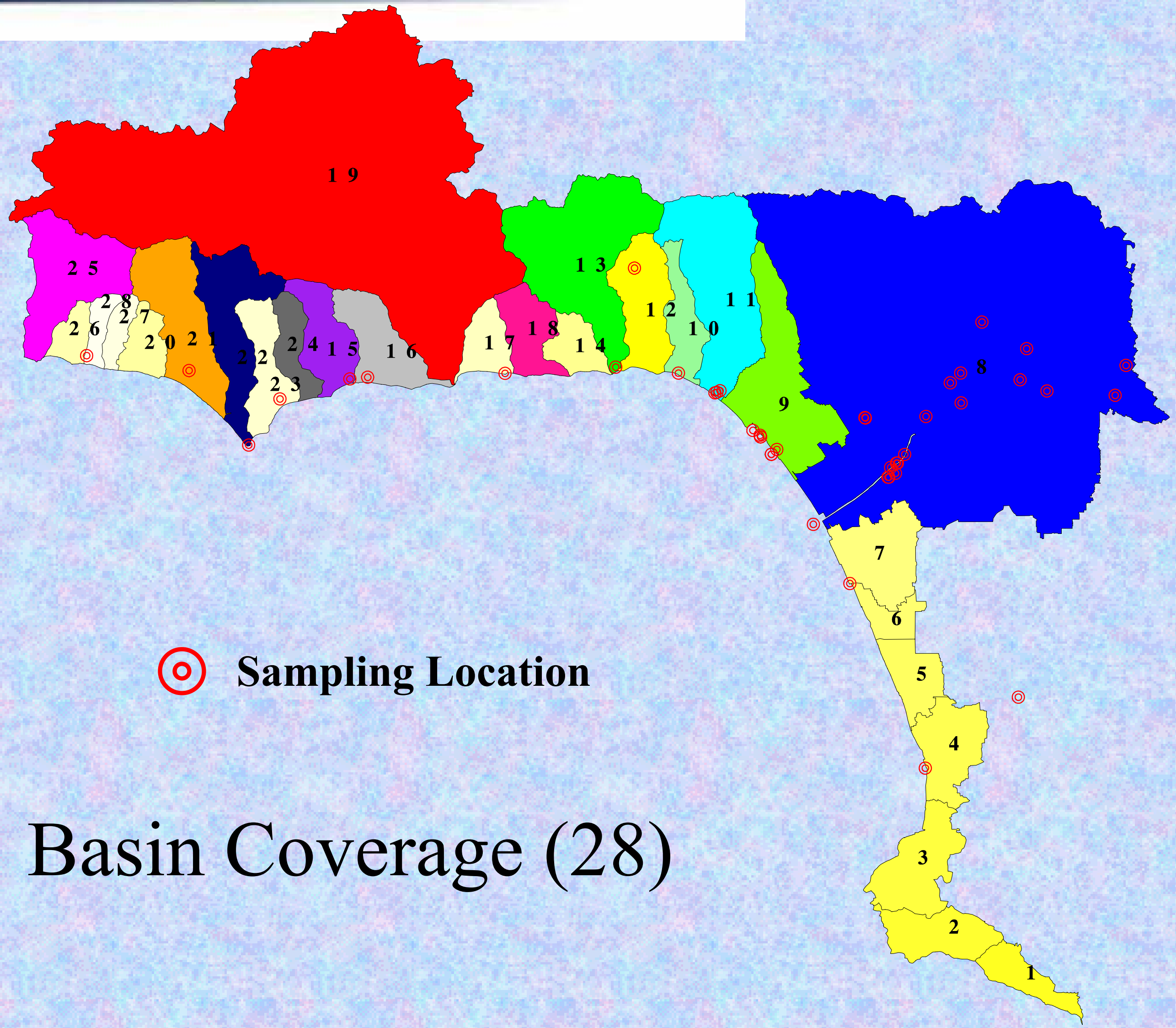

Basin Coverage (28)

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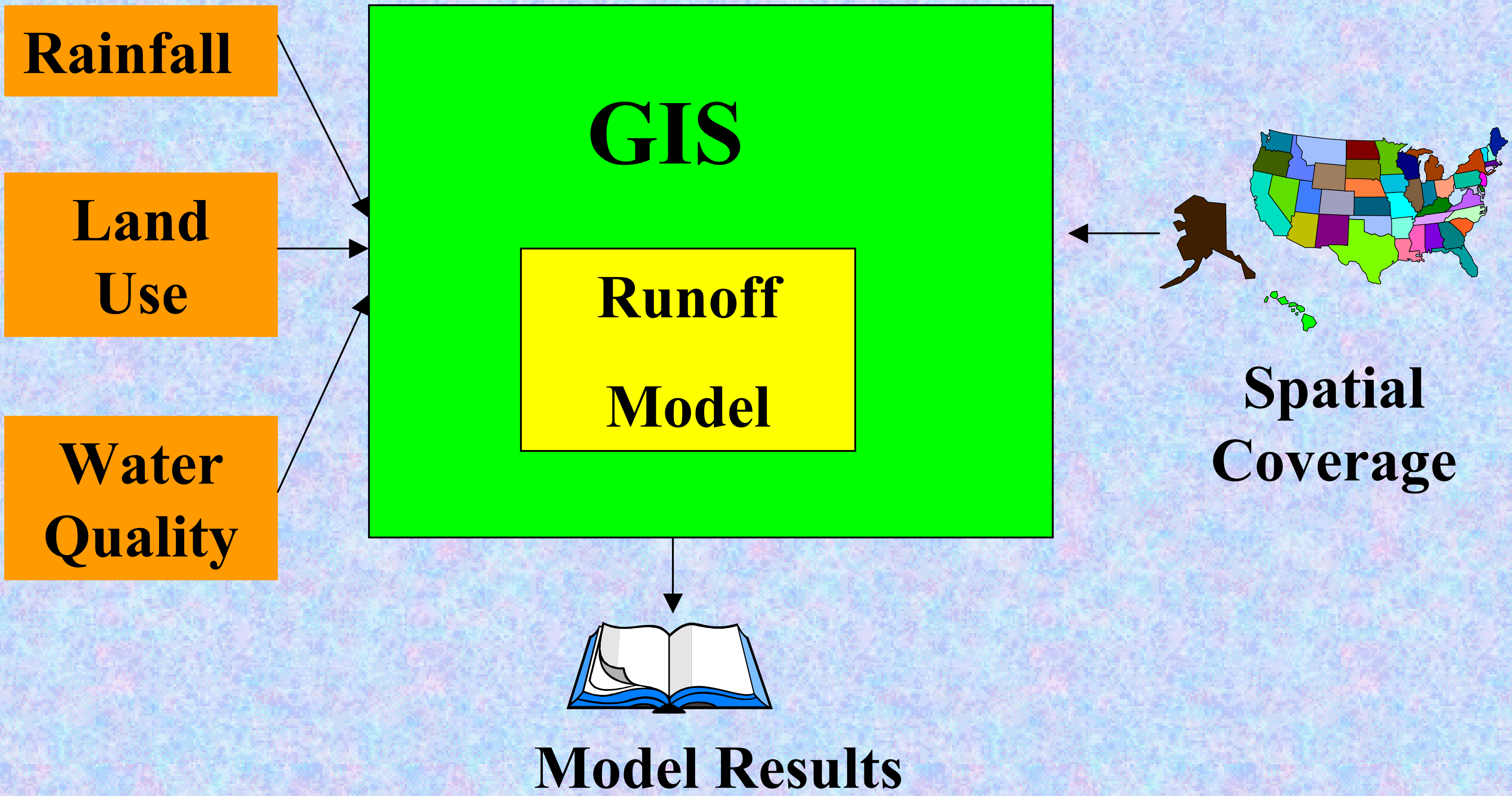
Model Schematic



Rainfall vs Runoff

$$ASV = RV*AREA*CF*ASRF$$

$$AASV = ASV*NSTORM$$

where: ASV = Average storm runoff volume

ASRF = Average storm rainfall

AASV = Annual average storm runoff

Spatial Union Operation of GIS

$$C_i = \sum_{k=1}^{8} \sum_{n=1}^{N} AASV_{n,k,i} * ME_{n,k,i} * G$$

$$B_j = \sum_{i=1}^{M} C_i$$

where	**AASV**	**=**	**Average Annual Storm Volume [m3/yr]**
	ME	**=**	**Event Mean Concentration[mg/L]**
	G	**=**	**Conversion Factor (m3*mg/L to kg) [10-3]**
	Ci	**=**	**Estimated Annual Pollutant Loading of catchment i [kg/yr]**
	Bj	**=**	**Estimated Annual Pollutant Loading of sub-basin j [kg/yr]**
	N	**=**	**Total number of land use polygons with land use type k within catchment i.**
	M	**=**	**Total number of catchment polygons within sub-basin j.**
	k	**=**	**Land use type.**
	n	**=**	**Land use polygon n within the catchment i.**

Water Quality

$$ME = SM\sqrt{1 + CV^2}$$

$$APLi = AASV*ME_i$$

Where: SM = Site Median EMC[mg/ L]

ME = Event Mean Concentration[mg/ L]

CV = Coefficient Variation

APL = Annual Pollutant Loadings[kg/ year]

i = Pollutant i

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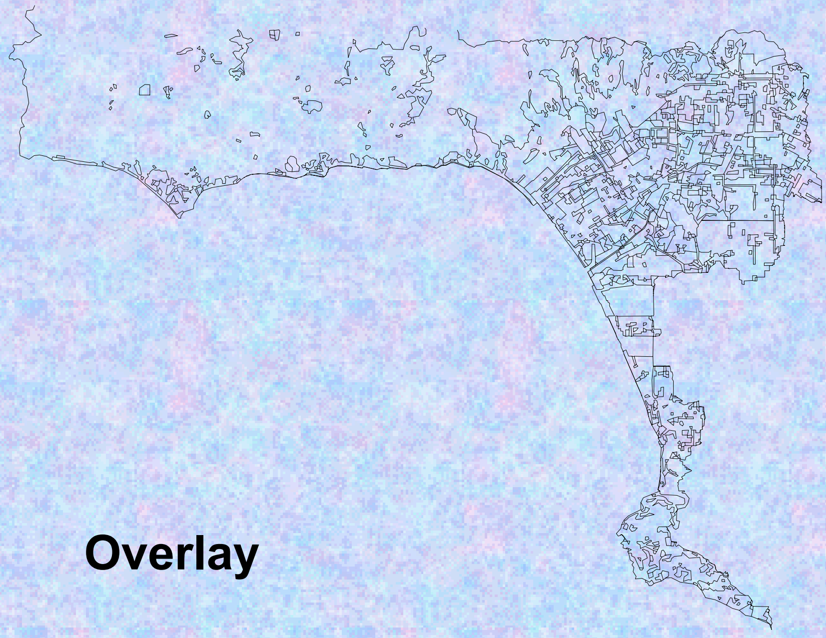
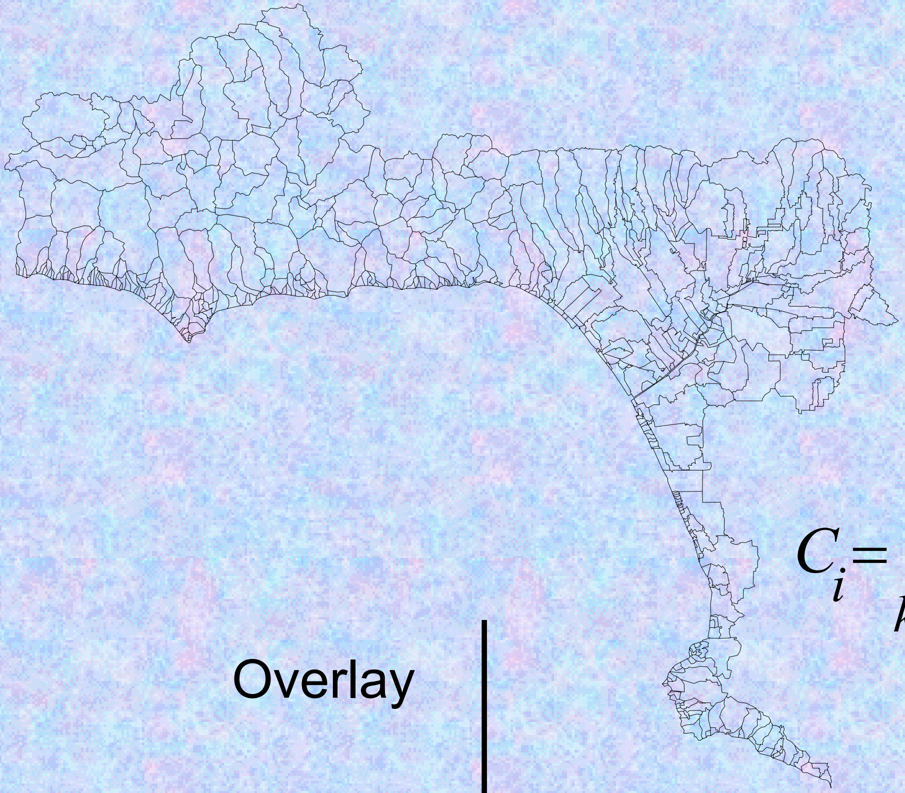
Spatial Union Operation Using GIS and Nonpoint Source Modeling

Land Use Polygons



Overlay

Catchment Polygons



$$C_i = \sum_{k=1}^{8} \sum_{n=1}^{N} AASV_{n,k,i} * ME_{n,k,i} * G$$

Overlay

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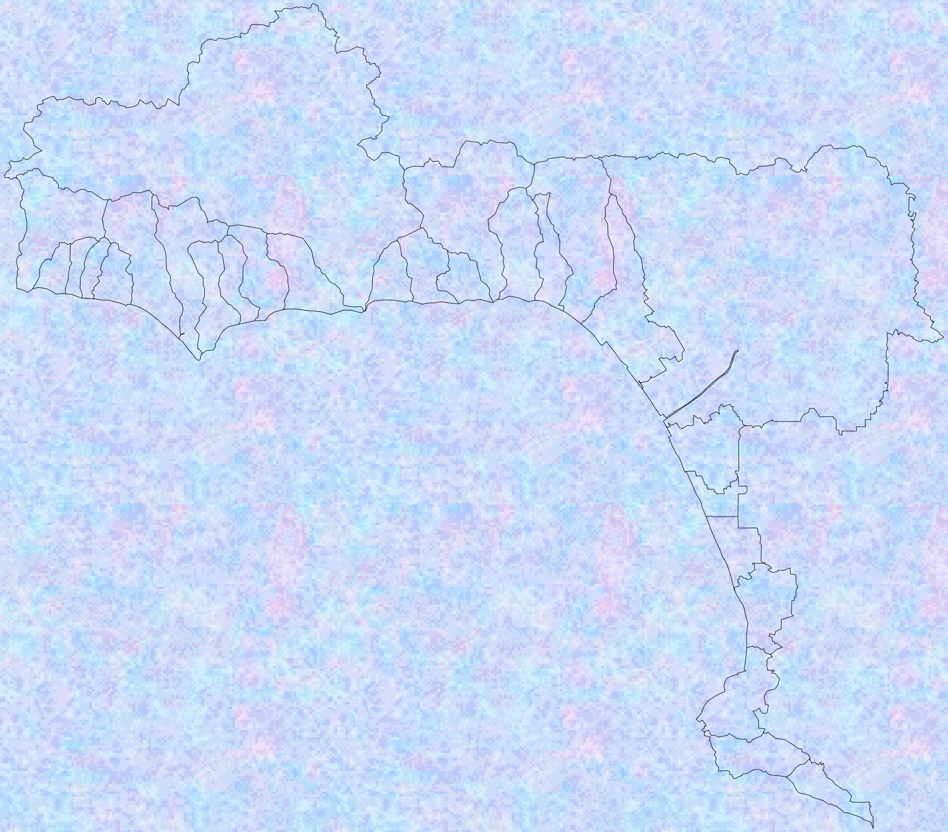
Basin Polygons



Model Calibration Using Ballona Creek

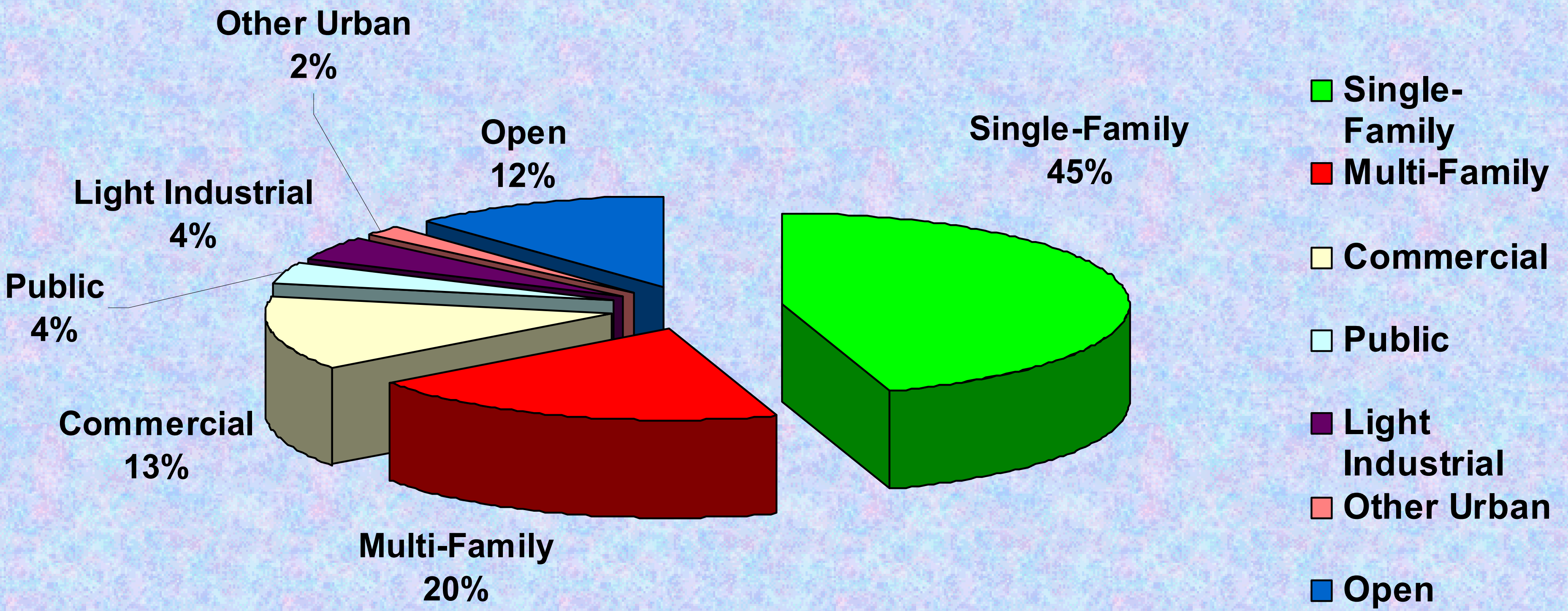
Total Area: 217 km^2 (84 mi^2)

