Groundwater-Surface Water Interactions in Henry's Fork basin

Presentation to Eastern Snake Hydrologic Modeling Committee
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THE VOICE OF THE RIVER
SINCE 1984
HENRY'S FORK
FOUNDATION

100
FOUNDED 1913

HUMBOLDT STATE UNIVERSITY

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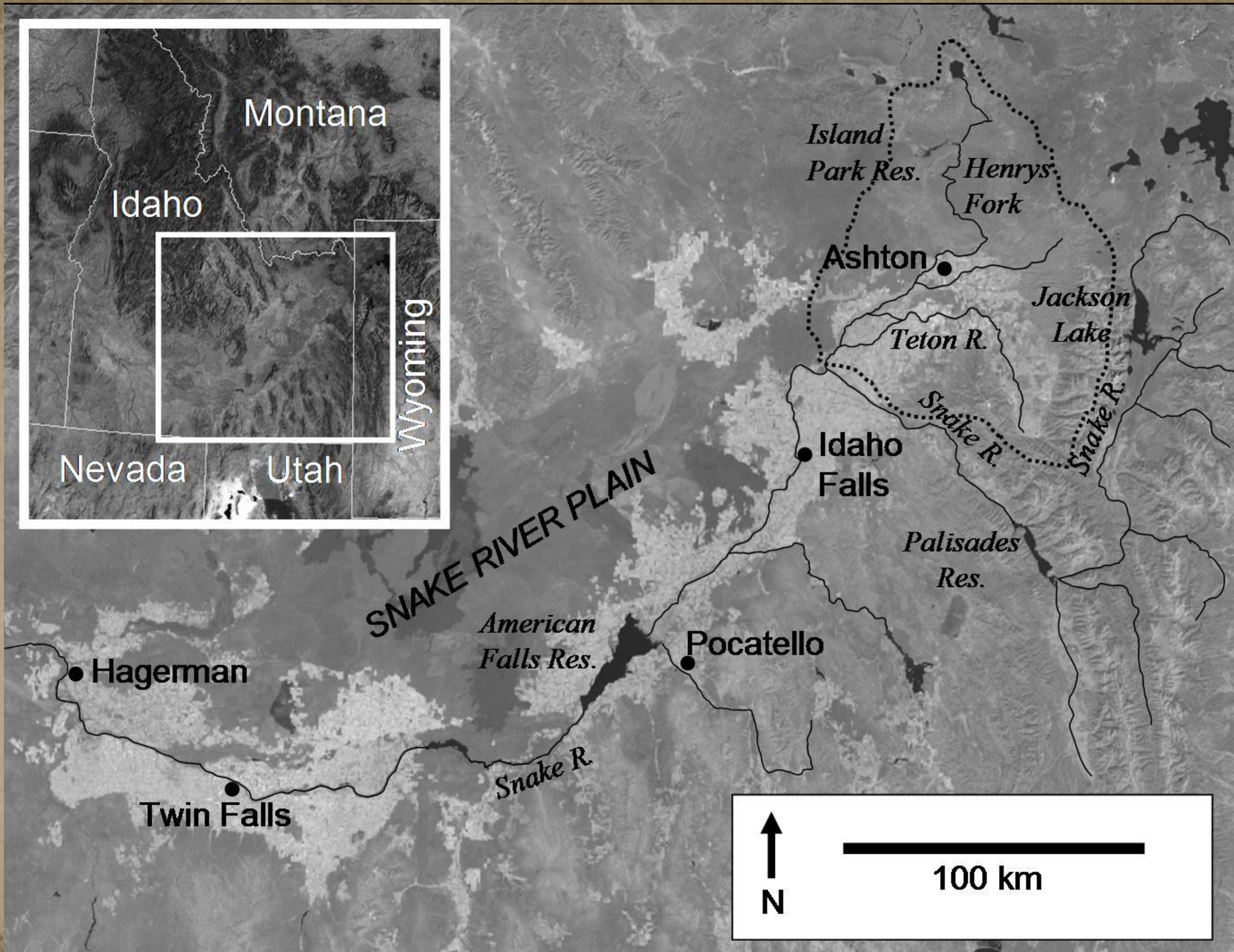
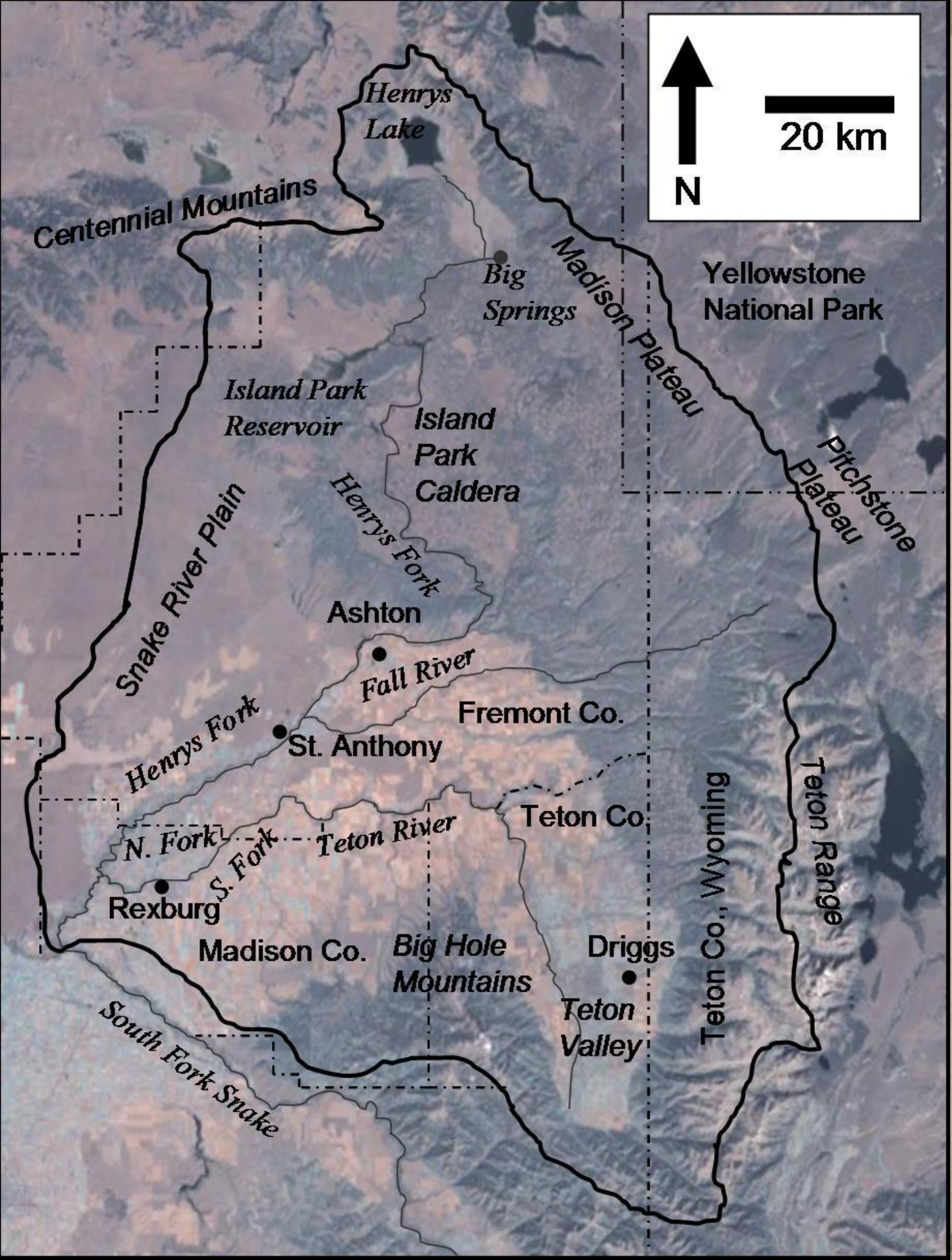
Outline

- Research topics
- Henry’s Fork basin hydrogeology and irrigation
- Methods
- General results
- Results from MODFLOW model of lower basin
- Conclusions

Research Topics

1. Hydrogeology of shallow aquifers
2. Watershed-scale water supply and budget
3. Hydrology of canal-served irrigation system
4. Irrigation water budgets by region
5. Stream reach gains/losses
6. Groundwater outflow from basin


Montana
Idaho
Wyoming
Nevada
Utah
Island Park Res.
Henrys Fork
Ashton
Jackson Lake
Teton R.
Snake R.
Snake R.
Idaho Falls
SNAKE RIVER PLAIN
Palisades Res.
American Falls Res.
Pocatello
Hagerman
Snake R.
Twin Falls
N
100 km

