*Center for Snow and Avalanche Studies*
*Silverton, Colorado*

*Chris Landry*

*www.snowstudies.org*

***Proposed***

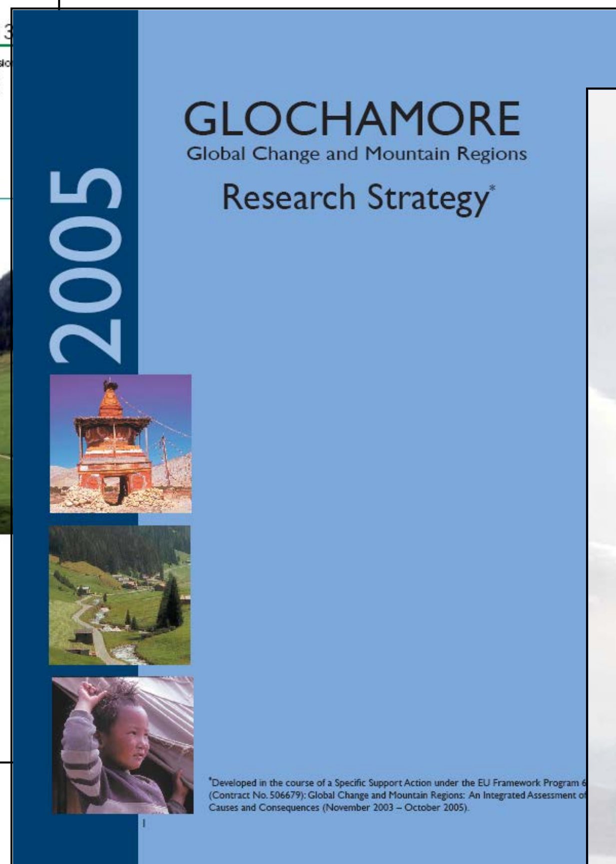
# "Alpine to Arid"
# Hydrologic & Ecological Observatory

**Uncompahgre River Watershed - San Juan Mountains, Colorado**

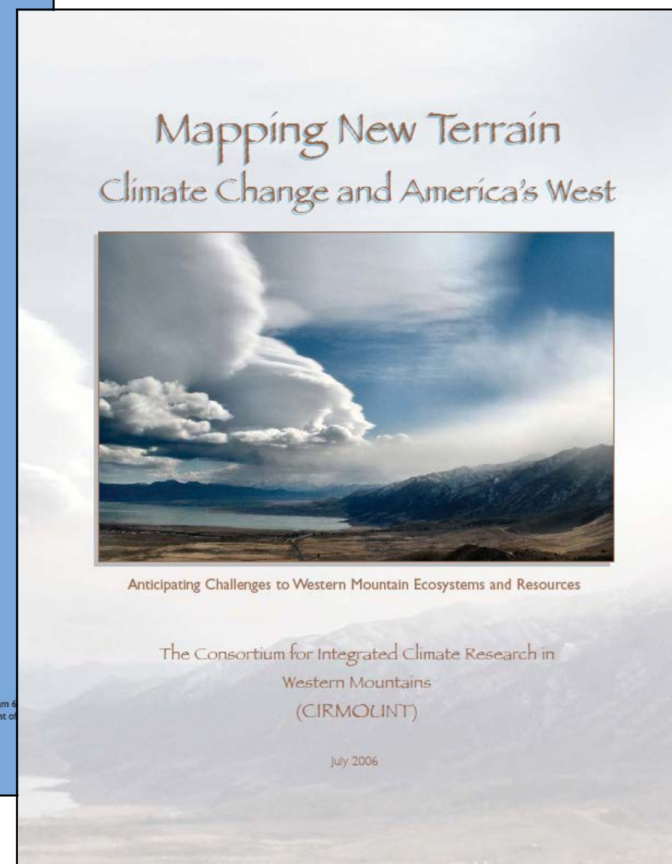
# Conducting Long-Term Mountain System Monitoring

**2001**


**2005**




**2006**



# Mountain Observatory Research and Monitoring Themes:

**Bales** et al. (2006) priorities for improving hydrologic understanding:

“ … to better understand the processes controlling the partitioning of energy and water fluxes within and out from these systems …”

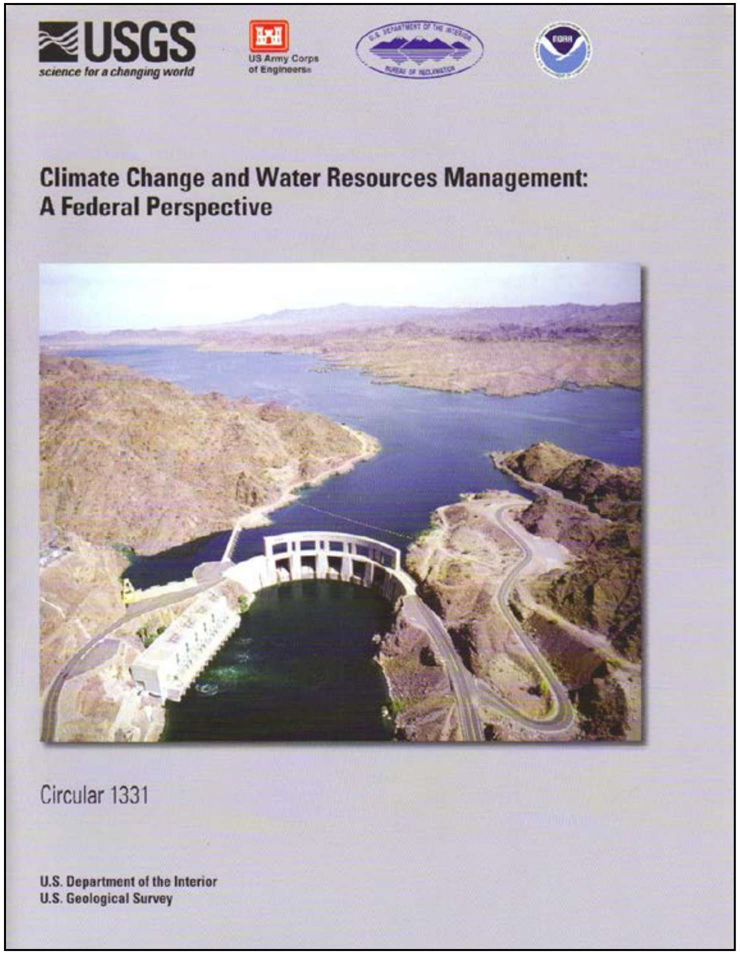
“ … to better understand feedbacks between hydrologic fluxes and biogeochemical and ecological processes …”

