APPENDIX A

STAKEHOLDER SLIDES

Total Maximum Daily Load for Fecal Pathogens in Buffalo Bayou and Whiteoak Bayou

University of Houston
PBS&J
Texas A&M Corpus Christi

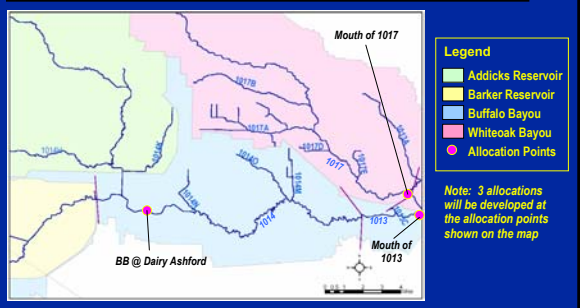
August 18, 2005

Texas Freshwater Bacteria Standards

Contact	Geometric Mean	126 MPN/100 mL
	Not-to-Exceed	394 MPN/100 mL
Non-Contact	Geometric Mean	605 cfu/100 mL
	Not-to-Exceed	No Standard

Standards do not specify time period for geometric mean calculations

Buffalo and Whiteoak Bayous



1013 – BB Tidal, 1013A – Little WO Bayou, 1013C – Unnamed Tributary of BB Tidal, 1014 – BB above Tidal, 1014H – South Mayde Creek, 1014K – Turkey Creek, 1014M – Neimans Bayou, 1014N – Rummel Creek, 1014O- Spring Branch, 1017 – WO Bayou, 1017A – Brickhouse Gully, 1017B- Cole Creek, 1017D- Unnamed Tributary of WO Bayou, 1017E – Unnamed Tributary of WO Bayou

The TMDL Equation

$$TMDL = \Sigma WLA + \Sigma LA + MOS$$

WLA: waste load allocation, i.e. point sources
LA: load allocation, i.e., nonpoint sources
MOS: margin of safety

Summary of WLA Sources – WWTP Loads

1. WWTP discharges
2. WWTP biosolids releases
3. Wet weather loads due to exceeding capacity of WWTP system

Allocated Load = 0

Summary of WLA Sources – MS4 Loads

1. Dry weather storm sewer discharges
2. Storm water system discharges
3. Wastewater collection/conveyance system leaks and overflows (both dry and wet weather)

Load reduction will be required

Summary of WLA Sources – Other

1. On-site sewage facilities (i.e., septic systems)

Allocated Load = 0

Summary of LA Sources

1. Direct deposition into the bayous
2. Stream sediment

Load reductions will be required

Summary of Sources – MOS

1. Margin of safety will be 5% in the allocations

Allocation Development Tools

- Spreadsheet Calculator - % Reduction needed
- HSPF model – evaluate if geometric mean standards are met for various flow and allocation scenarios

Allocation Spreadsheet – Median Flow Non-Contact Recreation Criterion Example

	MEDIAN FLOW TMDL (Billion MPN/day)	
	BB	WO
WLA = WWTPs	9	4
WWTP Biosolids Releases		
Sanitary Sewer releases		
Dry Weather	604	452
Wet Weather (SSOs)		

Average flows from sampling show EC concentrations <5 MPN/dL. Loads in BB reflect plants upstream of reservoirs.

No releases in relatively dry weather

Calculated from sewer overflow data assuming all volumes get to bayous

Allocation Spreadsheet – Median Flow Non-Contact Recreation Criterion Example

	MEDIAN FLOW TMDL (Billion MPN/day)	
	BB	WO
WLA = *continued*		
Bypasses		
MS4 Discharges		
Runoff	3,350	1,675
Dry Weather	203	24

No bypasses in watersheds

UH sampling data for dry weather storm sewer flows

Median flows for each bayou, w/ runoff fraction at 5,000 MPN/dL, low end of runoff range

Allocation Spreadsheet – Median Flow Non-Contact Recreation Criterion Example

		MEDIAN FLOW TMDL (Billion MPN/day)	
		BB	WO
LA =	Sediment contributions	0.65	0.02
	OSSFs	0.001	0.001
	NPS direct input to bayous	1,847	853

Sediment input calculated using estimated area of bayou bed and assumed delivery rate.

On-site sewage facilities (OSSF) are the same as septic systems

Direct deposition into the bayous from wildlife, domesticated animals, people in recreation areas, etc.

Allocation Spreadsheet – Median Flow Non-Contact Recreation Criterion Example

		MEDIAN FLOW TMDL (Billion MPN/day)	
		BB	WO
MOS =	Assume 25% or 151 (goal 454 MPN/dL)	369	185
	Actual Bayou Loads	6,013	3,008
	Target Bayou Loads	1,110	555

Noncontact criterion is 605 MPN/dL, and 25% is 151 MPN/dL. Flow x 151 (605-454) MPN/dL

Sum of all loads, yielding concentrations of about 2500 MPN/dL

Load calculated using target concentration of 454 multiplied by median flows

Example Percent Reduction Required

	BB	WO
Contact Recreation Standard	96%	96%
Noncontact Recreation Standard	81%	81%

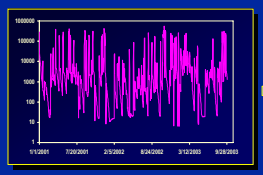
Note: Percentage reductions are those needed to meet standard (605 for non-contact recreation, 126 for contact recreation), assuming 25% margin of safety

Flow Conditions and Averaging Period

Allocations will be analyzed as follows:

1. Hourly EC data for all conditions over all simulation period will be analyzed
2. Hourly EC concentrations for median flows and below will also be examined
3. Frequency of hourly concentrations will be analyzed (through cumulative frequency curves, box plots, etc)
4. Daily values may also be examined
5. Moving 91-day geometric mean will be calculated
6. Frequency of moving geomean averages will be analyzed

Box Plot Development

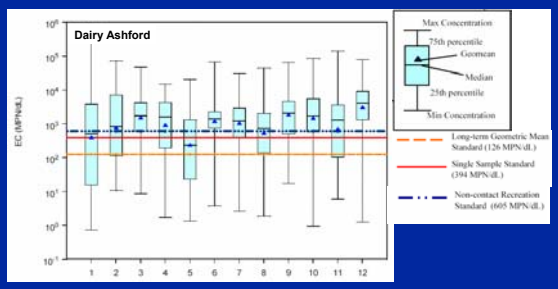


Daily and Hourly EC Data

Data broken down into months

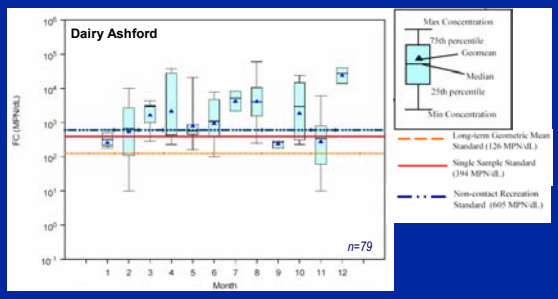
Statistical program calculates percentiles and geomeans

