Development of Lower Chickahominy River and Tributaries Bacteria TMDLs

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Why We Are Here

1. To review water quality conditions and pollutant sources for these creeks
2. To present model results for Total Maximum Daily Load (TMDL) development
3. To discuss allocation
4. To gather comments and encourage public participation

What is a TMDL ?
Total Maximum Daily Load

A TMDL is the amount of a particular pollutant that a stream can receive and still meet Water Quality Standards
AKA "Pollution Diet"

TMDL = Sum of WLA + Sum of LA + MOS

Where:

TMDL = Total Maximum Daily Load
WLA = Waste Load Allocation (point sources)
LA = Load Allocation (nonpoint sources)
MOS = Margin of Safety

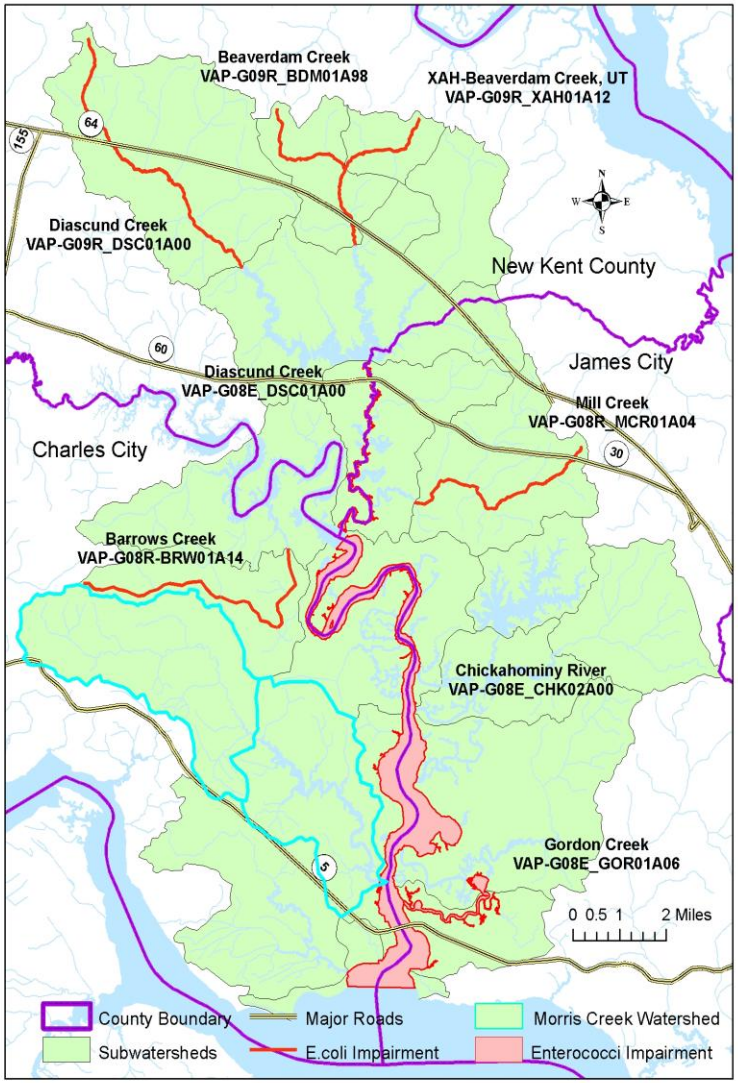
Current Load = current loads discharged to the water body, which will be determined during this study

Reduction = (current load –TMDL)/ current load x 100%

Impaired waters and pollutants

- Lower Chickahominy River and seven tributaries are impaired for elevated bacteria levels

- The Morris Creek bacteria TMDL study was completed in 2009. Source estimations from that study were used as inputs to this TMDL model during the derivation of daily loading for the estuary.



Water Quality Criteria

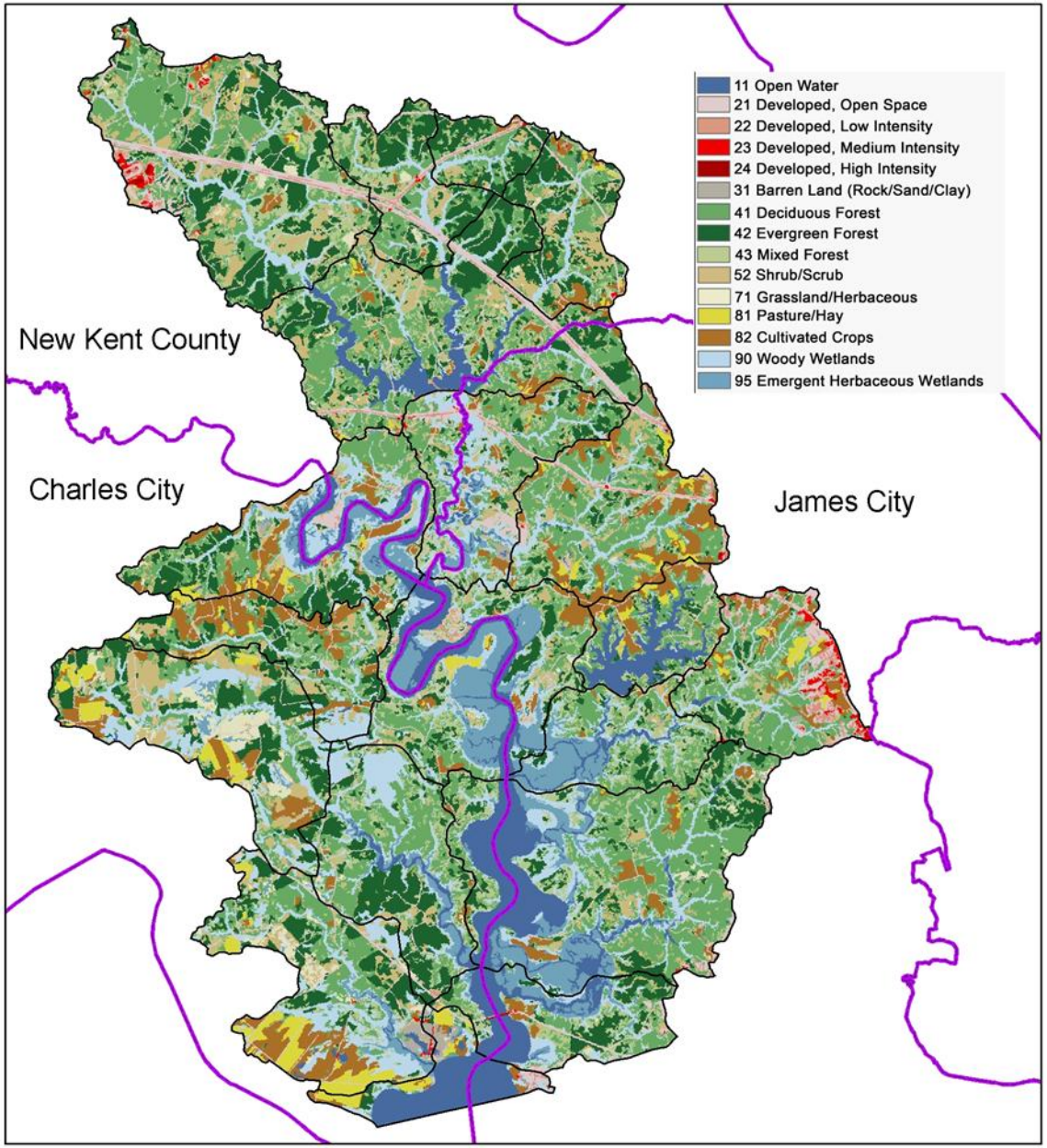
Use	Indicator Bacteria	Criteria
Recreation	*E. Coli* (freshwater)	Geometric Mean 126 cfu/100ml * Single Sample Maximum 235 cfu/100ml
	Enterococci (transition & salt water)	Geometric Mean 35 cfu/100ml * Single Sample Maximum 104 cfu/100ml

- *If there are insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 235 cfu/100 ml for E.coli .*

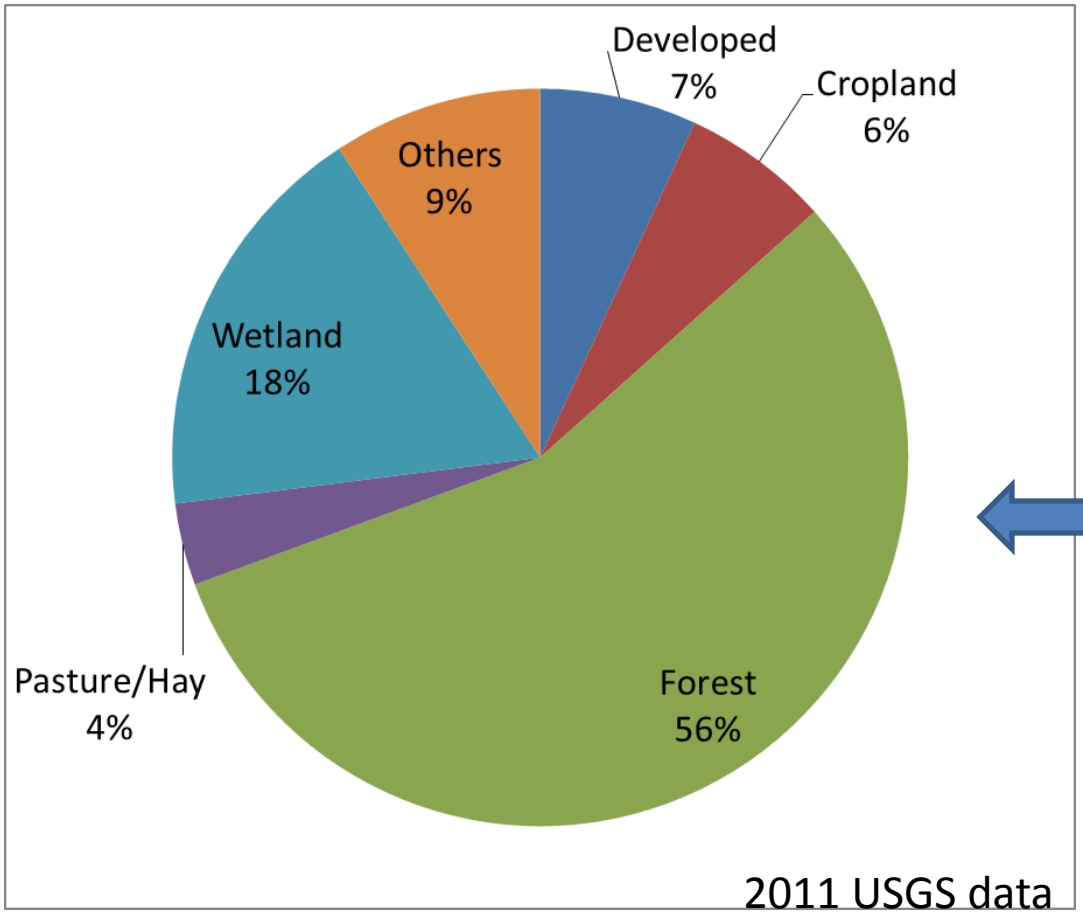
*** If there are insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed 104 cfu/100 ml for enterococci.*

Land Use

(USGS NLCD 2011 data)



Land Use Distribution



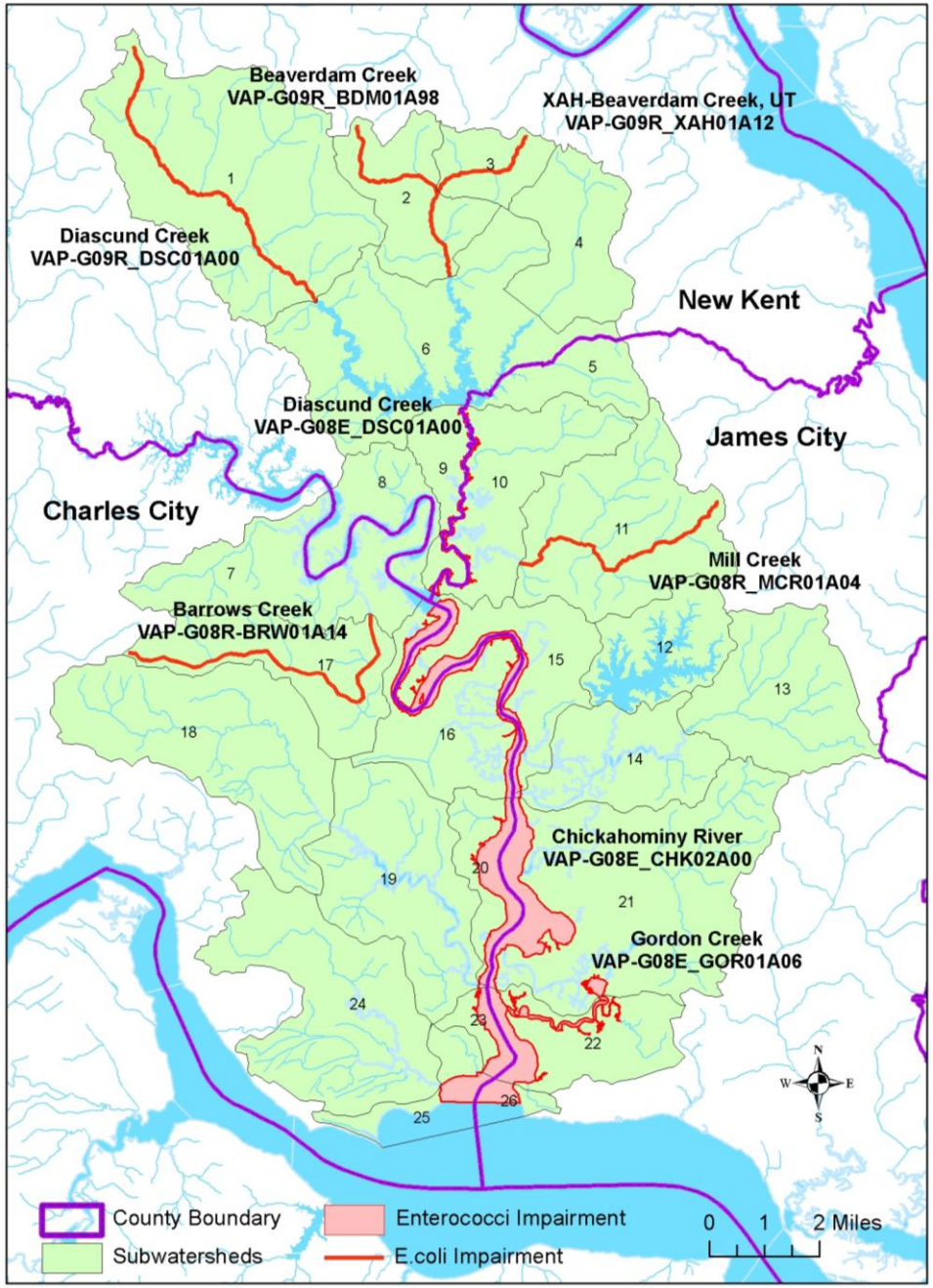
merge

- Open Water
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren Land
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrub/Scrub
- Grassland/Herbaceous
- Pasture/Hay
- Cultivated Crops
- Woody Wetlands
- Emergent Herbaceous Wetlands

Undeveloped = 74%
Ag. = 10 %
*Others: Includes Water and Barren Land (Rock, Sand, and Clay)

Subwatershed Delineation for Source Assessment and Modeling Purposes.
There are a total of 26 segments

