Water Resources Data for Evaluating Coastal Plain Ecological Flows in the Albemarle-Pamlico Basin

Michael O'Driscoll, Visiting Assistant Professor of Water Resources, Duke University / Associate Professor, East Carolina University

Cait Skibiel, CRM Student, East Carolina University

Charlie Humphrey, Associate Professor, East Carolina University

Isabel Hillman and Oshin Paranjape , MEM Students, Duke University

Coley Hughes Cordeiro, APNEP

APNEP Coastal Ecological Flows Working Group

Outline

- Why is coastal ecological flow assessment needed?
- What data is out there for this effort?
- What are challenges/limitations based on the data availability?

Why is coastal ecological flow assessment needed?

- Flow alterations have been shown to affect fish and macroinvertebrates.
- Recent evidence suggests that groundwater inputs and low flows may be declining along many Coastal Plain rivers.
- Population and economic growth in the Coastal Plain (and Piedmont) suggest we will need more water in the future.
- Changes in climate, land use, and water use may affect streamflow and water quality.

Freshwater Biology

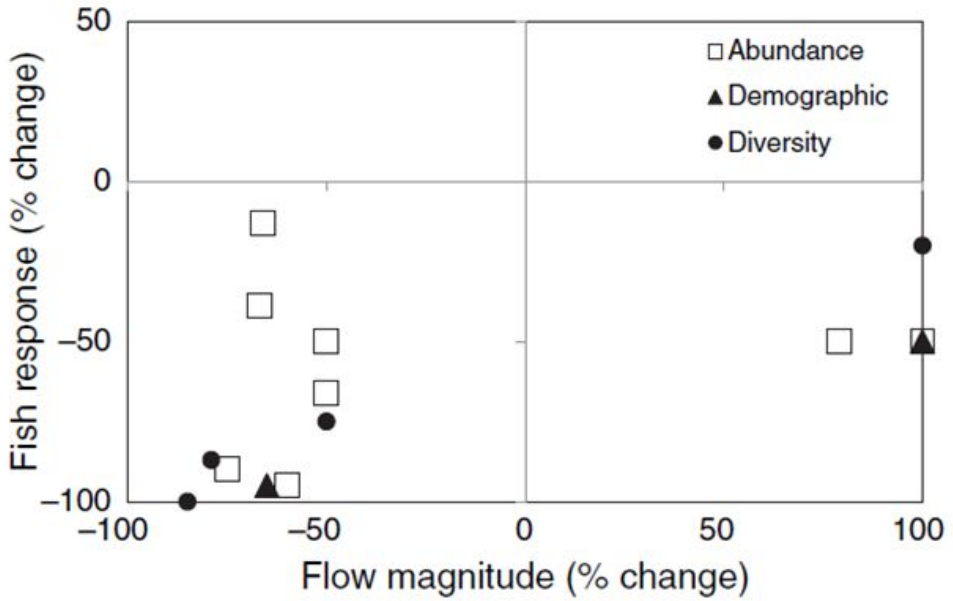
Freshwater Biology (2010) **55**, 194–205 doi:10.1111/j.1365-2427.2009.02272.x

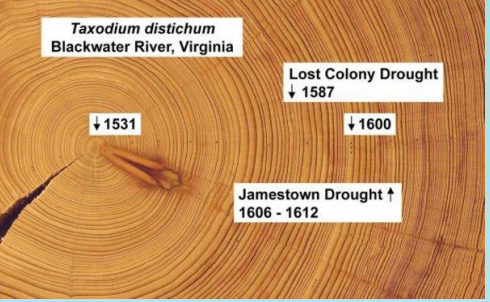
Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows

N. LEROY POFF* AND JULIE K. H. ZIMMERMAN†

*Department of Biology and Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO, U.S.A.

†The Nature Conservancy, Bethesda, MD, U.S.A.





Annual rings are thicker when water is plentiful, thinner when it is not. (R.D. Griffin/University of Arkansas Tree-Ring Laboratory).

Drought Cycles in Eastern North Carolina

North Carolina Climate Changes Reconstructed from Tree Rings: A.D. 372 to 1985

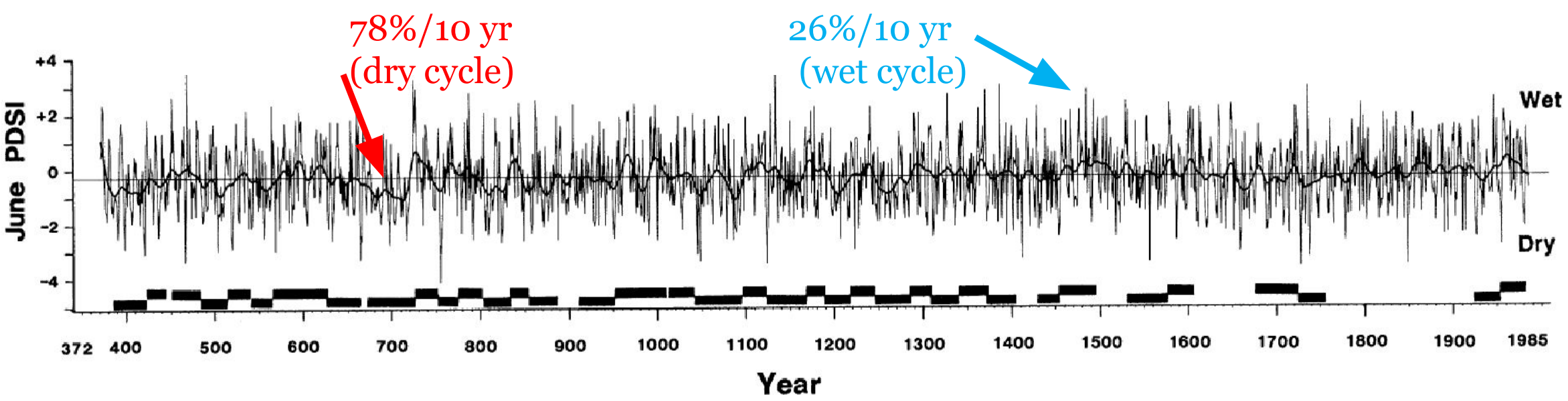
D. W. Stahle; M. K. Cleaveland; J. G. Hehr

Science, New Series, Vol. 240, No. 4858 (Jun. 10, 1988), 1517-1519.

From bald cypress tree rings from the Black River, NC- Stahle et al. (1988) reconstructed a ~1600 yr drought history

Drought cycles ~ 30 years

<u>NC Severe Drought Probability :</u> 56% /10 yr



PDSI- Palmer Drought Severity Index

Quantifying low flow conditions

7Q10 is a useful metric to characterize low flows. It is determined by statistical analysis of stream flow records, and represents the lowest stream flow average for seven consecutive days (in a given year) with a recurrence interval of ten years.

Average vs 7Q10 low flows at Tar River - Falkland, NC

Low-flow conditions can lead to:

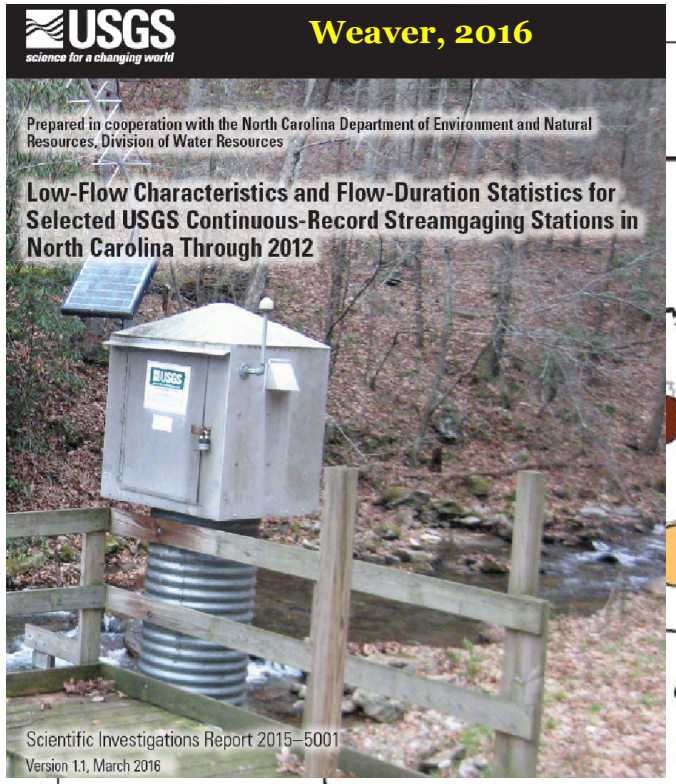
- reduced water supply
- deteriorated water quality
- diminished power generation
- disturbed riparian habitats

problems are likely to become more frequent under enhanced climate variability and increasing water demands.

Groundwater inputs are critical to low flow maintenance (baseflow=100% groundwater inputs)

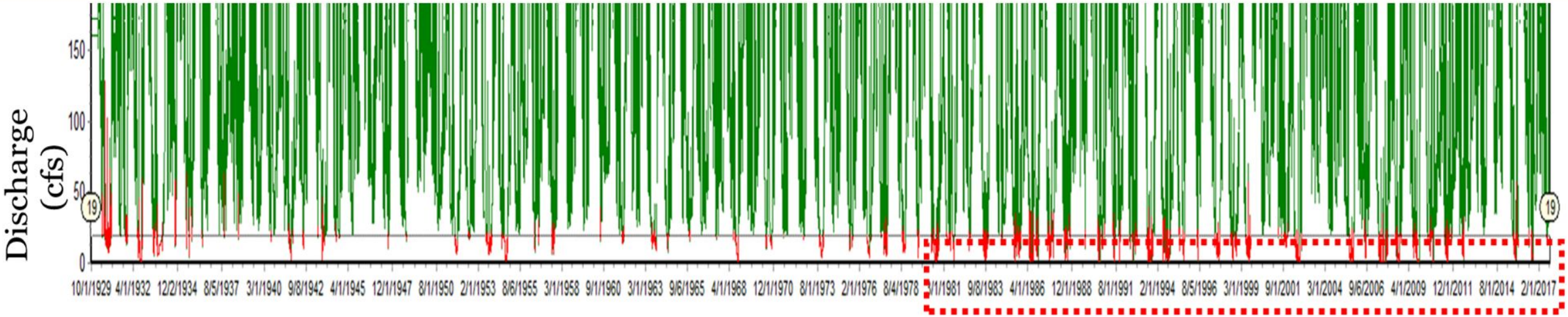
Recent USGS Low-Flow Characterization: Evidence that baseflow is declining in the NC Coastal Plain (pre-1998 vs pre-2011)

ALL Coastal Plain stream gauge sites that were evaluated showed recent declines in 7Q10 baseflow



Example: Little River near Princeton, NC: 2.4 cfs to 0.95 cfs (decline of 60.4%)

Low flows are getting lower along many Coastal Plain Rivers



Suggests groundwater inputs to the stream are declining.