Box plots of modeled hourly data



Time period for analysis is January 2001- October 2003

Box plots of historical data



Time period for analysis is 1993 - 2001; FC data were used as there were more data and was representative of long term conditions

Total Maximum Daily Load for Fecal Pathogens in Buffalo Bayou and Whiteoak Bayou

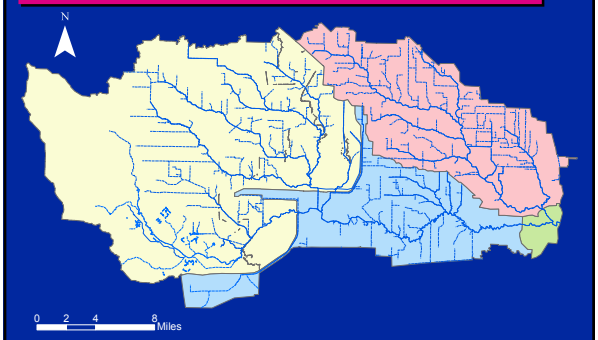
University of Houston
PBS&J
Texas A&M University – Corpus Christi

November 2004 Meeting

Texas Freshwater Bacteria Standards

E. coli	Geometric Mean	126 MPN/100 mL
	Not-to-Exceed	394 MPN/100 mL
Fecal coliform	Geometric Mean	200 cfu/100 mL
	Not-to-Exceed	400 cfu/100 mL

Buffalo and Whiteoak Bayous



Major Tasks WO6

- Stakeholder/Public education and involvement
- QAPP development
- Finalize BST sampling plan
- Assess impact of biosolids releases to the bayous
- Assess sediment contributions
- Investigate EC levels from reservoirs

Major Tasks WO6 - Continued

- Quantify loads of EC to the bayous from bypasses and overflows
- Assess impact of effluent discharges on in-stream EC levels
- Expand HSPF model for Buffalo Bayou to include biosolids, overflows and bypasses
- Expand ARP database
- Conduct bacteria source tracking sampling and analyses

Amendment 1-WO6

- Expand the HSPF TMDL model for BB to include areas above reservoirs
- Refine the existing modeling of point sources using time-varying flow and concentrations

Amendment 2-WO6

- Review Region H Water Availability Model (WAM) and applications for withdrawals and diversions in the 2 bayous
- Formulate how reductions in bayou flow would operate under different stream flow conditions
- Analyze effects of diversions and withdrawals on attaining WQ criteria using HSPF models
- Formulate draft limitations on withdrawals and diversions to maintain acceptable EC levels
- Expand the Houston bacteria source tracking database

Amendment 3-WO6

- Equipment acquisition to facilitate bacteria source tracking analysis

Stakeholder involvement

- Participation in three stakeholder meetings: 10/15/2003 (brainstorming session), 01/28/2004, 05/18/2004
- Preparation of responses to questions and information requests from stakeholders
- Development of informational materials
- Response to Ms. Ann Otto regarding Dog Park and Mrs. Terry Hershey regarding reservoirs

Project QAPP

- First draft submitted to TCEQ on December 1, 2003
- Second draft submitted to TCEQ on February 27, 2004
- Final QAPP submitted to TCEQ on March 26, 2004
- Final QAPP approved on June 4, 2004

Major Tasks WO6

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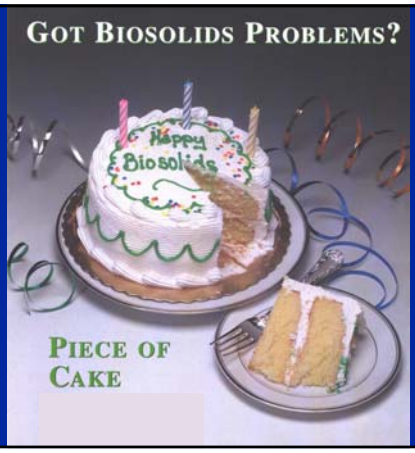


Biosolids releases

- Reconciliation of reported vs estimated biosolids for all the facilities
- Biosolids for each facility estimated using 2 different methods:
  - EPA's Biosolids Generating Factor (BGF)
  - Simplified Mass Balance
- Facility data compiled from TCEQ Region 12 records, TRACS, and EPA's ENVIRO database

Characteristics of Wastewater Treatment

Variable	Category	Number of Plants
Type	Municipal	85
	Industrial	3
Flow	< 1 MGD	74
	1< Flow <10 MGD	14
Treatment Method	aerobic digester	60
	Unknown	28

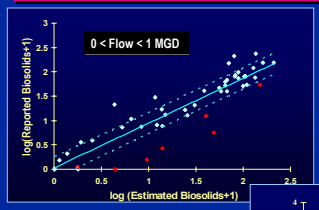
Estimated Sludge

(in dry metric tons/yr)

	Reported	Mass Balance	BGF
Buffalo	3,381	4,102	3,529
Whiteoak	5,187	3,356	2,881

Note: From August 2002 to July 2003, WOB n = 19, BB n = 34

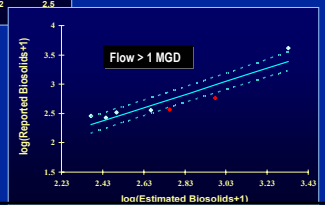
Comparison of Reported vs. Estimated Biosolids



Dashed lines represent the 50% prediction intervals

Estimated sludge using simplified mass balance method

Red points correspond to outfalls where reported sludge < estimated sludge



Biosolids by WWTP

Estimated Biosolids > Reported Biosolids
(outside 50% prediction interval)

Permit #	Plant Name	Flow rate (MGD)	Estimated Biosolids[1] (Met ton/yr)	Reported Biosolids (Met ton/yr)
12830	ROBINSON, J.W	0.004	0.80	0.00
12858	GEORGE BUSH PLANT	0.016	3.41	0.00
13245	GRAND LAKE MUD NO. 4	0.225	48.97	4.58
13484	NORTHWOODS INDUSTRIAL PARK WWTP	0.060	12.96	1.77
12132	WHITE OAK OWNERS ASSOCIATION	0.040	8.64	0.57
11005	CHAMP'S WATER COMPANY	0.182	39.42	11.37
11598	HARRIS COUNTY MUD NO. 61	0.691	150.42	50.61
10495-109	CITY OF HOUSTON	4.347	946.31	575.00
11290	JACKRABBIT ROAD PUBLIC UTIL DISTRICT	2.618	567.67	365.57

[1] Estimated using mass balance approach

Major Tasks WO6

- Stakeholder/Public education and involvement
- QAPP development
- Finalize BST sampling plan
- Assess impact of biosolids releases to the bayous
- Assess sediment contributions
- Investigate EC levels from reservoirs