Area	Subwatersheds
Chickahominy River	1-26
Diascund Creek (nontidal)	1
Beaverdam Creek	2, 3
UT Beaverdam Creek	3
Diascund Creek (tidal)	1-6,9-11
Mill Creek	11
Barrows Creek	17
Gordon Creek	22
Charles City County	7, 16-20, 23-25
James City County	5, 10-15,21,22,26
New Kent County	1-4, 6, 8, 9



Source Assessment
- Point Source Summary

Permit Number	Facility Name	Permit Type	Category	Design Flow (MGD)	Bacteria Limit (mg/L)	Allowable Loading (cfu/Day)
VA0080233	Hideaway STP	Municipal	VPDES-IP	0.039	35 (Enterococci)	5.17E+07
VAG403039	Single Family Home	General	Domestic Discharger	0.001	35 (Enterococci)	1.32E+06
VAG404050	Single Family Home	General	Domestic Discharger	0.001	126 (E.coli)	2.11E+06
VAG404144	Single Family Home	General	Domestic Discharger	0.001	35 (Enterococci)	1.32E+06
VAG404152	Single Family Home	General	Domestic Discharger	0.001	35 (Enterococci)	1.32E+06
VAG404198	Single Family Home	General	Domestic Discharger	0.001	126 (E.coli)	2.11E+06
VAG404284	Single Family Home	General	Domestic Discharger	0.001	126 (E.coli)	2.11E+06
VAR040037	Locality urbanized Service area - James City	General	MS4-Phase II	NA	35 (Enterococci)	3.68E+11
VAR040115	VDOT roads Within James City County					

Non-Point Sources Summary – by Impaired Water

Lower Chickahominy River

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	% Total Load
Lower Chickahominy River (Subwatersheds 1-26)	Wildlife	Deer	3971	2.0E+12	2.8%
		Ducks	629	1.5E+12	2.2%
		Geese	809	4.0E+13	56.5%
		Beavers	1120	2.8E+11	0.4%
		Raccoons	4184	5.2E+11	0.7%
		Muskrats	168488	5.7E+12	8.2%
		Totals	179199	5.0E+13	70.8%
	Livestock	Totals	635	9.2E+12	13.1%
	Pets	Dogs	2136	2.0E+12	2.9%
	Humans	Septic Tank Failures	4314	2.9E+12	4.1%
		Boating	1718	1.0E+12	1.5%
		Straight Pipes	83	1.5E+12	2.2%
		Biosolids	6644 (tons)	2.9E+12	4.2%
		SSOs	8	8.7E+11	1.2%
	Totals			7.0E+13	100%

Tidal Diascund Creek

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	% Total Load
Diascund Creek (Tidal) (Subwatersheds 1-6, 9-11)	Wildlife	Deer	1575	7.9E+11	3.6%
		Ducks	245	6.0E+11	2.7%
		Geese	315	1.5E+13	70.5%
		Beavers	393	9.8E+10	0.4%
		Raccoons	1660	2.1E+11	0.9%
		Muskrats	42675	1.5E+12	6.6%
		Totals	46863	1.9E+13	84.9%
	Livestock	Totals	62	1.6E+10	0.1%
	Pets	Dogs	998	9.4E+11	4.3%
	Humans	Septic Tanks	2011	1.4E+12	6.3%
		Boating	458	2.7E+11	1.3%
		Straight Pipes	39	7.0E+11	3.2%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			2.2E+13	100%

Gordon Creek

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	% Total Load
Gordon Creek (Subwatershed 22)	Wildlife	Deer	93	4.6E+10	2.6%
		Ducks	19	4.7E+10	2.7%
		Geese	25	1.2E+12	69.0%
		Beavers	67	1.7E+10	1.0%
		Raccoons	110	1.4E+10	0.8%
		Muskrats	7995	2.7E+11	15.6%
		Totals	8308	1.6E+12	91.6%
	Livestock	Totals	26	2.0E+10	1.1%
	Pets	Dogs	27	2.5E+10	1.5%
	Humans	Septic Tanks	195	2.7E+10	1.5%
		Boating	100	6.0E+10	3.4%
		Straight Pipes	1	1.4E+10	0.8%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			1.7E+12	100%

Nontidal Diascund Creek

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	% Total Load
Diascund Creek (Nontidal) (Subwatershed 1)	Wildlife	Deer	434	2.2E+11	4.1%
		Ducks	63	1.5E+11	2.9%
		Geese	81	4.0E+12	74.7%
		Beavers	33	8.3E+09	0.2%
		Raccoons	449	5.6E+10	1.1%
		Muskrats	8220	2.8E+11	5.2%
		Totals	9281	4.7E+12	88.1%
	Livestock	Totals	1	0.0E+00	0.0%
	Pets	Dogs	371	3.5E+11	6.5%
	Humans	Septic Tanks	268	1.9E+11	3.5%
		Boating	4	2.2E+09	0.0%
		Straight Pipes	5	9.7E+10	1.8%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			5.3E+12	100%

Beaverdam Creek

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	% Total Load
Beaverdam Creek (Subwatersheds 2, 3)	Wildlife	Deer	200	1.0E+11	4.1%
		Ducks	29	6.9E+10	2.9%
		Geese	37	1.8E+12	74.4%
		Beavers	32	7.9E+09	0.3%
		Raccoons	202	2.5E+10	1.0%
		Muskrats	4274	1.5E+11	6.0%
		Totals	4773	2.1E+12	88.7%
	Livestock	Totals	1	0.0E+00	0.0%
	Pets	Dogs	148	1.4E+11	5.7%
	Humans	Septic Tanks	126	8.8E+10	3.7%
		Boating	1	4.1E+08	0.0%
		Straight Pipes	2	4.5E+10	1.9%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			2.5E+12	100%

Beaverdam Creek, UT

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	% Total Load
Beaverdam Creek, UT (Subwatershed 3)	Wildlife	Deer	64	3.2E+10	4.2%
		Ducks	9	2.2E+10	3.0%
		Geese	12	5.8E+11	76.5%
		Beavers	11	2.7E+09	0.4%
		Raccoons	65	8.2E+09	1.1%
		Muskrats	1381	4.7E+10	6.2%
		Totals	1543	6.9E+11	91.3%
	Livestock	Totals	0	0.0E+00	0.0%
	Pets	Dogs	47	4.4E+10	5.9%
	Humans	Septic Tanks	20	1.4E+10	1.9%
		Boating	0	2.6E+08	0.0%
		Straight Pipes	0	0.0E+00	1.0%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			7.6E+11	100%

Mill Creek

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	% Total Load
Mill Creek (Subwatershed 11)	Wildlife	Deer	221	1.1E+11	3.3%
		Ducks	38	9.2E+10	2.8%
		Geese	48	2.4E+12	71.3%
		Beavers	23	5.9E+09	0.2%
		Raccoons	241	3.0E+10	0.9%
		Muskrats	6665	2.3E+11	6.8%
		Totals	7237	2.8E+12	85.3%
	Livestock	Totals	51	1.4E+10	0.4%
	Pets	Dogs	82	7.8E+10	2.3%
	Humans	Septic Tanks	400	2.6E+11	7.9%
		Boating	5	2.7E+09	0.1%
		Straight Pipes	8	1.3E+11	4.0%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			5.4E+12	100%

Barrows Creek

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	% Total Load
Barrows Creek (Subwatershed 17)	Wildlife	Deer	192	9.6E+10	1.2%
		Ducks	25	6.0E+10	0.8%
		Geese	32	1.6E+12	19.9%
		Beavers	32	7.9E+09	0.1%
		Raccoons	133	1.7E+10	0.2%
		Muskrats	5667	1.9E+11	2.5%
		Totals	6079	1.9E+12	24.7%
	Livestock	Totals	151	4.3E+12	55.4%
	Pets	Dogs	78	7.3E+10	0.9%
	Humans	Septic Tanks	114	7.8E+10	1.0%
		Boating	2	1.2E+09	0.0%
		Straight Pipes	2	4.2E+10	0.5%
		Biosolids	2329	1.0E+12	12.8%
		SSOs	1	3.5E+11	4.5%
	Totals			7.8E+12	100%

Non-Point Sources Summary – by County

Charles City County

County	Source		Number	Fecal Coliform Load (cfu/Day)	% Total Load
Charles City (Subwatersheds 7, 16-20, 23-25)	Wildlife	Deer	1426	7.1E+11	2.4%
		Ducks	194	4.7E+11	1.6%
		Geese	250	1.2E+13	40.7%
		Beavers	265	6.6E+10	0.2%
		Raccoons	1320	1.7E+11	0.5%
		Muskrats	58642	2.0E+12	6.6%
		Totals	62098	1.6E+13	52.1%
	Livestock	Totals	484	9.1E+12	30.4%
	Pets	Dogs	781	7.3E+11	2.4%
	Humans	Septic Tanks	488	3.1E+11	1.0%
		Boating	402	2.4E+11	0.8%
		Straight Pipes	10	1.8E+11	0.6%
		Biosolids	6644 (tons)	2.9E+12	9.7%
		SSOs	8	8.7E+11	2.9%
	Totals			3.0E+13	100%

James City County

County	Source		Number	Fecal Coliform Load (cfu/Day)	% Total Load
James City (Subwatersheds 5, 10-15, 21, 22, 26)	Wildlife	Deer	1314	6.6E+11	2.8%
		Ducks	250	6.1E+11	2.6%
		Geese	321	1.6E+13	67.6%
		Beavers	483	1.2E+11	0.5%
		Raccoons	1608	2.0E+11	0.9%
		Muskrats	79133	2.7E+12	11.5%
		Totals	83108	2.0E+13	85.9%
	Livestock	Totals	146	5.3E+10	0.2%
	Pets	Dogs	464	4.4E+11	1.9%
	Humans	Septic Tanks	2331	1.5E+12	6.6%
		Boating	750	4.5E+11	1.9%
		Straight Pipes	45	7.9E+11	3.4%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			2.9E+13	100%

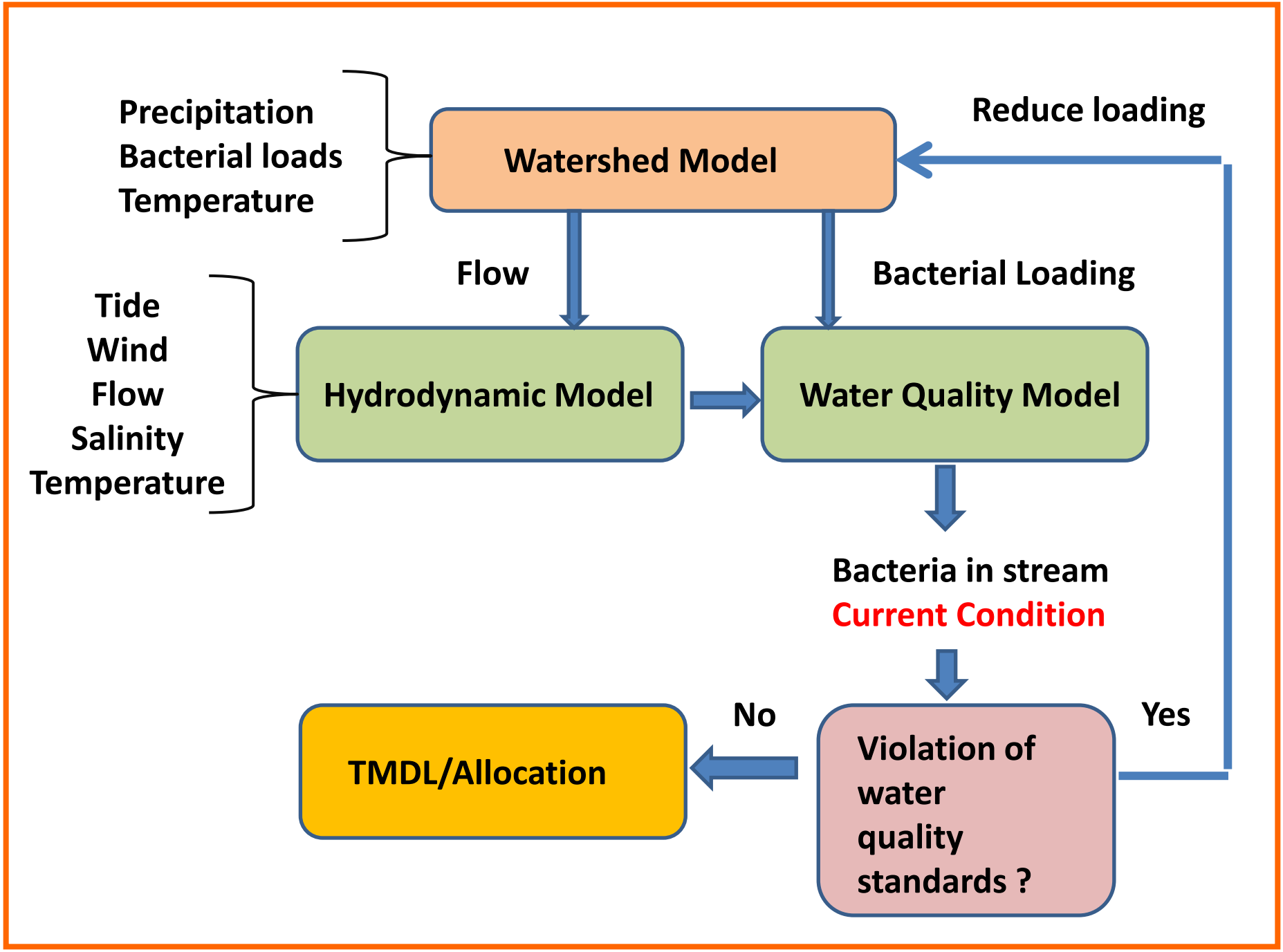
New Kent County

County	Source		Number	Fecal Coliform Load (cfu/Day)	% Total Load
New Kent (Subwatersheds 1-4, 6, 8, 9)	Wildlife	Deer	1231	6.2E+11	3.7%
		Ducks	185	4.5E+11	2.7%
		Geese	238	1.2E+13	69.4%
		Beavers	371	9.3E+10	0.6%
		Raccoons	1256	1.6E+11	0.9%
		Muskrats	30713	1.0E+12	6.2%
		Totals	33993	1.4E+13	83.5%
	Livestock	Totals	5	3.8E+09	0.0%
	Pets	Dogs	891	8.4E+11	5.0%
	Humans	Septic Tanks	1494	1.0E+12	6.3%
		Boating	565	3.4E+11	2.0%
		Straight Pipes	28	5.4E+11	3.2%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			1.7E+13	100%

Modelling Approach

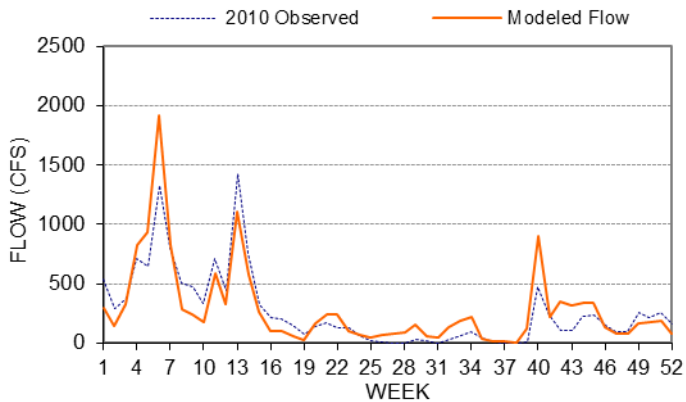
- Watershed Model
  - Use Loading Simulation Program C++ (LSPC) to simulate watershed processes - flow and bacteria

