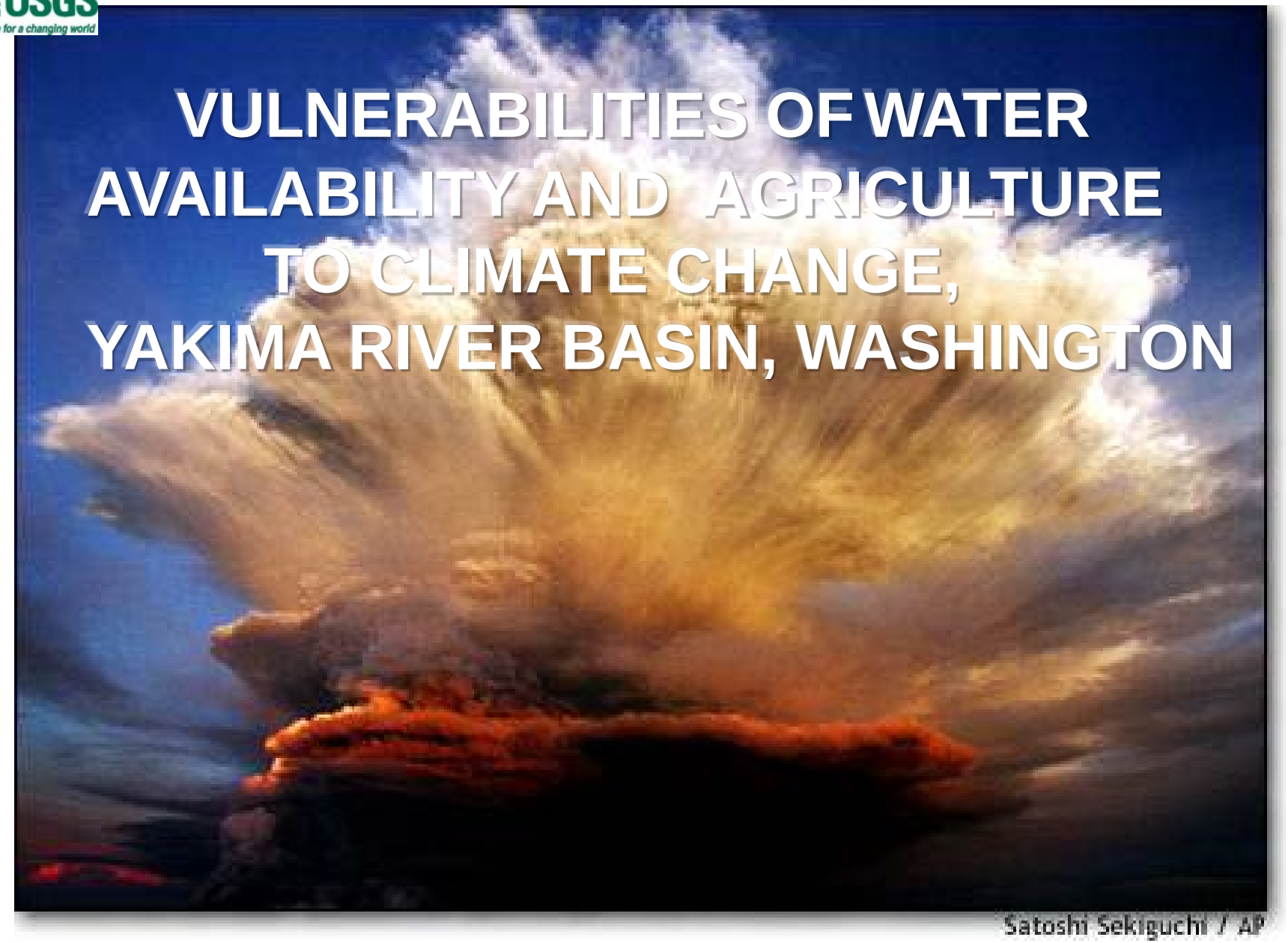
VULNERABILITIES OF WATER AVAILABILITY AND AGRICULTURE TO CLIMATE CHANGE, YAKIMA RIVER BASIN, WASHINGTON