Potential reasons may include:

- reductions in groundwater recharge
- shifting precipitation and/or evapotranspiration patterns
- effects of groundwater (GW) and surface water (SW) withdrawals
- interbasin transfers of water and/or wastewater

Population Growth and Water Use in The Coastal Plain

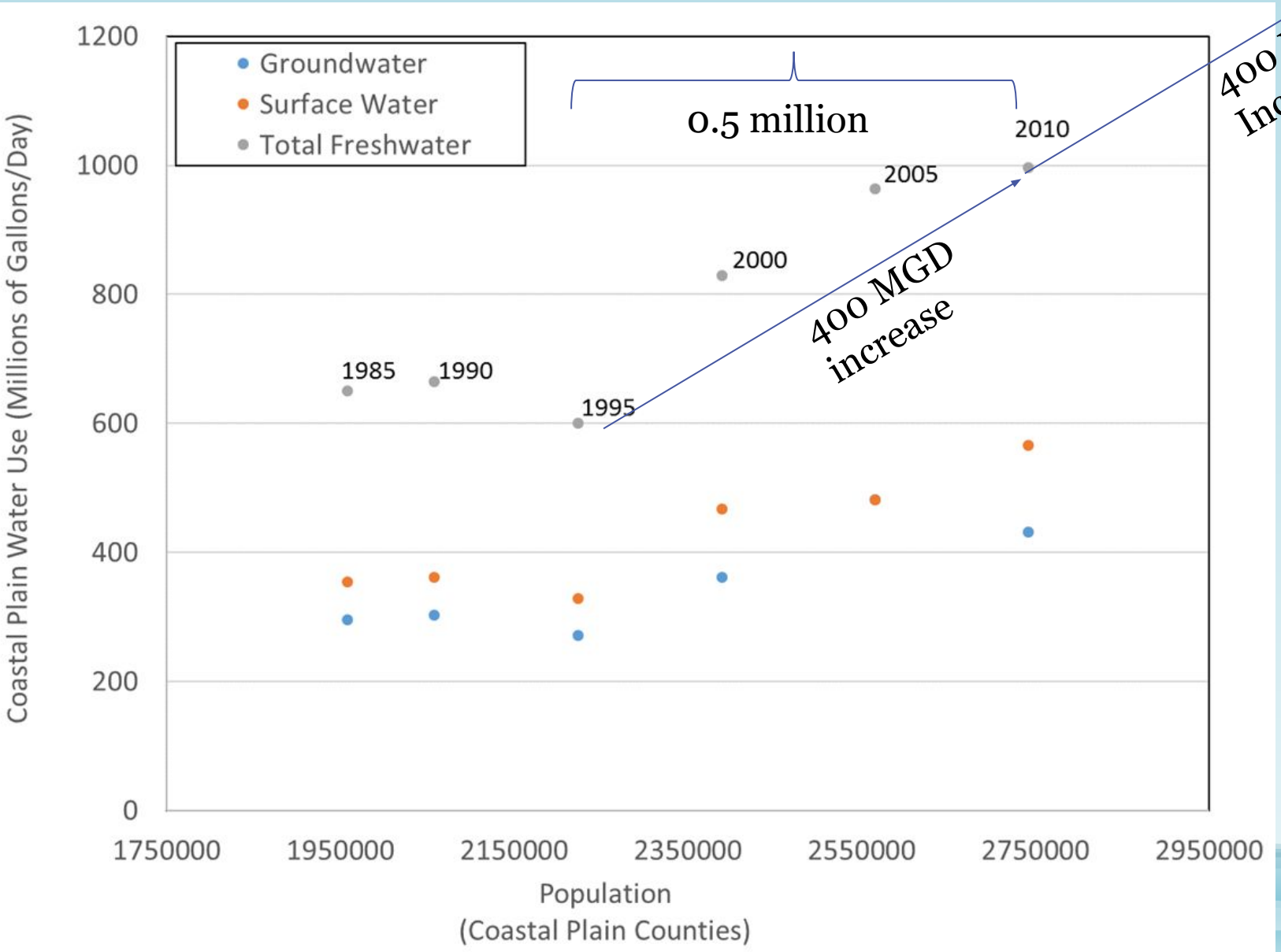
2010- CP water use ~ 1 billion gallons/d

Water use has generally increased with population increase.

From 1995-2000, a rapid increase in water use.

From 2005-2010, water use did not increase substantially.

Suggests economic, conservation, or other factors.



