Water-Climate-Society
Yampa/White/Green Basins

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Overall Study Objectives

- Understand vulnerability to climate variability and change in Y/W region
  - Based on climate trends and experience to date who, what, when most vulnerable to climate disturbances?
- Regional impacts, vulnerabilities, responses to 2002 drought
  - What happened "on the ground" in the Y/W region
  - How and why did people respond collectively and without conflict to 2002 drought?
- How is the BRT/IBCC process building capacity:
  - For water uncertainty in general
  - For climate uncertainty in particular

Study Methodology

- Systems approach
- Bottom-up, participatory, ethnographic
- Cross-sectoral, regional scale
- Key Stakeholder Interviews
- Extensive Interdisciplinary Literature Review
- Participant Observation
- Document Analysis
- Atlas.ti Grounded Theory
- Network Analysis

Study Methodology

Interviews

- Water commissioners, div 6 engineer
- County commissioners and city staff
- Conservancy districts (reservoir managers)
- CRWCD
- Agriculture
- Energy
- Recreation and tourism
- Water Law
- Academia
- State Parks
- CWCB staff (CRWAS, IBCC, BRT)
- Federal agency staff (BLM, USFWS)
- Russ George on HB1177

Field Work and Analysis

- Lived in/traveled around the region Aug 14 – Oct 22, 2010
- Conducted 41 interviews
- 3,050 interview minutes (approx 50 hours)
- 1,300+ pages of transcripts
- Attended YWBRT meetings from April 2010-October 2011
- Multiple other community events and water resource-related meetings, seminars, conferences

Colorado Modified Palmer Drought Severity Index
Yampa/White Basins Region 1999-2009

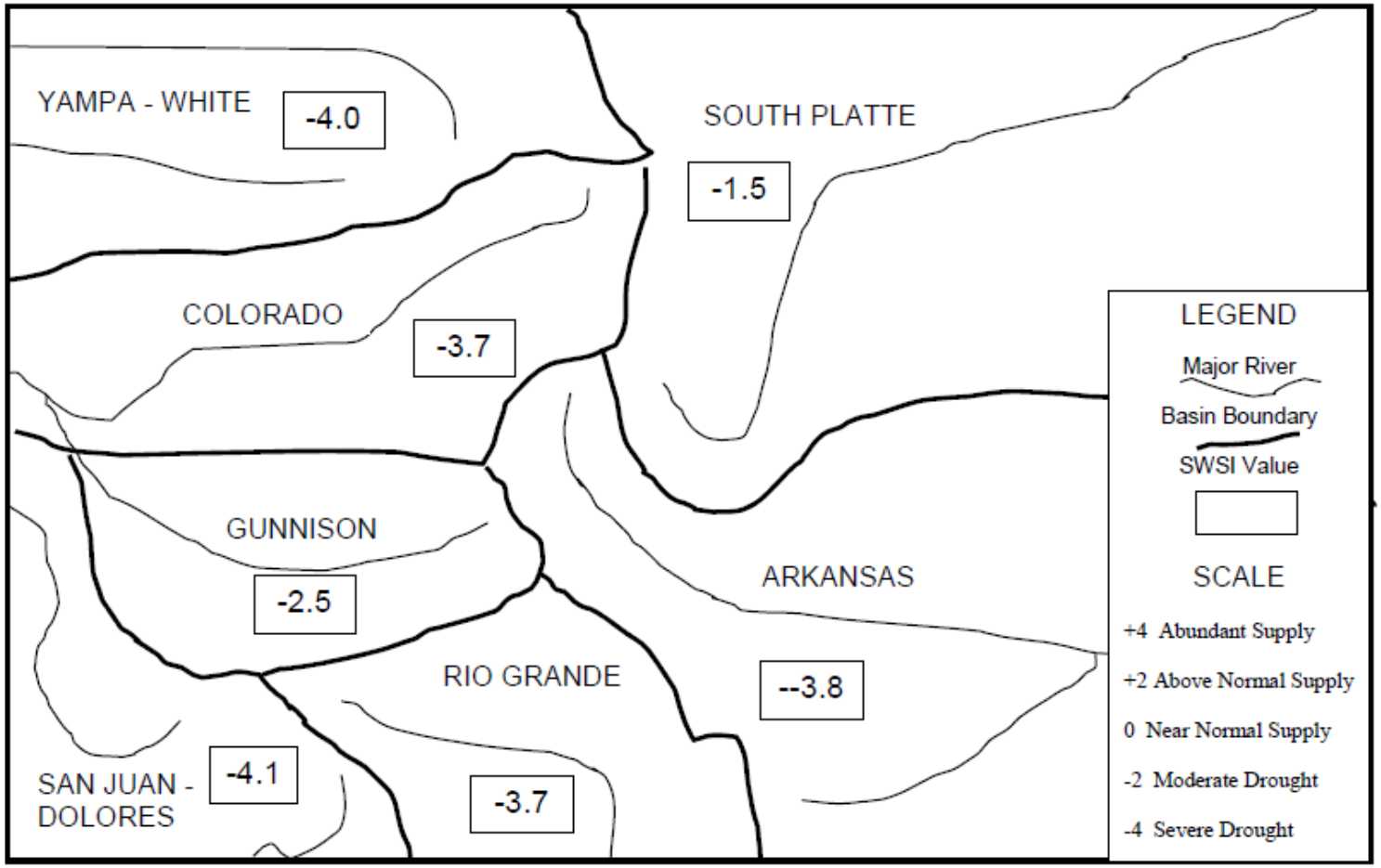
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1999	3.62	3.49	2.27	3.96	4.44	4.35	5.11	5.24	5.07	3.91	2.64	1.99
2000	1.87	1.80	1.19	-1.98	-2.30	-2.89	-3.62	-3.62	-2.55	-2.74	-2.36	-2.34
2001	-2.47	-1.93	-2.43	-2.55	-2.53	-3.28	-3.70	-3.55	-3.77	-3.50	-2.73	-2.78
2002	-2.84	-3.28	-3.04	-3.70	-4.57	-5.55	-5.94	-5.91	-4.87	-4.18	-3.86	-3.79
2003	-3.75	-3.19	-3.38	-3.56	-3.32	-3.31	-4.10	-4.80	-4.39	-5.04	-3.81	-3.21
2004	-3.05	-2.88	-3.73	-3.45	-3.48	-3.75	-3.96	-4.02	-2.76	-1.97	-1.14	-1.26
2005	-0.62	1.98	1.84	1.88	1.98	3.56	3.78	3.73	3.71	3.88	3.63	2.98
2006	2.92	2.31	2.53	1.66	0.83	-2.06	-2.36	-2.06	1.38	3.16	2.90	2.49
2007	2.51	2.56	2.00	1.01	0.85	-1.52	-2.05	-2.07	1.65	1.94	1.15	2.94
2008	3.22	3.45	3.91	3.70	4.17	4.33	4.06	3.07	3.33	2.56	2.05	2.28
2009	2.40	1.85	1.50	1.76	1.93	3.04	3.02	2.28	1.95	1.74	1.45	1.58