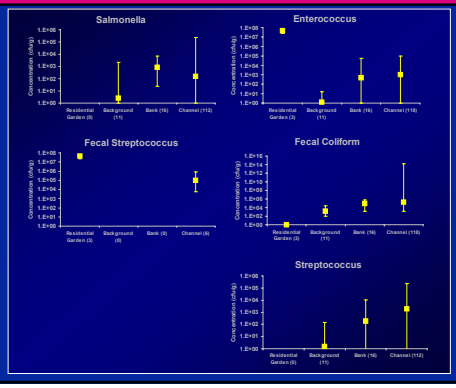
Sediment contributions

- Bacteria in soils
- Stream sediments with and without upstream WWTPs
- Settling tests for solids and bacteria

HCFCD Tests

- Samples of drainage channel sediments and other soils collected
- Analyzed for: fecal coliform, *Enterococcus*, *Streptococcus*, fecal *Streptococcus*, and *Salmonella*
- All common indicators and pathogens

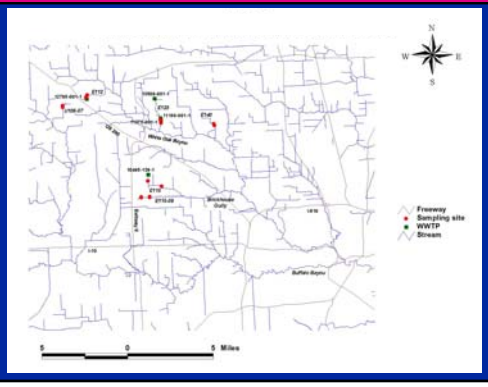
HCFCD Bacteria Sampling Results



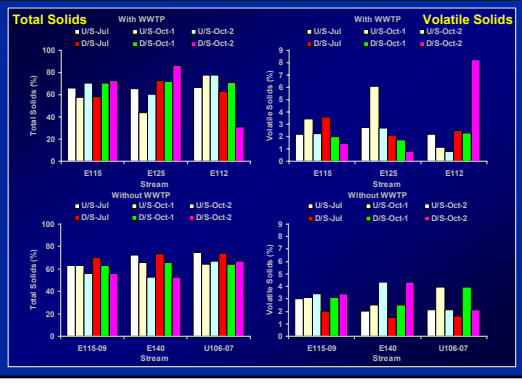
EC Sediment Samples With and Without Upstream WWTPs

- Three streams with and three without
- Two locations on each stream
- Three replicate samples
- Total Solids, Volatile Solids, Moisture % and EC levels

Locations of Sampling Sites for WWTP Effects



WWTP Effects on Stream Sediment



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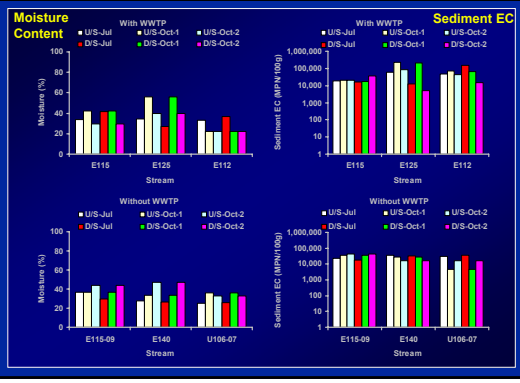
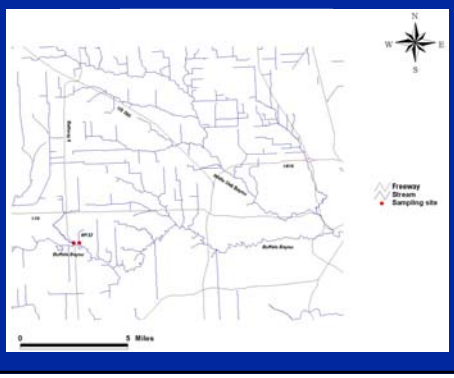


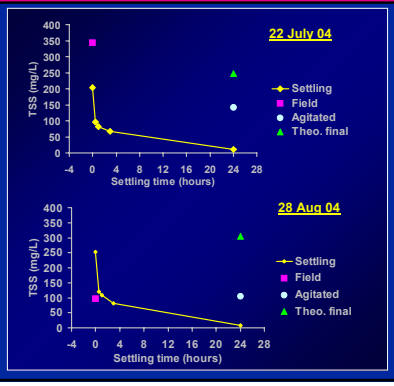
Settling Tests

- Goal is to better understand relation between high solids and bacteria in runoff, and removal in settling
- Two locations and two replicates
- General tracking of sediment and bacteria but short-term EC increases observed in half of tests

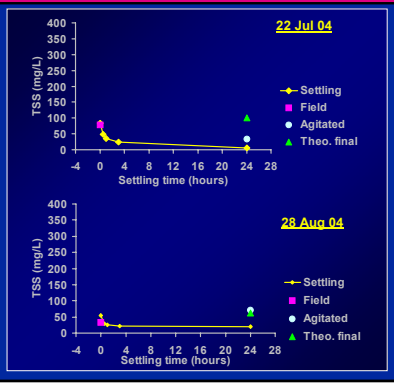
Locations of Sampling Sites for Settling Tests



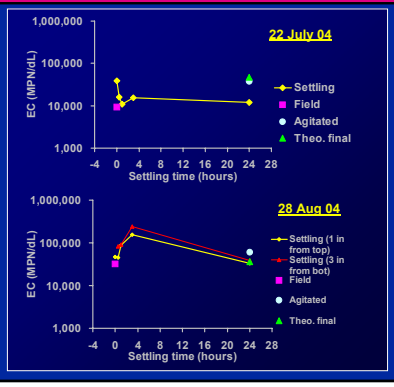
TSS Settling Test – Buffalo Bayou at West Belt



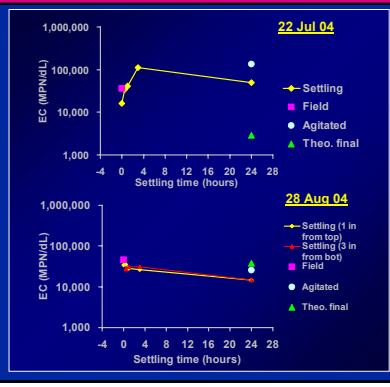
TSS Settling Test – W153 at Legend Lane



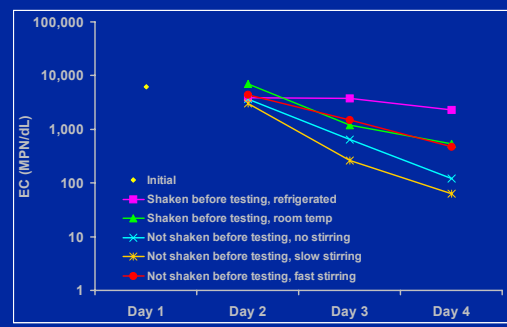
EC Settling Test – Buffalo Bayou at West Belt



