WSGS Statewide Groundwater Recharge Study

Wyoming State Geological Survey (WSGS)

Laramie, Wyoming

Karl Taboga, PG

Purpose

- Provide preliminary estimates of areal (from precipitation and snowmelt) groundwater recharge in Wyoming using an empirical model and geospatial analysis
- Model inputs should consist of readily available environmental data
- Results will be evaluated by comparing recharge estimates from the new model to estimates obtained from other existing models in selected areas.

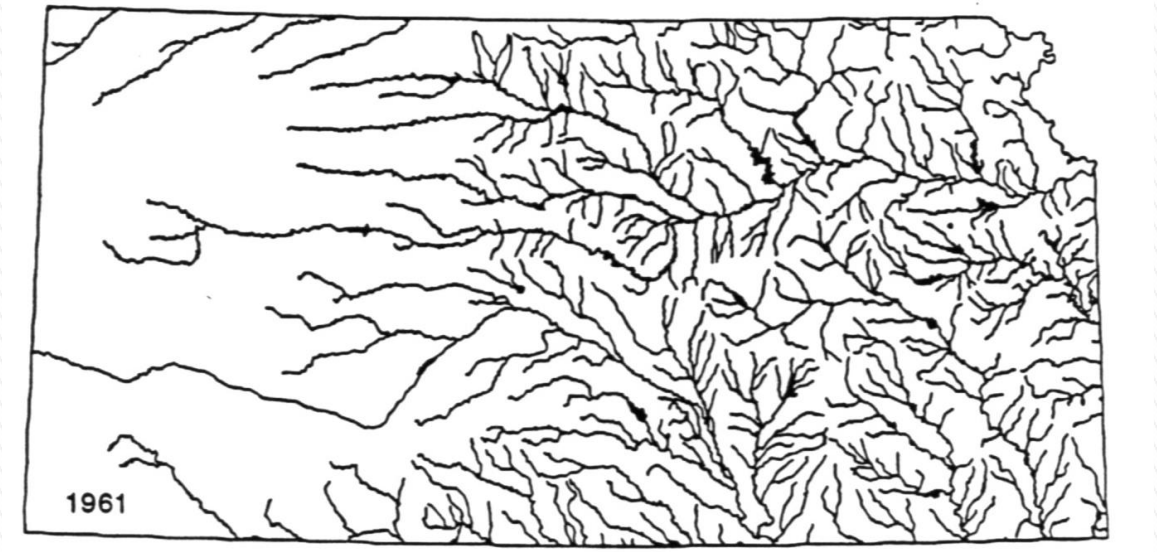
Previous Wyoming Recharge Models

- Statewide: Hamerlinck and Arneson (1998) – a GIS based DRASTIC model (U.S. EPA) that used average annual precipitation rates and U.S. Soil Conservation Service (SCS) soil infiltration rates

- Structural basins:
  - PRB – Long et al, 2014 –Soil Water Balance (SWB) Model
  - Denver Basin – Bartos et al, 2014 – GW fluctuation method; Stanton et al, 2011- SWB and SOWAT models;

Recharge – Baseflow component

- Baseflow – recharge that discharges to streams, springs, lakes, wetlands and seeps.
  - Has been interpreted to equal recharge (Arnold et al., 1995; Szilagyi et al., 2003; Green et al., 2012)
  - Represents the primary link between surface and groundwater, the two components of a single resource system
  - Receiving increased attention from water scientists (Barlow and Leake, 2012) and water law specialists (Platte River Basin decision and the recent Montana v. Wyoming litigation in the PRB)



Perennial streams in Kansas

1961 and 1994

(Angelo, 1994)

Baseflow modeling

Precipitation (P) + water inflow (Q_{in}) = evapotranspiration (ET) + water outflows (Q_{out}) + changes in water storage (ΔS)

- Precipitation from the PRISM Climate Group at OSU
- Water inflows - groundwater and surface water inflows
- Evapotranspiration is estimated from a WSGS ET model
- Outflows - streamflows and GW outflows from the basin
  - Streamflow = baseflow + overland flows (Data from USGS stream gaging stations)