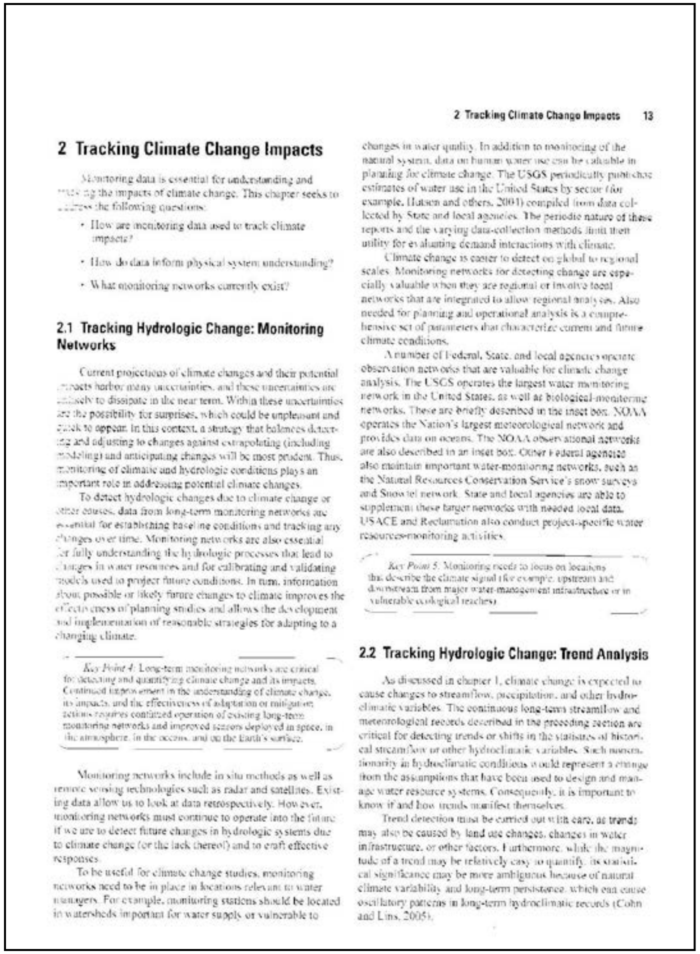
**GLOCHAMORE** Research Strategy (2005): Socio-economic questions are integrated with physical process questions.

**CIRMOUNT**, in Mapping New Terrain (2006): water supply, forest dieback, urban-wildland issues, wildfire, and biodiversity and wildlife.

**NEON** (2010): expand measurements of environmental variability and gather ecological data along elevation, precipitation, and land-use gradients.

# DOI-USGS Circular 1331 - 2009



2 Tracking Climate Change Impacts 13

## 2 Tracking Climate Change Impacts

Monitoring data is essential for understanding and tracking the impacts of climate change. This chapter seeks to address the following questions:

- How are monitoring data used to track climate impacts?
- How do data inform physical system understanding?
- What monitoring networks currently exist?

### 2.1 Tracking Hydrologic Change: Monitoring Networks

Current projections of climate changes and their potential impacts harbor many uncertainties, and these uncertainties are unlikely to dissipate in the near term. Within these uncertainties are the possibility for surprises, which could be unpleasant and quick to appear. In this context, a strategy that balances detecting and adjusting to changes against extrapolating (including modeling) and anticipating changes will be most prudent. Thus, monitoring of climatic and hydrologic conditions plays an important role in addressing potential climate changes.

To detect hydrologic changes due to climate change or other causes, data from long-term monitoring networks are essential for establishing baseline conditions and tracking any changes over time. Monitoring networks are also essential for fully understanding the hydrologic processes that lead to changes in water resources and for calibrating and validating models used to project future conditions. In turn, information about possible or likely future changes to climate improves the effectiveness of planning studies and allows the development and implementation of reasonable strategies for adapting to a changing climate.

*Key Point 4:* Long-term monitoring networks are critical for detecting and quantifying climate change and its impacts. Continued improvement in the understanding of climate change, its impacts, and the effectiveness of adaptation or mitigation actions requires continued operation of existing long-term monitoring networks and improved sensors deployed in space, in the atmosphere, in the oceans, and on the Earth's surface.

Monitoring networks include in situ methods as well as remote sensing technologies such as radar and satellites. Existing data allow us to look at data retrospectively. However, monitoring networks must continue to operate into the future if we are to detect future changes in hydrologic systems due to climate change (or the lack thereof) and to craft effective responses.

To be useful for climate change studies, monitoring networks need to be in place in locations relevant to water managers. For example, monitoring stations should be located in watersheds important for water supply or vulnerable to changes in water quality. In addition to monitoring of the natural system, data on human water use can be valuable in planning for climate change. The USGS periodically publishes estimates of water use in the United States by sector (for example, Hutson and others, 2004) compiled from data collected by State and local agencies. The periodic nature of these reports and the varying data-collection methods limit their utility for evaluating demand interactions with climate.

Climate change is easier to detect on global to regional scales. Monitoring networks for detecting change are especially valuable when they are regional or involve local networks that are integrated to allow regional analyses. Also needed for planning and operational analysis is a comprehensive set of parameters that characterize current and future climate conditions.

A number of Federal, State, and local agencies operate observation networks that are valuable for climate change analysis. The USGS operates the largest water monitoring network in the United States, as well as biological-monitoring networks. These are briefly described in the inset box. NOAA operates the Nation's largest meteorological network and provides data on oceans. The NOAA observational networks are also described in an inset box. Other Federal agencies also maintain important water-monitoring networks, such as the Natural Resources Conservation Service's snow surveys and Snowtel network. State and local agencies are able to supplement these larger networks with needed local data. USACE and Reclamation also conduct project-specific water resources-monitoring activities.

*Key Point 5:* Monitoring needs to focus on locations that describe the climate signal (for example, upstream and downstream from major water-management infrastructure or in vulnerable ecological reaches).

