The Effects of Climate Change on New Mexico's Mountain Snowmelt Runoff and How Acequias Might Become a Mitigating Factor

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New Mexico EPSCoR

The three-year old New Mexico Experimental Program to Stimulate Competitive Research (EPSCoR) recognizes that all states do not compete for research dollars on an equal basis. NSF is providing funding to make the 28 EPSCoR states more competitive in the research arena; in New Mexico, specific gaps in existing capabilities are being filled.

- Improved observations through upgraded sensor networks and remote sensing in mountain source regions
  - The major objective is to continuously measure the spatial distribution of key variables that affect the water quantity in New Mexico's mountains: snow cover and water equivalent, snowmelt, rainfall, evapotranspiration, soil moisture, runoff.
- Assemble a group of hydrological models that can be used for short-term forecasting and long-term assessments (for climate change)
  - These will include semi-operational basin models, fine resolution distributed basin models, regional scale climate models, and decision support and economic impact assessment models.
- Determine the quantitative effects that high elevation irrigation ditch systems (acequias) have on the characteristics of streamflow and water use in the larger basin.

NRCS SNOTEL stations

- Five new enhanced SNOTEL (SNOw TELemtry) stations have been procured and will be installed by NRCS. These SNOTELs will be located at manual snow survey sites.

- Twelve sets of additional equipment have been procured to upgrade existing basic SNOTEL sites to enhanced SNOTEL sites.

- The SNOTEL network in New Mexico will be improved to be more comparable to other western states.

Soil Climate Analysis Network (SCAN)

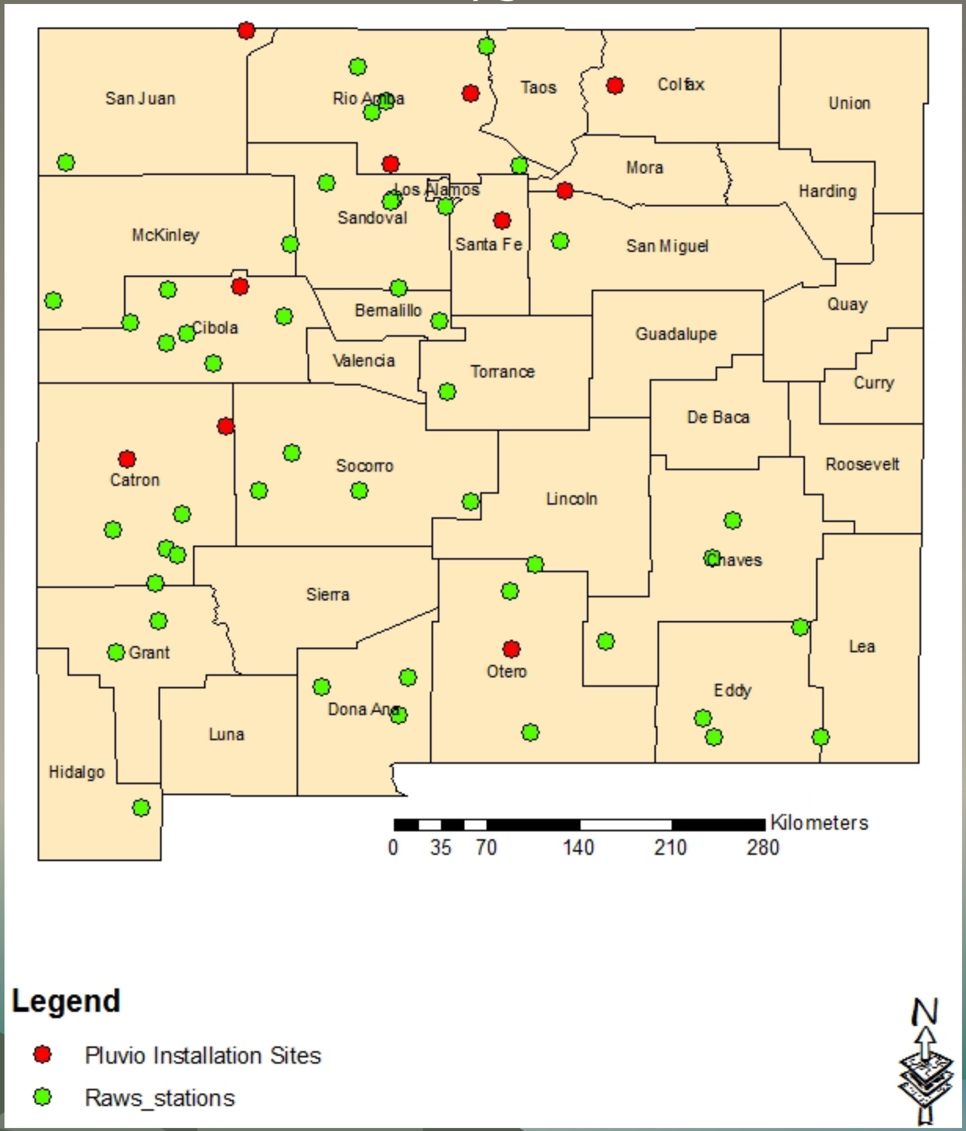
- Four new NRCS SCAN stations have been installed in the Rio Grande basin

- We have worked closely with USDA-NRCS NWCC to install the stations. They are located at:
  - Jornada Experimental Range
  - Sevilleta National Wildlife Refuge
  - Los Lunas Research Center
  - Alcalde Research Center

- These stations will be of value for assessing the fate of snowmelt runoff when it flows into the lower elevation valleys

Weather stations in the interagency Remote Automatic Weather Stations (RAWS) network, the Navajo Nation Weather Station network, and the New Mexico State University Climate Center network are being upgraded using EPSCoR resources

New Mexico RAWS network and sites of 10 upgrades



Weather stations

- Install 3 weather stations
  - 2 Middle Rio Grande & Flux Tower
  - 1 El Rito
- Working out telemetry obstacles
- Five more stations to be installed in 2010-2011

Navajo Nation weather station installations

- Site visit to the Navajo reservation:
  - Searched for existing weather stations
  - Identified 7 possible locations for new stations, of which 5 will be used
    - Tohatchi
    - Sheep Springs
    - Shiprock –
      - Orchard Demo Project @ Dine College
    - Crownpoint
    - NAPI
    - Pueblo Pintado
    - Pueblo Baca
  - MOA - NAPI

Student involvement high

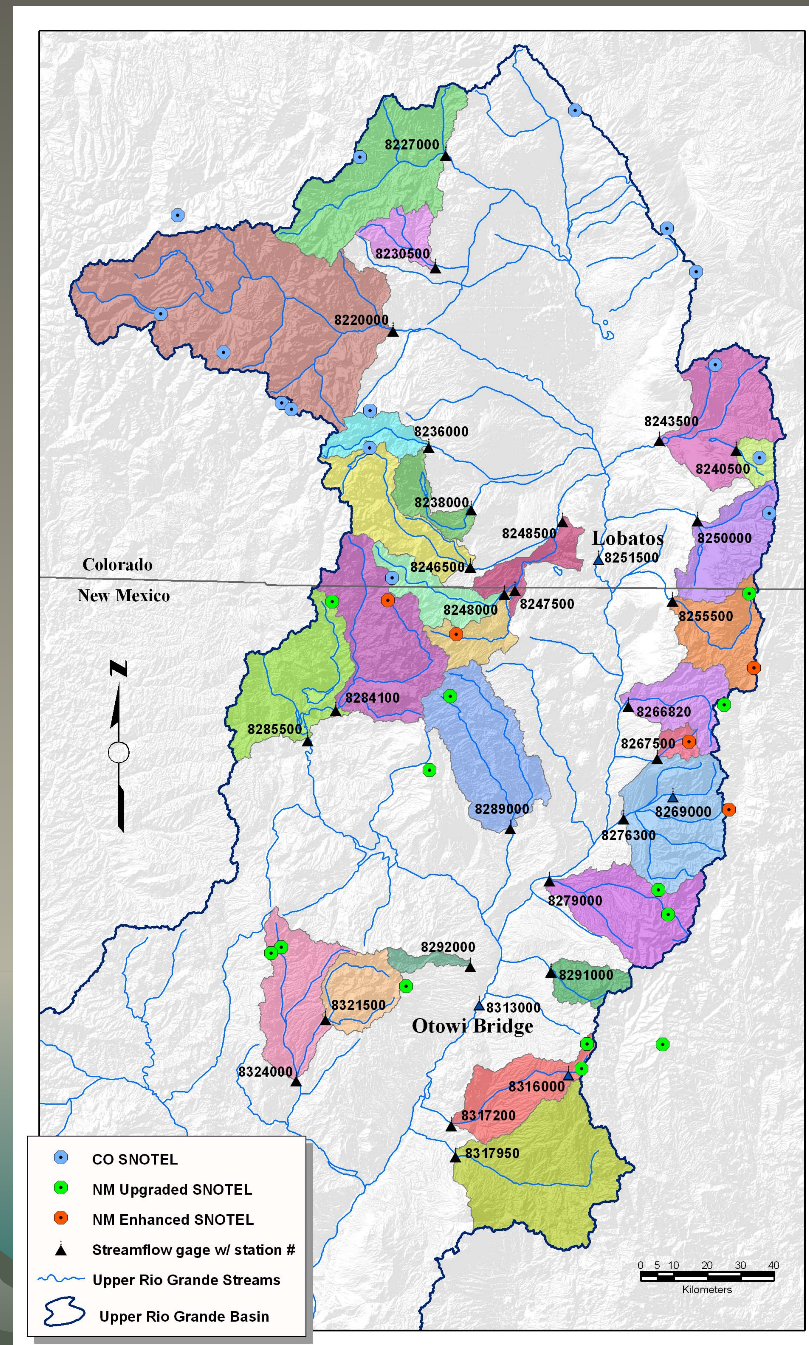
- 3 graduate students (1 PhD candidate and 2 MS candidates)
- 16 undergraduate students
- 7 UROP students