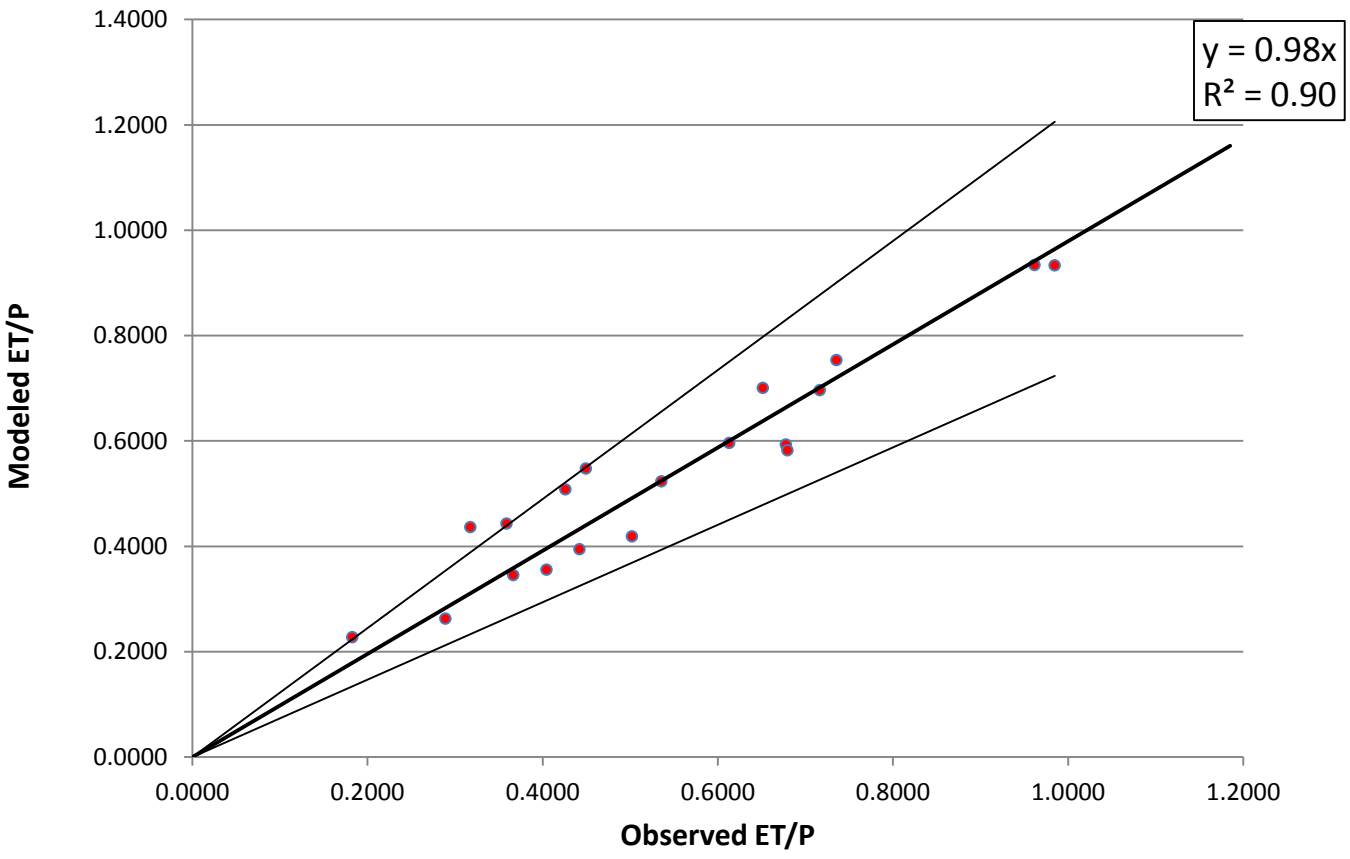
- Precipitation (P) = ET + streamflows (baseflow + overland flows)

