Flow Monitoring: Dollars and Sensors

March 12, 2008 * 1:00-3:00pm EDT

Water Environment Federation®
Preserving & Enhancing the Global Water Environment

Topics

- Flow monitoring programs
- Planning and performing the field work
- Common data issues and QA/QC
- Lessons learned
- Managing competing priorities
  - modeling
  - operations
  - consent decree reporting
  - billing

Speakers

- Stuart Bowns, Hydromax USA
- Abraham Araya, Ph.D., King County/DNRP, Wastewater Treatment Division
- Susan E. Moisio, P.E., CH2M HILL
- Moderator: Jean Vieux, Vieux, Inc.




Stu Bowns

- Project Manager, Hydromax USA, Florence, KY
- B.S. in Geography from S.U.N.Y. at Brockport
- First CCTV project in 1972 and first flow monitoring project in 1975

Planning the Field Work

- Project Objectives
- Site Selection
- Site Conditions
- History of Technology (open channel)

Performing the Field Work

- Selection of Equipment
- Installations
- Maintenance
- Data Requirements

Project Objectives

- Used for billing, capacity analysis, cso occurrence, operations, etc.
- Flow or Occurrence
- Short or Long Term (Permanent?)

- Sampling time
  - 5 minute, 15 minute, flow or depth adjusted, etc.
- Uptime and accuracy
- Data requirements
  - Format
  - Monthly, Weekly, Daily, Web based

Site Selection

- Project Objectives
- System maps
- In-house personnel experienced with field conditions
- Multiple manholes for each selected site
- Attempt to avoid stacking meter sites

Site Conditions

Perform Field Inspections and Document

Field Inspections Need to Identify:

Access

Safety

Structural

Operational

Hydraulics




History of Technology
Open Channel

- Level only (dipper, bubbler, float)
- Differential pressure & ultrasonic level
- Electro-magnetic velocity
- Doppler velocity
- Transit time velocity

- Range gated doppler velocity
- Radar velocity
- Wireless communications
- End user product with web data presentation & data analysis tools
- ???????????

