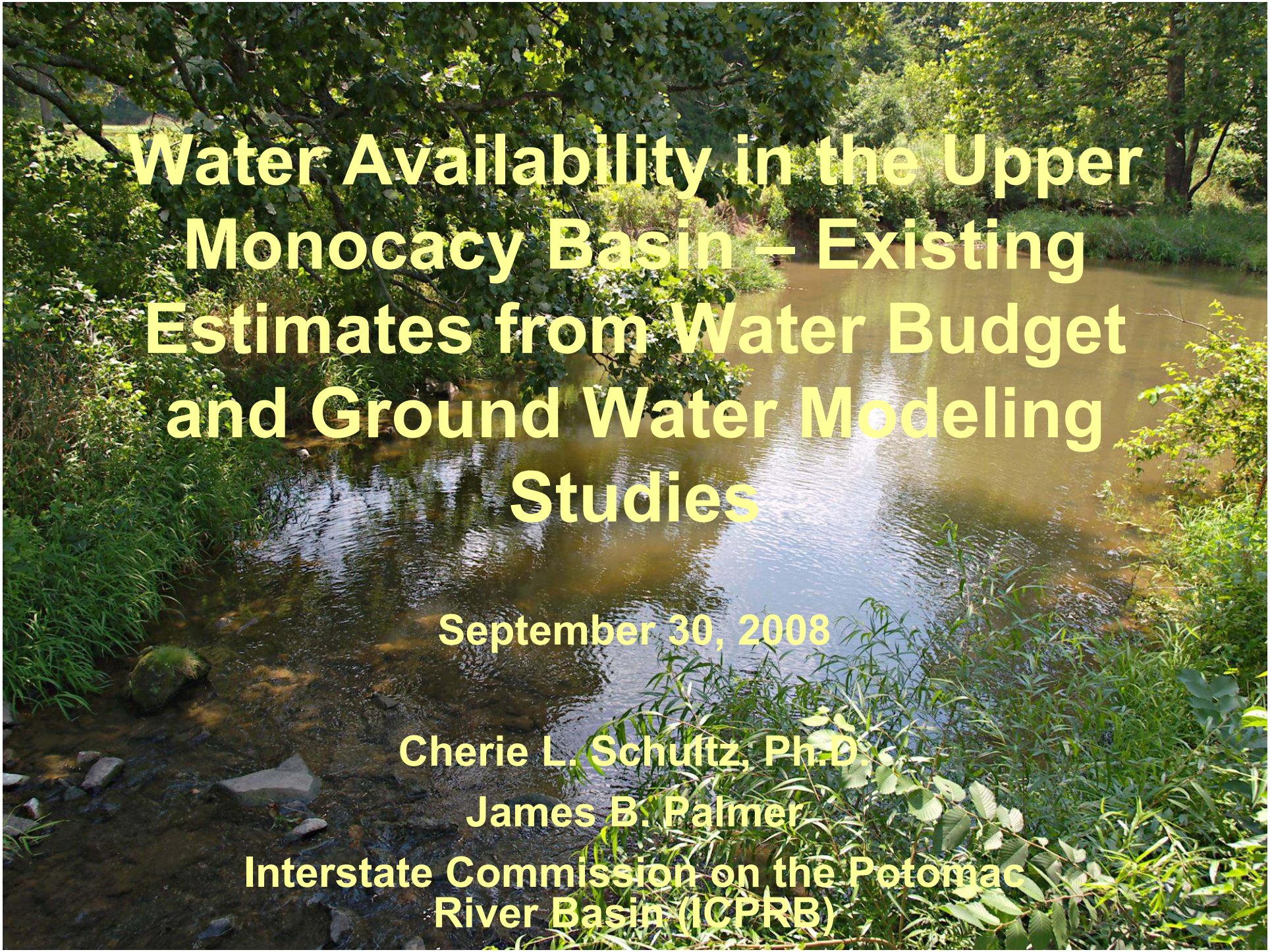


Water Availability in the Upper Monocacy Basin – Existing Estimates from Water Budget and Ground Water Modeling Studies

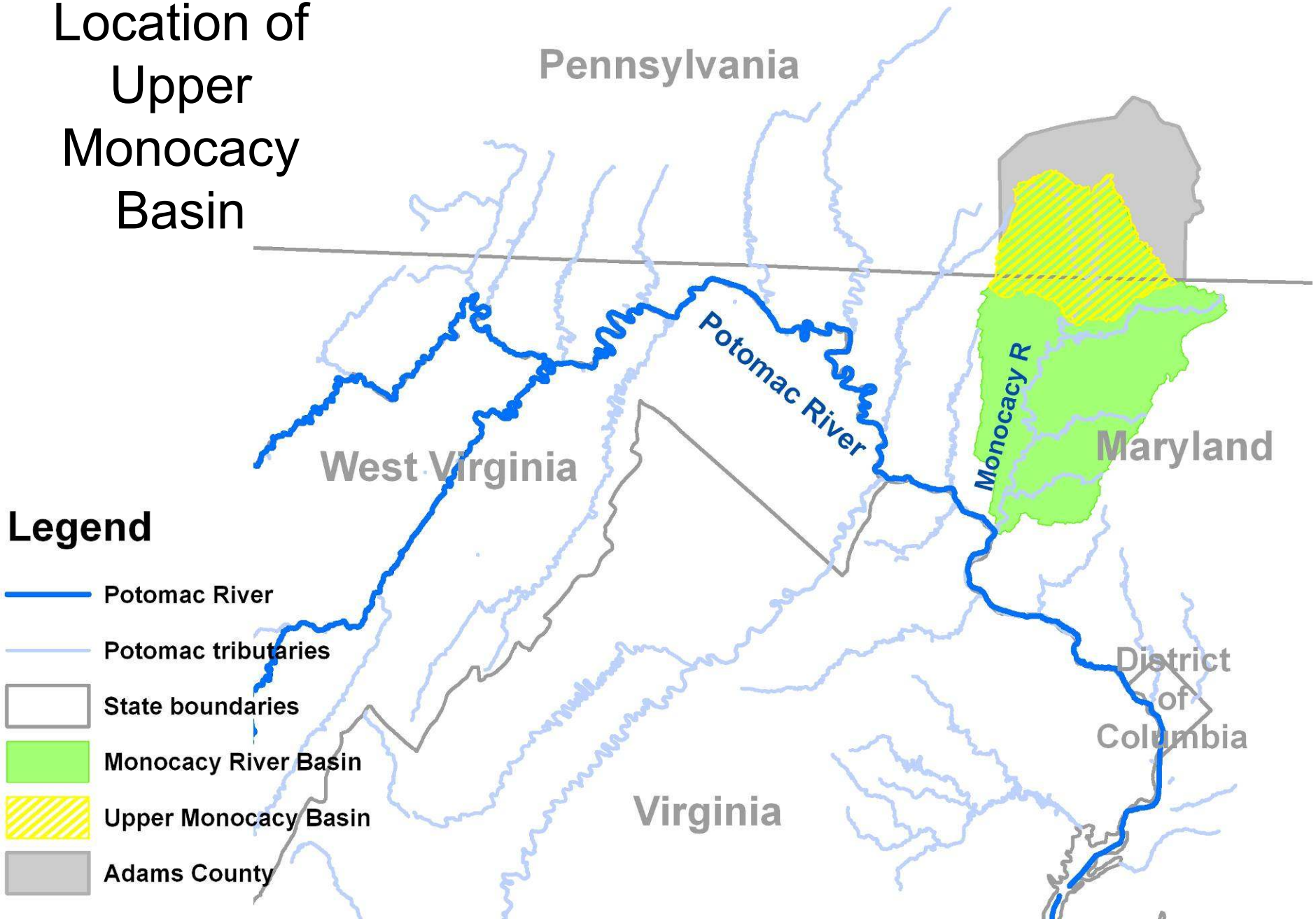
September 30, 2008

Cherie L. Schultz, Ph.D.