### 2.2 Tracking Hydrologic Change: Trend Analysis

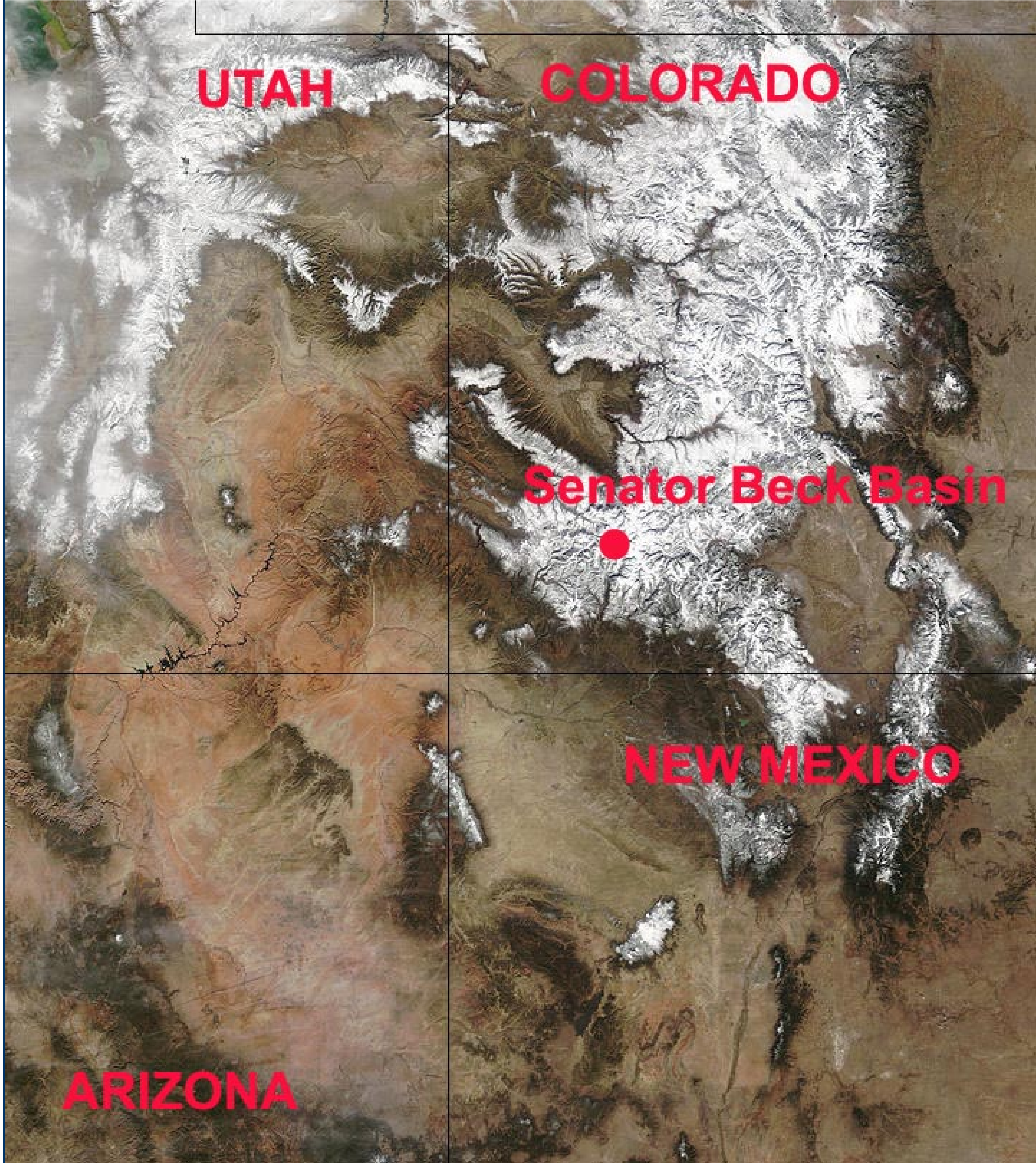
As discussed in chapter 1, climate change is expected to cause changes to streamflow, precipitation, and other hydroclimatic variables. The continuous long-term streamflow and meteorological records described in the preceding section are critical for detecting trends or shifts in the statistics of historical streamflow or other hydroclimatic variables. Such nonstationarity in hydroclimatic conditions would represent a change from the assumptions that have been used to design and manage water resource systems. Consequently, it is important to know if and how trends manifest themselves.

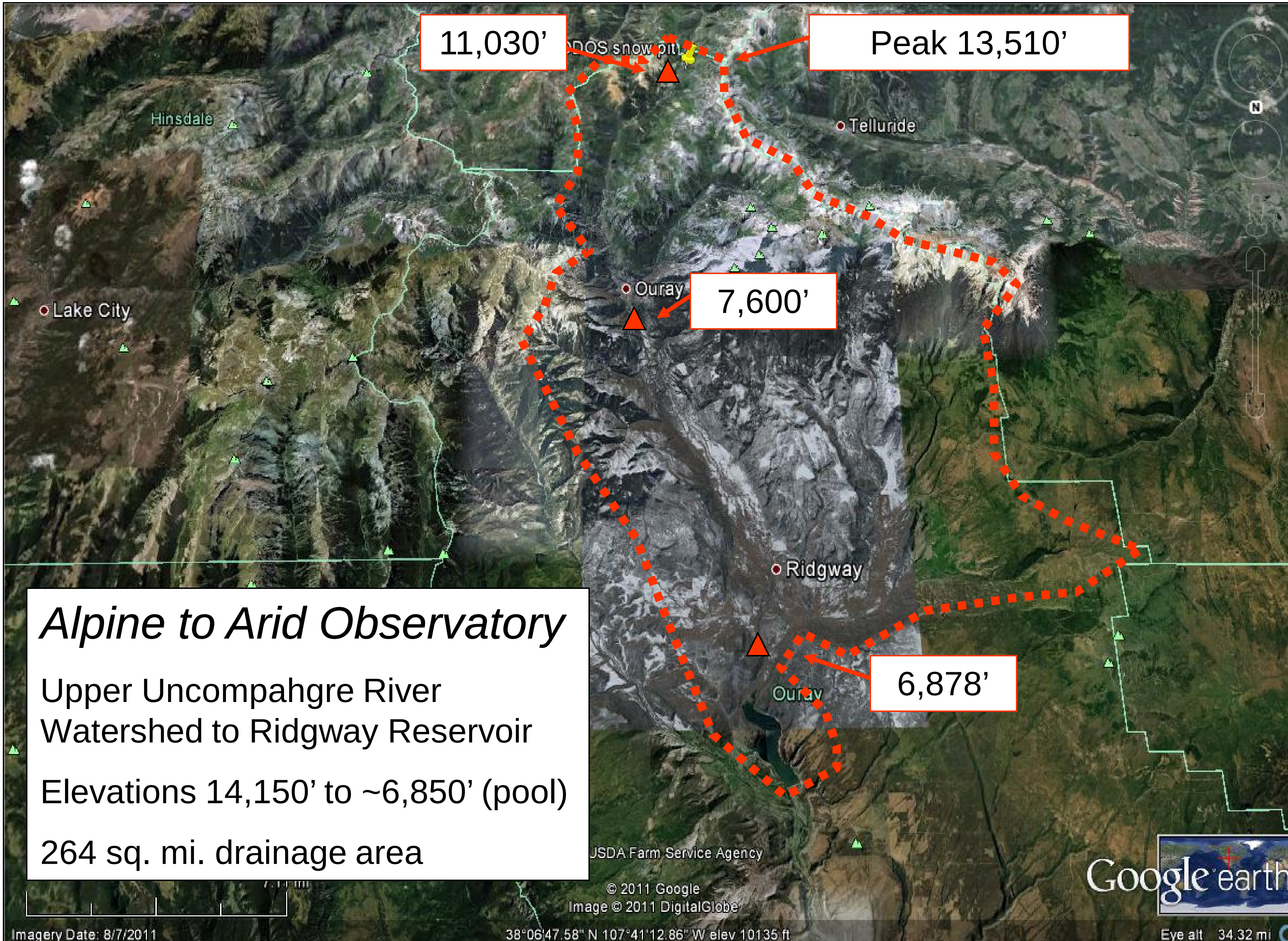
Trend detection must be carried out with care, as trends may also be caused by land use changes, changes in water infrastructure, or other factors. Furthermore, while the magnitude of a trend may be relatively easy to quantify, its statistical significance may be more ambiguous because of natural climate variability and long-term persistence, which can cause oscillatory patterns in long-term hydroclimatic records (Cohn and Lins, 2005).