Snowmelt runoff research objectives

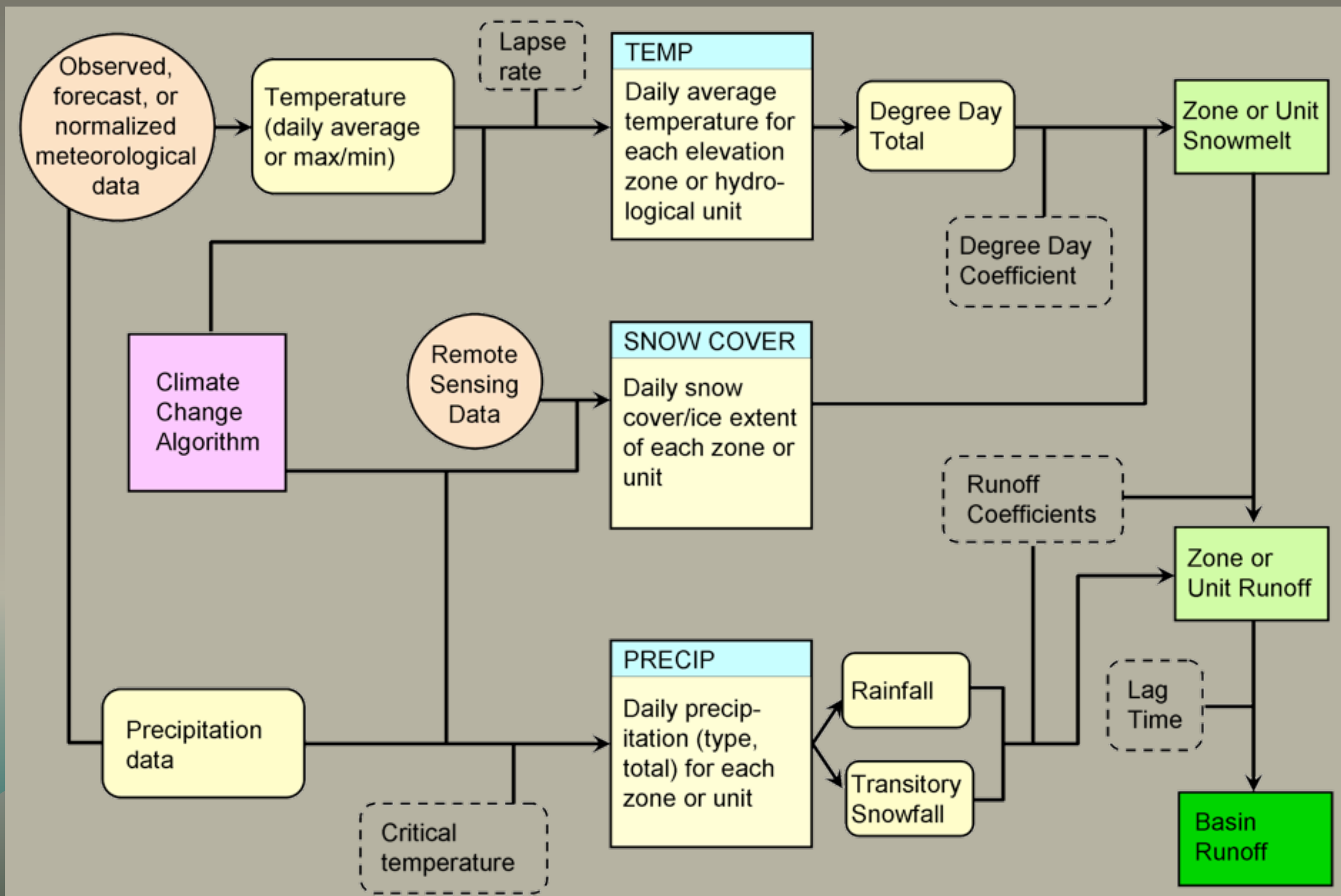
1. Identify the most appropriate satellite snow mapping algorithm for use in Rio Grande basin (and perhaps for similar semi-arid snow basins)
2. Test these methods using MODIS data against results using Landsat-TM on four selected sub basins (Rio Grande near Del Norte, CO; Rio Chama; Costilla Creek; Rio Hondo)
3. Implement the selected snow cover algorithm in all 25 important snowmelt sub-basins in the Rio Grande and use it to provide the necessary input to run SRM
4. Develop simulations and forecasts for short-term (~2 weeks) to long-term (3-12 months) applications
5. Generate snowmelt runoff hydrographs to evaluate change under different climate change scenarios

25 significant snowmelt runoff basins in the upper Rio Grande used to evaluate the potential effects of climate change

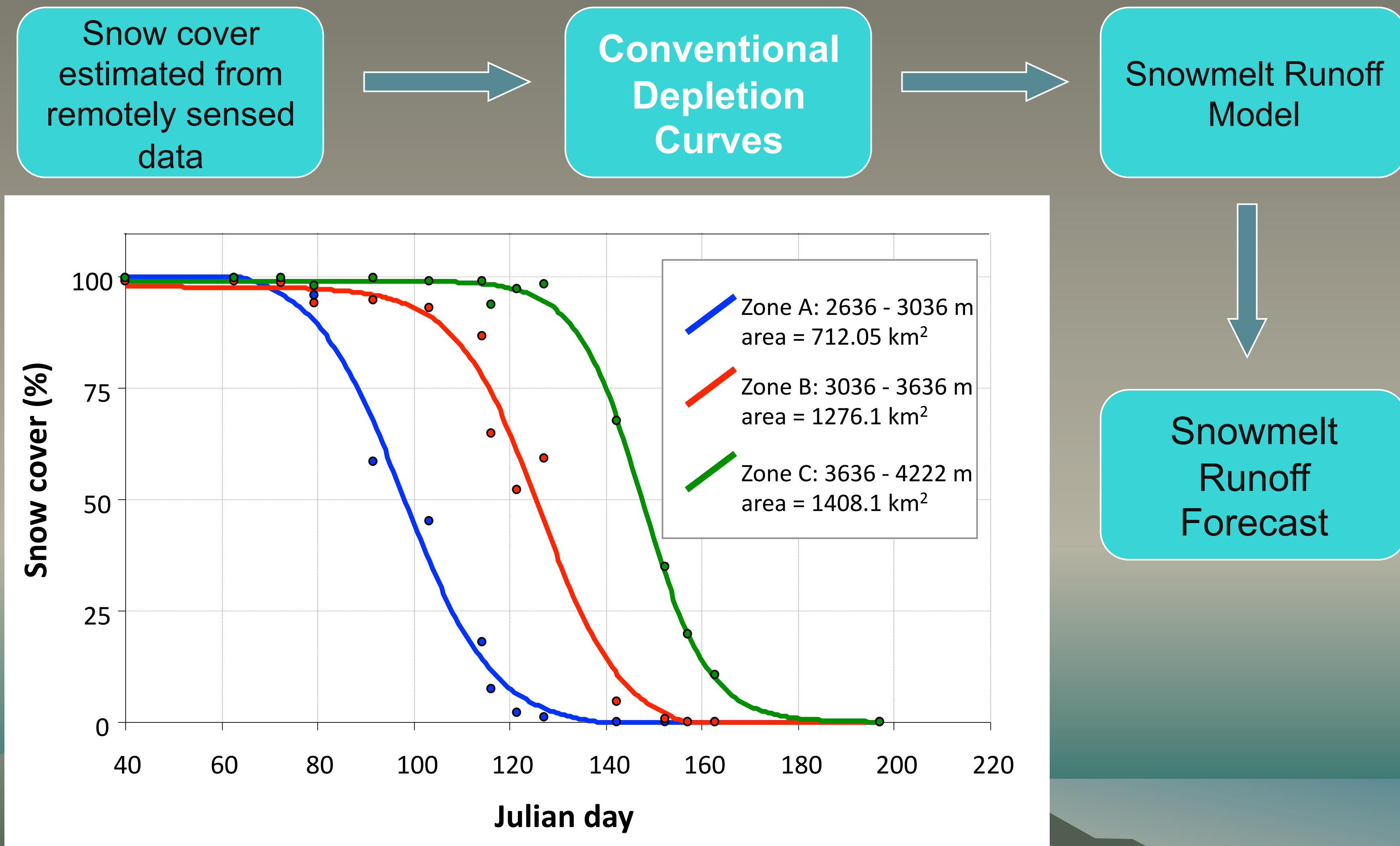
We are currently developing snow cover mapping techniques on each of these sub-basins and applying the Snowmelt Runoff Model (SRM) to the sub-basins



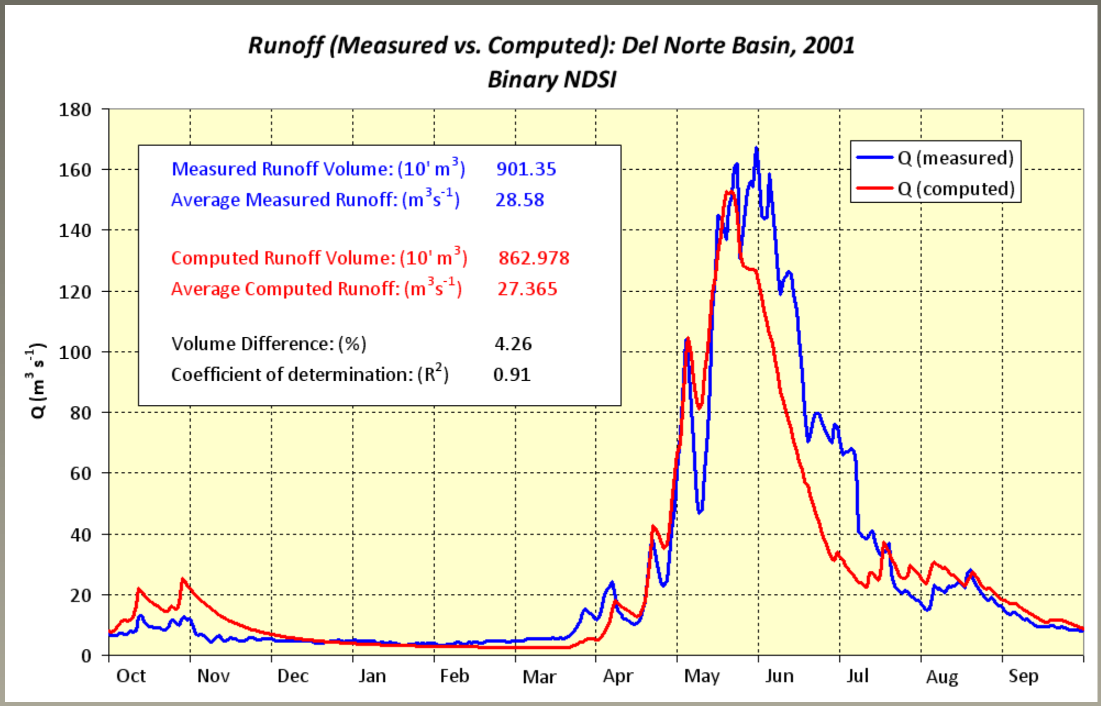
Schematic diagram of the organization of the Snowmelt Runoff Model (SRM)