James B. Palmer

Interstate Commission on the Potomac River Basin (ICPRB)

Location of Upper Monocacy Basin



Water Availability: Considerations

- Spatial scale
- Interconnection between ground water and surface water resources
- Seasonal variations in water availability
- Importance of data

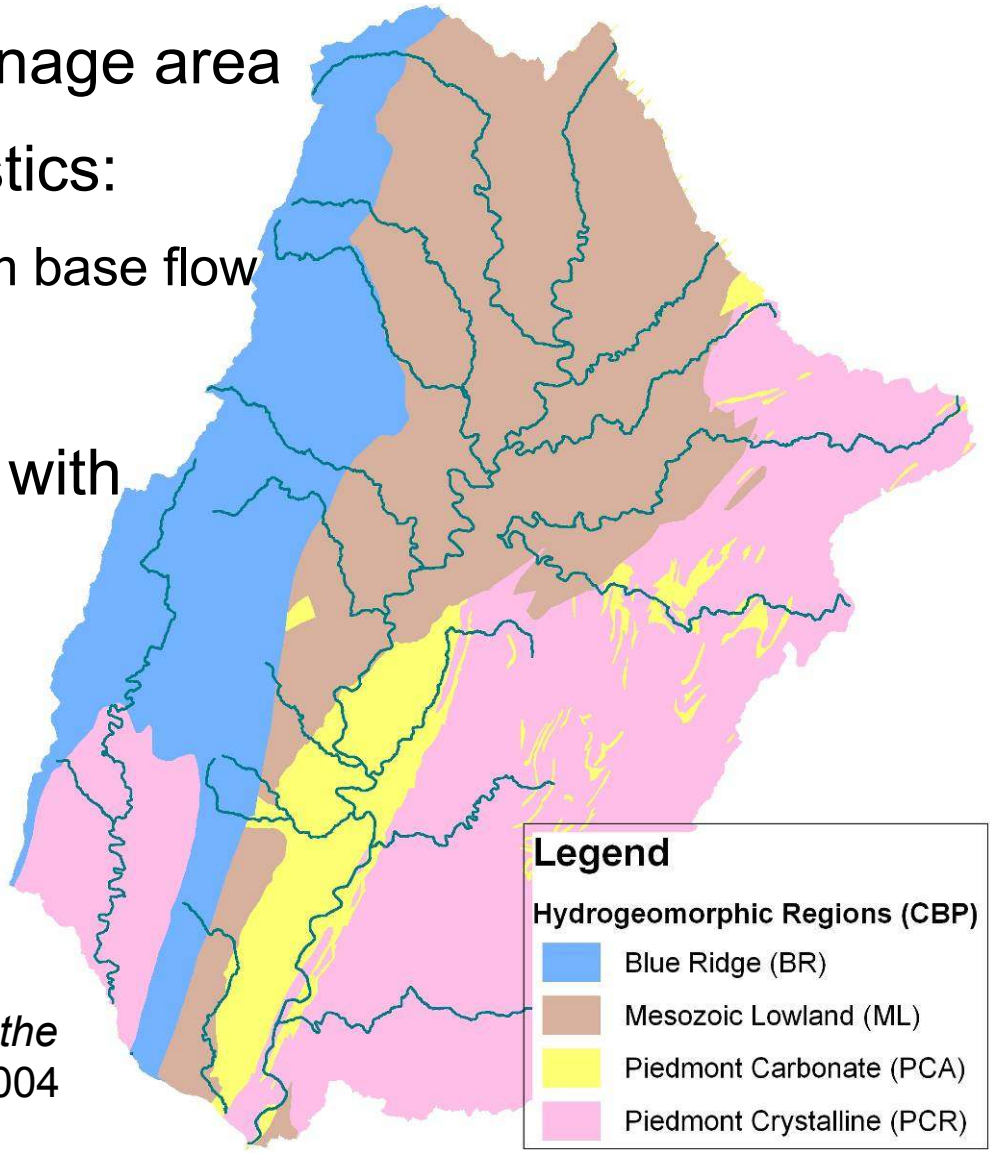
Water Availability Estimates from ICPRB

- Annual recharge estimates for the Monocacy River basin by hydrogeomorphic region
- Seasonal water availability estimates in 4 watersheds of the Monocacy basin using stream flow recession analyses
- Ground water/stream flow model of upper Monocacy basin, estimating of impact of ground water withdrawals on stream flow

Annual Recharge Estimates

- For Monocacy/Catoctin drainage area
- Uses annual baseflow statistics:

  annual recharge ~ annual stream base flow
- Data from 34 stream gages
- Spatial regression analysis, with explanatory variables:
  - Drainage area
  - % watershed in each of 4 hydrogeomorphic regions (Chesapeake Bay Program)

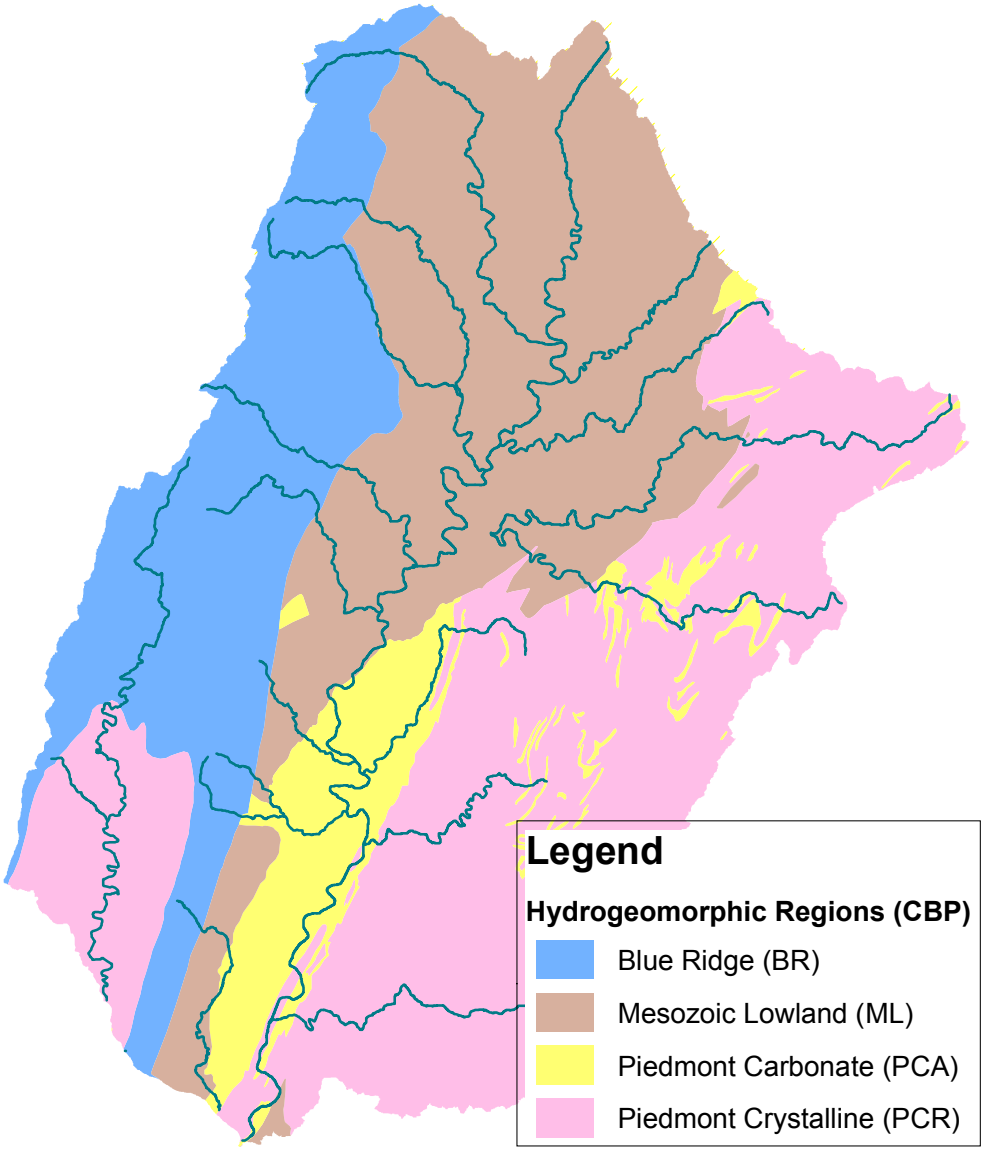


See *Annual and Seasonal Water Budgets for the Monocacy/Catoctin Drainage Area*, ICPRB, 2004