**Sec. 2**: …monitoring needs to focus on locations that describe the climate signal …

Senator Beck Basin
& Uncompahgre
Watershed

Sentry Site for
Upper Colorado
River Basin
Climate Change

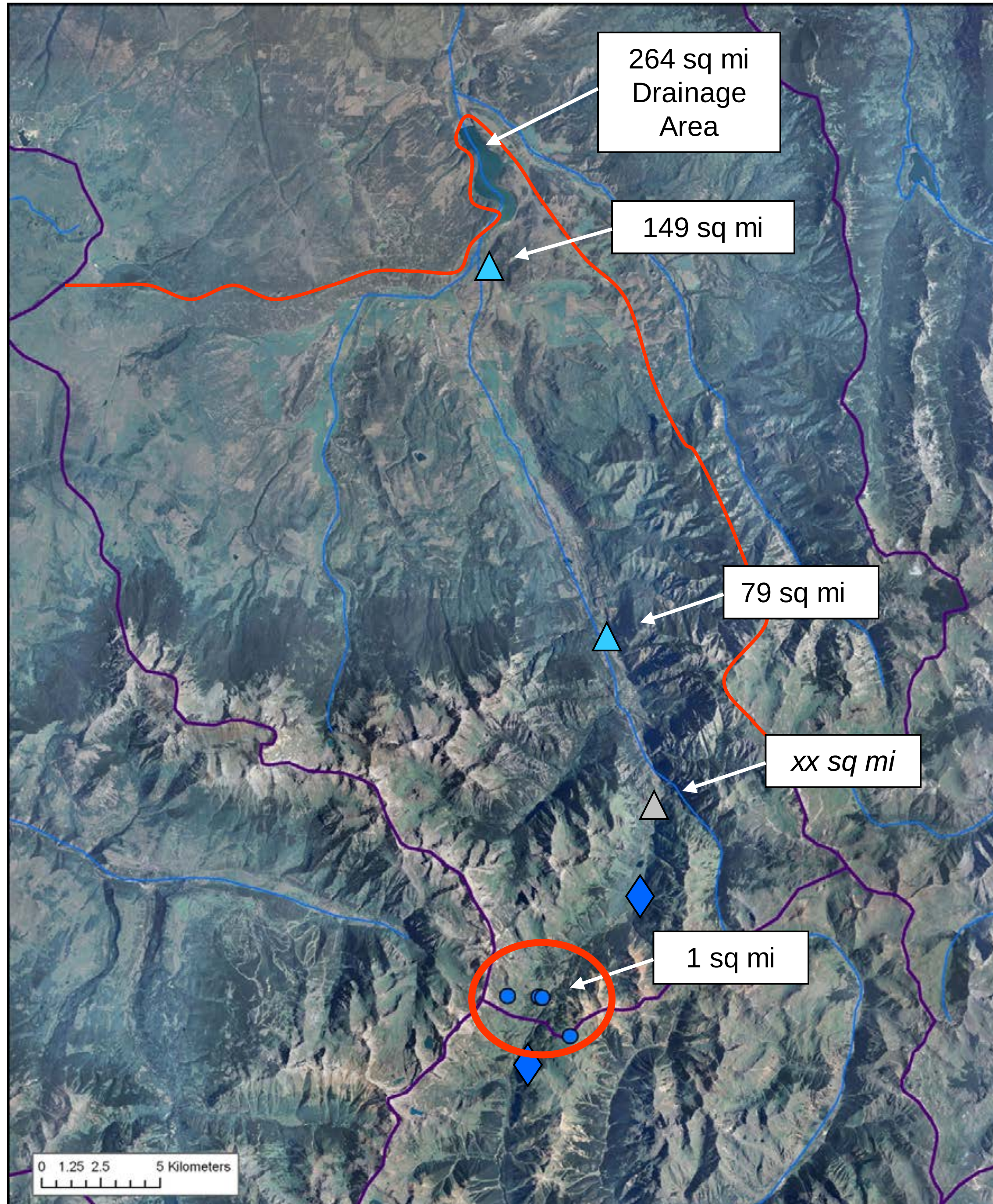


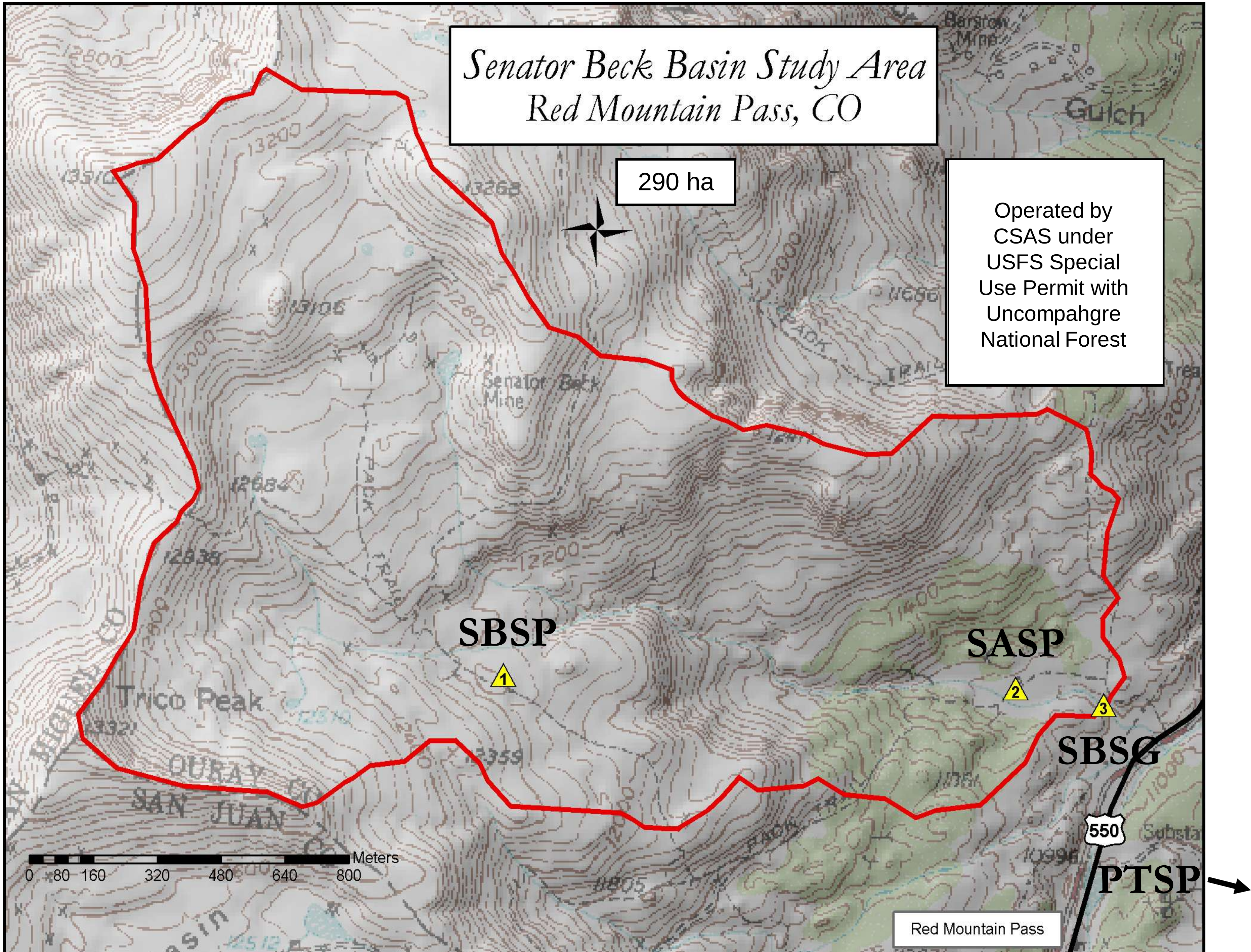


11,030’
DOS snow pit
Peak 13,510’
Hinsdale
Telluride
Ouray
7,600’
Lake City
Ridgway
6,878’
Ouray
Alpine to Arid Observatory
Upper Uncompahgre River
Watershed to Ridgway Reservoir
Elevations 14,150’ to ~6,850’ (pool)
264 sq. mi. drainage area
USDA Farm Service Agency
© 2011 Google
Image © 2011 DigitalGlobe
Google earth
Imagery Date: 8/7/2011
38°06'47.58" N 107°41'12.86" W elev 10135 ft
Eye alt 34.32 mi