U.S. Department of the Interior
U.S. Geological Survey

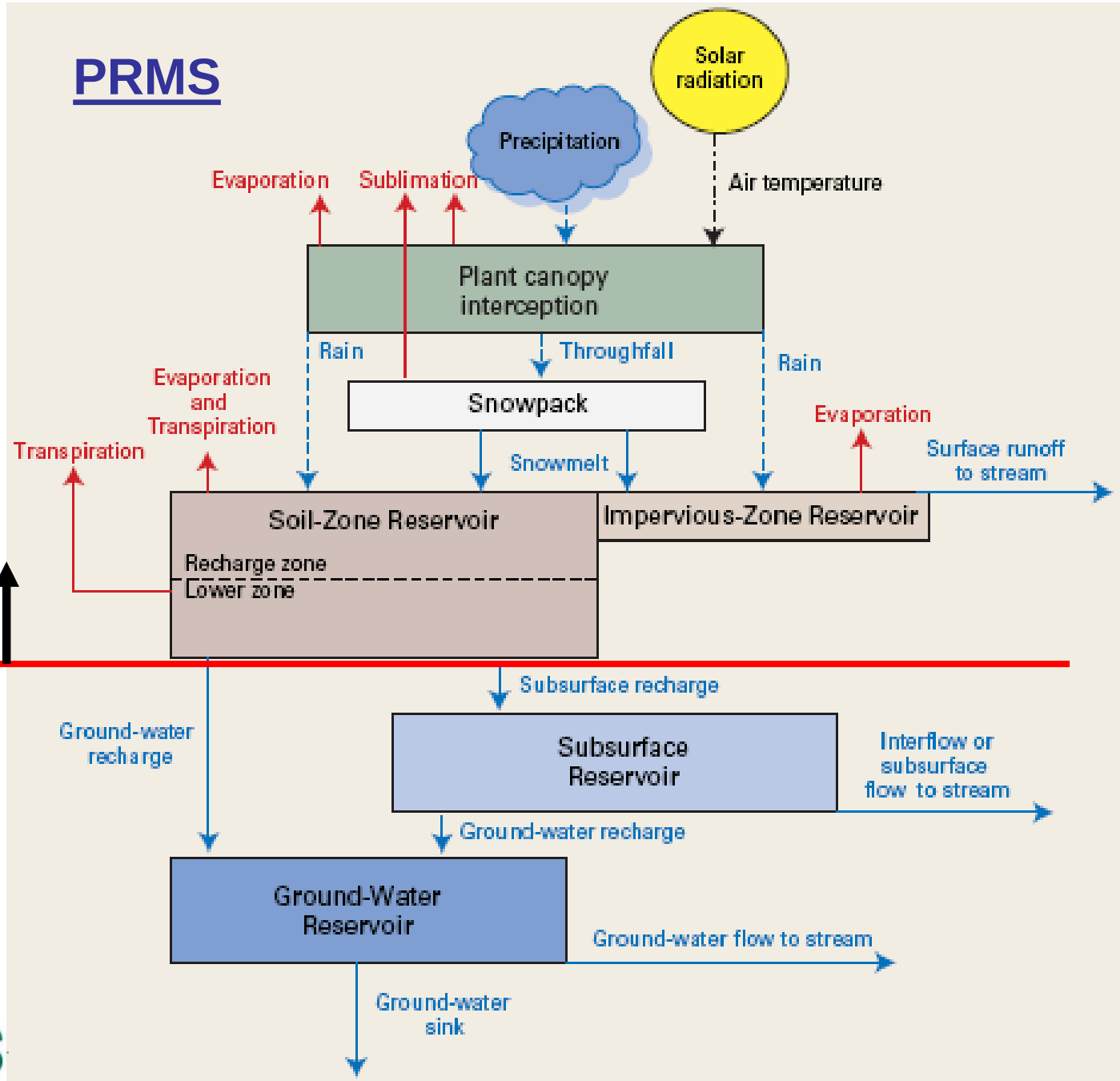
Start With Overview of Tools Used to Assess Global Warming