Selection of Equipment

Use

- Project Objectives
- Site Selection and Conditions
- Knowledge of Technology

Selection of Equipment

Use

- Project Objectives
- Site Selection and Conditions
- Knowledge of Technology

Accuracy and repeatability starts with the right meter in the right site

Low DWF level with maximum surcharges

- Depth of manhole is factored into any dp or ultrasonic level limits

Silt debris changes frequently

- Multiple dp level sensors set at offsets

Foaming on water surface

- Dp level and doppler sensor in invert

Low level

- Low profile sensor
- Ultrasonic level

Low level with fast velocities

- Ultrasonic level with radar velocity

High level

- Range gated doppler

Very clear flow

- Electro-magnetic velocity

Frequent rags, solids, grease, hard to access

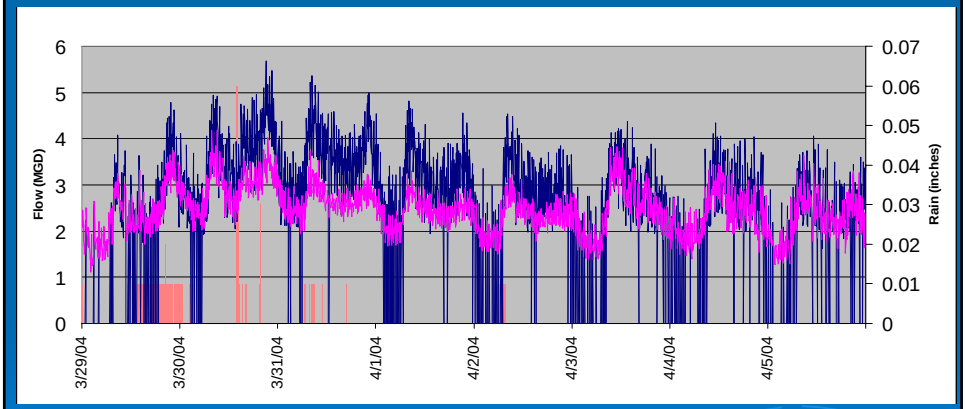
- Wireless communication

Constant surcharge

- Doppler velocity mounted on crown of pipe

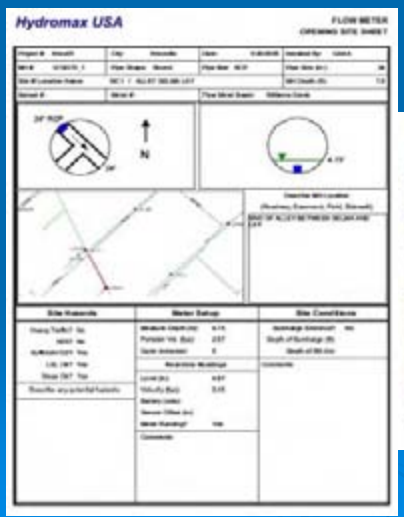
CSO occurrence

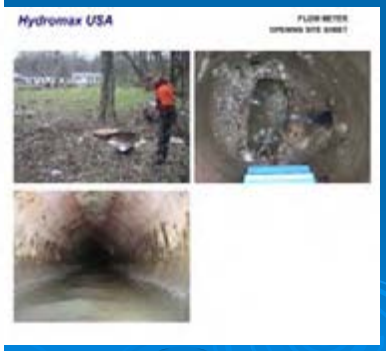
- Ultrasonic level

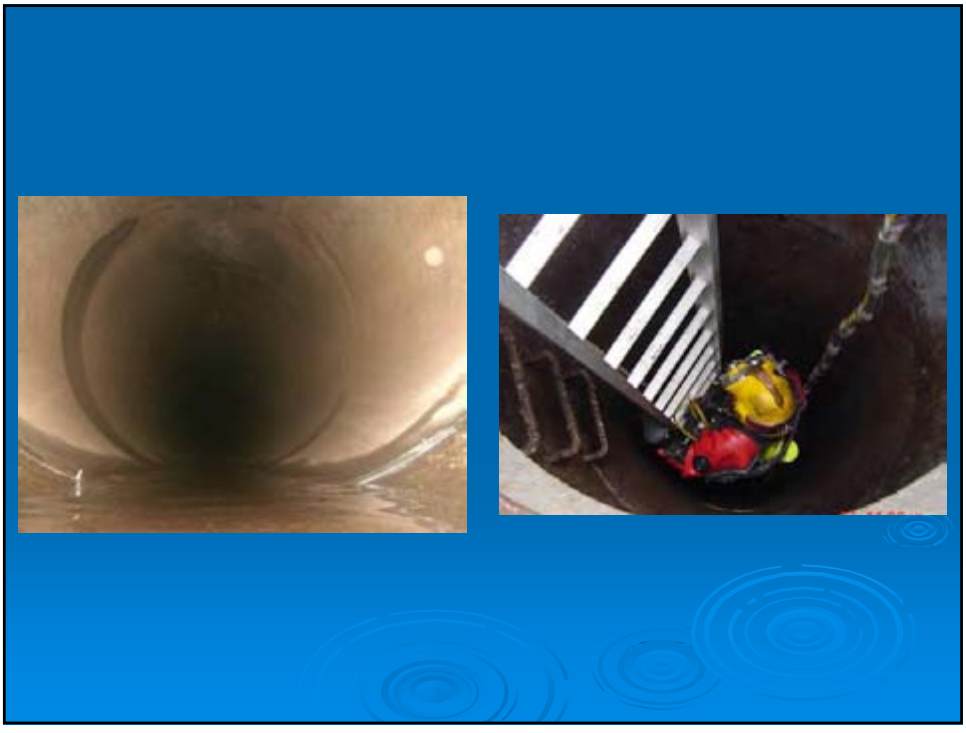


Installations

Document

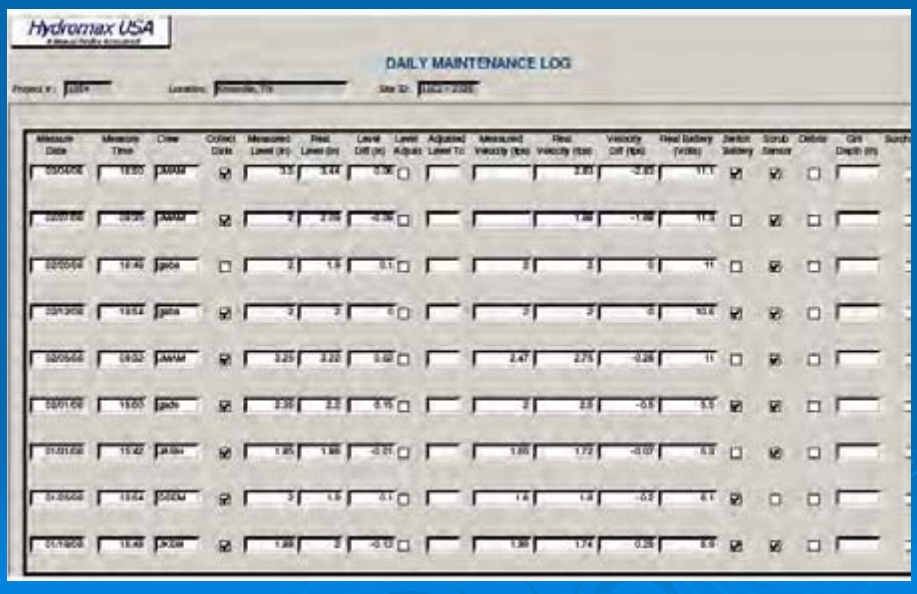






Maintenance

Document



8-inch Line

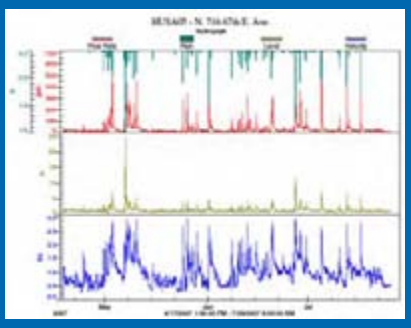
Flow Depth (in)	Velocity (FPS)	Debris Depth (in)	Flow
3	2	0	Recorded
3.25	2	0	11% Low
3	2.25	0	13% Low
3	2	0.5	8% High
6	2	0	Recorded
6.25	2	0	4% Low
6	2.25	0	11% Low
6	2	0.5	3% High

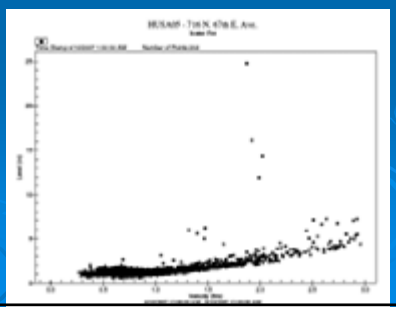
24-inch Line

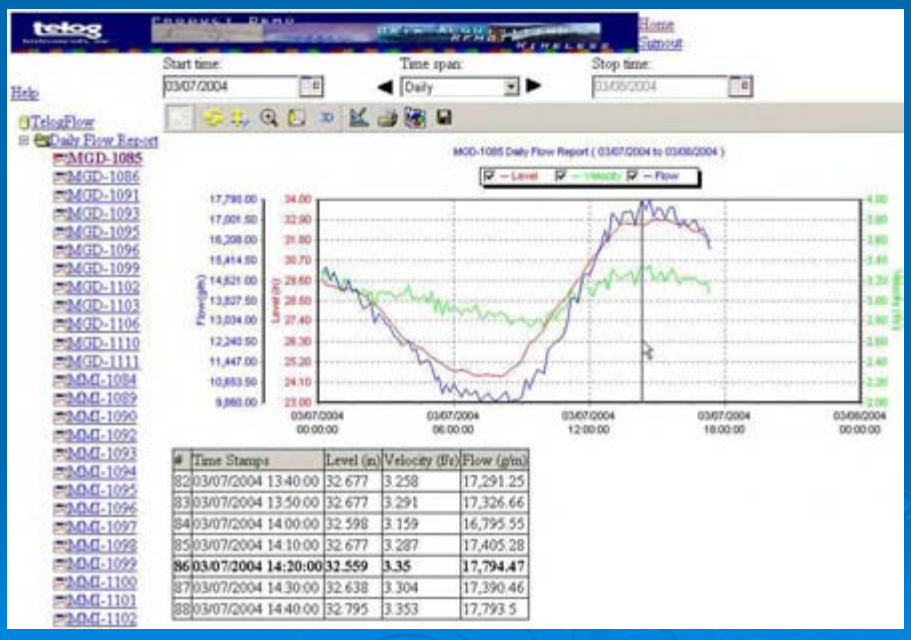
Flow Depth (in)	Velocity (FPS)	Debris Depth (in)	Flow
4	2	0	Recorded
4.25	2	0	9% Low
4	2.25	0	13% Low
4	2	0.5	5% High
16	2	0	Recorded
16.25	2	0	2% Low
16	2.25	0	13% Low
16	2	0.5	1% High
22	2	0	Recorded
22.25	2	0	1% Low
22	2.25	0	9% Low
22	2	0.5	1% High

Data Requirements

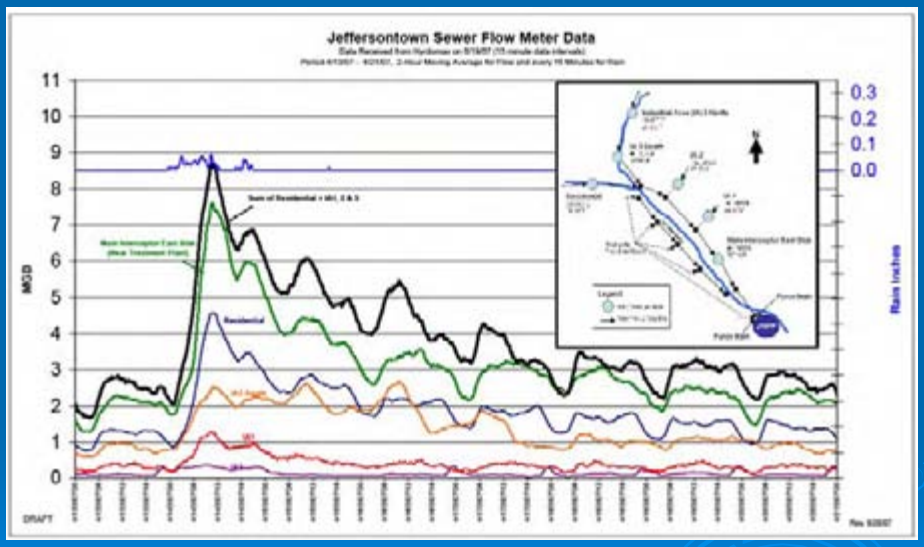
Site Name	HUSA06 - 5th Pl. and Sheridan Rd.		
Label	Level	Velocity	Flow Rate
Units	in	ft/s	gpm
04/19/07 20:15	3.84	1.08	105
04/19/07 20:30	4.17	1.32	144
04/19/07 20:45	4.07	1.33	140
04/19/07 21:00	4.21	1.33	147
04/19/07 21:15	4.14	1.29	139
04/19/07 21:30	4.20	1.35	148
04/19/07 21:45	4.16	1.34	145
04/19/07 22:00	4.20	1.38	152
04/19/07 22:15	4.11	1.34	143
04/19/07 22:30	4.16	1.32	143
04/19/07 22:45	4.12	1.42	152
04/19/07 23:00	4.07	1.32	139
04/19/07 23:15	3.99	1.31	134
04/19/07 23:30	3.85	1.24	121
04/19/07 23:45	3.88	1.28	126
04/20/07 00:00	3.82	1.28	124
04/20/07 00:15	3.78	1.24	118
04/20/07 00:30	3.68	1.23	113
04/20/07 00:45	3.61	1.19	106
04/20/07 01:00	3.52	1.18	102
04/20/07 01:15	3.48	1.10	93
04/20/07 01:30	3.42	1.09	90
04/20/07 01:45	3.43	1.07	89
04/20/07 02:00	3.39	1.11	91