From: http://climate.colostate.edu/palmerindex.php

COLORADO PALMER DROUGHT INDEX

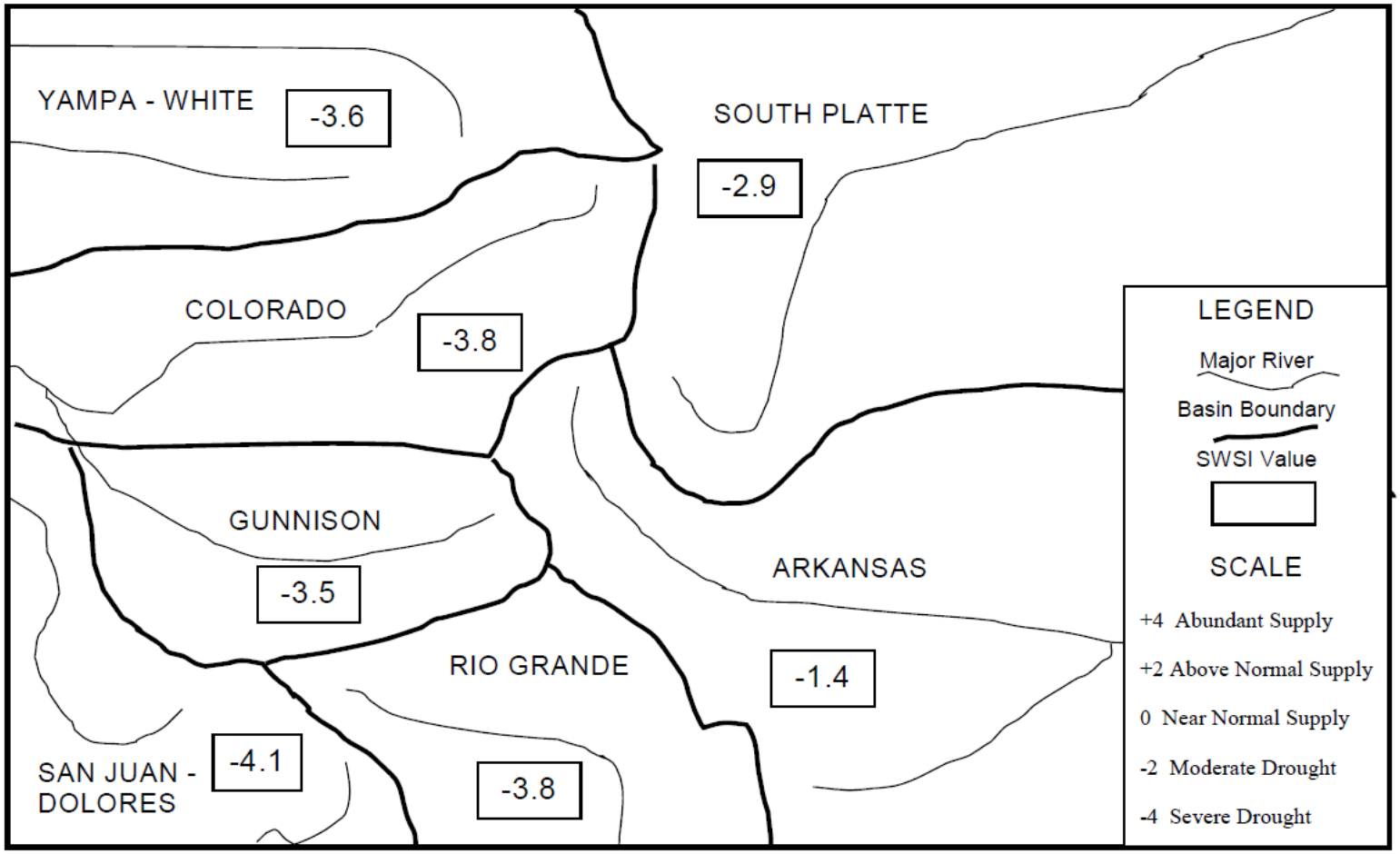
		2002 Jan	2002 Feb	2002 Mar	2002 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ARKANSAS DRAINAGE:													
1	Plateau South of Valley	2.05	1.55	0.82	-2.12	-3.03	-2.98	-3.49	-1.84	-0.84	2.21	1.58	2.46
2	Valley Bottom	-0.96	-0.98	-1.27	-2.01	-3.22	-3.85	-4.93	-5.11	-4.17	-3.39	-3.39	-2.95
3	North of Valley	0.93	0.69	99.00	-1.42	-2.73	-2.83	-3.94	-4.44	-4.06	-3.05	-3.08	-2.75
4	Mesas	-1.82	-1.66	-1.92	-2.97	-4.27	-4.85	-4.40	-5.36	-3.95	-3.50	-3.71	-3.26
5	Foothills	-1.80	-1.94	-2.34	-3.39	-4.34	-4.80	-5.35	-6.21	-5.29	-4.69	-4.83	-4.96
6	Collegiate Valley	-3.05	-3.13	-3.10	-3.75	-4.64	-5.46	-5.75	-6.82	-5.64	-5.12	-4.81	-4.88
7	Upper Valley	-1.88	-2.67	-3.57	-4.45	-4.95	-5.61	-5.57	-6.04	-5.19	-4.53	-3.68	-4.00
KANSAS DRAINAGE:													
8	South Plains	99.00	99.00	99.00	-1.38	-2.73	-3.06	-4.21	-3.83	-3.25	-2.19	-2.19	-2.33
9	North Plains	99.00	99.00	-1.01	-1.51	-2.88	-3.98	-5.37	-3.68	-3.22	-2.17	-2.04	-2.12
PLATTE DRAINAGE:													
10	Lower Plains	99.00	99.00	99.00	-1.20	-2.50	-3.62	-4.71	-3.37	-3.49	-2.43	-2.25	-2.35
11	North Front Range	-1.49	-1.22	-1.01	-2.05	-2.39	-3.03	-4.00	-4.34	-3.87	-3.26	-2.97	-3.08
12	South Front Range	99.00	99.00	99.00	-1.56	-1.95	-2.85	-3.88	-4.10	-3.54	-2.91	-2.77	-2.95
13	Pikes Peak	99.00	99.00	99.00	-1.70	-2.51	-3.29	-4.01	-4.59	-3.85	-3.47	-3.61	-3.59
14	Front Range Foothills	99.00	99.00	-1.20	-2.18	-2.40	-2.91	-4.09	-4.58	-3.81	-3.04	-2.86	-3.28
15	South Park	-2.81	-2.77	-2.80	-3.88	-4.89	-5.68	-6.50	-7.27	-6.24	-5.30	-5.15	-5.16
16	North Park	-4.70	-4.95	-4.87	-5.84	-6.02	-7.09	-7.12	-7.00	-6.75	-5.84	-5.38	-5.54
RIO GRANDE DRAINAGE:													
17	San Luis Valley	-1.04	-1.00	-1.32	-2.37	-3.57	-4.20	-4.84	-5.57	-3.97	-3.58	-3.61	-3.50
COLORADO DRAINAGE:													
18	Lower Valleys	-2.56	-2.91	-2.93	-3.13	-3.87	-4.72	-5.29	-4.99	-3.19	-2.55	-1.99	-2.26
19	San Juan, Dolores, Animas	-4.53	-5.07	-5.27	-6.04	-6.84	-8.02	-8.61	-8.48	-6.78	-6.03	-5.65	-5.49
20	Yampa-White	-2.84	-3.28	-3.04	-3.70	-4.57	-5.55	-5.94	-5.91	-4.87	-4.18	-3.86	-3.79
21	Upper Gunnison	-3.50	-4.18	-4.86	-5.64	-6.72	-7.99	-8.73	-8.37	-6.20	-5.58	-4.29	-4.26
22	Upper Valley	-6.50	-6.79	-6.93	-7.70	-7.71	-8.81	-9.54	-9.49	-8.24	-6.64	-5.53	-5.61
23	San Juans	-3.17	-3.98	-4.62	-5.05	-5.37	-5.79	-5.70	-5.72	-4.11	-3.42	-2.95	-2.71
24	Central Mountains	-1.40	-1.68	-1.83	-2.74	-3.33	-4.01	-4.55	-4.66	-3.58	-2.81	-1.94	-2.02
25	Northern Mountains	-4.06	-4.06	-4.11	-4.93	-5.38	-5.81	-6.15	-6.14	-5.44	-4.69	-4.19	-4.38