Population projections: +0.5 million from 2010-2035

Will need approx. 400 MGD (1.4 BGD total) by 2035

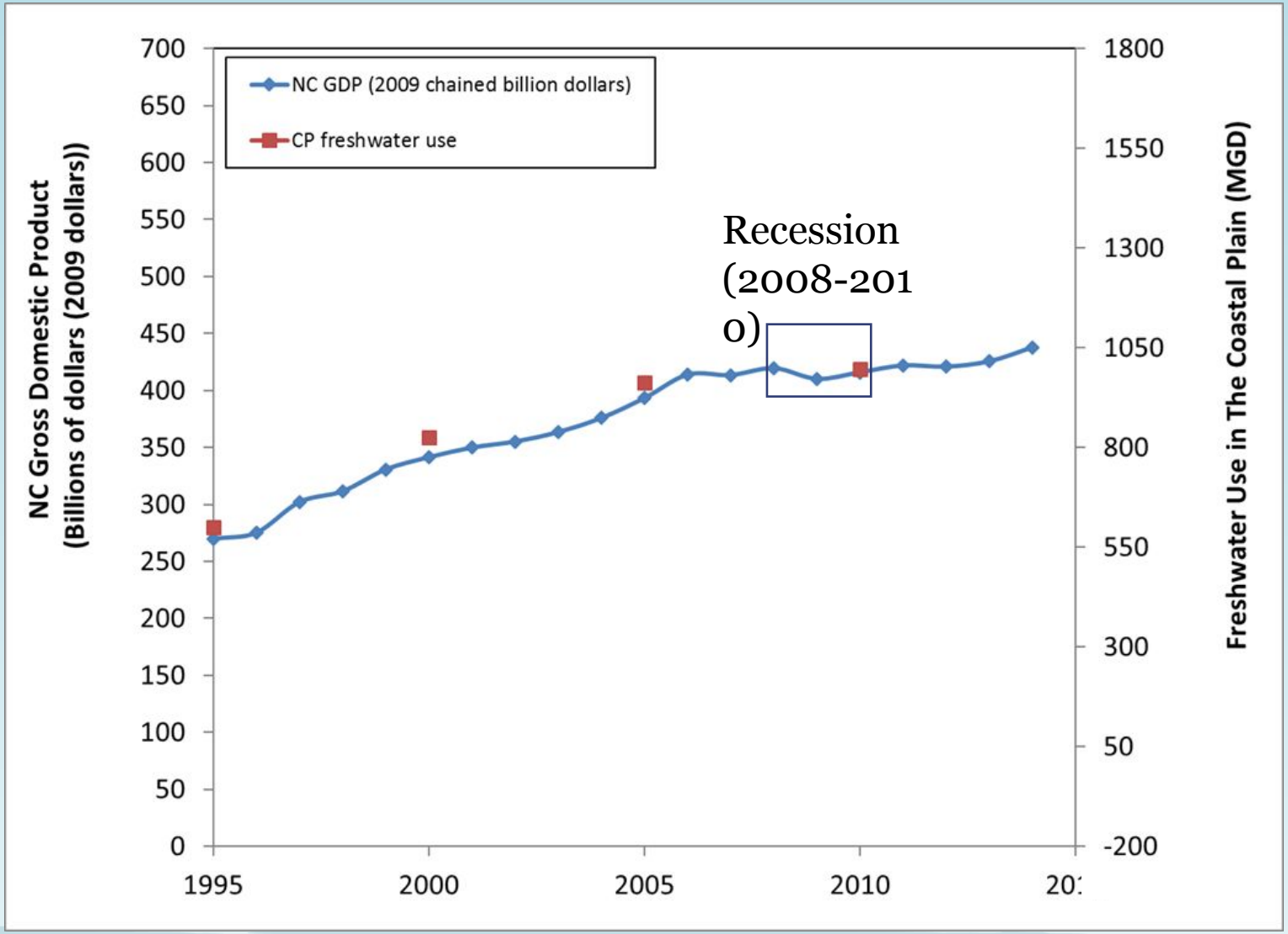
Data source: USGS

Economic Conditions also Influence Coastal Plain Water Use

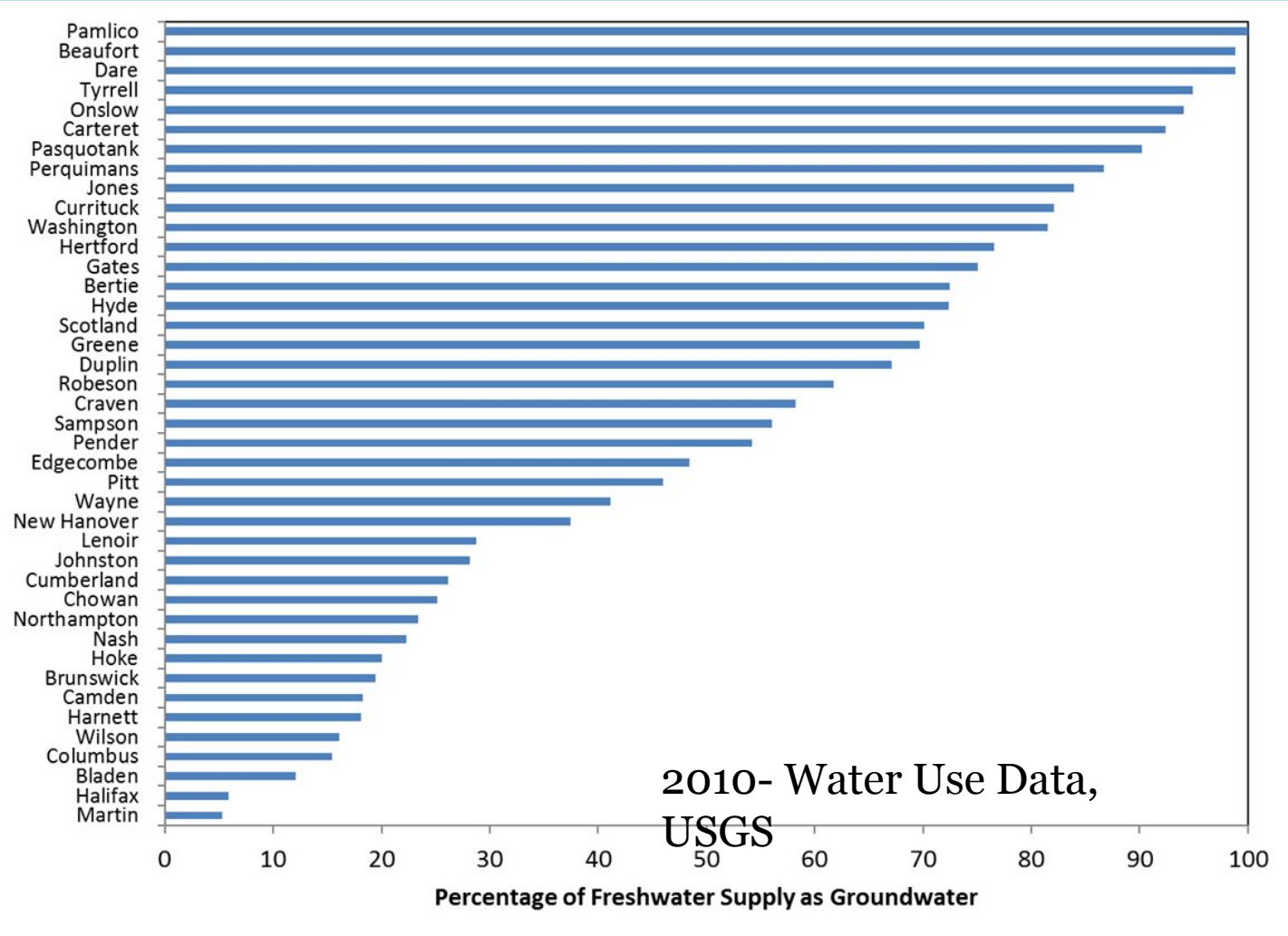
NC Gross Domestic Product (GDP) increased from 270 billion (1995) to 437 billion (2014) (US BEA 2016).

Coastal Plain freshwater use increased with GDP, suggesting a relationship between economic activities and water use.

If economic conditions continue to improve- should expect increased water use



Coastal Plain Counties: Heavy Reliance on Groundwater



2010- Water Use Data, USGS

- 54% of Coastal Plain Counties utilized groundwater for more than 1/2 of their supply.
- The total groundwater use from Coastal Plain counties is 62% (431 million gallons/day) of groundwater usage statewide (694 million gallons/day) (2010)

Due to reliance on groundwater in the Coastal Plain: potential for groundwater withdrawals to influence streamflow

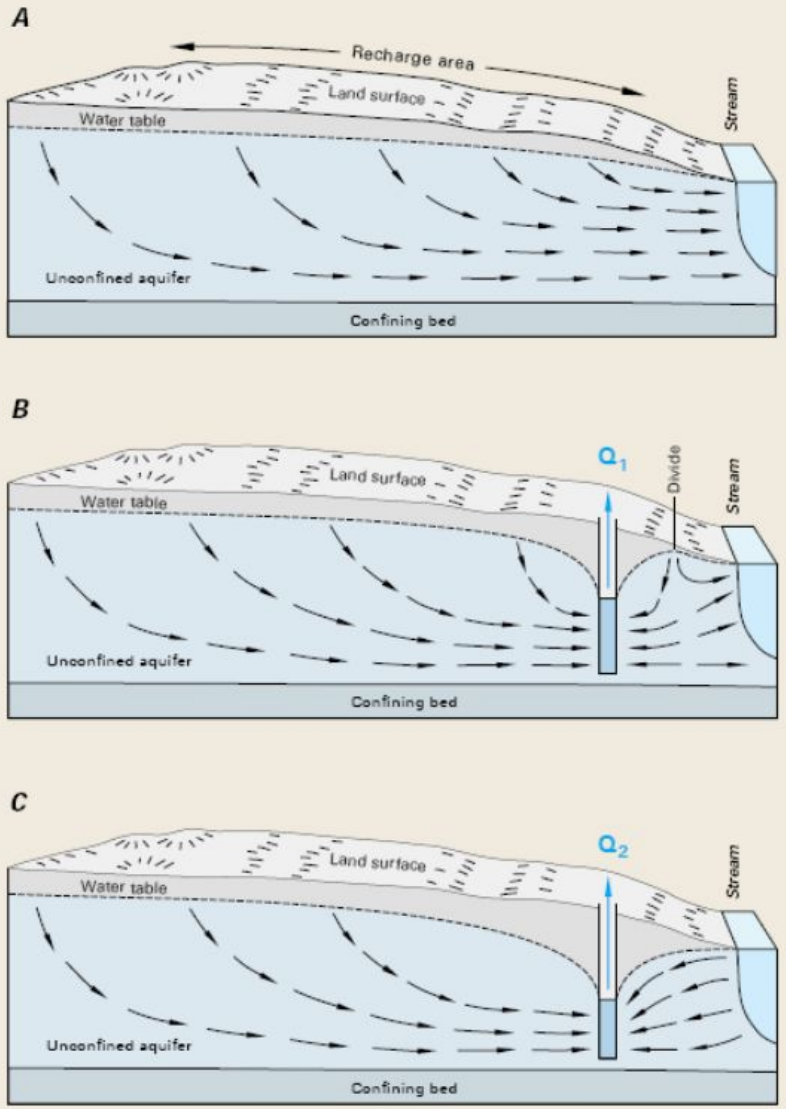
Groundwater Pumping May Affect the Water Table and Streams

-can remove source of baseflow from streamflow

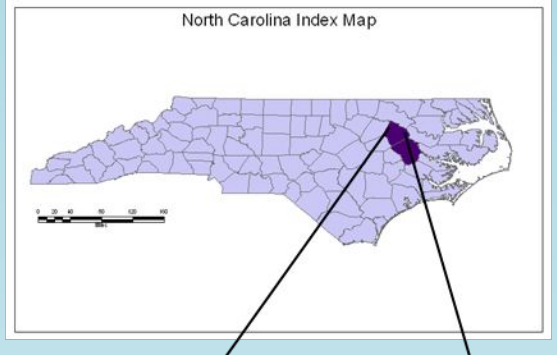
-over time can reverse stream-groundwater relationship

- may lead to declines in baseflow over time

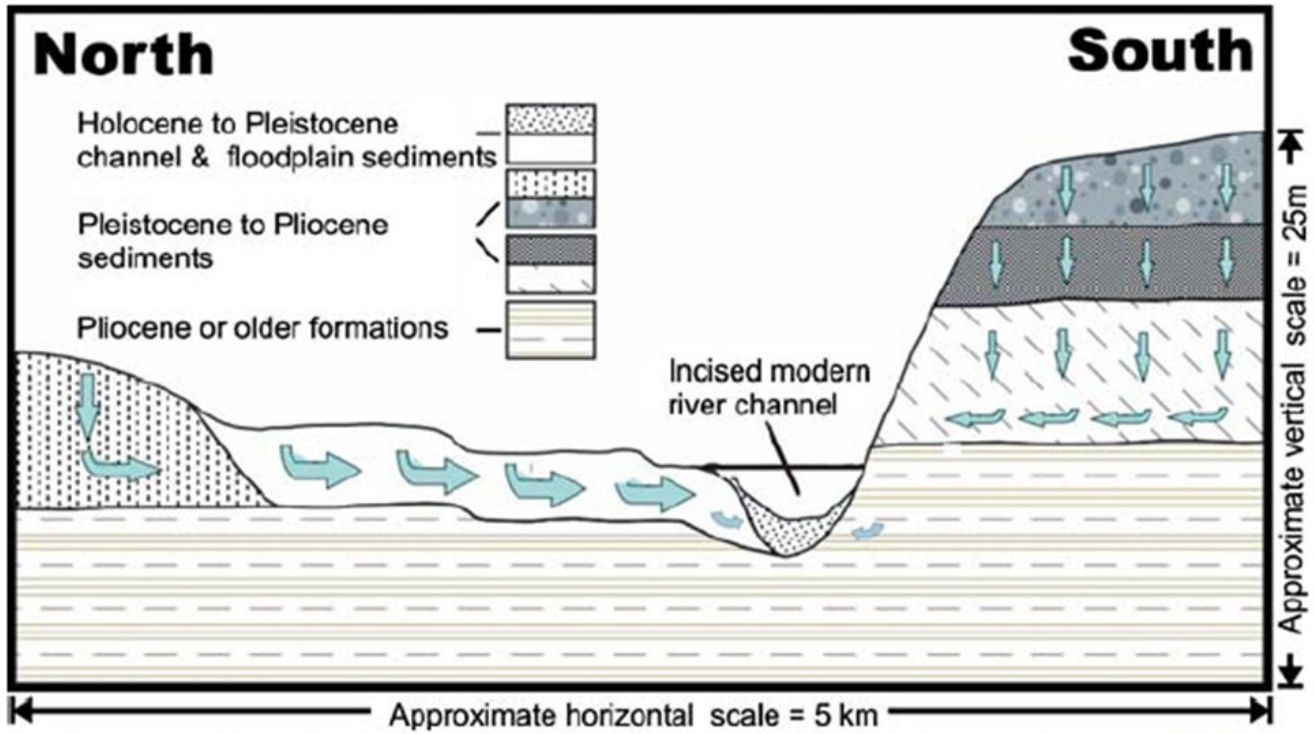
What is the relative role of meteorological controls and water withdrawals on changes in low-flow statistics?