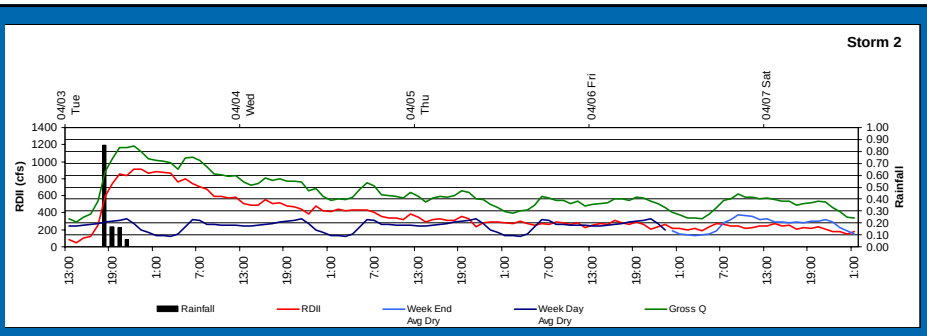


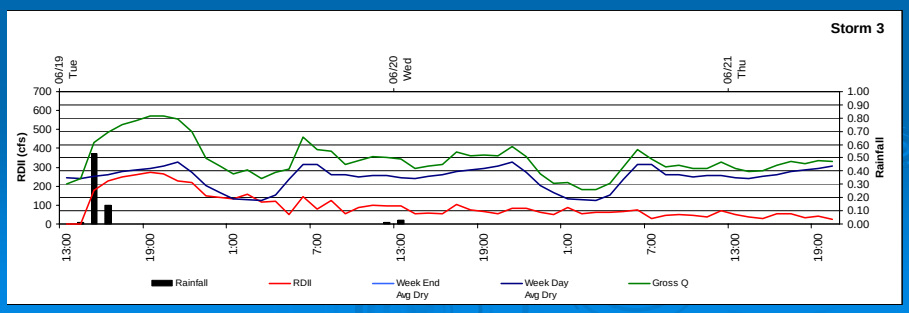




#	Time Stamps	Level (in)	Velocity (ft/s)	Flow (gpm)
82	03/07/2004 13:40:00	32.677	3.258	17,291.25
83	03/07/2004 13:50:00	32.677	3.291	17,326.66
84	03/07/2004 14:00:00	32.598	3.159	16,795.55
85	03/07/2004 14:10:00	32.677	3.287	17,405.28
86	**03/07/2004 14:20:00**	**32.559**	**3.35**	**17,794.47**
87	03/07/2004 14:30:00	32.638	3.304	17,390.46
88	03/07/2004 14:40:00	32.795	3.353	17,793.5


Jeffersontown Sewer Flow Meter Data
MGD
Rain Inches
11
10
9
8
7
6
5
4
3
2
1
0
0.3
0.2
0.1
0.0
DRAFT


Storm 2
RDII (cfs)
Rainfall
04/03 Tue
04/04 Wed
04/05 Thu
04/06 Fri
04/07 Sat
1400
1200
1000
800
600
400
200
0
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
13:00
19:00
1:00
7:00
Rainfall
RDII
Week End Avg Dry
Week Day Avg Dry
Gross Q


Storm 3
RDII (cfs)
Rainfall
06/19 Tue
06/20 Wed
06/21 Thu
700
600
500
400
300
200
100
0
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
13:00
19:00
1:00
7:00
Rainfall
RDII
Week End Avg Dry
Week Day Avg Dry
Gross Q

Questions?

Abraham Araya, PhD

- Water Quality Planner, King County/DNRP, Wastewater Treatment Division
- M.Sc. (1987) and PhD (1993) in Geology from The New Mexico Institute of Mining and Technology (NM Tech) in Socorro, New Mexico.
- 8 years of Flow Monitoring Experience

Overview

- King County Wastewater Treatment Division (WTD) Facilities.
- Flow Monitoring - What we need and how we use it.
- Flow Monitoring Background
- Lessons Learned
- Flow Monitoring and Data QA/QC Process.
  - Field work.
  - Office work.

Facilities

- Treatment plants
  - Two regional, one local, two under construction
- CSO facilities: 4
- Conveyance pipes: 330 miles
- Pump stations: 42
- Regulator stations: 19
- 35 Local Agencies
- Service Area: 414 Mi2
- Serves 1.4 million
- Combined: 70 Mi2

Why We Need It & How We Use It

- Track long-term trends.
- Analyze conveyance system capacity.
- Conduct hydraulic modeling and calibration.
- Analyze Inflow/infiltration.
- Calculate CSO volume for NPDES reporting.
- Plan inspections and schedule maintenance and repair activities

Flow Monitoring - Background

- Pre 2000
  - 90 to 100 short and long-term (LTM) sites
- 2000 – 2002 KC Regional I/I Control Program
  - 775 – 806 mini basins
  - Average Size: 150 Acres, 22,000 LF of Sewer Main
  - 75 Long -Term
- Post 2002
  - 75 to 120 Long Term & “Short Term” Monitoring Sites
    - Combined System = 37 (NPDES = 11)
    - Separated System = 82
    - Telemetry Units = 57
    - Manually collected = 62

Lessons Learned
Local Agency Participation

- All Local Agencies Participated in Flow Monitoring
- Provided GIS Information
- Assisted in Permitting, Access to Local Lines, and traffic Control
- Helped Select, Design, and Implement Pilot Projects
- Participated in Pre & Post-Project Flow Monitoring

Contractor

- Set Performance Measurement Criteria
  - Data Uptime and Flow Verification
- Trained Staff Working With Contractor
  - **QA/QC Data for Consistency and Accuracy Before Project Completion and the Modeling Phase**
  - **Audit Any Changes Made to Flow Data**

Vendor

- One Size Does NOT Fit ALL
  - Research Products and References
- Training and Product Demonstration
  - Request Training and Product Demonstration
  - Verify Meter Accuracy
  - Evaluate Data Collection and Communication Protocols
  - Evaluate Software and Hardware
- Customer Service / Technical Support
  - Ease of Access to Support
  - Quality and Level of Support

Pre vs. Post 2000 Data Issues

- Proper Site selection & Meter Installations
- Timely Maintenance
- Field Verifications & Onsite Data Review
- Office Data Review to Identify Problems

- Increased Uptime
- Increased Data Quality and Reliability
- Responsiveness to Clients
- Timely Delivery of Quality Data
- Flexibility to Accommodate Client's Needs

Changes Implemented

- Staffing Level
- Additional Metering Technology
- Continuous Staff Training
  - Site Inspection and Selection
  - Monitor Installation
  - Field Verification of Meter Accuracy
  - Onsite Data Quality Verification and Troubleshooting

Staff Training

Meter Installation and Verification

Meter Installation & Verification

Site Investigation

Data Quality Verification and Troubleshooting

Changes Implemented

- Standard Operating Procedures
- Site Visit Logs
- Weekly Meetings With Field & Office Staff

Flow Monitoring Process

- Field work
  - Site Investigation.
  - Equipment Installation.
  - Field Verification.
  - Data Collection and Record Keeping.
- Office work
  - Flow Data Evaluation and Finalization.
  - Troubleshooting Equipment/Sites.

Flow Monitoring Equipment

- Area – Velocity meters (devices that measure velocity and depth for flow rate calculation (Q= A x V))

Meter Type	Depth Sensor	Velocity Sensor
I	Ultrasonic / Pressure	Ultrasonic/ Doppler Peak
II	Pressure Transducer	Electromagnetic
III	Ultrasonic / Pressure (only during surcharged conditions)	Radar or Electromagnetic sensor (during surcharge)

Field Verification of Meter Accuracy

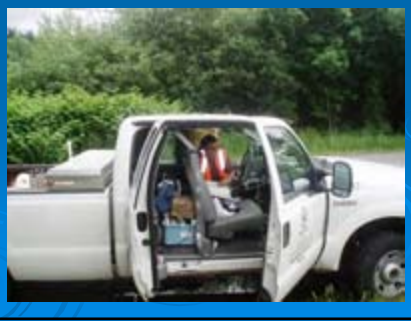
Depth confirmation

Velocity Confirmation

- Flows > 2 inches measured using a portable velocity meter.
- Low flow (usually < 1 to 2 inches of DOF) using volumetric Weirs or Propeller Meter.

Data Collection/Transfer

- Data collected weekly/biweekly using a laptop computer (and remotely from the office).
- Onsite data review (and maintenance).
- Daily data back up to king county server (DNRP/WTD).
- Daily update of site visit logs and verification reports.
- Notify data analyst.