SURFACE WATER SUPPLY INDEX FOR COLORADO



June 1, 2002

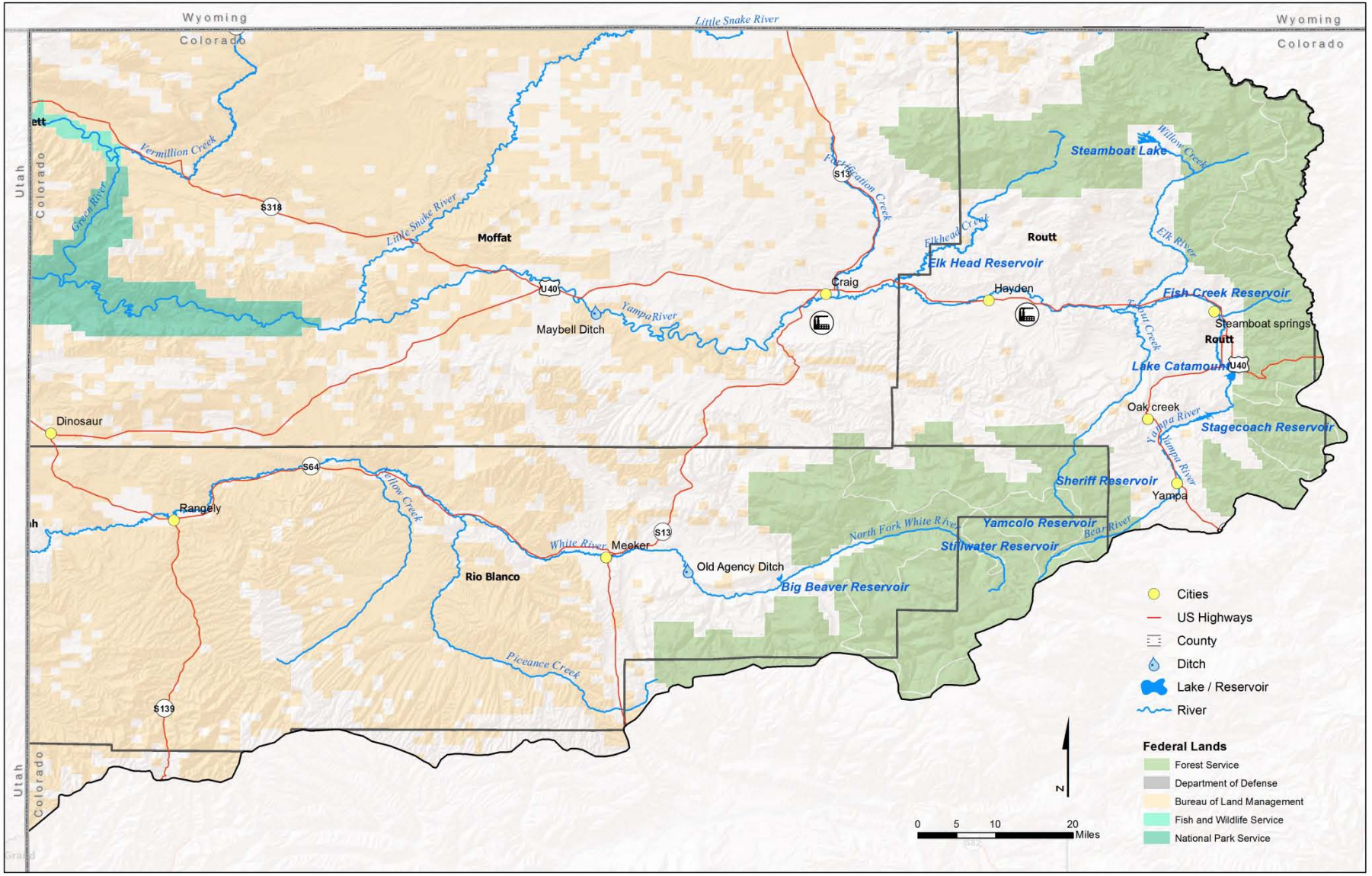
SURFACE WATER SUPPLY INDEX FOR COLORADO