PRMS - USGS Watershed Model

DPM - USGS Water-Budget Model

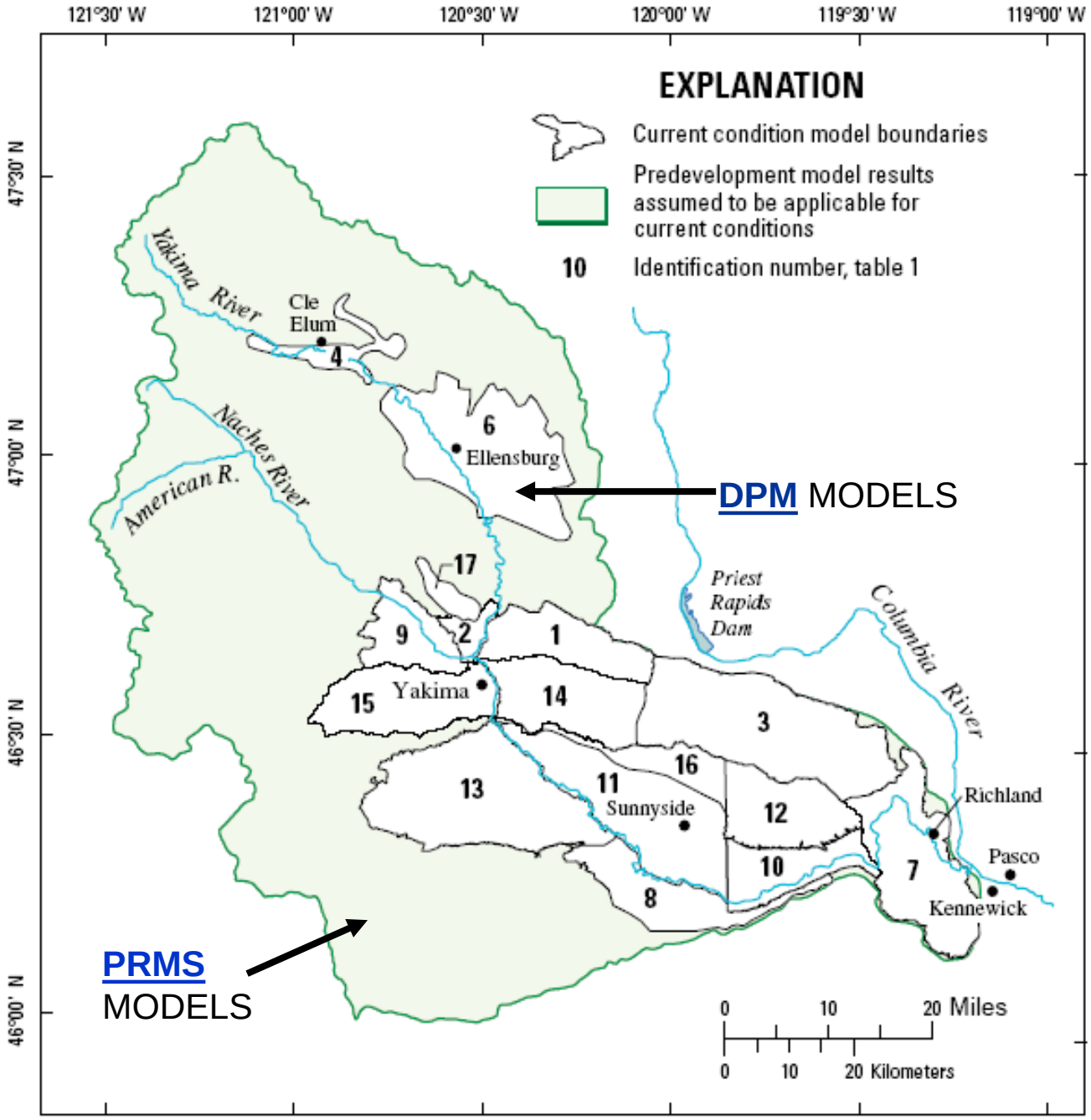
(Both Use a Daily Time-Step)