Office Work
Flow Monitoring Data Evaluation

- Review Meter Functionality and Accuracy
  - Perform Diagnostics to Verify Sensor Functionality
  - Compare Meter Readings to Field Readings
  - Review Field Notes and Any Service Records
- Data Editing
- Data Finalization

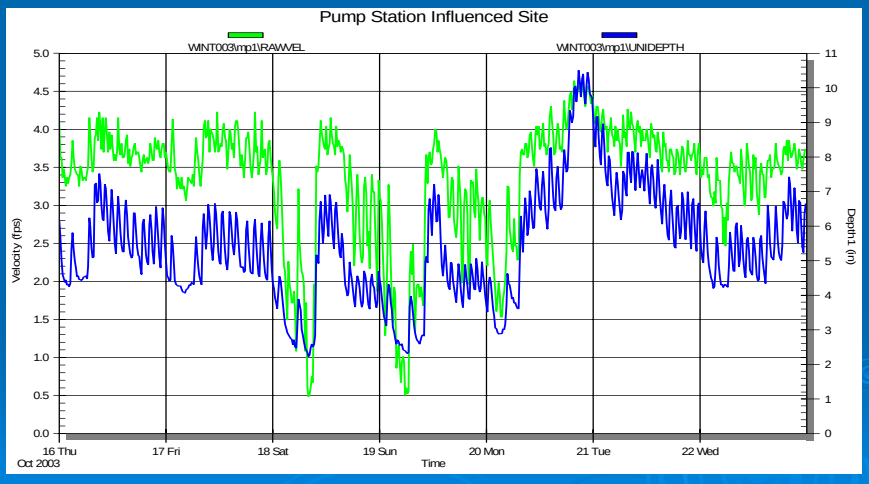
Il buono, Il brutto, Il cattivo

Hydrographs and Scattergraphs

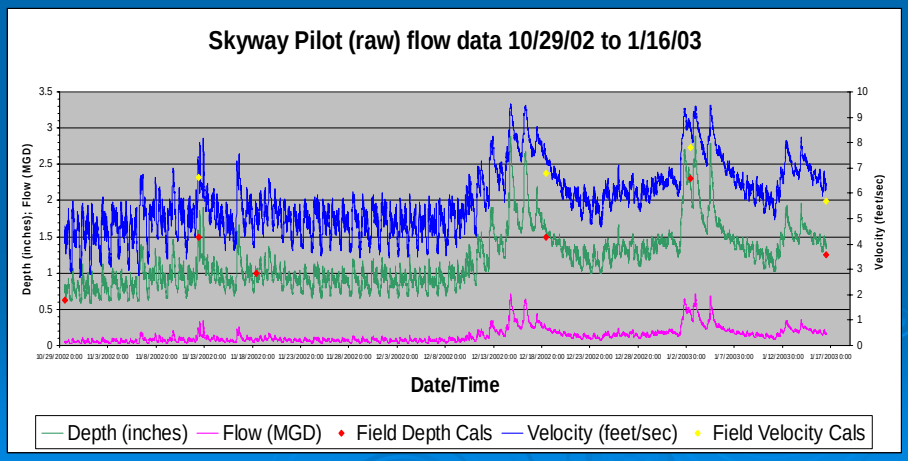
Review Meter Functionality and Accuracy

- Comparison of Depth and Velocity Patterns
- Consistency With site hydraulics (ex. P/S)
- Identify sites that have equipment/installation problems
- Identify sites with unusual hydraulics

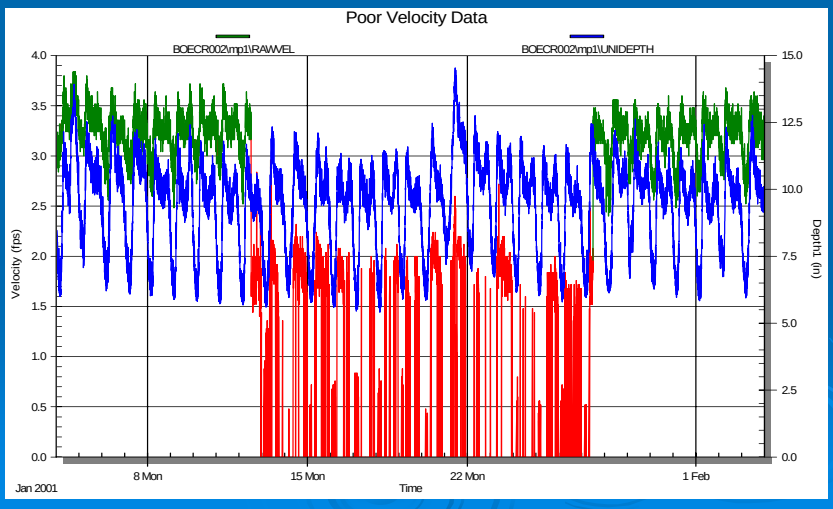
Consistency With Site Hydraulics



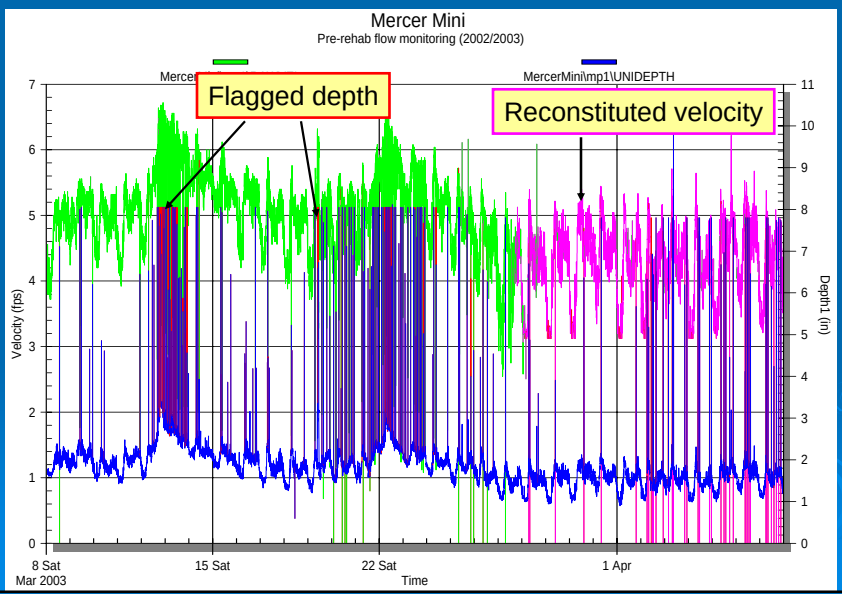
Comparing Meter & Field Readings



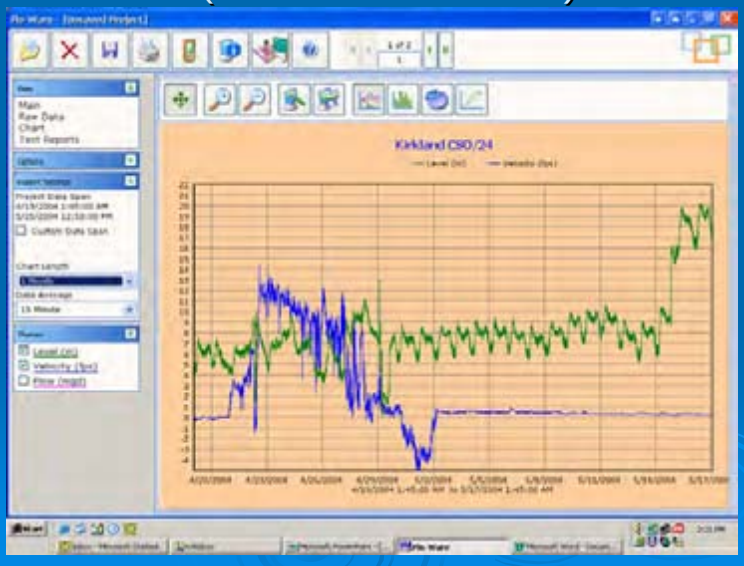
Verifying Sensor Functionality and Data Quality