Annual Recharge Estimates

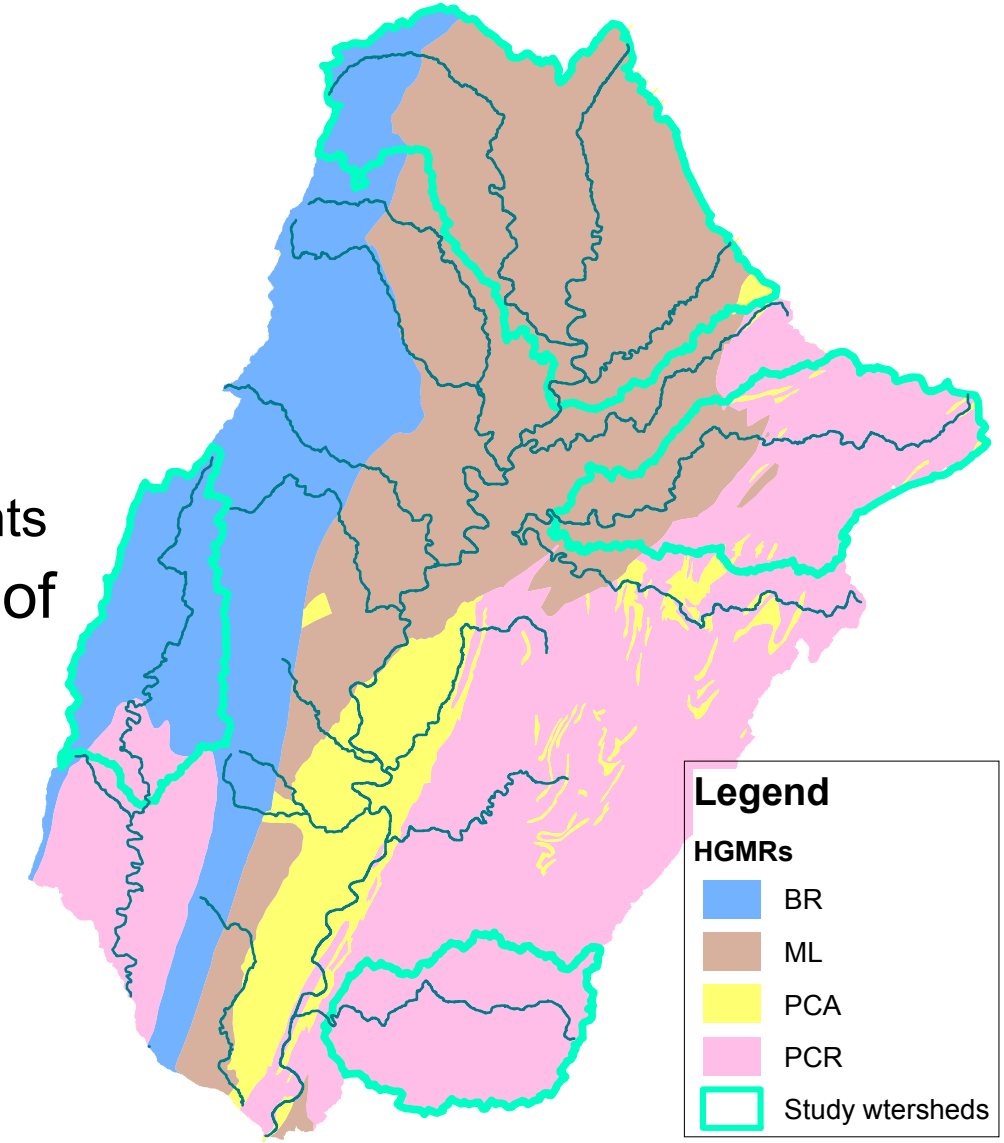
Annual recharge (inches/year)*

	Recurrence Interval		
	2-year	10-year	20-year
BR	12.2	7.8	6.8
ML	5.3	2.9	2.4
PCA	14	14	14
PCR	8.5	5.8	5.2



Seasonal Water Availability Estimates

- For 4 Monocacy/Catoctin watersheds
- Study period: 1960 - 2002
- Analyses based on:
  - Mean seasonal baseflow
  - Baseflow recession coefficients
- Results include time series of seasonal estimates for:
  - Base flow (BF)
  - Storm flow (SF)
  - Evapotranspiration (ET)
  - Net recharge (R)
  - Storage (S) (above zero-flow level)



Seasonal Water Availability Estimates

Long-term averages of estimated seasonal water budget components, Marsh/Rock/Alloway Creek watershed (inches per quarter)

	Precip	SF	BF	ET	R	ΔS	S
Q1 (J,F,M)	10	4.5	2.9	2.3	3.1	0.2	0.3
Q2 (A,M,J)	12	2.5	1.7	8.2	1.3	-0.4	0.5
Q3 (J,A,S)	11.5	1	0.4	10.1	0.4	0	0.1
Q4 (O,N,D)	9.9	2.2	1.2	6.2	1.5	0.2	0.1
Annual	43.4	10.3	6.2	26.8	6.3	0	

From *Annual and Seasonal Water Budgets for the Monocacy/Catoctin Drainage Area*, ICPRB, 2004

Seasonal Water Availability Estimates

Annual water budget

- Based on estimates of annual recharge
- Assumes no annual change in storage

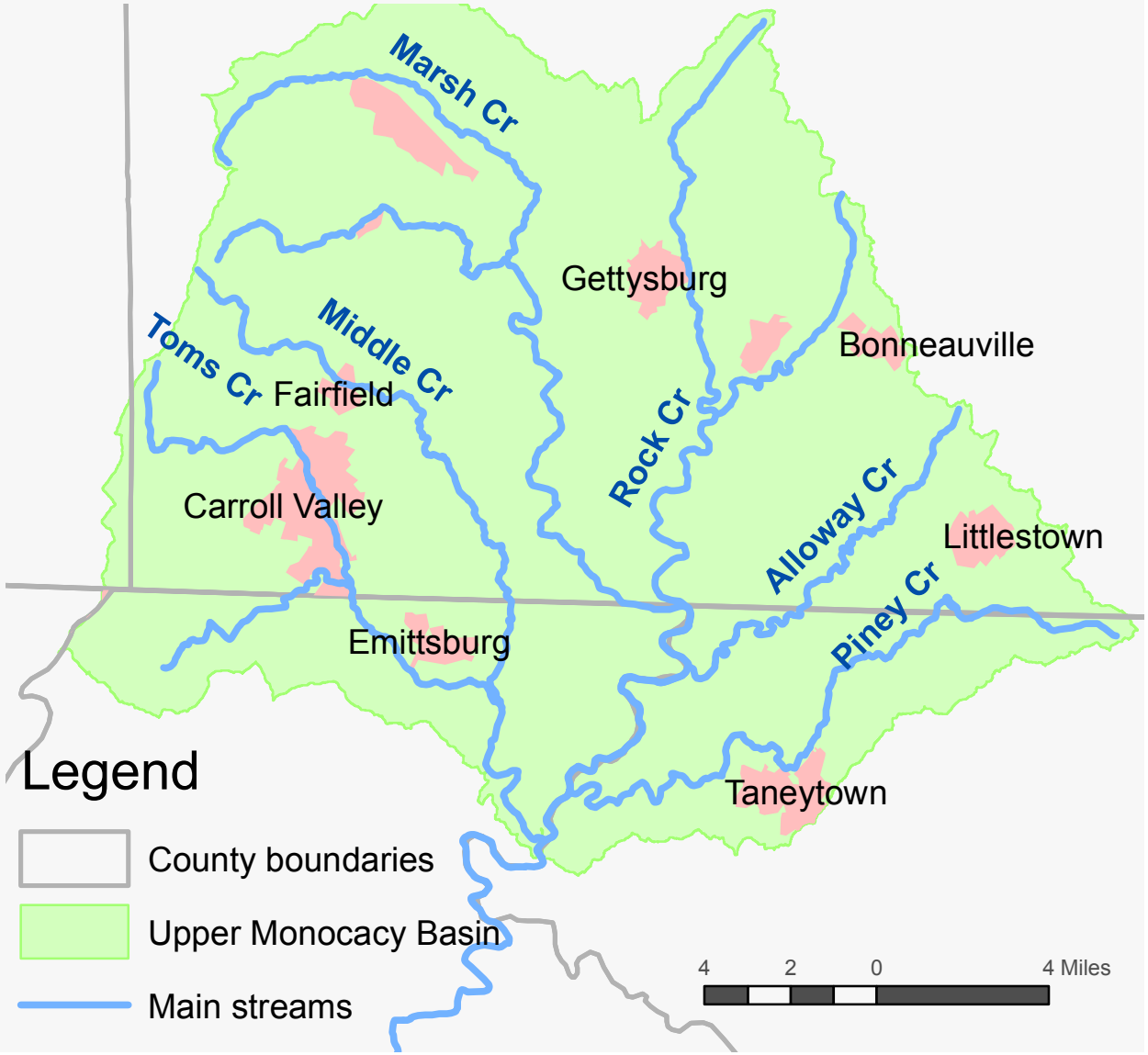
Seasonal water budget

- Based on estimates of recharge and recession
- Estimates seasonal changes in storage

Station	Annual Recharge (gpd/acre) 1 in 20 year	Seasonal Summer recharge + summer storage (gpd/acre) Median	1 in 10-year	1 in 20 year
Catoctin Creek (01637500)	350	210	65	60
Upper Monocacy (01639000)	230	120	42	30
Big Pipe Creek (01639500)	350	460	190	150
Bennett Creek (01643500)	390	420	220	160