# Existing Infrastructure

98,000 acre feet annual inflow at Ridgway Reservoir




Senator Beck Basin Study Area
Red Mountain Pass, CO
290 ha
Operated by CSAS under USFS Special Use Permit with Uncompahgre National Forest
SBSP
SASP
SBSG
PTSP
550
Senator Beck Mine
Trico Peak
Red Mountain Pass
0 80 160 320 480 640 800 Meters


# SASP Instrumentation

6 m Mast

Campbell CR10X Dataloggers (2), Multiplexer (1)

Campbell Precipitation Gauge

Wind Speed & Direction (2)

Air Temp and RH (2)

Barometric Pressure

Height of Snow

Broadband SW (2 up, 1 down, shadow array)

NIR SW (1 up, 1 down)

Pyrgeometer (1 up)

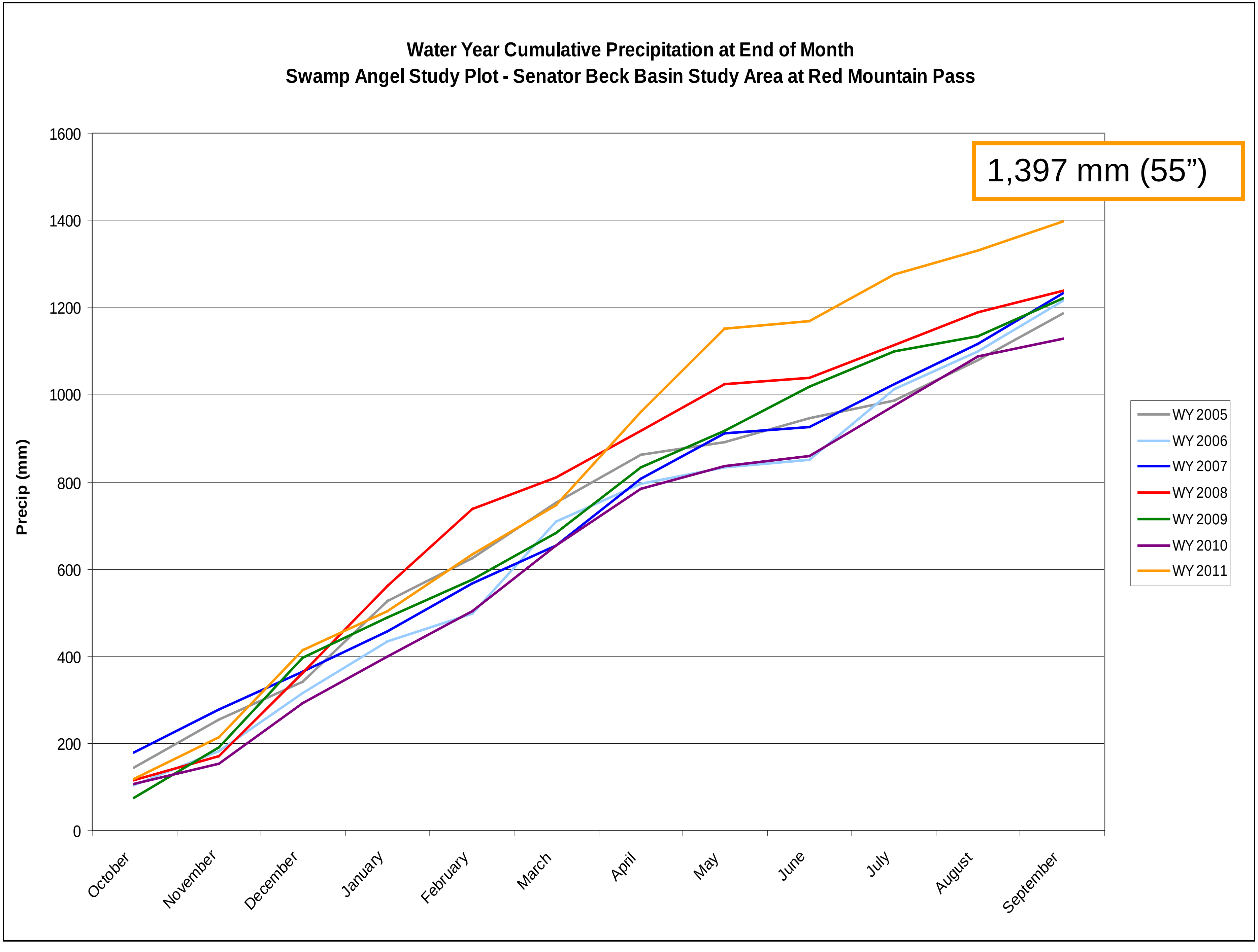
Infrared Snow Surface Temp

Snow Temperature (5)

Soil Temperature (4)

Soil Volumetric Water Content

Soil Heat Flux


Water Year Cumulative Precipitation at End of Month
Swamp Angel Study Plot - Senator Beck Basin Study Area at Red Mountain Pass
1,397 mm (55")
Precip (mm)
0
200
400
600
800
1000
1200
1400
1600
October
November
December
January
February
March
April
May
June
July
August
September
WY 2005
WY 2006
WY 2007
WY 2008
WY 2009
WY 2010
WY 2011


# SBSP Instrumentation

10 m Mast

Campbell CR10X Dataloggers (2), Multiplexer (1)

Wind Speed & Direction (2)

Air Temp and RH (2)

Height of Snow

Broadband SW (2 up, 1 down, shadow array)

NIR SW (1 up, 1 down)

Pyrgeometer (1 up)

Infrared Snow Surface Temp

Snow Temperature (5)