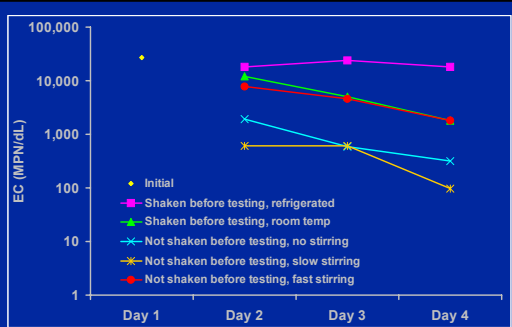
EC Settling Test – W153 at Legend Lane



Die-Off Test, Piney Point Road



Die-Off Test, Voss Road



Sediment Summary

- Rich topsoils contain high levels of bacteria
- Runoff flowing through and eroding soil can be expected to have high bacteria
- Upstream WWTPs do not appear to have major effect on stream sediment
- Bacteria removed by settling, but rate may not be governed by particle size
- Short-term spikes in concentration seen
- More data coming

Major Tasks WO6

- Stakeholder/Public education and involvement
- QAPP development
- Finalize BST sampling plan
- Assess impact of biosolids releases to the bayous
- Assess sediment contributions
- Investigate EC levels from reservoirs

EC levels from Addicks and Barker Reservoirs

- Sampling from June to August 2004
- 3 wet weather and 3 dry weather events
- Sampling undertaken after June 2004 rains to investigate impact of water releases from reservoir

Sampling Locations for Reservoirs

Dry Weather Summary Statistics

Dry Weather	Avg	Geomean	Std Dev	Min	Max
E. coli (MPN/dL)	3,033	363	6,857	<1	27,685
TSS (mg/L)	65	43	56	9	223
TDS (mg/L)	358	316	127	22	513
TOC (mg/L)	10.7	10.6	1.4	8.5	13.6
DOC (mg/L)	9.4	9.3	1.2	7.7	12.1
Conductivity (ms/cm)	575	528	205	156	860
DO (mg/L)	4.1	3.8	1.7	1.2	6.9
Phosphorous (mg/L)	3.2	2.4	1.8	0.1	7.0

Samples greater than detection limit assumed to be detection limit; samples less than detection limit assumed to be ½ detection limit

Wet Weather Summary Statistics

Wet Weather	Avg	Geomean	Std Dev	Min	Max
E. coli (MPN/dL)	15,416	4,165	23,413	14	108,305
TSS (mg/L)	175	98	231	6	1,146
TDS (mg/L)	344	301	169	68	992
Conductivity (ms/cm)	542	486	220	97	880
DO (mg/L)	4.5	3.5	3.5	0.0	8
Phosphorous (mg/L)	3.0	2.2	1.9	0.2	6.9

Samples greater than detection limit assumed to be detection limit

Comparison of EC at Various stations

	EC Geomean (MPN/dL)	
	Dry Weather	Wet Weather
11142 - Barker Discharge	189	3,768
11158 - Langham Creek	1,430	3,047
11164 - Turkey Creek	146	8,605
11165 - S. Mayde Creek	260	3,635
11166 - Bear Creek	491	6,514
11362 - Dairy Ashford	1,695	29,413
16428 - BB at Westheimer	17	178
TBD 2 - Addicks Discharge	1276	2,560
TBD4[a] - Mason Creek	1,883[a]	38,387
Barker Reservoir Sites	94	1,571
Addicks Reservoir Sites	509	4,533

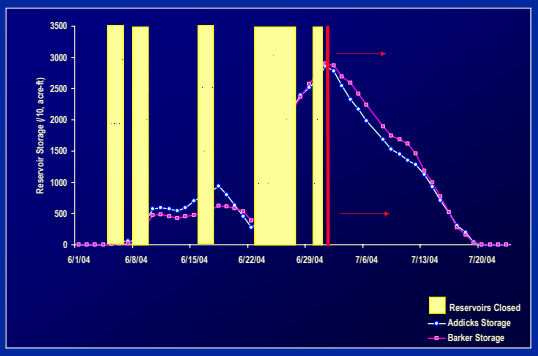
[a] Mason Creek sampled only once during dry weather

Loads from Reservoirs during Wet Weather

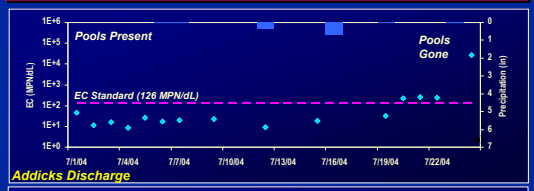
		EC Load (MPN/hr)	TSS Load (mg/hr)
Barker Discharge	Geomean	2.20E+11	1.11E+09
	Maximum	1.23E+13	1.25E+10
	Minimum	2.40E+09	2.63E+08
Addicks Discharge	Geomean	1.75E+11	6.26E+08
	Maximum	3.88E+12	1.56E+10
	Minimum	4.47E+09	5.38E+07
Dairy Ashford	Geomean	6.94E+12	5.01E+09
	Maximum	5.65E+13	5.36E+11
	Minimum	3.02E+10	3.00E+08

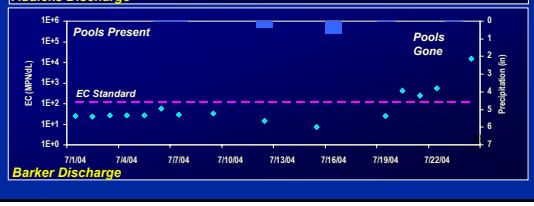
Dry weather n=9 Wet weather n=33

Sampling after June 2004 Rains



Sampling after June 2004 Rains





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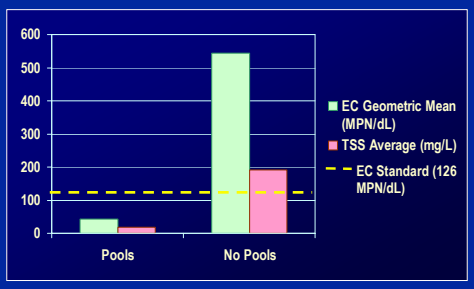


Excludes wet weather sampling data; average includes TBD1, TBD2, TBD3, 11142, and 11362

Major Tasks WO6 - Continued

- Quantify loads of EC to the bayous from bypasses and overflows
- Assess impact of effluent discharges on in-stream EC levels
- Expand HSPF model for Buffalo Bayou to include biosolids, overflows and bypasses
- Expand ARP database
- Conduct bacteria source tracking sampling and analyses

Quantify EC loads from overflows and bypasses

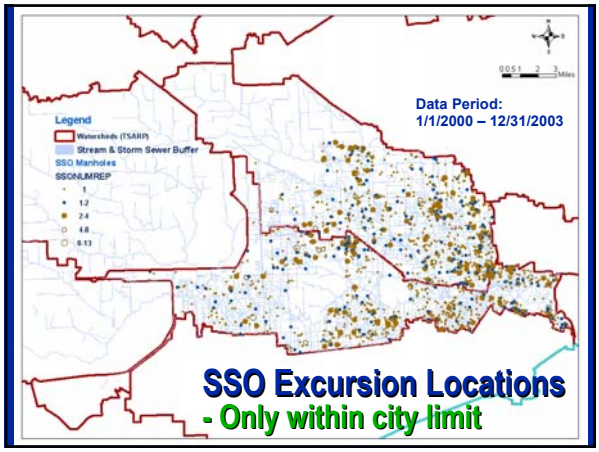
- No bypasses at treatment plants
- Overflows in sanitary sewers—SSOs
- Two types of SSOs
  - Dry weather—from line failure or blockage at normal flows
  - Wet weather—from capacity exceedance driven by I&I

