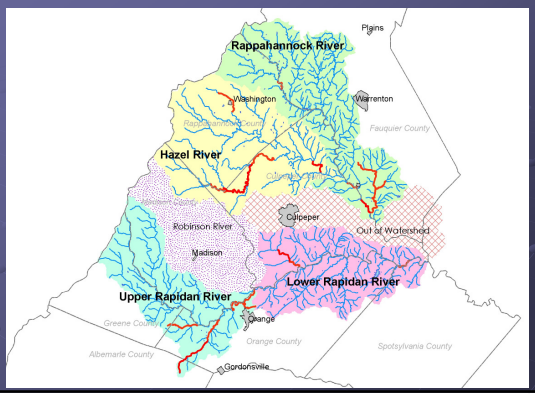
UPPER RAPPAHANNOCK RIVER BASIN BACTERIA TMDL DEVELOPMENT

Virginia Department of Environmental Quality
Rappahannock-Rapidan Regional Commission
Engineering Concepts, Inc.

TECHNICAL ADVISORY MEETING
July 27, 2006

MODEL REGIONS



WATERSHED WITHIN COUNTIES

County	County Total Acreage	Watershed Acreage in County	% of Watershed in County
Albemarle	463,100	3,000	1
Culpeper	245,700	166,500	68
Fauquier	418,000	152,500	36
Greene	101,300	41,600	41
Madison	205,200	92,000	45
Orange	218,900	124,600	57
Rappahannock	169,900	168,800	99
Spotsylvania	267,200	13,900	5

TMDL DEVELOPMENT PROCESS

- WATERSHED HISTORY
  - Characterize watershed and identify critical contamination conditions
- SOURCE ASSESSMENT
  - Identify and quantify pollutant sources
- MODELING
  - Link pollutant sources to stream water quality
- ALLOCATION
  - Develop and evaluate allocation scenarios

WATERSHED HISTORY

- Characterize watershed
  - Size
  - Land use
  - Slope
  - Soils and geology
  - Stream channel dimension
- Identify critical contamination conditions
  - Timeseries of bacteria concentration
  - Seasonality
  - Bacteria concentration versus flow

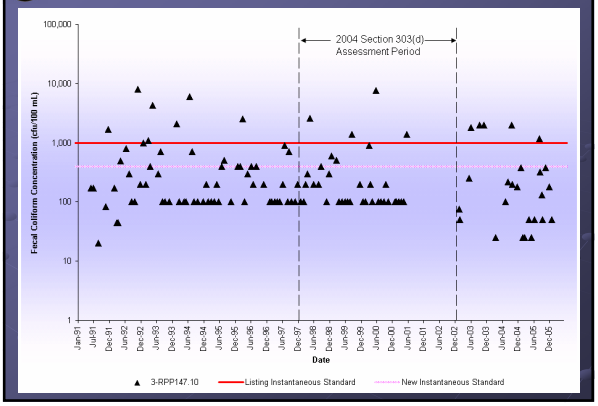
WATERSHED CHARACTERISTICS

Impairment	Drainage Size (sq. mi.)	Land use			
		Agricultural (%)	Residential (%)	Forest (%)	Water (%)
Rappahannock River (VAN-E01R-03)	76	30	1	68	1
Hughes River (VAN-E03R-01)	72	25	<1	74	<1
Hazel River (VAN-E04R-01)	125	28	<1	71	<1
Rush River (VAN-E05R-01)	15	20	<1	79	<1
Hazel River (60076)	316	32	<1	67	<1

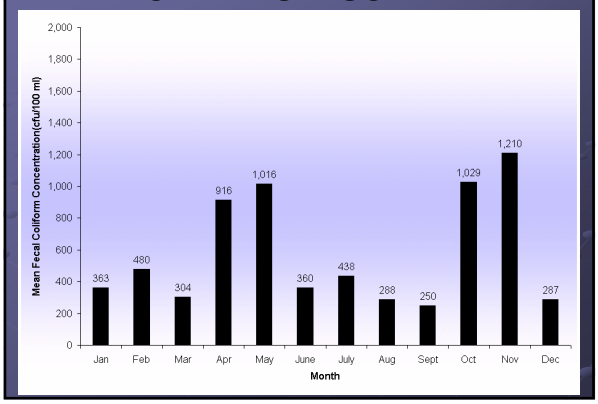
WATERSHED CHARACTERISTICS

Impairment	Drainage Size (sq. mi.)	Land use			
		Agricultural (%)	Residential (%)	Forest (%)	Water (%)
Rappahannock River (VAN-E08R-04)	619	36	1	63	<1
Rappahannock River (60081)	641	37	1	62	<1
Browns Run (VAN-E08R-02)	11	50	2	47	1
Craig Run (VAN-E08R-03)	8	70	6	24	<1
Marsh Run (VAN-E08R-01)	46	55	3	41	1