Number of Storm Drains: 255

Number of Catch Basins/Manholes: 6600

Total Length of Storm Drains: 282.2 km (175.4 miles)

Land Use of Ballona Watershed



Ballona Watershed

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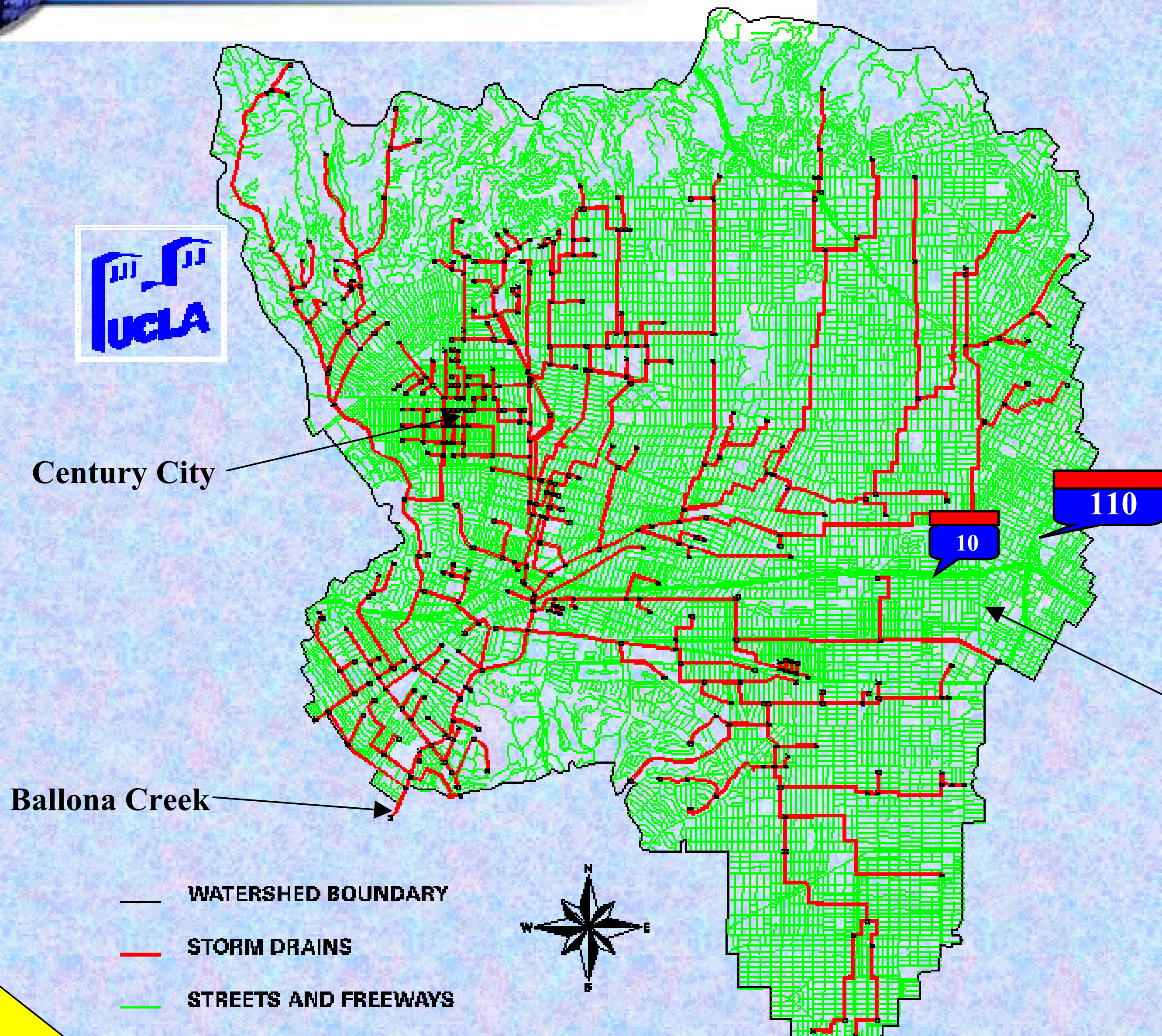

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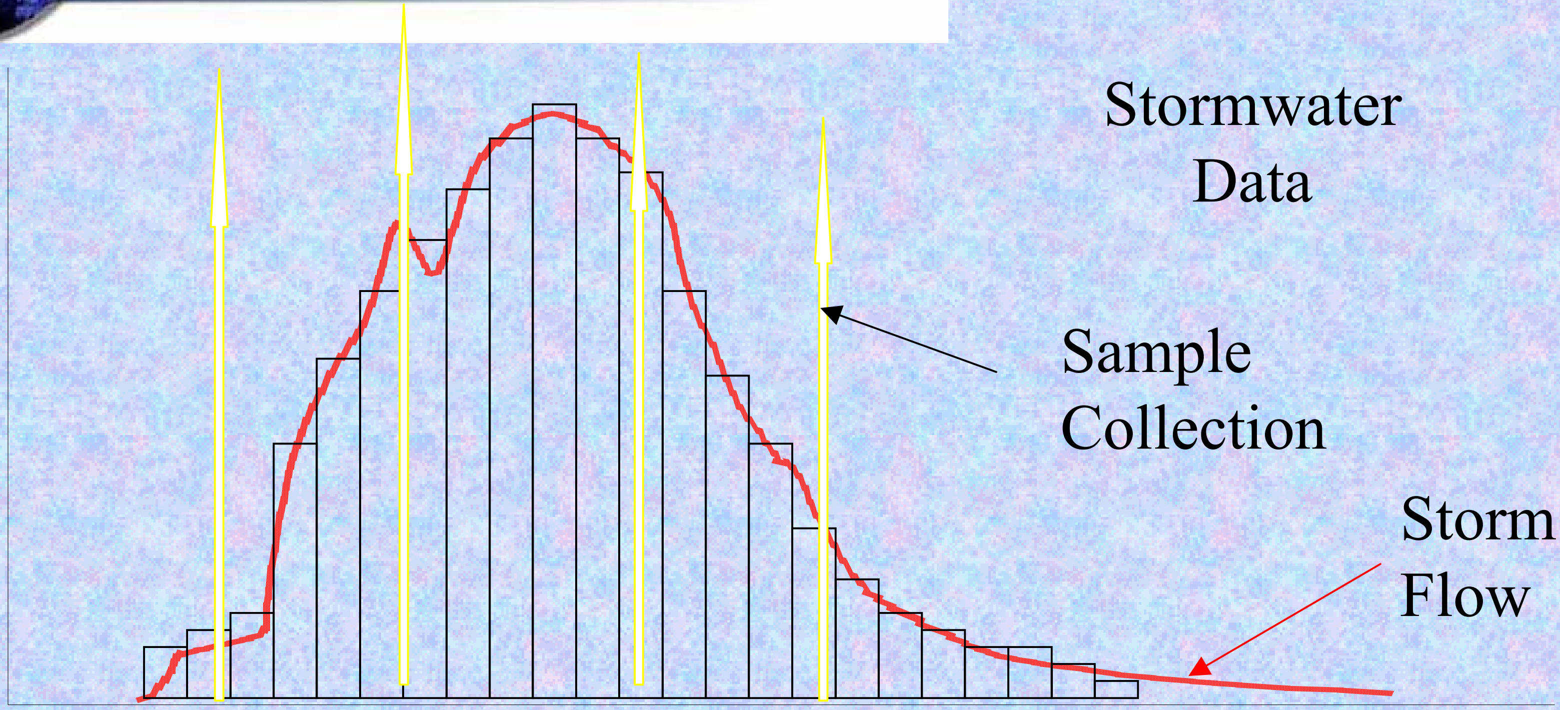
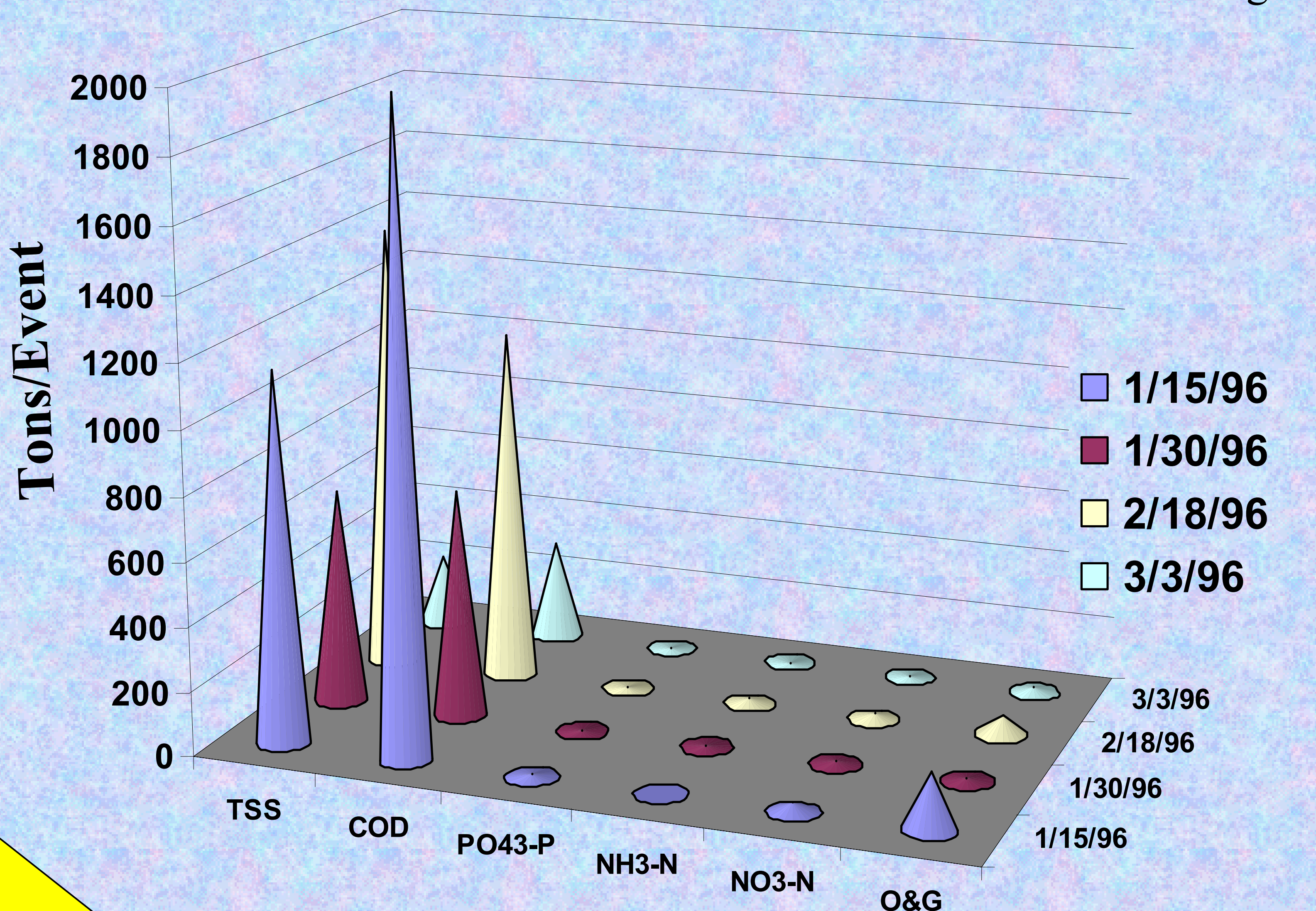


$$Total\ Mass\ Loadings = M_{t1}$$

$$= \int C(t)\ Q(t)\,dt$$

$$= \sum_k C_k \left(\sum_i Q_i \Delta t\right)$$

Mass Pollutant Loadings



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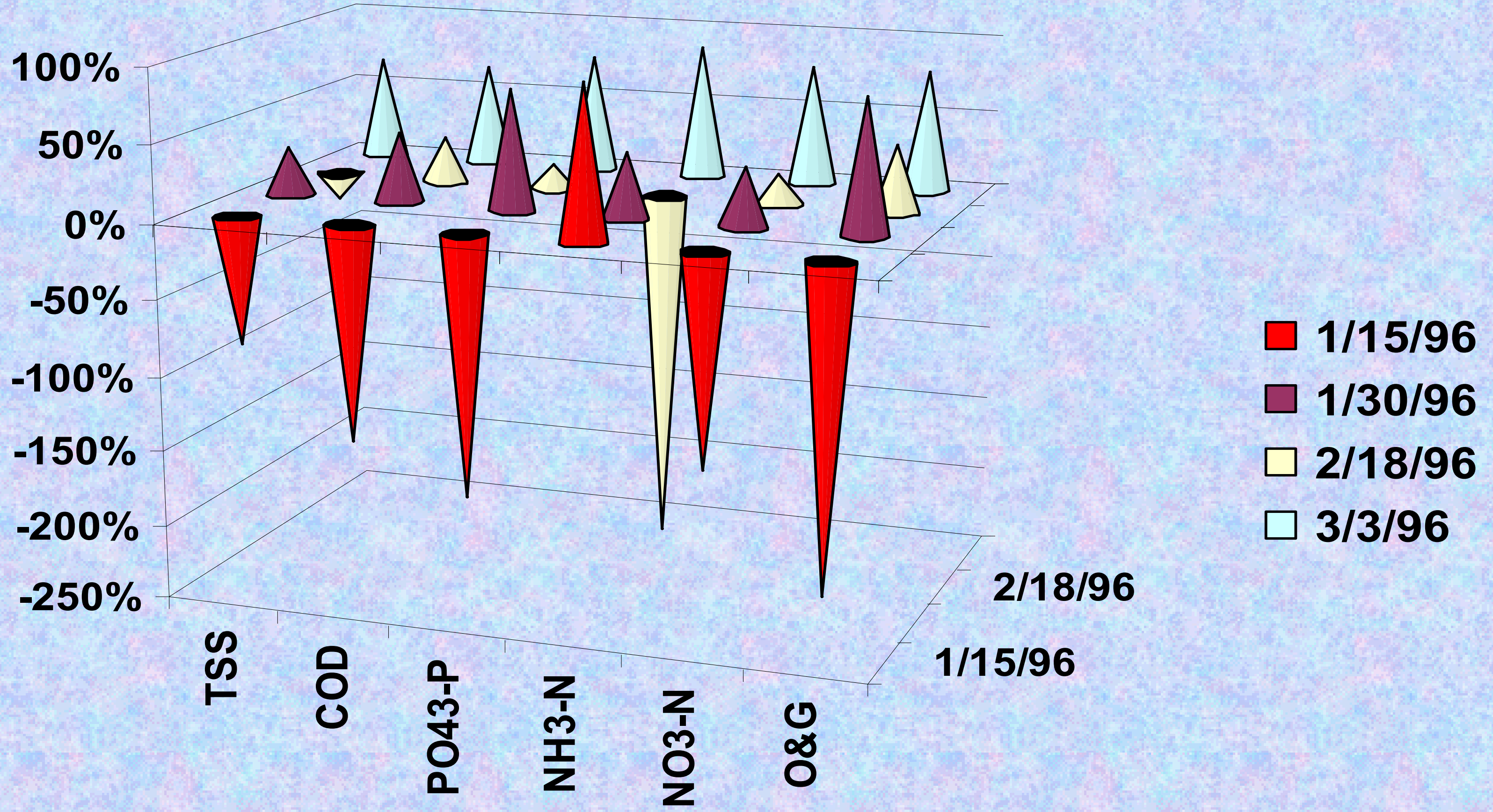
Error Analysis

Error (%) = (Loadings$_{calibration}$-Loadings$_{sample}$)/Loadings$_{calibration}$



What can you do with this?