WSGS ET Model

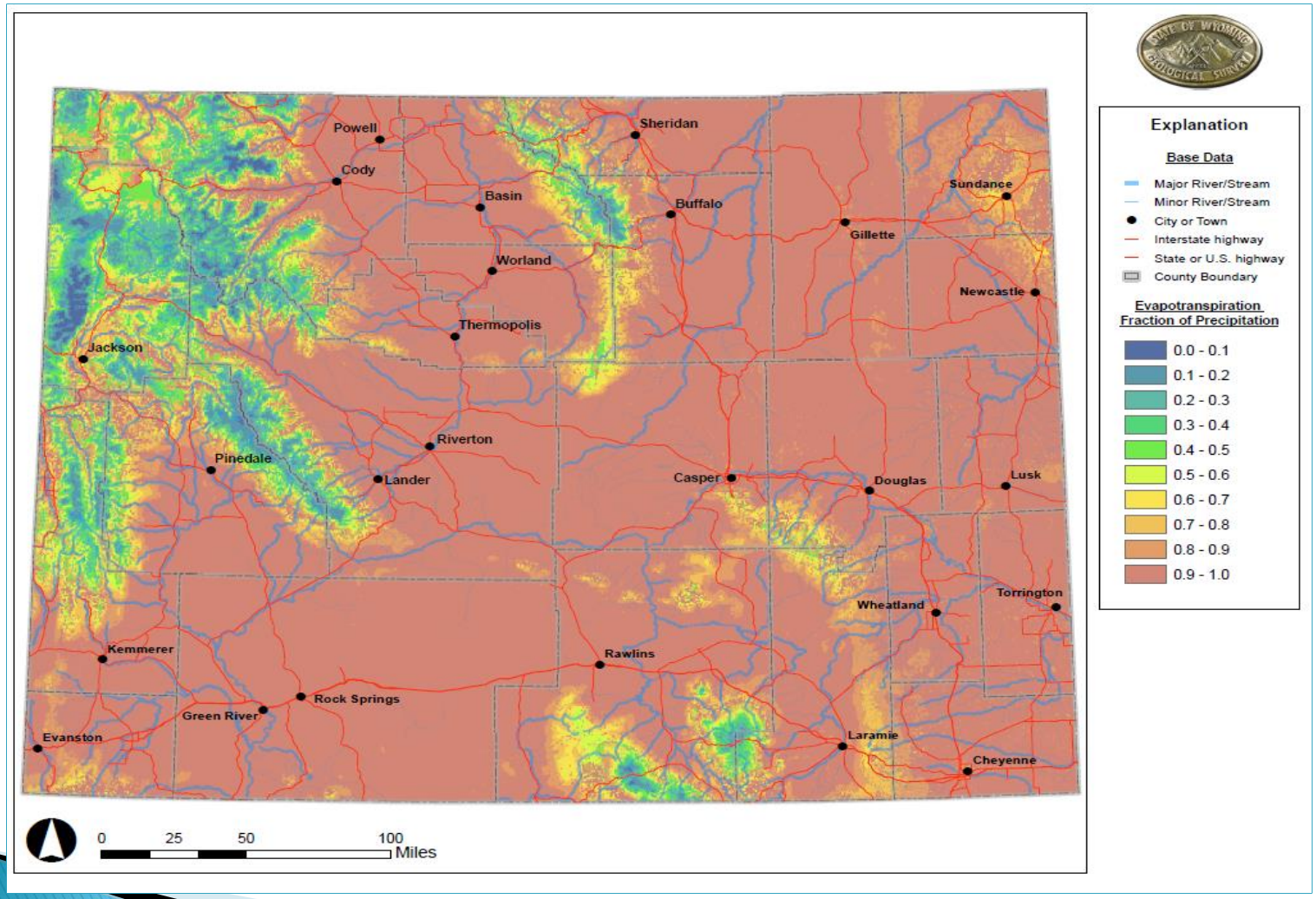
P = ET + streamflows (aka runoff)

- Based on an empirical formula developed by Sanford and Selnick (2013) for the contiguous United States
- WSGS used 19 unregulated Wyoming drainage basins to generate model coefficients
- Inputs consisted of landcover type, precipitation and air temperature data