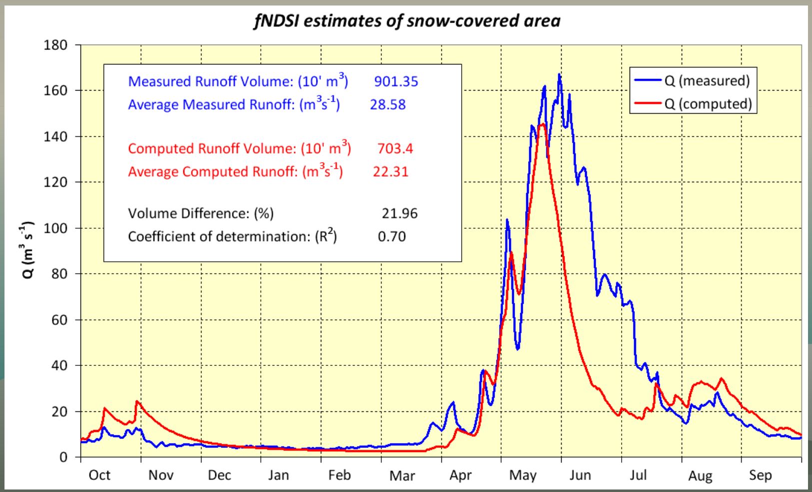


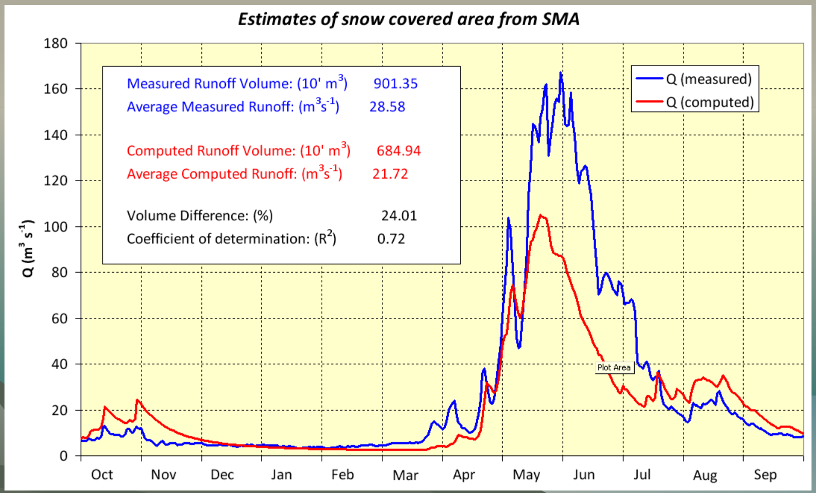
Use of satellites to map snow depletion curves: Rio Grande near Del Norte, CO, 2001



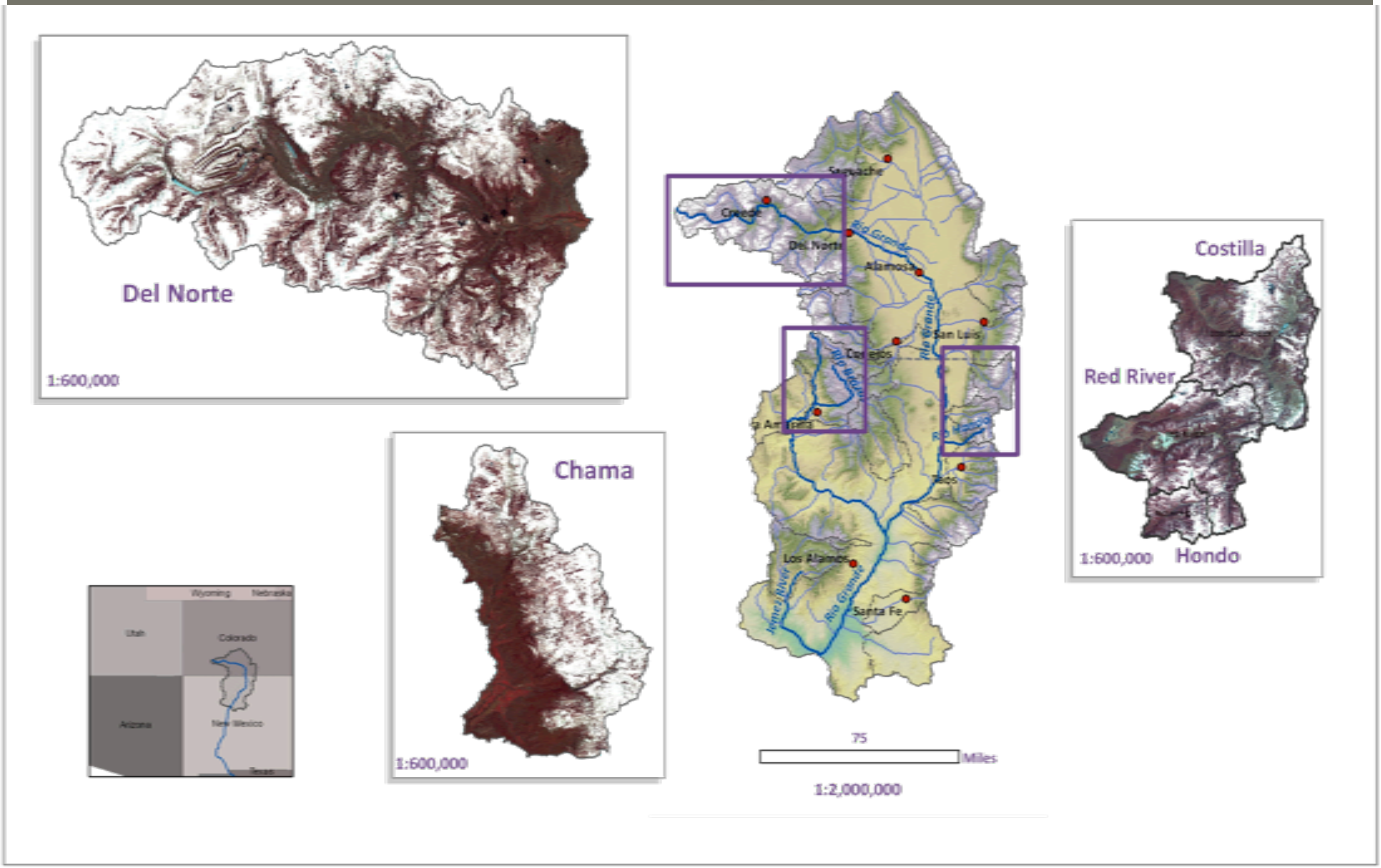
Runoff results: Rio Grande







Five sub basins used for determining the best snow cover mapping method



Methodology I

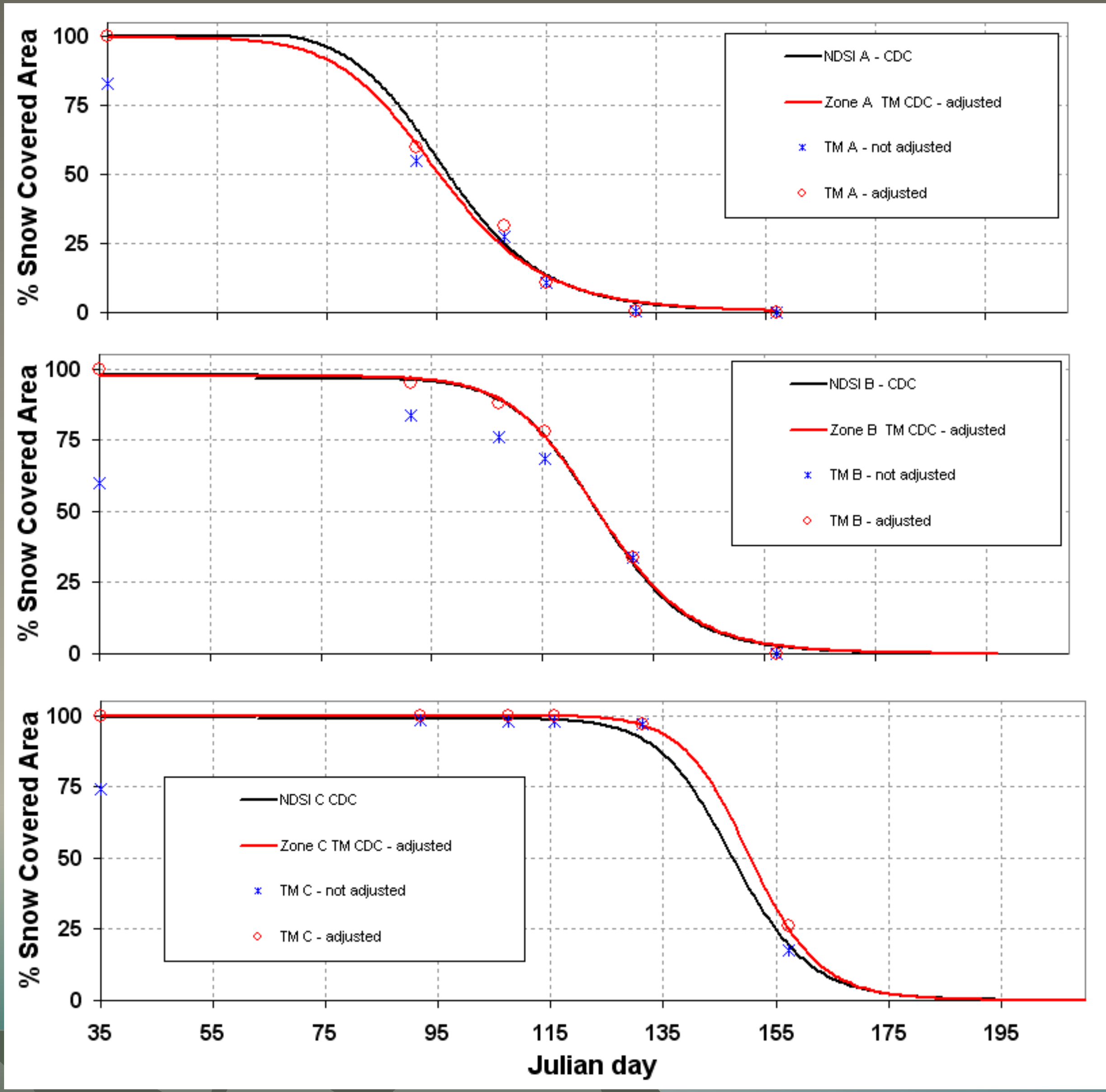
- Direct comparison of snow cover estimates for a range of years: 2000 to 2008
- Comparison of conventional depletion curves from snow cover estimates from Landsat TM (30 m) and MODIS (500 m) algorithms
- Comparison of output from SRM for different conventional depletion curves
- SCA estimates derived from both TM and MODIS data are affected by forest cover
    - TM: Nearest neighbor classification – moderate to dense forested areas are not mapped as snow covered. **SCA underestimated**
    - MODIS: Spectral Mixing Analysis - moderate to dense forested areas are not mapped as snow covered. **SCA underestimated**
    - MODIS: Fractional Snow Cover Product – empirical model that relates SCA to NDSI. Developed over less heavily forested / non-forested areas, pronounced under-estimation of SCA in basin middle zone. **SCA underestimated**
    - MODIS: SNOMAP (binary) algorithm underestimates late season SCA when snow patches exist. **SCA underestimated**