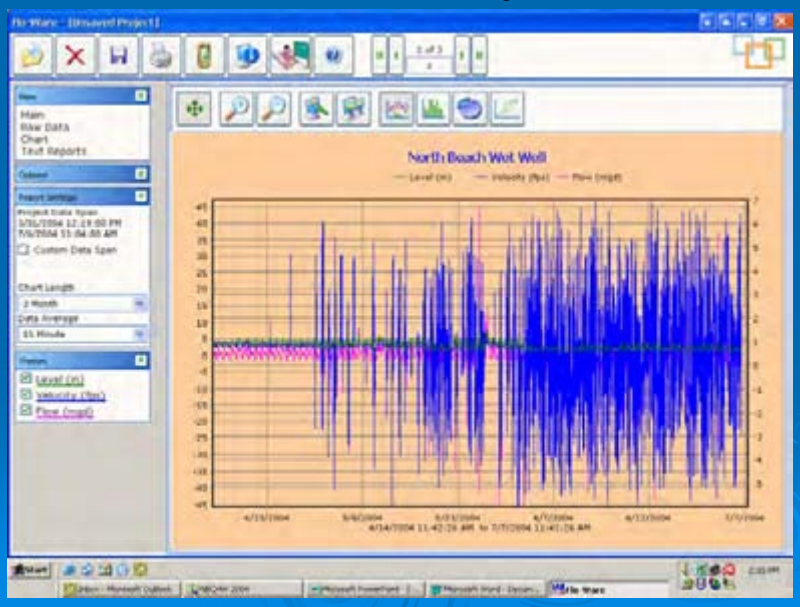
Data Editing



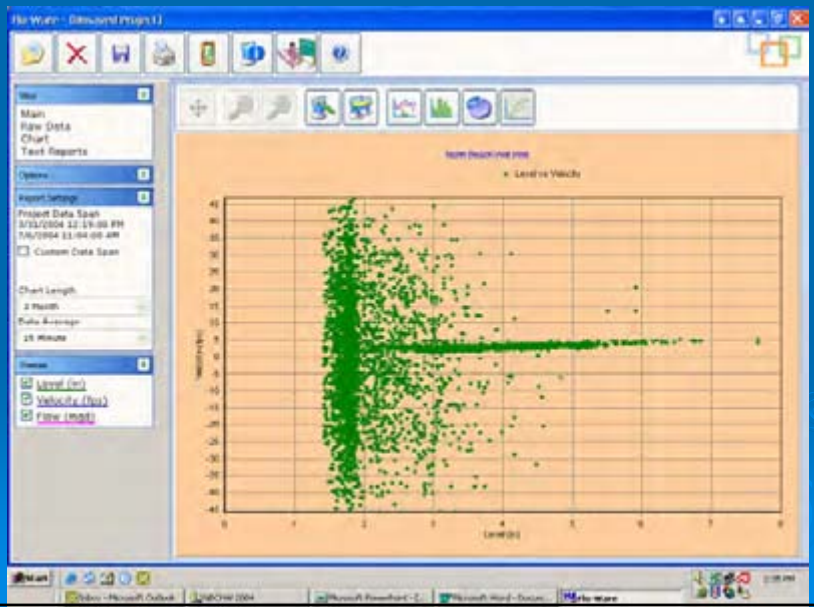
Depth Drifting & Poor Velocity Data (Sediment Problem)



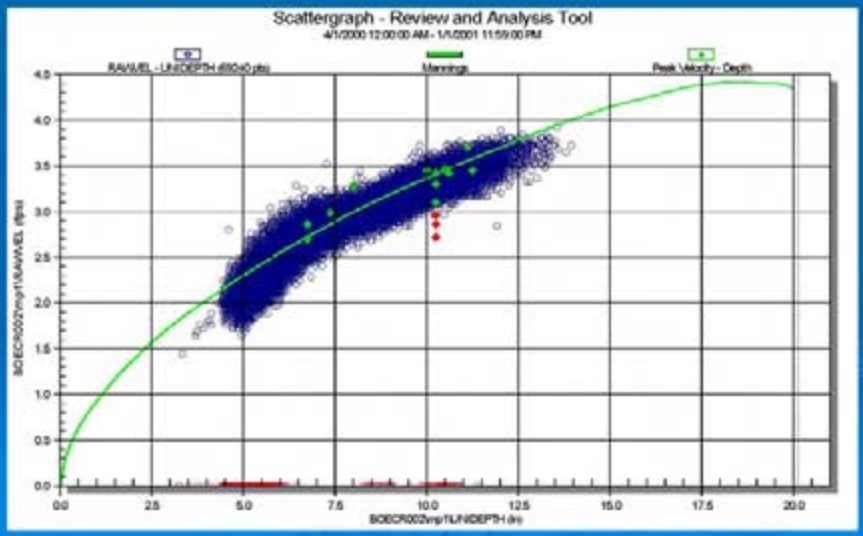
Poor Velocity Data



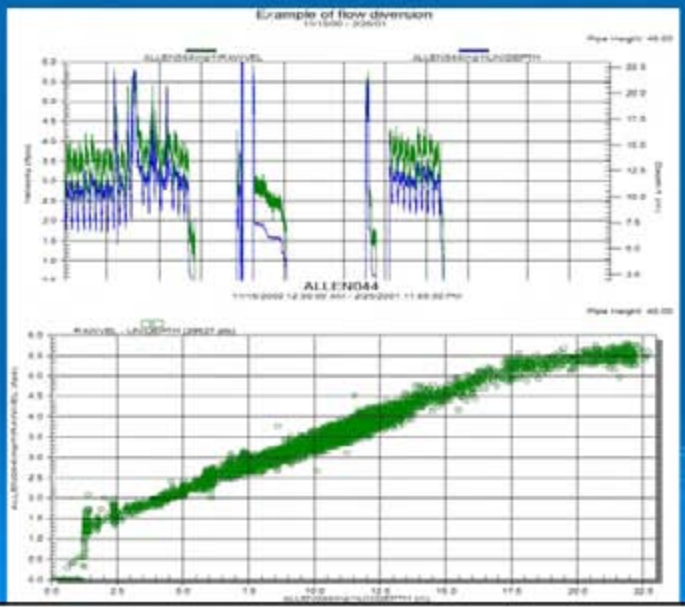
Poor Velocity Data



Scattergraph Analysis



Field Verification Required to Confirm Flow Pattern



Data Finalization

RAW DATA
- Velocity
- Depth

Data Review
- Hydrograph Analysis
- Scattergraph Analysis
- Review Field Notes and Service Logs

Data Editing
- Flagging Erroneous Data
- Reconstructing Velocity Data
- Check Data Anomalies

Data Finalization
- Verify Pipe Dimension
- Verify Silt Level
- Calculate Gain or Average Velocity
- Depth/Velocity Adjustments
- Flow Balancing
- Generate Flow Quantities

FINAL DATA

Questions?

Susan Moisio, PE

- Senior technologist with CH2M HILL.
- M.S Civil Engineering Youngstown State University
- B.S. in Civil Engineering from Arkansas State University
- 21 years of experience in collection system engineering, including 16 years with the Metropolitan Sewer District of Greater Cincinnati

Agenda

- Monitoring programs
- Local Monitoring vs System Wide Monitoring
- Data Analysis

Monitoring Programs *–driven by*

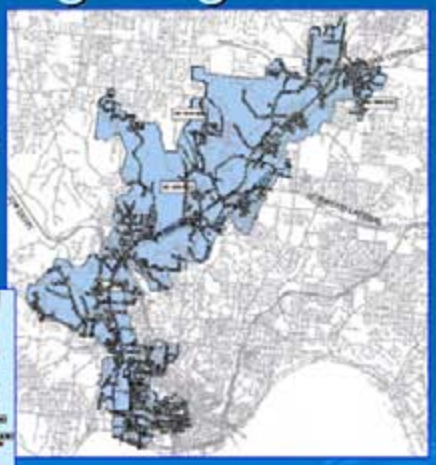
- Consent Decrees/Master Planning
- Operations
- Hydraulic Understanding of System

Monitoring Programs
–driven by

- **Consent Decrees/Master Planning**
- Operations
- Hydraulic Understanding of System

Monitoring Programs

- Consent Decree Driven
  - Capacity Assessment
  - Capacity Assurance
- Master Planning

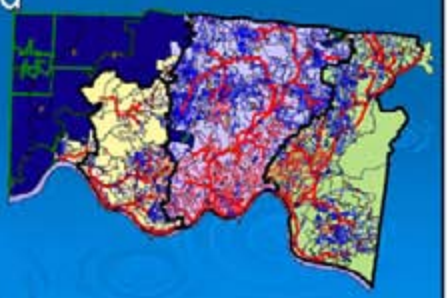


Monitoring Programs

- Consent Decree Driven
- Operations
- Hydraulic Understanding of System

Metropolitan Sewer District of Greater Cincinnati Case Study

- Hamilton County in SW Ohio
- 400 Square Mile Service Area
- 3000 miles of sewer
- Sanitary and Combined
- SSOs
- CSOs
- Basement Backups



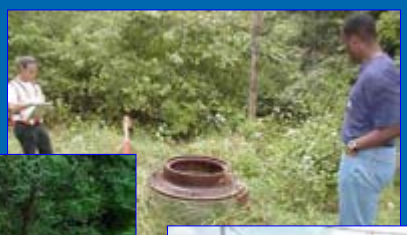
Metropolitan Sewer District of Greater Cincinnati Case Study

- Master Plan in late 80s
- Permanent Meters
- Basement backups
- Sanitary Sewer Overflows
- Data Needs
- Temporary Meters

Local Monitoring Focus

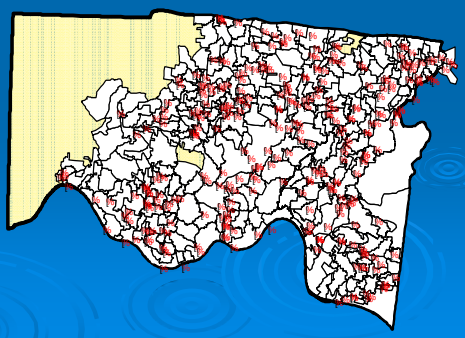
- Identified Problem Areas
- Short Monitoring Period
- Defined Boundary Condition
- Solving Localized Problems
- Hydraulic Model Development
- SSOs
- Basement Backups
- Did not focus on pre RDI/I Monitoring