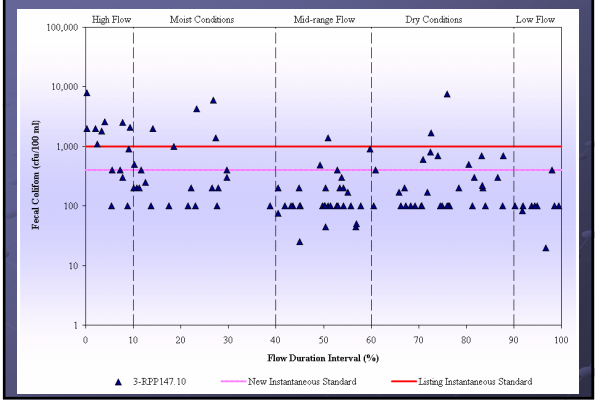
BACTERIA TIMESERIES



BACTERIA SEASONALITY



BACTERIA VS. FLOW

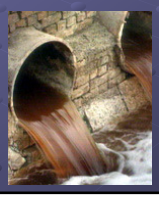


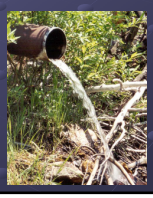
SOURCE ASSESSMENT

Source Category	Source / Animal Type
Human and Pets	Permitted Discharges
	Sanitary Sewer
	Straight Pipes
	Failing Septic Systems
	Biosolids Applications
	Dogs / Cats
Agricultural	Dairy & Beef Cattle
	Horses
	Sheep
	Chicken
	Turkey
Wildlife	Deer
	Raccoon
	Muskrats
	Beavers
	Turkeys
	Geese
	Ducks

PERMITTED POINT SOURCES

- Virginia Pollution Discharge Elimination System
  - Types
    - Municipal, industrial, general
    - Municipal separate storm sewer systems (MS4)
  - Categories – major, minor, general



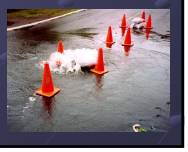


PERMITTED DISCHARGES

Impairment	Facility Type (#)			Design Flow (MGD)	
	Municipal	Industrial	General	Minimum	Maximum
Rappahannock River (VAN-E01R-03)	0	0	0	N/A	N/A
Hughes River (VAN-E03R-01)	0	0	0	N/A	N/A
Hazel River (VAN-E04R-01)	1	0	0	0.015	0.015
Rush River (VAN-E05R-01)	0	1	0	0.006	0.006
Hazel River (60076)	5	1	4	0.001	0.055
Rappahannock River (VAN-E08R-04)	14	1	8	0.001	2.500
Rappahannock River (VAN-E08R-RPP01A02)	16	1	8	0.001	2.500
Browns Run (VAN-E08R-02)	0	0	5	0.001	0.001
Craig Run (VAN-E08R-03)	0	0	0	N/A	N/A
Marsh Run (VAN-E08R-01)	0	0	10	0.001	0.001

HUMAN SOURCES

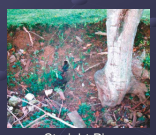
- Population, houses, onsite treatment system based on U.S. Census Bureau, municipality, & E-911 data
- Sanitary sewer
  - Loading type
    - Overflows
    - Exfiltration
  - Land-applied / direct deposition
    - Loading type
    - Proximity to stream



HUMAN SOURCES

- Failed septic systems
  - Failure to soil surface throughout year
  - Failure rate based on age of home
- Straight pipes
  - Direct continuous input to stream
  - Based on proximity to stream and house age
- Biosolids applications
  - Records kept by Virginia Department of Health
  - Land-applied

Failed Septic System



Straight Pipe

PET SOURCES

- American Veterinary Medical Association estimates 0.53 dogs and 0.60 cats per household
- Potentially updated through veterinarians, animal control, treasurer, and residents
- Population = population density * houses
- Land-applied