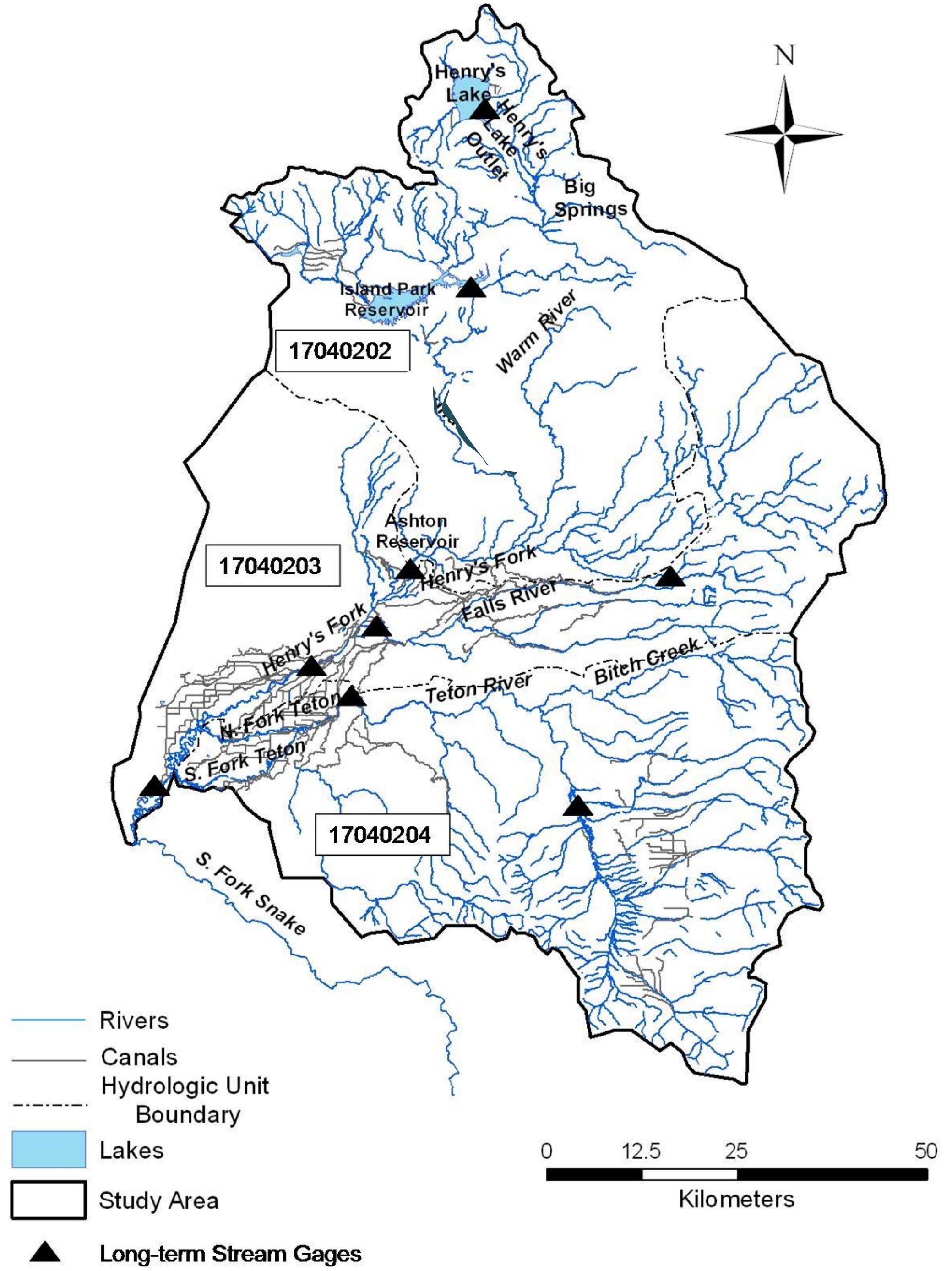


- Area: 3,250 sq. mi
- Mean ann. precip.: 28.2 in.
- Min. elevation: 4,820 ft.
- Max. elevation: 11,400 ft.
- Forested area: 36.7%
- Agricultural land: 20.9%
- Water & snow: 1.89%
- Urban land cover: 1.5%

Storage Reservoirs

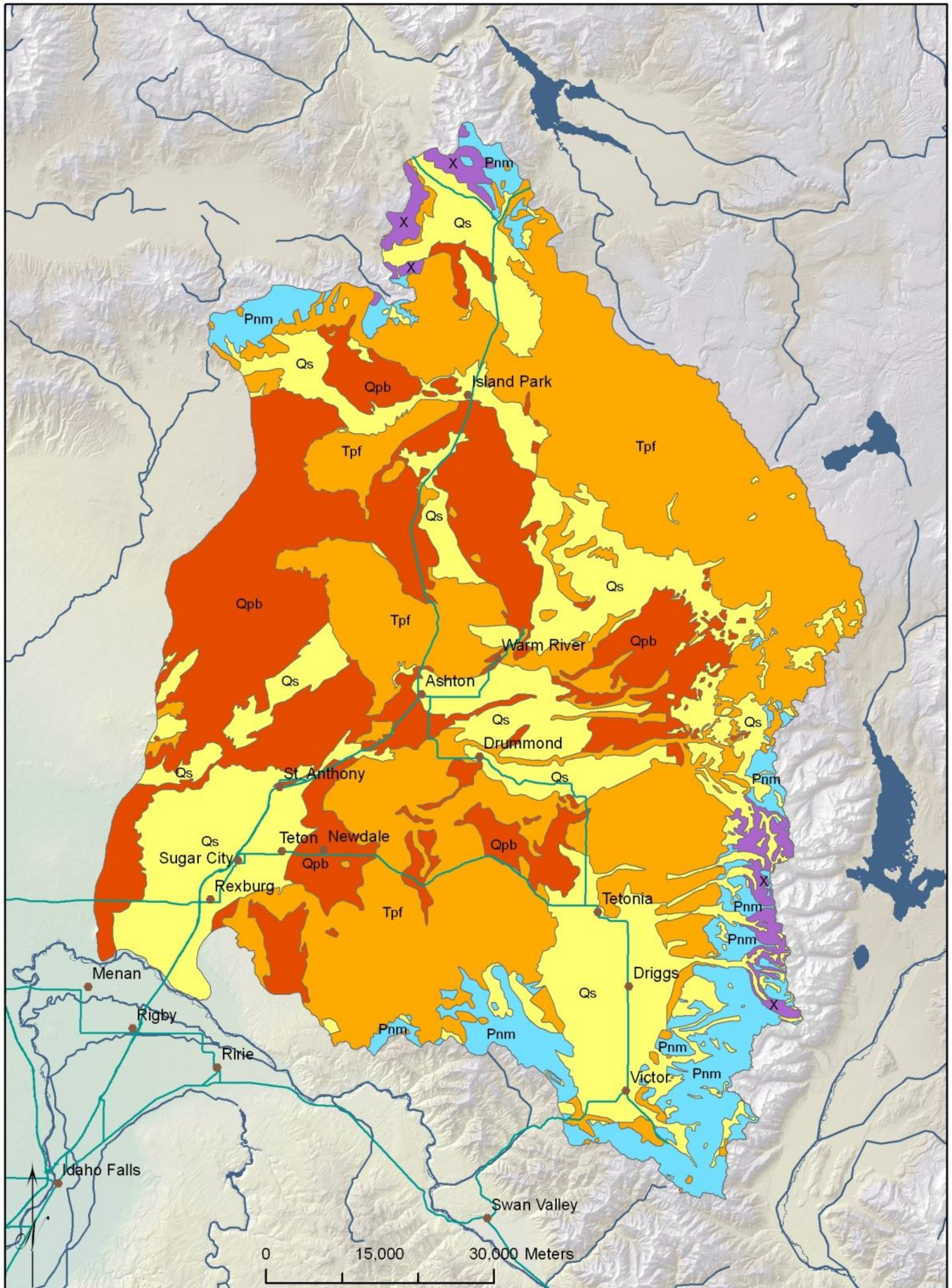
- Henrys Lake*: 90,000 a-f
- Island Park Res.: 135,000 a-f
- Grassy Lake: 15,000 a-f

*Original, natural lake held about 25,000 a-f



Long-term USGS Flow Gages

- -Henrys Fk. nr. Lake 13039500
- -HF nr. Island Park 13042500
- -HF nr. Ashton 13046000
- -Falls River nr. Squirrel 13047500 (between Marysville hydroelectric diversion and return since August 1993; two new gages added in WY 1994; USE CAUTION with FR flow and IDWR accounting!)
- -Falls R. nr. Chester 13049500
- -HF at St. Anthony 13050500
- -Teton R ab S Leigh Cr. 13052200
- -Teton R. ab. St. Anth. 13055000 (immediately downstream of Crosscut canal delivery; INTERPRET CAREFULLY!)
- -HF nr. Rexburg 13056500