Winter et al. 1998



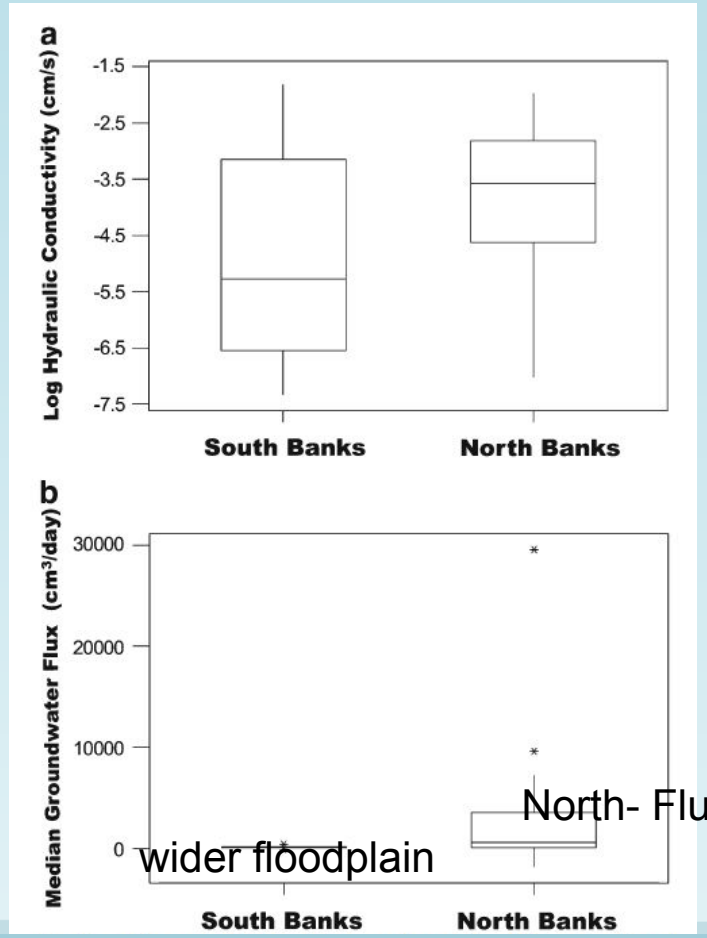
River-Groundwater Interactions are Complex in the Coastal Plain



Conceptual hydrogeologic model of the Tar River, floodplain and adjacent uplands (Johnson 2007). *Arrows* indicate direction of groundwater flow. Stratigraphic interpretations are based on NC DENR well logs, cores and auger samples collected during this study, GPR data, and a conceptual model for the evolution of the Roanoke River developed by S.R. Riggs (East Carolina University, Greenville, NC, personal communication, 2007). Regional confining units inhibit the downward infiltration of water to deeper units, causing lateral flow atop the confining unit and towards the river channel. Coarse-grained channel and floodplain sediments, frequently located on the *north* side of the river, transmit larger quantities of groundwater than older (and lower permeability) Pleistocene through Cretaceous (typically marine) sediments on the *south* side of the river

Coastal Plain Streams – Groundwater Interactions

South - Marine seds, steeper



North- Fluvial seds, more permeable- >gw

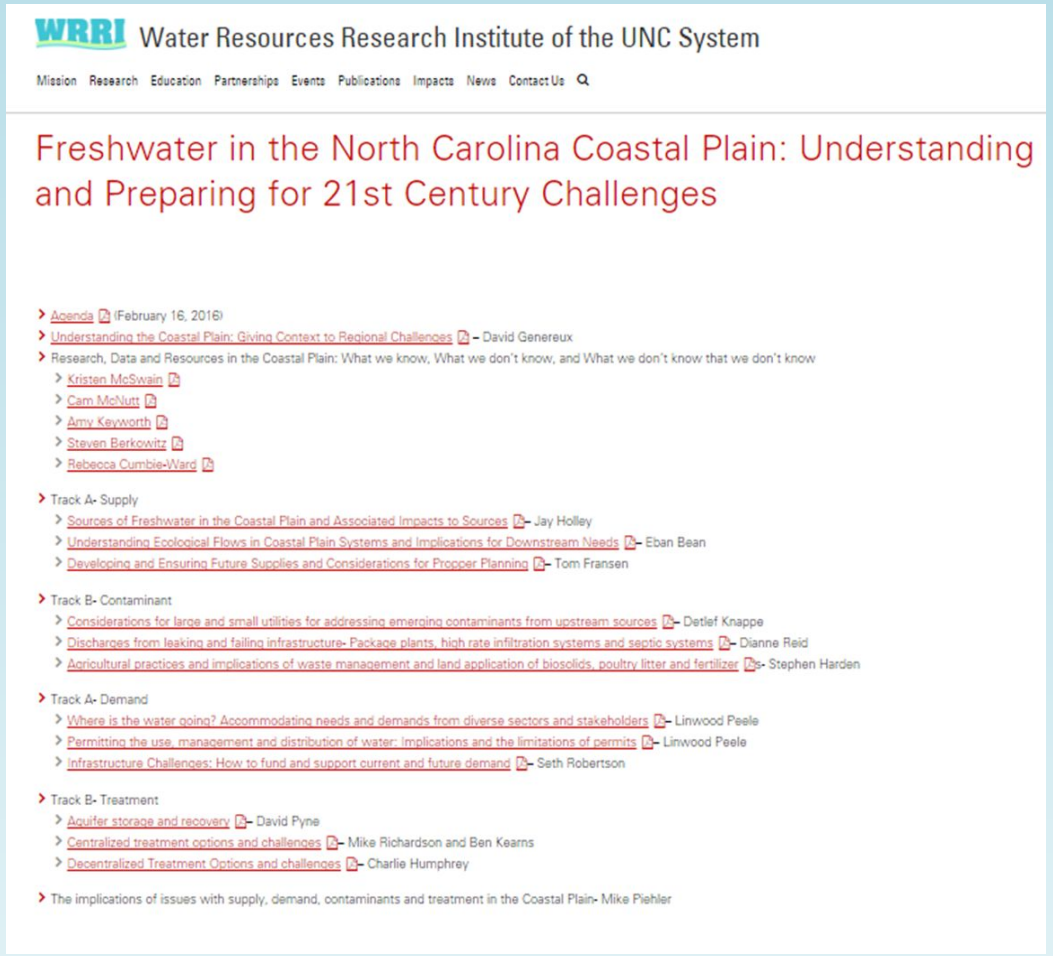
wider floodplain

What data is available for ecological flow assessment?

- Coastal water data presentations from Feb. 2016 conference:

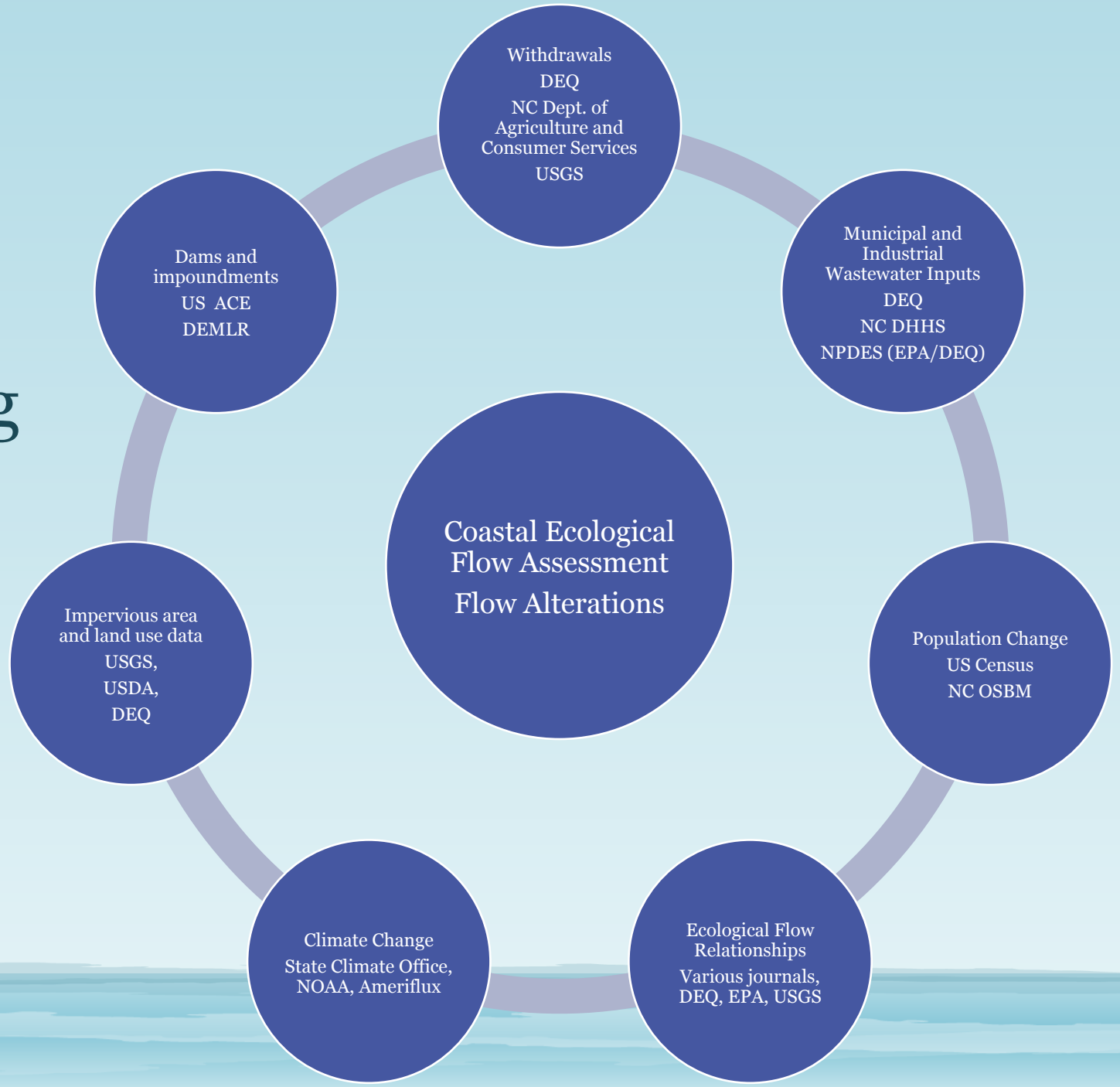
https://wrri.ncsu.edu/wrri-events/coastal-plain/