Local Monitoring Focus

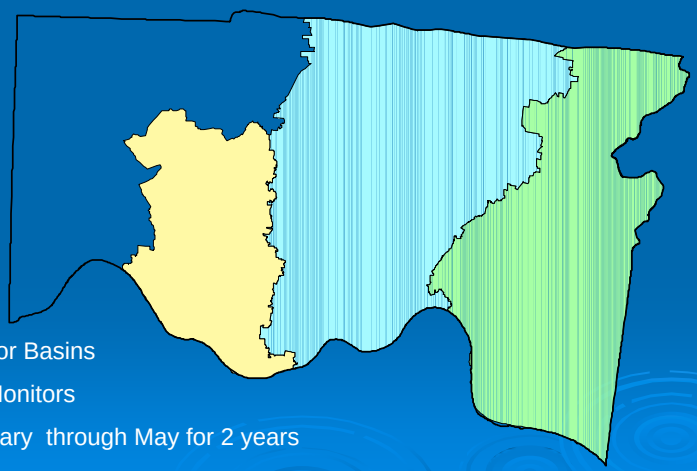


System Wide Monitoring

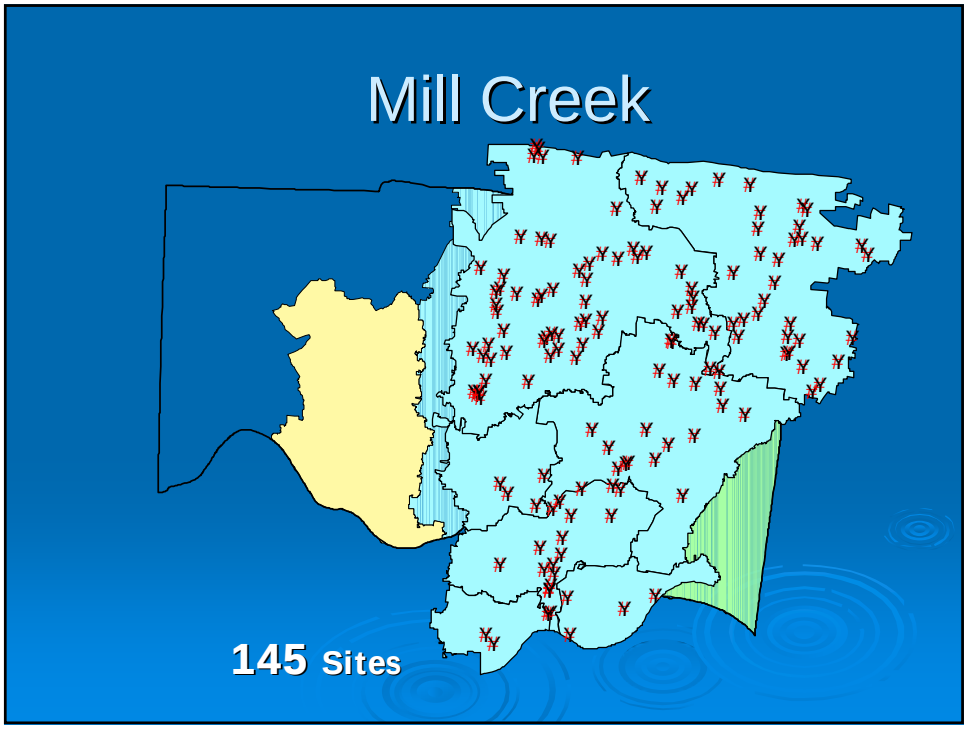
- Consent Decree Driven
- Both Sanitary and Combined
- 18” Above Combined
- 12” Above Sanitary
- Build Dynamic Hydraulic Model
- Keep > 100 Permanent Meters