- **Rank pollutants, find out pollutant origins.**
- **Compare nonpoint and point sources**
- **Simulate BMPs and growth**

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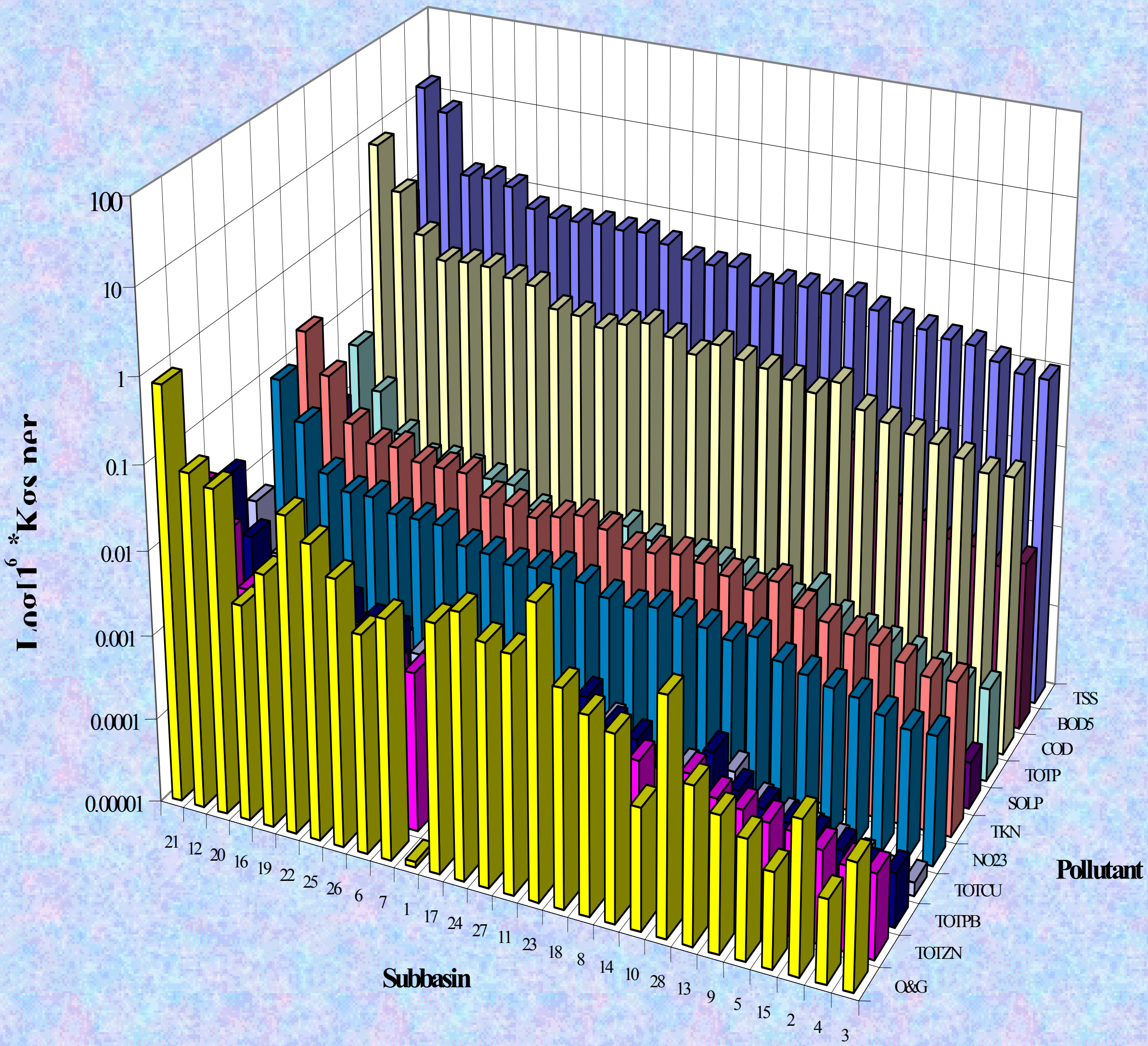
Annual Pollutant Loadings



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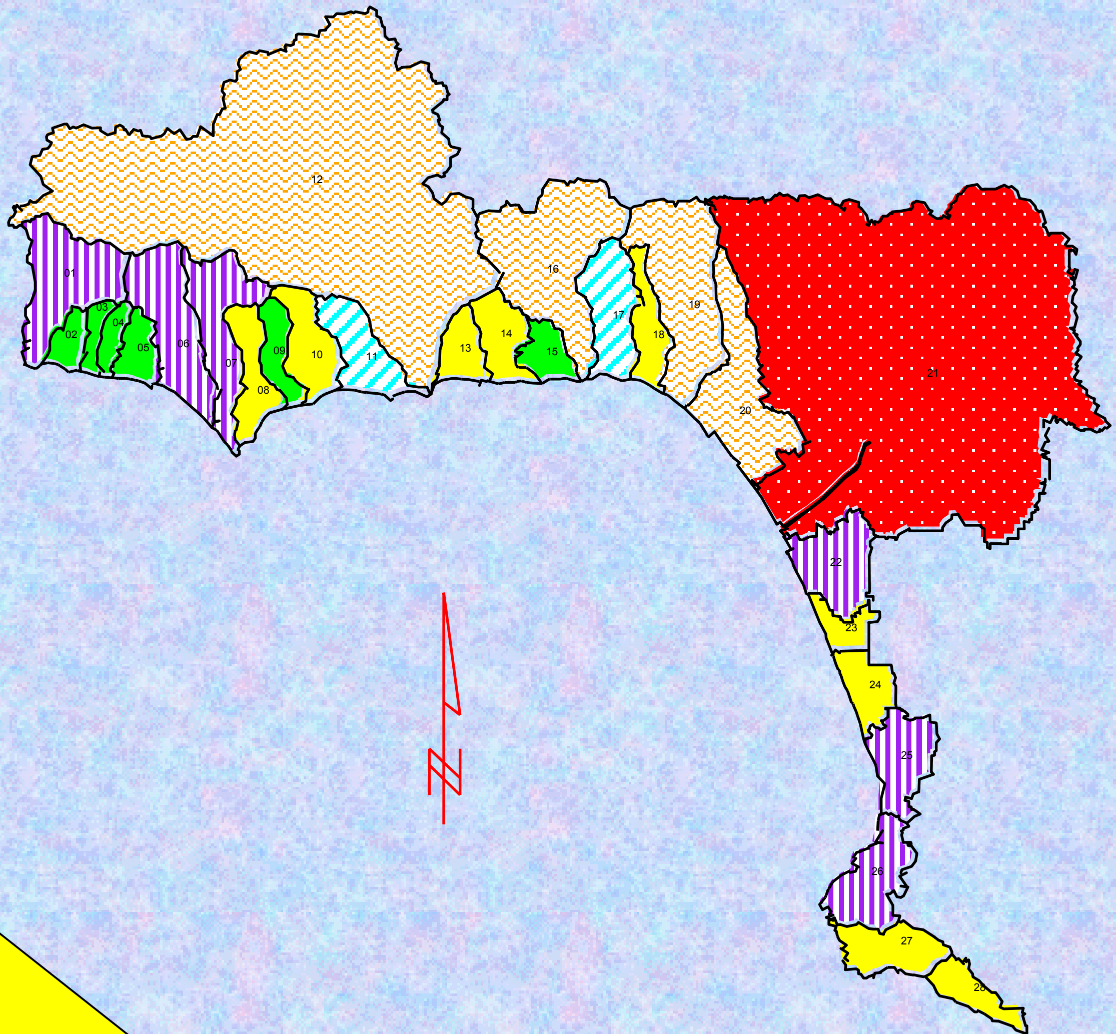
Drainage Basin Ranking by TSS Loadings



Ranking = 1

Ranking = 2

Ranking = 3

Ranking = 4

Ranking = 5

Ranking = 6

Basin Boundary

1=highest mass loading

Two Hypothetical BMPs
or **What if** ?

- Case One
  - 50% reduction in fertilizer for single and multiple family land uses
  - 50% reduction in oil & grease for commercial and industrial land uses

Assumption: 50% reduction in ME

- Case Two
  - Land use transformation (20% Open)

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Case One: Annual NO23 and O&G Loadings (MT/Yr)

	SMB		
	Before	After	Decrease (%)
NO23	182	133	26
O&G	1,336	1,103	17

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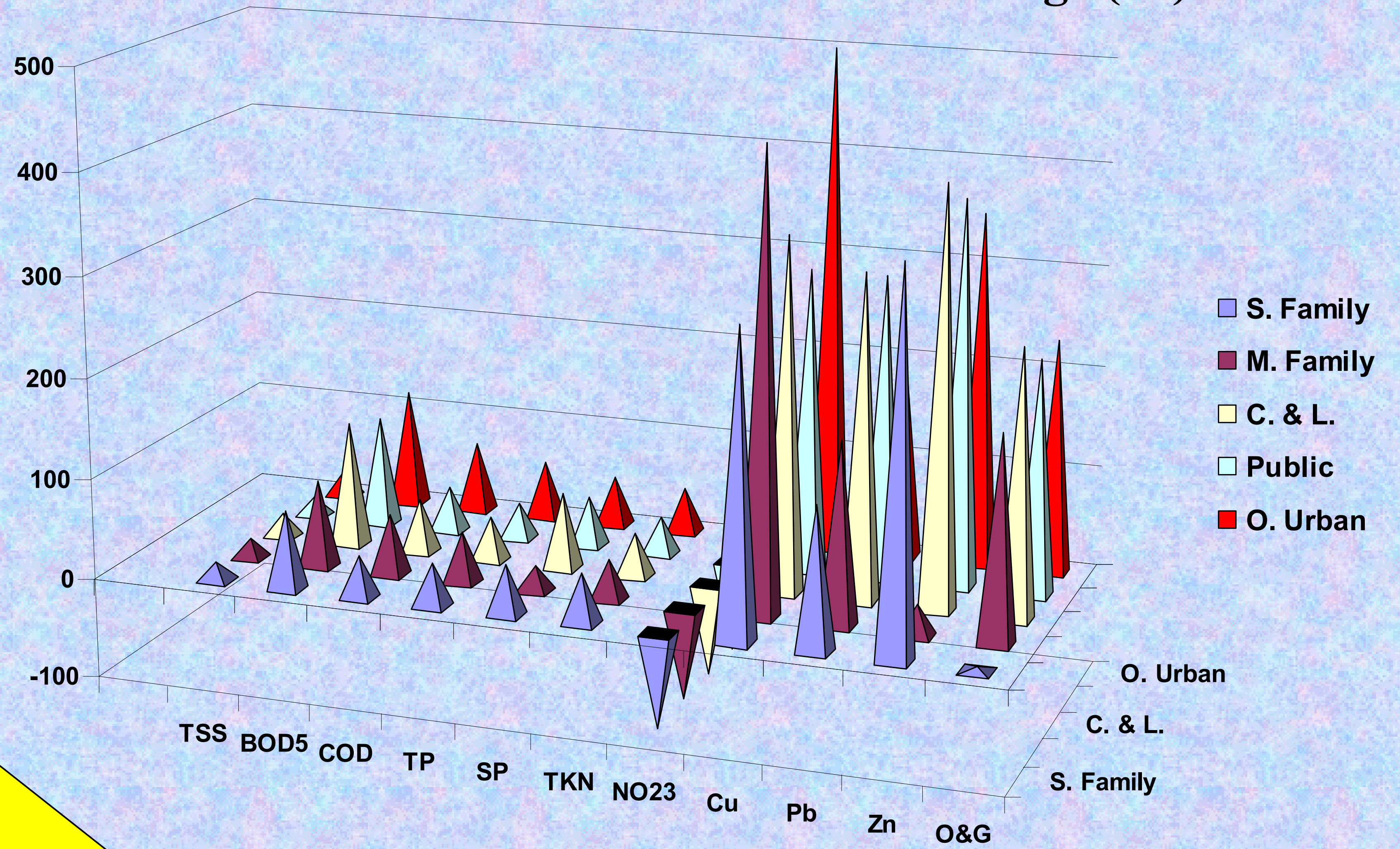
Increase(%) of Annual Loading in Subbasin 12 Landuse Transformation (20% Open)

Pollutant	S. Family	M. Family	C. & LI.	Public	O. Urban
TSS	18	20	23	19	25
BOD5	78	86	124	109	117
COD	41	60	53	45	70
TP	43	50	43	36	57
SP	50	25	75	50	50
TKN	50	40	43	37	46
NO23	-94	-91	-91	-91	-91
Cu	300	450	350	300	500
Pb	140	180	320	300	200
Zn	370	30	410	380	350
O&G	5	201	263	232	232

Increase of Annual Pollutant Loadings (%)



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Model Prediction vs. Hyperion Wastewater Treatment Plan

(30% secondary, MT/Yr)

Parameter	Model	HTP	T. Load	%NPS	
TSS	37,000	30,000	67,000	55	88
BOD	1,500	60,000	61,500	3	11
TP	80	1,500	1,580	5	7
NO2+NO3	180	250	430	42	47
Cu	10	30	40	25	44
Pb	37	22	59	63	80
Zn	54	90	144	38	59
O&G	1,200	7,800	9,000	13	50

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Final Remarks

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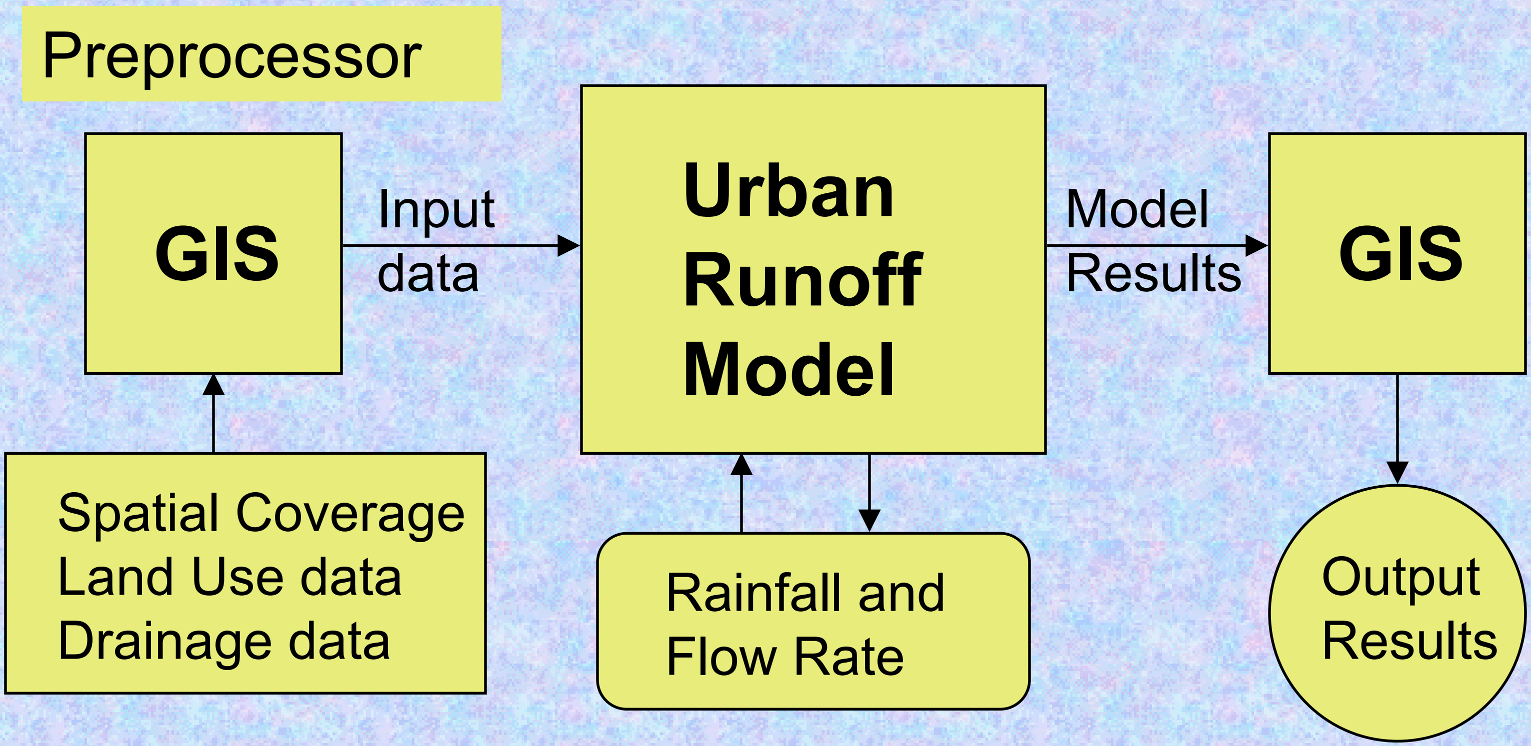
Second Generation Model