Methodology II

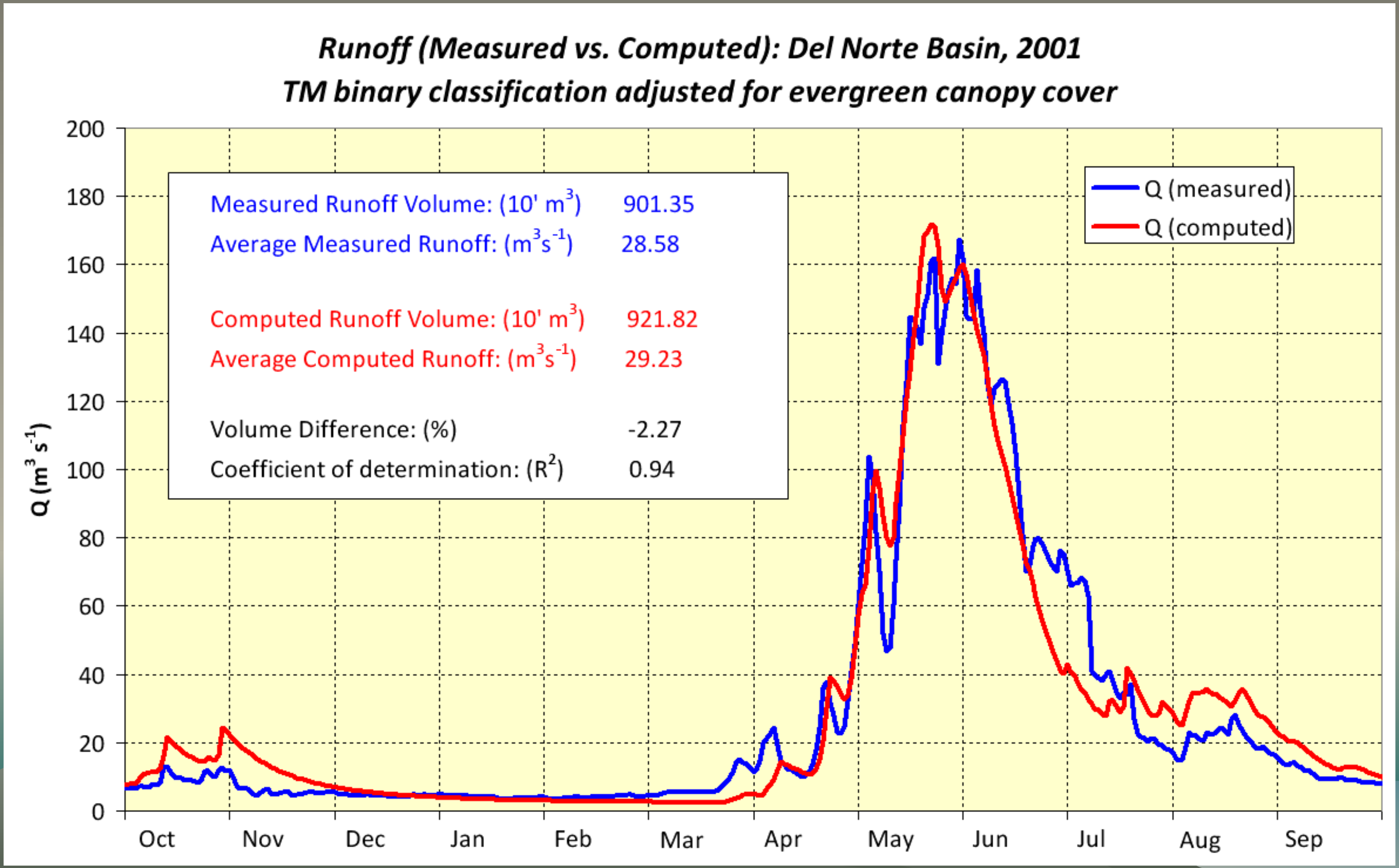
- Depletion curves from under-estimated SCA result in under-estimates of runoff
  - SCA must be corrected for sub-canopy snow cover
  - Forest cover mapped for all study basins

- Correcting for forest cover
  - Simple rule-based methodology based on distribution of viewable SCA detected in an image
  - Random sample of “viewable snow cover” pixels
  - Values for elevation, aspect, slope and % forest cover extracted for each pixel
  - Ruleset developed using decision tree (CART™) analysis
  - Non-Snow pixels assessed for reclassification using ruleset derived from CART™
  - Requires testing for different dates / basins. Question: Is it possible to identify a standard adjustment factor for each basin for a given SCA?

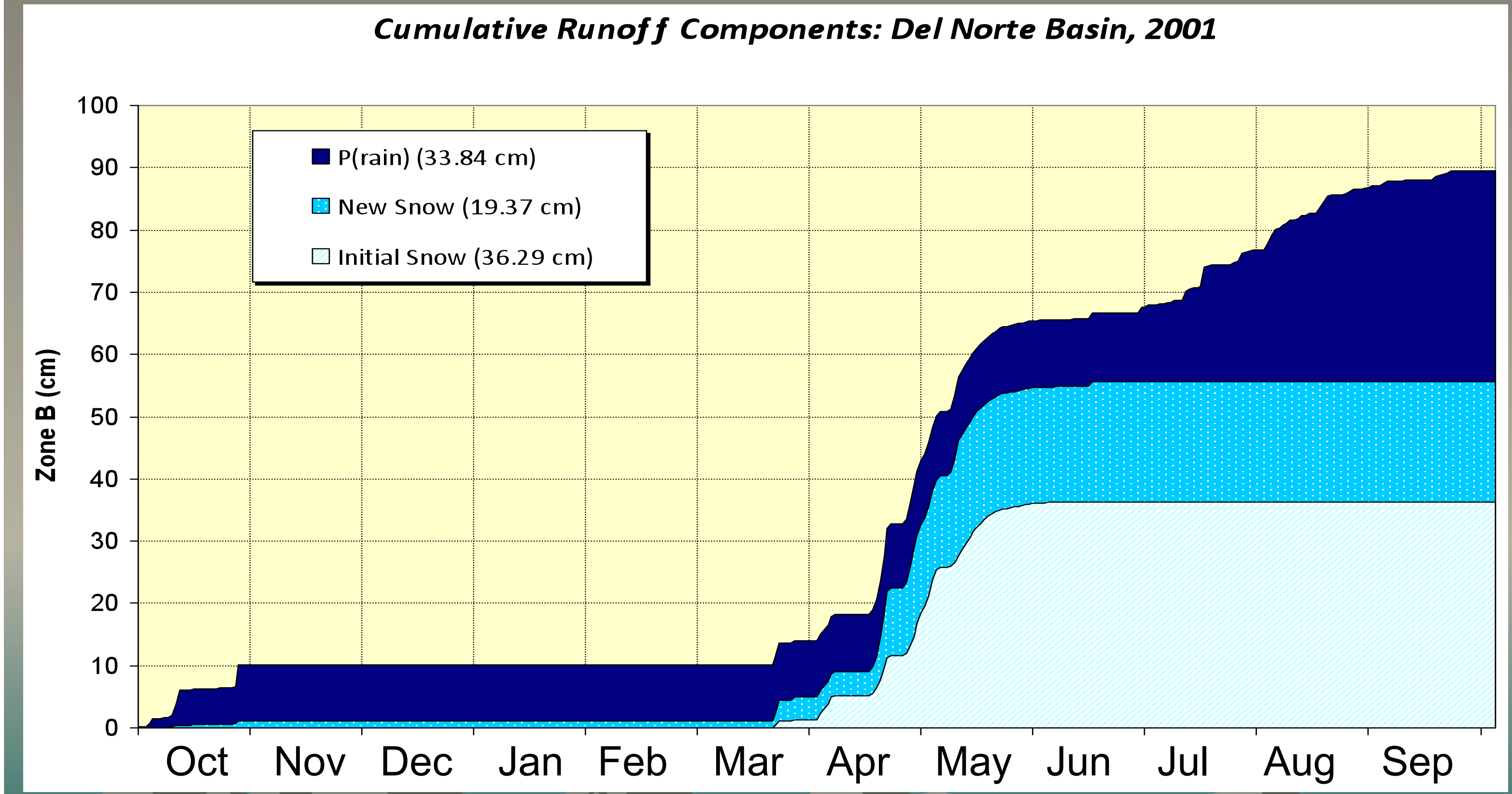
Depletion curves for TM-derived snow cover estimates adjusted for evergreen canopy cover



Runoff results after adjusting snow covered area for underestimates caused by evergreen canopy cover



SRM is capable of providing cumulative runoff components in Rio Grande near Del Norte, CO ($3415\ km^2$, 2636 – 4222 m), for example, 2001