- For ecological flow data - there is some effort needed to acquire hydrological, meteorological, ecological, and water use data across various agencies with different objectives/regulations/ data formats, etc.



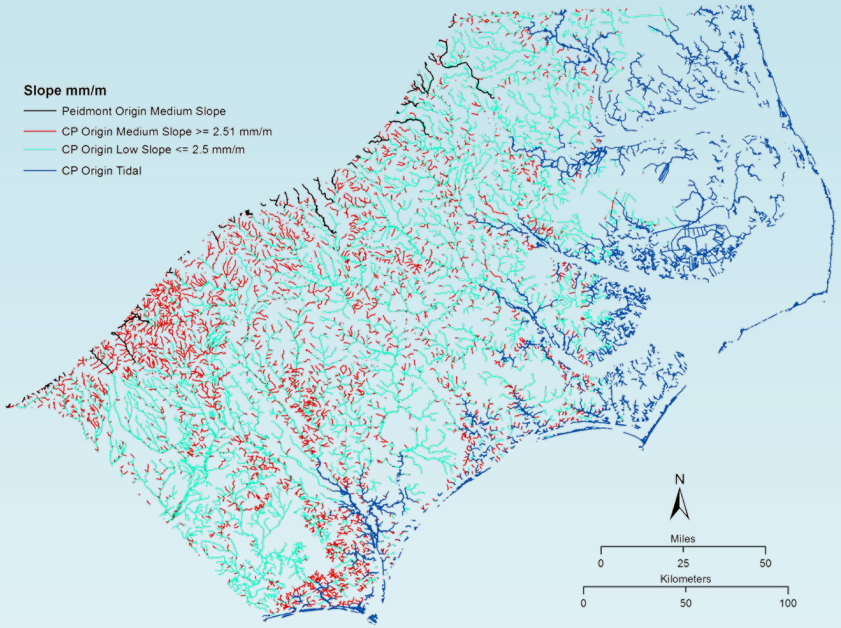
Data Needs:

To understand the magnitude and timing of flow alterations and ecological effects



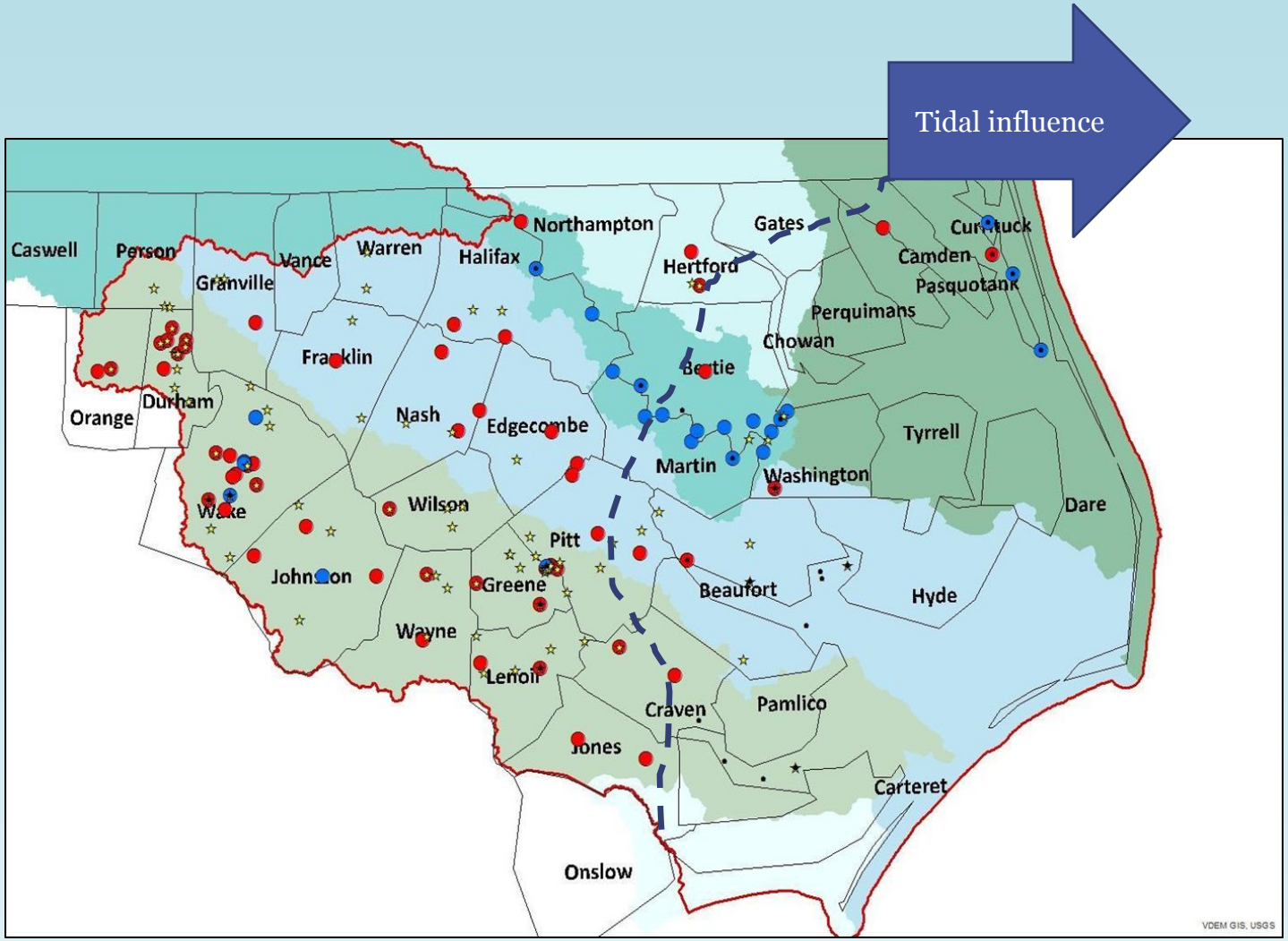
Data Needs:

To understand reference conditions and classify streams



E. Bean/M. Griffin

USGS Streamflow and Stage Monitoring Network

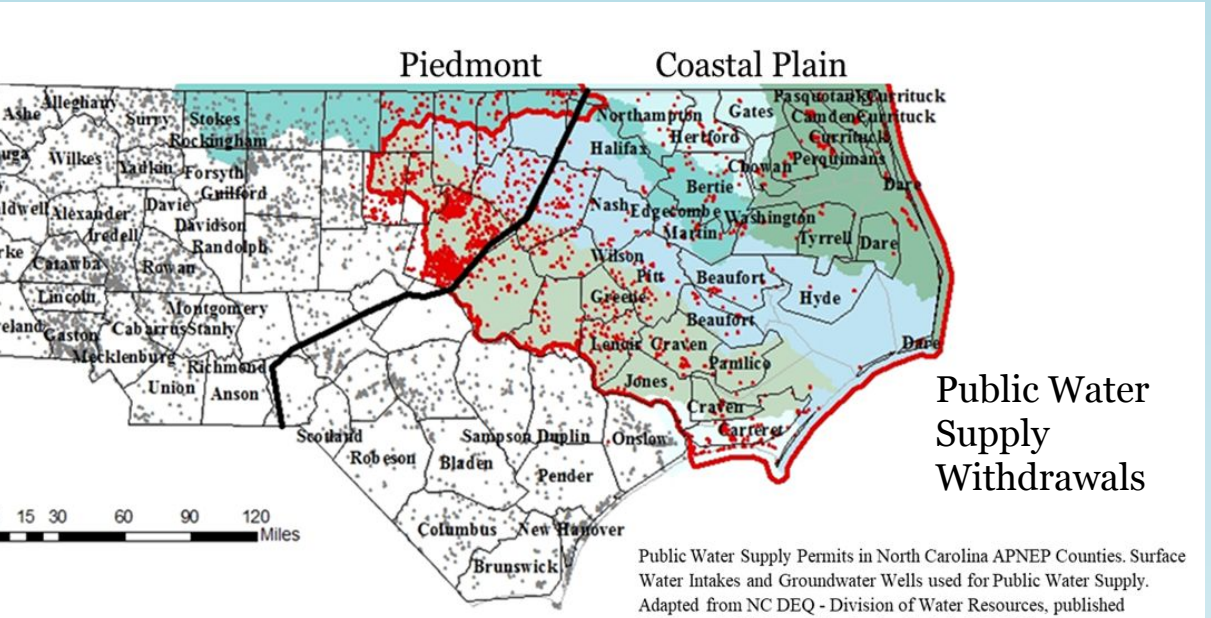


Minimal flow data available in zone of tidal influence

Map of where current USGS streamflow gages are in NC APNEP watersheds. Red gages indicate stage and discharge sites. Blue gages indicate stage only. Yellow stars indicate inland water quality data available. Black circles indicate water quality data available in the estuary.