Surface lithology

Precambrian

Paleozoic and Mesozoic sedimentary

Cenozoic silicic volcanics from Yellowstone hotspot explosive eruptions

Quaternary basalts

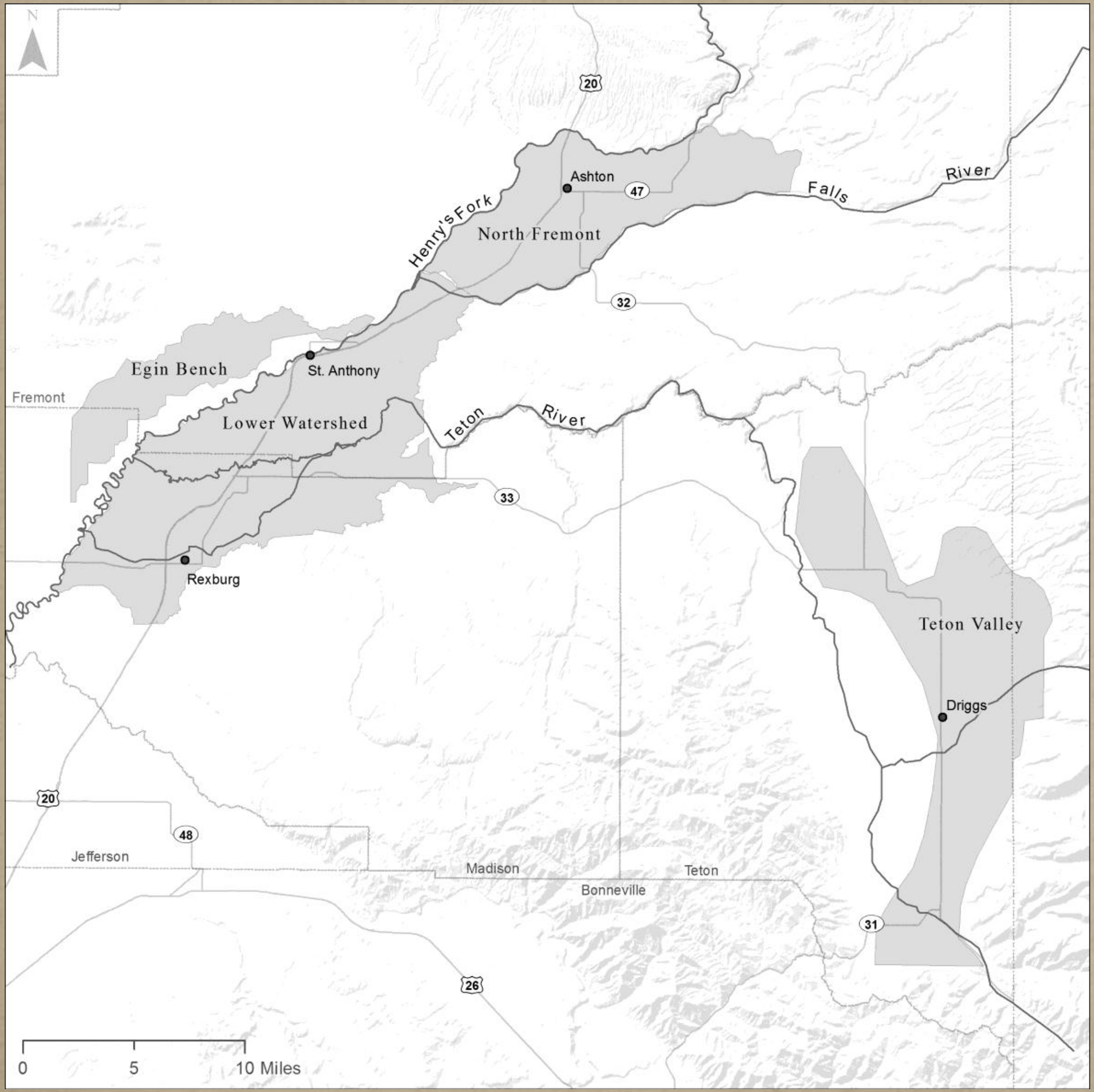
Quaternary alluvium and glacial drift

Source: Bayrd 2006 M.S. Thesis, Idaho State University

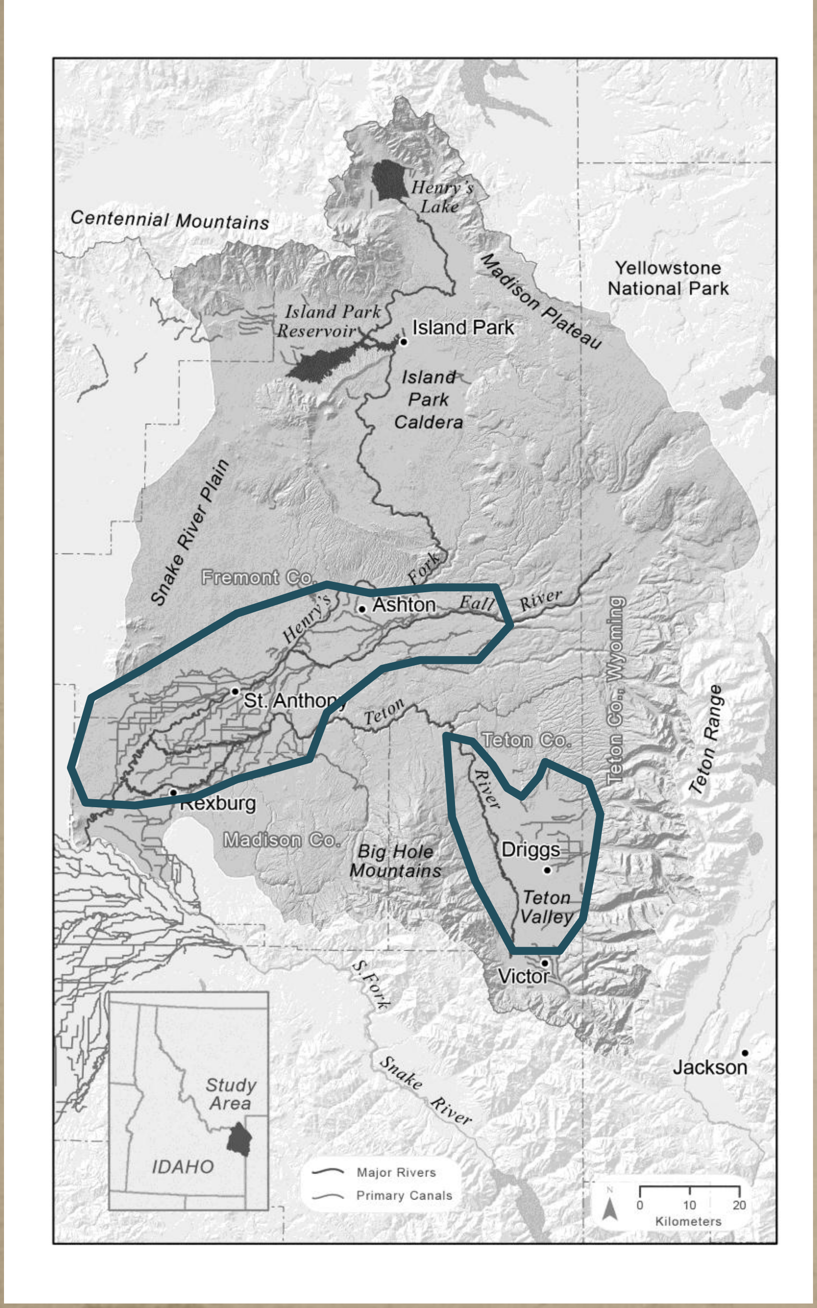
Research Topic 1: Hydrogeology

- Hydrologic conductivities are high (10^1-10^3 ft/day) in alluvium and basalt/sediment systems.
- Conductivities are ~100 times lower (10^{-1}-10^1 ft/day) in rhyolite.
- Shallow aquifers generally < 500 ft. thick, hosted in alluvium and basalt/sediment systems, and bounded below and sometimes laterally by rhyolite.
- Shallow aquifers generally coincide with canal-irrigated areas.

Four primary canal-irrigated regions:



- Teton Valley
- North Fremont
- Egin Bench
- Lower Watershed



Two primary shallow aquifers:

1. Teton Valley (alluvial valley fill)
- Essentially all recharge discharges to Teton River
- Modeled with simple 1-D analytical model (unconfined)

2. Lower Basin (alluvium and basalt/sediment systems)
- Discharges to lower Henrys Fork and Teton rivers and to regional aquifers
- Modeled with MODFLOW as single-layer, unconfined

Water Supply Calculation Methods

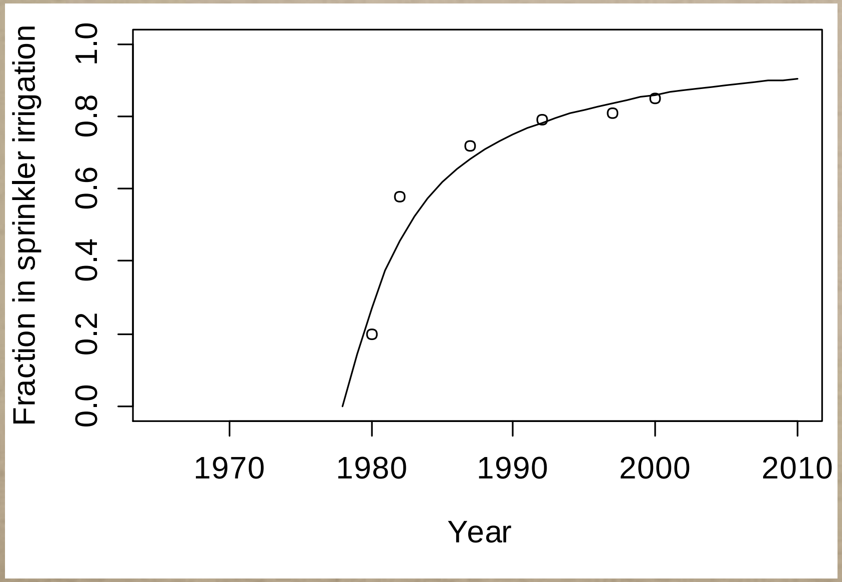
- Water years 1979 – 2008
- Surface supply defined as natural flow at:
  - HF nr. Ashton (contribution from upper Henry's Fork)
  - Fall River nr. Chester (contribution from Fall River)
  - Teton River at. St. Anthony (majority of Teton River contribution)
- Natural inflow not captured at these locations:
  - West side of HF below Ashton: ≈ 6,000 a-f/year
  - Teton R. below St. Anthony gage ≈ 15,000 a-f/year
- Natural flow defined as:

  Regulated flow + Δstorage +res. evap. + diversion– return (surf. and ground)
- IDWR accounting travel times used
- Moving averages used to smooth resulting calculations