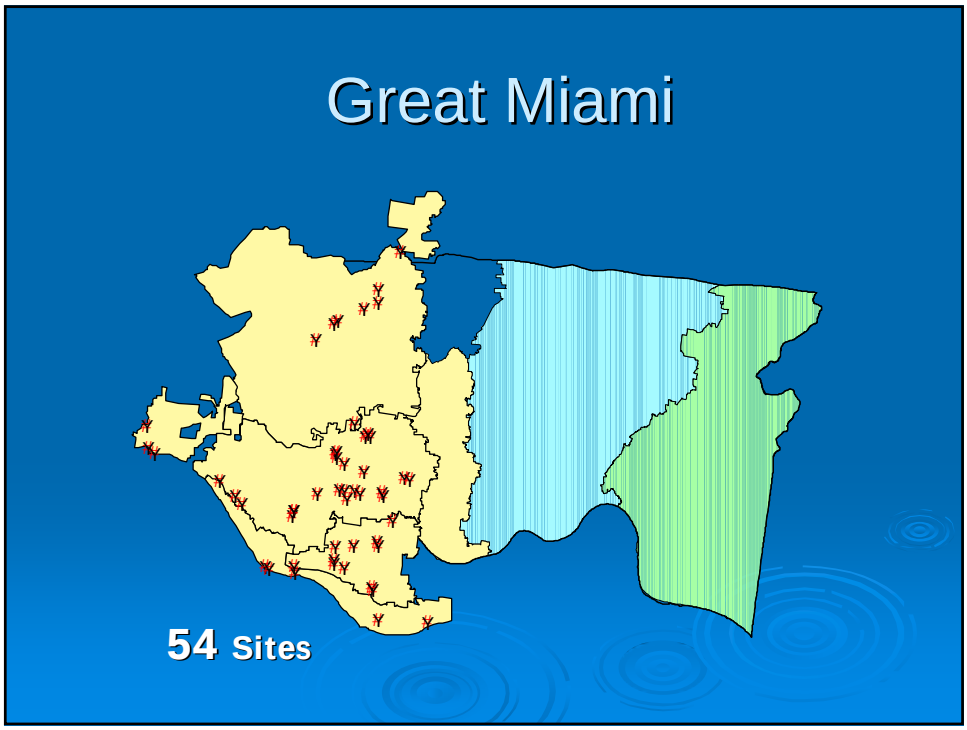


System Wide Monitoring

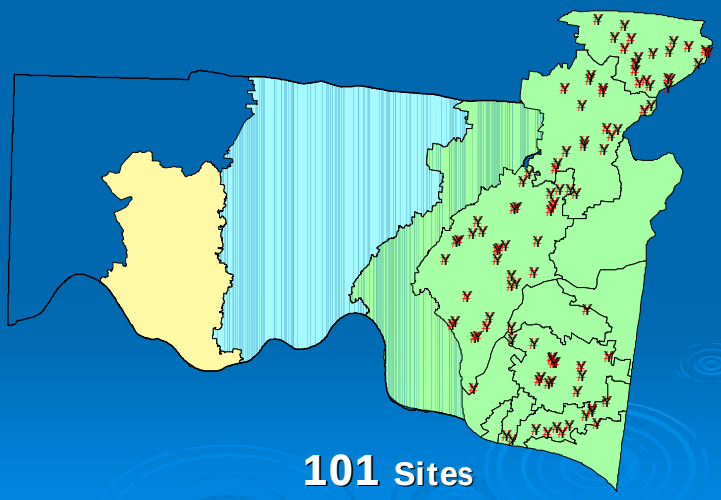


- 3 Major Basins
- 300 Monitors
- February through May for 2 years


Mill Creek
145 Sites


Great Miami
54 Sites

Little Miami



101 Sites

Monitoring Sites

System Wide Monitoring

- Different Site Conditions
- Safety Concerns
- Access

System Wide Monitoring

Large Diameter Combined Sewers

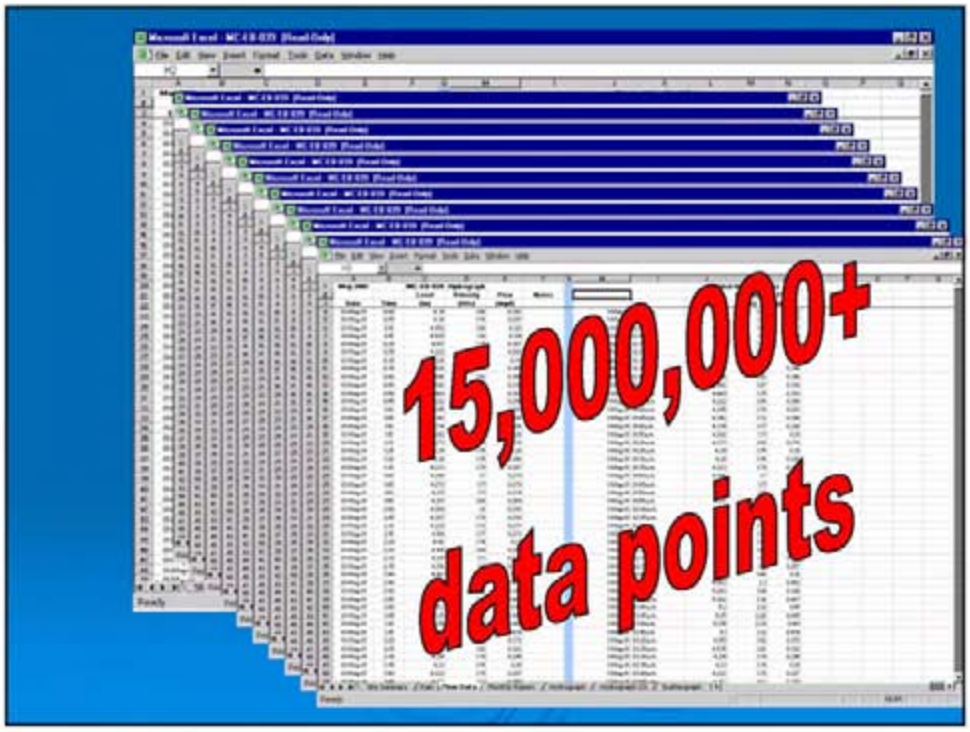
Site and Hydraulic Conditions

Main Interceptors Into Mill Creek WWTP

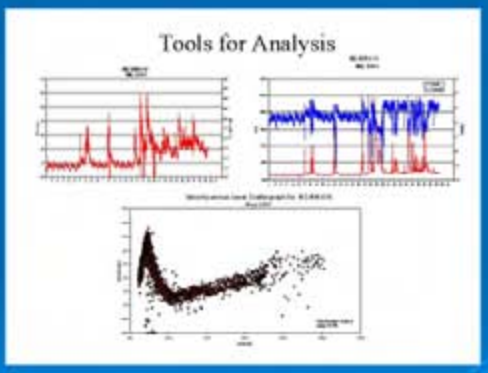
- Surcharged during installation
- Surcharged during maintenance

System Wide Monitoring – *SSO 700 metering before and after monitoring program*

Data Analysis

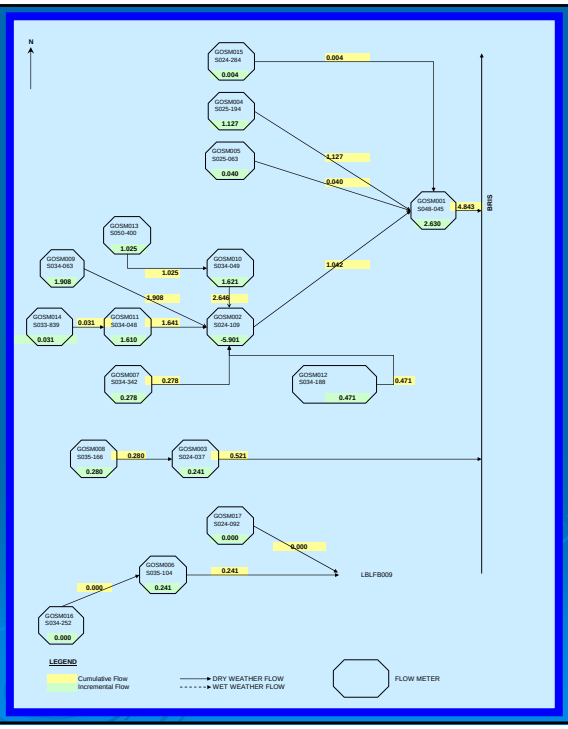


Analysis of Flow Data



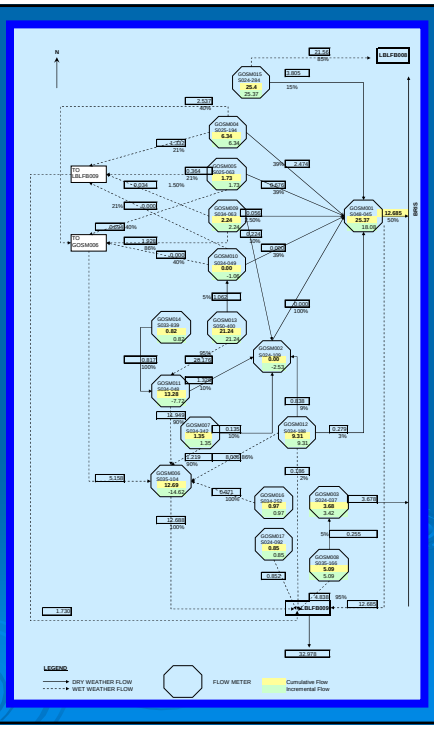
Bubble Diagram

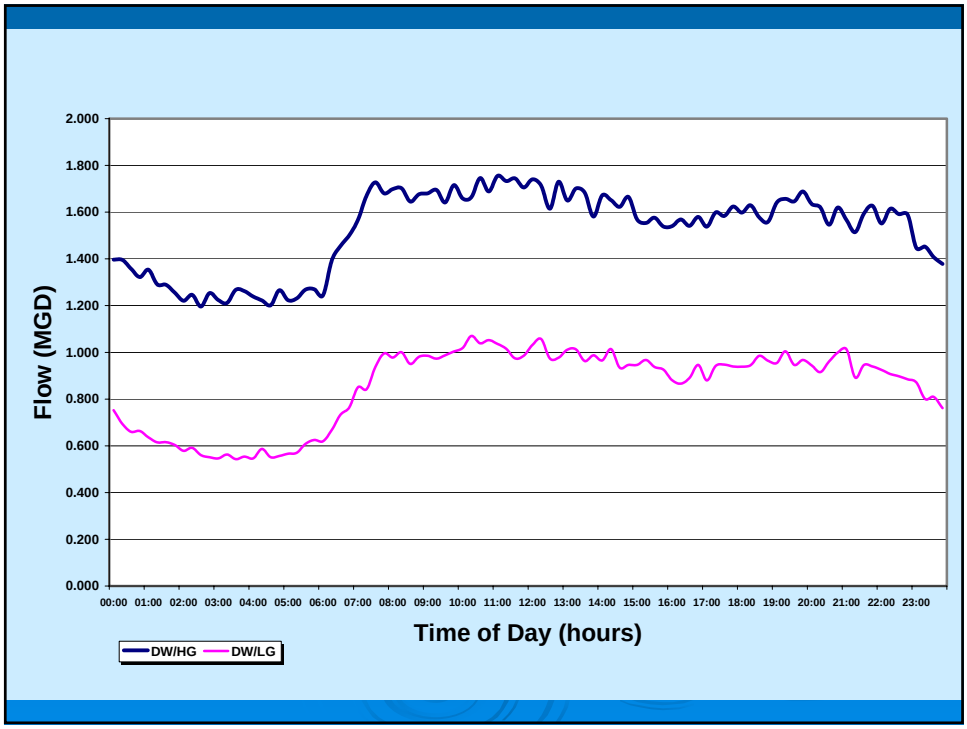
- Relationship between meters
- Sets up project understanding
- Understand how flows are entering and leaving the system
- Field Inspection