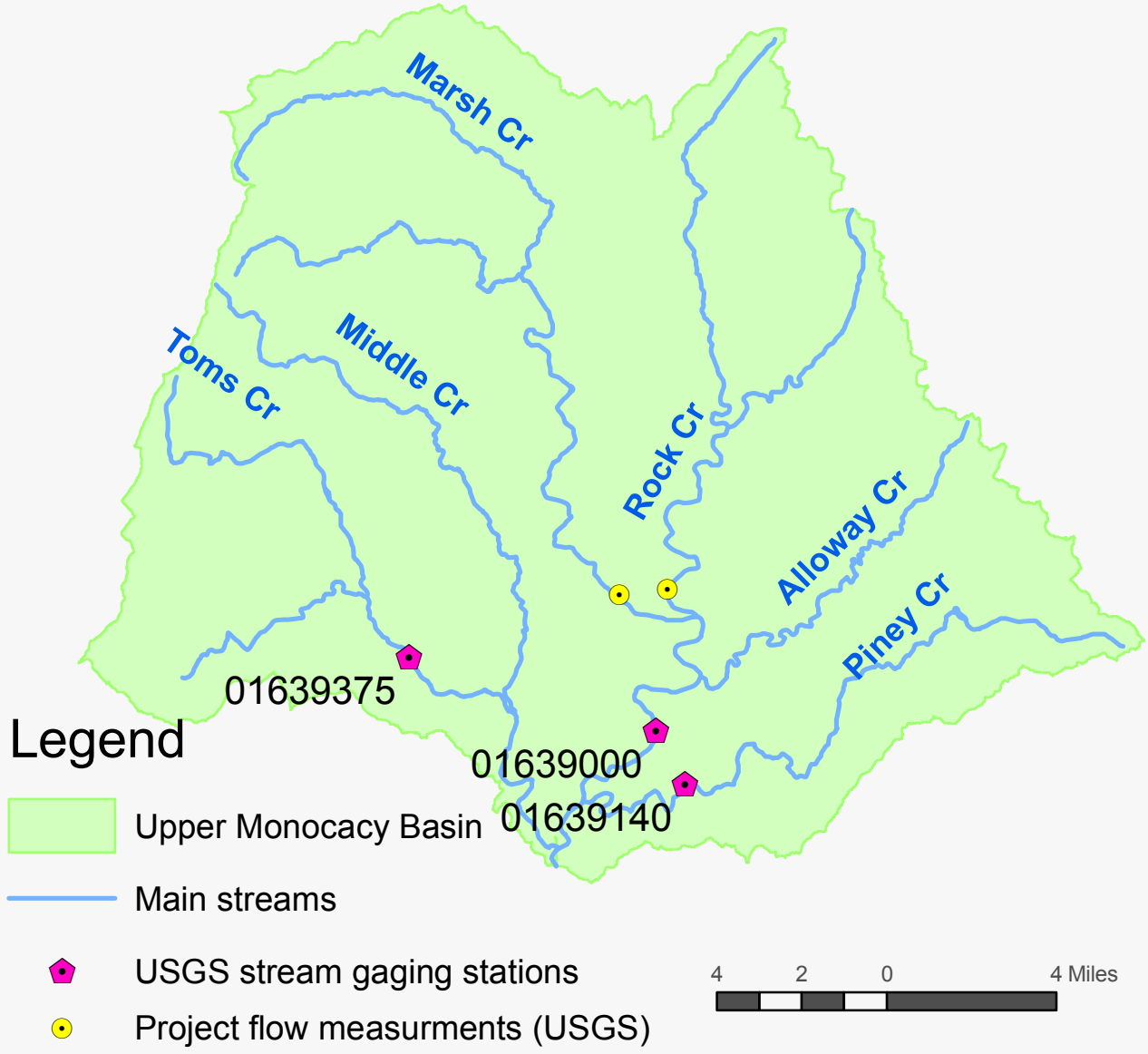
Upper Monocacy Basin
Ground Water/Stream Flow Model

- Objective: investigate impact of ground water withdrawals on summertime stream flow
- Scale: regional (309 mi^2)
- Study period: 1960 to 2002
- Funding: National Fish and Wildlife Foundation/ICPRB



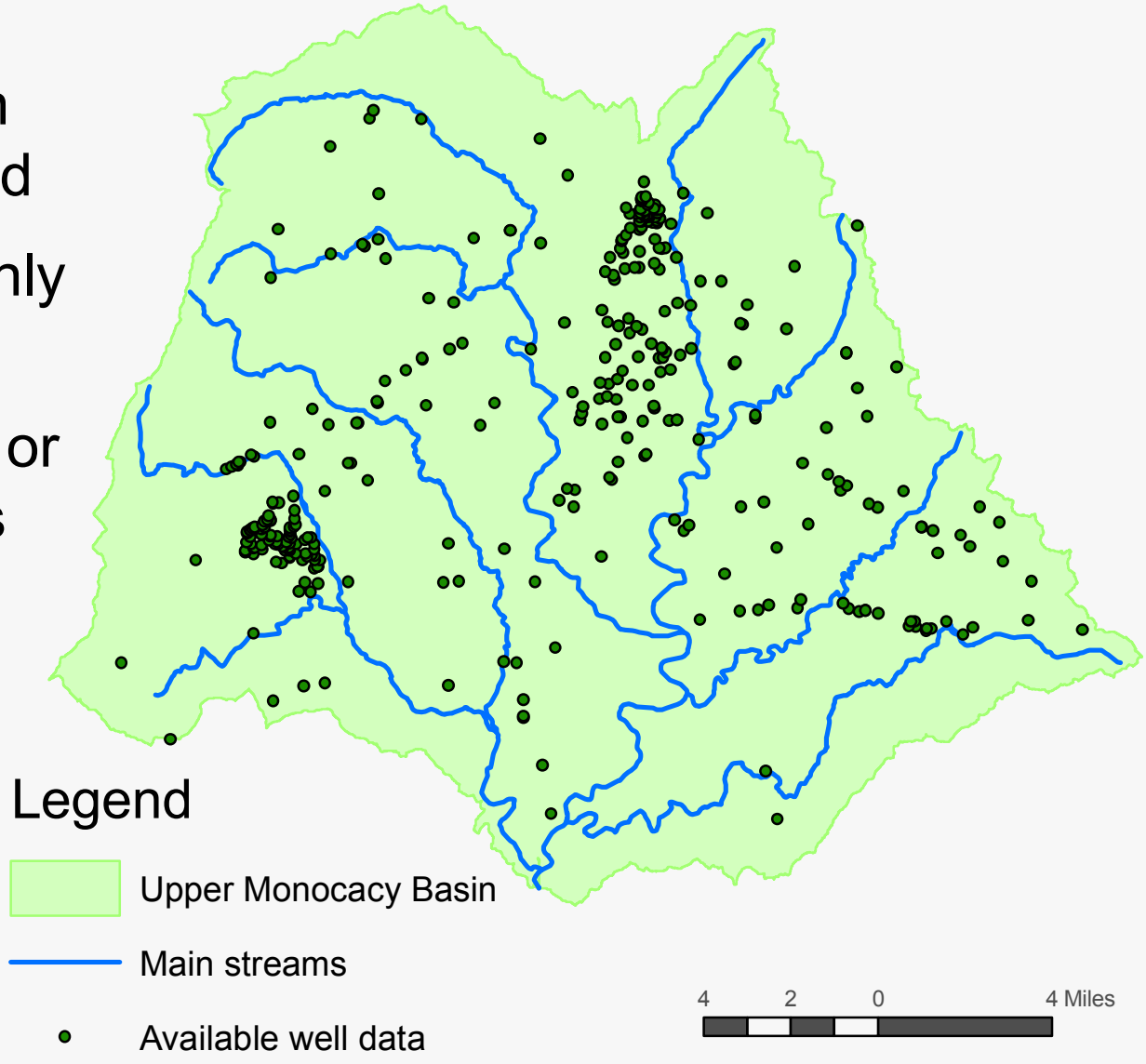
Available Stream Flow Data

- Daily flow data:
  - Monocacy R at Bridgeport, MD
  - Piney Cr near Taneytown, MD
  - Toms Cr at Emittsburg, MD
- Six flow measurements made for project on Marsh Cr & Rock Cr (USGS)



Available Well Data

- Data at 361 wells in 43-year study period
- 59% of wells had only 1 measurement
- 92% of wells had 3 or less measurements



Classification of Summertime Conditions

Condition	Summertimes	Mean summertime baseflow at 01639000 (cfs)
Dry	1962, 1963, 1964, 1965, 1986, 1988, 1991, 1997, 2001, 2002	3.6 to 6.6
Average-dry	1961, 1966, 1974, 1977, 1980, 1983, 1998, 1999	7.1 to 9.7
Average	1968, 1969, 1971, 1976, 1981, 1982, 1985, 1987	11.2 to 16.3
Average-wet	1960, 1967, 1973, 1978, 1990, 1992, 1993, 1994	17.3 to 21.9
Wet	1970, 1972, 1975, 1979, 1984, 1989, 1995, 1996, 2000	27.0 to 92.8