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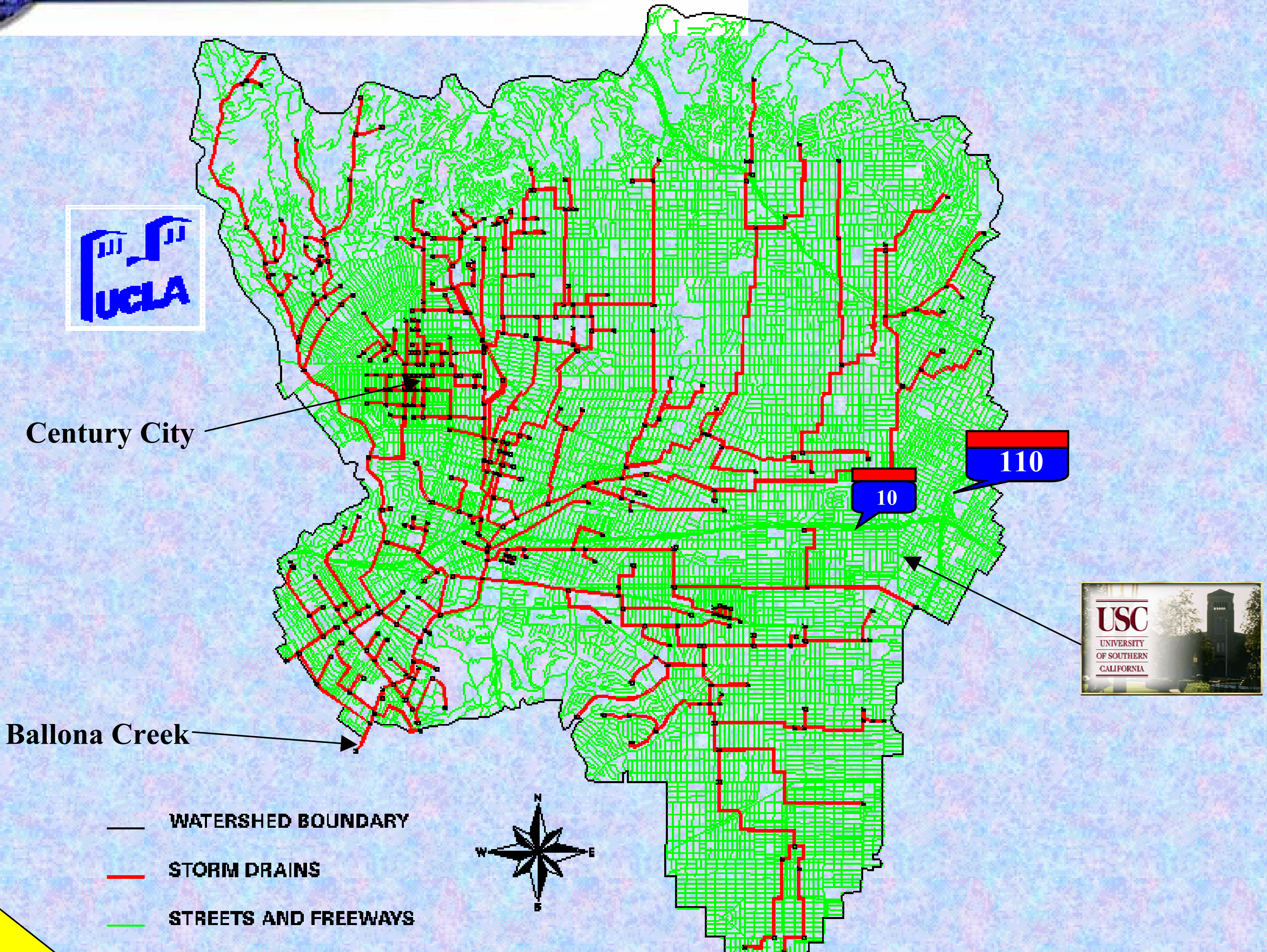
Ballona Watershed



Modeling Approach

- Preprocessor (GIS/Scripting Language)
  - Convert GIS Spatial Coverage and Attribute data to ASCII Input data set
- Urban Runoff Model (SWMM)
  - Use the ASCII Input data set
- Model Calibration
  - Rainfall and Stream Flow from the Outlet gage station
- Postprocessor (GIS/Scripting Language)
  - Convert Model Results to Graphical Displays within GIS

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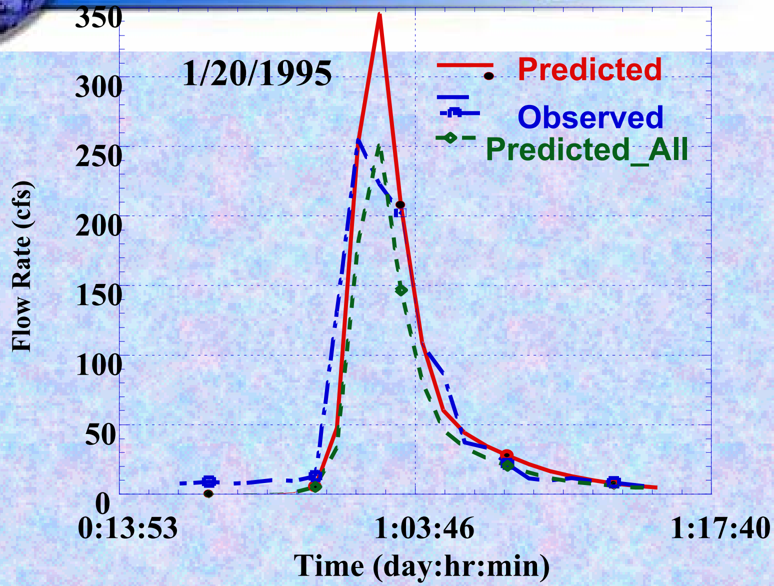

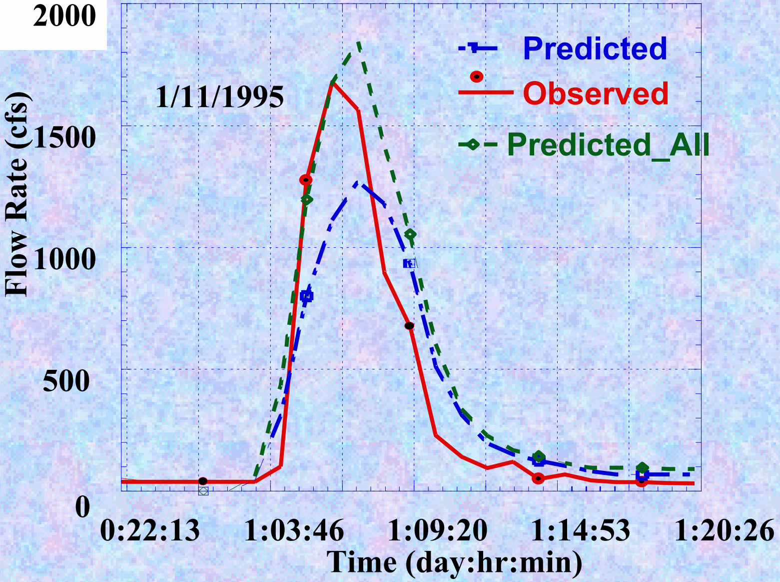

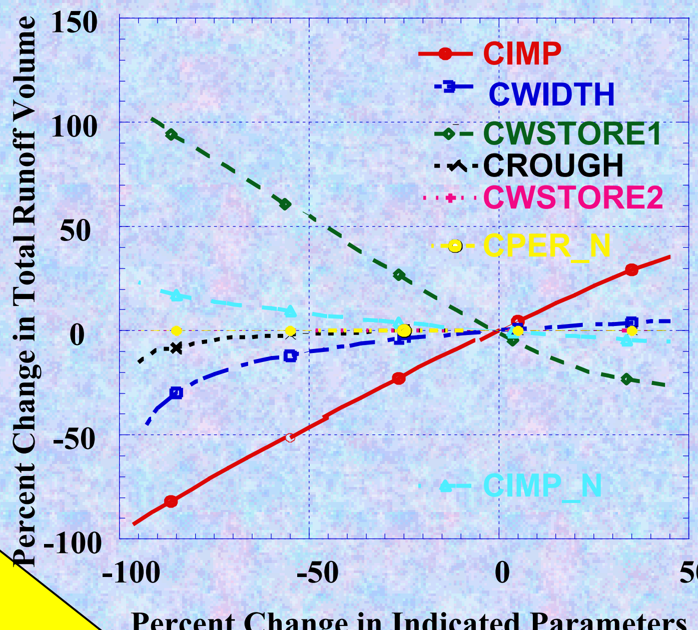

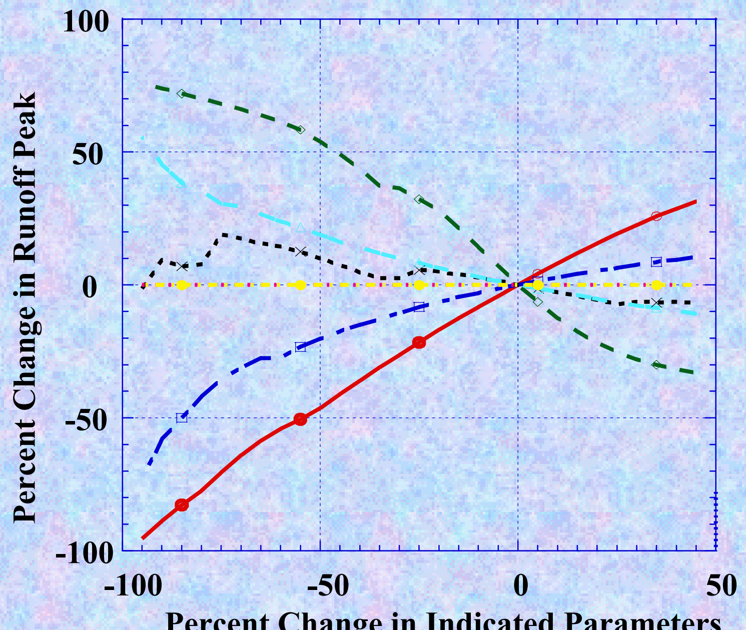

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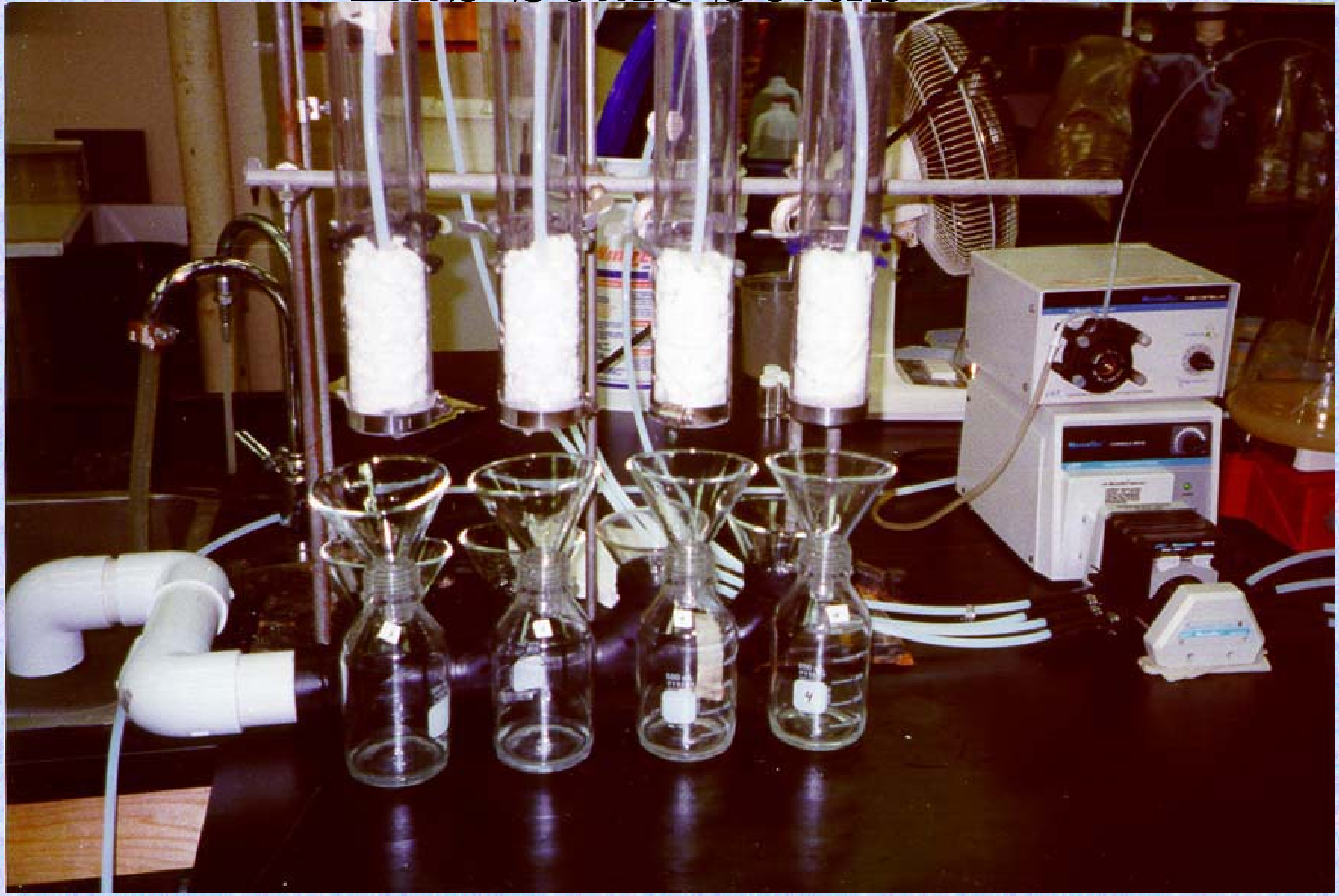
Some New Ideas for BMPs

- Boardover and Flat Screens
- Catch Basin Inserts
- Special Screens
- Bioinfiltration

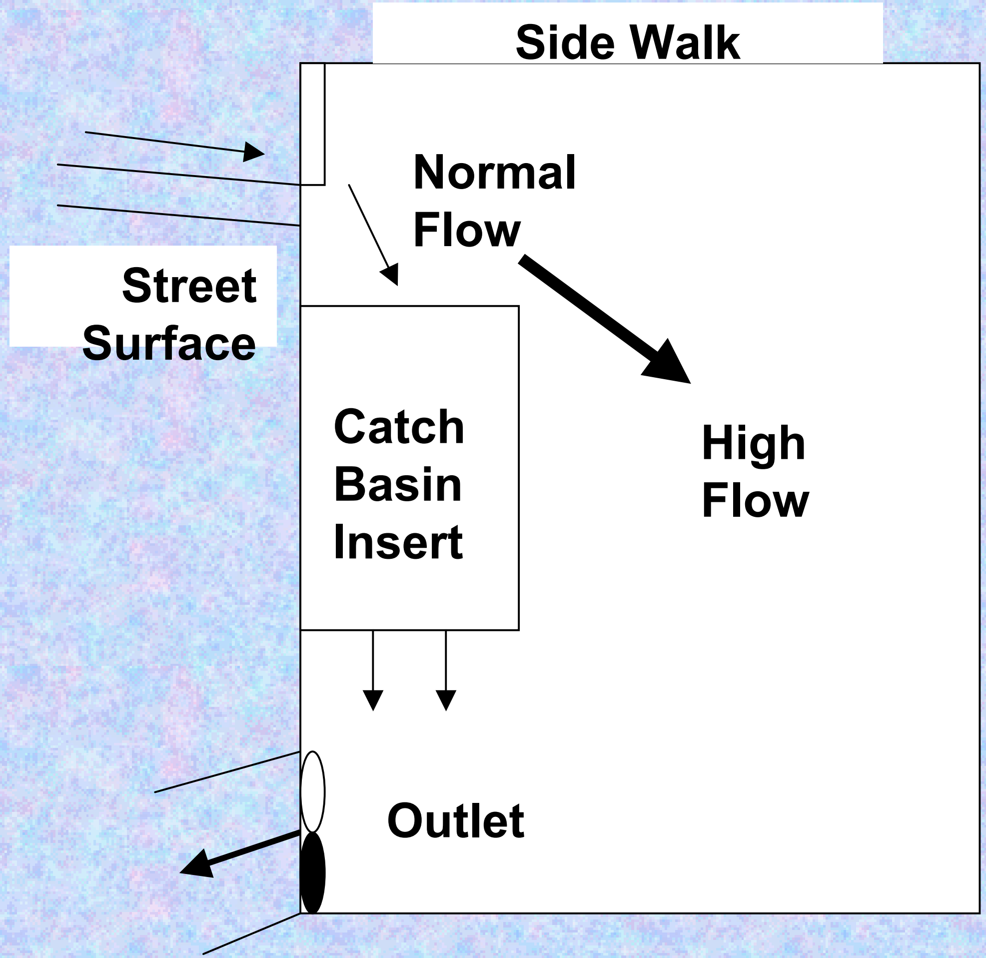
Lab Scale Setup



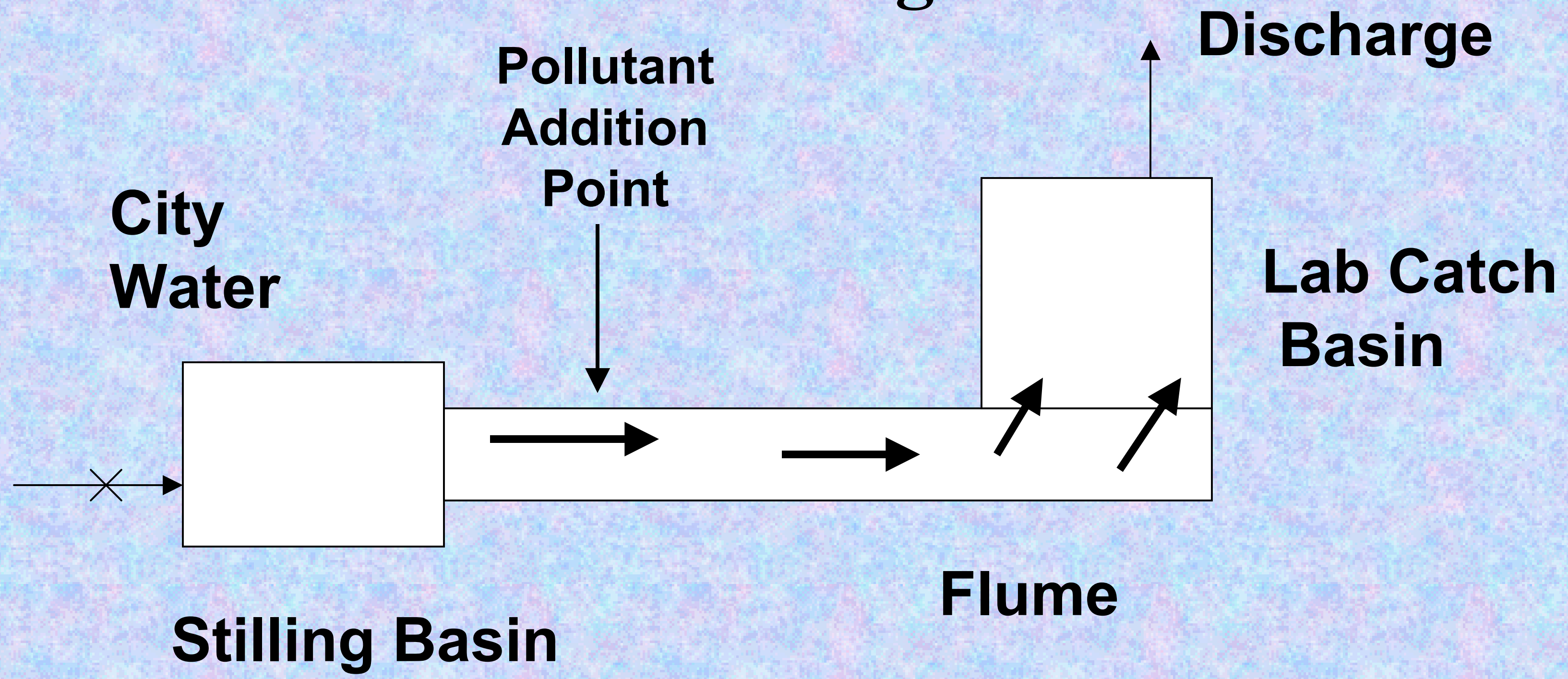
Lab Scale Results

Sorbent Type	Oil and Grease Type	Removal Efficiency (%)
Activated Carbon	Emulsified	11
Aluminum Silicate (e.g., Perlite, Xsorb, straw, compost, OARS)	Emulsified	0-3
OARS Polymer	Free	88, 91
Aluminum Silicate (e.g., Perlite, Xsorb)	Free	88,91,94,89
Compost	Free	28,49
Polypropylene (type 1 & 2)	Free	86,92, 78,85