HUMAN AND PET SOURCES

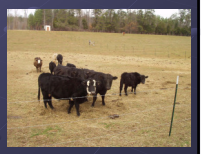
Impairment	Human Pop. (#)	Housing Unit (#)	Dogs (#)	Cats (#)
Rappahannock River (VAN-E01R-03)	2,683	1,023	542	614
Hughes River (VAN-E03R-01)	1,745	757	401	454
Hazel River (VAN-E04R-01)	5,725	2,050	1,087	1,230
Rush River (VAN-E05R-01)	377	180	95	108
Hazel River (VAN-60076)	15,286	5,327	2,823	3,196

HUMAN AND PET SOURCES

Impairment	Human Pop. (#)	Housing Unit (#)	Dogs (#)	Cats (#)
Rappahannock River (VAN-E08R-04)	36,837	12,170	6,450	7,302
Rappahannock River (60081)	40,128	13,152	6,971	7,891
Browns Run (VAN-E08R-02)	1,148	369	196	222
Craig Run (VAN-E08R-03)	1,836	532	282	319
Marsh Run (VAN-E08R-01)	14,874	5,091	2,698	3,054

LIVESTOCK SOURCES

- Population
  - Virginia Agricultural Statistics
  - Confined Animal Feeding Operation
  - Consultation with SWCD, VADCR, VCE, NRCS, and producers
  - Windshield survey
- Distribution of waste
  - Confined: waste collected and spread
  - Pastured: land-applied
  - Stream access: direct deposition
  - Imported sources
- Seasonal varying applications



LIVESTOCK SOURCES

Impairment	Beef* (#)	Dairy+ (#)	Horse (#)	Sheep (#)	Turkey (#)	Chicken (#)
Rappahannock River (VAN-E01R-03)	2,106	0	776	29	0	0
Hughes River (VAN-E03R-01)	1,632	0	599	22	0	0
Hazel River (VAN-E04R-01)	3,206	0	1,176	43	0	0
Rush River (VAN-E05R-01)	288	0	106	4	0	0
Hazel River (60076)	9,254	0	3,394	124	0	0

* Cow/calf pairs; + Milking herd

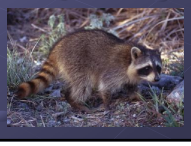
LIVESTOCK SOURCES

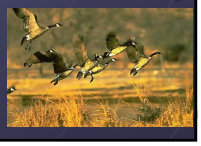
Impairment	Beef* (#)	Dairy+ (#)	Horse (#)	Sheep (#)	Turkey (#)	Chicken (#)
Rappahannock River (VAN-E08R-04)	17,900	620	7,869	452	0	0
Rappahannock River (60081)	18,650	620	8,337	499	0	0
Browns Run (VAN-E08R-02)	317	285	242	16	0	0
Craig Run (VAN-E08R-03)	335	250	255	17	0	0
Marsh Run (VAN-E08R-01)	1,467	815	1,117	73	0	0

* Cow/calf pairs; + Milking herd

WILDLIFE SOURCES

- Populations based on habitat and population densities provided by Virginia Department of Game and Inland Fisheries biologists
- Distribution of waste based on habitat
  - Land-applied
  - Direct deposition to stream
- Seasonal variations based on migration patterns and food sources





WILDLIFE SOURCES

Impairment	Deer (#)	Raccoon (#)	Muskrat (#)	Beaver (#)	Geese (#)	Duck (#)	Turkey (#)
Rappahannock River (VAN-E01R-03)	1,583	1,752	3,837	198	251	126	152
Hughes River (VAN-E03R-01)	1,367	1,454	3,539	163	237	120	92
Hazel River (VAN-E04R-01)	2,917	2,835	6,292	318	414	209	195
Rush River (VAN-E05R-01)	448	327	695	38	51	26	36
Hazel River (60076)	8,482	7,418	17,642	832	1,048	529	558

WILDLIFE SOURCES

Impairment	Deer (#)	Raccoon (#)	Muskrat (#)	Beaver (#)	Geese (#)	Duck (#)	Turkey (#)
Rappahannock River (VAN-E08R-04)	16,263	14,656	34,590	1,636	2,142	983	1,187
Rappahannock River (60081)	16,800	15,051	35,881	1,679	2,224	1,012	1,218
Browns Run (VAN-E08R-02)	308	240	564	26	43	15	22
Craig Run (VAN-E08R-03)	225	171	753	18	32	11	8
Marsh Run (VAN-E08R-01)	1,272	996	2,987	109	177	62	77