Classification of Summertime Conditions

Condition	Summertimes	Mean summertime baseflow at 01639000 (cfs)
Dry	1962, 1963, 1964, 1965, 1986, 1988, 1991, 1997, 2001, 2002	3.6 to 6.6
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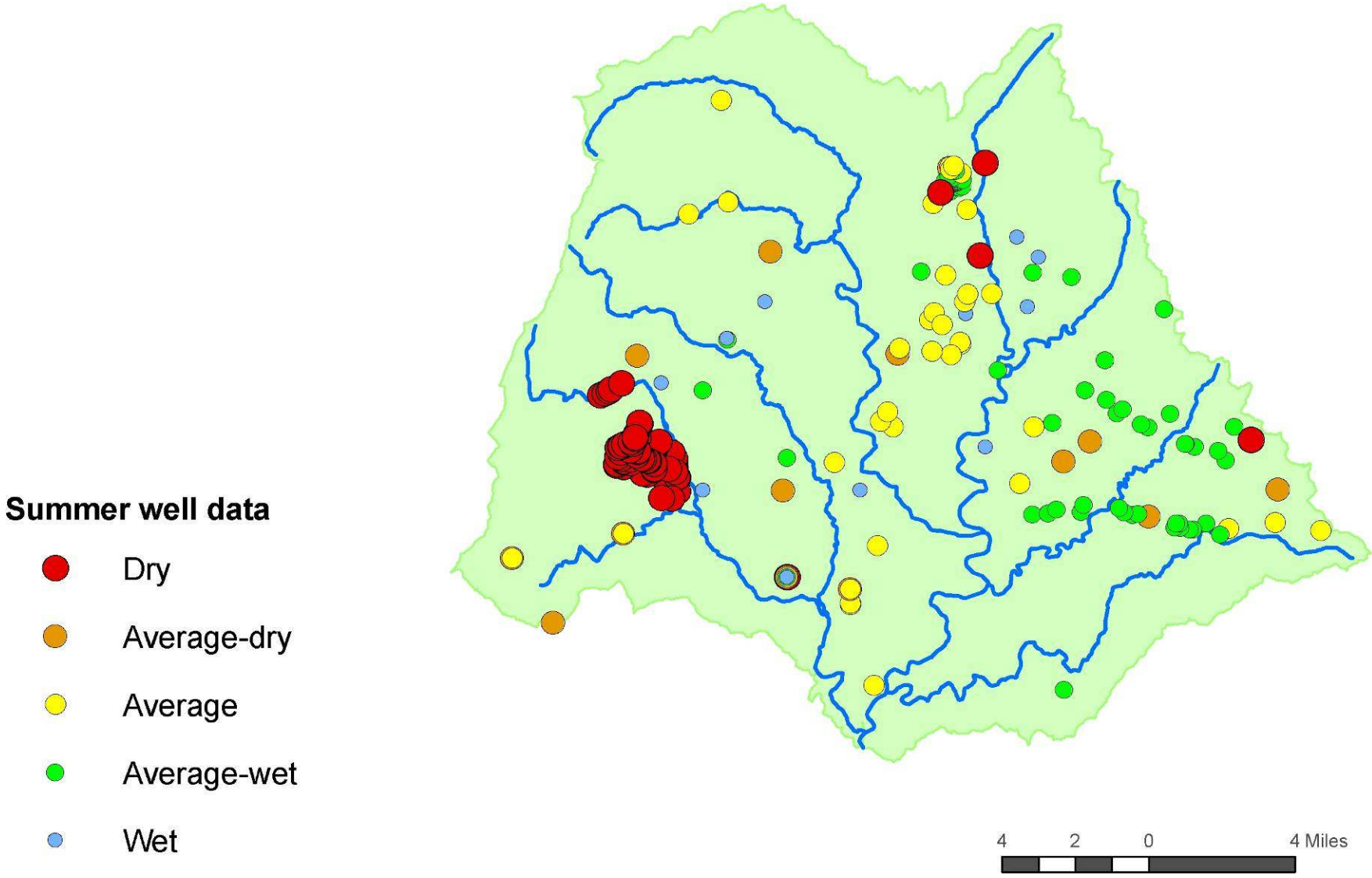
Average	1968, 1969, 1971, 1976, 1981, 1982, 1985, 1987	11.2 to 16.3
Average-wet	1960, 1967, 1973, 1978, 1990, 1992, 1993, 1994	17.3 to 21.9
Wet	1970, 1972, 1975, 1979, 1984, 1989, 1995, 1996, 2000	27.0 to 92.8

calibration

Classification of Summertime Conditions

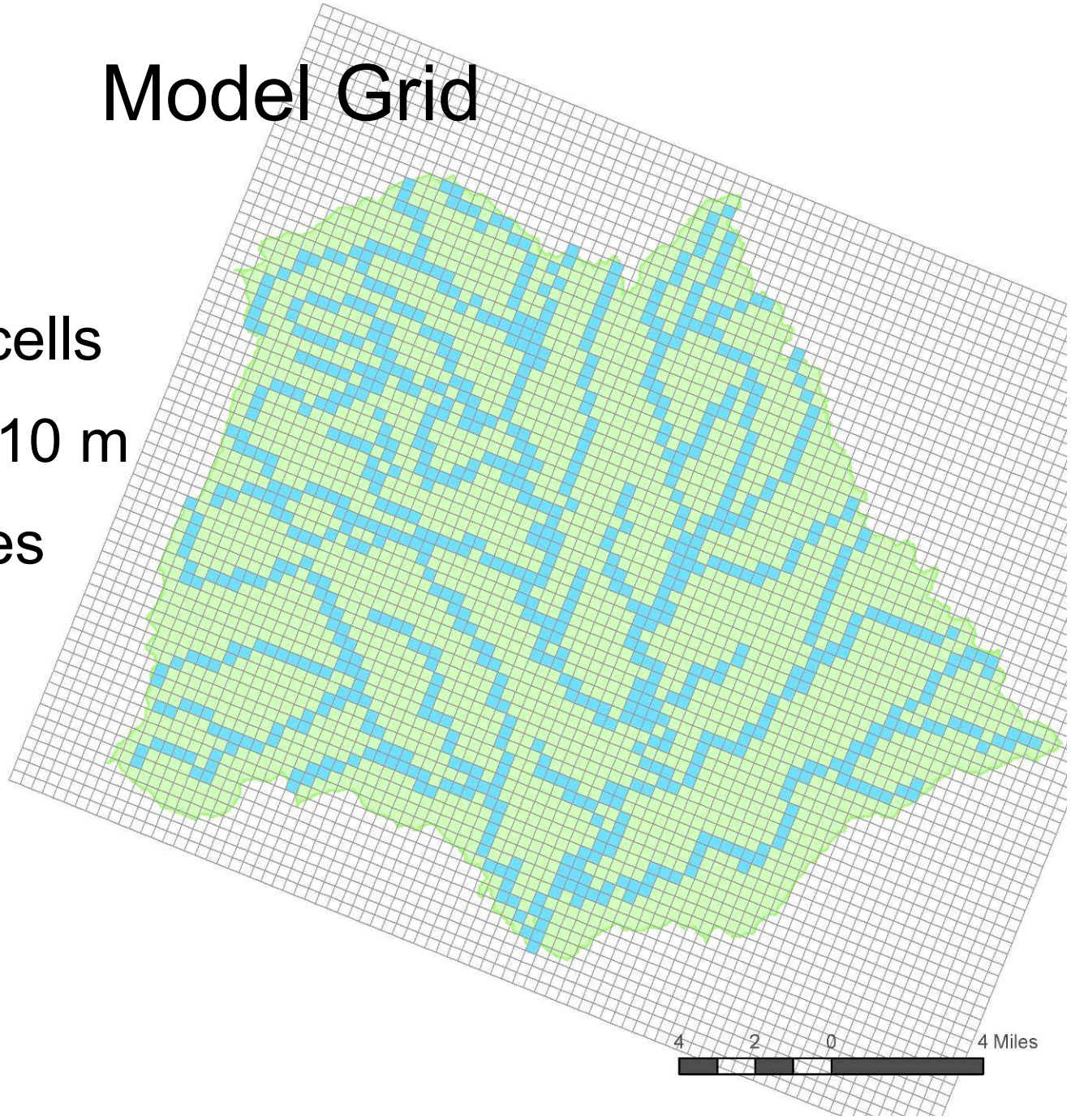
Condition	Summertimes	Mean summertime baseflow at 01639000 (cfs)	
Dry	1962, 1963, 1964, 1965, 1986, 1988, 1991, 1997, 2001, 2002	3.6 to 6.6	verification
Average-dry	1961, 1966, 1974, 1977, 1980, 1983, 1998, 1999	7.1 to 9.7	verification
Average	1968, 1969, 1971, 1976, 1981, 1982, 1985, 1987	11.2 to 16.3	
Average-wet	1960, 1967, 1973, 1978, 1990, 1992, 1993, 1994	17.3 to 21.9	verification
Wet	1970, 1972, 1975, 1979, 1984, 1989, 1995, 1996, 2000	27.0 to 92.8	verification