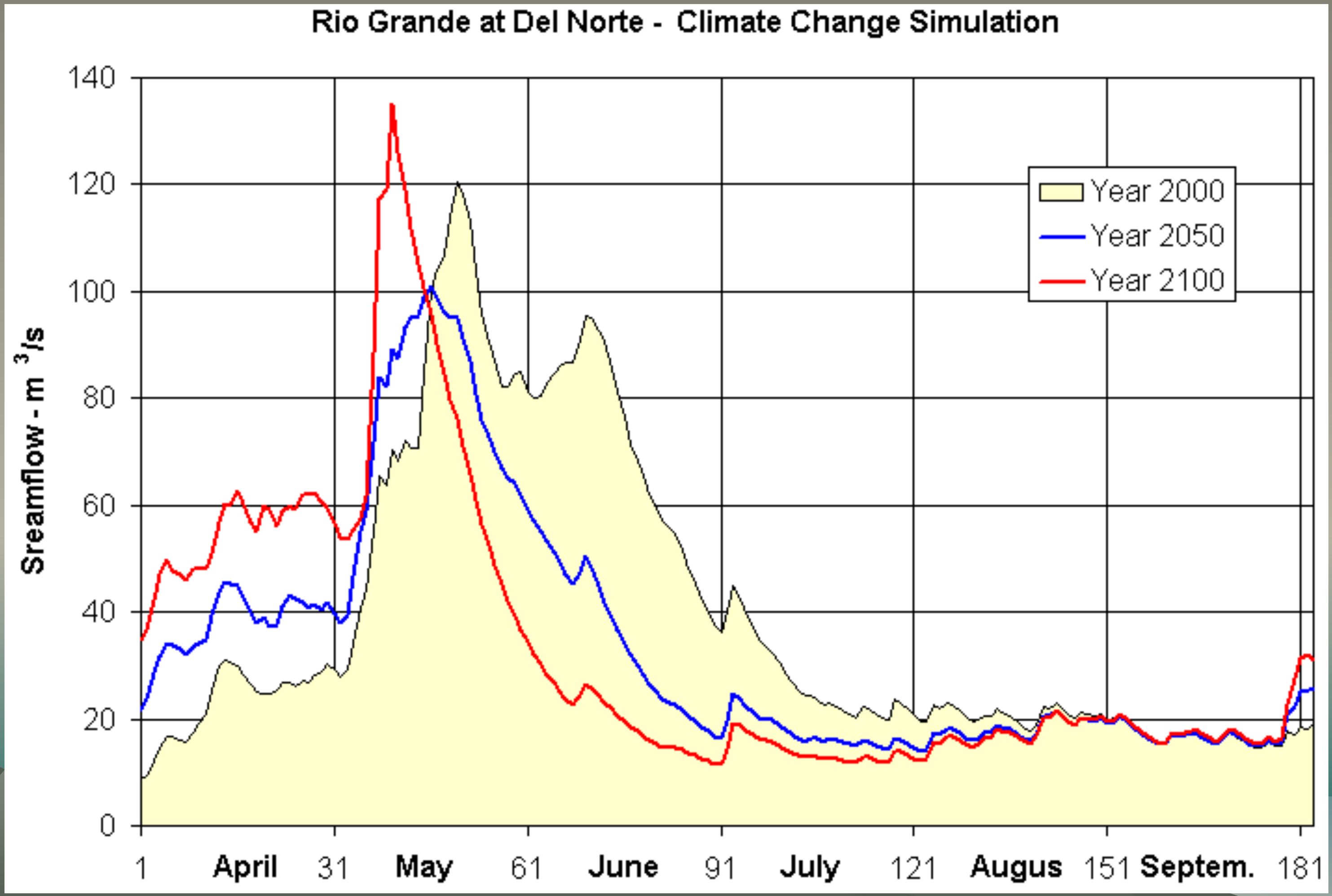


38% Rain

21% New Snow

41% Seasonal Snowpack

Climate change simulation Rio Grande at Del Norte with periodic changes throughout the 21st century. By 2100, temperature has increased by 4°C, the diurnal temperature range has decreased by 1.4°C, model parameters are shifted, and a 10% increase in precipitation is expected. SRM has a formalized climate change algorithm to assist the user.

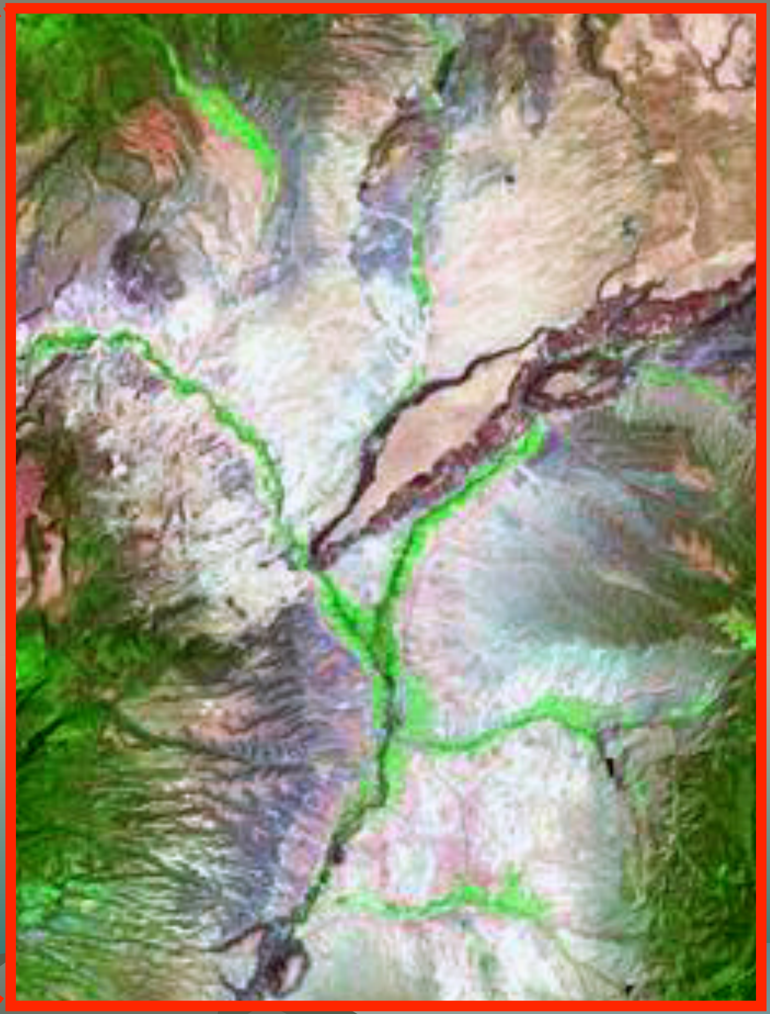


What we know so far about hydrologic responses to climate change

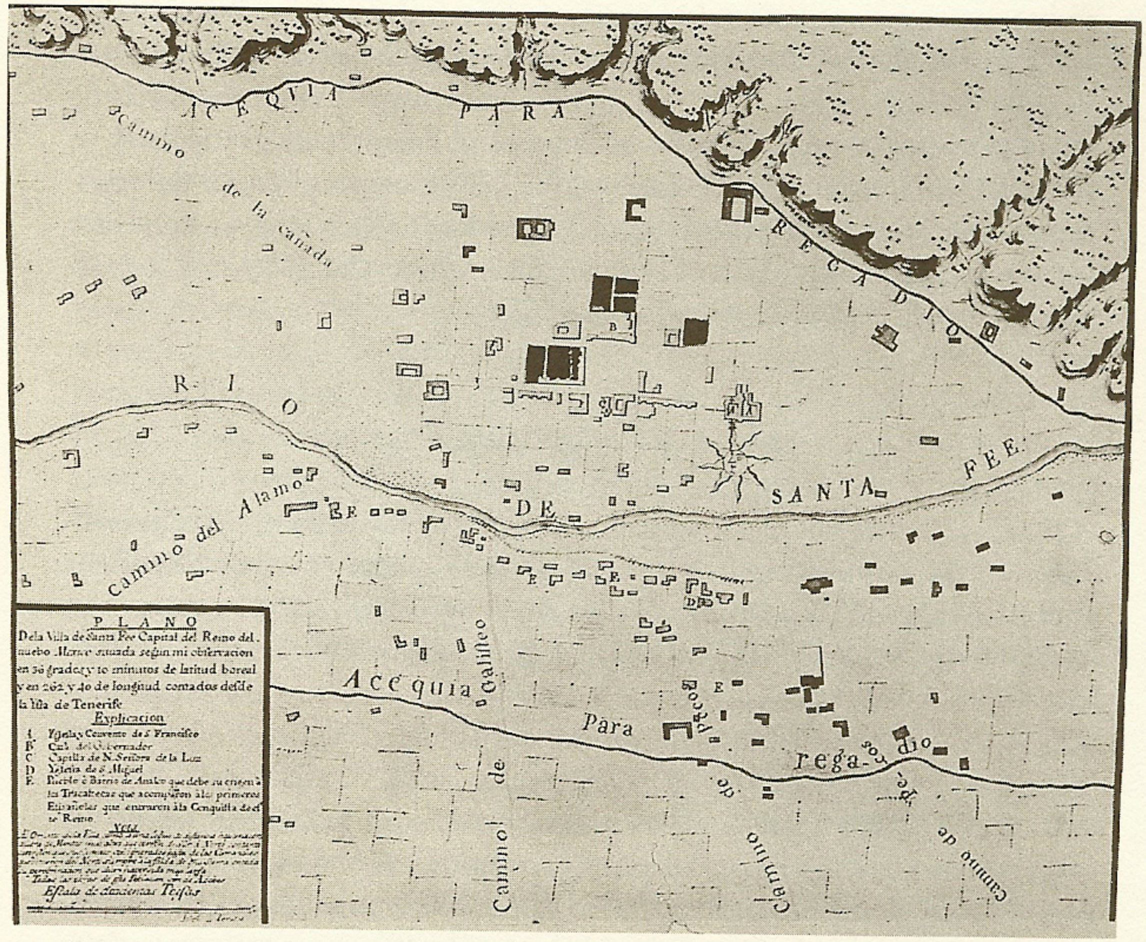
- In extreme years: a) droughts will be intensified and b) floods will become more common.
- The gap between water supply and water demand will grow even faster than it is now. Even without a volume reduction, the temporal redistribution of runoff will cause this. Acequias may be able to mitigate some of the temporal effect.
- GCM generated changes are required as inputs to hydrologic models, but it is difficult to come to a consensus on the climate changes to be expected for a particular basin. We are working with climatologist Dr. Dave Gutzler to produce climate scenarios for the next 100 years for our 25 sub basins.
- States like New Mexico will be the first to experience reduced runoff from mountain snowpacks and will be the first to need improved modeling to establish alternative approaches for use by water managers.
- Reservoir operating rules will have to change. Old and weakened water systems will fail. New or reinforced reservoirs and distribution systems will be needed.

Ribbons of green

- Irrigated river valleys are green swaths across arid regions
- In northern New Mexico, traditional acequias are the main irrigation systems



Acequias brought to New Mexico in 1500s by Spanish settlers



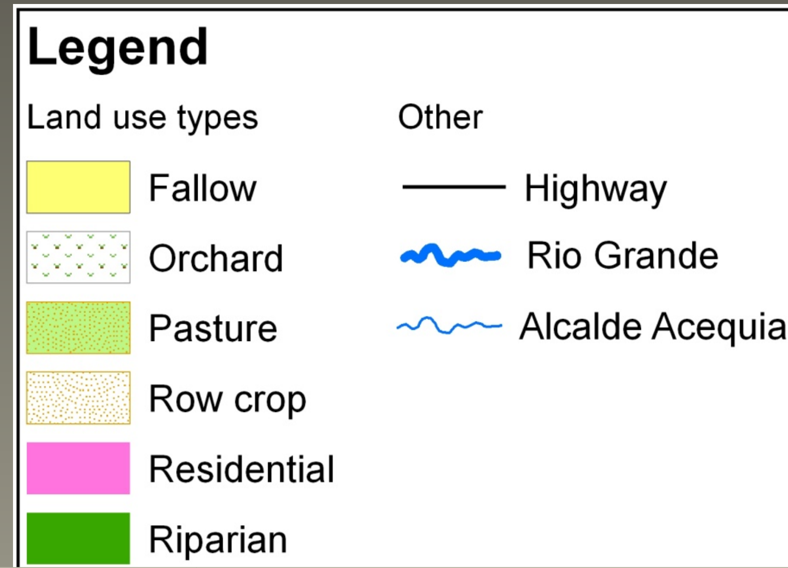
José de Urrutia's Map of Villa de Santa Fe, c. 1767, Depicting Town Layout and Acequias.
Courtesy Museum of New Mexico, Neg. No. 15048.