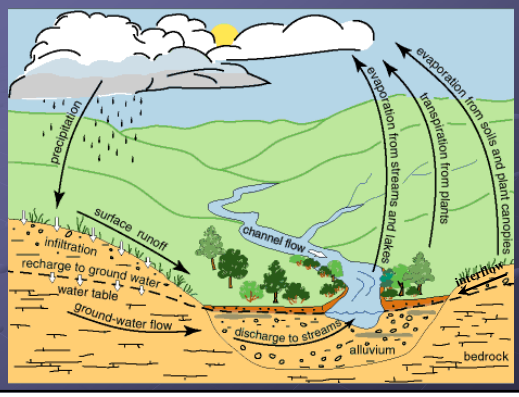
MODELING

- Link pollutant sources to stream water quality
- Mathematically represent processes that are occurring in the watershed
- Processes
  - Hydrology – water balance
  - Water quality - pollutant fate and transport
- Accuracy Evaluation
  - Based on observed data
    - Flow: USGS gauge = model output
    - Bacteria: VADEQ station = model output

MODELING

- Hydrologic Simulation Program - Fortran
  - Developed by USGS
  - Simulates point and non-point sources
  - Temporal variations in pollutant loadings
  - Seasonal patterns in climatic data

HYDROLOGIC MODELING



HYDROLOGIC MODELING COMPONENTS

- Land use
- Climatic data
- Topography
- Soils
- Stream channel characteristics
- Point source discharge / withdrawal
- Flow data

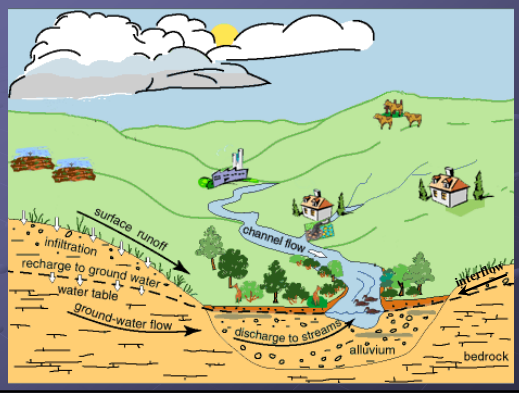
NCDC PRECIPITATION STATIONS

COOPID	Station Name	County	Time-step
442159	Culpeper Riverside CG	Culpeper	Hourly
446712	Piedmont Research St	Orange	Hourly
442155	Culpeper	Culpeper	Daily
440860	Boston 4 SE	Culpeper	Daily
443466	Gordonsville 3 S	Louisa	Daily
445050	Louisa	Louisa	Daily
440720	Big Meadows	Madison	Daily
445150	Madison	Madison	Daily
444692	Lake of the Woods	Orange	Daily
443462	Gordonsville FAA AP	Orange	Daily
447904	Somerset	Orange	Daily
443192	Fredricksburg Natl Pk	Spotsylvania	Daily

USGS GAUGING STATIONS

Site Number	Site Name	Data Available		Drainage Area
		From	To	(sq. mi.)
01665500	Rapidan River near Ruckersville	10/1942	09/2003	114
01667500	Rapidan River near Culpeper	10/1930	09/2003	472
01663500	Hazel River at Rixeyville	08/1942	09/2003	287
01664000	Rappahannock R. at Remington	10/1942	09/2003	620
01662800	Battle Run near Laurel Mills	05/1958	09/2003	28
01666500	Robinson River near Locust Dale	07/1943	09/2003	179
01667870	Mountain Run near Burr Hill	10/1989	04/1992	29

WATER QUALITY MODELING



WATER QUALITY MODELING COMPONENTS

- Sources
  - Fecal production
  - Fecal coliform densities
  - Fecal coliform distribution
- Delivery mechanisms
  - Direct
  - Land-applied
- Temporal variation

DEQ MONITORING STATIONS

Impairment	DEQ Station
Rappahannock River (VAN-E01R-03)	3-RPP175.51
Hughes River (VAN-E03R-01)	3-HUE000.20
Hazel River (VAN-E04R-01); Hazel River (VAN-E07R-HAZ01A04)	3-HAZ018.29
Rush River (VAN-E05R-01)	3-RUS005.66
Rappahannock River (VAN-E08R-04); Rappahannock River (VAN-E08R-RPP01A02)	3-RPP147.10
Browns Run (VAN-E08R-02)	3-BOS000.72
Craig Run (VAN-E08R-03)	3-CRA000.82
Marsh Run (VAN-E08R-01)	3-MAH000.19 3-MAH004.18