Flow Alterations

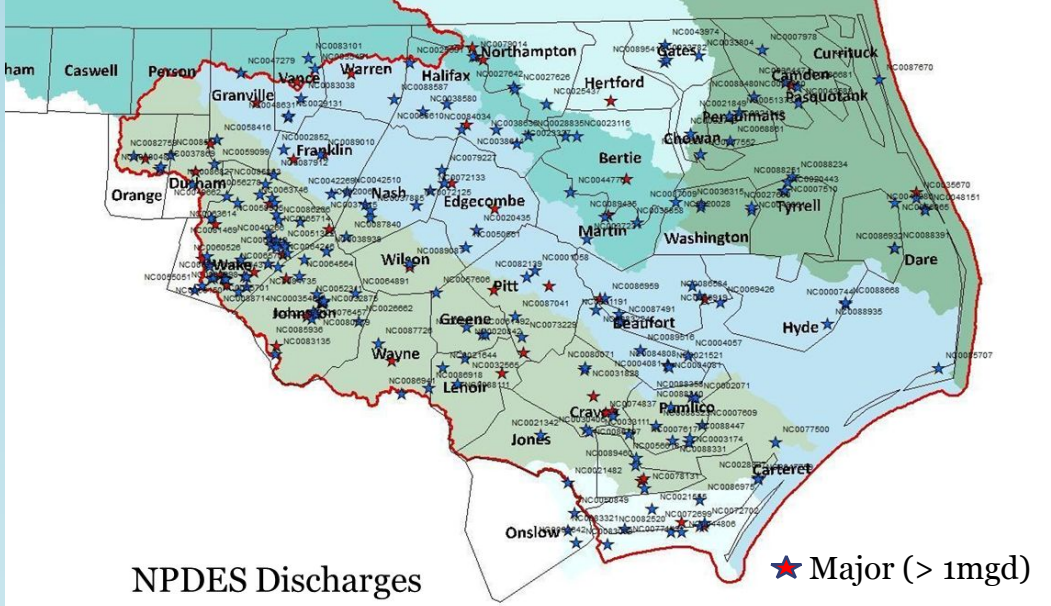
Withdrawals



Public Water Supply Withdrawals

Public Water Supply Permits in North Carolina APNEP Counties. Surface Water Intakes and Groundwater Wells used for Public Water Supply. Adapted from NC DEQ - Division of Water Resources, published February, 2017. Feature Service by Melanie M. Williams.

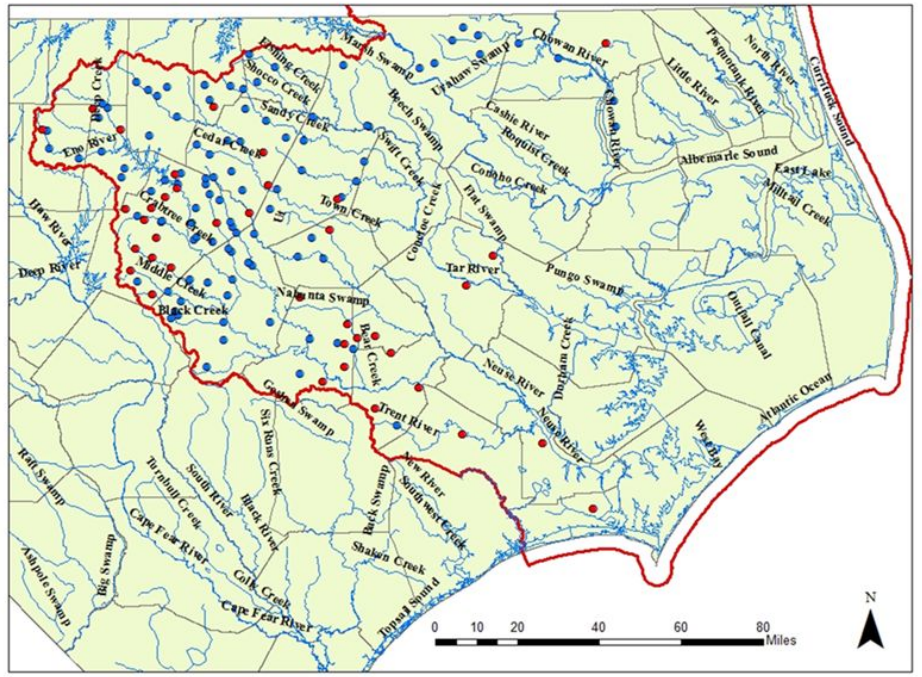
Discharges



NPDES Discharges

★ Major (> 1mgd)

Dams



High hazard dams in red

Obstructions

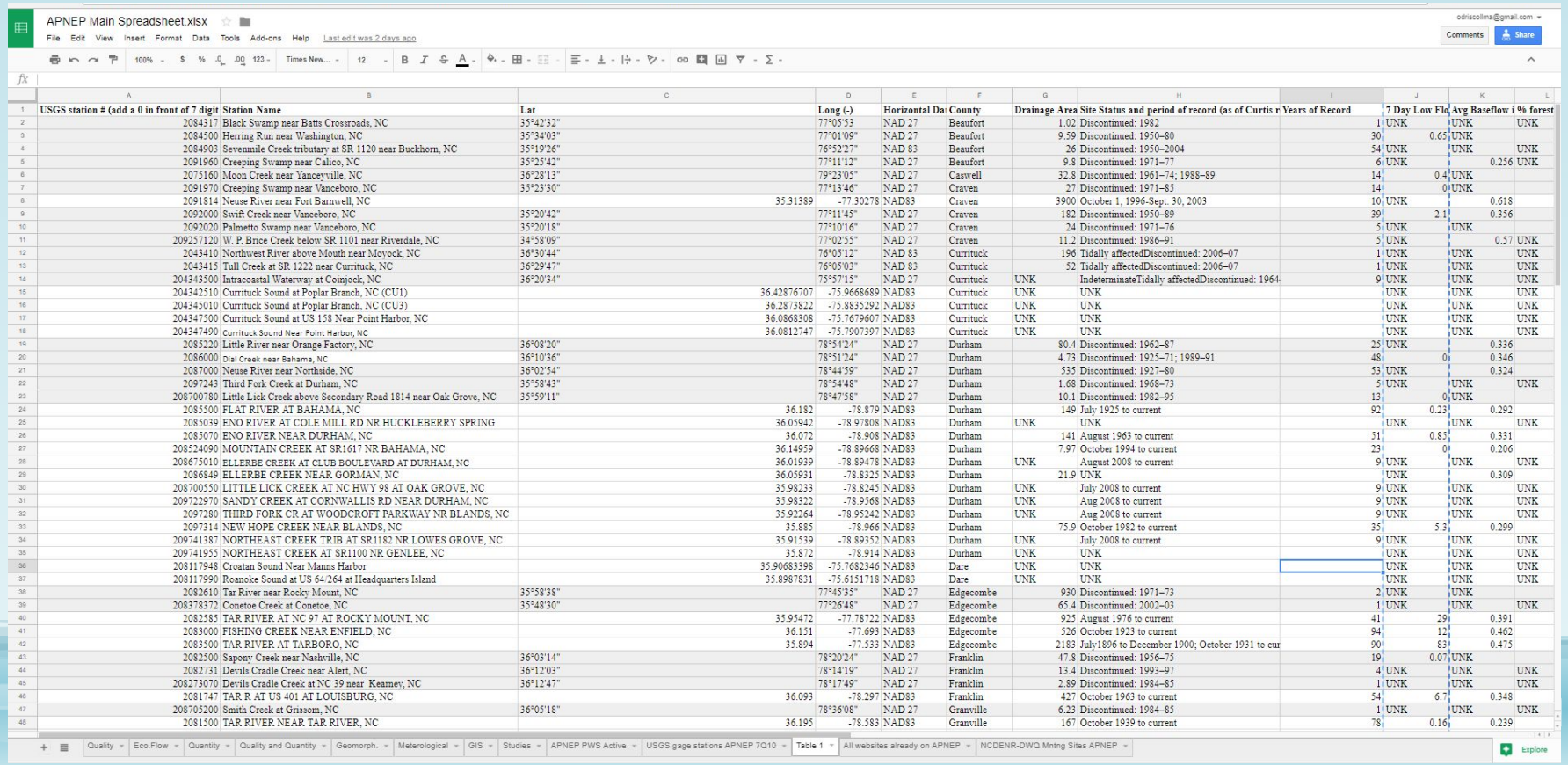
Database and maps developed by Cait Skibiel
Source data from DEQ and Nationalmap.gov

Compiled/compiling publically available data:

Surface Water Discharge
Stage and Flood Recurrence
Geomorphological, Soils, and Land Cover
Meteorological
Groundwater and Baseflow
Water Use
Flow Alteration/ Dams
NPDES Discharges
Water Quality
Ecological Flow Relationships for Coastal Plain

Example: 7Q10 data

- 49 discharge stations in the Albemarle Pamlico Drainage
- USGS Streamstats – calculated 7Q10
  - range from 0-83 cfs
- Median 7Q10 – 0.39 cfs ~250K gallons/d or 0.25 MGD