Irrigation Seepage Methodology

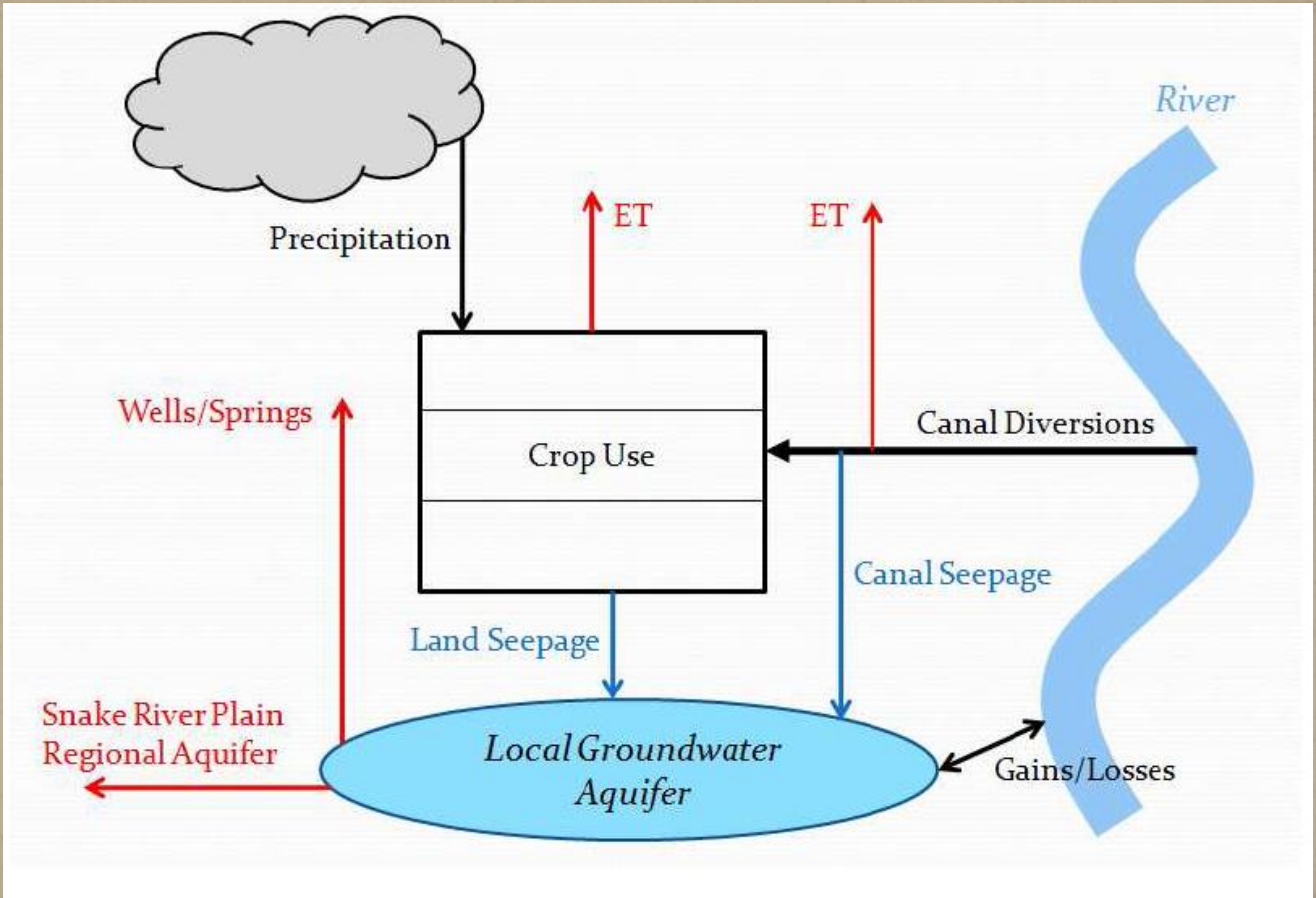
- Estimate mean seepage rates and other parameters in field
- Divide canal systems into branches: 43 canal systems, > 300 branches
- Measure canal branch lengths and widths and vegetation on Google Earth
- Use daily diversion data from IDWR
- Irrigation budget components:
    1. Total canal loss (seepage rate x wetted perimeter x length)
    2. Evaporation from canal surface (using ET rates from ET Idaho)
    3. ET from canal-side vegetation
    4. Canal seepage: Total canal loss – ET (recharges shallow aquifer)
    5. Return flow to streams via surface
    6. Outflow to other canals (added to diversion in receiving canals)
    7. Delivery = diversion – loss – return flow – outflow
    8. Applied to crop ET = minimum of delivery or net crop ET demand (after precipitation), less sprinkler evaporation
    9. Excess demand (if any) is deficit
    10. Excess application (if any) is “application seepage to GW”

Irrigation practices

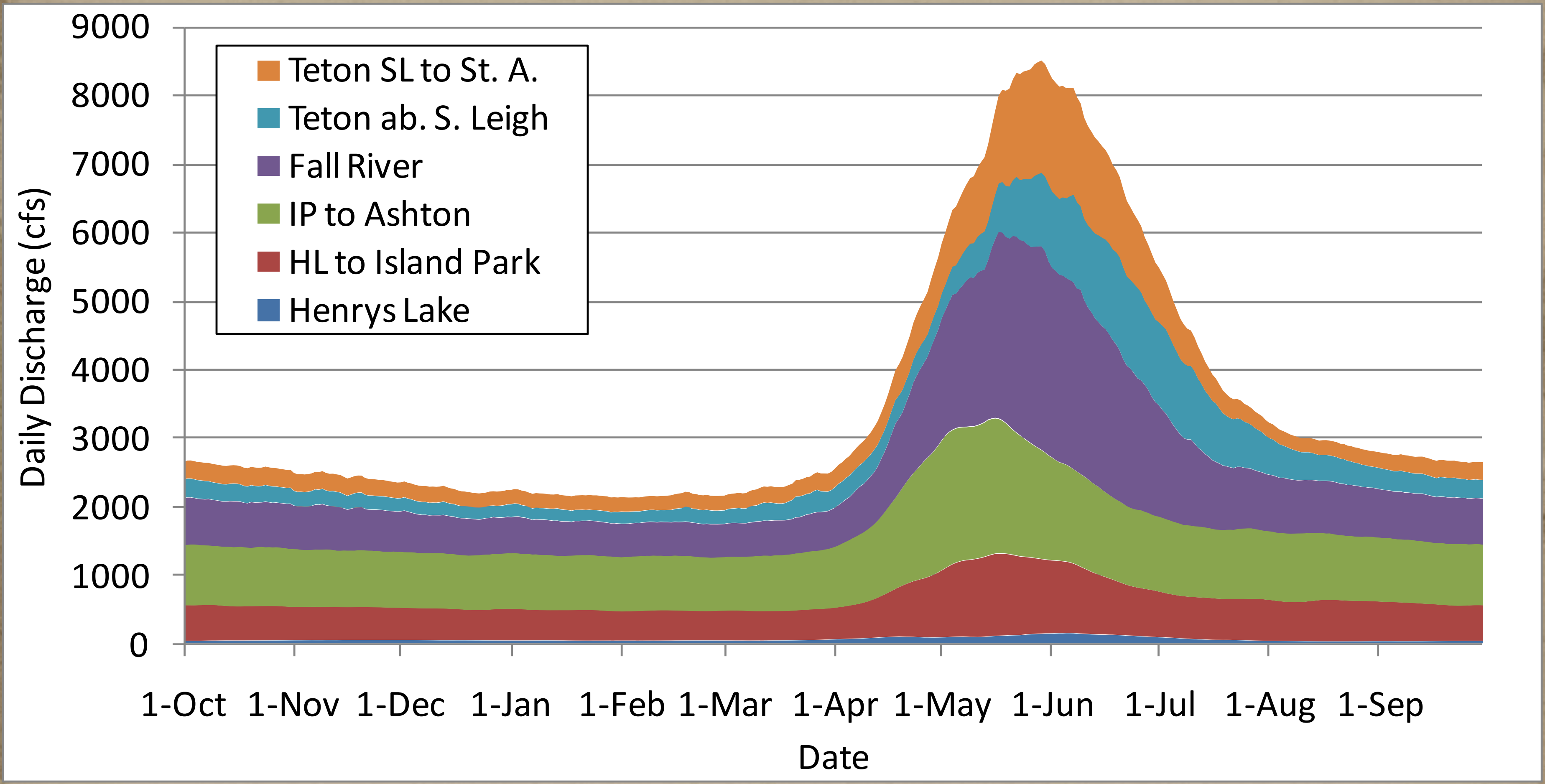


Empirical model of conversion from surface to sprinkler application, fit to data from Contor (2004).

Schematic of GW Models



Results, Topic 2: Water supply



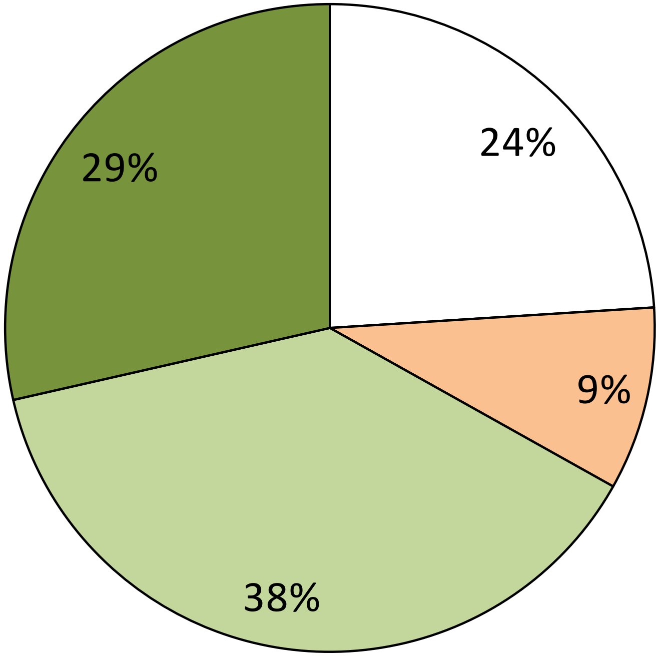
30-year Mean Water Supply Hydrograph

Results, Topic 2: Water budget

Component	Volume (acre-ft)
Precipitation (total supply)	4,880,480
Recharge to Shallow GW not in surface supply	(206,476)
Crop ET supplied by direct precipitation	(89,926)
Crop ET supplied by GW pumping	(186,800)
Domestic, Commercial, Industrial use	(14,766)
Other ET and deep GW recharge from precipitation	(1,779,076)
Surface Supply	2,603,436
Reservoir, canal and sprinkler evaporation	(22,929)
Surface-Irrigated Crop ET	(278,076)
Surface outflow from basin	(1,666,326)
Outflow of shallow GW from basin	(636,105)
BALANCE	0