WW Overflow Data Collection

- City of Houston database provided by Public Works and Engineering
- Storm sewer and sanitary manholes GIS shape files provided by GIMS
- TCEQ headquarters and regional office contacted confirming TCEQ having the same data set as City of Houston

Dry Weather SSO Characterization

- Data sources
- Flows and Bacteria loads assuming all of overflows reach bayous in dry weather
- Percentage effects on bayous
- Potential to reach bayous
  - Based on Flow Location field in database
  - Based on proximity to drainage pathway



SSO SUMMARY

	Data Period		Manholes	No. Excursions	
	From	To	With SSO	Total	w/ Vol
Entire Database	1/1/2000	12/31/2003	4,282	6,184	6,160
Within BB	1/2/2000	12/30/2003	797	1,180	1,173
Within WOB	1/4/2000	12/18/2003	730	1,078	1,071

SSO Volumes & Flows

	SSO Vol	SSO Flow*		Typ. Dry
	(gal)	(gal/day)	(cfs)	Flow (cfs)
Entire Database	16,876,954	16,877	0.0261	
Within BB	3,155,877	3,191	0.0049	100
Within WOB	2,386,960	2,390	0.0037	50

*Assume 250 dry days per year

SSO Contribution Assuming All Flow goes to Bayou (with No Other Sources In Bayous)

- SSO EC = 5x106 MPN/dL
- Flow 100 cfs for BB and 50 cfs for WO
- BB – (.0049 x 5x106 MPN/dL)/100.0049
- BB = 245 MPN/dL
- WO – (.0037 x 5x106 MPN/dL)/50.0037
- WO = 370 MPN/dL

SSO % EC increase assuming all flow goes to Bayous

- Geomean EC = 5 x 106 MPN/dL in SSO (raw sewage)
- Assume EC = 2,000 MPN/dL in bayous upstream of SSO
- EC concentration downstream of SSO would be:
  - BB: $(5x10^6 * 0.0049 + 2,000 * 100) / (0.0049 + 100) =$ 2,245 MPN/dL, or 12% increase
  - WO: $(5x10^6 * 0.0037 + 2,000 * 50) / (0.0037 + 50) =$ 2,370 MPN/dL, or 19% increase

Estimating % of SSOs getting to bayous based on records

SSO Destinations	SSO Excursions	SSO Volume (gallons)	% of Total SSO Excursions		% of Total SSO Volume	
			w/"Blank"	non-"Blank"	w/"Blank"	non-"Blank"
Buffalo Bayou						
"Blank"	529	1,296,452	45%		49%	
Bayou	35	143,885	3%	5%	5%	10%
Contained On Site	169	207,788	14%	26%	8%	15%
Drainage Ditch	73	127,082	6%	11%	5%	9%
Storm Sewer	375	892,989	32%	58%	33%	65%
Total	1181	2,668,196	100%	100%	100%	100%
White Oak Bayou						
"Blank"	493	979,158	46%		51%	
Bayou	23	44,220	2%	4%	2%	5%
Contained On Site	154	190,409	14%	26%	10%	20%
Drainage Ditch	95	159,149	9%	16%	8%	17%
Storm Sewer	311	538,335	29%	53%	28%	58%
Total	1076	1,911,271	100%	100%	100%	100%

Estimating if SSO can reach bayous based on proximity to drainage path

- Import SSO manhole locations into GIS
- Intercept SSO locations with BB and WOB watershed boundaries
- Estimate if SSO will reach bayous
  - Create buffer along storm sewer lines (75 ft) and along streams (100 ft)
  - Calculate SSO volumes within and outside the buffer areas
- BB-36% and WOB-27% of SSO volume in buffer zones

Example Buffer Analysis

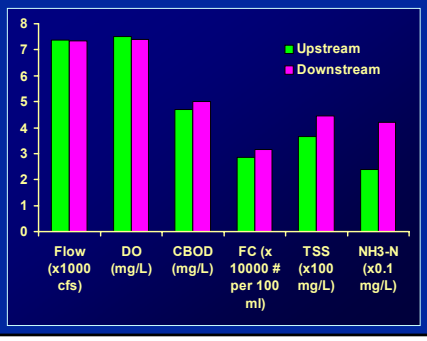
Wet Weather SSOs

- Common situations, particularly in older parts of city
- Very hard to find and measure
- City has three Wet Weather Facilities
  - Northside (lower BB)
  - Belmont (Brays Bayou)
  - Bretshire (Halls Bayou)

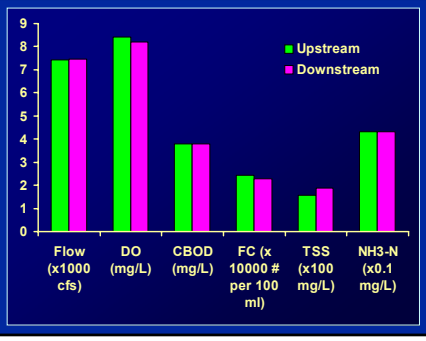
Wet Weather WWF Monitoring

- USGS monitors upstream and downstream of each facility for each event
- Data from 1998-2004 tabulated
- In general, it is hard to see effects of WWF discharges

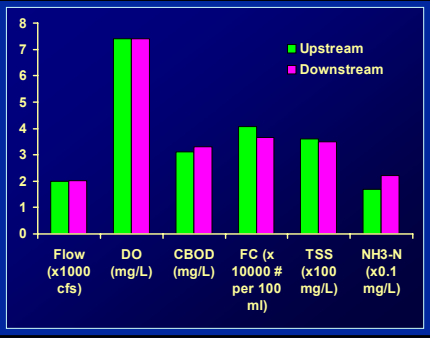
Upstream and Downstream Sampling of Northside WWF



Upstream and Downstream Sampling of Belmont WWF



Upstream and Downstream Sampling of Bretshire WWF



Overflow/Bypass Summary

- Collection systems with raw sewage need to be maintained and periodically rebuilt
- Continued and improved efforts to control SSOs must be part of TMDL
- Available data suggest even complete elimination of SSOs will not greatly change ambient bacteria levels

Major Tasks WO6 - Continued

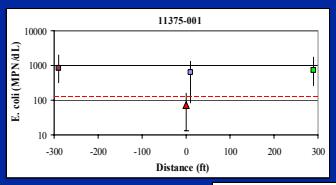
- Quantify loads of EC to the bayous from bypasses and overflows
- Assess impact of effluent discharges on in-stream EC levels
- Expand HSPF model for Buffalo Bayou to include biosolids, overflows and bypasses
- Expand ARP database
- Conduct bacteria source tracking sampling and analyses