APNEP Main Spreadsheet.xlsx

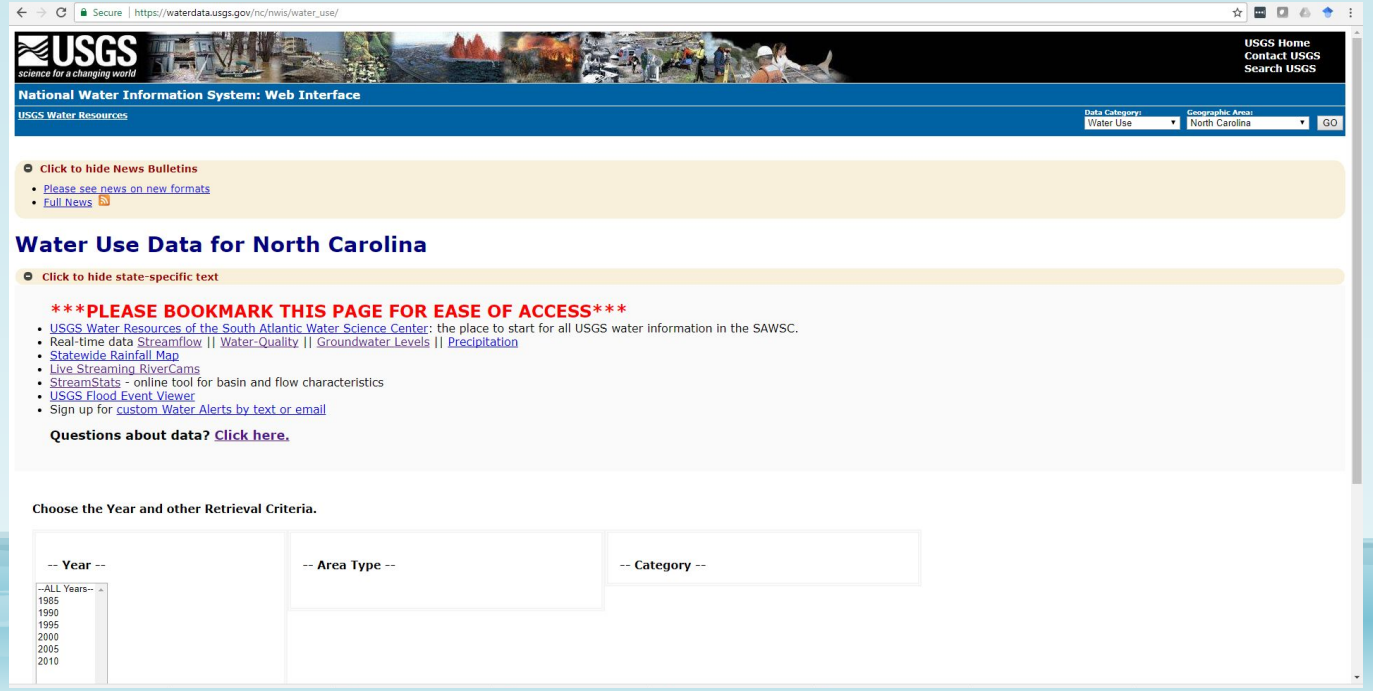
USGS station # (add a 0 in front of 7 digit	Station Name	Lat	Long (-)	Horizontal Da	County	Drainage Area	Site Status and period of record (as of Curtis r	Years of Record	7 Day Low Flo	Avg Baseflow i	% forest	
2084317	Black Swamp near Batts Crossroads, NC	35°42'32"	77°05'53	NAD 27	Beaufort	1.02	Discontinued: 1982	1	UNK	UNK	UNK	
2084500	Herring Run near Washington, NC	35°34'03"	77°01'09"	NAD 27	Beaufort	9.59	Discontinued: 1950–80	30	0.65	UNK		
2084903	Sevenmile Creek tributary at SR 1120 near Buckhorn, NC	35°19'26"	76°52'27"	NAD 83	Beaufort	26	Discontinued: 1950–2004	54	UNK	UNK	UNK	
2091960	Creeping Swamp near Calico, NC	35°25'42"	77°11'12"	NAD 27	Beaufort	9.8	Discontinued: 1971–77	6	UNK	0.256	UNK	
2075160	Moon Creek near Yanceyville, NC	36°28'13"	79°23'05"	NAD 27	Caswell	32.8	Discontinued: 1961–74; 1988–89	14	0.4	UNK		
2091970	Creeping Swamp near Vanceboro, NC	35°23'30"	77°13'46"	NAD 27	Craven	27	Discontinued: 1971–85	14	0	UNK		
2091814	Neuse River near Fort Barnwell, NC	35.31389	-77.30278	NAD83	Craven	3900	October 1, 1996-Sept. 30, 2003	10	UNK	0.618		
2092000	Swift Creek near Vanceboro, NC	35°20'42"	77°11'45"	NAD 27	Craven	182	Discontinued: 1950–89	39	2.1	0.356		
2092020	Palmetto Swamp near Vanceboro, NC	35°20'18"	77°10'16"	NAD 27	Craven	24	Discontinued: 1971–76	5	UNK	UNK		
209257120	W. P. Brice Creek below SR 1101 near Riverdale, NC	34°58'09"	77°02'55"	NAD 27	Craven	11.2	Discontinued: 1986–91	5	UNK	0.57	UNK	
2043410	Northwest River above Mouth near Moyock, NC	36°30'44"	76°05'12"	NAD 83	Currituck	196	Tidally affectedDiscontinued: 2006–07	1	UNK	UNK	UNK	
2043415	Tull Creek at SR 1222 near Currituck, NC	36°29'47"	76°05'03"	NAD 83	Currituck	52	Tidally affectedDiscontinued: 2006–07	1	UNK	UNK	UNK	
204343500	Intracoastal Waterway at Coinjock, NC	36°20'34"	75°57'15"	NAD 27	Currituck	UNK	IndeterminateTidally affectedDiscontinued: 1964	9	UNK	UNK	UNK	
204342510	Currituck Sound at Poplar Branch, NC (CU1)	36.42876707	-75.9668689	NAD83	Currituck	UNK	UNK		UNK	UNK	UNK	
204345010	Currituck Sound at Poplar Branch, NC (CU3)	36.2873822	-75.8835292	NAD83	Currituck	UNK	UNK		UNK	UNK	UNK	
204347500	Currituck Sound at US 158 Near Point Harbor, NC	36.0868308	-75.7679607	NAD83	Currituck	UNK	UNK		UNK	UNK	UNK	
204347490	Currituck Sound Near Point Harbor, NC	36.0812747	-75.7907397	NAD83	Currituck	UNK	UNK		UNK	UNK	UNK	
2085220	Little River near Orange Factory, NC	36°08'20"	78°54'24"	NAD 27	Durham	80.4	Discontinued: 1962–87	25	UNK	0.336		
2086000	Dial Creek near Bahama, NC	36°10'36"	78°51'24"	NAD 27	Durham	4.73	Discontinued: 1925–71; 1989–91	48	0	0.346		
2087000	Neuse River near Northside, NC	36°02'54"	78°44'59"	NAD 27	Durham	535	Discontinued: 1927–80	53	UNK	0.324		
2097243	Third Fork Creek at Durham, NC	35°58'43"	78°54'48"	NAD 27	Durham	1.68	Discontinued: 1968–73	5	UNK	UNK	UNK	
208700780	Little Lick Creek above Secondary Road 1814 near Oak Grove, NC	35°59'11"	78°47'58"	NAD 27	Durham	10.1	Discontinued: 1982–95	13	0	UNK		
2085500	FLAT RIVER AT BAHAMA, NC	36.182	-78.879	NAD83	Durham	149	July 1925 to current	92	0.23	0.292		
2085039	ENO RIVER AT COLE MILL RD NR HUCKLEBERRY SPRING	36.05942	-78.97808	NAD83	Durham	UNK	UNK		UNK	UNK	UNK	
2085070	ENO RIVER NEAR DURHAM, NC	36.072	-78.908	NAD83	Durham	141	August 1963 to current	51	0.85	0.331		
208524090	MOUNTAIN CREEK AT SR1617 NR BAHAMA, NC	36.14959	-78.89668	NAD83	Durham	7.97	October 1994 to current	23	0	0.206		
208675010	ELLERBE CREEK AT CLUB BOULEVARD AT DURHAM, NC	36.01939	-78.89478	NAD83	Durham	UNK	August 2008 to current	9	UNK	UNK	UNK	
2086849	ELLERBE CREEK NEAR GORMAN, NC	36.05931	-78.8325	NAD83	Durham	21.9	UNK		UNK	0.309		
208700550	LITTLE LICK CREEK AT NC HWY 98 AT OAK GROVE, NC	35.98233	-78.8245	NAD83	Durham	UNK	July 2008 to current	9	UNK	UNK	UNK	
209722970	SANDY CREEK AT CORNWALLIS RD NEAR DURHAM, NC	35.98322	-78.9568	NAD83	Durham	UNK	Aug 2008 to current	9	UNK	UNK	UNK	
2097280	THIRD FORK CR AT WOODCROFT PARKWAY NR BLANDS, NC	35.92264	-78.95242	NAD83	Durham	UNK	Aug 2008 to current	9	UNK	UNK	UNK	
2097314	NEW HOPE CREEK NEAR BLANDS, NC	35.885	-78.966	NAD83	Durham	75.9	October 1982 to current	35	5.3	0.299		
209741387	NORTHEAST CREEK TRIB AT SR1182 NR LOWES GROVE, NC	35.91539	-78.89352	NAD83	Durham	UNK	July 2008 to current	9	UNK	UNK	UNK	
209741955	NORTHEAST CREEK AT SR1100 NR GENLEE, NC	35.872	-78.914	NAD83	Durham	UNK	UNK		UNK	UNK	UNK	
208117948	Croatan Sound Near Manns Harbor	35.90683398	-75.7682346	NAD83	Dare	UNK	UNK		UNK	UNK	UNK	
208117990	Roanoke Sound at US 64/264 at Headquarters Island	35.8987831	-75.6151718	NAD83	Dare	UNK	UNK		UNK	UNK	UNK	
2082610	Tar River near Rocky Mount, NC	35°58'38"	77°45'35"	NAD 27	Edgecombe	930	Discontinued: 1971–73	2	UNK	UNK		
208378372	Conetoe Creek at Conetoe, NC	35°48'30"	77°26'48"	NAD 27	Edgecombe	65.4	Discontinued: 2002–03	1	UNK	UNK	UNK	
2082585	TAR RIVER AT NC 97 AT ROCKY MOUNT, NC	35.95472	-77.78722	NAD83	Edgecombe	925	August 1976 to current	41	29	0.391		
2083000	FISHING CREEK NEAR ENFIELD, NC	36.151	-77.693	NAD83	Edgecombe	526	October 1923 to current	94	12	0.462		
2083500	TAR RIVER AT TARBORO, NC	35.894	-77.533	NAD83	Edgecombe	2183	July1896 to December 1900; October 1931 to cur	90	83	0.475		
2082500	Sapony Creek near Nashville, NC	36°03'14"	78°20'24"	NAD 27	Franklin	47.8	Discontinued: 1956–75	19	0.07	UNK		
2082731	Devils Cradle Creek near Alert, NC	36°12'03"	78°14'19"	NAD 27	Franklin	13.4	Discontinued: 1993–97	4	UNK	UNK	UNK	
208273070	Devils Cradle Creek at NC 39 near Kearney, NC	36°12'47"	78°17'49"	NAD 27	Franklin	2.89	Discontinued: 1984–85	1	UNK	UNK	UNK	
2081747	TAR R. AT US 401 AT LOUISBURG, NC	36.093	-78.297	NAD83	Franklin	427	October 1963 to current	54	6.7	0.348		
208705200	Smith Creek at Grissom, NC	36°05'18"	78°36'08"	NAD 27	Granville	6.23	Discontinued: 1984–85	1	UNK	UNK	UNK	
2081500	TAR RIVER NEAR TAR RIVER, NC	36.195	-78.583	NAD83	Granville	167	October 1939 to current	78	0.16	0.239		