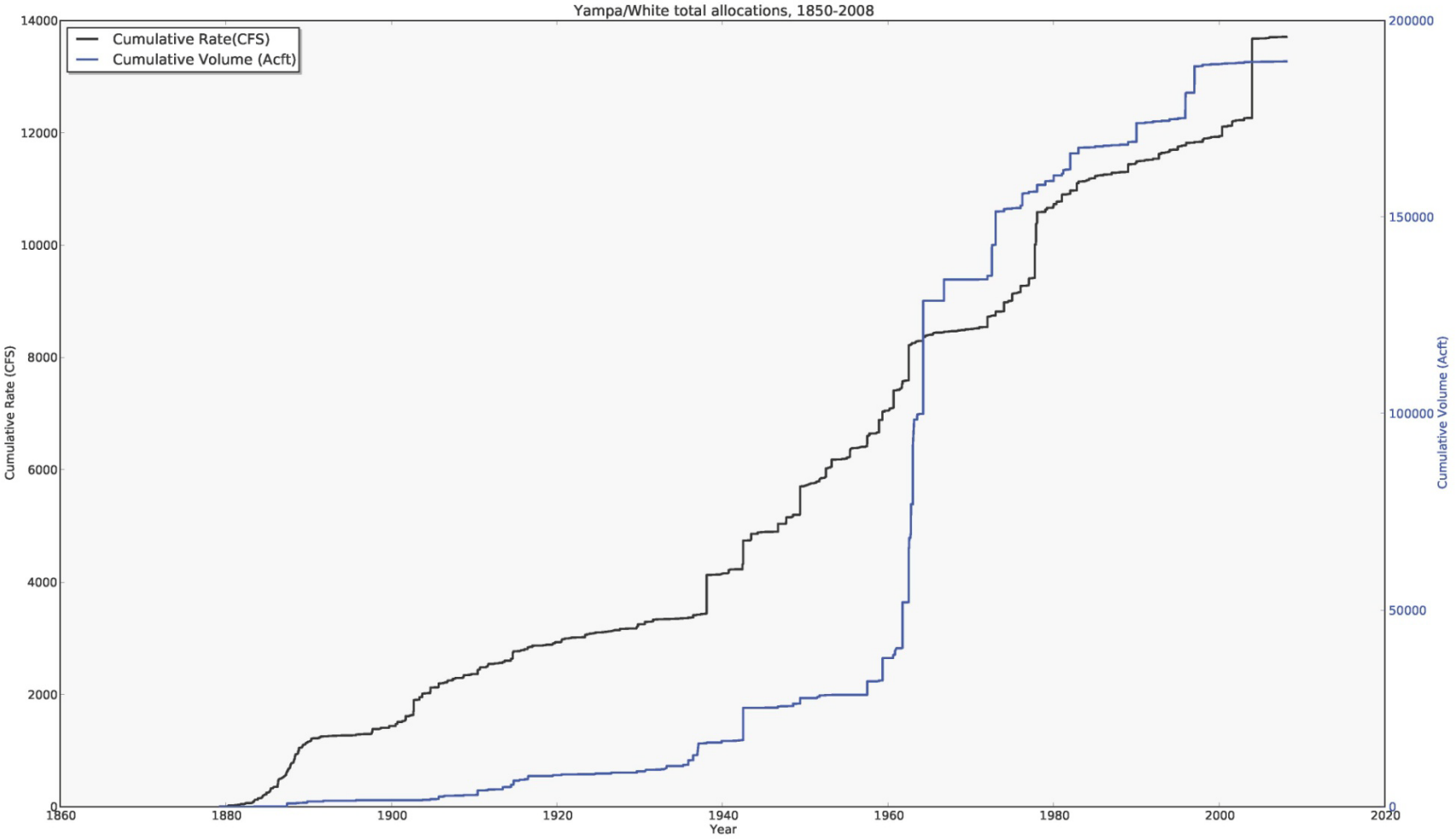


August 1, 2002

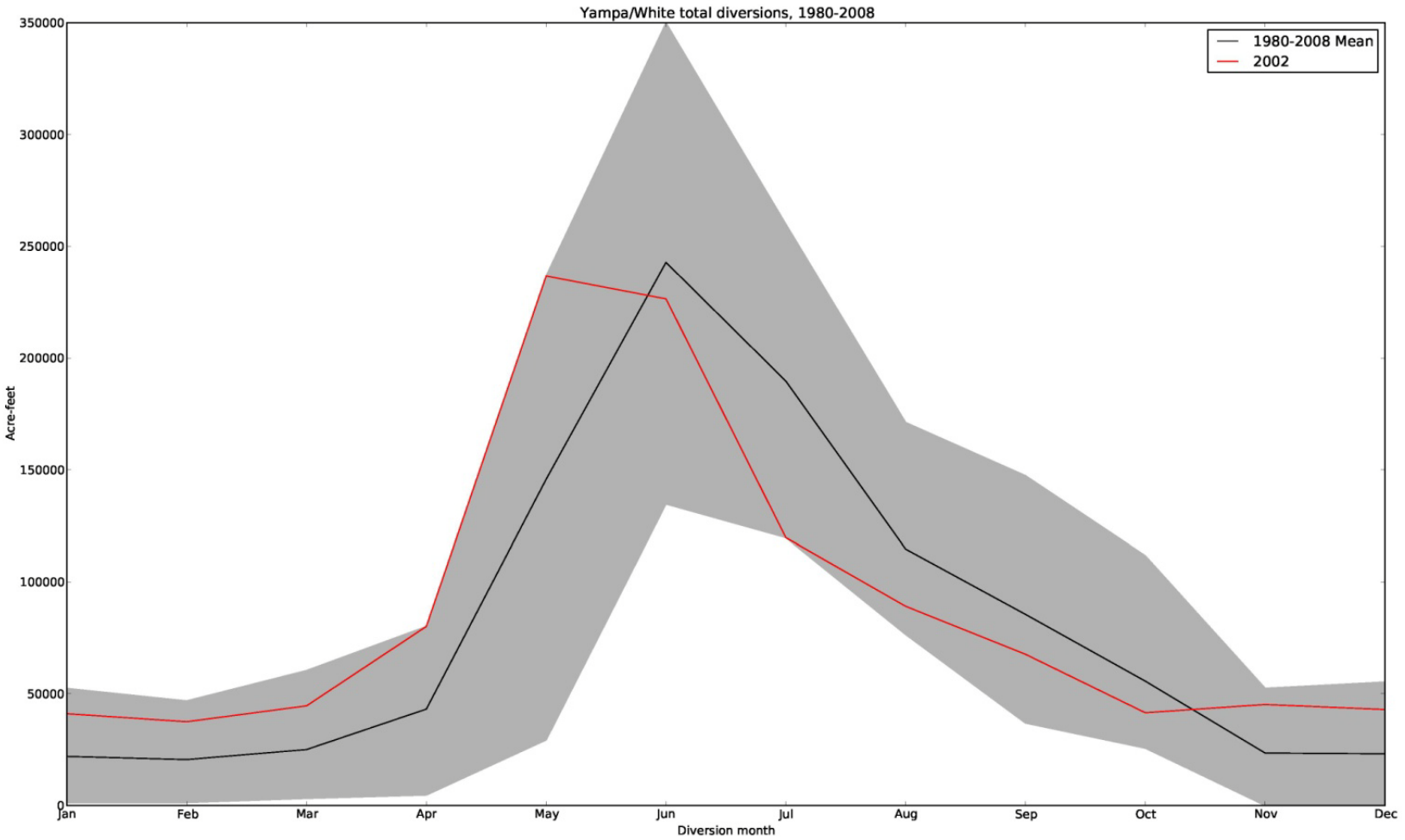
2002 "Severe" Drought in the Yampa River