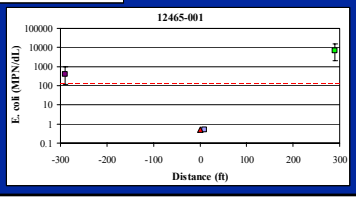
EC Levels downstream of WWTP

- Sampling up, downstream, effluent outfall and within the mixing zone of the outfall location at 10 WWTP
- Plants were sampled in both Buffalo and Whiteoak Bayou watersheds

Location of Sampled WWTPs

Results from selected WWTPs





- Upstream
- Downstream
- Instream
- Effluent
- 126 MPN/dL

Summary Statistics for Sampled WWTPs

EC (MPN/dL)	n	Avg	Geomean	# > WQ Std	Min	Max
Downstream	10	2,481	140	7	<1	15,117
Upstream	10	1,111	489	9	70	6,833
Instream	10	367	80	6	<1	1,221
Effluent	8	887	27	1	<1	5,905

Notes:
WQ Std = 126 MPN/dL
Samples less than detection limit assumed to be ½ detection limit
Some effluent samples were not collected due to submerged pipe

Major Tasks WO6 - Continued

- Quantify loads of EC to the bayous from bypasses and overflows
- Assess impact of effluent discharges on in-stream EC levels
- Expand HSPF model for Buffalo Bayou to include biosolids, overflows and bypasses
- Expand ARP database
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Bacteria Source Tracking

- The determination of the animal source(s) of fecal contamination using characteristics of fecal bacteria (*E. coli*)
- Antibiotic resistance analysis (ARA) screening
- Pulse Field Gel Electrophoresis (PFGE) subset

Sample Collection

- Fecal samples collected June-July 2004
- Locations within the watershed – identified by UH personnel
- Animals included are based on UH sanitary survey
- All samples transported to Texas A&M University-Corpus Christi for analysis

E. coli isolation

- Swabbed onto mTEC Agar
- Transferred to Rainbow Agar
- Verified as *E. coli* using the Biolog MicroLog™ or MicroStation™ Microbial Identification System
- Temporary storage on Tryptic Soy Agar slants
- Storage at –70 C

Analysis

Animal Source	# Isolates	ARA	PFGE
Bird	365	171	63
Cow	426	219	58
Dog	306	182	59
Horse	348	200	53
Bat	389	204	59
Human	449	202	52
TOTAL	2283	1178	344

Antibiotic Resistance Analysis

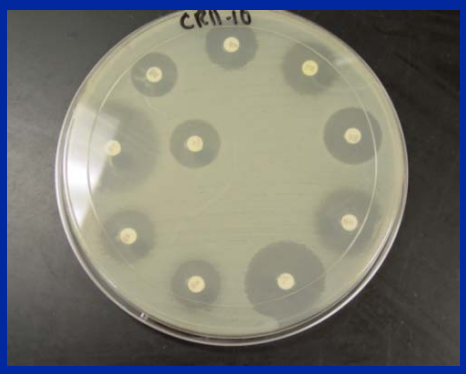
- ARA utilizes patterns of resistance among indicator bacteria
- Bacteria from GI tracts of a range of animals should exhibit different profiles of resistance due to:
  - environmental factors
  - exposure or lack of exposure to antibiotics
  - variation in food source (diet)

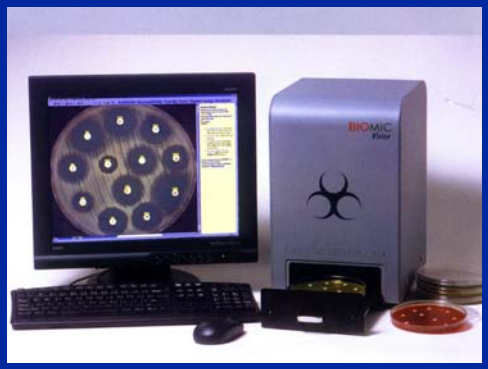
Antibiotic Resistance Analysis

- ARA was performed using the Kirby Bauer Disk Diffusion Test, a clinically approved, standard method
- Commercial disks, each containing an antibiotic are placed on a plate, pre-inoculated with the E. coli isolate
- After incubation, plates are read using a BIOMIC Microbiology Analyzer System with a digital camera

Antibiotic Resistance Analysis

- Plates assessed for zones of inhibition (no growth) around the disks i.e. susceptible to the antibiotic or reduced zones indicating resistance to the antibiotic
- The information is compared with NCCLS tables of standard zones for *E. coli* included in the computer software





Antibiotic Resistance Analysis

- A printout is generated which includes zones of inhibition and resistance classification
- The information for each isolate is entered into a database, converted to SPSS and analyzed to determine whether isolates from different animals have different ARPs.
- This "library" can then be used to identify sources of *E. coli* from water/sediment samples by comparing the profiles

Two-way classification

	% Correct classification		
ARCC	77.4	64.8	85.7
Non-human	83.3	68.8	88.4
Human	49.0		
Human-S		42.5	
Human-P		49.0	57.9

Four-way classification

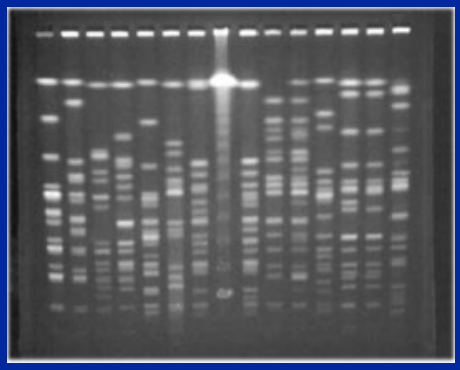
	% Correct classification		
ARCC	45.9	42.4	50.8
Wildlife	60.5	55.5	64.0
Livestock	40.1	35.3	43.7
Pet	39.6	39.6	41.8
Human	36.1		
Human-S		26.4	
Human-P		44.8	47.4

Pulse Field Gel Electrophoresis

- A molecular technique which generates a DNA "fingerprint" specific for different strains of the bacteria
- The confirmed *E. coli* isolates were batch cultured for DNA analysis
- The total DNA was extracted from the cultures and fingerprinted

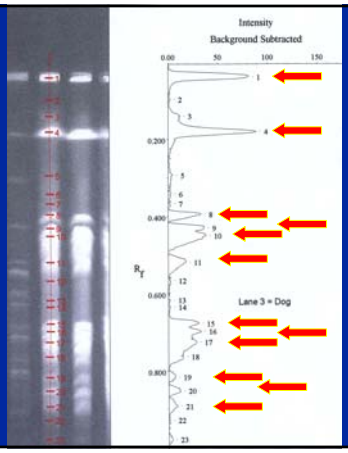
Pulse Field Gel Electrophoresis

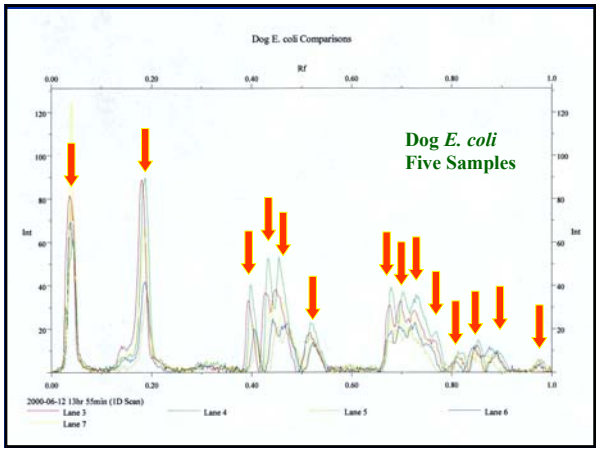
- A comparative analysis was performed against the database using Diversity Database©.
- Similarity searches of all bands using the Jaccard Coefficient Method were completed.
- The Diversity Database© report displays all the members of the population, sorted in order of decreasing similarity from the reference sample.