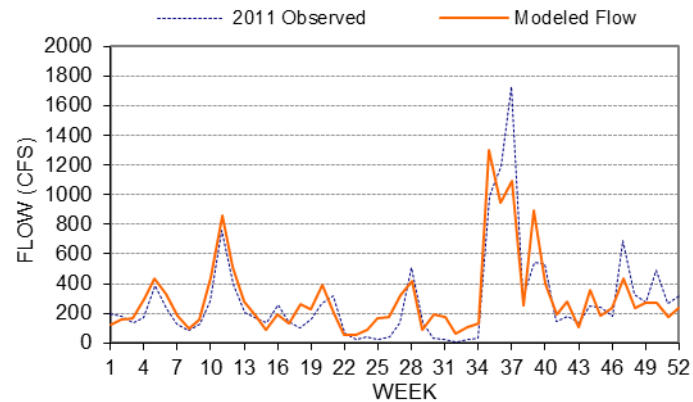
- Hydrodynamic-Water Quality Model
  - Use 3D hydrodynamic fluid environmental computation code (EFDC) to simulate instream processes - bacteria transport and fate

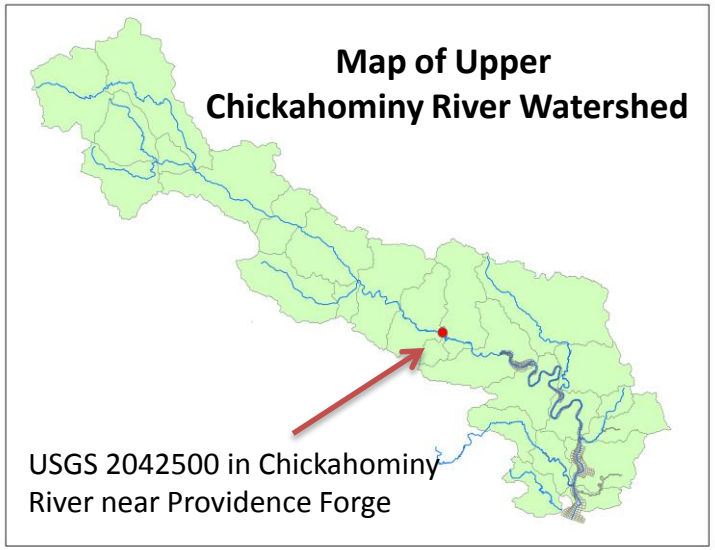

Precipitation
Bacterial loads
Temperature
Watershed Model
Reduce loading
Flow
Bacterial Loading
Tide
Wind
Flow
Salinity
Temperature
Hydrodynamic Model
Water Quality Model
Bacteria in stream
Current Condition
No
Yes
TMDL/Allocation
Violation of water quality standards ?

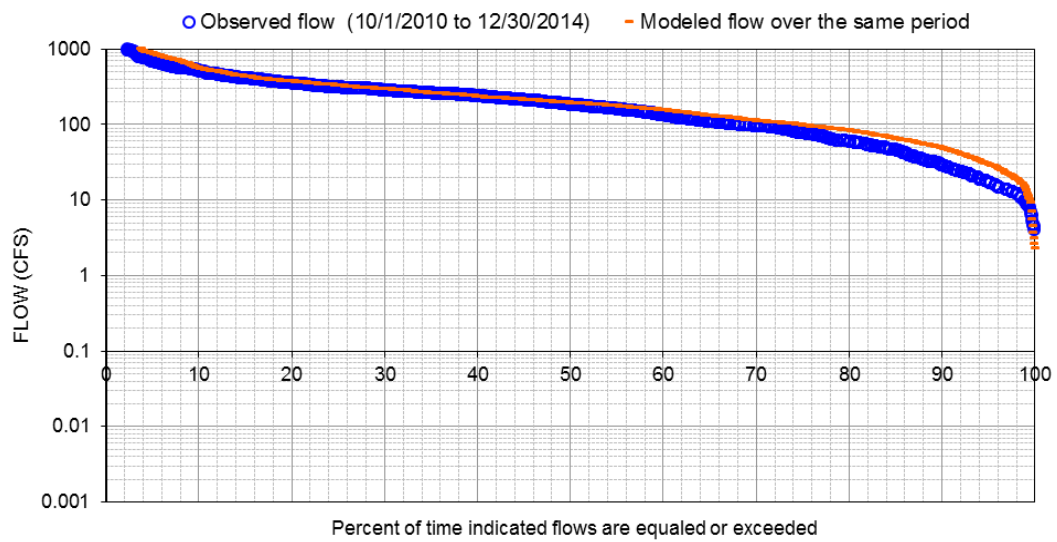
1. Watershed Model Development

- Flow Calibration Result







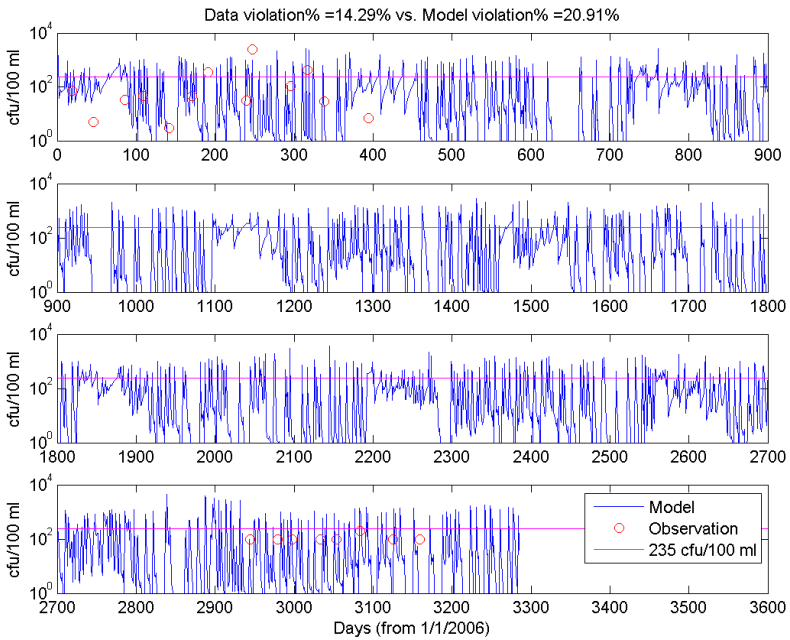


• Bacteria Concentration Calibration Result

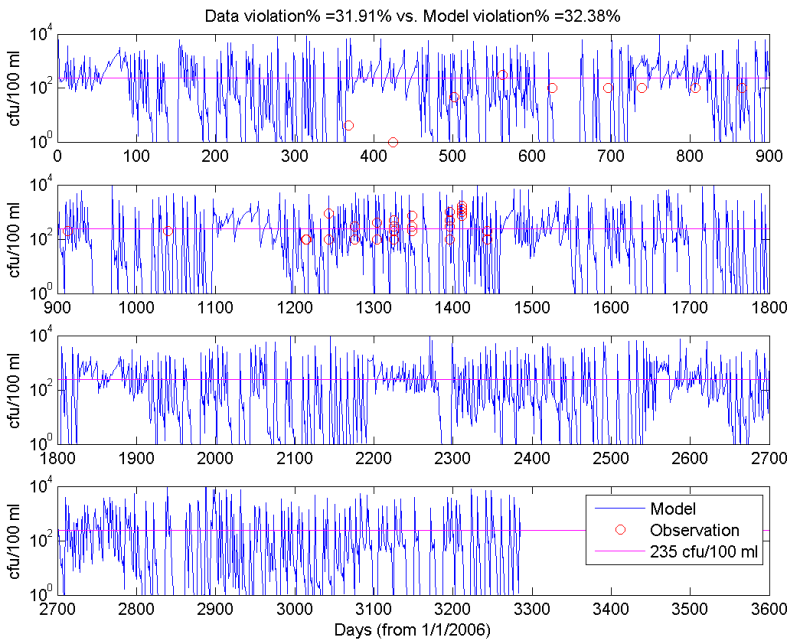
Criteria:

1. The model concentration range covers the observed concentration range, and
2. The violation rates of the modeled and observed data are similar.

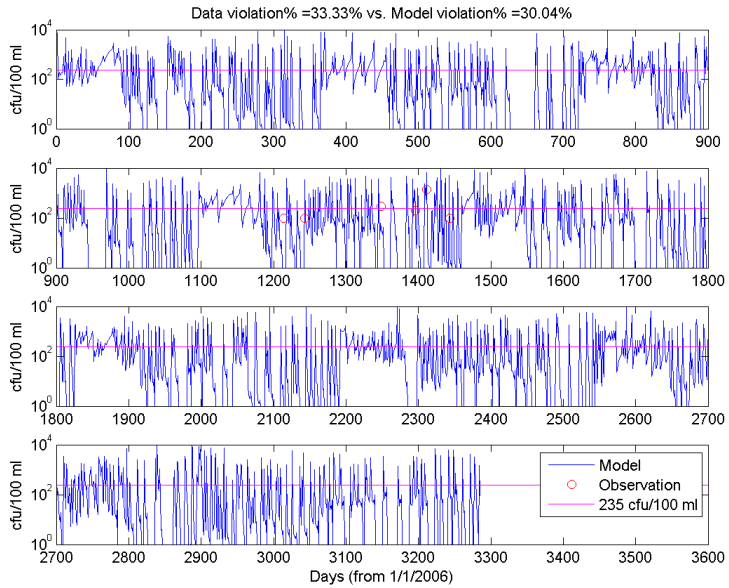
Diascund Creek



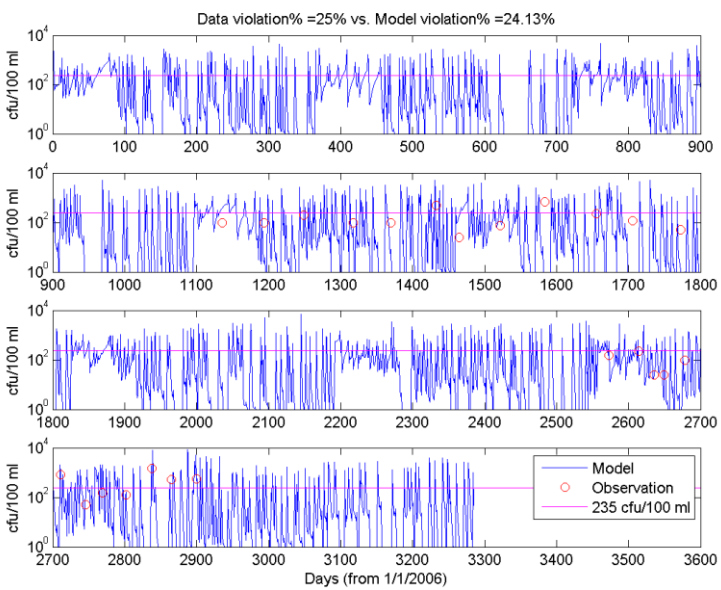
Beaverdam Creek



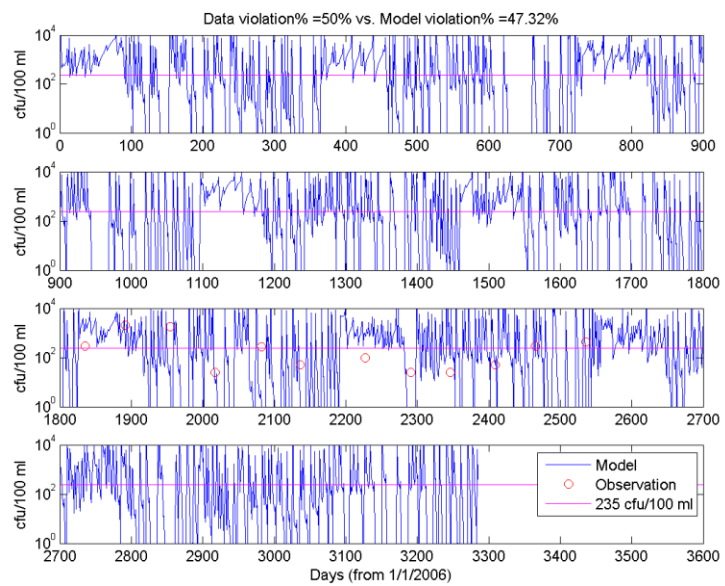
Beaverdam Creek, UT



Mill Creek



Barrows Creek



Summary of Watershed Model Calibration

1. The model concentration range covers the observed concentration range.

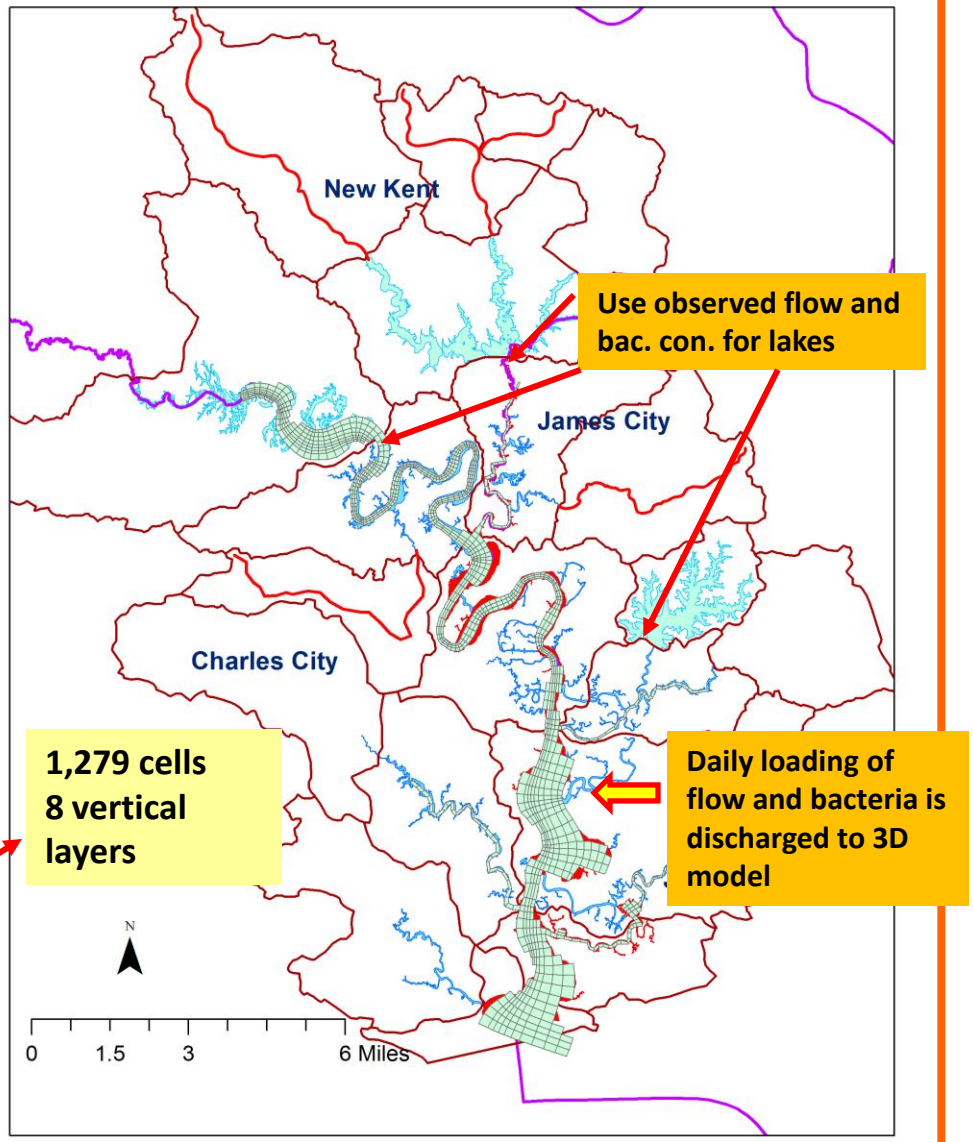
2. The violation rates of the modeled and observed data are similar.