April	4/18 – Call on Roaring Fork	4/19 - Call on Bear R	UYWCD "all hands" meeting	
May	5/1 - Admin on Fish Cr & Fortification Cr	Early runoff late May/early June (week to 10 days early)		
June	Peak flows 1/3 of average	Oak Creek on call and releases out of Sheriff Reservoir June 24-Sept 16		
July	By mid-July Stillwater and Yamcolo had released all available irrigation water	7/12-24 releases out of Elkhead Reservoir for Tristate	Jul/Aug SBS voluntary ban all activities in town and fishing from Stagecoach to Elk R (flows at 17cfs mid-July)	Upper Yampa voluntary releases out of Stagecoach
Aug	Mid-Jul-Sept 18th Elkhead & Stagecoach to Tristate and Hayden	End of summer: City of Craig nearly placed a call	High water transit losses and water not reaching owner's diversion structure	Aug 30 – Xcel released from Steamboat Lake for Hayden Power Plant
Sept	9/5-9/18 curtailments on main stem between reservoirs and Tristate power station in Craig	Sept 18th RAIN. Reservoir releases ceased		

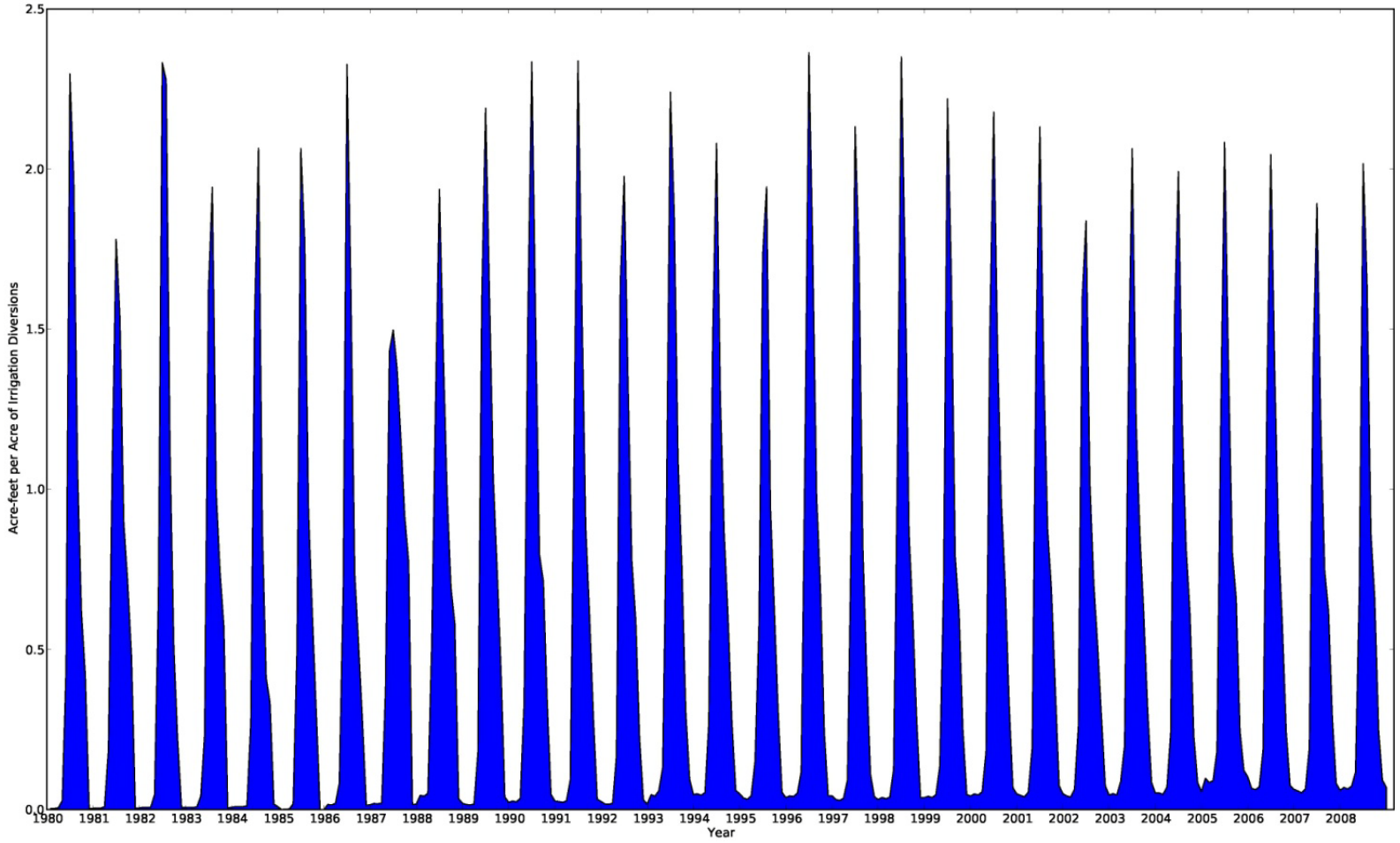

Wyoming
Colorado
Utah
Colorado
Little Snake River
Vermillion Creek
Green River
Little Snake River
Moffat
Maybell Ditch
Yampa River
Fortification Creek
Craig
Elkhead Creek
Elk Head Reservoir
Routt
Hayden
Steamboat Lake
Willow Creek
Elk River
Fish Creek Reservoir
Steamboat springs
Routt
Lake Catamount
Trout Creek
Oak creek
Yampa River
Stagecoach Reservoir
Sheriff Reservoir
Yampa
Dinosaur
Rangely
Yellow Creek
White River
Meeker
Old Agency Ditch
Rio Blanco
North Fork White River
Bear River
Yamcolo Reservoir
Stillwater Reservoir
Big Beaver Reservoir
Piceance Creek
S318
S64
S13
S139
U40
Cities
US Highways
County
Ditch
Lake / Reservoir
River
Federal Lands
Forest Service
Department of Defense
Bureau of Land Management
Fish and Wildlife Service
National Park Service
N
0 5 10 20
Miles