What are limitations based on the data availability?

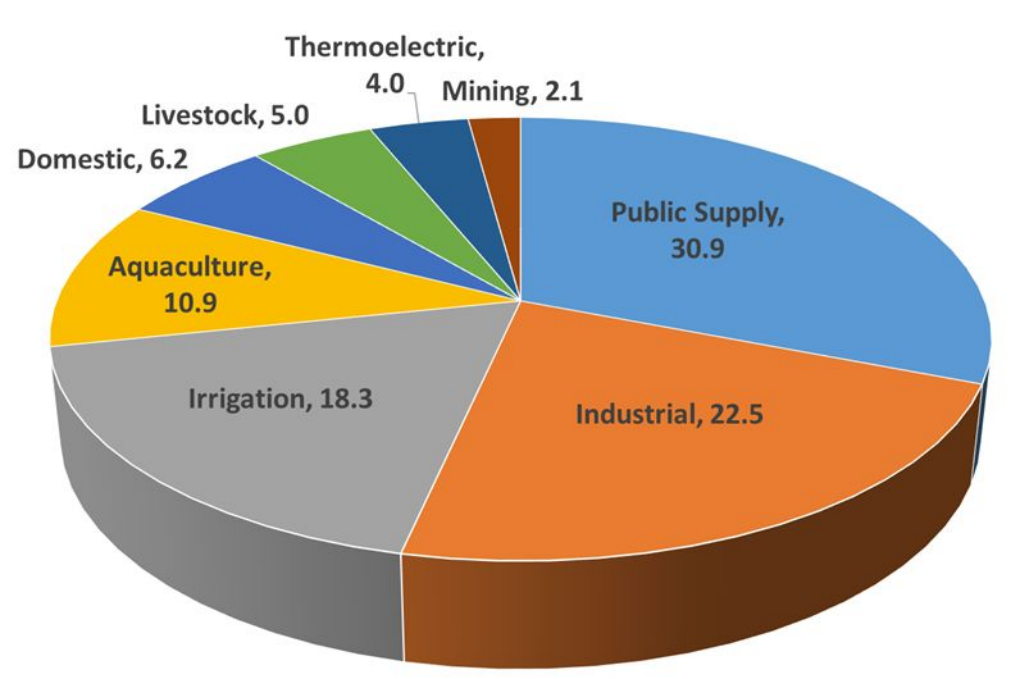
- Many USGS discharge stations have been decommissioned so > 30 year records to capture drought cycle are not available at many sites (18 sites out of 119)
- Spatial data gaps - low order streams and tidal coastal streams are rarely monitored for discharge
- Generally speaking at land elevations below approximately 3 m above sea level, there is an absence of flow monitoring (due to tidal and wind issues)
- Difficulties delineating catchments with subtle elevation differences and extensive drainage alteration
- More information is also needed on groundwater inputs along Coastal Plain streams (magnitude, spatial and temporal variability, and source aquifer).
- Seepage runs (nested discharge measurements along a stream) during summer low-flow conditions would be helpful to help characterize the spatial variability in groundwater inputs.

Water Use Data in the Coastal Plain

- More challenging than dealing with discharge due to differences in reporting thresholds, when programs were implemented, and data availability
- Need to work with DEQ, USGS, and NCDACS
- Currently, comprehensive publically available water use estimates in NC are available every 5 years (since 1985) from USGS



Coastal Plain Counties- Water Use (USGS 2010 estimates)



- Dominant Coastal Plain freshwater uses for 2010 were public supply (312 MGD), industrial (225 MGD), and irrigation (162 MGD)
- Total use ~ 1 billion gallons/day (USGS, 2010).
- Public supply ~ 31% of water use
- If you categorize livestock, aquaculture, irrigation as agricultural use~34 % (agricultural- major use)

Water Use Data in the Coastal Plain

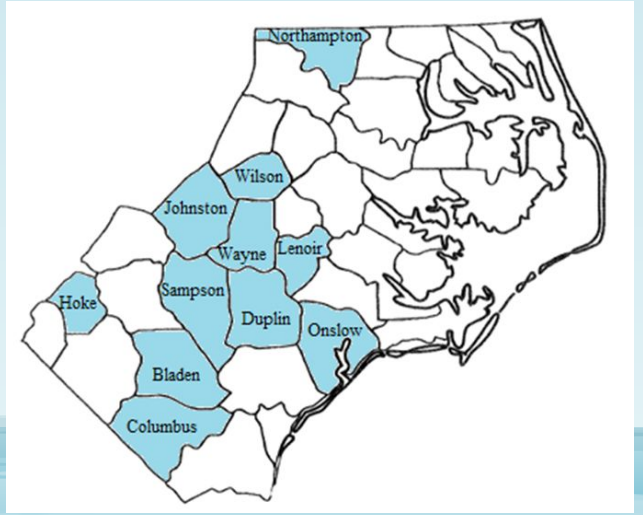
Thanks to Fred Tarver, Linwood Peele, and Nat Wilson at DEQ for helping to clarify!

Challenges Tracking Water Use in the Coastal Plain

- Reporting based on different rules that were put in place at various times and reporting thresholds may vary
- Generally speaking online data is not available before 1997 (paper data back to 1991)
- Comparisons of estimates across the different groups may not always be in agreement
- Example: Coastal Plain agricultural water use estimates for 2010 USGS estimate: 350 MGD vs. 21 MGD NC DACS.

	USGS 2010	NCDA&CS 2010	
County	Total (Mgal/day)	Total (Mgal/day)	Difference (Mgal/day)
Bladen County	42.74	2.01	40.73
Columbus County	12.59	0.00	12.59
Duplin County	28.34	2.02	26.32
Hoke County	21.72	0.00	21.72
Johnston County	14.13	0.88	13.25
Lenoir County	15.72	0.16	15.56
Northampton County	18.32	0.28	18.04
Onslow County	10.20	0.09	10.11
Sampson County	31.23	3.07	28.16
Wayne County	10.55	0.52	10.03
Wilson County	14.16	0.00	14.16

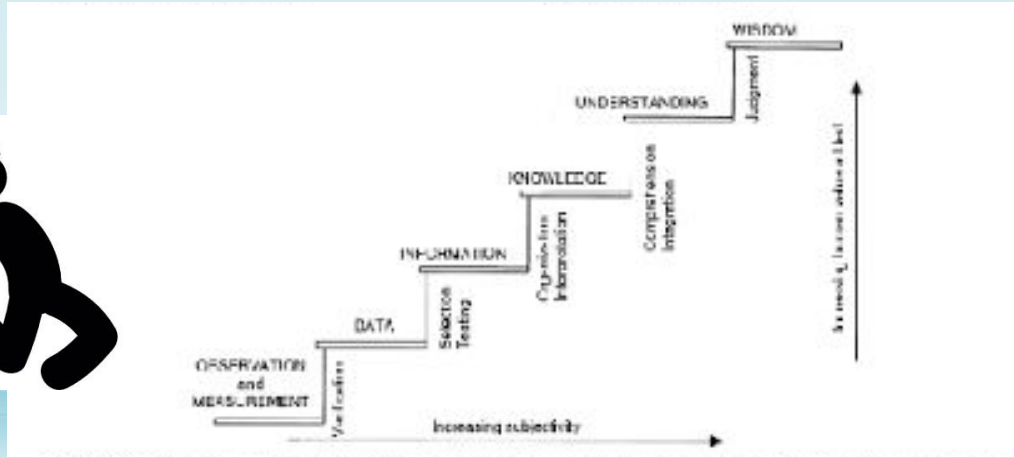
Coastal Plain counties where estimates from USGS and NCDA&CS differ by more than 10 million gallons per day (approximately 15 cubic feet/s) (Isabel Hillman)



Future work

- Complete report and database this year
- Virginia – collaborate
- Potential pilot study- CCPCUA sub-watershed detailed water budget and water use study
- Ecological flow research in APNEP region – flow and stage effects on fish and macroinvertebrates, salinity aspects
- River groundwater interactions in CP- effects of climate change and withdrawals on low flows

DEQ, 2016



Artiola et al.