WSGS ET Model Results



WSGS ET Map


Powell
Sheridan
Cody
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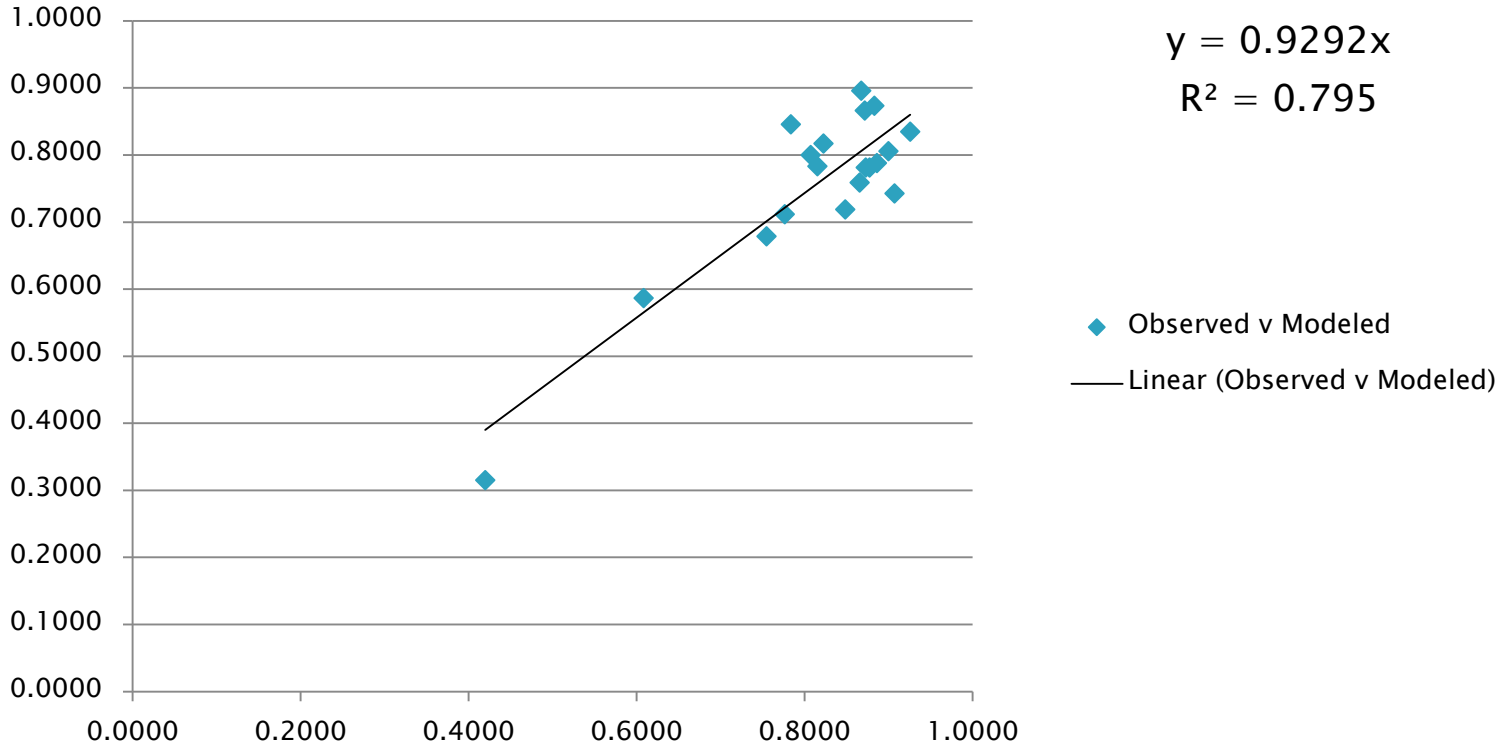
Buffalo
Sundance
Gillette
Worland
Newcastle
Thermopolis
Jackson
Riverton
Pinedale
Lander
Casper
Douglas
Lusk
Torrington
Wheatland
Kemmerer
Rawlins
Rock Springs
Green River
Evanston
Laramie
Cheyenne
0 25 50 100 Miles
Explanation
Base Data
Major River/Stream
Minor River/Stream
City or Town
Interstate highway
State or U.S. highway
County Boundary
Evapotranspiration Fraction of Precipitation
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0