ALLOCATION

1. Calculate existing loads for all sources
2. Create load reductions scenarios controlling anthropogenic sources first
3. Run model with scenarios
4. Calculate water quality standard (WQS) violation rate
5. Select scenario with 0% WQS violation rate
6. Calculate allocation loads for all sources

EXAMPLE ALLOCATION

Source	Existing Condition Load (cfu/yr)
Direct Deposition	
Straight Pipes	8.09E+13
Livestock	1.76E+12
Wildlife	5.93E+13
Total	*1.58E+14*
Land-based	
Residential	1.61E+14
Cropland	1.16E+13
Pasture	9.53E+15
Forest	2.95E+14
Total	*9.99E+15*

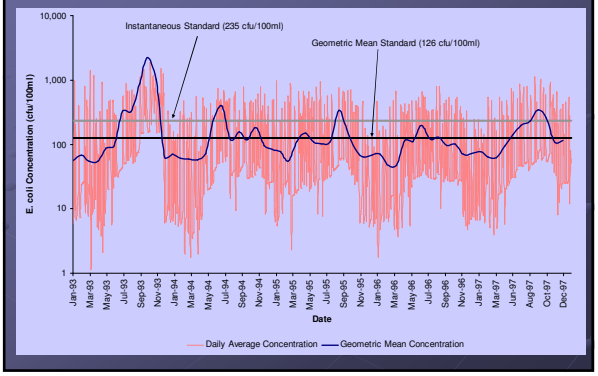
EXAMPLE ALLOCATION SCENARIOS

Scenario Number	Percent Reduction in Fecal Coliform Loading From Existing Conditions							% Violation of *E. coli* Standard	
	Straight Pipes	Livestock DD	Wildlife DD	Cropland	Pasture	Residential	Forest	Geometric Mean	Instantaneous
0	0	0	0	0	0	0	0	75	35
1	100	75	75	0	0	0	0	50	34
2	100	100	0	25	25	25	0	0	10
3	100	100	0	50	50	50	0	0	0

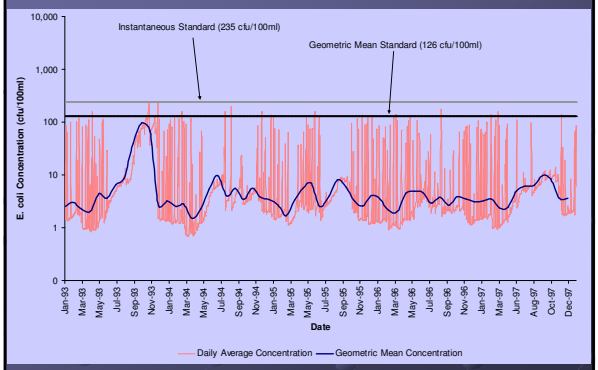
EXAMPLE ALLOCATION

Source	Existing Condition Load (cfu/yr)		Scenario 3 Reduction (%)		Source	Allocation Condition Load (cfu/yr)
Direct Deposition					**Direct Deposition**	
Straight Pipes	8.09E+13		100		Straight Pipes	0.00E+00
Livestock	1.76E+12		100		Livestock	0.00E+00
Wildlife	5.93E+13	X	0	=	Wildlife	5.93E+13
Total	*1.58E+14*				*Total*	*5.93E+13*
Land-based					**Land-based**	
Residential	1.61E+14		50		Residential	8.05E+13
Cropland	1.16E+13		50		Cropland	5.80E+12
Pasture	9.53E+15		50		Pasture	4.77E+15
Forest	2.95E+14		0		Forest	2.95E+14
Total	*9.99E+15*				*Total*	*5.15E+15*

EXAMPLE EXISTING CONDITIONS



EXAMPLE ALLOCATION CONDITIONS



TIMELINE

- POLLUTANT SOURCE INVENTORY
  - Revisions based on feedback
  - On-site sewage disposal systems
  - Biosolids applications

FIRST PUBLIC MEETING
Presentation of watershed history and pollutant source inventory

- MODELING
  - Hydrology calibration and validation
  - Water quality calibration and validation

SECOND TAC MEETING
Presentation of modeling results and revisions to pollutant source inventory

- ALLOCATION DEVELOPMENT
  - Scenario development, assessment of scenarios, selection of allocation

THIRD TAC MEETING
Presentation of allocation scenarios

FINAL PUBLIC MEETING
Presentation of model results, allocation scenarios, and draft TMDL document

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