3. The predictions of the LSPC model have reasonably matched the observations.

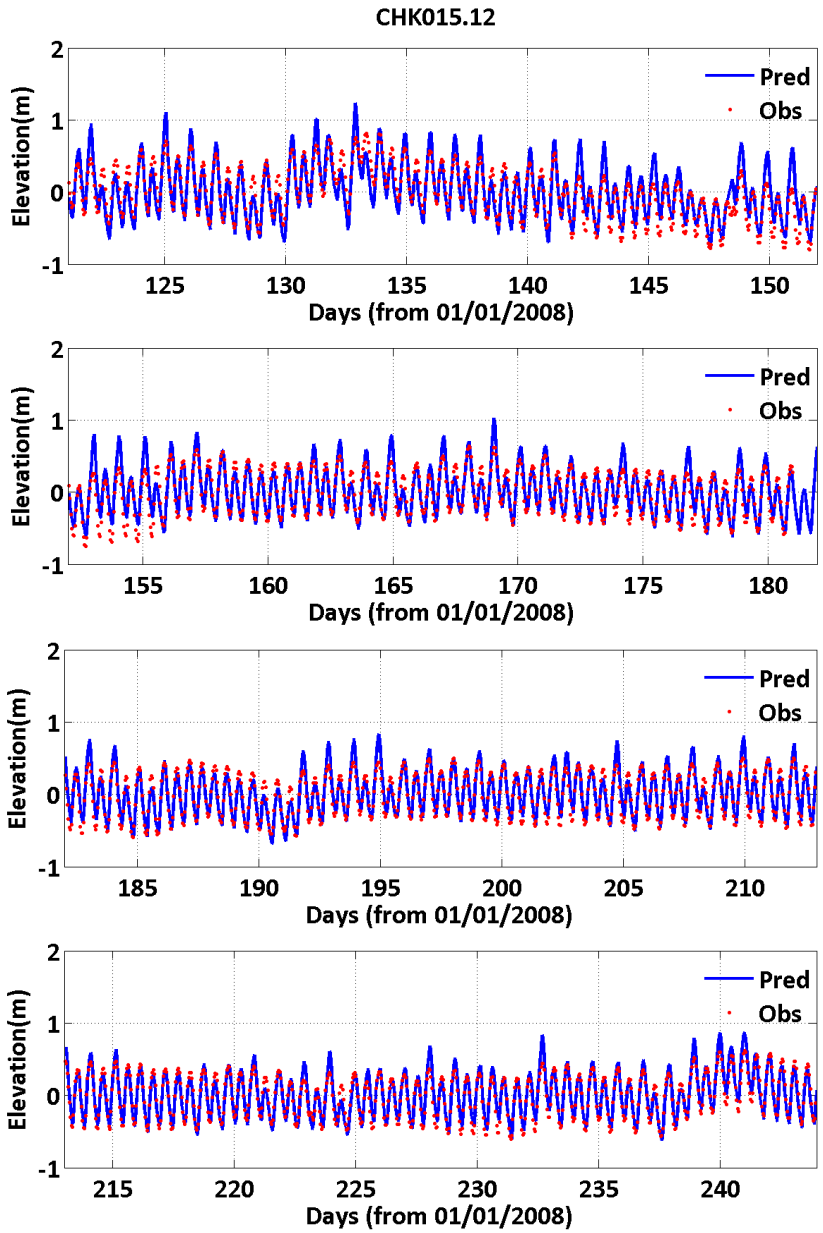
2. Hydrodynamic-Water Quality Model Development

- Use EFDC to simulate flow and bacterial transport in estuary
- Model calibration was conducted for dynamics (tide, salinity, and bacteria concentration)

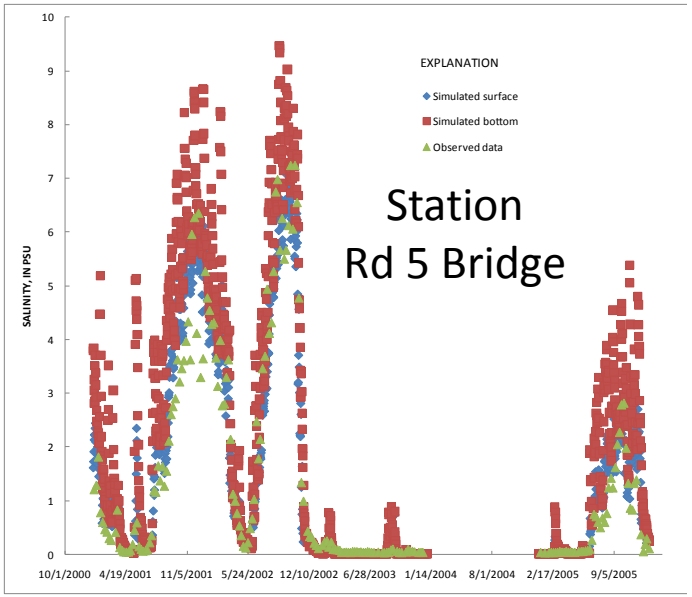
Model Grid

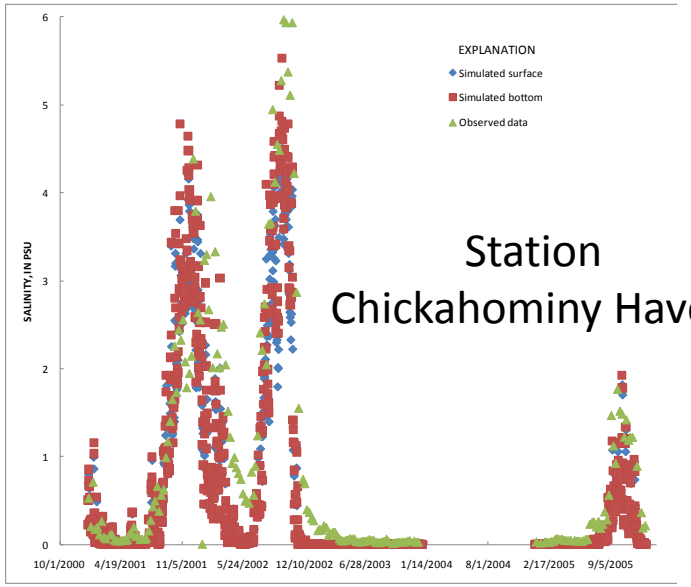


- Surface Elevation Calibration Result

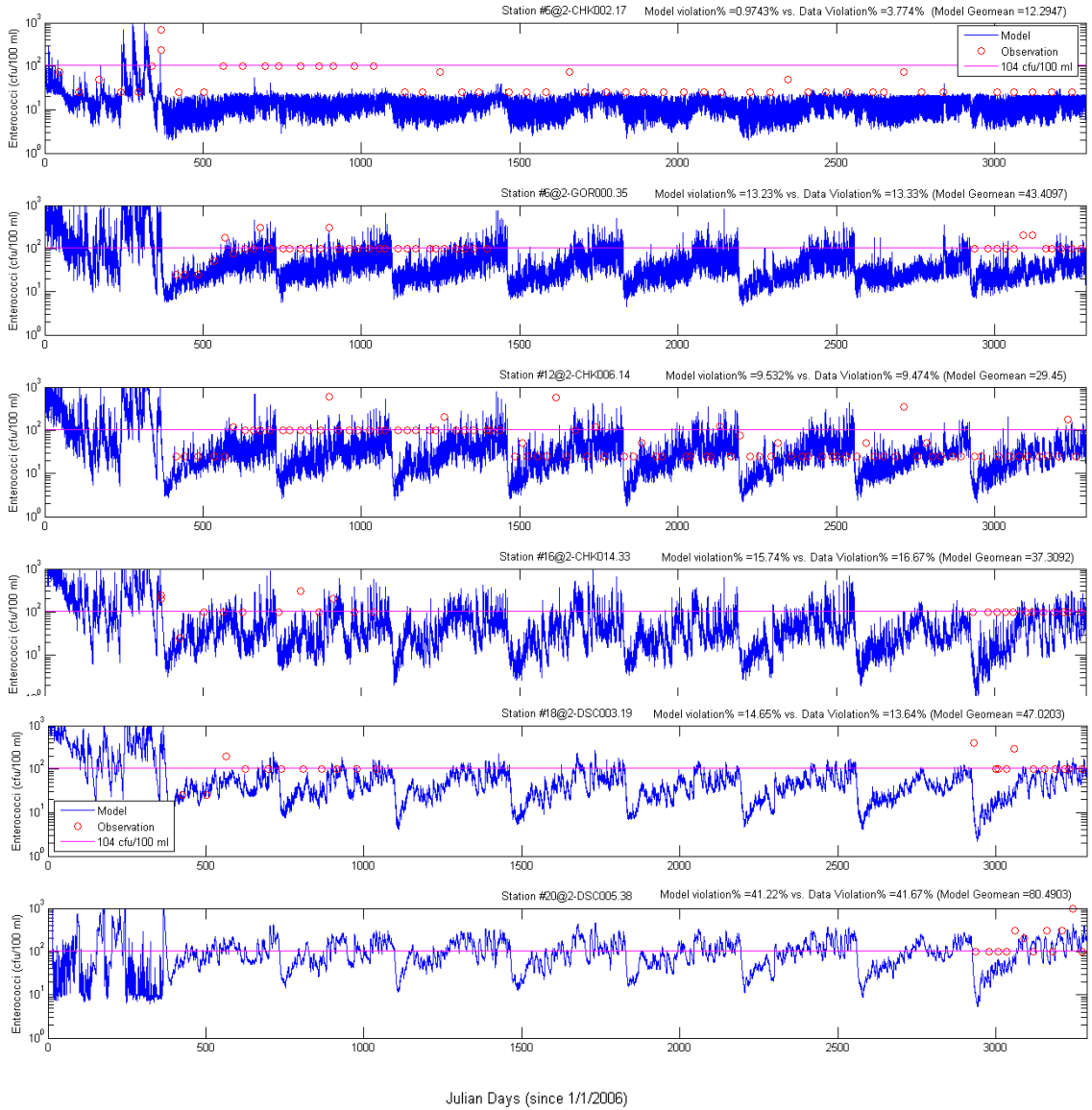


- Salinity Calibration Result





Tidal Water Bacteria Concentration Calibration Result

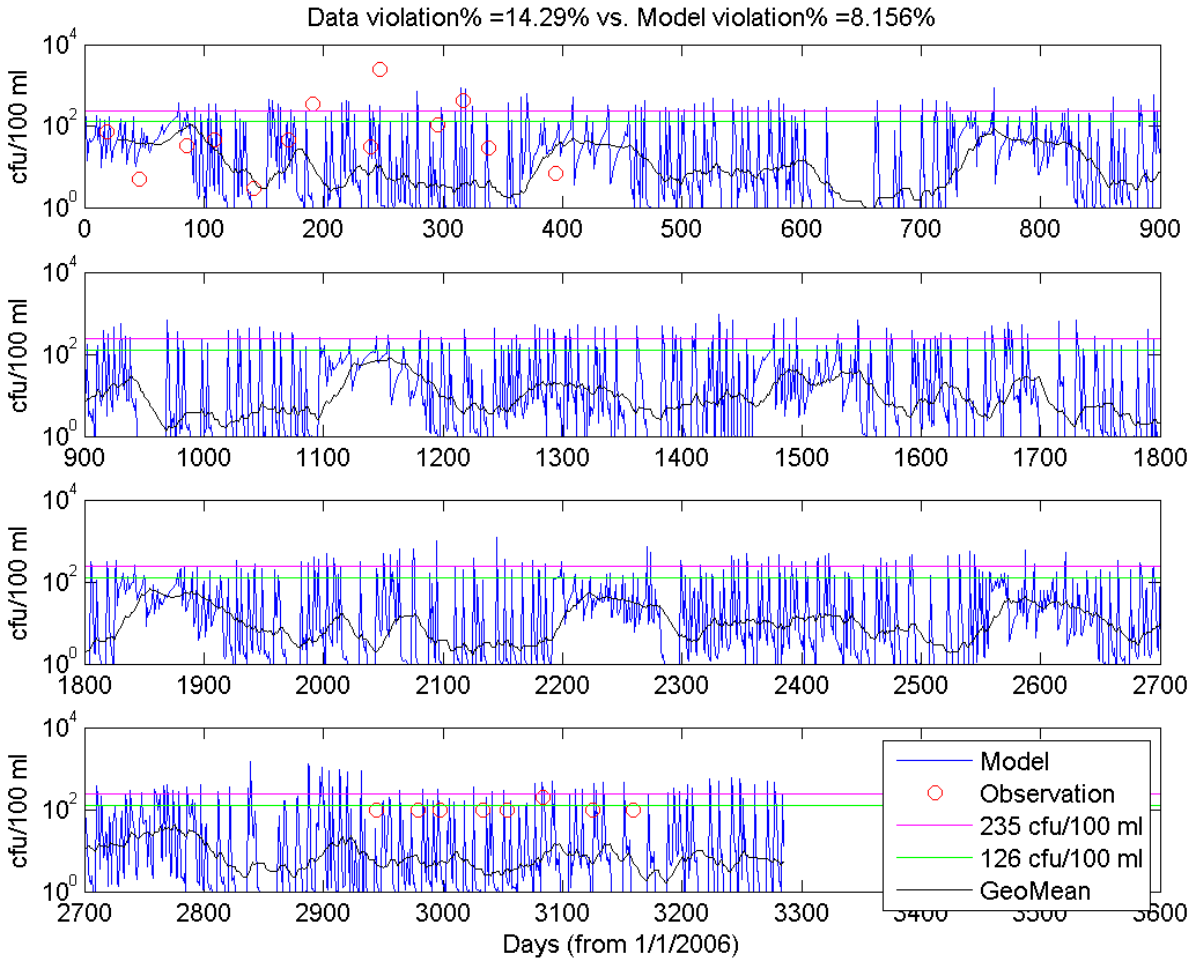


3. TMDL Development

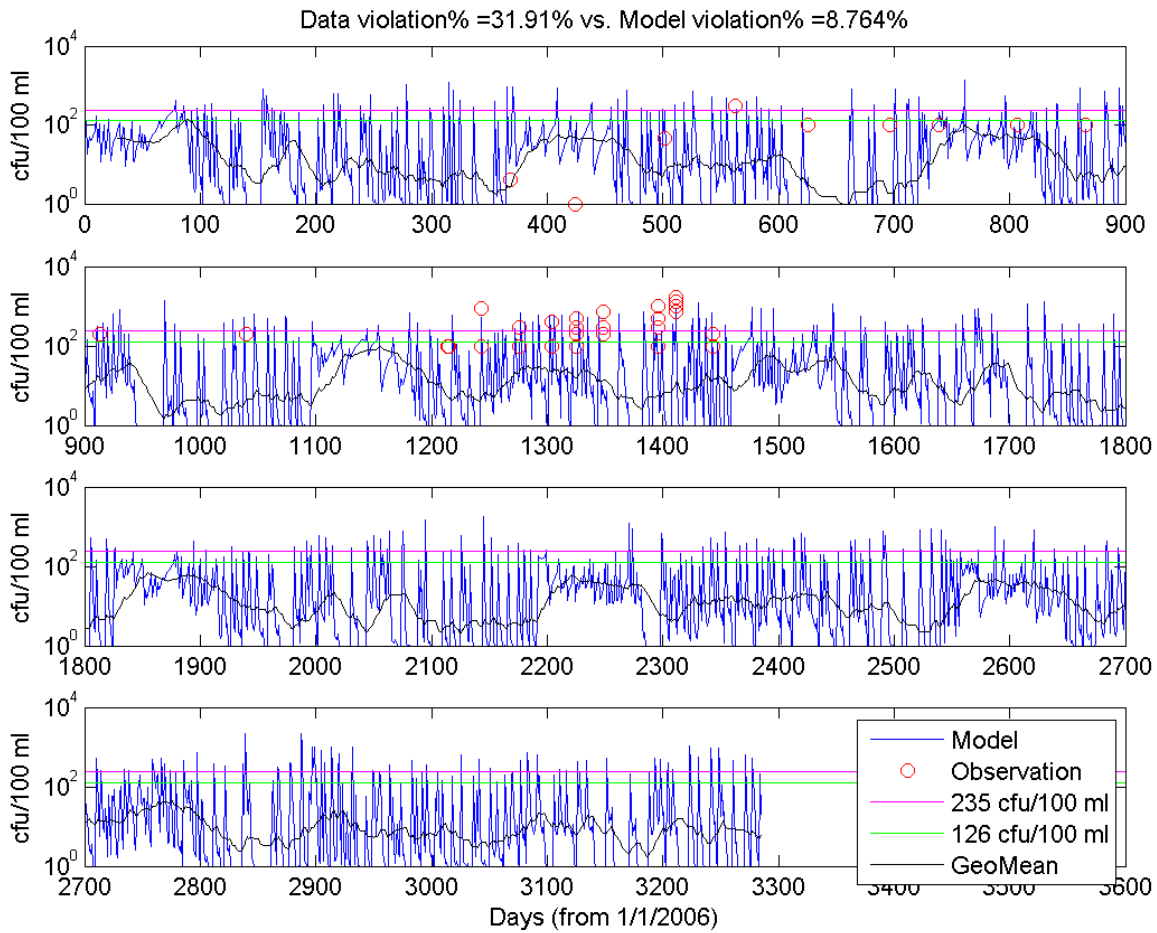
- Reduce the loads so the WQS is met in the receiving water.