General Insert Sketch



Schematic Diagram



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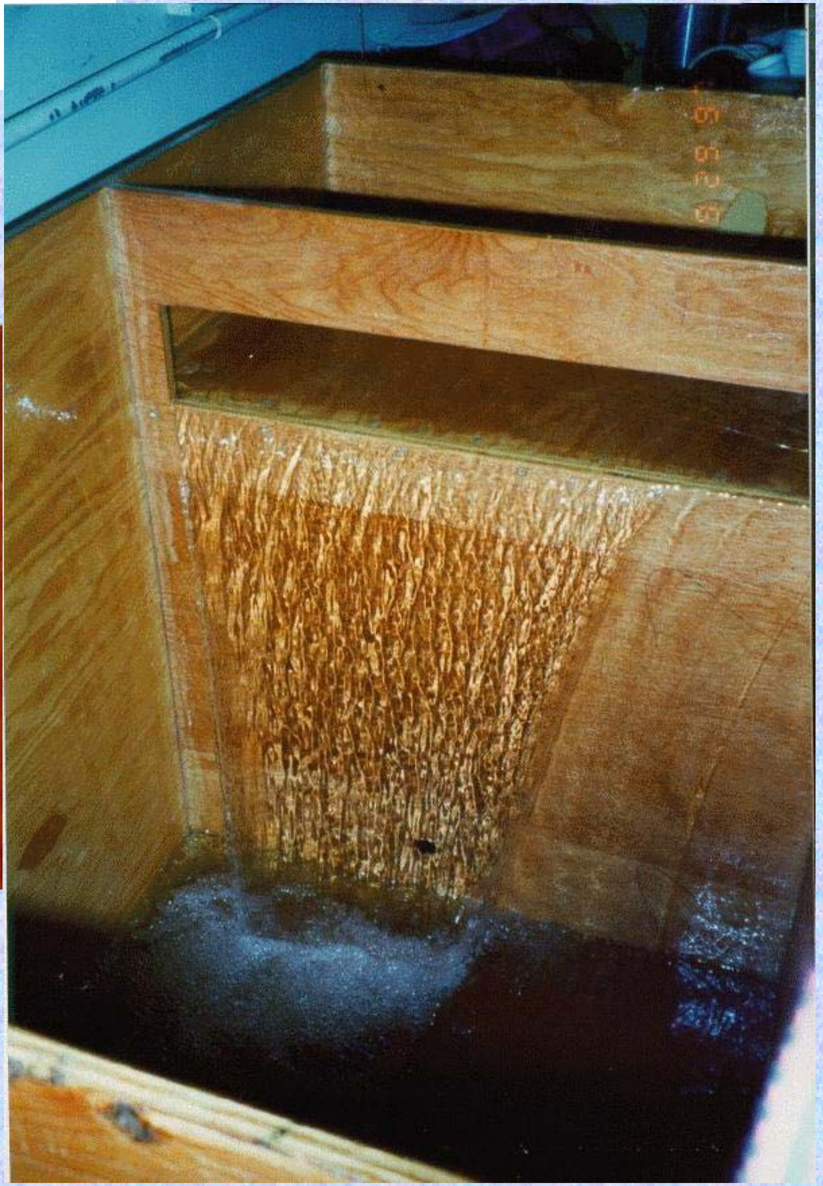
Simulator

Simulator



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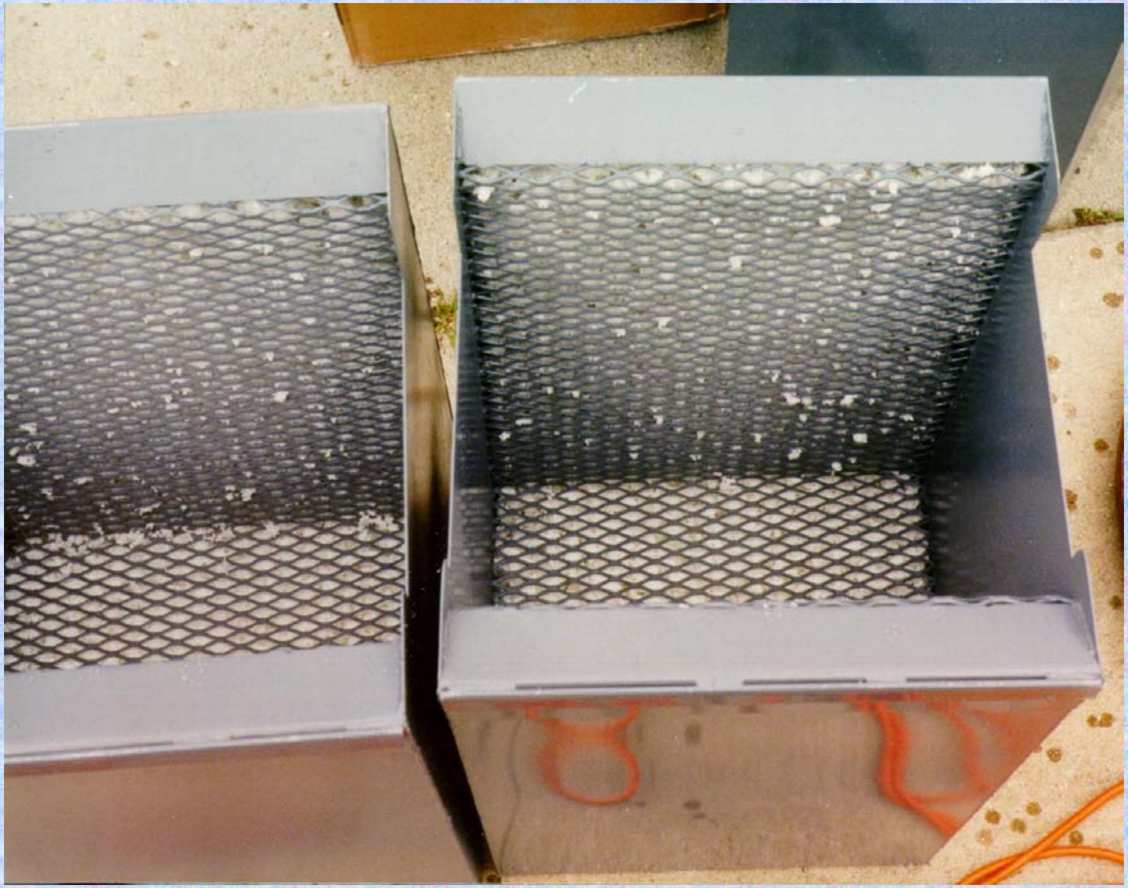
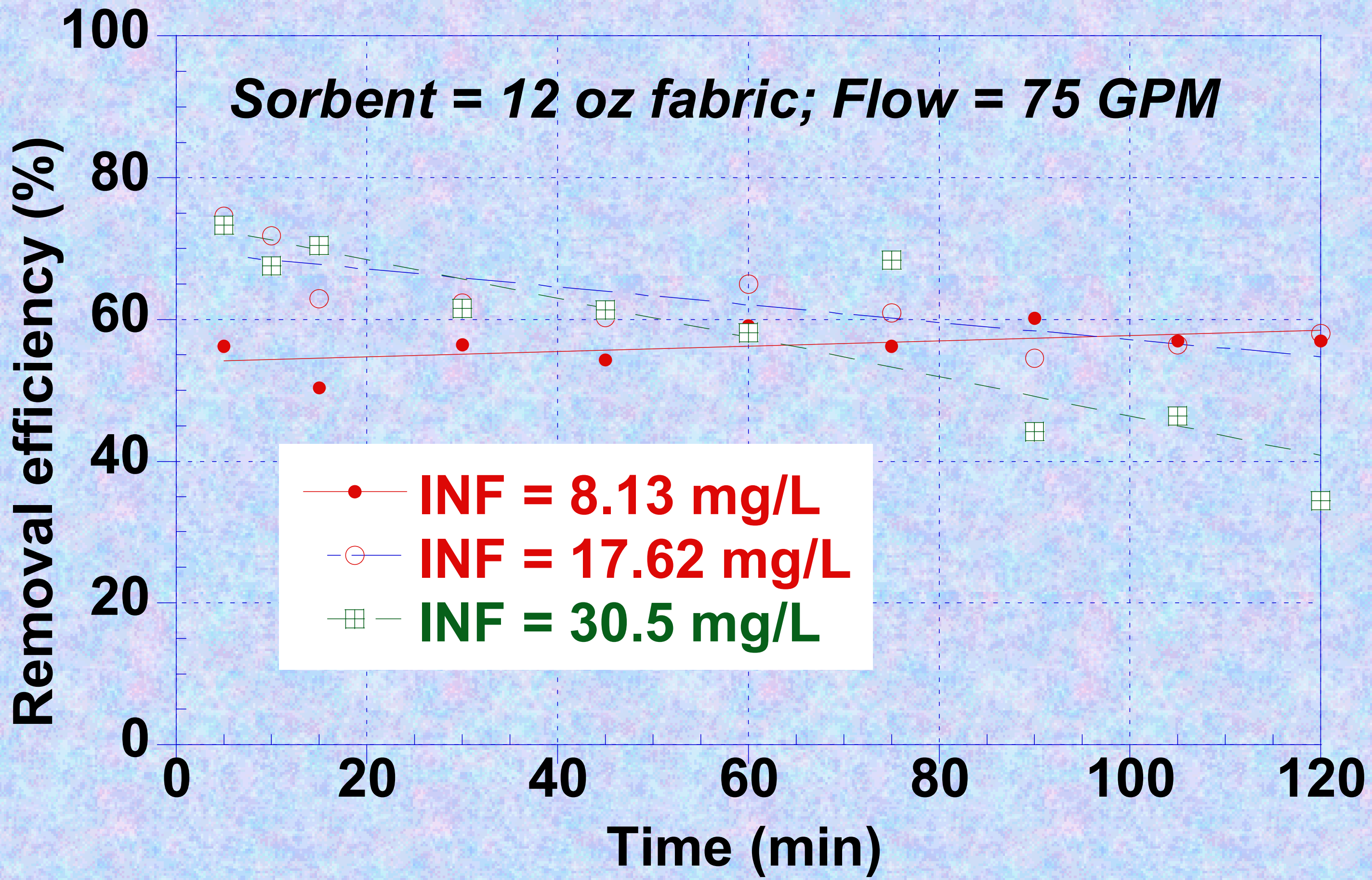
Polypropylene - United Pumping

AbTech New



United - Influent Conc



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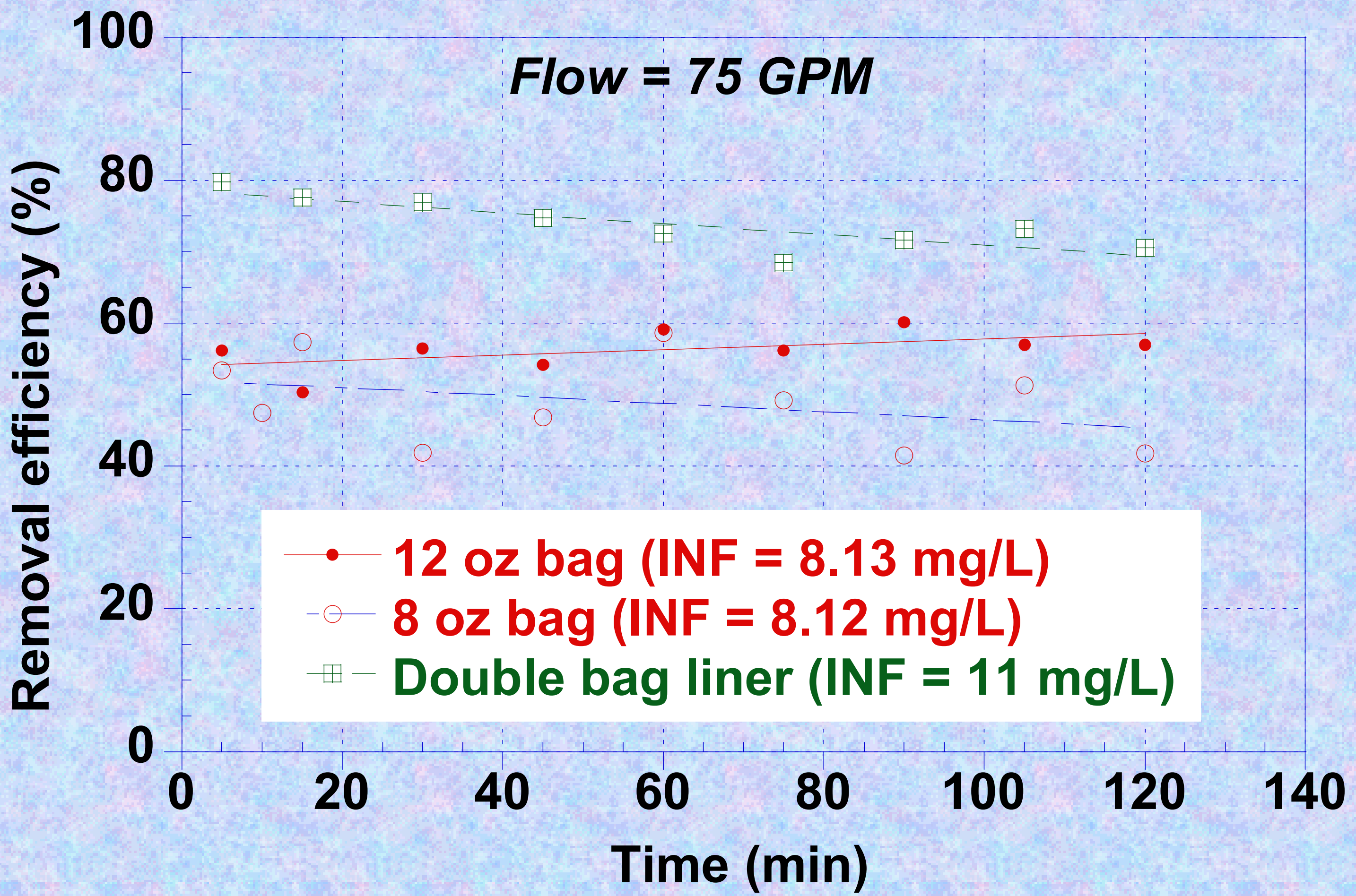
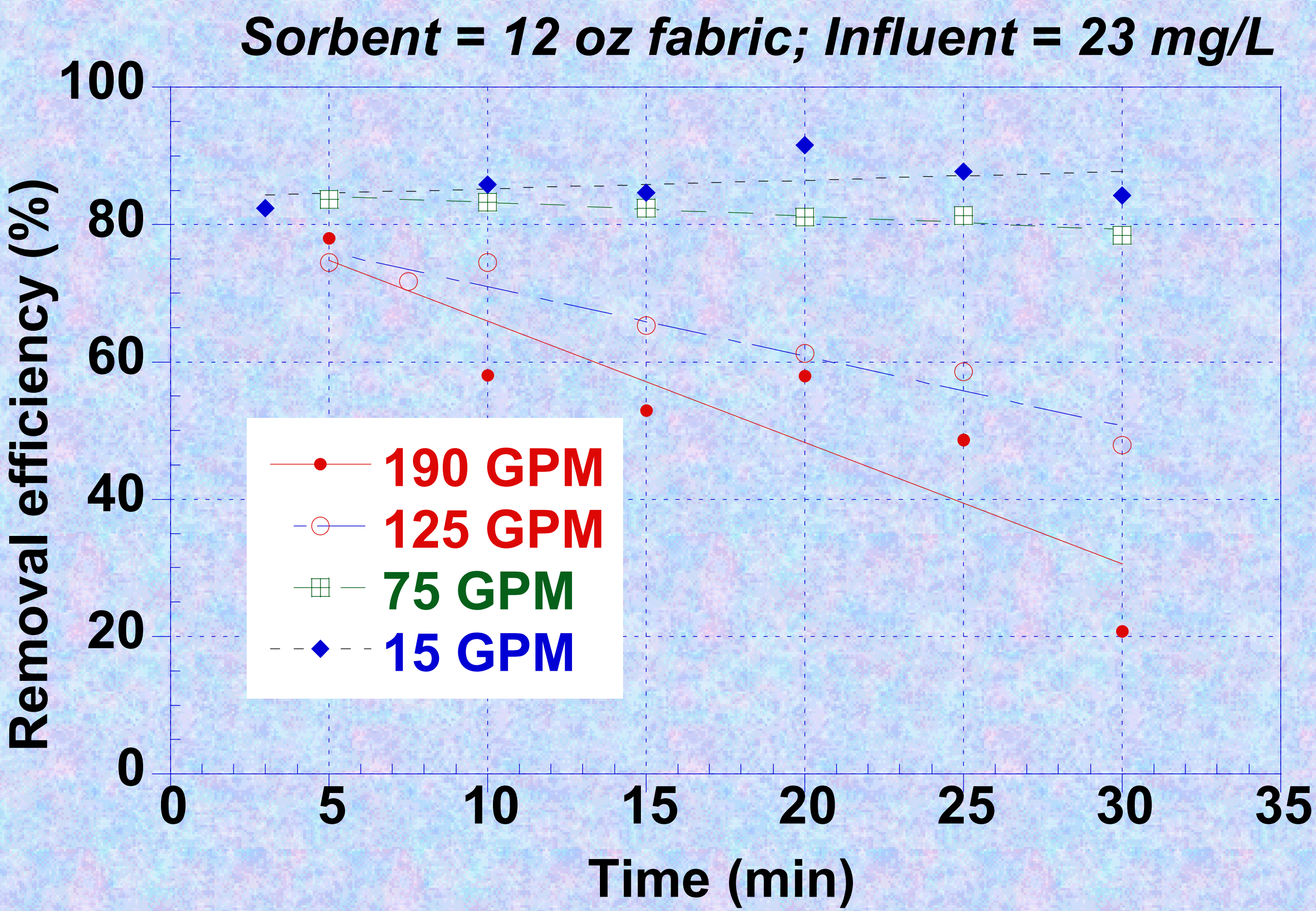
United - Influent Conc