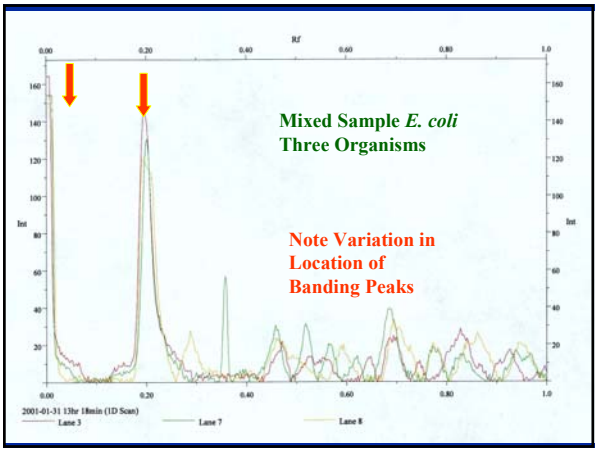


Typical Set of *E. coli* Bands from PFGE

Lane 3 = Dog







Summary

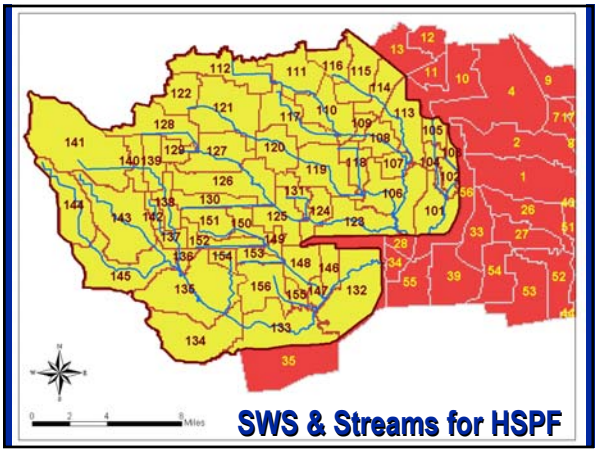
- A library of *E. coli* isolates from 6 animal sources has been developed for ARA and PFGE
- *E. coli* isolates from water/sediment samples have been verified and stored at –70 C for future analysis
- The library will be used to identify sources of *E. coli* isolates by comparing their profiles with the database

Amendment 1-WO6

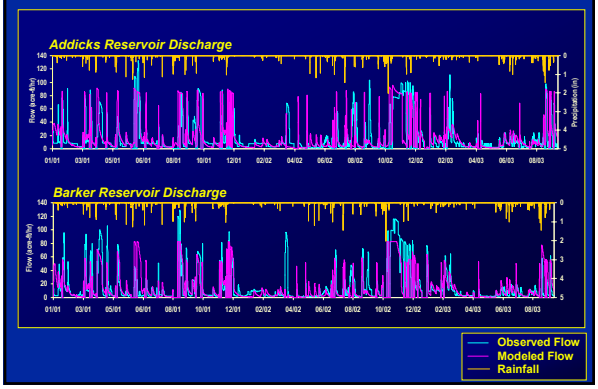
- Expand the HSPF TMDL model for BB to include areas above reservoirs
- Refine the existing modeling of point sources using time-varying flow and concentrations

Adding Reservoirs to HSPF

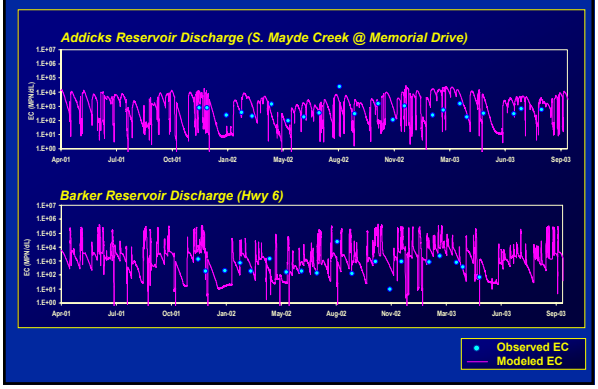
- Collect TSARP subwatershed, stream system (CAP), & LIDAR shape files
- Collect HGAC landuse shape file
- Collect WMP DrainLn_AP200 (proposed channels) shape files from LAN and Cobb-Fendley



Flow Calibration



EC Calibration



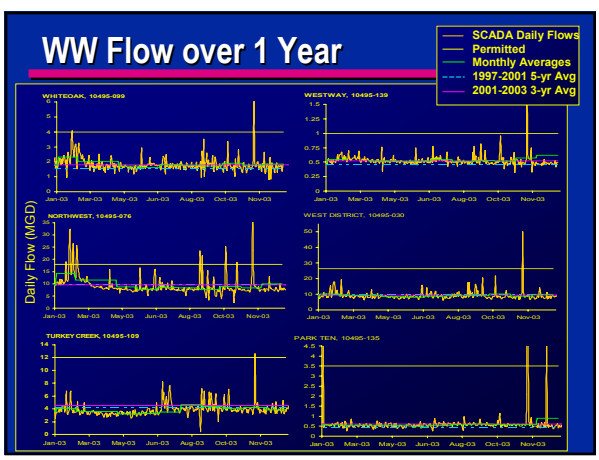
Amendment 1-WO6

- Expand the HSPF TMDL model for BB to include areas above reservoirs
- Refine the existing modeling of point sources using time-varying flow and concentrations

Refine HSPF Using Time-Varying WWTP Flows

- Daily flow variability at six City of Houston WWTPs is high
- WWTP discharge flows for 2003
  - Monthly flow is skewed higher by high flow events