- Endpoint – Select the Most Stringent:
  - Nontidal Water: no more than 10% exceedance of the single sample maximum of 235 *E.coli* cfu/100ml.
  - Tidal Water: geometric mean of 35 enterococci cfu/100ml.
  - When they are met, the WQSs are met.

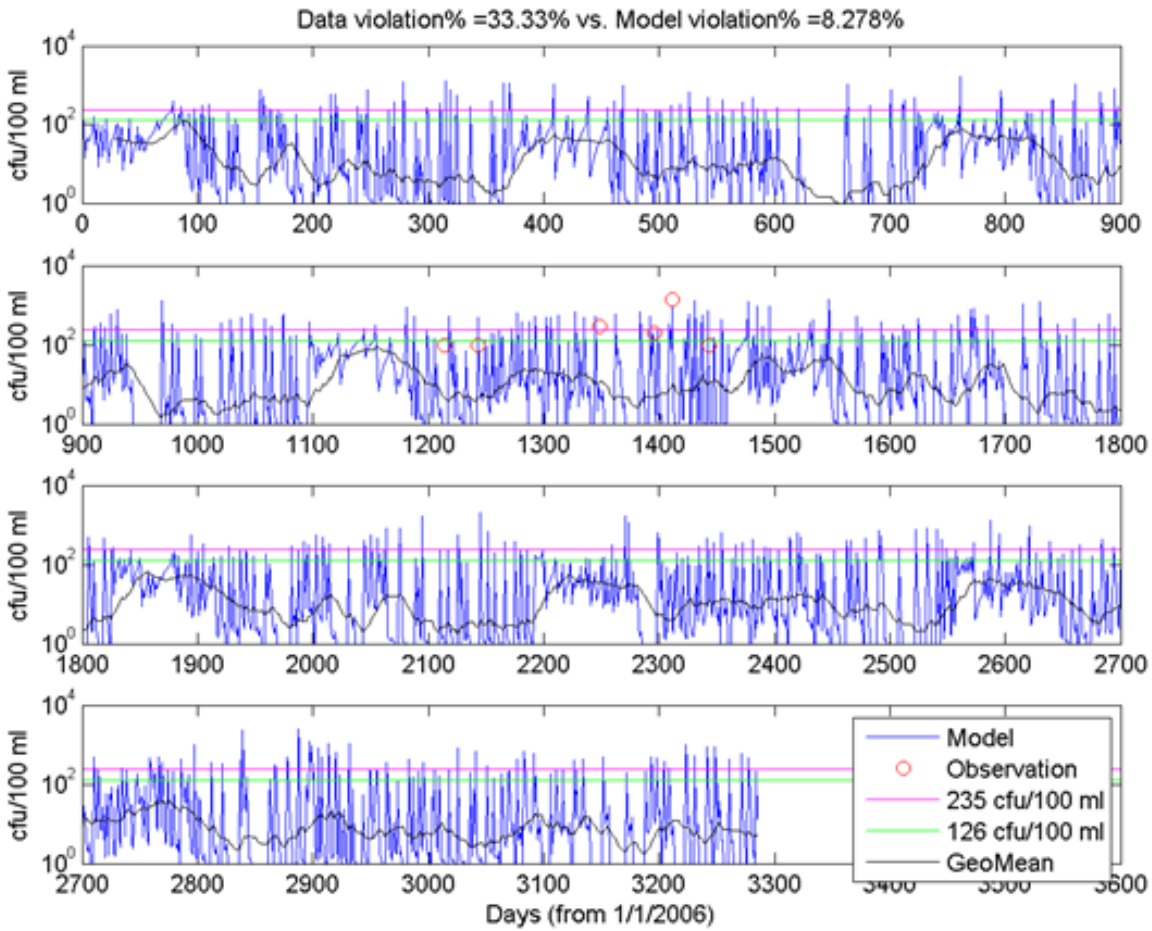
Nontidal Diascund Creek



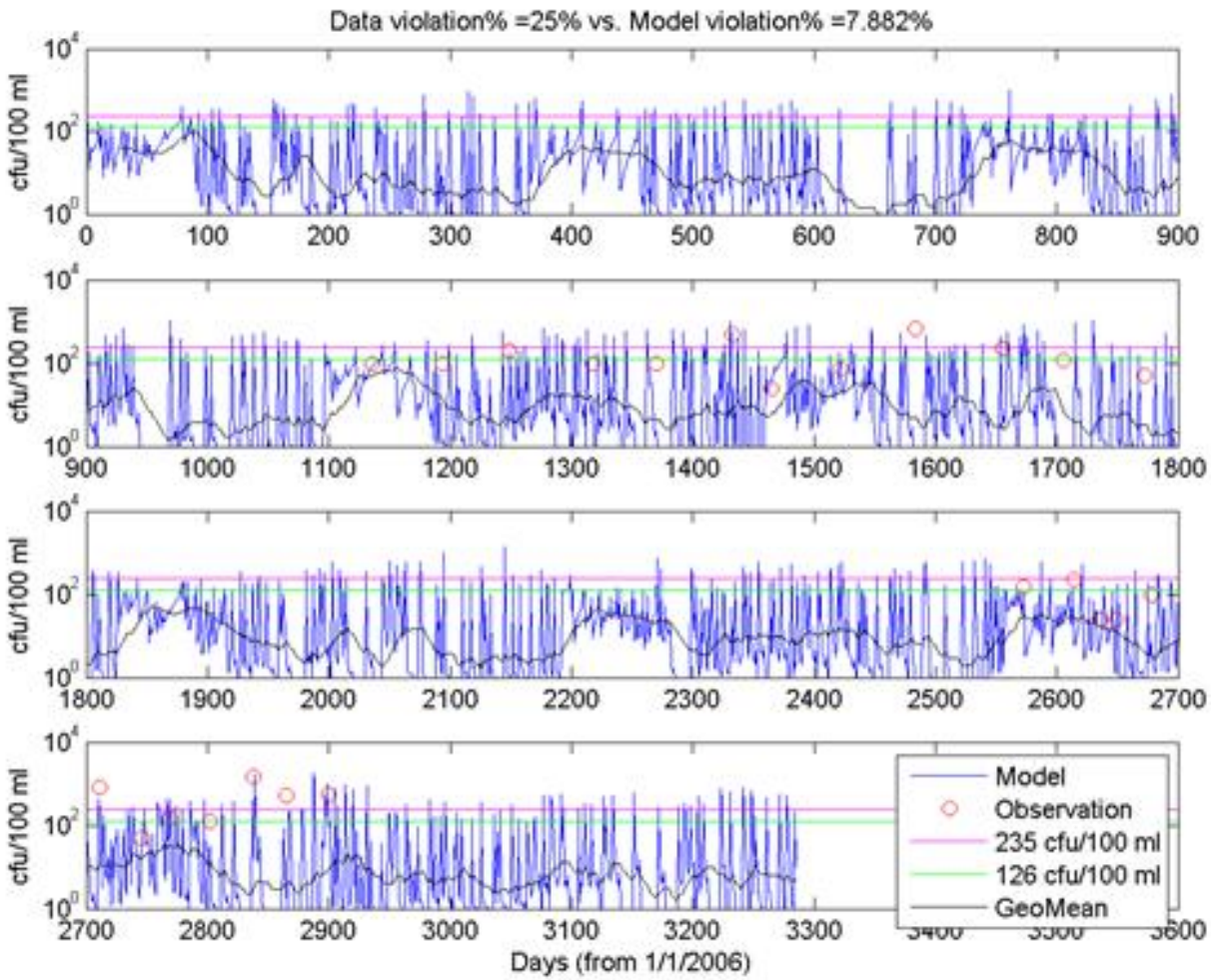
Beaverdam Creek



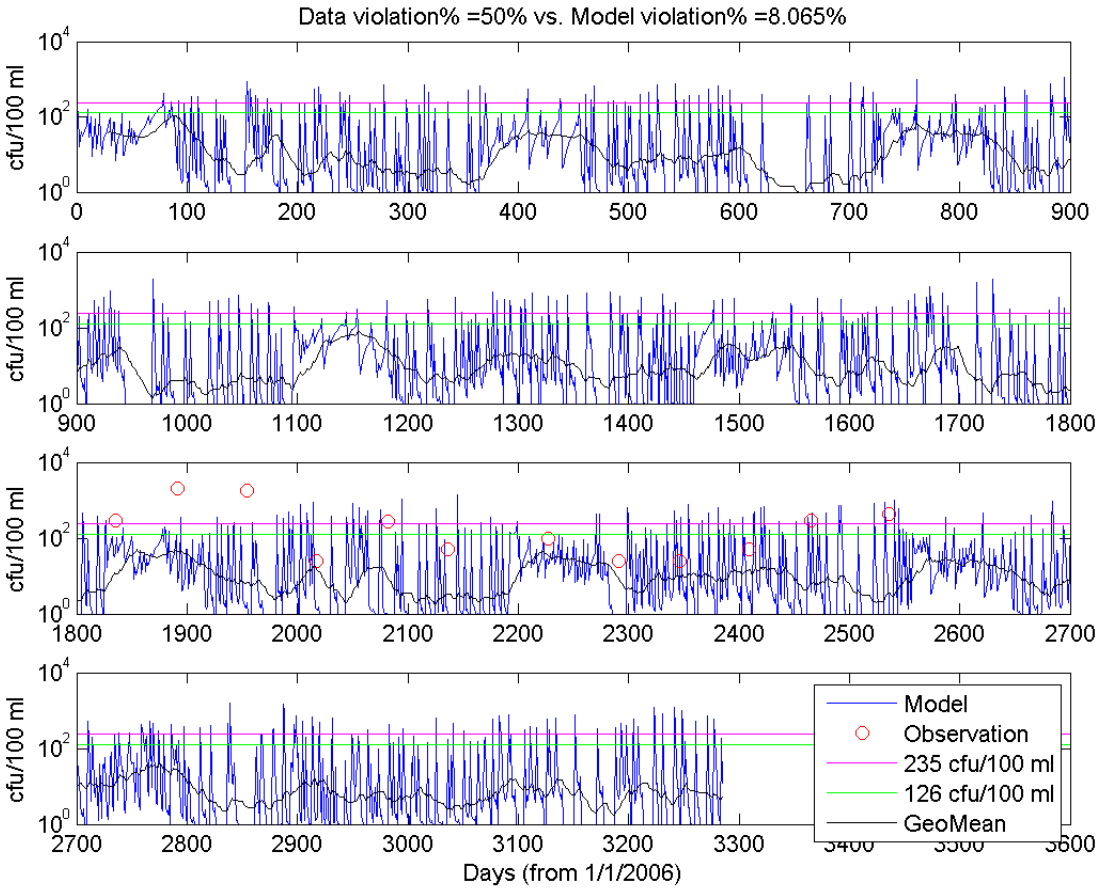
Beaverdam Creek, UT

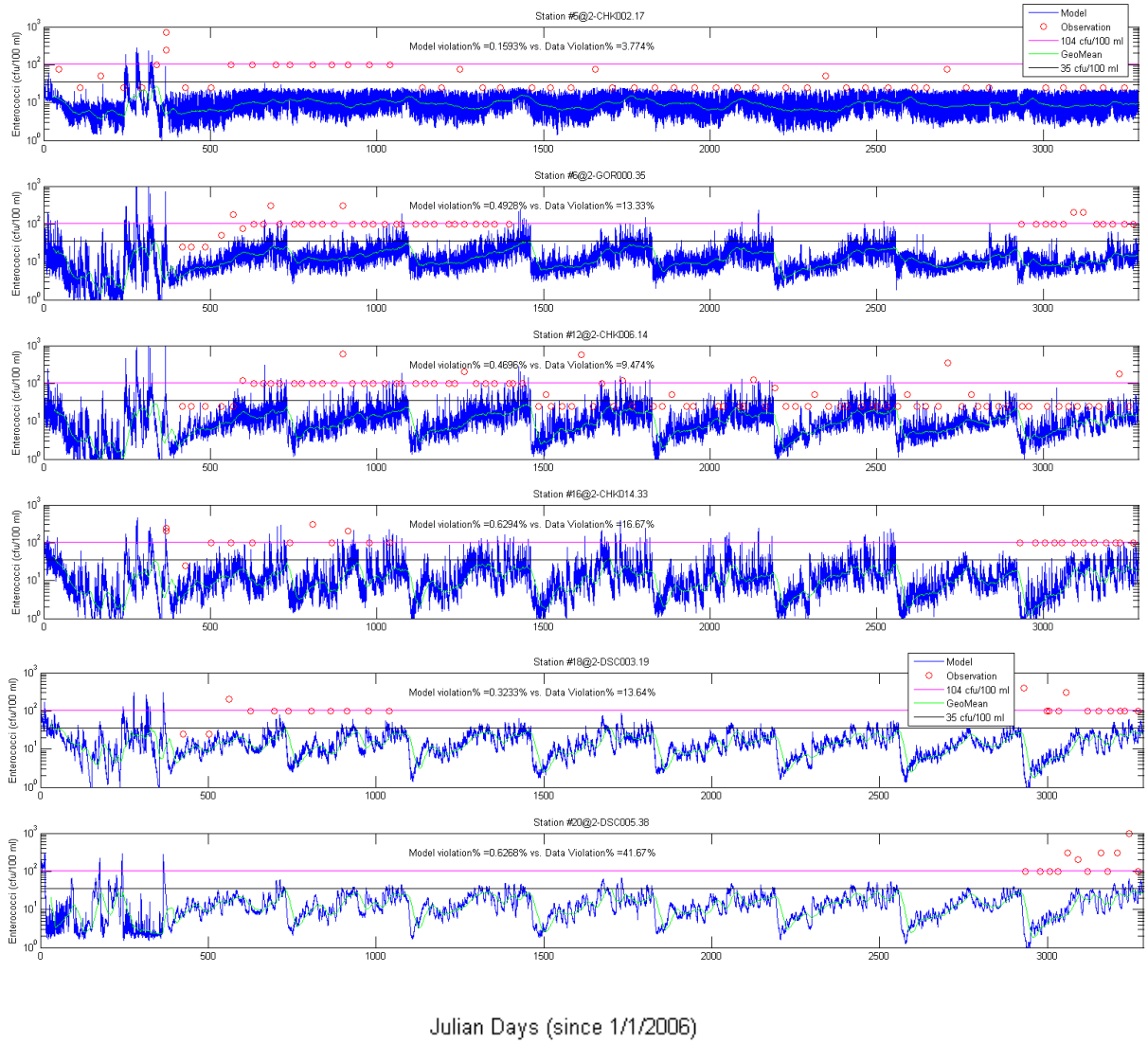


Mill Creek


Data violation% =25% vs. Model violation% =7.882%
cfu/100 ml
Days (from 1/1/2006)
Model
Observation
235 cfu/100 ml
126 cfu/100 ml
GeoMean

Barrows Creek





Stations in the Tidal Waters (Gordon Creek, Lower Chickahominy River, and Tidal Diascund Creek)

Estimation of 95th Percentile Loading Based on Long-term Model Simulations

$$TMDL = LTA \cdot \exp(Z_p \sigma_y - 0.5\sigma_y^2)$$

Where Zp is p^{th} percentage point of the standard normal distribution. For the 95th percentile, Zp = 1.645 (for the 90th percentile, Zp = 1.28). LTA is long-term mean daily loading and σ_y is computed as:

$$\sigma_y = \sqrt{\ln(CV^2 + 1)}$$

where the CV is coefficient of variation of the untransformed data, which equals the standard deviation divided by the mean.