Recharge to shallow aquifers

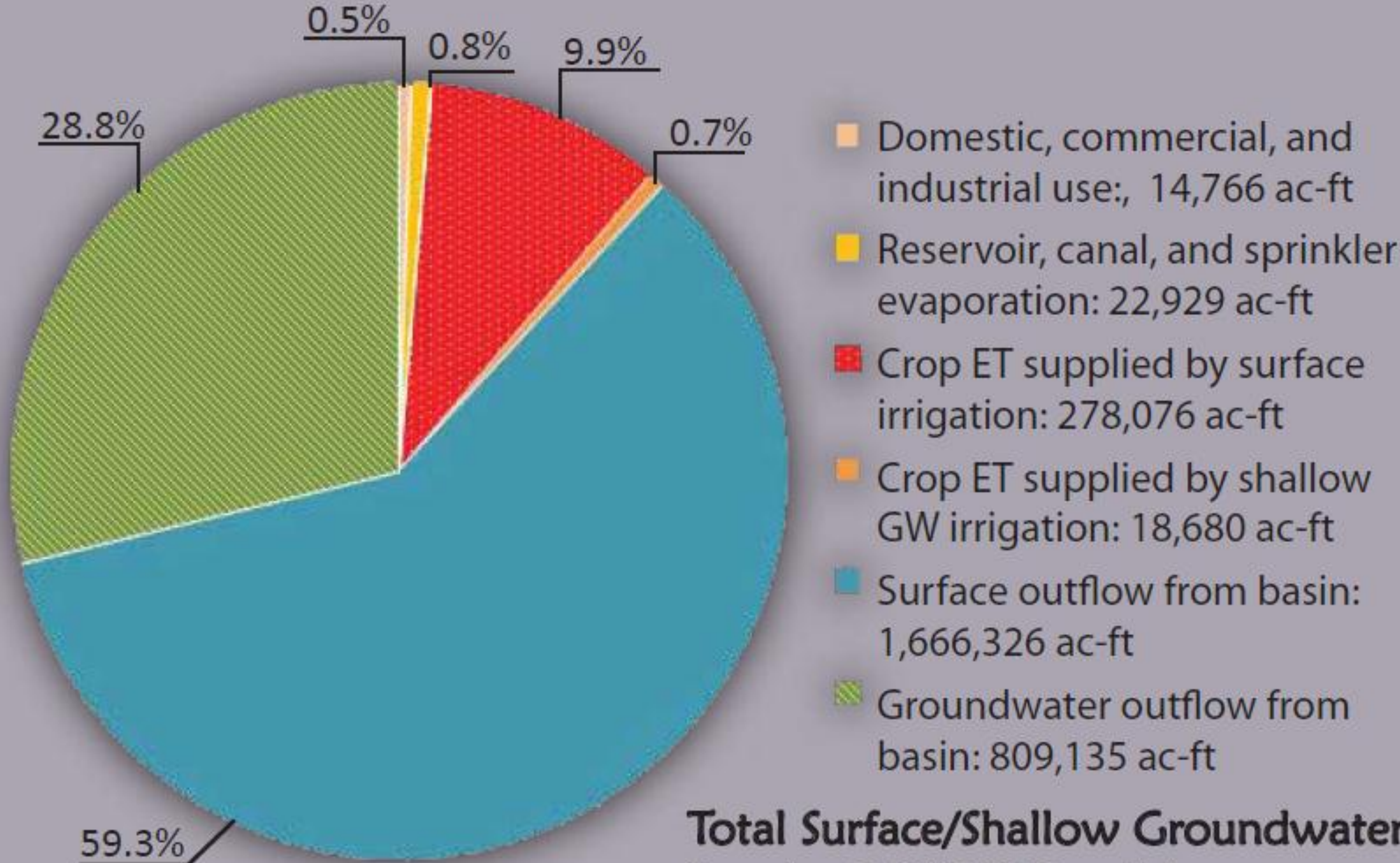
Mean Annual Shallow Groundwater Recharge in Valley Areas



- Direct Precipitation: 291,032 a-f
- Stream Channel Seepage: 110,984 a-f
- Canal Seepage: 464,508 a-f
- Irrigation Application Seepage: 346,587 a-f