Snow Wetness Sensor

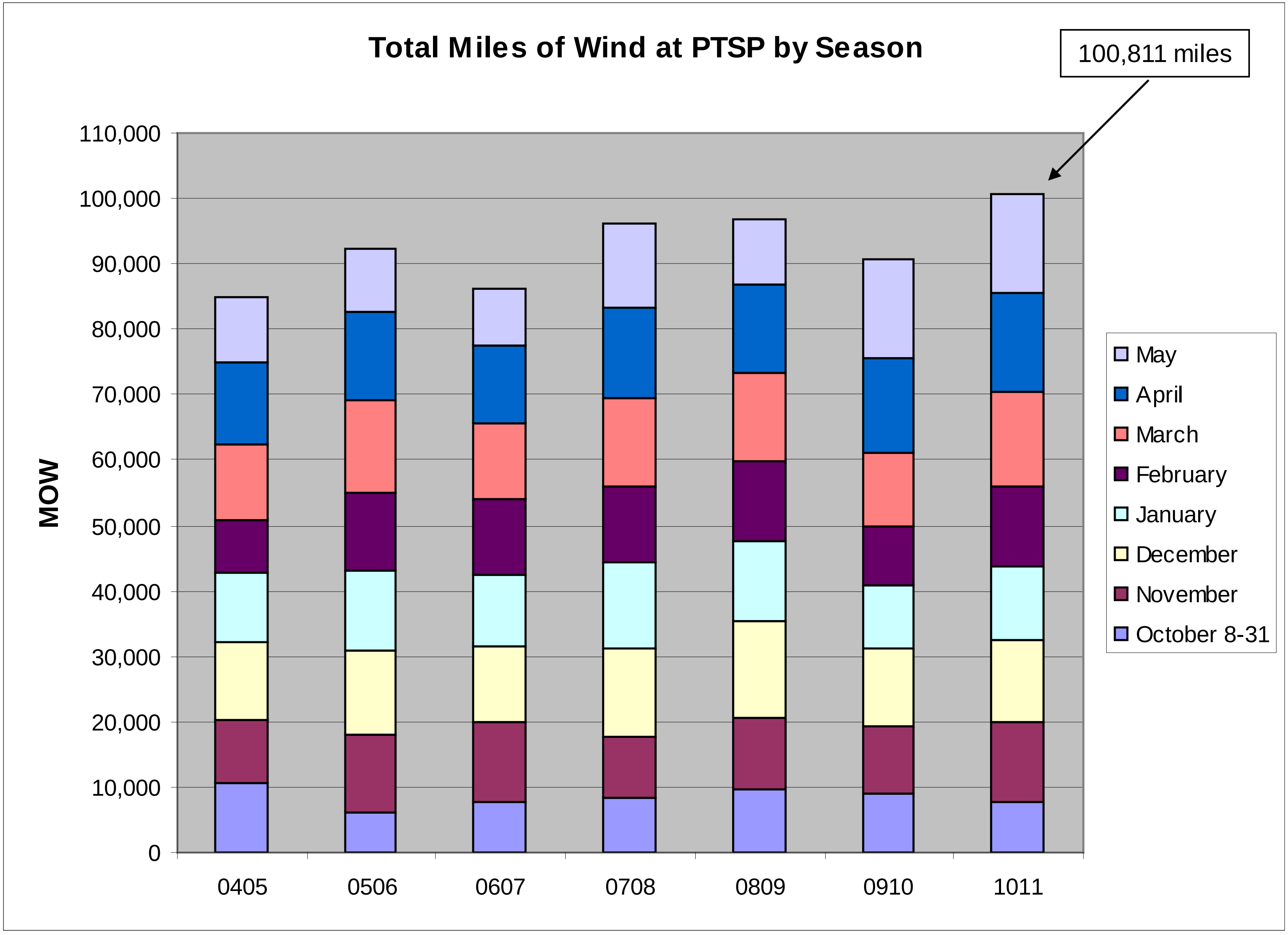
Soil Temperature (4)

Soil Volumetric Water Content

Soil Heat Flux


# PTSP Instrumentation

10 m Mast
Campbell CR10X Datalogger
Wind Speed & Direction
Air Temp and RH


Total Miles of Wind at PTSP by Season
100,811 miles
MOW
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0405
0506
0607
0708
0809
0910
1011
May
April
March
February
January
December
November
October 8-31