USEPA 2007

Bacteria TMDLs in Lower Chickahominy River (cfu/Day)

Impaired Water (Pollutant)	WLA		LA	MOS	TMDL
	Permit #	WLA			
Diascund Creek (Nontidal) (E. coli)	NA	0	6.63E+10	Implicit	6.70E+10
	FA (1%)	6.70E+08			
	Total WLA	6.70E+08			
Beaverdam Creek (E. coli)	NA	0	3.30E+10	Implicit	3.33E+10
	FA (1%)	3.33E+08			
	Total WLA	3.33E+08			
XAH-Beaverdam Creek, UT (E.coli)	NA	0	1.16E+10	Implicit	1.17E+10
	FA (1%)	1.17E+08			
	Total WLA	1.17E+08			
Barrow's Creek (E. coli)	NA	0	1.79E+10	Implicit	1.81E+10
	FA (1%)	1.81E+08			
	Total WLA	1.81E+08			
Mill Creek (E. coli)	VAR040037 and VAR040115	9.74E+09	2.52E+10	Implicit	3.53E+10
	FA (1%)	3.53E+08			
	Total WLA	1.04E+10			

Impaired Water (Pollutant)	WLA		LA	MOS	TMDL
	Permit #	WLA			
Diascund Creek (Tidal) (Enterococci)	VAG404284	2.11E+06	6.76E+11	Implicit	7.55E+11
	VAR040037 and VAR040115	7.07E+10			
	FA (1%)	7.55E+09			
	Total WLA	7.83E+10			
Chickahominy River (Enterococci)	VA0080233	5.17E+07	1.31E+13	Implicit	1.36E+13
	VAG403039	1.32E+06			
	VAG404050	2.11E+06			
	VAG404144	1.32E+06			
	VAG404152	1.32E+06			
	VAG404198	2.11E+06			
	VAG404284	2.11E+06			
	VAR040037 and VAR040115	3.68E+11			
	FA (1%)	1.36E+11			
	Total WLA	5.04E+11			
Gordon Creek (Enterococci)	VAR040037 and VAR040115	2.77E+09	1.18E+12	Implicit	1.19E+12
	FA (1%)	1.19E+10			
	Total WLA	1.47E+10			

Summary of Current and Allowable Load by Impaired Water

Impaired Water	Pollutant	Current Load		Allowable Load		Required Reduction
		Daily (cfu/Day)	Annual (cfu/Year)	Daily (cfu/Day)	Annual (cfu/Year)	
Diascund Creek (Nontidal)	E. coli	2.04E+11	3.81E+13	6.70E+10	1.25E+13	67.1%
Beaverdam Creek		2.49E+11	4.73E+13	3.33E+10	6.34E+12	86.6%
XAH-Beaverdam Creek, UT		8.37E+10	1.61E+13	1.17E+10	2.26E+12	86.0%
Barrows Creek		6.59E+11	1.26E+14	1.81E+10	3.45E+12	97.3%
Mill Creek		1.71E+11	3.30E+13	3.53E+10	6.80E+12	79.4%
Diascund Creek (Tidal)	Enterococci	3.20E+12	5.22E+14	7.55E+11	1.23E+14	76.4%
Chickahominy River (Entire Watershed)		2.97E+13	4.94E+15	1.36E+13	2.26E+15	54.2%
Gordon Creek		4.46E+12	7.54E+14	1.19E+12	2.02E+14	73.2%

Summary of Current and Allowable Load by County

County	Pollutant	Current Load		Allowable Load		Required Reduction
		Daily (cfu/Day)	Annual (cfu/Year)	Daily (cfu/Day)	Annual (cfu/Year)	
New Kent	E. coli	5.37E+11	1.02E+14	1.12E+11	2.11E+13	79%
Charles City		6.59E+11	1.26E+14	1.81E+10	3.45E+12	97%
James City		1.71E+11	3.30E+13	3.53E+10	6.80E+12	79%
New Kent	Enterococci	3.00E+12	4.88E+14	2.25E+12	3.66E+14	25%
Charles City		9.55E+12	1.58E+15	5.83E+12	9.68E+14	39%
James City		1.72E+13	2.88E+15	5.52E+12	9.27E+14	68%

Allocation

- The TMDL seeks to eliminate 100% of the human-derived fecal component regardless of the allowable load determined through the LA process.
- If attainment of WQS cannot be achieved by reducing all human-derived loads, a reduction is also applied to the wildlife source.

Impaired Water	Pollutant	Source	Current Load (cfu/day)	Allowable Load (cfu/day)	Reduction Needed
Diascund Creek (Nontidal)	E.coli	Wildlife	1.79E+11	6.63E+10	63.0%
		Livestock	0.00E+00	0.00E+00	NA
		Pets	1.33E+10	0.00E+00	100.0%
		Human	1.09E+10	0.00E+00	100.0%
		Total	2.04E+11	6.63E+10	67.4%
Beaverdam Creek	E.coli	Wildlife	2.21E+11	3.30E+10	85.1%
		Livestock	0.00E+00	0.00E+00	NA
		Pets	1.43E+10	0.00E+00	100.0%
		Human	1.38E+10	0.00E+00	100.0%
		Total	2.49E+11	3.30E+10	86.8%
XAH-Beaverdam Creek, UT	E.coli	Wildlife	7.64E+10	1.16E+10	84.8%
		Livestock	0.00E+00	0.00E+00	NA
		Pets	4.91E+09	0.00E+00	100.0%
		Human	2.37E+09	0.00E+00	100.0%
		Total	8.37E+10	1.16E+10	86.1%
Barrow's Creek	E.coli	Wildlife	1.63E+11	1.79E+10	89.0%
		Livestock	3.66E+11	0.00E+00	100.0%
		Pets	6.16E+09	0.00E+00	100.0%
		Human	1.25E+11	0.00E+00	100.0%
		Total	6.59E+11	1.79E+10	97.3%
Mill Creek	E.coli	Wildlife	1.06E+11	2.52E+10	76.2%
		Livestock	5.07E+08	0.00E+00	100.0%
		Pets	2.88E+09	0.00E+00	100.0%
		Human	1.48E+10	0.00E+00	100.0%
		Total	1.24E+11	2.52E+10	79.7%

Impaired Water	Pollutant	Source	Current Load (cfu/day)	Allowable Load (cfu/day)	Reduction Needed
Diascund Creek (Tidal)	Enterococci	Wildlife	2.46E+12	6.76E+11	72.5%
		Livestock	2.17E+09	0.00E+00	100.0%
		Pets	1.24E+11	0.00E+00	100.0%
		Human	3.11E+11	0.00E+00	100.0%
		Total	2.90E+12	6.76E+11	76.7%
Chickahominy River	Enterococci	Wildlife	2.05E+13	1.31E+13	36.0%
		Livestock	3.79E+12	0.00E+00	100.0%
		Pets	8.27E+11	0.00E+00	100.0%
		Human	3.81E+12	0.00E+00	100.0%
		Total	2.89E+13	1.31E+13	54.7%
Gordon Creek	Enterococci	Wildlife	4.08E+12	1.18E+12	71.1%
		Livestock	5.11E+10	0.00E+00	100.0%
		Pets	6.49E+10	0.00E+00	100.0%
		Human	2.56E+11	0.00E+00	100.0%
		Total	4.45E+12	1.18E+12	73.5%

Questions and Comments

This presentation will be made available at the DEQ web site at:

www.deq.virginia.gov

Comment Period April 27 – May 27

Comments send to:
Kelley West
(Kelley.West@deq.virginia.gov)
Department of Environmental Quality
Office: (804) 527-5029

Thanks!

Appendix

Enterococci Impaired Waters

Stream and Assessment Unit	Impairment Description	Listing Date	County	Designated Uses
Chickahominy River G08E-04-BAC VAP-G08E_CHK02A00	The Chickahominy River from the confluence with Diascund Creek downstream to the James River. (5.92 mi^2)	2006	Charles City & James City	Recreation
Diascund Creek G08E-03-BAC VAP-G08E_DSC01A00	Diascund Creek from the Diascund Reservoir dam to the mouth at the Chickahominy River. (0.27 mi^2)	2010	James City & New Kent	
Gordon Creek G08E-05-BAC VAP-G08E_GOR01A06	Tidal limit to mouth (0.2 mi^2)	2012	James City	

E. coli Impaired Waters

Stream Name and Assessment Unit	Impairment Description	Listing Date	County	Designated Use
Beaverdam Creek G09R-01-BAC VAP-G09R_BDM01A98	Beaverdam Creek from its headwaters to the upstream limit of Diascund Reservoir. (4.34 mi^2)	2012	New Kent	Recreation
XAH-Beaverdam Creek, UT G09R-06-BAC VAP-G09R_XAH01A12	Headwaters to mouth at Beaverdam Creek. (2.23 mi^2)	2012		
Diascund Creek G09R-02-BAC VAP-G09R_DSC01A00	Diascund Creek from its headwaters to the upstream limit of Diascund Creek Reservoir. (6.88 mi^2)	2008		
Mill Creek G08R-02-BAC VAP-G08R_MCR01A04	Mill Creek from its headwaters downstream to its tidal limit. (4.81 mi^2)	2004	James City	
Barrows Creek G08R-05-BAC VAP-G08R-BRW01A14	Headwaters to tidal limit. (6.93 mi^2)	2014	Charles City	

Source Assessment Summary --- Lower Chickahominy River

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	Percentage of Total Load
Lower Chickahominy River (Subwatersheds 1-26)	Wildlife	Deer	3971	2.0E+12	2.8%
		Ducks	629	1.5E+12	2.2%
		Geese	809	4.0E+13	56.5%
		Beavers	1120	2.8E+11	0.4%
		Raccoons	4184	5.2E+11	0.7%
		Muskrats	168488	5.7E+12	8.2%
		Totals	179199	5.0E+13	70.8%
	Livestock	Totals	635	9.2E+12	13.1%
	Pets	Dogs	2136	2.0E+12	2.9%
	Humans	Septic Tank Failures	4314	2.9E+12	4.1%
		Boating	1718	1.0E+12	1.5%
		Straight Pipes	83	1.5E+12	2.2%
		Biosolids	6644	2.9E+12	4.2%
		SSOs	8	8.7E+11	1.2%
	Totals			7.0E+13	100%

Source Assessment Summary --- Diascund Creek (Tidal)

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	Percentage of Total Load
Diascund Creek (Tidal) (Subwatersheds 1-6, 9-11)	Wildlife	Deer	1575	7.9E+11	3.6%
		Ducks	245	6.0E+11	2.7%
		Geese	315	1.5E+13	70.5%
		Beavers	393	9.8E+10	0.4%
		Raccoons	1660	2.1E+11	0.9%
		Muskrats	42675	1.5E+12	6.6%
		Totals	46863	1.9E+13	84.9%
	Livestock	Totals	62	1.6E+10	0.1%
	Pets	Dogs	998	9.4E+11	4.3%
	Humans	Septic Tanks	2011	1.4E+12	6.3%
		Boating	458	2.7E+11	1.3%
		Straight Pipes	39	7.0E+11	3.2%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			2.2E+13	100%

Source Assessment Summary --- Gordon Creek

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	Percentage of Total Load
Gordon Creek (Subwatershed 22)	Wildlife	Deer	93	4.6E+10	2.6%
		Ducks	19	4.7E+10	2.7%
		Geese	25	1.2E+12	69.0%
		Beavers	67	1.7E+10	1.0%
		Raccoons	110	1.4E+10	0.8%
		Muskrats	7995	2.7E+11	15.6%
		Totals	8308	1.6E+12	91.6%
	Livestock	Totals	2	2.0E+10	1.1%
	Pets	Dogs	27	2.5E+10	1.5%
	Humans	Septic Tanks	195	2.7E+10	1.5%
		Boating	100	6.0E+10	3.4%
		Straight Pipes	1	1.4E+10	0.8%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			1.7E+12	100%

Source Assessment Summary --- Diascund Creek (Non-Tidal)

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	Percentage of Total Load
Diascund Creek (Non-Tidal) (Subwatershed 1)	Wildlife	Deer	434	2.2E+11	4.1%
		Ducks	63	1.5E+11	2.9%
		Geese	81	4.0E+12	74.7%
		Beavers	33	8.3E+09	0.2%
		Raccoons	449	5.6E+10	1.1%
		Muskrats	8220	2.8E+11	5.2%
		Totals	9281	4.7E+12	88.1%
	Livestock	Totals	1	0	0.0%
	Pets	Dogs	371	3.5E+11	6.5%
	Humans	Septic Tanks	268	1.9E+11	3.5%
		Boating	4	2.2E+09	0.0%
		Straight Pipes	5	9.7E+10	1.8%
		Biosolids		0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			5.3E+12	100%

Source Assessment Summary --- Beaverdam Creek

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	Percentage of Total Load
Beaverdam Creek (Subwatersheds 2, 3)	Wildlife	Deer	200	1.0E+11	4.1%
		Ducks	29	6.9E+10	2.9%
		Geese	37	1.8E+12	74.4%
		Beavers	32	7.9E+09	0.3%
		Raccoons	202	2.5E+10	1.0%
		Muskrats	4274	1.5E+11	6.0%
		Totals	4773	2.1E+12	88.7%
	Livestock	Totals	1	0.0E+00	0.0%
	Pets	Dogs	148	1.4E+11	5.7%
	Humans	Septic Tanks	126	8.8E+10	3.7%
		Boating	1	4.1E+08	0.0%
		Straight Pipes	2	4.5E+10	1.9%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			2.5E+12	100%