WSGS Recharge/Baseflow Model

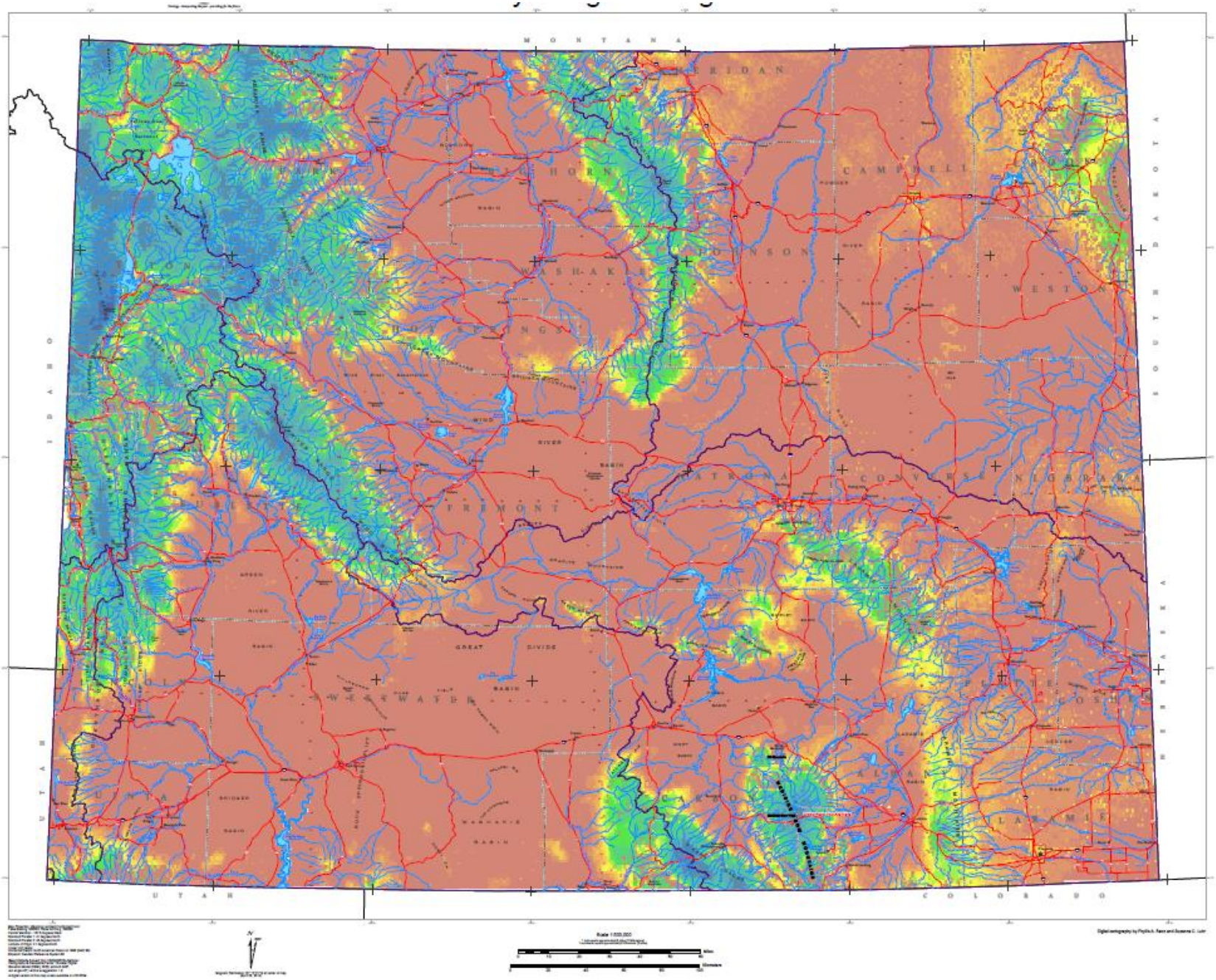
$$P = ET + runoff$$

- WSGS developed a nonlinear formula to estimate baseflows in 19 unregulated Wyoming drainage basins using runoff, land surface slope and soil permeability data
- Model coefficients were optimized with a non-linear optimization algorithm
- Results were evaluated by comparing modeled baseflows in the 19 watersheds to baseflows calculated from the USGS groundwater toolbox http://water.usgs.gov/ogw/gwtoolbox/

Observed v Modeled Baseflow



$$Baseflow/Runoff = 0.485\ (RO^{4.069}\ (M^{2.751} + 0.013)\ P^{0.01})^{0.0253}$$


MONTANA
SHERIDAN
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CAMPBELL
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WESTON
WASHAKIE
BIG HORN
IDAHO
FREMONT
NATRONA
CONVERSE
NIOBRARA
GREAT DIVIDE
BASIN
SWEETWATER
PLATTE
ALBANY
CARBON
LARAMIE
UTAH
COLORADO
SOUTH DAKOTA

How does the WSGS model compare?

- To streamflows from Wyoming's major river basins and Hamerlinck and Arneson (1998)?

Basin Name	Outflows[1]	Inflows[1]	Streamflow Depletions[2]	Net Annual Outflows[3]	WSGS Recharge	H&A Recharge[4]
Bear	348,604	185,241	101,370	264,733	254,257	201,880
Green/Great Divide/Little Snake	1,841,836	442,131	636,348	2,036,054	1,907,840	2,129,986
North Platte/South Platte	1,428,394	509,649	829,564	1,748,309	1,554,486	1,735,521
Powder/Tongue/NE Basins	851,299	3,332	312,233	1,160,200	851,360	1,271,844
Snake/ Salt/ Falls Rivers/ Teton Creek	5,216,626	43,901	202,965	5,375,690	4,505,935	2,942,359
Wind/Bighorn/Yellowstone/ Missouri Headwaters	6,369,781	408,154	1,365,402	7,327,029	5,867,476	5,661,326

[1] Stafford, and others (2009)

[2] WWC (2007); Meyers (1962)

[3] Outflows minus inflows and streamflow depletions

[4] Hamerlinck and Arneson (1998)

To USGS recharge models in Wyoming?

- Powder River Structural Basin

  Long et al. (2014) SWB model: 0.18 in/yr.

  WSGS model – 0.20 in/yr.

- High Plains Aquifer in Wyoming

  Stanton et al. (2011) SWB: 0.53 in/yr.;

  SOWAT 6.5 in/yr.

  WSGS model – 0.31 in/yr.

SWB / SOWAT - Soil Water Balance models

Conclusion

- The WSGS empirical recharge model appears to provide reasonable estimates of baseflow/recharge for the State of Wyoming.

Thank you

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