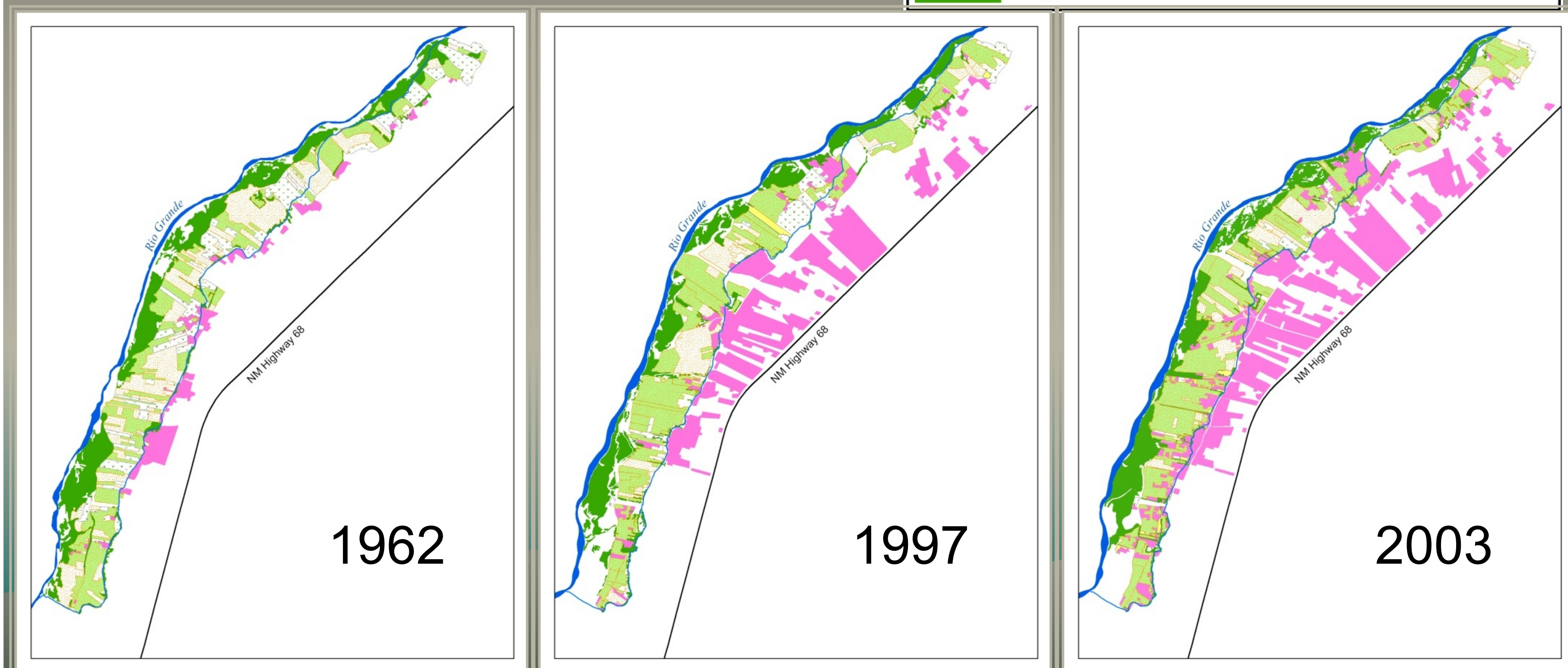
Acequias

- Ditch systems to irrigate fields
- Community acequia associations to allocate water
  - more for all in wet years
  - less for all in dry years

Threats to acequia systems

- Agricultural to residential land use
- Water transfers out of agriculture



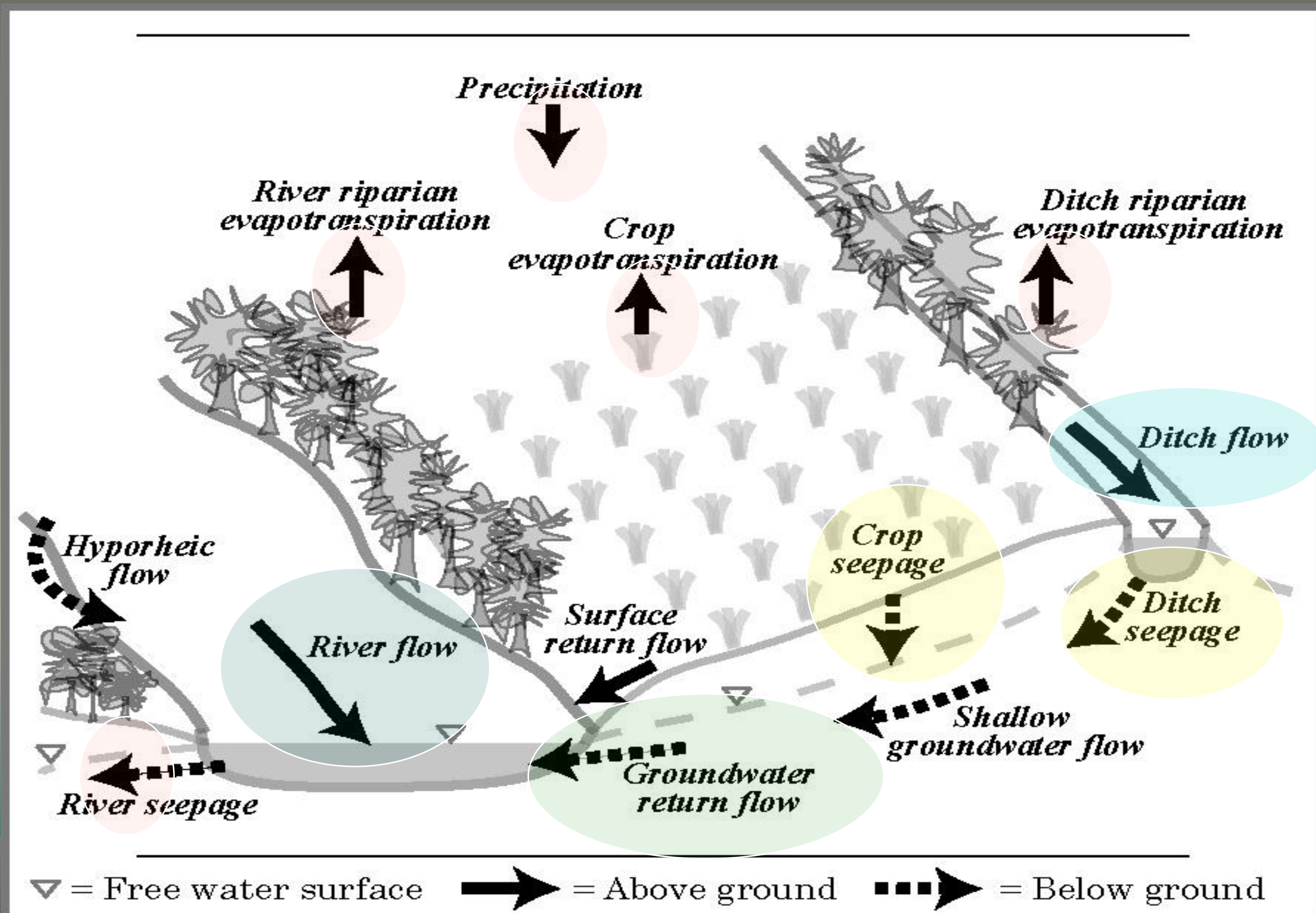


NMSU Acequia
Seepage research 2002-2009

Determine hydrologic, water quality, and ecosystem benefits of acequia system seepage

Alcalde acequia

Hydrologic budget approach



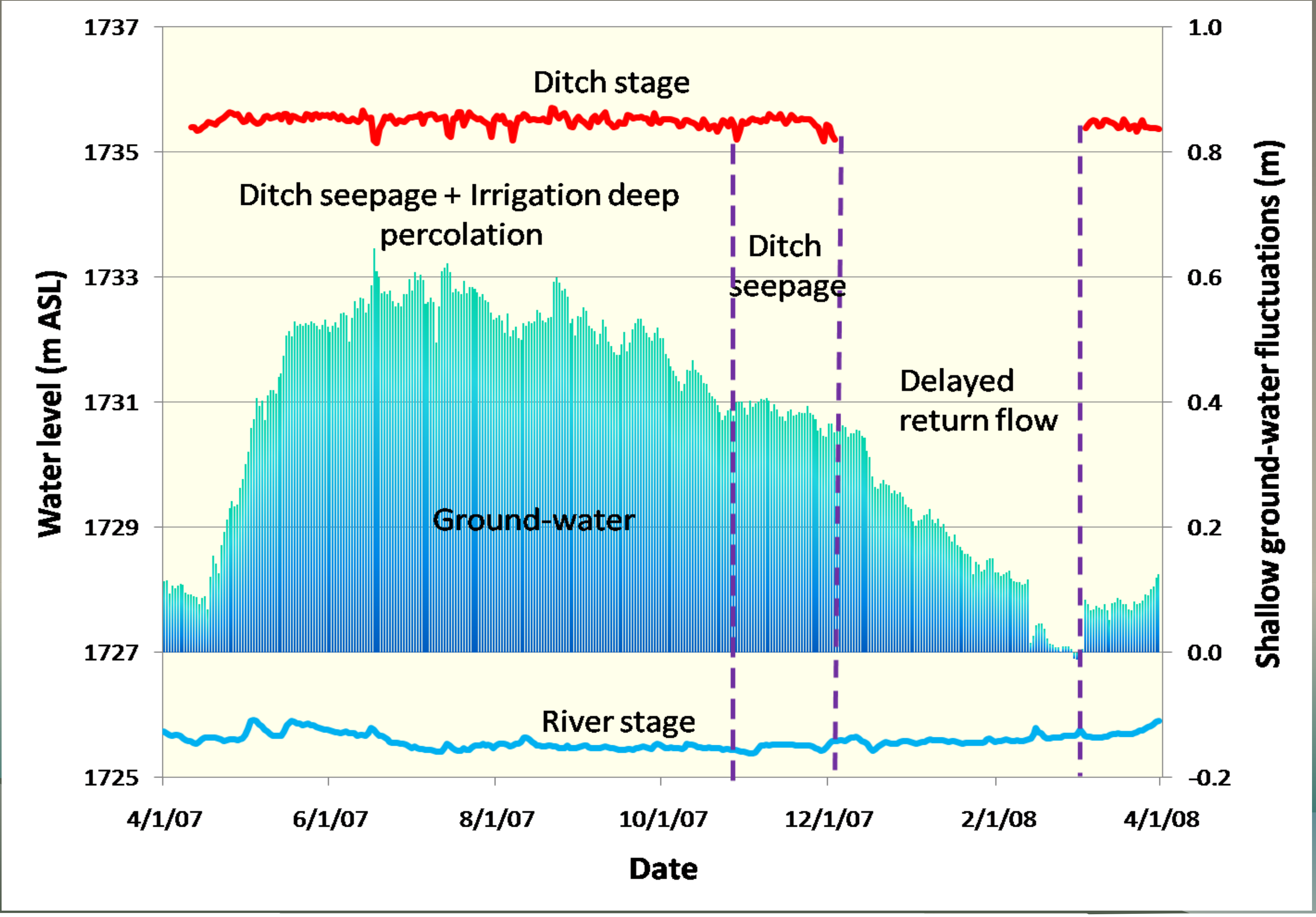
Water budget

Alcalde Acequia three year (2005-2007) averaged water balance.