Source Assessment Summary --- Beaverdam Creek, UT

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	Percentage of Total Load
Beaverdam Creek, UT (Subwatershed 3)	Wildlife	Deer	64	3.2E+10	4.2%
		Ducks	9	2.2E+10	3.0%
		Geese	12	5.8E+11	76.5%
		Beavers	11	2.7E+09	0.4%
		Raccoons	65	8.2E+09	1.1%
		Muskrats	1381	4.7E+10	6.2%
		Totals	1543	6.9E+11	91.3%
	Livestock	Totals	0	0.0E+00	0.0%
	Pets	Dogs	47	4.4E+10	5.9%
	Humans	Septic Tanks	20	1.4E+10	1.9%
		Boating	0	2.6E+08	0.0%
		Straight Pipes	0	7.2E+09	1.0%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			7.6E+11	100%

Source Assessment Summary --- Mill Creek

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	Percentage of Total Load
Mill Creek (Subwatershed 11)	Wildlife	Deer	221	1.1E+11	**3.3%**
		Ducks	38	9.2E+10	**2.8%**
		Geese	48	2.4E+12	**71.3%**
		Beavers	23	5.9E+09	**0.2%**
		Raccoons	241	3.0E+10	**0.9%**
		Muskrats	6665	2.3E+11	**6.8%**
		Totals	**7237**	**2.8E+12**	**85.3%**
	Livestock	Totals	51	1.4E+10	**0.4%**
	Pets	Dogs	82	7.8E+10	**2.3%**
	Humans	Septic Tanks	400	2.6E+11	**7.9%**
		Boating	5	2.7E+09	**0.1%**
		Straight Pipes	8	1.3E+11	**4.0%**
		Biosolids	0	0.0E+00	**0.0%**
		SSOs	0	0.0E+00	**0.0%**
	Totals			3.3E+12	100%

Source Assessment Summary --- Barrows Creek

Impaired Water	Source		Number	Fecal Coliform Load (cfu/Day)	Percentage of Total Load
Barrows Creek (Subwatershed 17)	Wildlife	Deer	192	9.6E+10	1.2%
		Ducks	25	6.0E+10	0.8%
		Geese	32	1.6E+12	19.9%
		Beavers	32	7.9E+09	0.1%
		Raccoons	133	1.7E+10	0.2%
		Muskrats	5667	1.9E+11	2.5%
		Totals	6079	1.9E+12	24.7%
	Livestock	Totals	151	4.3E+12	55.4%
	Pets	Dogs	78	7.3E+10	0.9%
	Humans	Septic Tanks	114	7.8E+10	1.0%
		Boating	2	1.2E+09	0.0%
		Straight Pipes	2	4.0E+10	0.5%
		Biosolids	2329	1.0E+12	12.8%
		SSOs	1	3.5E+11	4.5%
	Totals			7.8E+12	100%

Source Assessment Summary --- by County

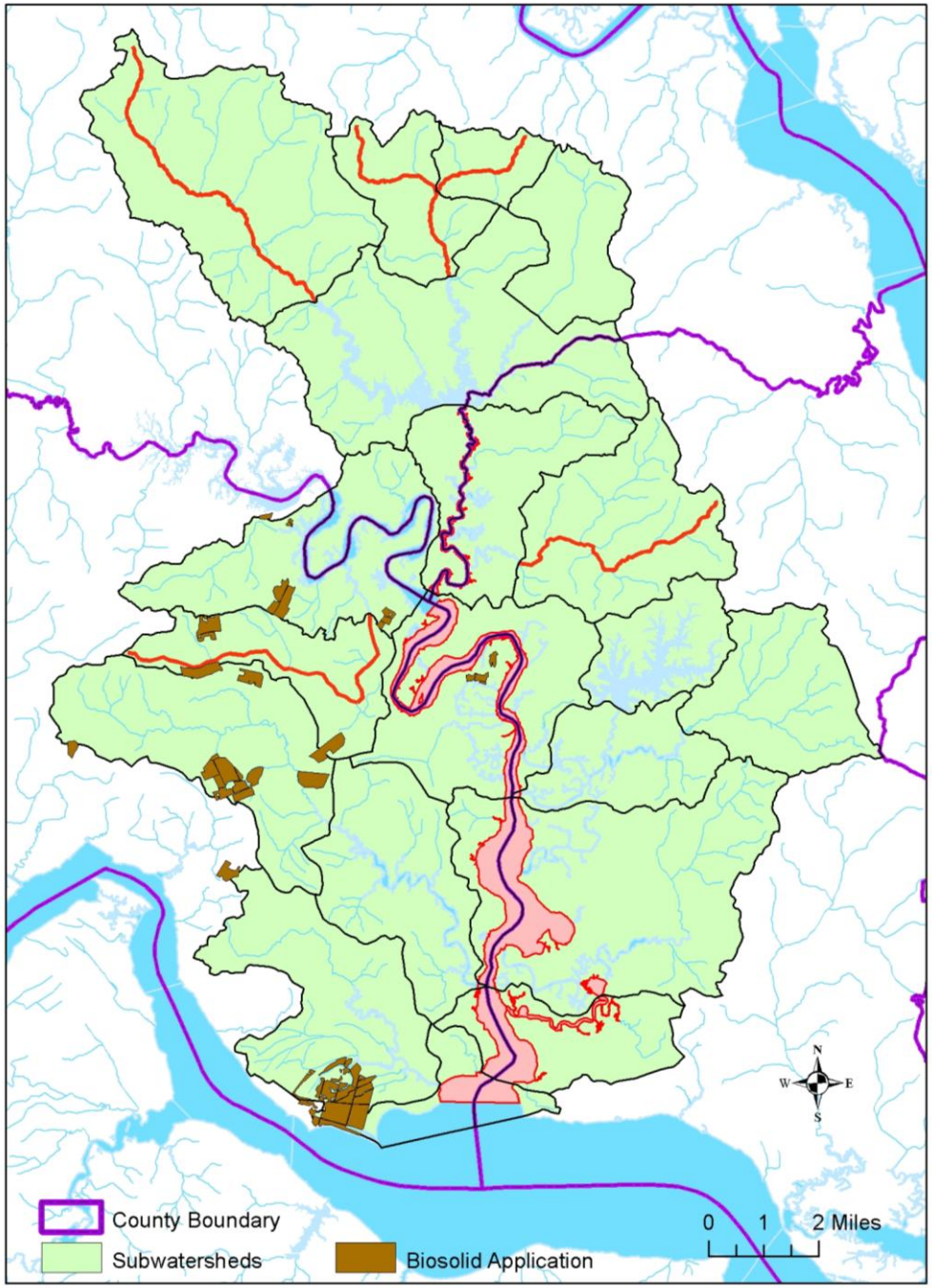
County	Source		Number	Fecal Coliform Load (cfu/Day)	Percentage
Charles City (Subwatersheds 7, 16-20, 23-25)	Wildlife	Deer	1426	7.1E+11	2.4%
		Ducks	194	4.7E+11	1.6%
		Geese	250	1.2E+13	40.6%
		Beavers	265	6.6E+10	0.2%
		Raccoons	1320	1.7E+11	0.5%
		Muskrats	58642	2.0E+12	6.6%
		Totals	62098	1.6E+13	51.9%
	Livestock	Totals	484	9.1E+12	30.4%
	Pets	Dogs	781	7.3E+11	2.4%
	Humans	Septic Tanks	488	3.1E+11	1.0%
		Boating	402	2.4E+11	0.8%
		Straight Pipes	14	2.6E+11	0.9%
		Biosolids	6644 (tons)	2.9E+12	9.7%
		SSOs	8	8.7E+11	2.9%
	Totals			3.0E+13	100%

County	Source		Number	Fecal Coliform Load (cfu/Day)	Percentage
James City (Subwatersheds 5, 10-15, 21, 22, 26)	Wildlife	Deer	1314	6.6E+11	2.2%
		Ducks	250	6.1E+11	2.1%
		Geese	321	1.6E+13	53.9%
		Beavers	483	1.2E+11	0.4%
		Raccoons	1608	2.0E+11	0.7%
		Muskrats	79133	2.7E+12	9.2%
		Totals	83108	2.0E+13	68.5%
	Livestock	Totals	653	6.0E+12	20.4%
	Pets	Dogs	464	4.4E+11	1.5%
	Humans	Septic Tanks	2331	1.5E+12	5.3%
		Boating	750	4.5E+11	1.5%
		Straight Pipes	45	7.9E+11	2.7%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			2.9E+13	100%

County	Source		Number	Fecal Coliform Load (cfu/Day)	Percentage
New Kent (Subwatersheds 1-4, 6, 8, 9)	Wildlife	Deer	1231	6.2E+11	3.6%
		Ducks	185	4.5E+11	2.7%
		Geese	238	1.2E+13	68.8%
		Beavers	371	9.3E+10	0.5%
		Raccoons	1256	1.6E+11	0.9%
		Muskrats	30713	1.0E+12	6.2%
		Totals	33993	1.4E+13	82.7%
	Livestock	Totals	5	3.8E+09	0.0%
	Pets	Dogs	891	8.4E+11	4.9%
	Humans	Septic Tanks	1494	1.0E+12	6.2%
		Boating	565	3.4E+11	2.0%
		Straight Pipes	37	7.0E+11	4.1%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			1.7E+13	100%

Point Source – Biosolids

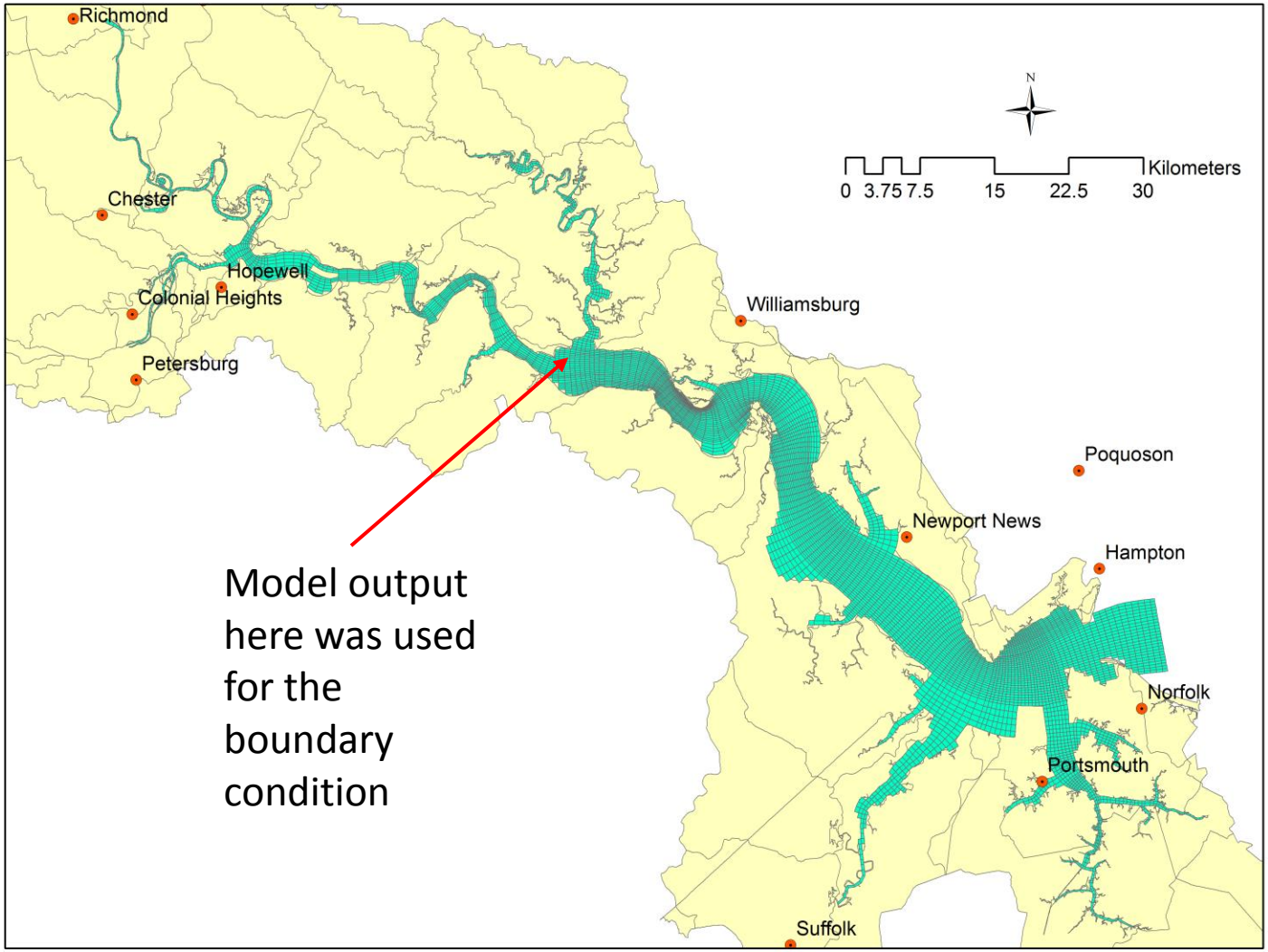
Total Area of Application
=
1503.5 Acres



James River Model

- The James River 3D model uses the EFDC model, which has been used to study sea level rise in James by USGS (Rice et al., 2011). Simulated changes in salinity in the York and Chickahominy Rivers result from projected sea-level rise in Chesapeake Bay. USGS Open-File Report 2011e1191, 31 p. http://pubs.usgs.gov/of/2011/1191/), and DEQ for James River algal study.
- The model is forced by freshwater, tide, salinity, and wind. There are 8 vertical layers. The model has been calibrated and verified. Please refer to the above reference for a detailed description of the model.
- EFDC model (Environmental Fluid Dynamic Code) (http://www.epa.gov/exposure-assessment-models/environment-fluid-dynamics-code-efdc-download-page)