Yampa/White total allocations, 1850-2008
Cumulative Rate(CFS)
Cumulative Volume (Acft)
Cumulative Rate (CFS)
Cumulative Volume (Acft)
Year
0
2000
4000
6000
8000
10000
12000
14000
0
50000
100000
150000
200000
1860
1880
1900
1920
1940
1960
1980
2000
2020

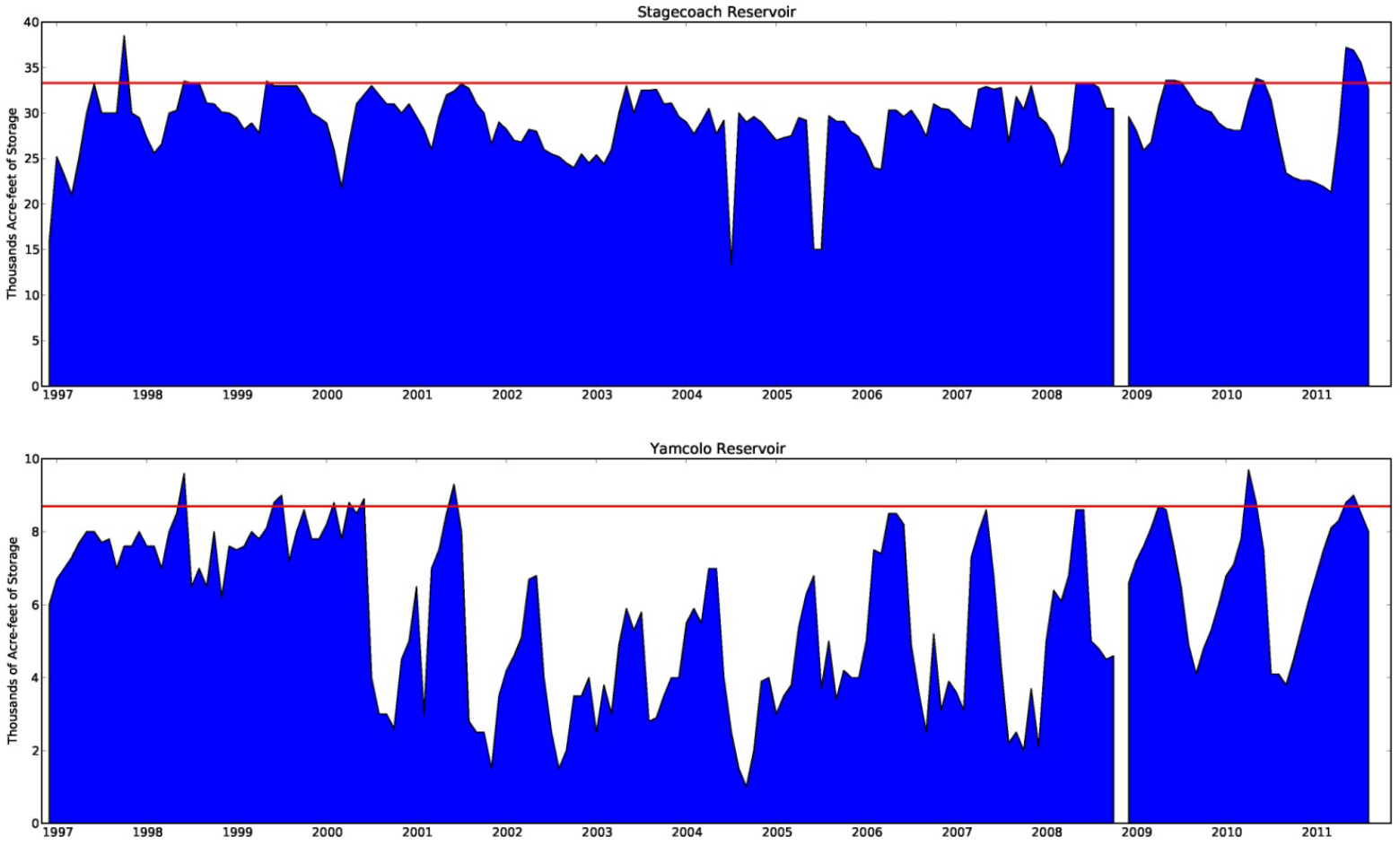
Yampa/White Total Diversions 1980-2008



Yampa/White Irrigation Diversions



Stagecoach and Yamcolo Reservoirs



DRAFT: Incomplete table

Climate observations and projections for Yampa/White Basins region

Climate Observations	Local Observations	Scientific Obs	Climate Change Projections
Temp increase	Yes/No	CWCB Colo. Climate Ctr YWBRT Ag Study Ray et al 2008	CRWAS Ray et al 2008
Earlier runoff and peak stream flow	Yes	YWBRT Ag Study	YWBRT Ag Study CRWAS
Decreased stream flow	Yes		Battaglin et al 2011
Decreased snow pack	Yes	Pederson et al 2011	Mastin, M. C., K. J. Chase, et al. (2010)
Decreased late season flows	Yes		
Decreased Summer Precip	No		YWBRT Ag Study Ray et al 2008
Changes in snow melt timing	Yes	Clow 2010	

Social Learning: Local Climate Change Perceptions

- Yampa/White region will stay much the same and not as impacted as other parts of Colorado
- Temperature will trump precip for available water
- Changes in *timing* of precip
- Effects felt more in southern part of the state; northern (esp. Yampa Basin) maybe be same temp and more precip
- Earlier spring runoff; lower late season flows
- Vulnerable/unprepared for a multi-year 2002-like drought
- Need more storage to prepare for future
- Recreation, tourism, fisheries/riparian ecosystems, and some agriculture and tributaries most vulnerable