Component		Amount from canal diversion (%)	Range (%)
Surface water return flow	Turnouts	9.5	0 to 14
	Crop field tailwater	8.9	0 to 19
	Canal outflow	40.9	28 to 67
Ground water return flow	Ditch seepage	12.1	5 to 17
	Deep percolation	21.2	9 to 32
Evapotranspiration		7.4	1 to 15
	Total	100.0	

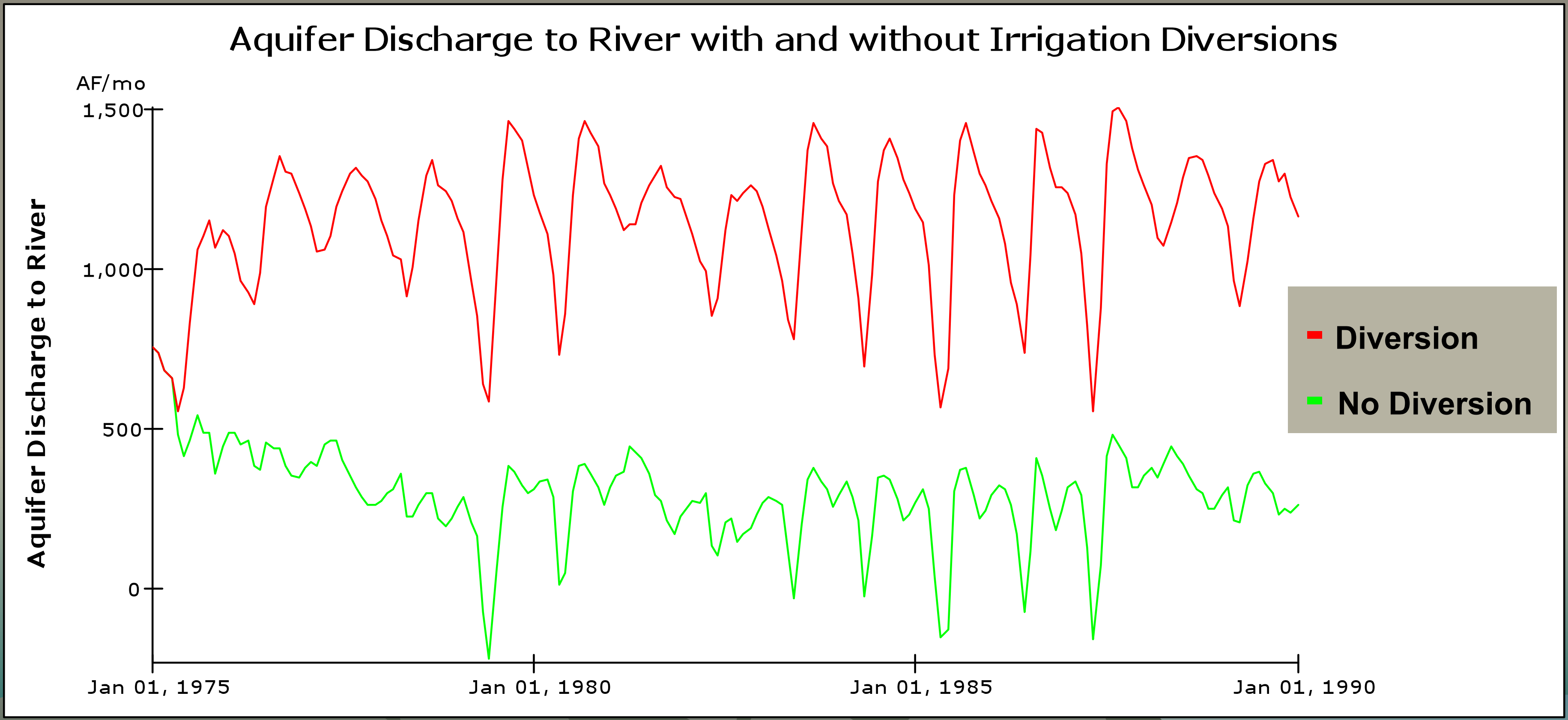
Surface water and ground-water interactions

A significant amount of delayed return flow is observed after the end of the ditch flow season.



System dynamics model future scenario testing

- The system dynamics model allows scenario testing of aquifer-river interactions with and without irrigation diversions.
- Aquifer discharge to the river is reduced without diversions.



NM EPSCoR Acequia Hydrology and Socio-economics 2008-2013
NMSU, UNM, NM Tech, Sandia

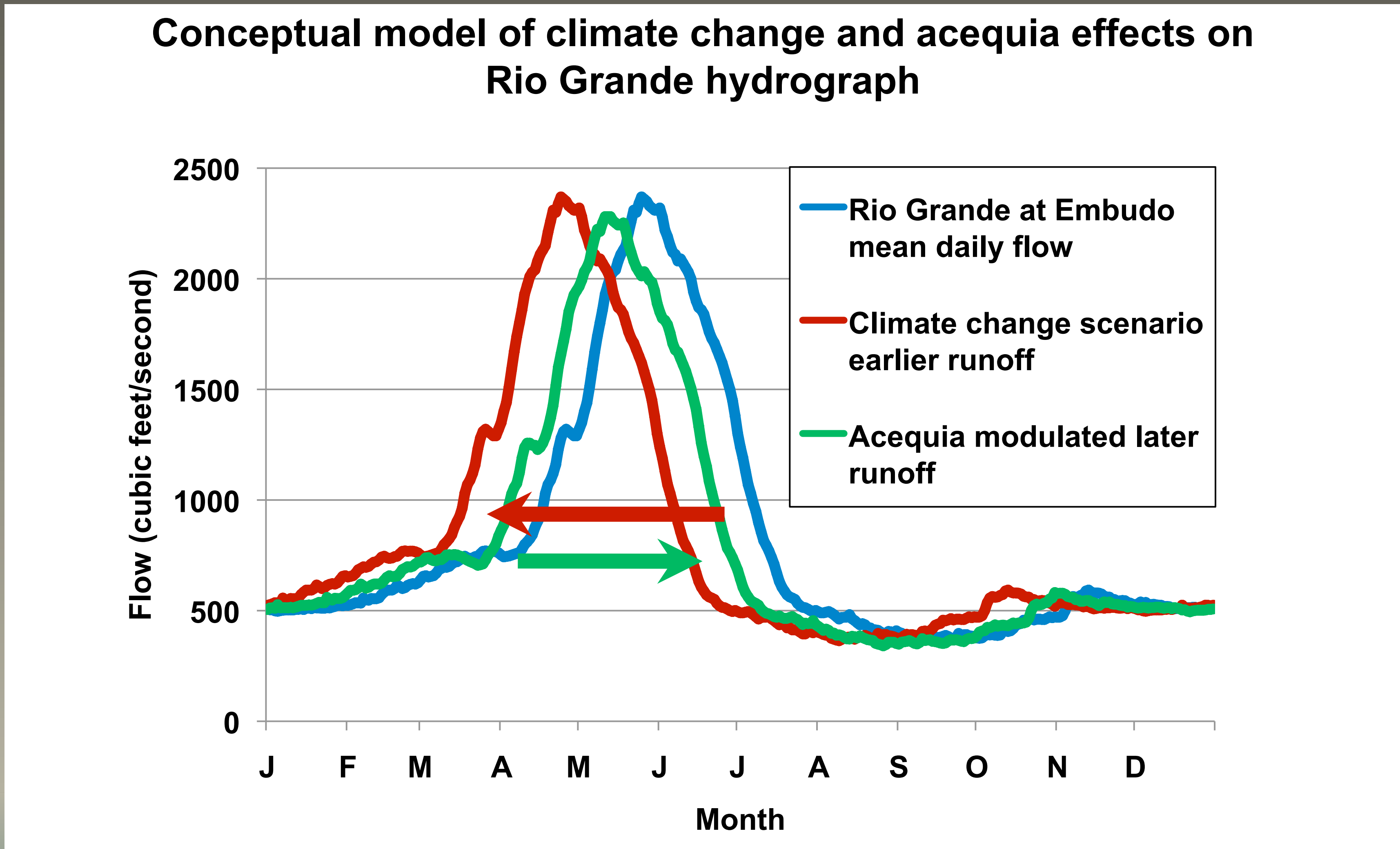
Measurement infrastructure

- Flow of river and acequias
  - stilling wells and flumes
- Weather parameters
  - central weather station (temperature, rain, wind, etc.)
- Soil moisture
  - various soil moisture stations located in representative fields in region
- Groundwater table
  - Sensors placed in wells in region