Available summertime well data by hydrologic condition

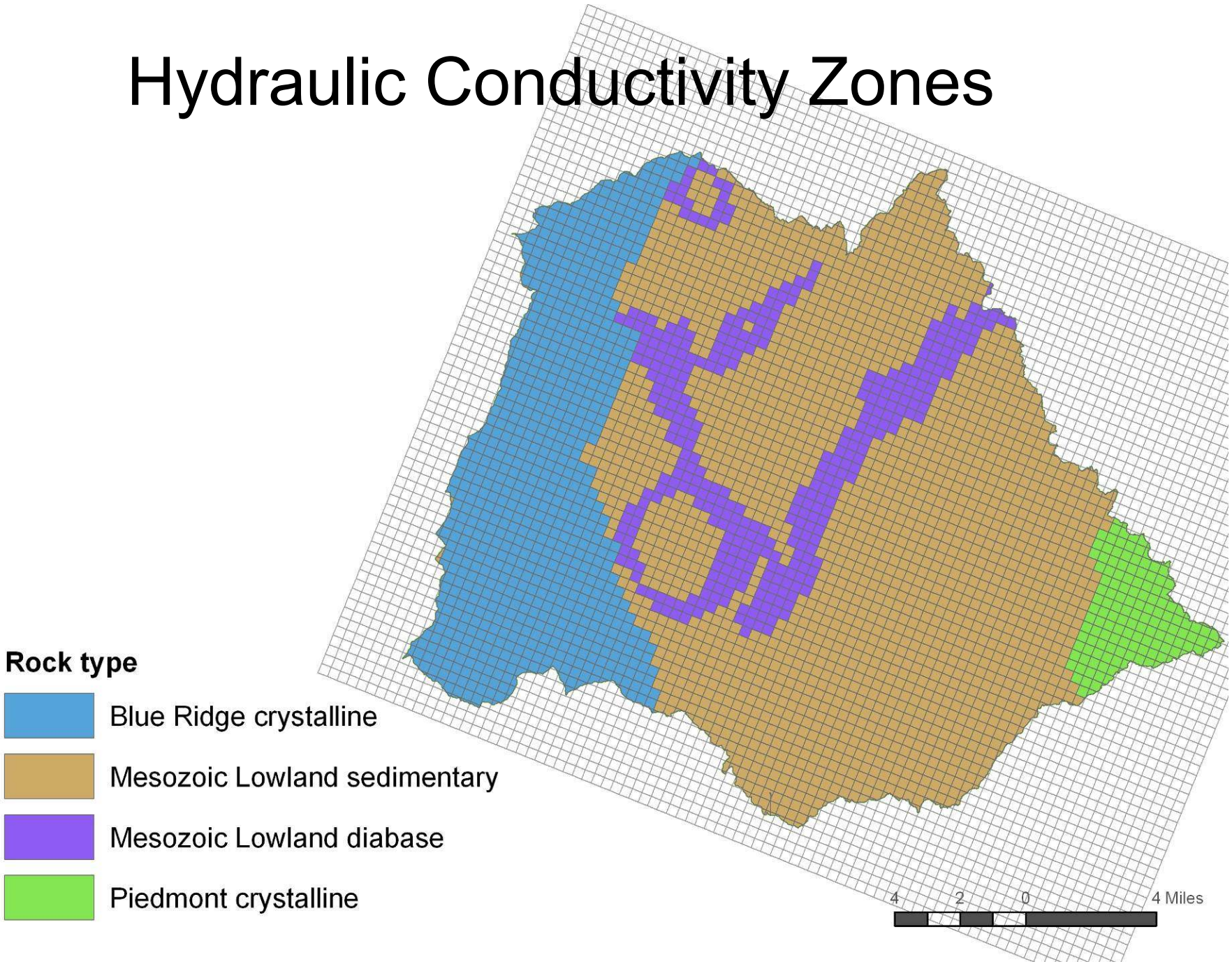


Model Grid

- 500 m x 500 m horizontal grid cells
- 10 layers each 10 m
- 271 stream miles

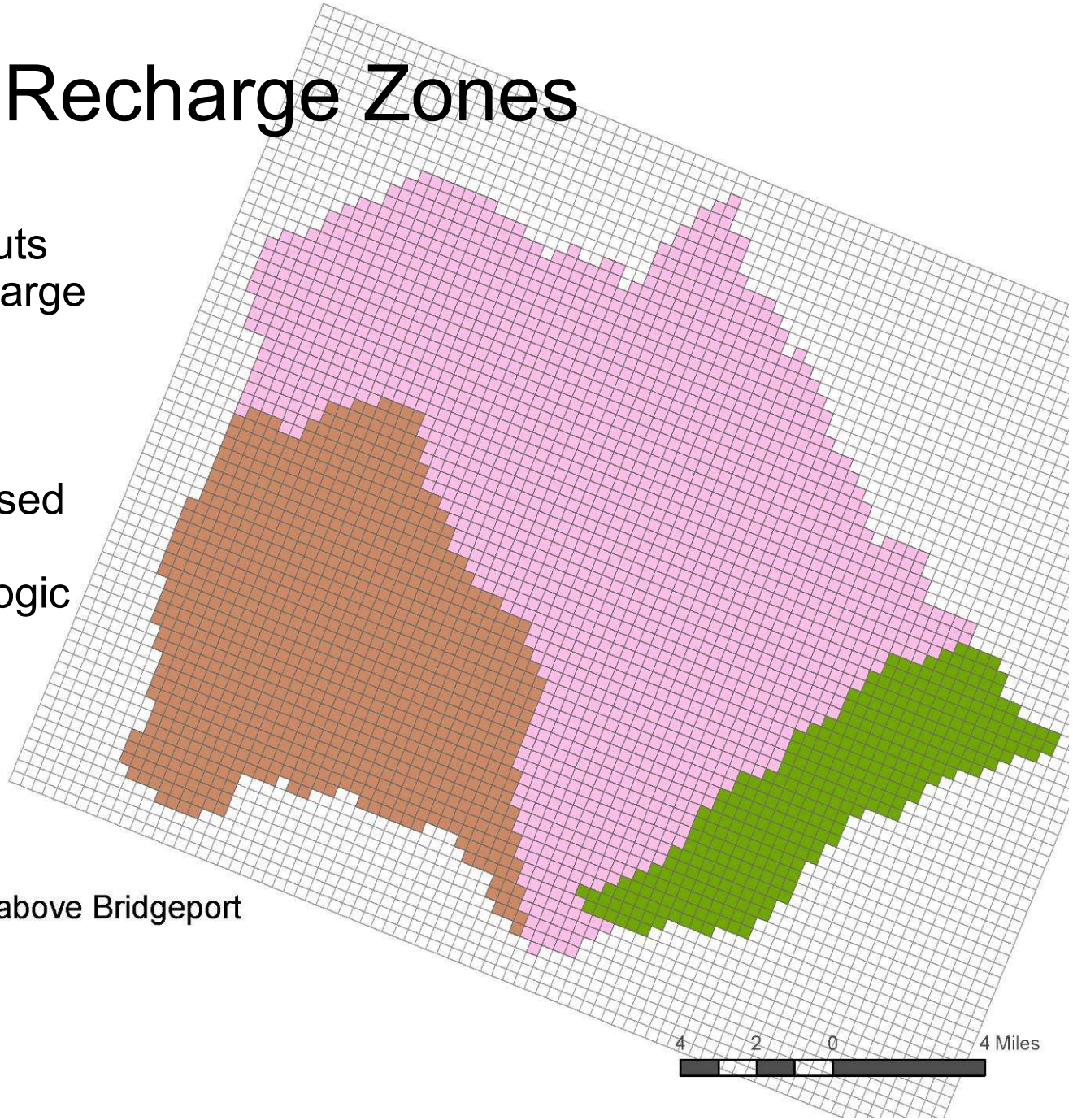


Hydraulic Conductivity Zones