# SBSG

Broad-crested, notched weir

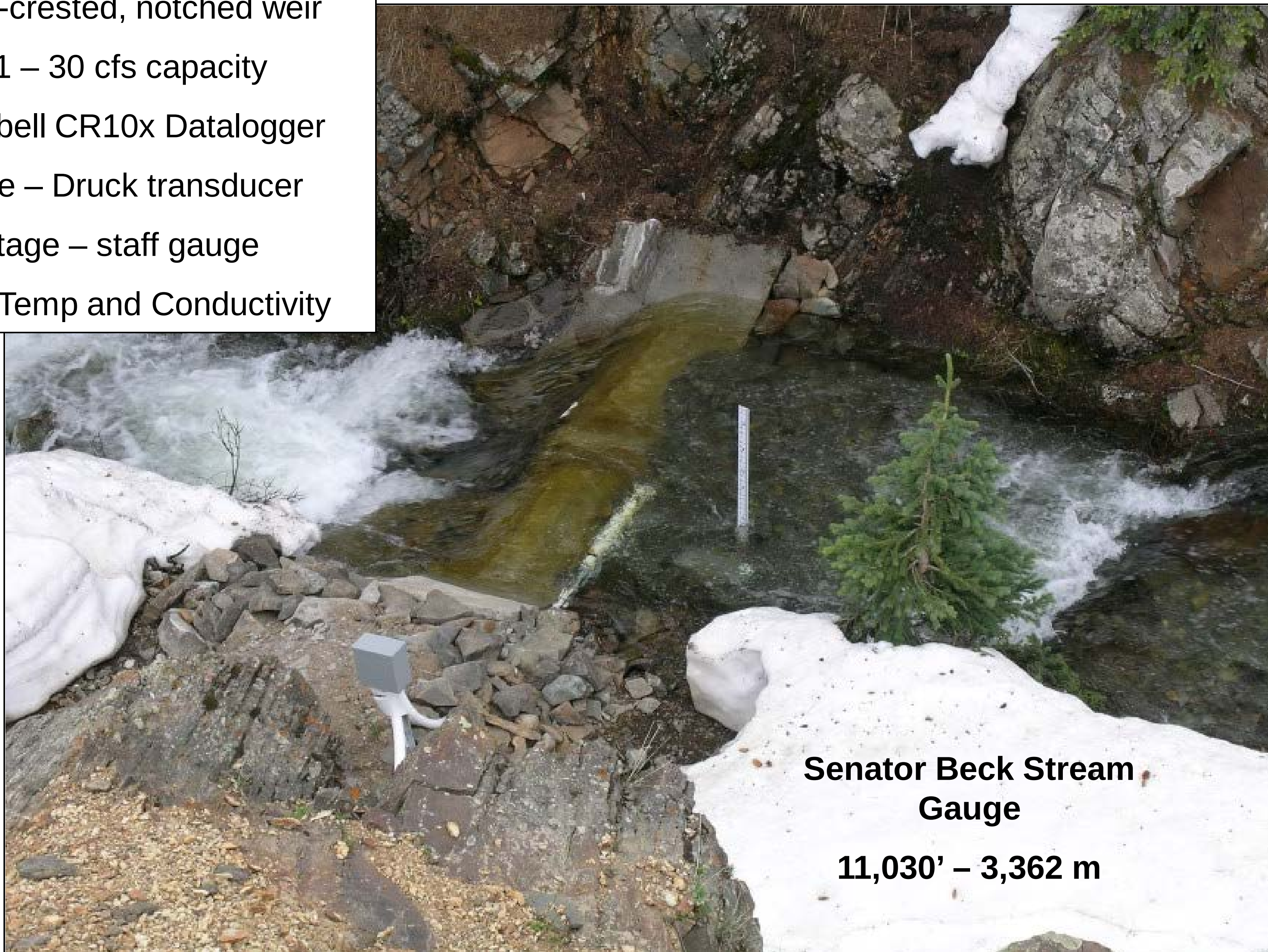
0.1 – 30 cfs capacity

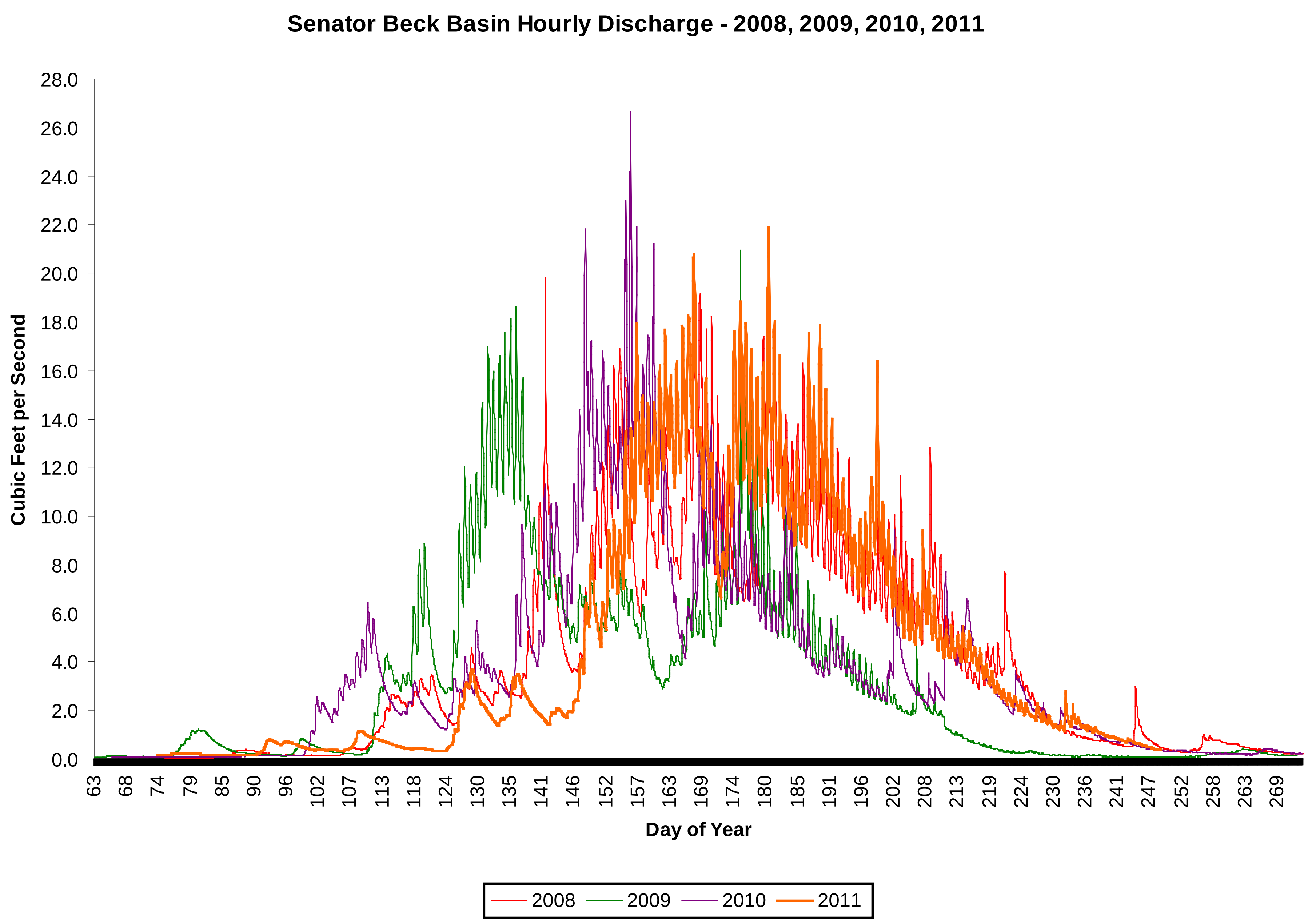
Campbell CR10x Datalogger

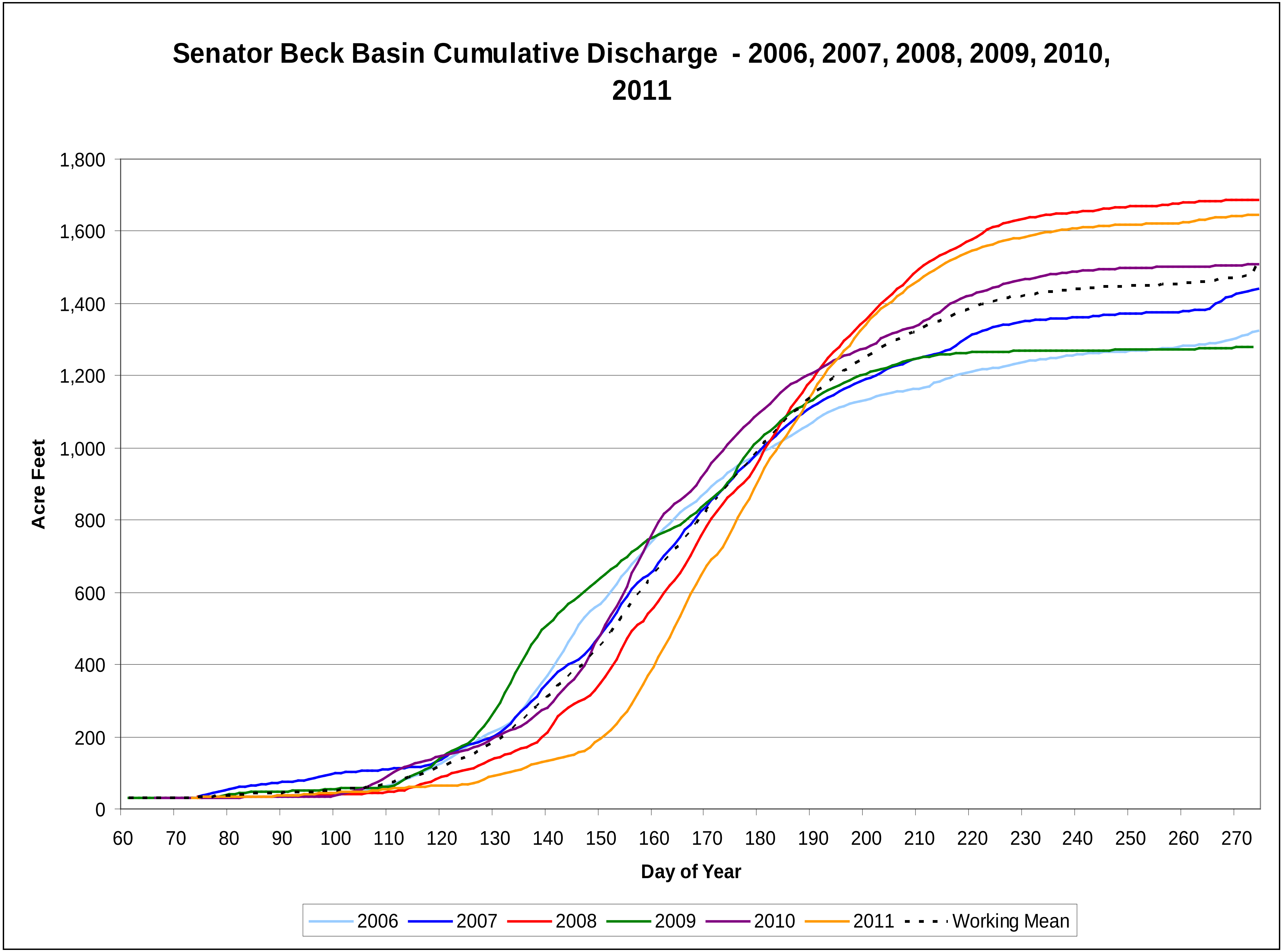
Stage – Druck transducer

Stage – staff gauge

Water Temp and Conductivity




Senator Beck Basin Hourly Discharge - 2008, 2009, 2010, 2011
Cubic Feet per Second
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
63
68
74
79
85
90
96
102
107
113
118
124
130
135
141
146
152
157
163
169
174
180
185
191
196
202
208
213
219
224
230
236
241
247
252
258
263
269
Day of Year
2008
2009
2010
2011