United - Influent Flow Rate



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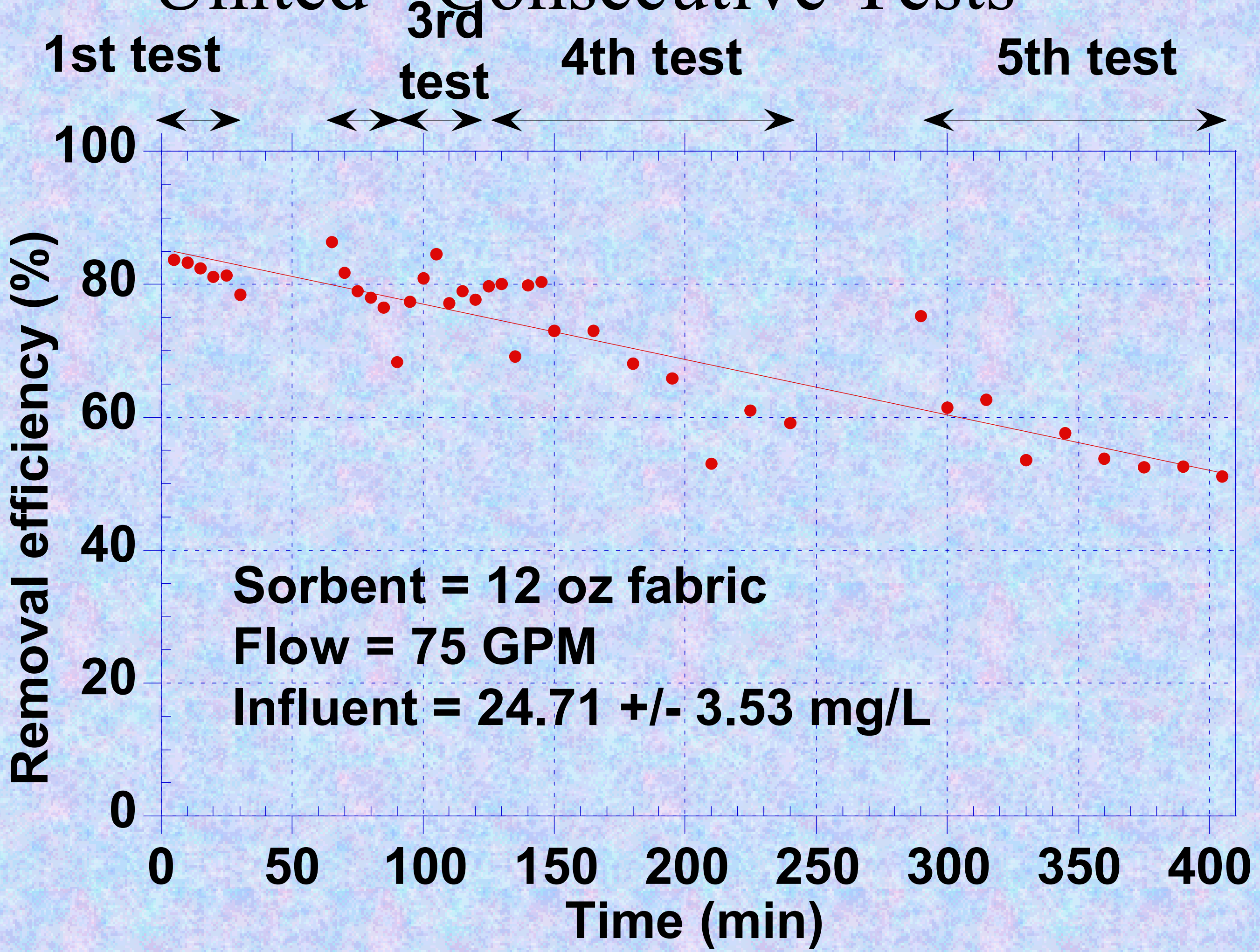
United - Consecutive Tests



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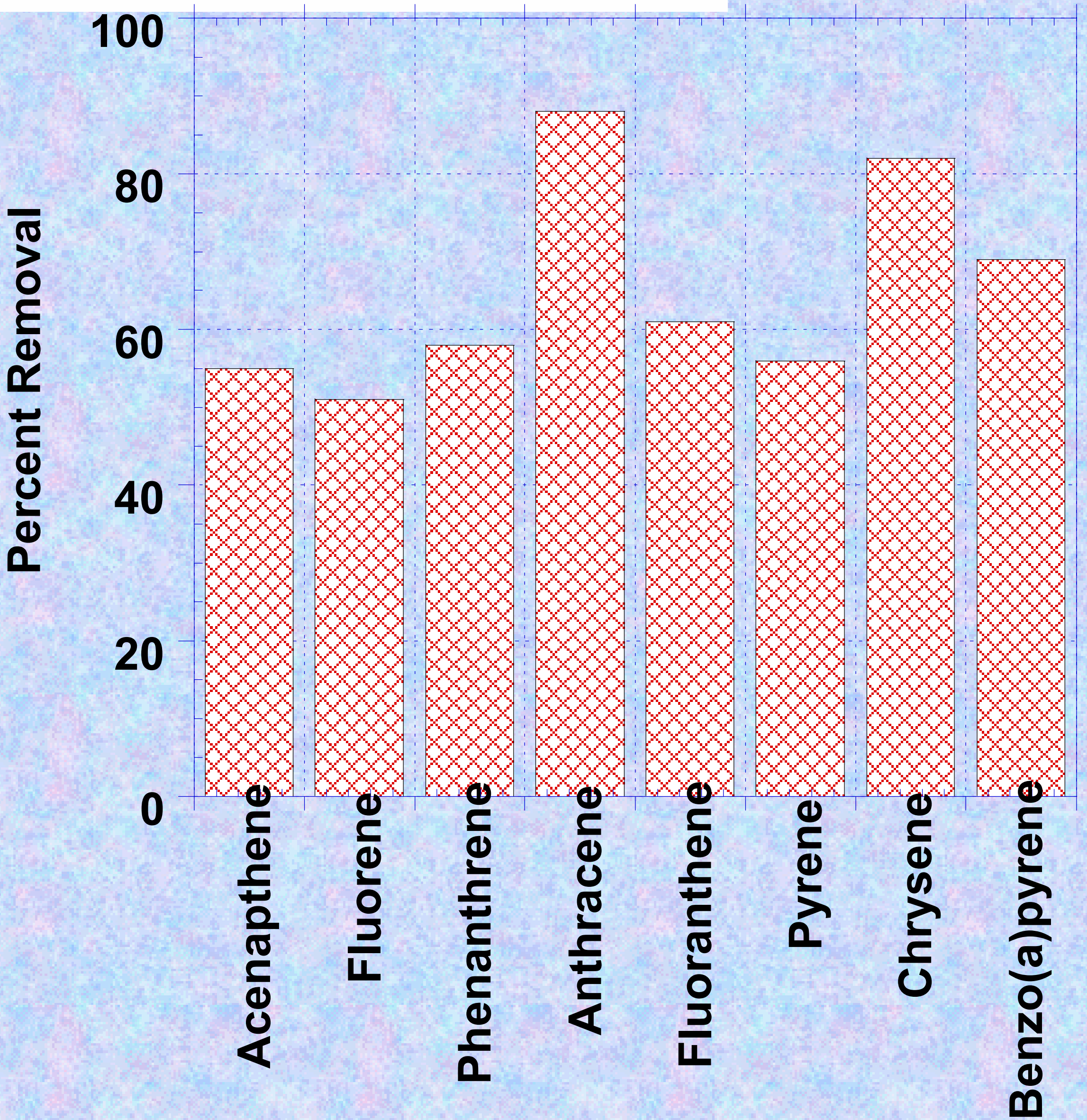
United - PAHs



AbTech Results - Influent Conch

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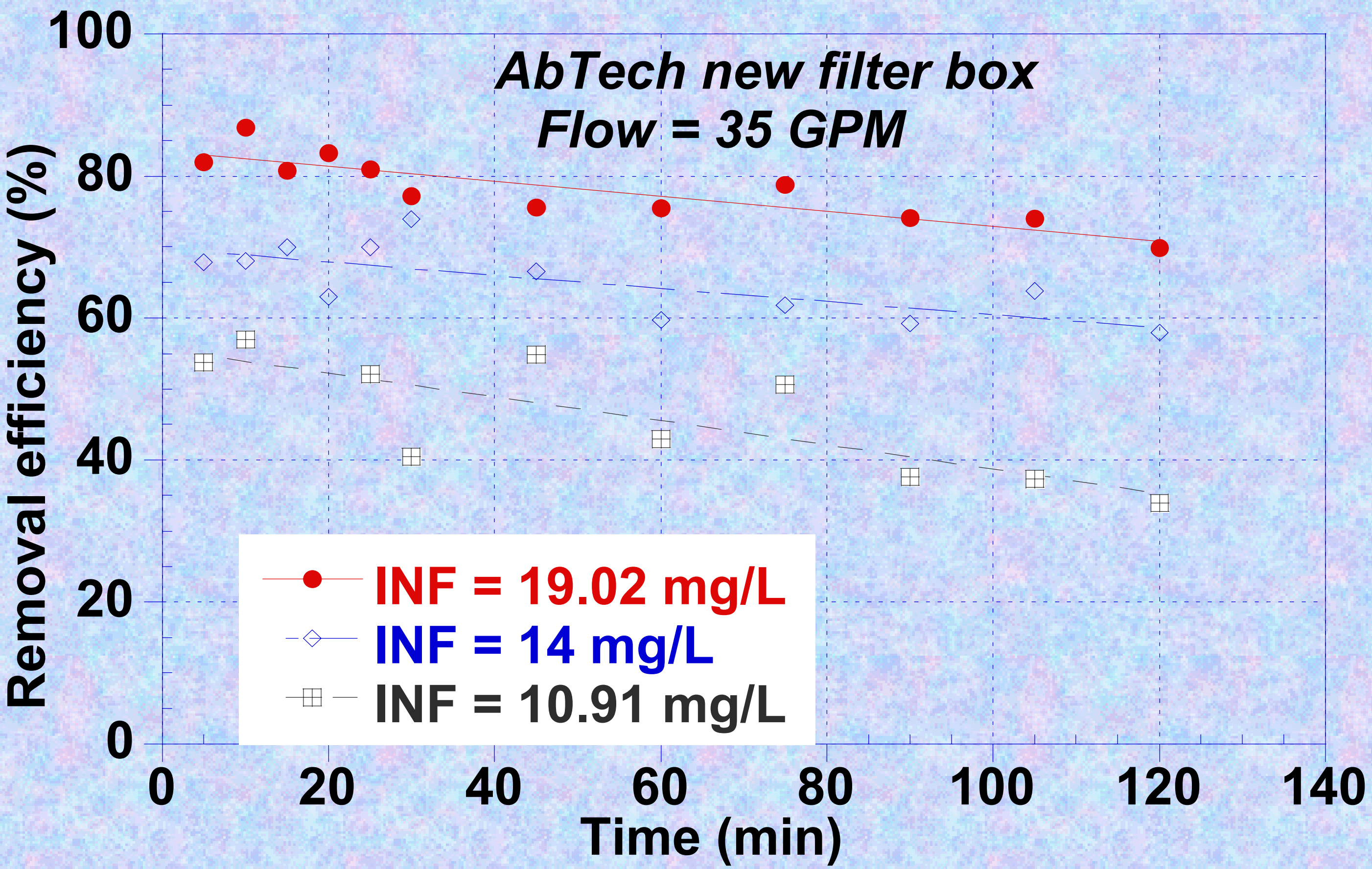

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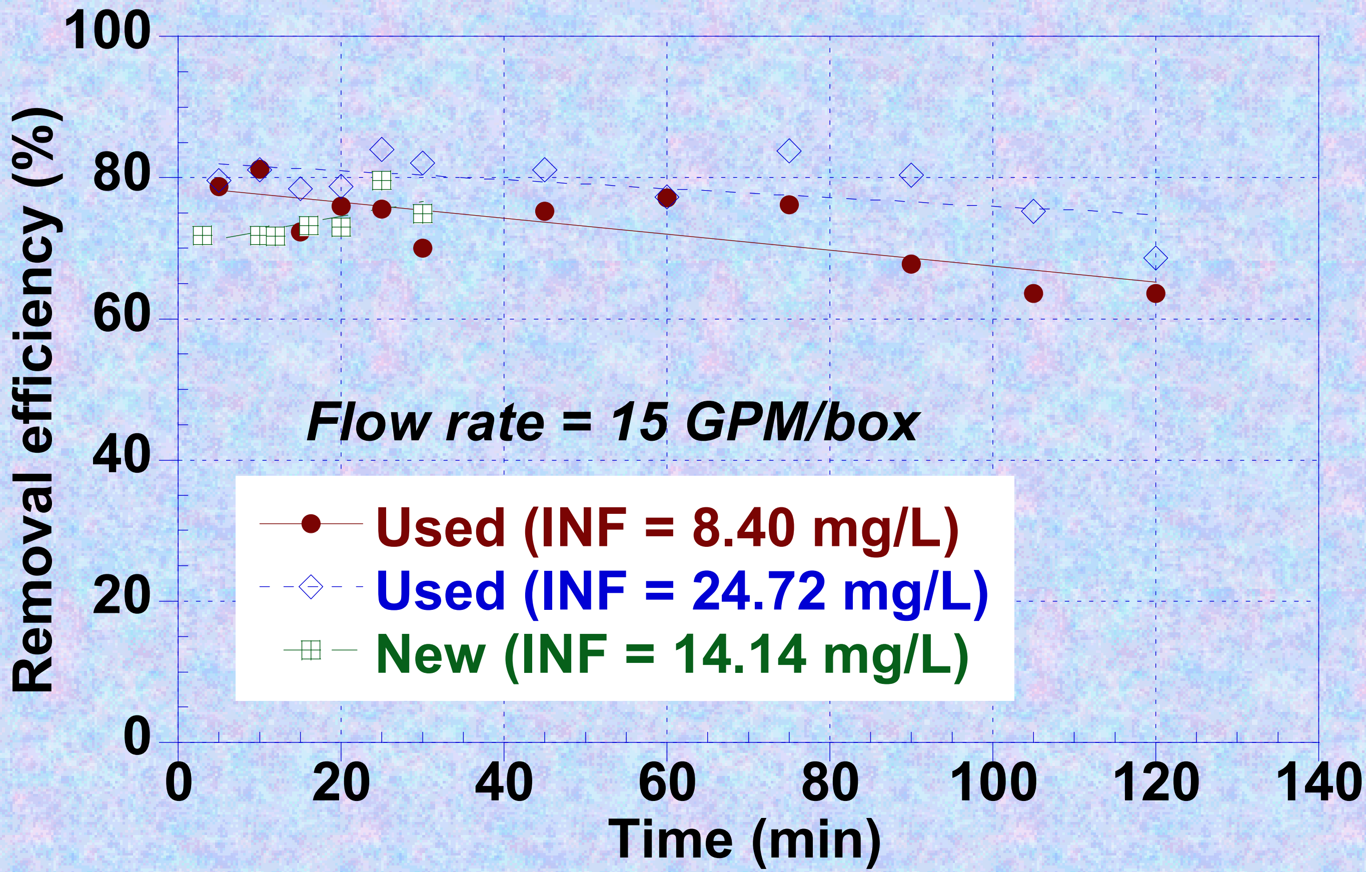
AbTech Results - New vs Used