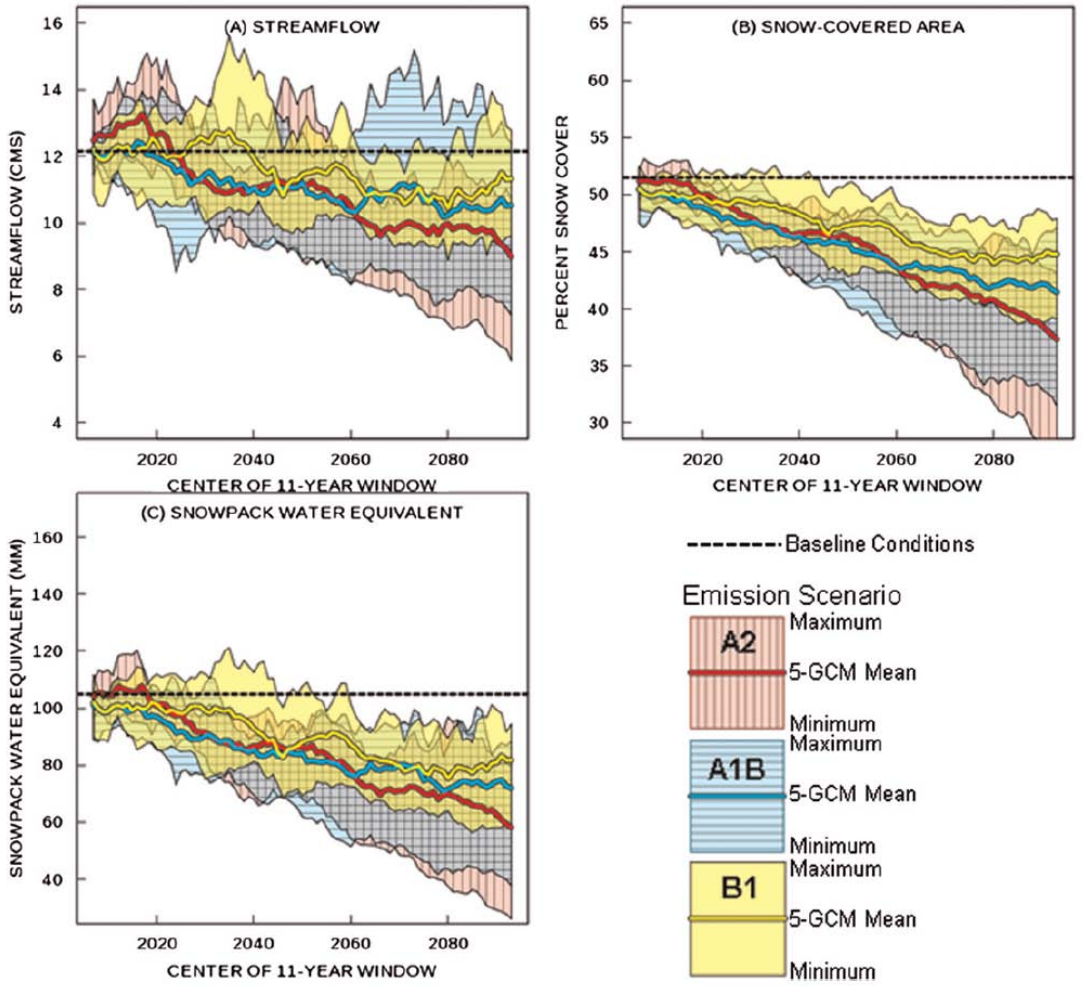


Figure 6. Basin mean daily (a) streamflow, (b) snow-covered area, and (c) snowpack water equivalent for the Yampa River at Steamboat Springs, Colorado. Baseline conditions (1989–99) are shown as the black dashed line, and the range in future conditions from five GCM simulations are shown for emission scenarios B1 (yellow), A1B (cyan), and A2 (red).

Battaglin, W., L. Hay, et al. (2011). "Simulating the Potential Effects of Climate Change in Two Colorado Basins and at Two Colorado Ski Areas." Earth Interactions **15(22): 1-23.**

Table 5. Change in simulated spring SCA (1 Apr for basins in western United States and 1 Mar for Cathance River basin in Maine) since 2006 for three time periods and three climate-change scenarios. Values represent averages based on five GCMs. The year in the table is the central year for a 12-yr moving window.

	Change in spring SCA since 2006 (percentage of 2006 spring SCA)								
	SRES A2			SRES B1			SRES A1B		
River/creek basin	2030	2060	2090	2030	2060	2090	2030	2060	2090
Cathance	0.0	−3.7	−1.0	0.0	0.0	−1.0	0.0	−3.7	−5.9
East	−2.0	−7.0	−14.4	−2.0	−2.0	−2.0	−2.0	−7.0	−9.1
Feather	−52.6	−68.4	−81.9	−46.5	−62.2	−73.7	−52.5	−73.7	−77.6
SF Flathead	−3.8	−4.9	−14.8	−3.8	−4.9	−5.5	−3.8	−4.9	−13.2
Naches	−10.3	−25.6	−61.4	−9.8	−28.2	−53.4	−16.3	−35.9	−53.2
Sagehen	0.0	−5.2	−25.4	0.0	−0.7	−18.6	−0.3	−0.7	−22.7
Sprague	−13.2	−24.9	−50.5	−19.7	−30.6	−47.2	−33.0	−52.2	−57.0
Yampa	−19.5	−24.4	−33.6	−8.4	−21.0	−24.4	−19.5	−25.1	−28.0

Mastin, M. C., K. J. Chase, et al. (2010). "Changes in Spring Snowpack for Selected Basins in the United States for Different Climate-Change Scenarios." Earth Interactions **15(23): 1-18.**

Table 6. Change in simulated spring SWE (1 Apr for basins in western United States and 1 Mar for Cathance River basin in Maine) since 2006 for three time periods and three climate-change scenarios. Values represent averages based on five GCMs. The year in the table is the central year for a 12-yr moving window.