James River Model Grid



Available Observation Date*

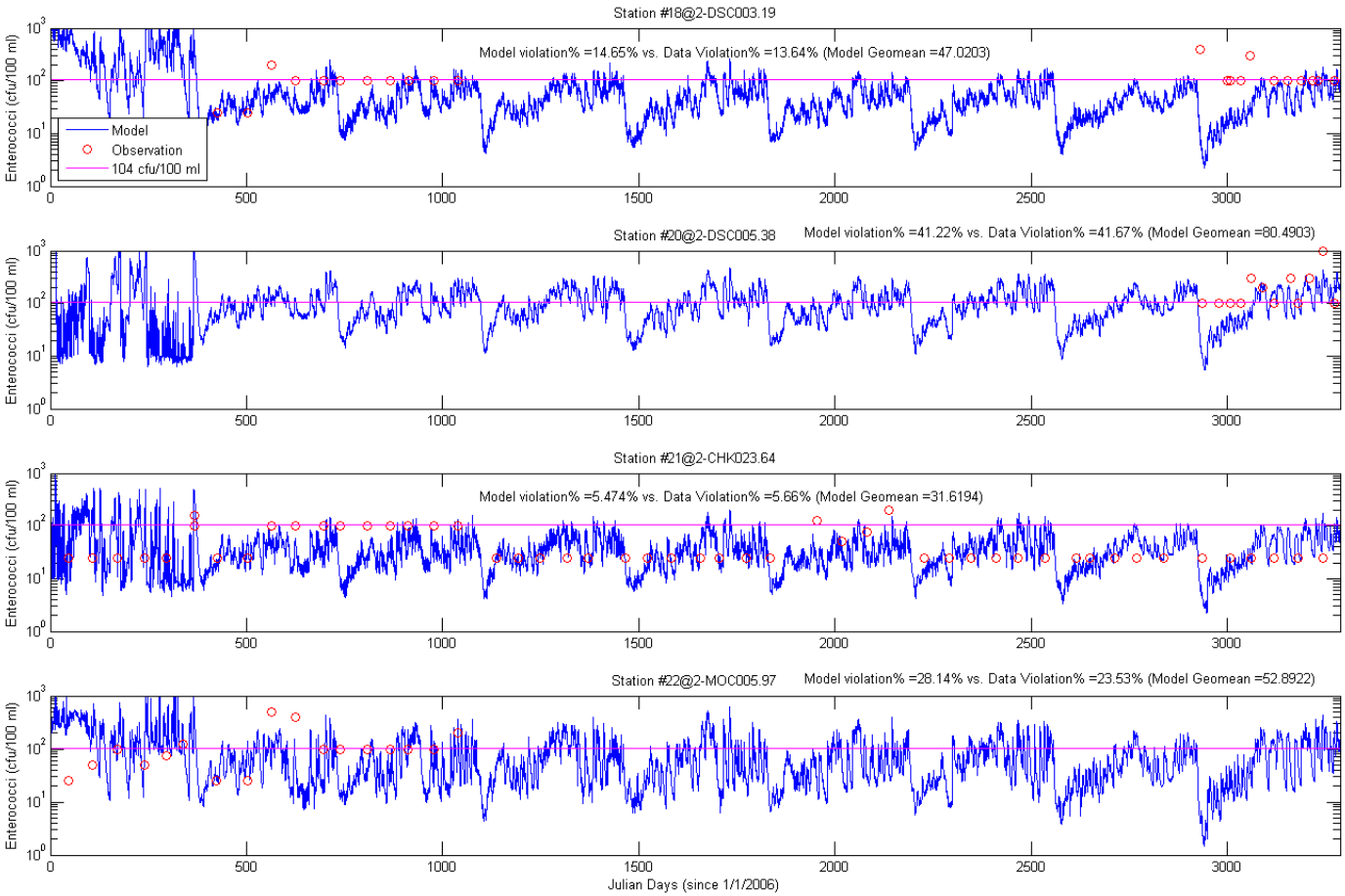
Station Id	Stream Name	Sample Size	Average	Standard Deviation	Minimum	Maximum	Monitoring Period
2-BDM003.16	Beaverdam Creek	9	311	395	100	1300	4/29/2009-12/14/2009
2-BDM004.12	Beaverdam Creek	20	208	362	1	1700	1/4/2007-12/14/2009
2-BDM004.60	Beaverdam Creek	9	267	218	100	700	4/29/2009-12/14/2009
2-BDM005.70	Beaverdam Creek	9	500	394	100	1000	4/29/2009-12/14/2009
2-BRW002.50	Barrows Creek	12	444	684	25	2000	1/10/2011-12/10/2012
2CXAH000.35	Beaverdam Creek, UT	6	367	513	100	1400	4/29/2009-12/14/2009
2-DSC012.67	Diascund Creek	31	168	445	3	2500	7/2/2003-8/6/2004
2-MCR002.38	Mill Creek	24	271	338	25	1450	2/9/2009-12/9/2013

* Contact DEQ or VIMS to obtain observation data

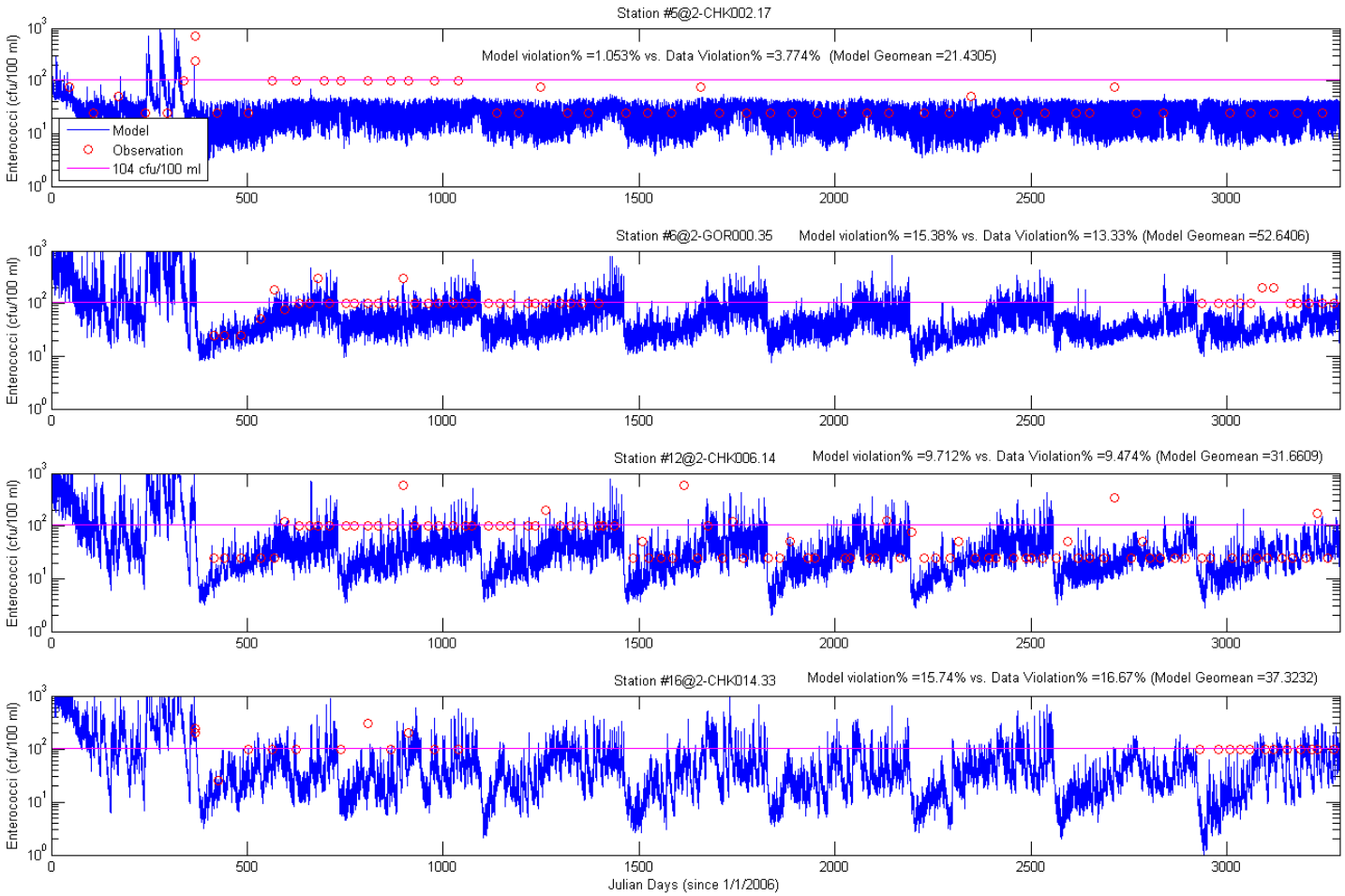
Station Id	Sample Size	Average	Standard Deviation	Minimum	Maximum	Monitoring Period
2CDSC003.11	1	10		10	10	6/27/2011
2-DSC003.19	22	120	82	25	400	3/1/2007-12/16/2014
2-DSC005.38	12	233	257	100	1000	1/13/2014-12/16/2014

Stream Name	Station Id	Sample Size	Average (#/100mL)	Standard Deviation	Minimum	Maximum	Monitoring Period
Chickahominy River	2CCHK002.10	1	50		50	50	7/16/2008
	2CCHK004.74	1	130		130	130	6/21/11
	2CCHK006.68	1	10		10	10	7/7/14
	2CCHK015.28	1	20		20	20	7/1/13
	2CXAC000.20	1	70		70	70	7/21/08
	2-CHK000.77	1	30		30	30	7/10/07
	2-CHK001.27	1	10		10	10	8/12/04
	2-CHK002.17	64	62	94	10	700	7/2/2003-2/3/2015
	2-CHK004.82	1	10		10	10	7/10/2007
	2-CHK006.14	95	91	218	10	2000	2/20/2007-3/12/2015
	2-CHK014.33	24	119	58	25	300	1/4/2007-12/16/2014

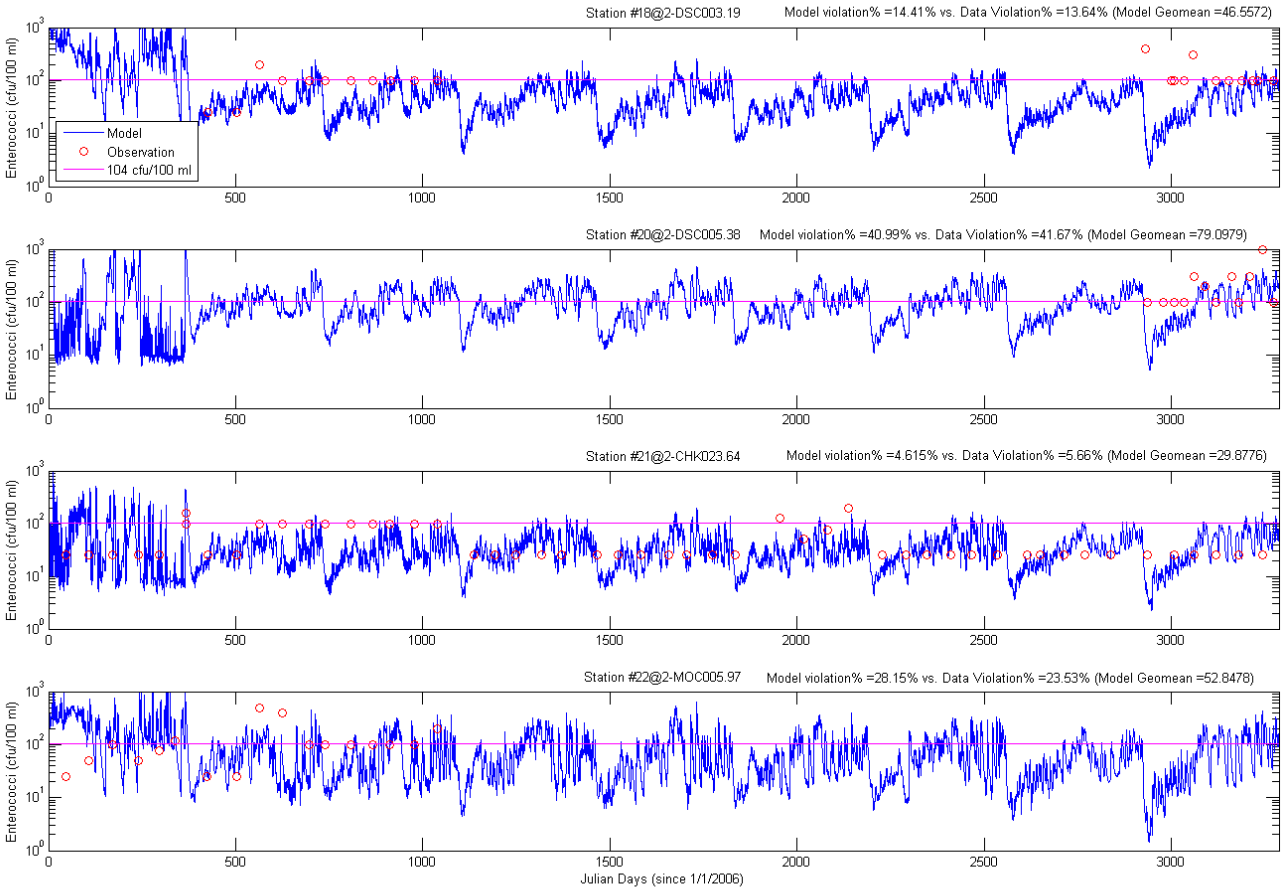
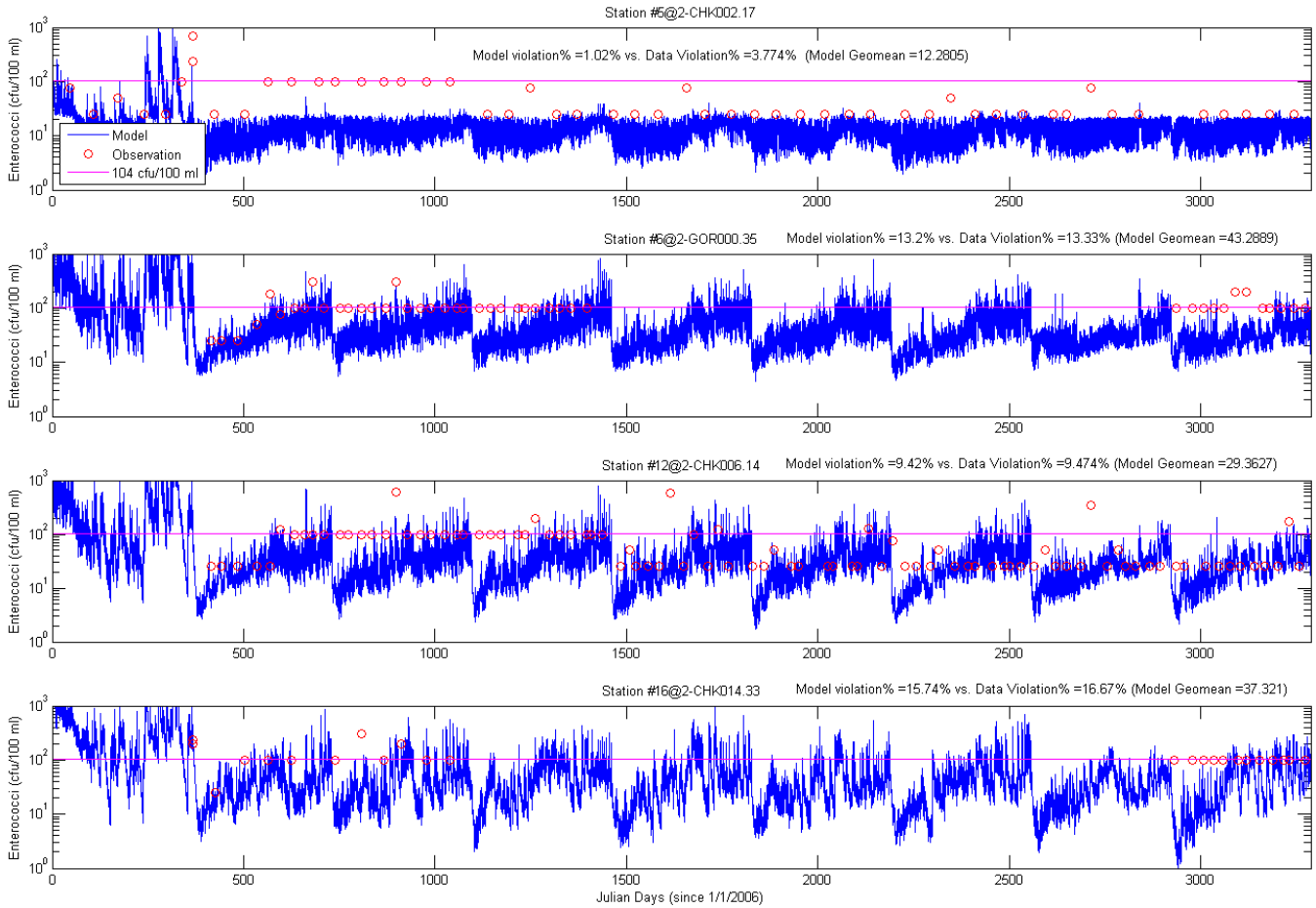
Sensitivity Test By Increasing Open Boundary Condition (enterococci) from 25 cfu/100ml (Baseline) to 50 cfu/100ml



Sensitivity Test By Increasing Open Boundary Condition (enterococci) from 25 cfu/100ml (Baseline) to 50 cfu/100ml - continued



Sensitivity Test By Increasing Dam Flow by 25% for The Baseline Condition



Sensitivity Test By Increasing Dam Flow by 25% for The Baseline Condition -continued