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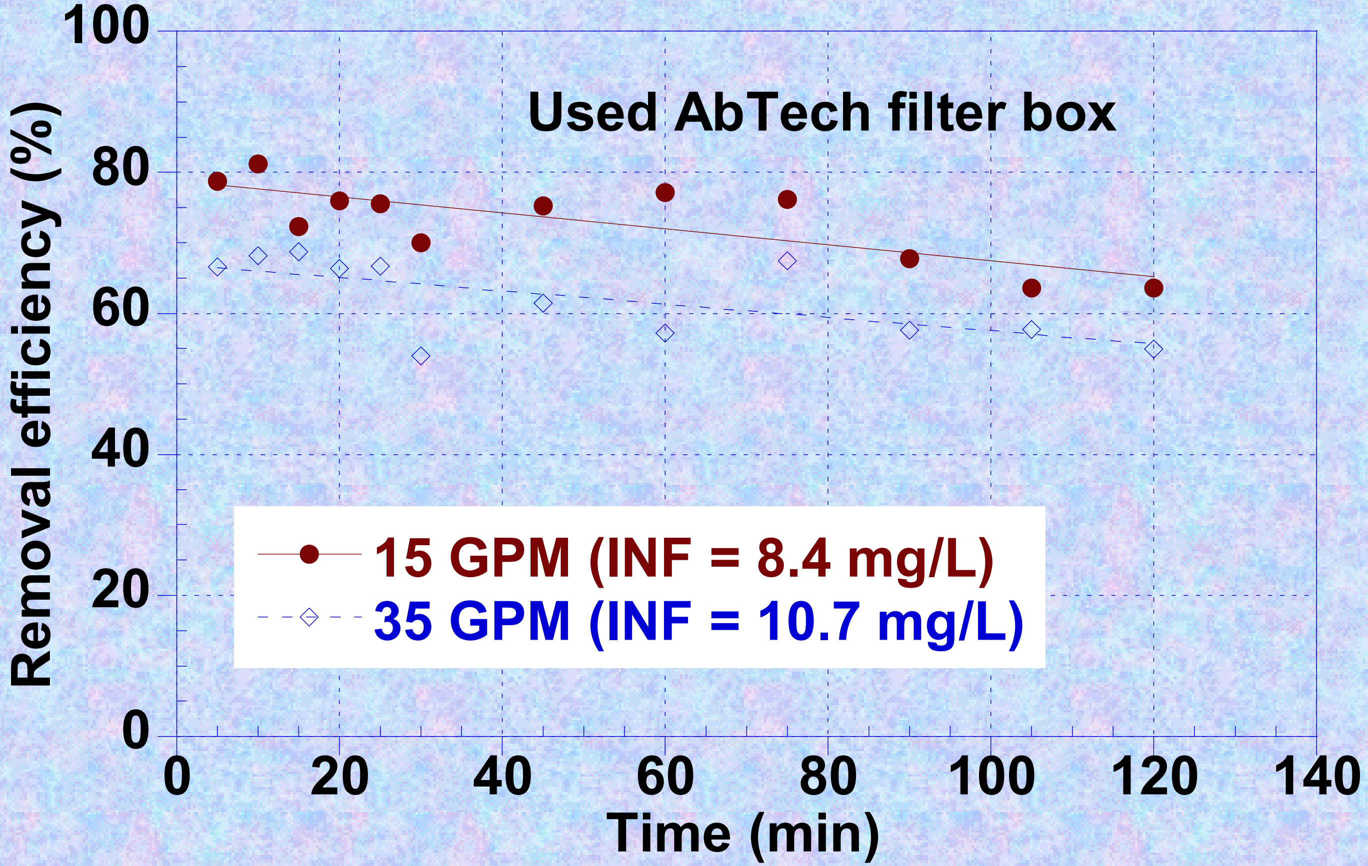
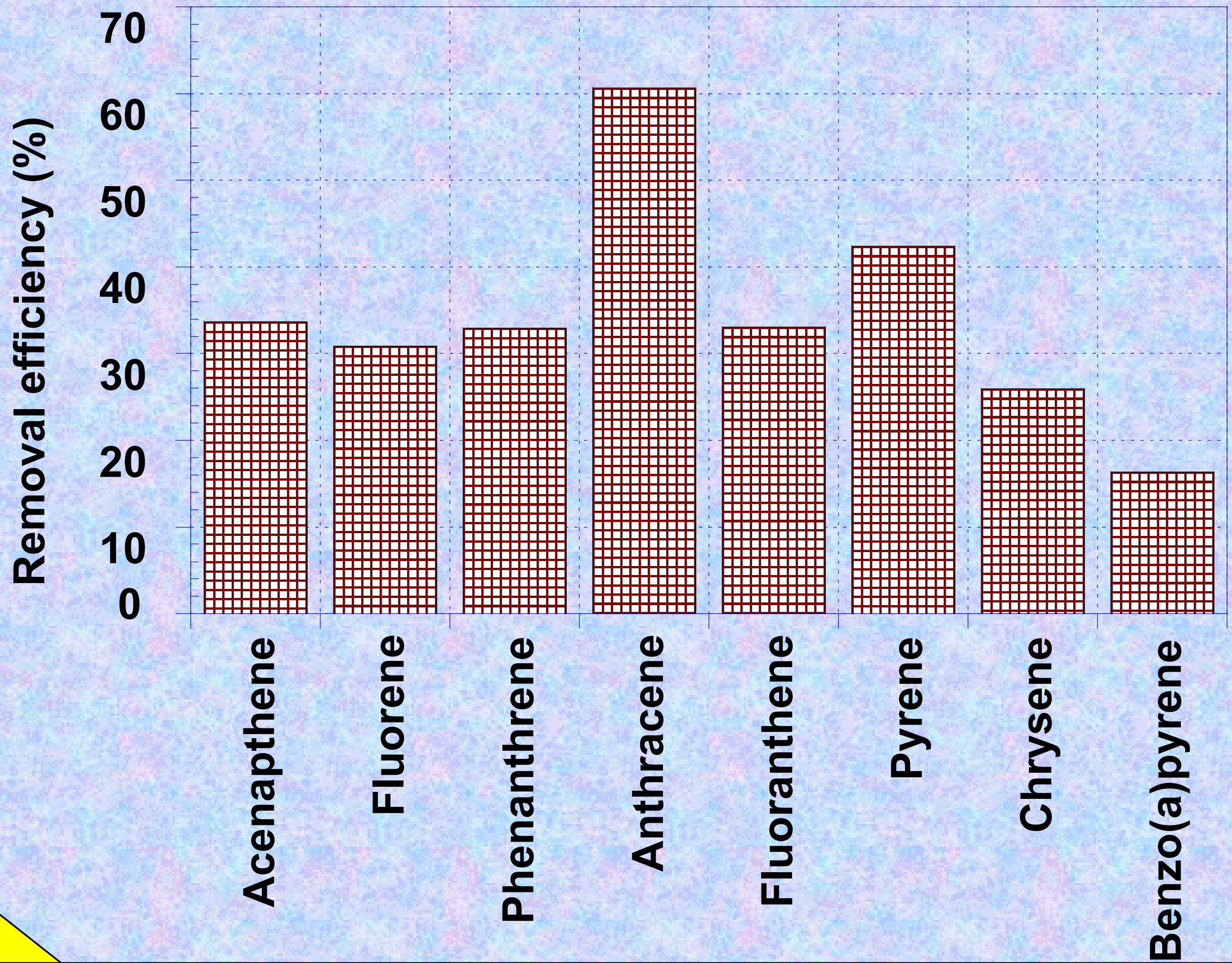
AbTech Results - used box



AbTech Results - PAHs

Nominal influent concentration = 50 ppb

AbTech new filter box (with bottom blocked); Flow = 35 GPM



Catchbasin Analysis

Table CB-2.	**Estimated Number of Catch Basin Associated with the Corresponding Land Uses in the Santa Monica Bay Watershed**	
Land Use	Area (acres)	Estimated Number of Catch Basins
Single family	64,500	6,694
Multi-family	19,942	4,114
Commercial	12,113	3,586
Light Industrial	5,486	1,008
Totals of above Land Uses	102,041	15,401

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Catchbasin Design Factors

- Catchbasins in Southern California are typically sized on opening length, not on volume.
- Opening length is a function of slopes and drainage area as it effects gutter velocity and side channel spillway design.
- High calculated gutter velocity lead to long below ground chambers (up to 28 feet).
- Chamber volume is then a function of standard depth and width applied to the calculated length.
- Sometimes depth is extended to allow easier connection to pipe system.
- Therefore, below ground chambers volumes are often very over designed and excess volume should be available for retrofits.

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Catchbasin Retrofit Potential for Trash and Debris Removal

Table 5-5 Analysis of Potential Trash/Debris Retofits of Catchbasins

	Land Use/Trash Loading Percentages:								
	Single Family	Multi-Family	Commercial	Public	Light Industrial	Other Urban	Open	Unknown	Total
Land Use as a Percent of Total	24.4%	7.5%	4.6%	2.4%	2.1%	2.7%	56.5%	0.01%	100%
Land Use as a Percent of Developed Area	56.1%	17.2%	10.6%	5.5%	4.8%	6.2%	0.0%	0.02%	100%
Trash Factor	1	1	3	1	1	1	0	1	
Estimated Trash Production*	46.1%	14.2%	26.1%	4.5%	4.0%	5.1%	0.0%	0.02%	100.0%

*Expressed as a percentage of total trash discharged from stormwater systems

Potential Catchbasin Retrofit Potential for Trash and Debris Removal

Catch Basins Retrofit (%)	Trash Removal (%)	Reduction from Commercial Areas	Trash Reduction (% of total)	Number of Retrofits
90	80	72%	19%	3227
50	80	40%	10%	1793

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Boardovers

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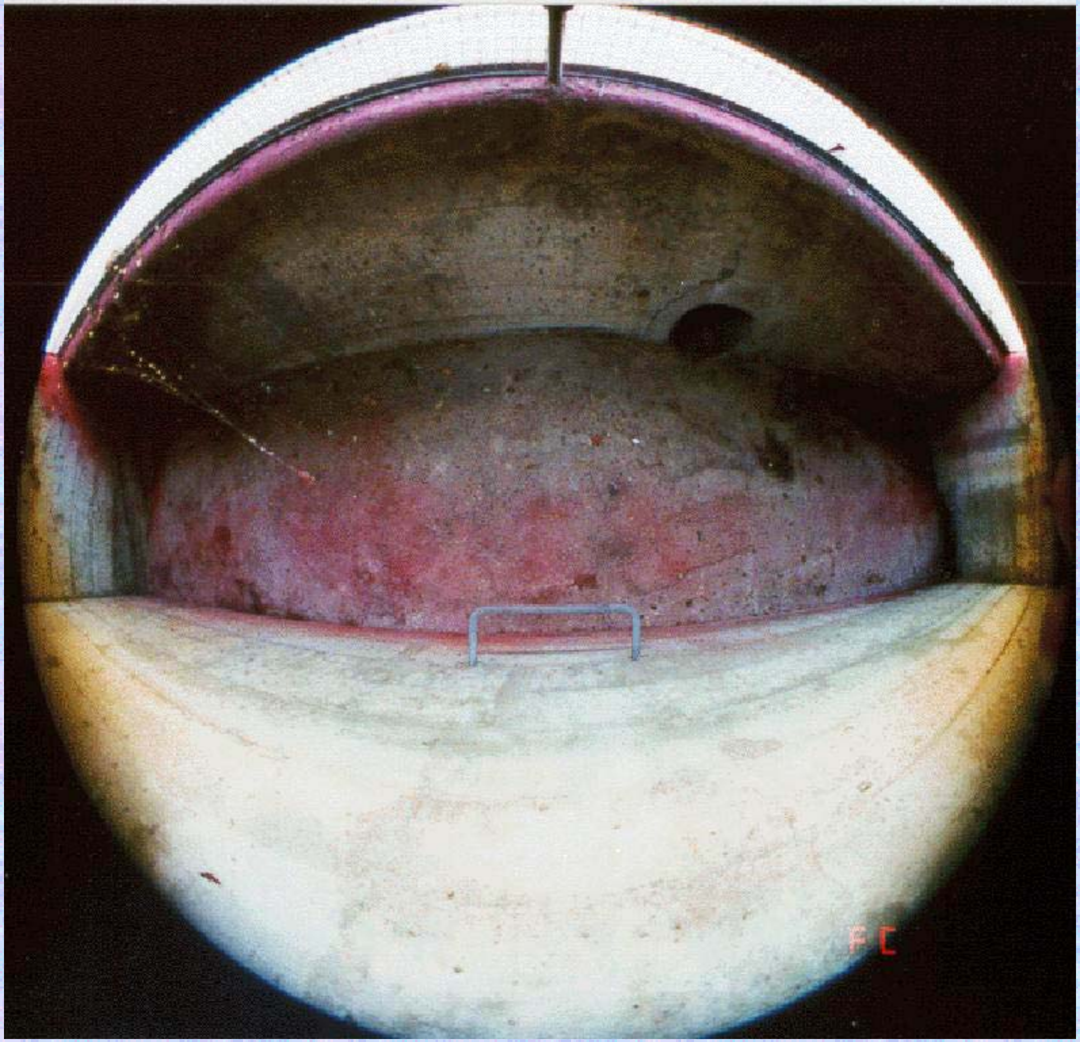
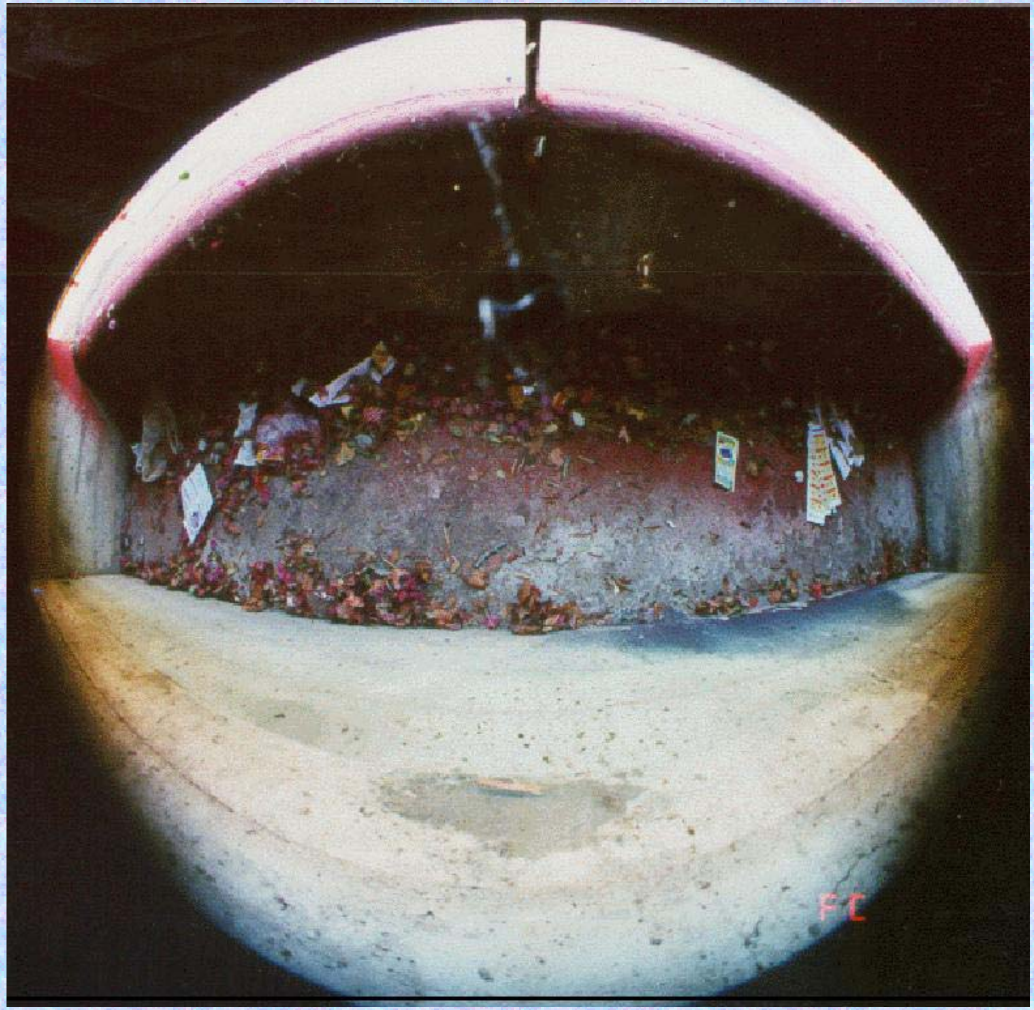
Screens

Screen 1 inch wire mesh

Accumulation - Wire Screen



Accumulation - Control (Open)



Accumulation - Control (open)