	Change in spring SWE since 2006 (percentage of 2006 spring SWE)								
	SRES A2			SRES B1			SRES A1B		
River/creek basin	2030	2060	2090	2030	2060	2090	2030	2060	2090
Cathance	−20.8	−61.0	−79.1	−8.1	−34.7	−51.8	−15.8	−52.5	−70.6
East	−10.5	−21.9	−38.1	−0.8	−8.6	−12.9	−9.0	−19.8	−25.2
Feather	−29.9	−43.8	−64.9	−10.2	−33.4	−55.0	−26.4	−50.3	−60.6
SF Flathead	−4.1	−13.7	−42.1	−2.6	−13.4	−25.1	−11.0	−15.4	−35.1
Naches	−10.6	−26.7	−59.0	−17.9	−31.5	−51.5	−18.5	−29.3	−47.7
Sagehen	−23.0	−23.9	−46.1	−0.5	−22.3	−38.5	−21.4	−25.3	−47.5
Sprague	−31.0	−50.4	−70.3	−25.9	−55.9	−81.1	−33.3	−61.3	−74.0
Yampa	−14.2	−24.5	−40.6	−1.9	−13.7	−17.4	−9.5	−21.6	−25.7

Mastin, M. C., K. J. Chase, et al. (2010). "Changes in Spring Snowpack for Selected Basins in the United States for Different Climate-Change Scenarios." Earth Interactions **15(23): 1-18.**

Recommendations

- **Iterative risk management approach**

Wilhite, D. A. and R. S. Pulwarty (2005). Drought and Water Crises: Lessons Learned from the Road Ahead. Drought and Water Crises. D. A. Wilhite, Taylor & Francis.

Mishra, A. K. and V. P. Singh (2011). "Drought modeling - A review." Journal of Hydrology 403(1-2): 157-175.

- **Risk buffering**
  - Prepare for wide range of climatic conditions
  - Research needed and planning for water losses in an exceptional drought situation

- **Incorporate non-stationarity into planning**

Milly, P. C. D., J. Betancourt, et al. (2008). "Climate Change: Stationarity Is Dead: Whither Water Management?" Science 319(5863): 573-574.

  - Past is not a predictor for the future

- **Understanding and including different risk perceptions**

- **Scenario planning and Robust Adaptive Planning (RAP)**
  - Lempert, R., S. Popper, et al. (2002). "Confronting **surprise**." Social Science Computer Review 20(4): 420-440.
  - Makropoulos, C. K., F. A. Memon, et al. (2008). "Futures: an exploration of **scenarios** for sustainable urban water management." Water Policy 10(4): 345-373.
  - Moriarty, P. and D. Honnery (2011). **Uncertainty** in Global Environmental and Resource Problems:Rise and Fal of the Carbon Civilisation, Springer London**: 59-77.**

Social Learning, Reflexivity → adaptive governance/management/adaptation planning

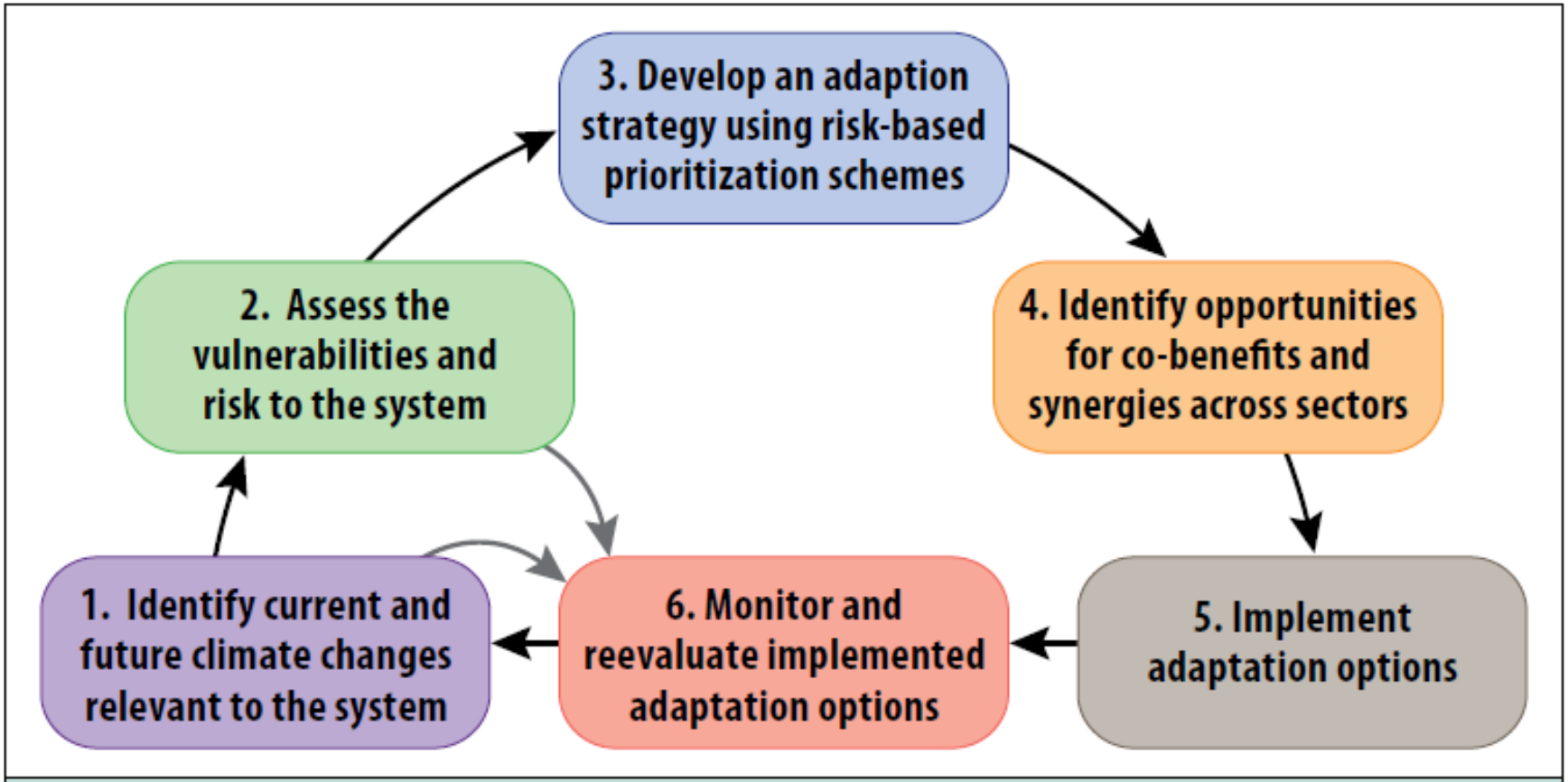


Figure 1. Adaptation planning is envisioned as a cyclical, iterative process incorporating these six steps.

http://americasclimatechoices.org/paneladaptation.shtml