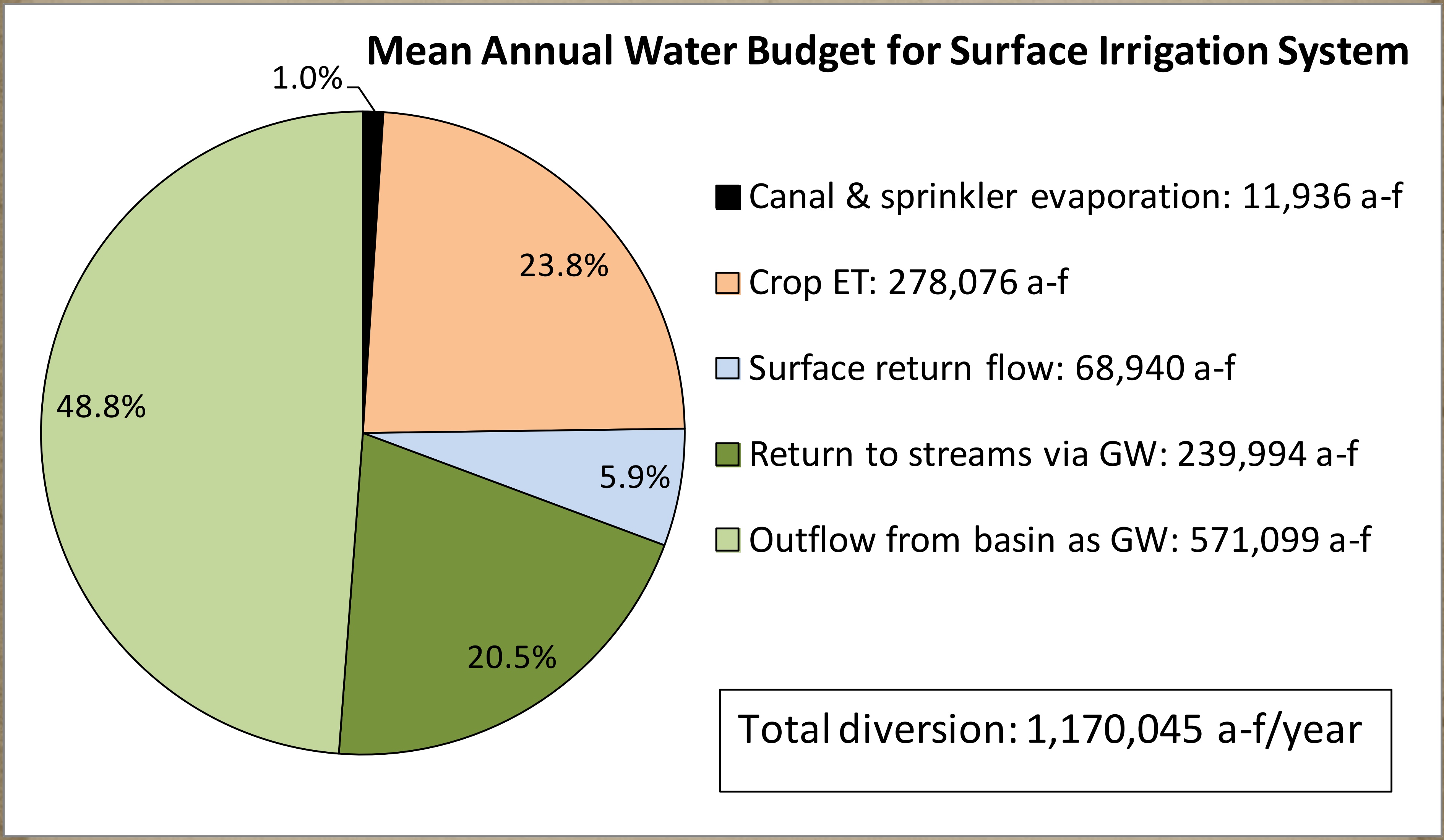
Total Recharge: 1,213,112 a-f/year

Mean Annual Water Budget for Surface and Shallow Groundwater System

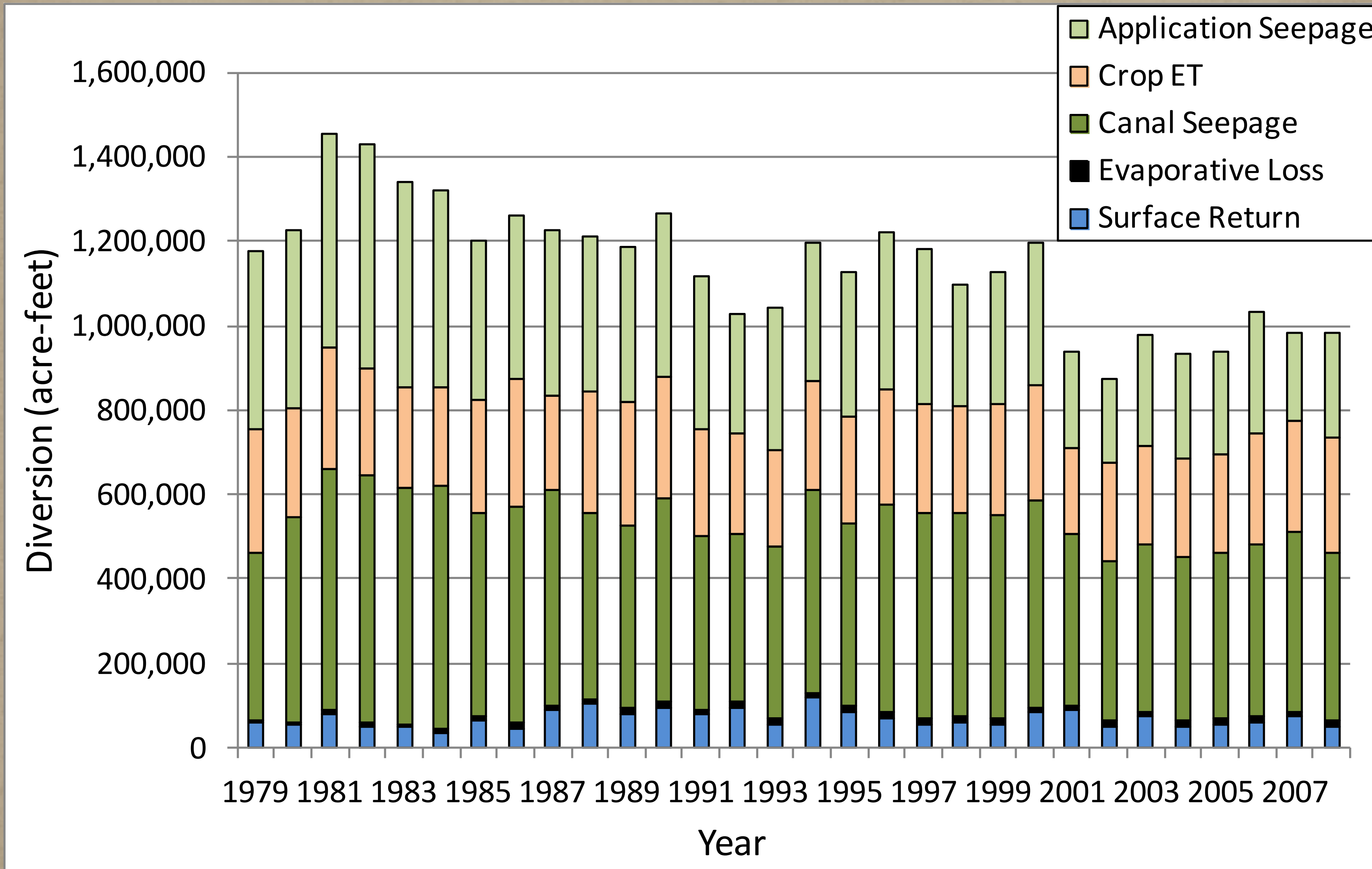


Total Surface/Shallow Groundwater Supply: 2,809,912 ac-ft/year

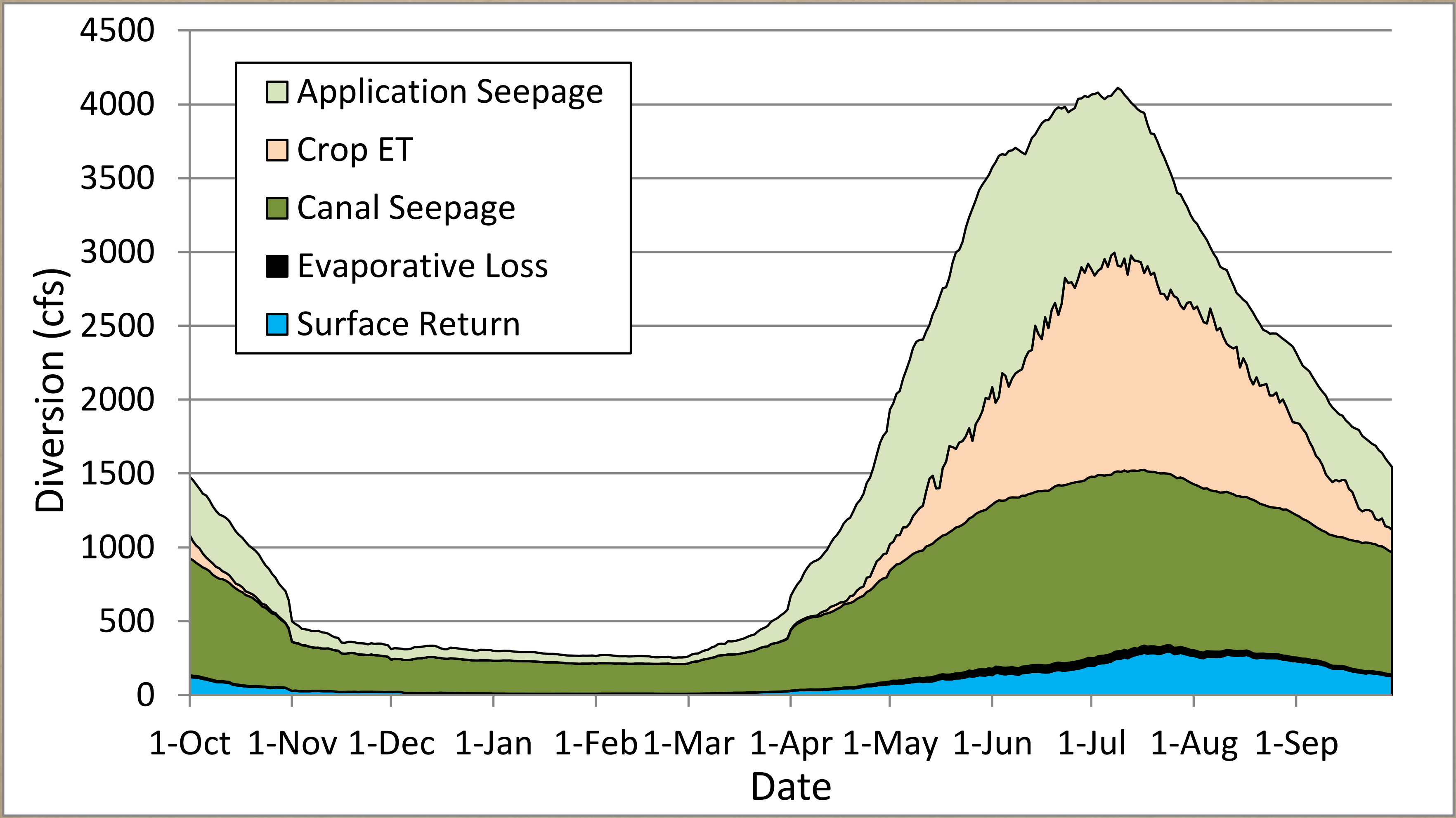
Topic 3: Surface Irrigation System



Time series of diversion in four primary irrigation regions



Mean irrigation hydrograph for four primary regions

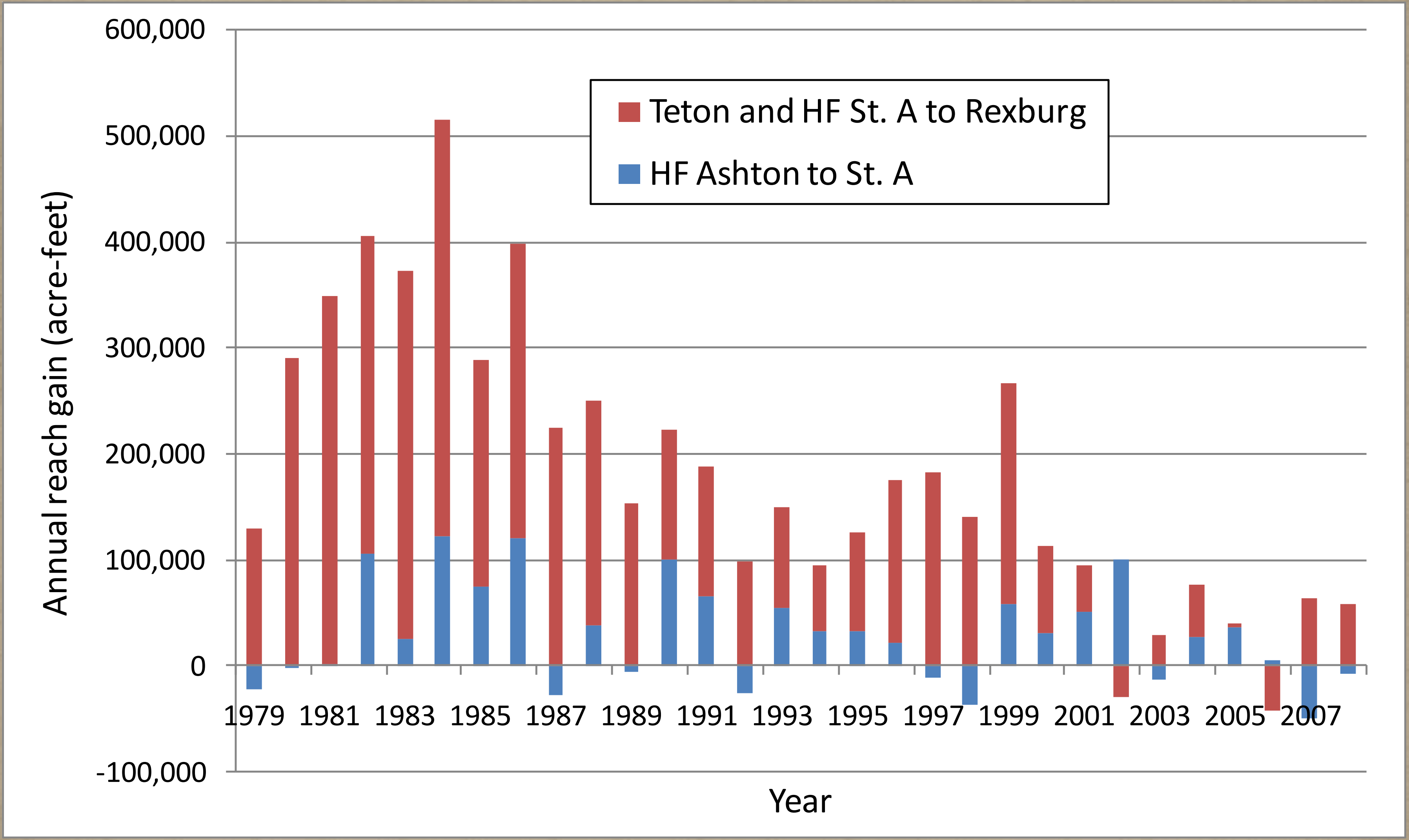


Topic 4: Irrigation budgets by region

Region	Area (ac)	Canal length (mi)	Diversion (ac-ft)	Surf. Ret. (ac-ft)	Evap-orative Loss (ac-ft)	Crop ET from irrig. (ac-ft)	GW rchg. (ac-ft)
Teton Valley	53,000	106	92,290	3,501	1,063	36,650	51,076
North Fremont	32,500	51	41,681	575	510	16,552	24,044
Egin Bench	30,500	111	368,351	11,588	3,499	61,156	292,110
Lower Watershed	73,000	222	641,723	53,007	6,604	142,573	439,540
Others	61,000	22	26,000	270	260	21,145	4,325
TOTAL	250,000	512	1,170,045	68,941	11,936	278,076	811,095