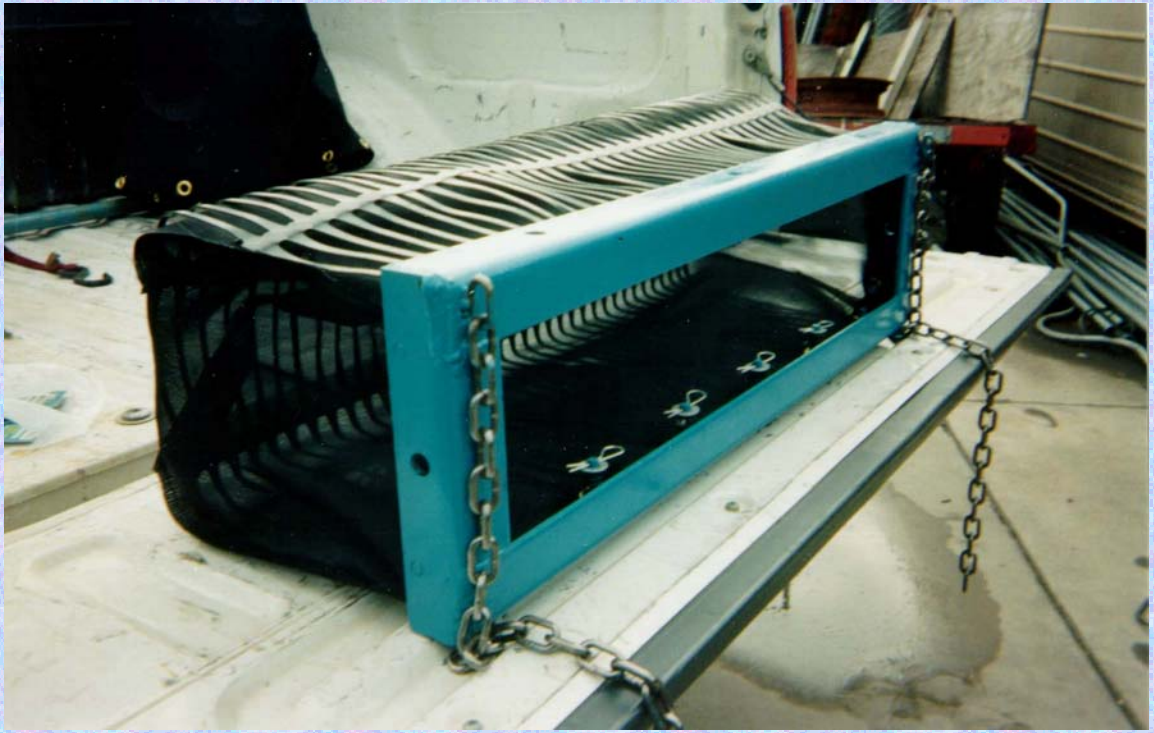
Clogging in Wet Weather

Hanging Wire Basket

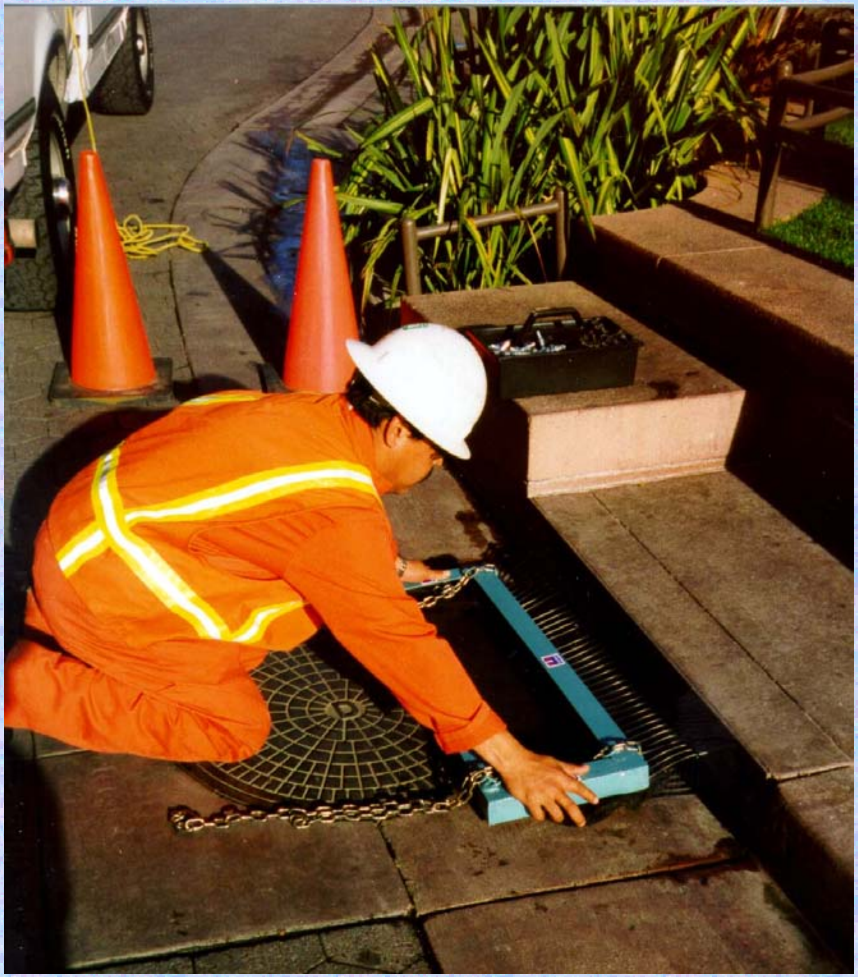
Removal

AbTech

UPS



UPS Installation



UPS

Bioinfiltration

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Current Research

- **Knowledge Based Tools**
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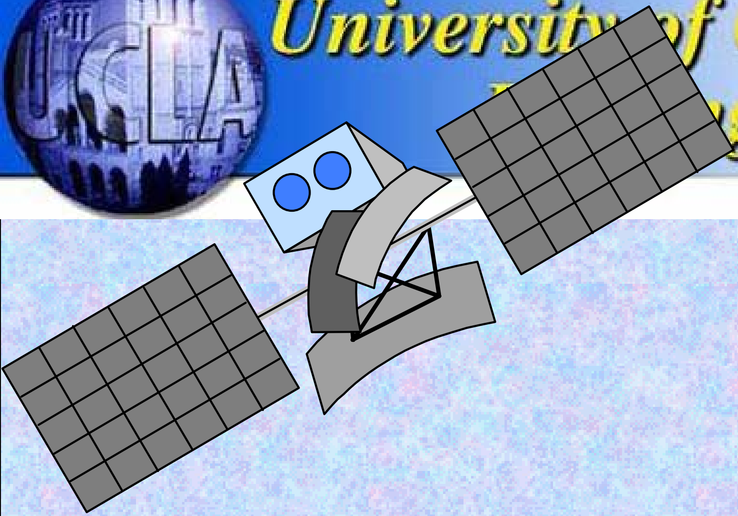
Final Remarks

On Going Research

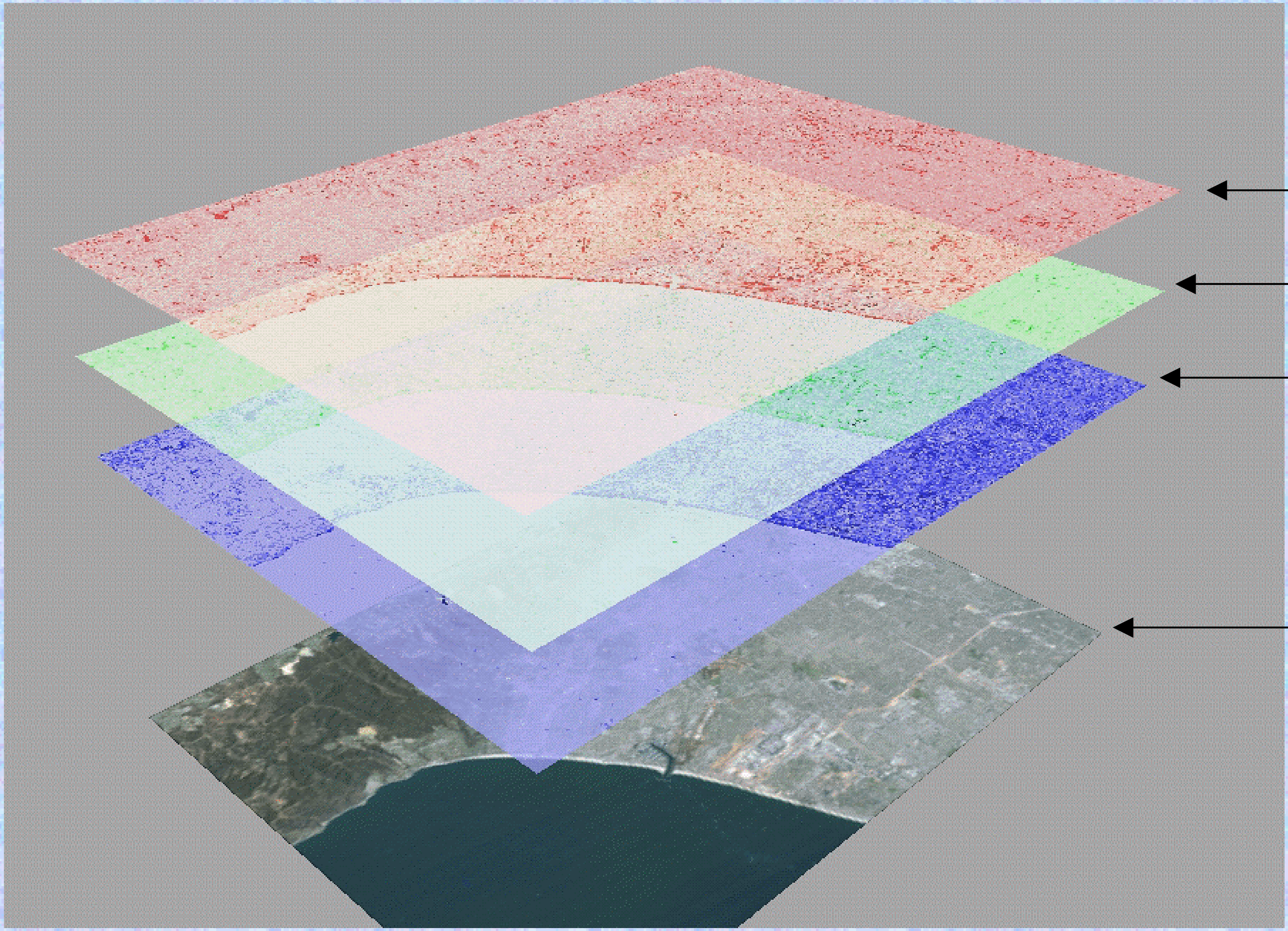
- Knowledge Based Tools to Develop Model Data
- Better Calibrations and Techniques
- Molecular Markers for Different Types of Land Use
- Nutrients



Landsat

Satellite	Launch Date	Decommision date	Sensors
Landsat 1	July 23/72	Jan. 6/78	MSS-RBV
Landsat 2	Jan. 23/95	Feb. 25/82	MSS-RBV
Landsat 3	Mar. 5/78	Mar. 31/83	MSS-RVB
Landsat 4	July 16/82	Aug. /93	MSS-TM
Landsat 5	Mar. 1/84		MSS-TM
Landsat 6	Oct. 5/93		ETM
Landsat 7			ETM+

Composite Image (Normal)



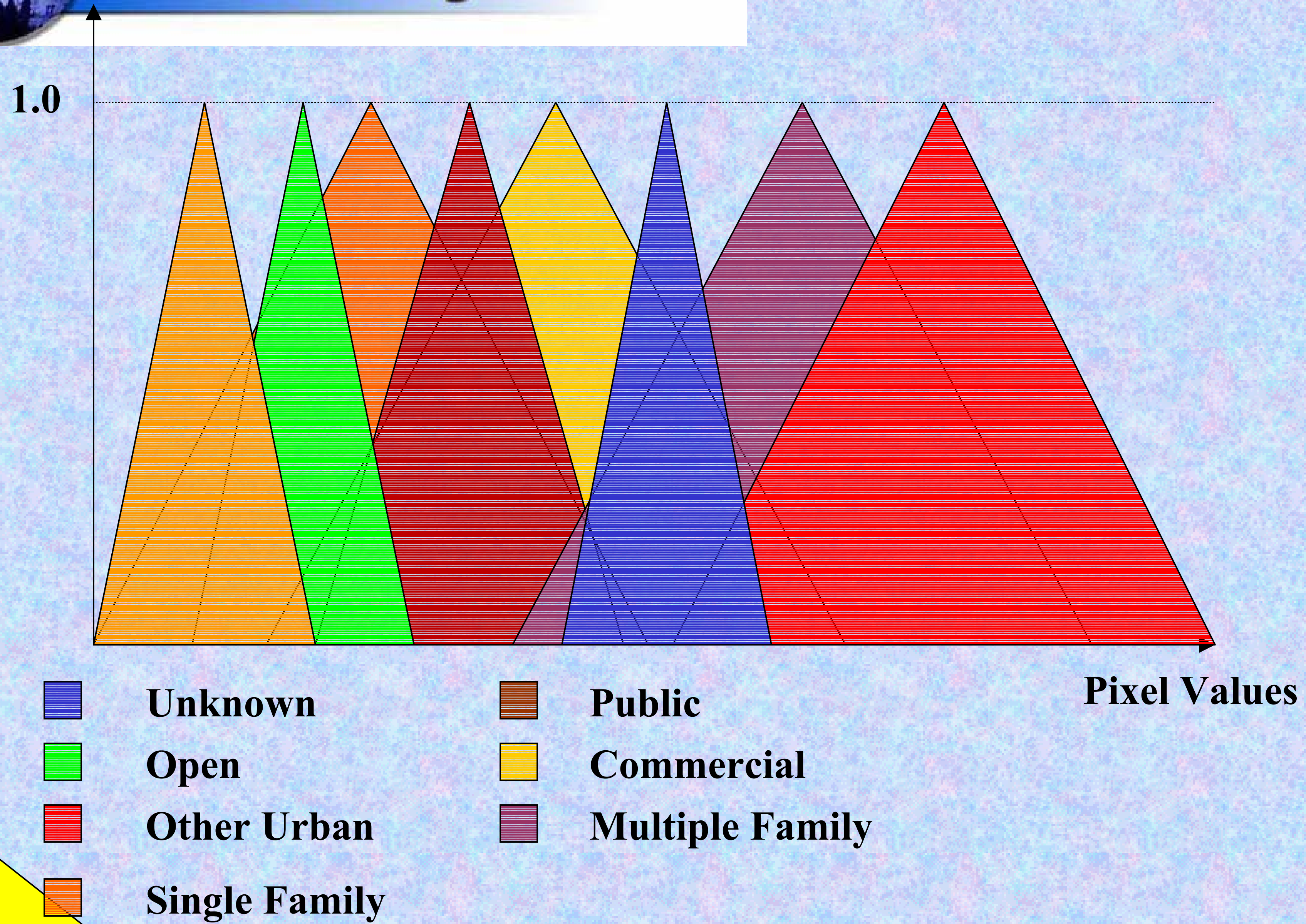
Band3

Band2

Band1

Normal Color

Fuzzy Categories



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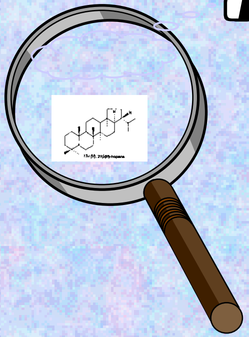
Molecular Markers

What is a molecular marker?

A compound found consistently in specific wastes.



What is the role of the molecular marker?

Provides information on the source of pollutants.

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Concept of Marker Approach

Runoff Samples

Organic Analysis

Information

Identify the source of pollutants

Determine the concentration of the markers

Application

Estimate the mass loading of wastes

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Land Use

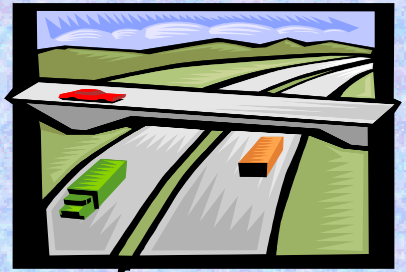
- Relative levels of runoff volume are related to land use

- Relative levels of pollution are closely related to land use


residential


open


commercial


freeway

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Objectives

- **Select molecular markers.**
- **Determine the distribution of the molecular markers.**
- **Estimate the marker mass loading**

Literature Review

- *Criteria for ideal markers*
- *Selected Molecular markers*

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Criteria for Ideal Markers

- Source Specificity - fewer sources
- Conservative Behavior - highly resistant
- Magnitude - large concentration
- Analysis - easy to analyze, little cost

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Summary of selected Markers

Sources	Markers
Vehicular emissions	17α(H)21β(H)-hopane
Tire dust	Benzothiazole(BT) and 24MoBT
Detergent	Linearalkylbenzenes(LABs)
Animal feces	Coprostanol and Cholesterol
Pesticides	Atrazine, Simazine and Diazinon

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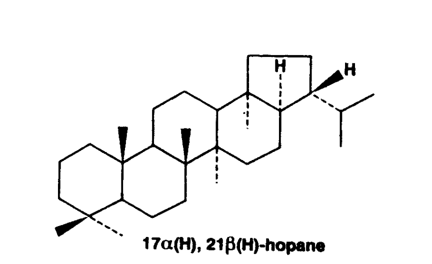
17α(H)21β(H)-Hopane

- Structure and sources



- Lubricant oil
- Vehicular emission

17α(H)21β(H)-hopane

- Marker of vehicular emissions in atmosphere
  Rogge et al., 1993
- Marker of the lubricating oil contamination
  Bieger, 1996

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Molecular Markers

- Measure presence or absence of markers for various land uses
- Use regressions to predict water quality as a function of land use
- Develop fuzzy reasoning to infer land use and contributors from marker distribution

Outline

Santa Monica Bay
- *Facts and Data Sources*
- *Statistics*
- *Land Use*
- *Data Sources*

Spreadsheet Model
- *Parameters*
- *Calibration*
- *Predictions*

SWMM Model
- *Network*
- *Calibration*

Some Simple Solutions
- *Sorbents*
- *Simple Screens*
- *Boardovers*

Current Research
- *Knowledge Based Tools*
- *Molecular Markers*

Final Remarks

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Some thoughts

- For developed areas in the United States, stormwater (urban runoff) the next frontier for water pollution control.
- GIS in combination with empirical runoff models are useful for predicting stormwater emissions
- GIS/SWMM can be used for extremely complex networks, such as the Ballona Creek sub-basin
- Some very simple solutions exist, and have yet to be exploited
- Some advanced tools need to be developed to help understand this very complex issue

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~ End ~

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