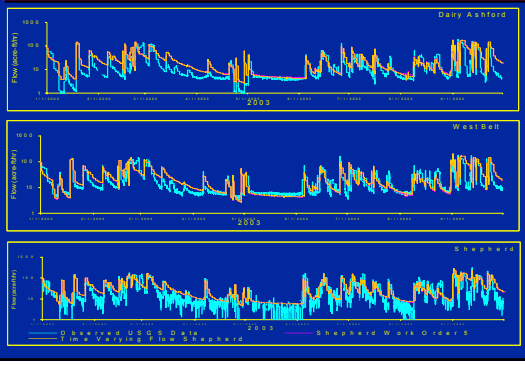
WW Flow over 1 Year



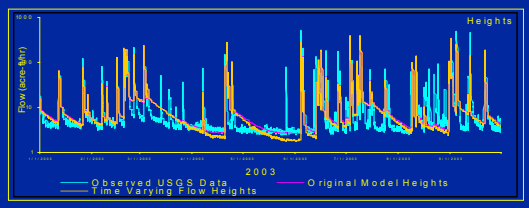
Time Series Statistics Time-Varying WWTP Flows

- Predict WWTP discharge flows using monthly self-reported average
- WO5 used the five year average to predict WWTP flows
- WO6 (TVF) uses time varying flow to better match low flows

Time Varying Flows-Buffalo Bayou



Time Varying Flows-White Oak



Overall Results for Time-Varying WWTP Flows

- Comparison of WO5 and TVF model predictions with USGS bayou flows
  - Shows that even with TVF
    - Model still over-predicts low flows
    - Low flow volumes in the bayous are not matched
- new method to better match hourly and daily flows from WWTPs ongoing

Amendment 2-WO6

- Review Region H Water Availability Model (WAM) and applications for withdrawals and diversions in the 2 bayous
- Formulate how reductions in bayou flow would operate under different stream flow conditions
- Analyze effects of diversions and withdrawals on attaining WQ criteria using HSPF models
- Formulate draft limitations on withdrawals and diversions to maintain acceptable EC levels
- Expand the Houston bacteria source tracking database

Water Withdrawals and Diversions

- Much of Texas short on water
- To allocate scarce resource, seniority system evolved—FIRST IN TIME, FIRST IN RIGHT
- Rights only issued if water is available
  - No prior rights
  - No environmental restrictions

Regulatory Process For Withdrawals And Diversions

- Assess historical flow record
- Determine naturalized flow
- Use Water Availability Model
- Assess environmental needs
- Staff at TCEQ make recommendation
- Commission decides

Proposed Permits

- CoH surface water application
  - 60,000 ac-ft/yr or 83 cfs for BB
  - 40,000 ac-ft/yr or 55 cfs for WO
- CoH Reuse applications
  - 65 cfs for BB
  - 36 cfs for WO

NOTE: estimated volumes, actual volumes may change.

Effects of Withdrawal from Bayous

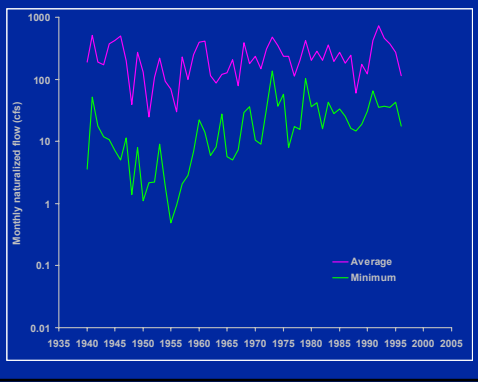
Reduction of Total Flow:

Ecological Fresh Water Flow Requirements
Availability of Water in Bayous
Impact on Existing Water Rights

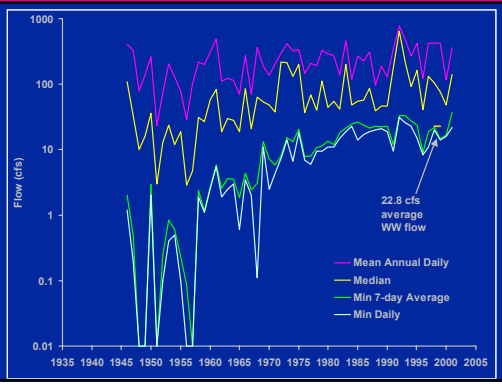
Impact on Bacteria Levels within the Bayous:

Reduced Flow Rate
Variation in Scour/Deposition

Naturalized flow – Buffalo Bayou at Dairy Ashford

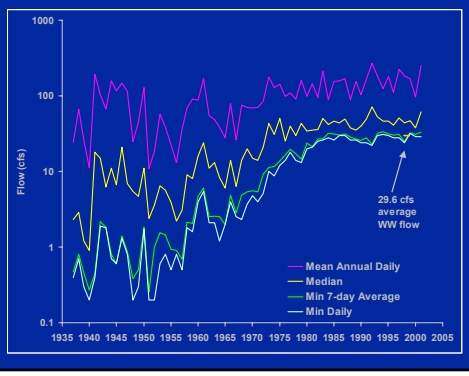


Naturalized flow – Buffalo Bayou at Dairy Ashford



Naturalized flow – White Oak Bayou at Heights Blvd

Naturalized flow – White Oak Bayou at Heights Blvd



Water Withdrawal Effects on Bacteria Levels

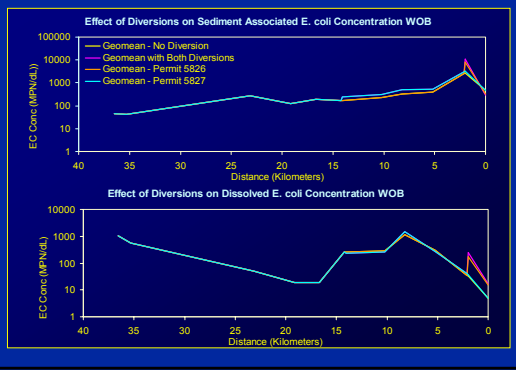
Association of Bacteria:
- Adsorbed to Suspended Sediment
- Dissolved within the Water Column

Physical Characteristics of the Bayou:
- Portion of White Oak Bayou has Concrete Bed
- Buffalo Bayou has Natural Sediment Bed

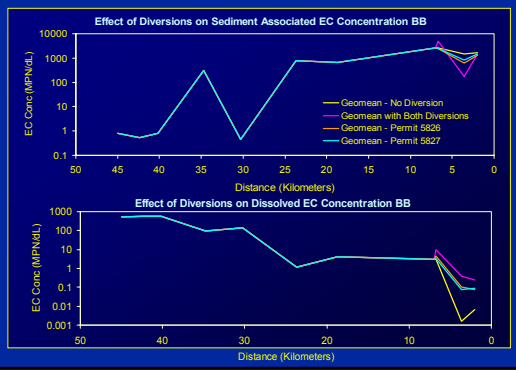
Water Withdrawal Effects on Bacteria Levels

- Concentrations of dissolved bacteria increase for both bayous
- Sediment Associated Bacteria Levels
  - Increase for White Oak Bayou
  - Decrease for Buffalo Bayou

Withdrawals and Diversions Modeling of WOB



Withdrawals and Diversions Modeling of BB



Future Plans

- Sample for biosolids releases
- Sample sediment downstream of WWTPs
- Sample overflows and bypasses
- Complete BST analyses
- Finalize HSPF models for low flow
- Refine withdrawal and diversion analysis
- Complete load allocation scenarios
- Select BMPs