Senator Beck Basin Cumulative Discharge - 2006, 2007, 2008, 2009, 2010, 2011
Acre Feet
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
Day of Year
2006
2007
2008
2009
2010
2011
Working Mean

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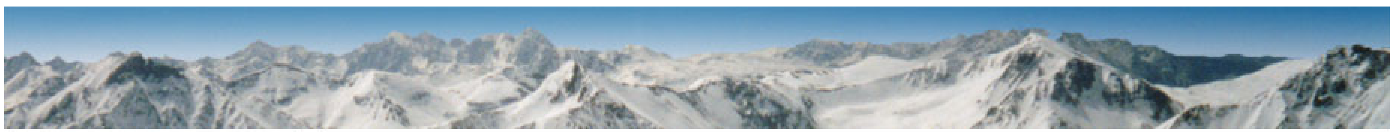


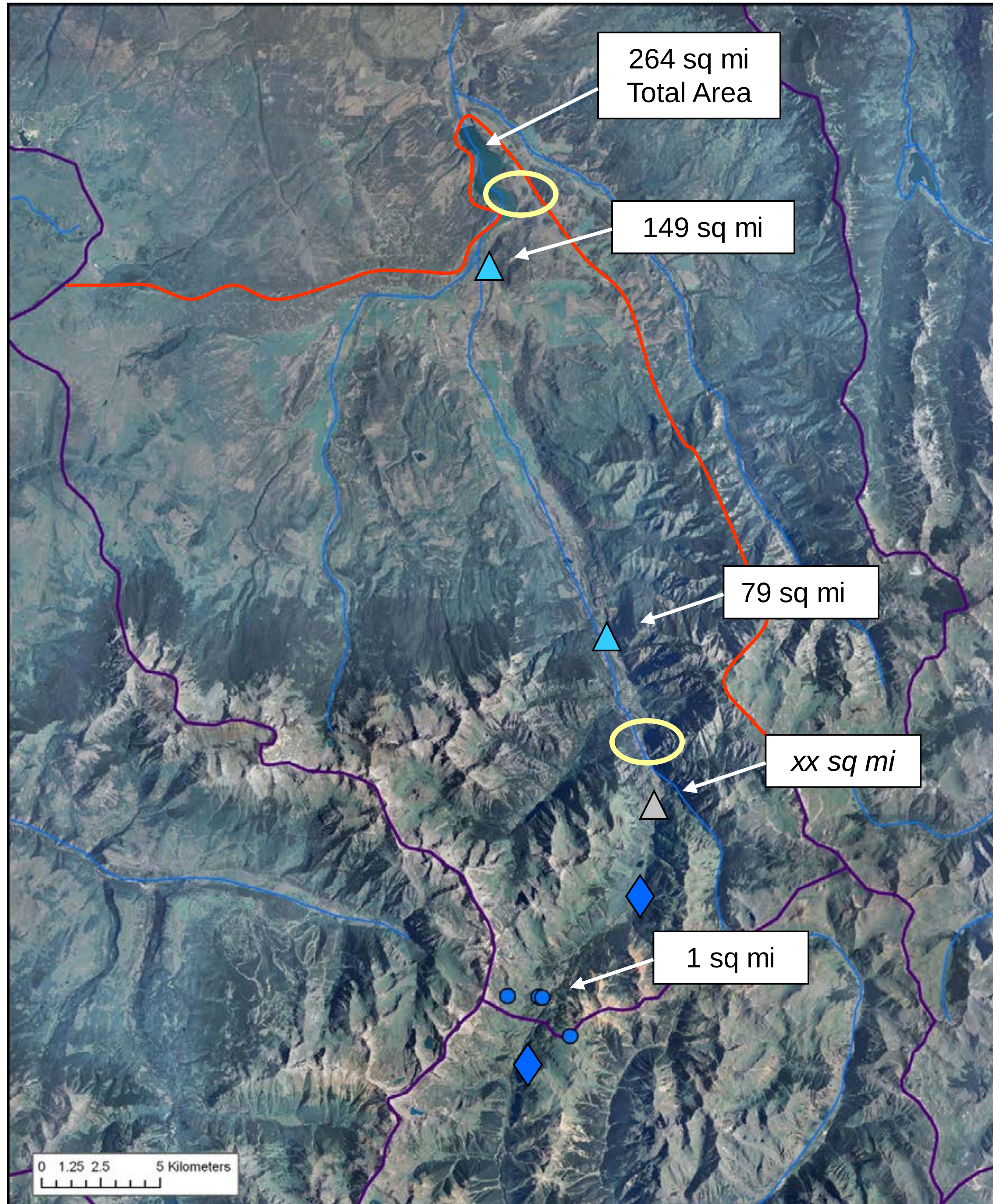
# CSAS ARCHIVAL DATA FROM SENATOR BECK BASIN

Before using any of the following data, you must agree to the policies governing use of CSAS data.
Click links below for access to data, metadata and snow profile sets.

| | Swamp Angel Study Plot | Senator Beck Study Plot | Putney Study Plot | Senator Beck Stream Gauge |
|---|---|---|---|---|
| **Summer 2010** | Data (Excel 3.64 Mb) | Data (Excel 3.45 Mb) | Data (Excel 1.45 MB) | Data (Excel 3.55 MB) |
| | Metadata (MS Word) | Metadata (MS Word) | Metadata (MS Word) | Metadata (MS Word) |
| **Winter 2009/2010** | Data (Excel 12 Mb) | Data (Excel 12.15 Mb) | Data (Excel 59 Kb) | |
| | Metadata (MS Word) | Metadata (MS Word) | Metadata (MS Word) | |
| | Snow Profiles (pdf) from 21 pits in Senator Beck Basin during the '09-'10 season<br>Snow Profile Metadata (pdf) | | | |
| | Data | Data | Data | Data |

# Upper Uncompahgre River Watershed Infrastructure

~ 98,000 acre feet average yield at Ridgway Reservoir



Ouray #09146020
Elev. 7,600’
May 22, 2011


Near Ridgway #09146200
Elev. 6,878'
May 22, 2011

Ridgway State Park

# CSAS motives for Alpine to Arid Program

Integrative science opportunity

Agency utilization of Senator Beck Basin

CSAS supports stakeholder-driven applied research

# Alpine to Arid - Next Steps

1. Firming of agency engagement, science goals, budgets
2. Formalizing Alpine to Arid program structure, CSAS role, CSAS O&M support
3. Infrastructure development & operations plan (what instruments, for what purpose, operated by whom)
4. Securing additional monitoring infrastructure sites, as required
5. New monitoring site development
6. Engagement with academic partners

***clandry@snowstudies.org***