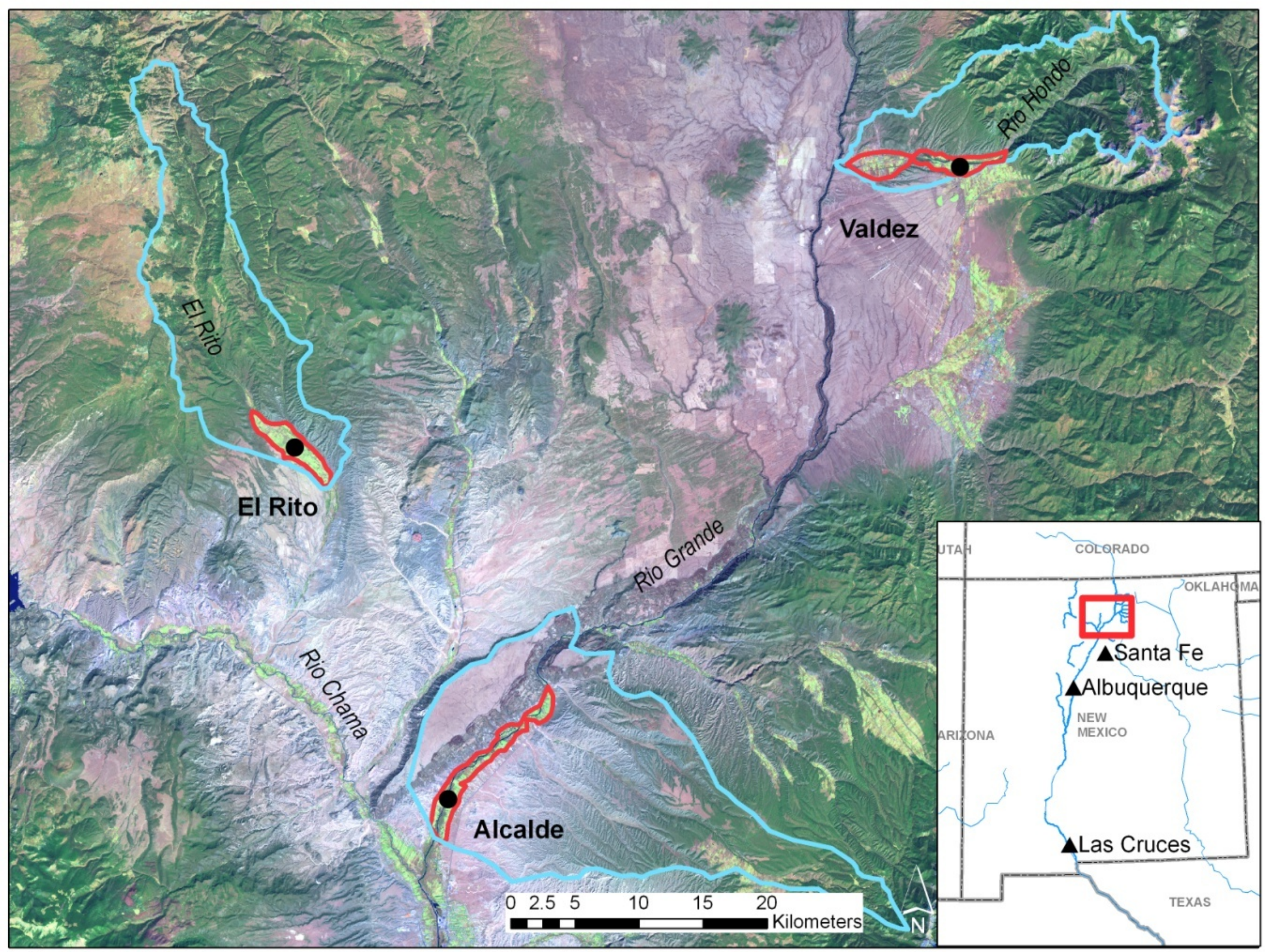
Student involvement

2010 UROP summer research team

- Olijahwon Hosteen
- William Morgan
- Heather Wade

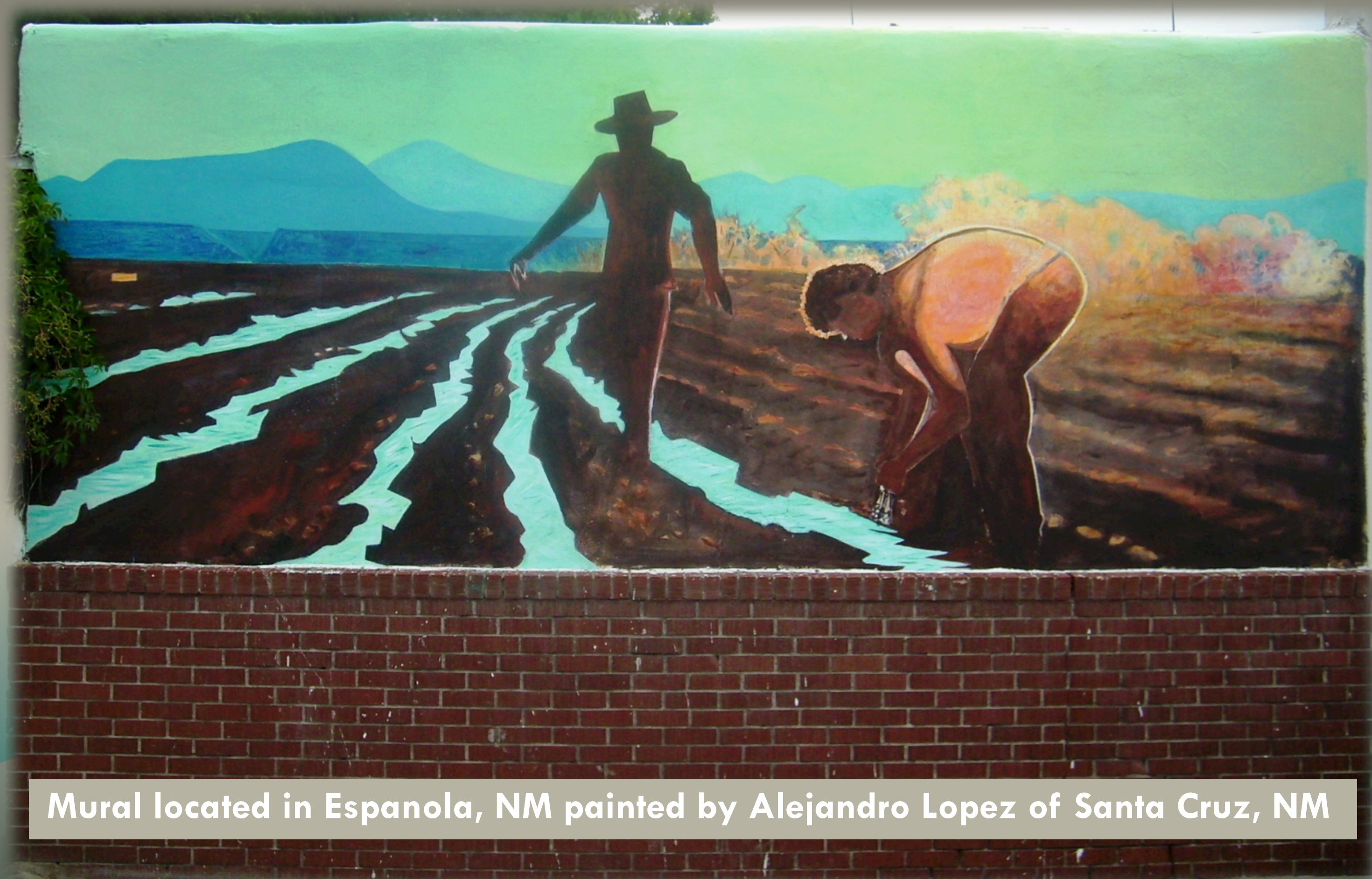


At a regional scale, the acequia surface-groundwater interactions may ameliorate effects of climate variability by delaying spring runoff that is projected to be earlier in the year



Study communities (black circles), associated irrigated valleys (red lines), and contributing watersheds (blue lines)

NSF coupled natural and human systems
"acequia water systems linking culture and nature: integrated analysis of community resilience to climate and land use changes"
2010-2015



Mural located in Espanola, NM painted by Alejandro Lopez of Santa Cruz, NM

Acequias linking culture and nature

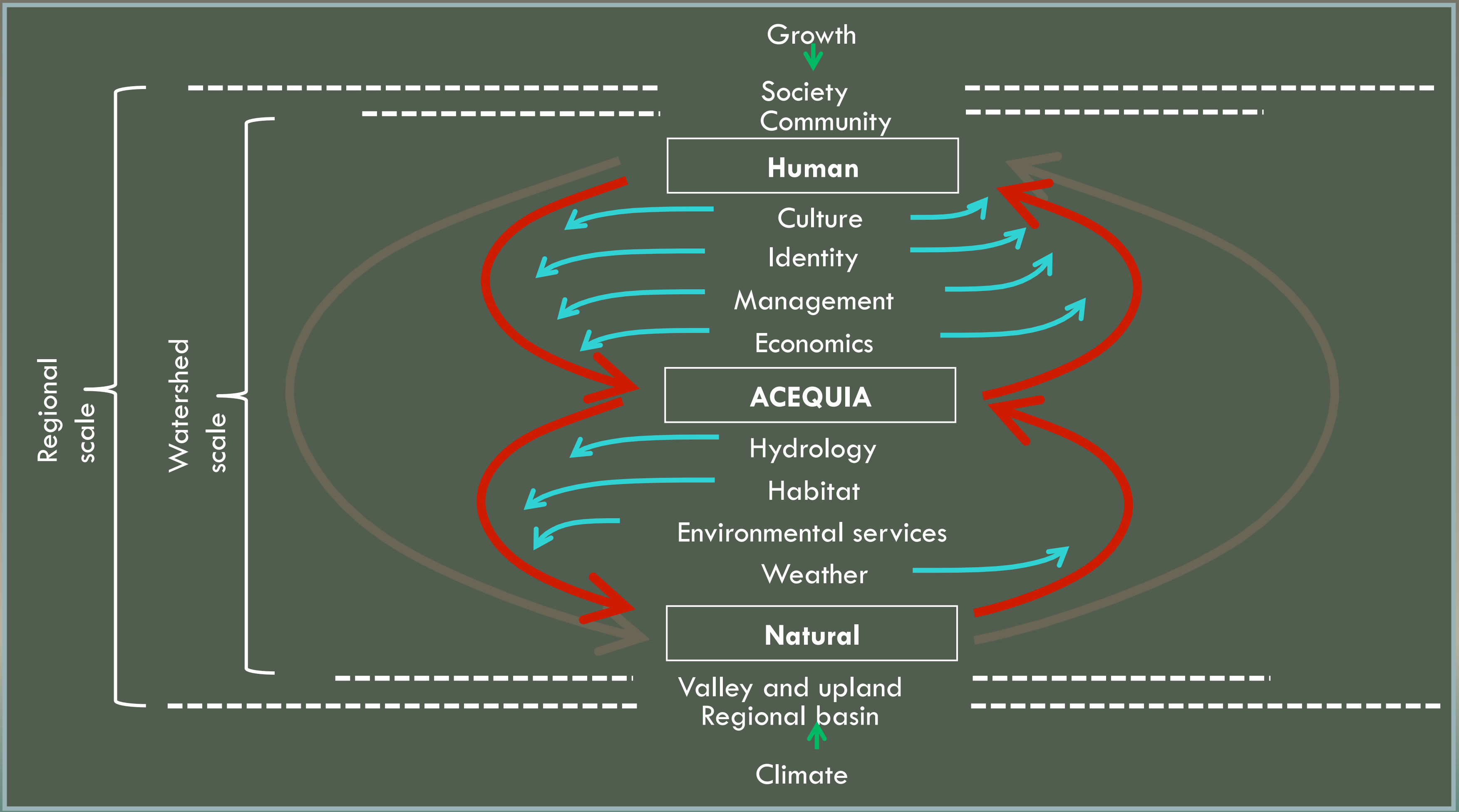


Figure 1. Causal flow chart with human and natural linkages through an acequia.

Acequia hydrology conclusions:

1. Large flows are rapidly exchanged between river, irrigation system, and fluvial aquifer.
2. A significant amount of water being diverted into the valley returns back to the river after completing important production and ecological tasks.
3. The irrigation systems collectively take spring and summer runoff from the river and retransmit the flow to later in the year through seepage and groundwater return flow.
4. Storage underground for 1-3 months should save water at a regional scale by reducing evapotranspiration losses.