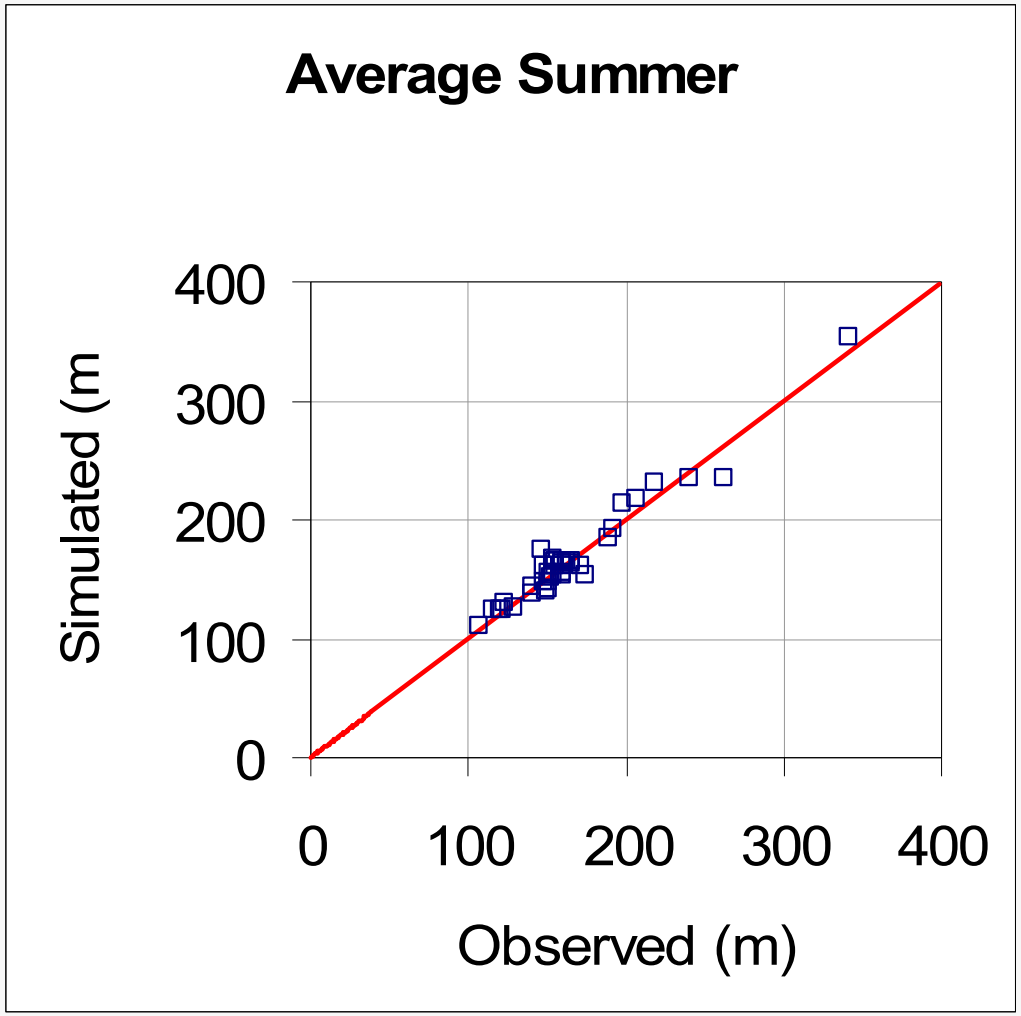


Recharge Zones

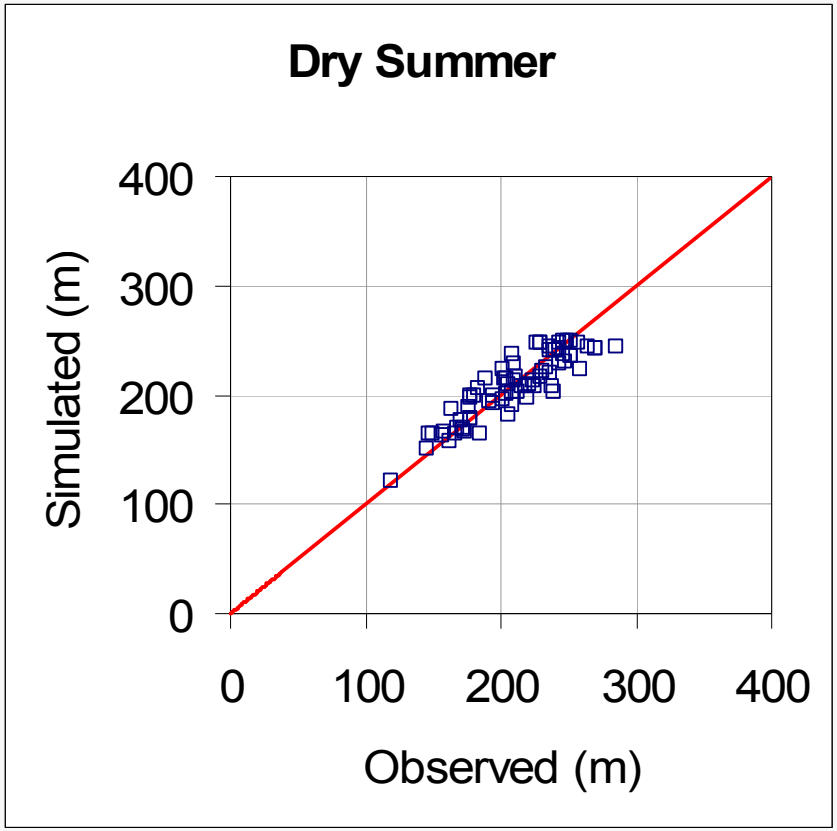
- Model recharge inputs represent “net” recharge - include impact of ground water withdrawals
- Recharge inputs based on means summer baseflow, by hydrologic condition