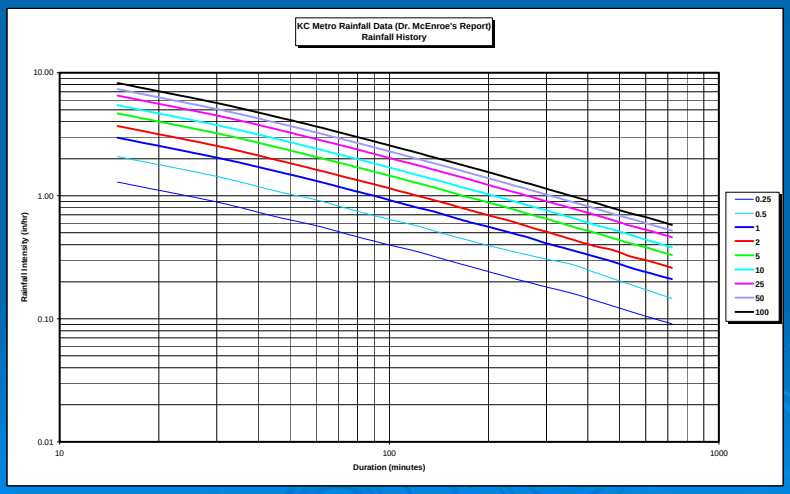
Bubble Diagram

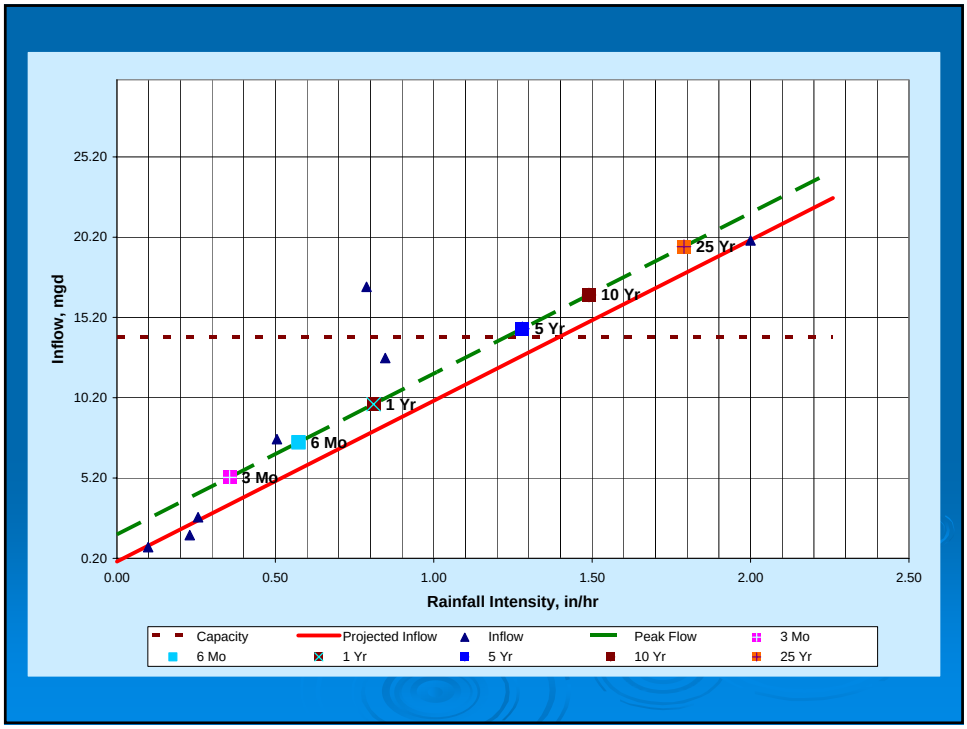
How does the flow REALLY go?

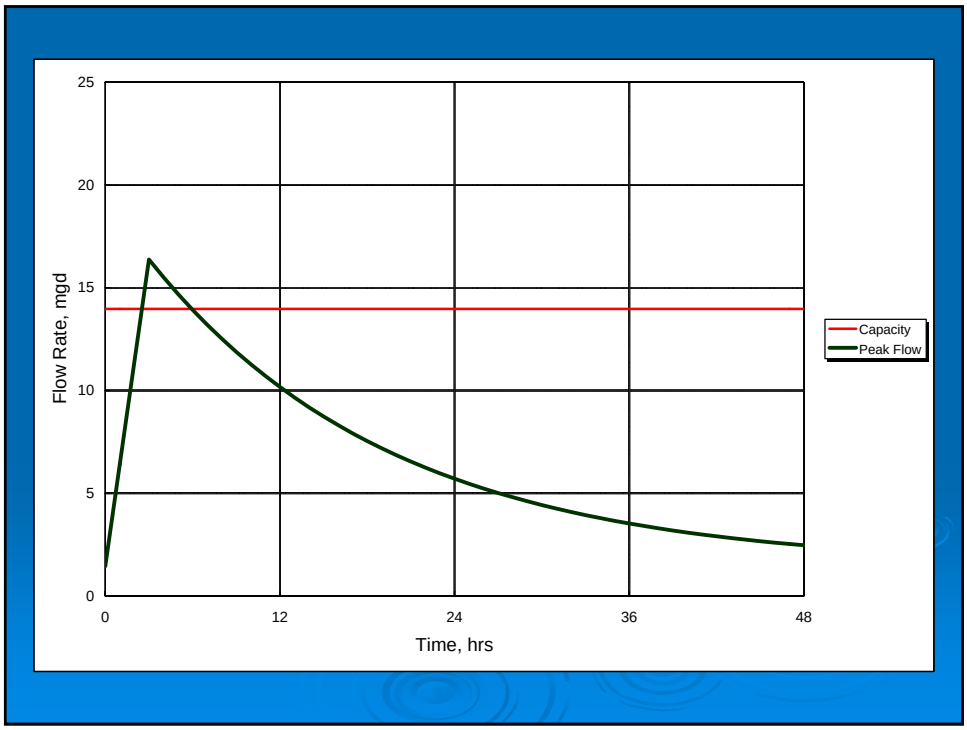




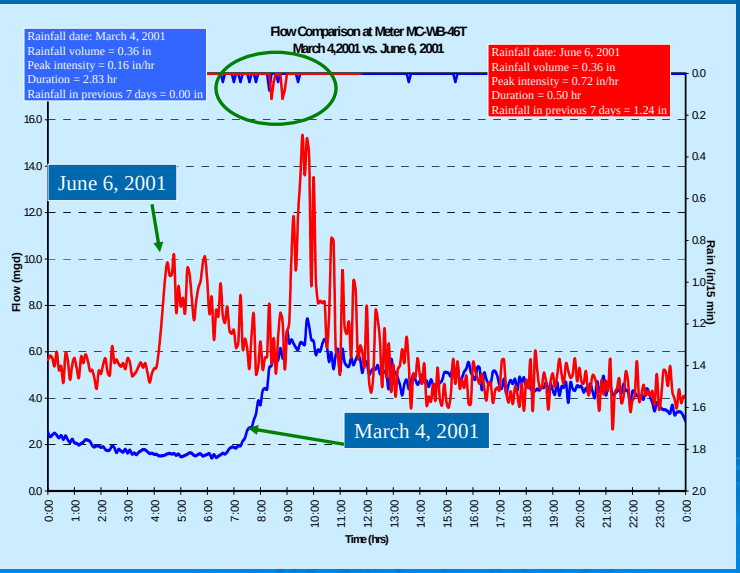
Data Analysis




Inflow, mgd
25.20
20.20
15.20
10.20
5.20
0.20
0.00
0.50
1.00
1.50
2.00
2.50
Rainfall Intensity, in/hr
3 Mo
6 Mo
1 Yr
5 Yr
10 Yr
25 Yr
Capacity
Projected Inflow
Inflow
Peak Flow
3 Mo
6 Mo
1 Yr
5 Yr
10 Yr
25 Yr


Flow Rate, mgd
25
20
15
10
5
0
0
12
24
36
48
Time, hrs
Capacity
Peak Flow

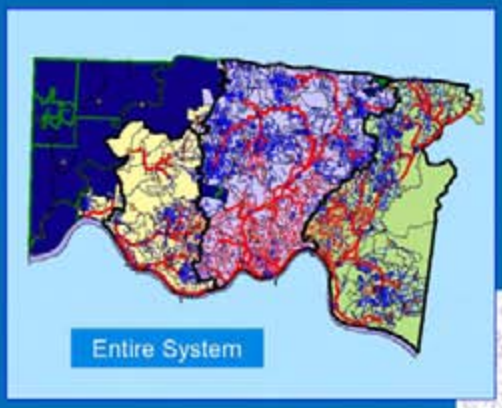
Data Analysis



Conclusions

- Purpose of monitoring program
- Use of the data
- Length of the monitoring period
- Long term data needs

Conclusions



Entire System

Sewershed

Trunk Sewer

Questions?

Q & A Session

- Stuart Bowns, Hydromax USA
- Abraham Araya, Ph.D., King County/DNRP, Wastewater Treatment Division
- Susan E. Moisio, P.E., CH2M HILL
- Moderator: Jean Vieux, Vieux, Inc.

Thank You

- Our Distinguished Presenters
- WEF AND WEF Collections Systems Committee
  - Tina Wolff, Malcolm Pirnie
  - Renee Kayal, WEF
  - Christine Handog, WEF
- Site coordinators
- Attendees
- See your site coordinator for Professional Development Hours (PDHs).
- The next Collection Systems Committee sponsored webcast is on August 13, 2008, focusing on CMOM's Re'sewer" reaction.
- For more info on the WEFCSC and activities, please go to www.wef.org

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