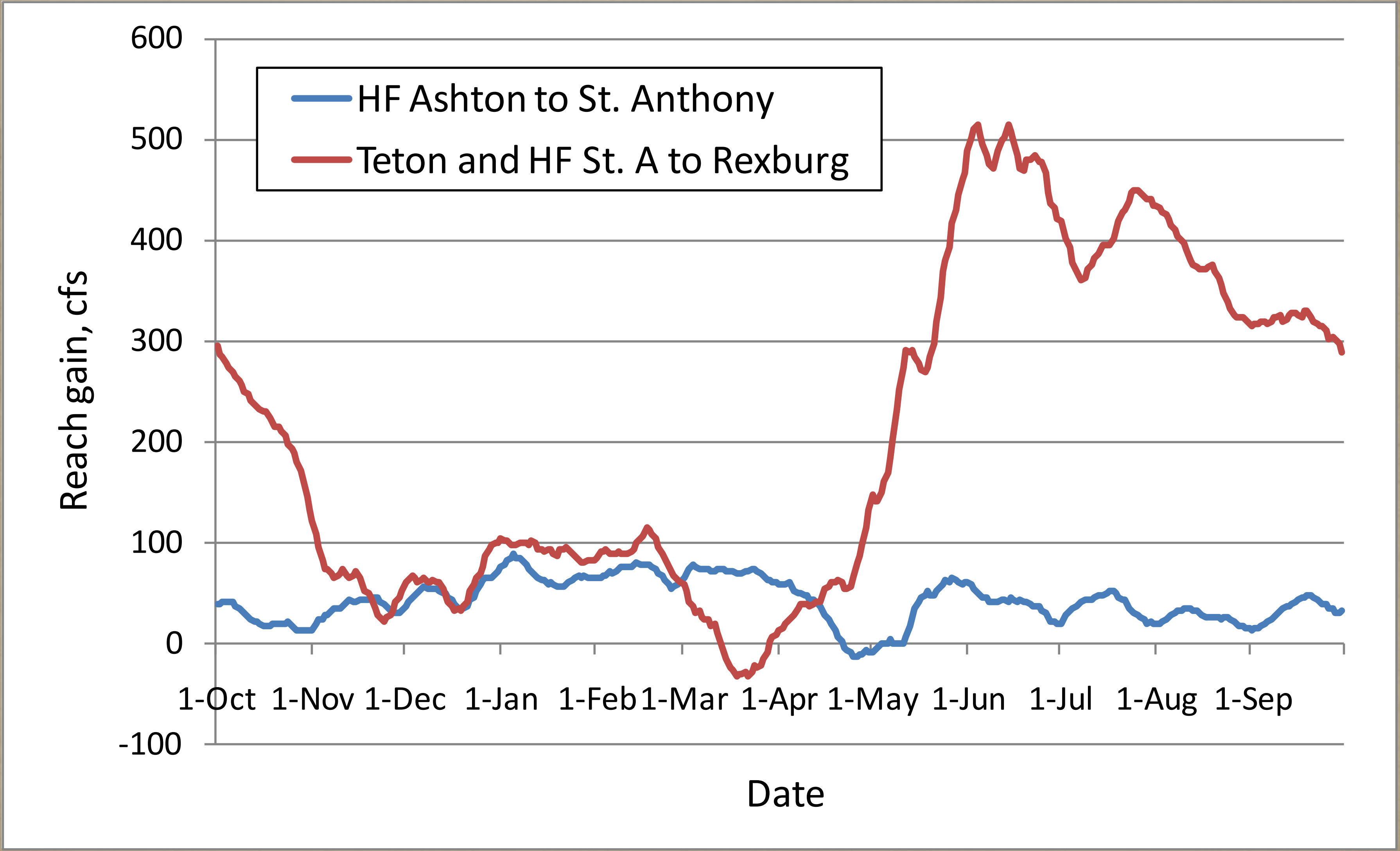
30-year means

Topic 5: River reach gains/losses

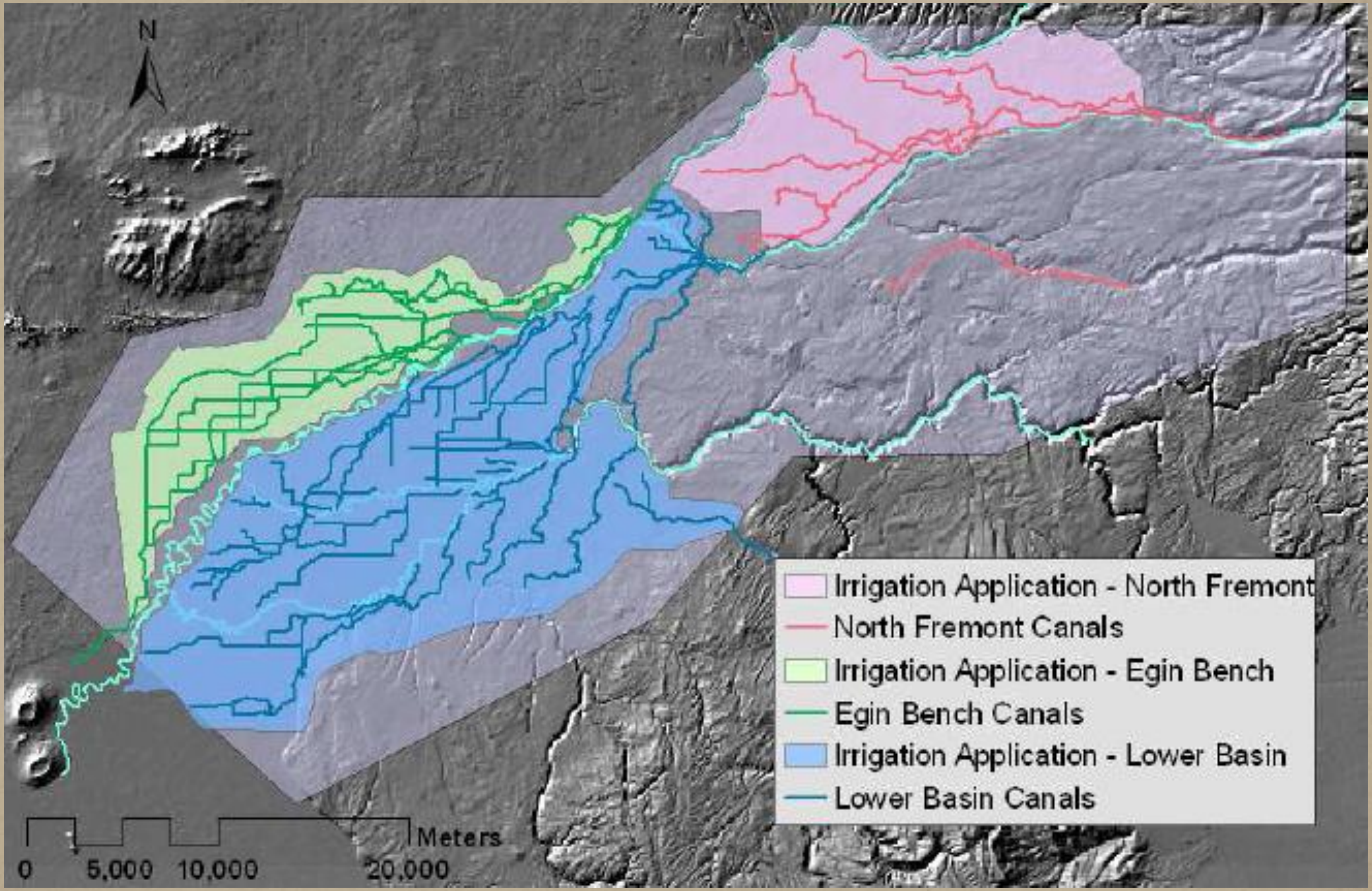


Observed river reach gains in lower HF and Teton River

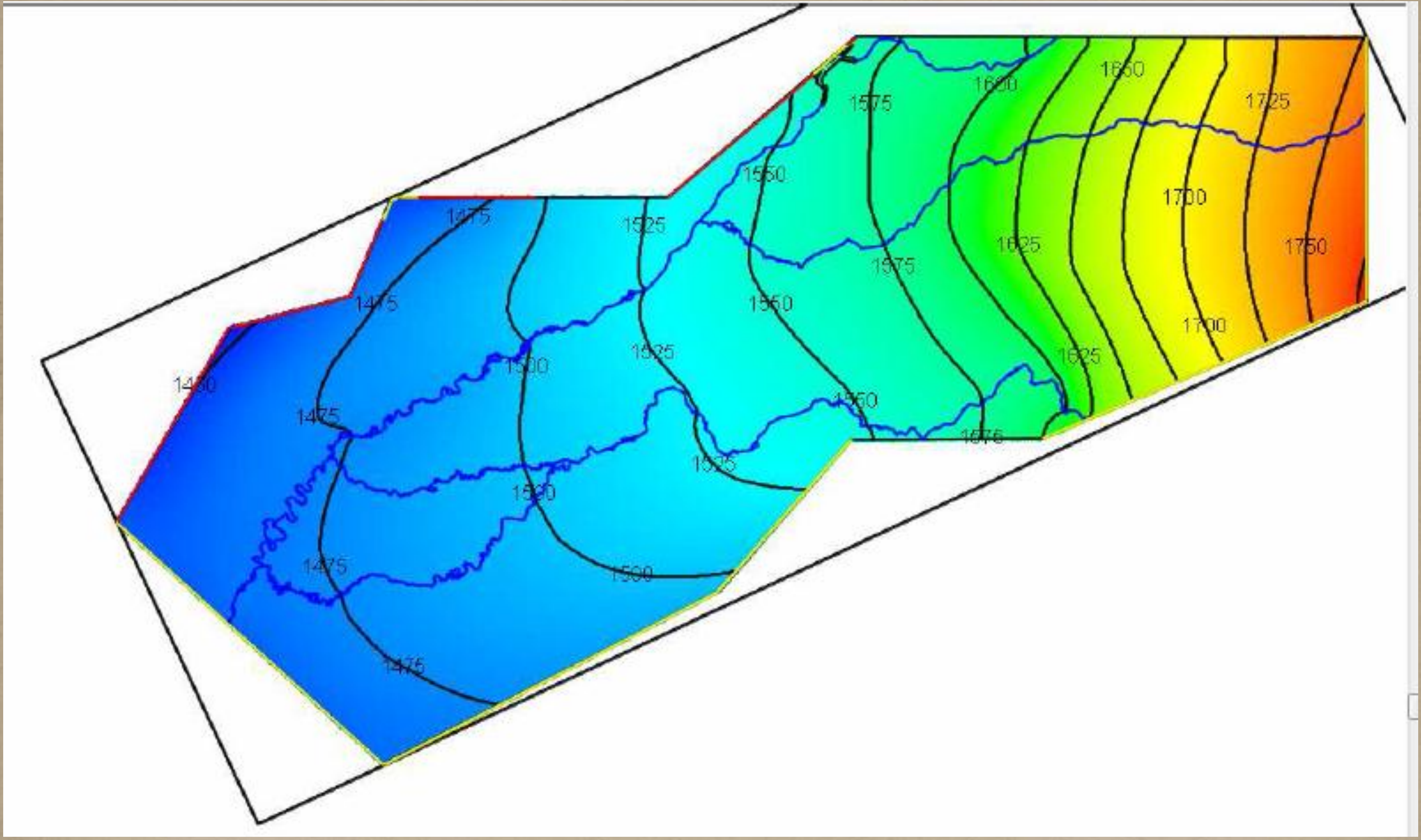
Reach Gain Hydrographs



MODFLOW Model Domain

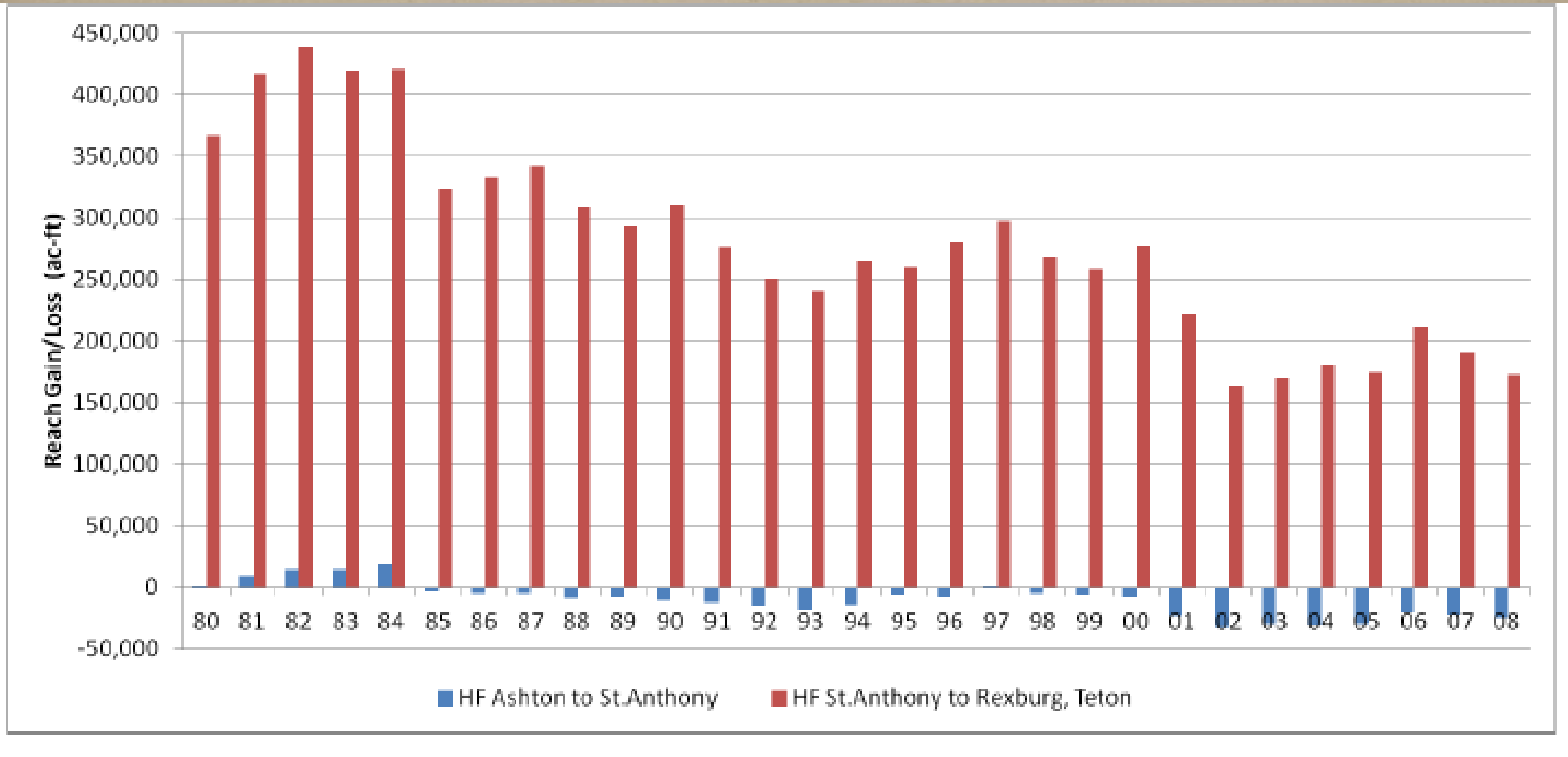


MODFLOW Model Results



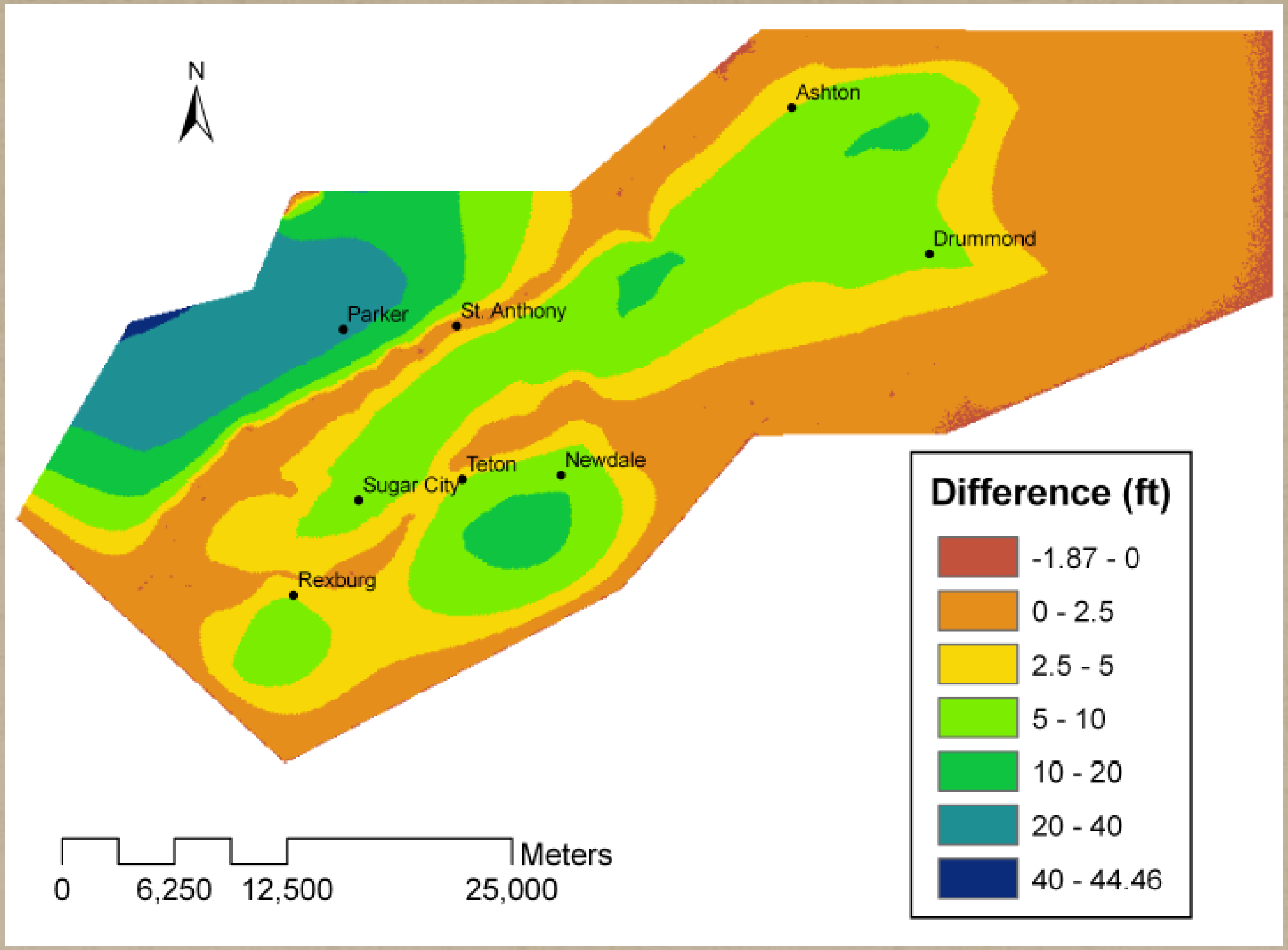
Simulated hydraulic head at end of WY 2005 (meters)

MODFLOW Model Results



Simulated river reach gains in lower HF and Teton River

MODFLOW Model Results



Difference in hydraulic head between current conditions and “natural” hydrology (no irrigation): positive = lower water table

MODFLOW Results, Topic 6: GW outflow

Component	1979-2008 conditions	No-irrigation scenario
GW inflow (primarily from northeast)	568,713	570,896
Recharge from precipitation	221,294	221,294
Recharge from canal seepage	356,459	0
Recharge from irrigation application	352,003	0
TOTAL INFLOW	1,498,469	792,190
River gains (all reaches in domain)	(694,961)	(71,234)
GW outflow (primarily to southwest)	(846,451)	(764,042)
TOTAL OUTFLOW	(1,541,412)	(835,276)
Change in storage	-42,943	-43,083

Model-domain water budget under current conditions and “natural” hydrology (no irrigation); volumes in ac-ft/yr

Conclusions

- Consumptive use is ~25% of total irrigation diversion.
- Current GW outflow from HF basin is ~850,000 ac-ft/yr.
- “Natural” GW outflow from basin was ~760,000 ac-ft/yr.
- Current SW outflow from basin is 1.67 M ac-ft/yr.
- “Natural” SW outflow from basin is 2.05 M ac-ft/yr.
- Water table is perched seasonally in Egin Bench area; GW flows both to ESPA and back into river.
- Upper Teton has little GW hydraulic connection to ESPA.
- Greatest effect of irrigation recharge is to store water seasonally and increase river gains, relative to “natural”.
- Lower Teton and lower HF reach gains are strongly correlated with irrigation seepage and have decreased with decreased diversion.
- These reaches would lose ~250,000 ac-ft/yr under “natural” conditions.