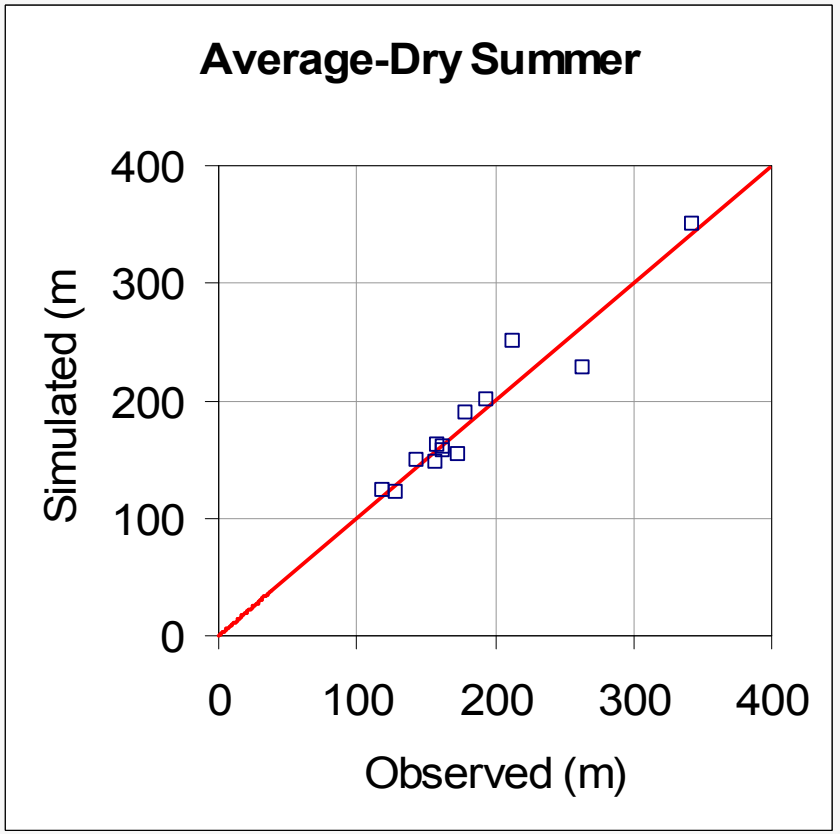


Model Aquifer Level Predictions - Calibration

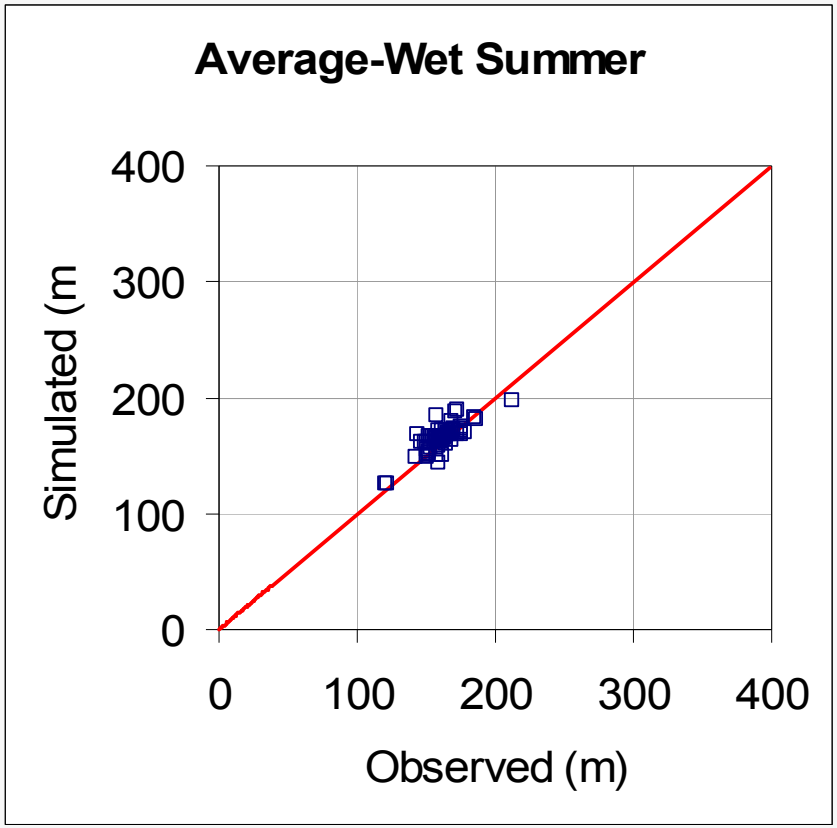


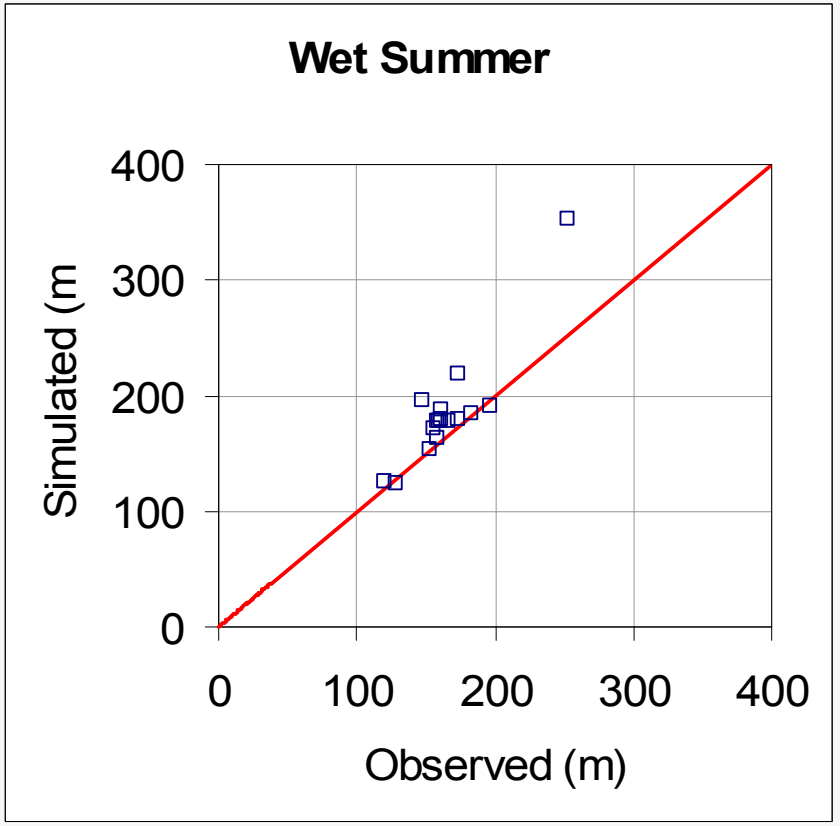
Model Aquifer Level Predictions - Verification



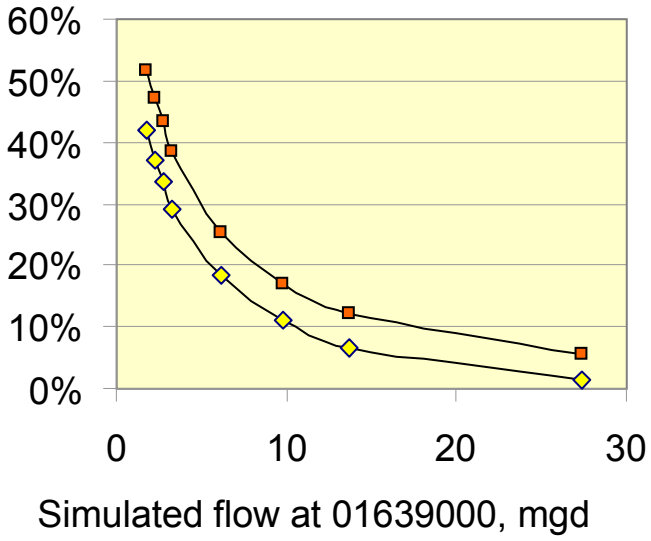


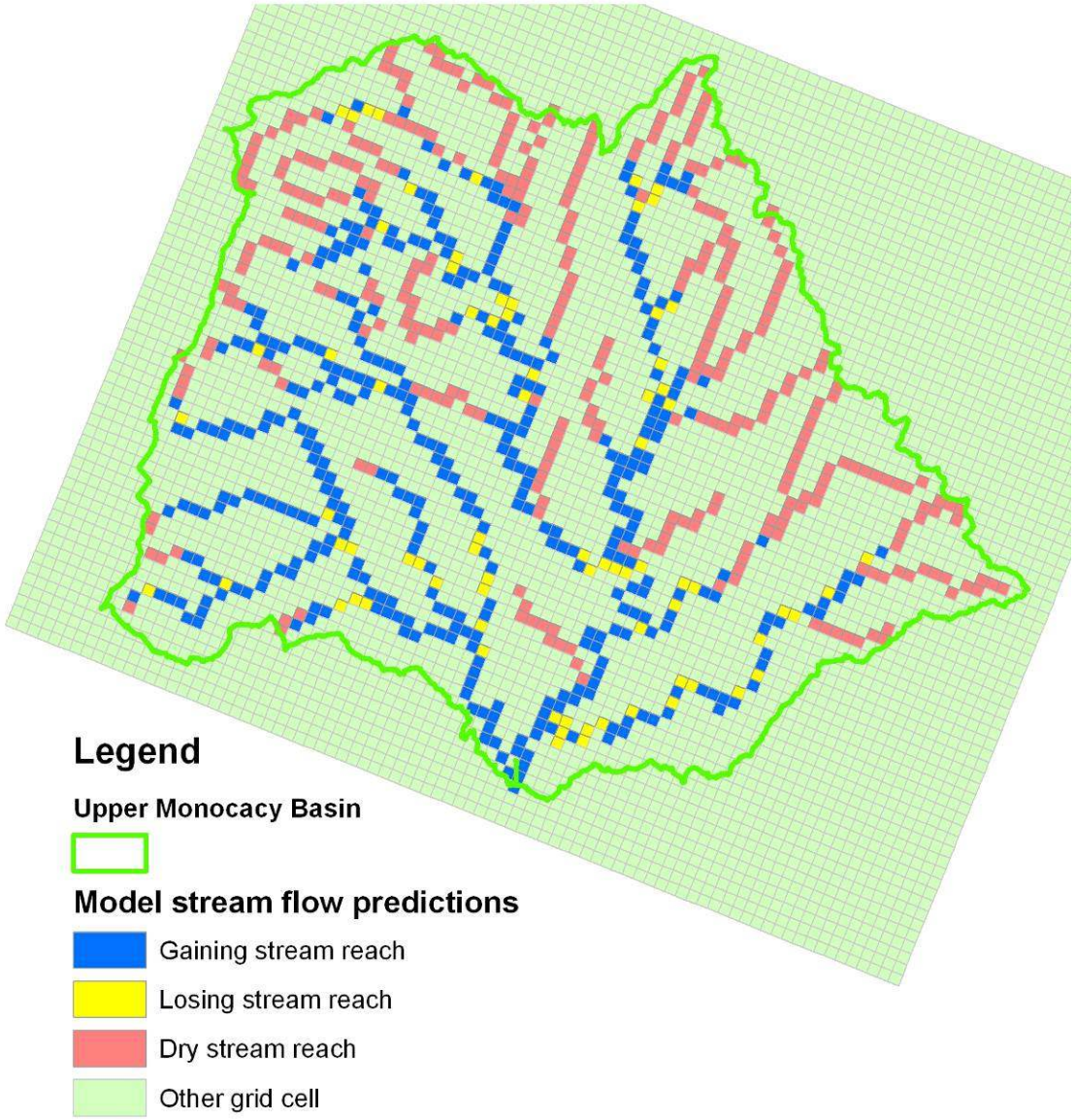
Model Aquifer Level Predictions - Verification





Model Predictions of Dry & Losing Stream Reaches





Upper Monocacy Ground Water/Stream Flow Model – Conclusions

- Model limitations:
  - Regional model, so predictions not likely reliable at local scale
  - Ground water withdrawals simulated as uniform reduction in net recharge
  - Needs further verification – with stream observations
- Model capabilities:
  - Fairly good simulation of typical summertime aquifer levels
  - Indicates that additional ground water withdrawals of ~ several mgd will likely have significant impact on basin streams