USGS

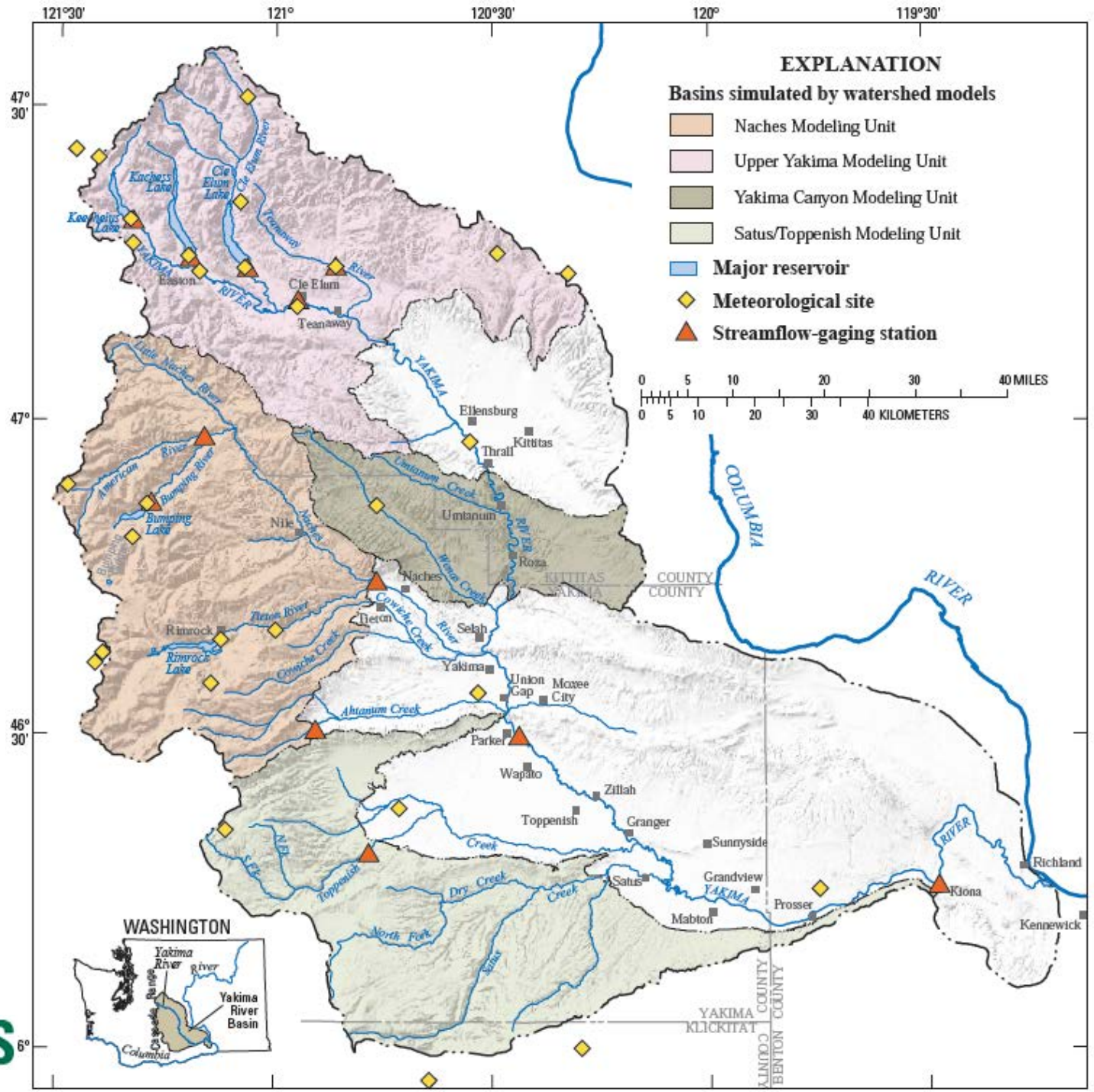

PRMS
Solar radiation
Precipitation
Evaporation
Sublimation
Air temperature
Plant canopy interception
Rain
Throughfall
Rain
Evaporation and Transpiration
Snowpack
Evaporation
Transpiration
Snowmelt
Surface runoff to stream
Soil-Zone Reservoir
Impervious-Zone Reservoir
Recharge zone
Lower zone
DPM
Subsurface recharge
Ground-water recharge
Subsurface Reservoir
Interflow or subsurface flow to stream
Ground-water recharge
Ground-Water Reservoir
Ground-water flow to stream
Ground-water sink

USGS

Areas modeled for estimating current condition recharge for input to a regional groundwater model



USGS


121°30'
121°
120°30'
120°
119°30'
47° 30'
47°
46° 30'
46°
EXPLANATION
Basins simulated by watershed models
Naches Modeling Unit
Upper Yakima Modeling Unit
Yakima Canyon Modeling Unit
Satus/Toppenish Modeling Unit
Major reservoir
Meteorological site
Streamflow-gaging station
0 5 10 20 30 40 MILES
0 5 10 20 30 40 KILOMETERS
Kachess Lake
Cle Elum Lake
Cle Elum River
Teanaway River
Keechelus Lake
YAKIMA RIVER
Easton
Cle Elum
Teanaway
Little Naches River
American River
Bumping River
Bumping Lake
Nile
Naches
Umtanum Creek
YAKIMA RIVER
Ellensburg
Thrall
Kittitas
Umtanum
Rosa
Wenas Creek
KITTITAS COUNTY
YAKIMA COUNTY
COLUMBIA RIVER
Tieton River
Rimrock
Rimrock Lake
Cowiche Creek
Tieton
Cowiche Creek
Selah
Yakima
Union Gap
Moxee City
Ahtanum Creek
Parker
Wapato
Zillah
Toppenish
Granger
Sunnyside
Toppenish Creek
North Fork Toppenish Creek
Dry Creek
Satus Creek
Satus
Grandview
YAKIMA RIVER
Prosser
Mabton
Kiona
Richland
Kennewick
YAKIMA COUNTY
KLICKITAT COUNTY
BENTON COUNTY
WASHINGTON
Yakima River Basin
Columbia River

USGS

WHAT HAPPENS IF YOU WARM UP THE BASIN?

Methods :

1) GCM time-varying output modifying current climate

2) Look at temperature increase at some point in “time” and modify current climate

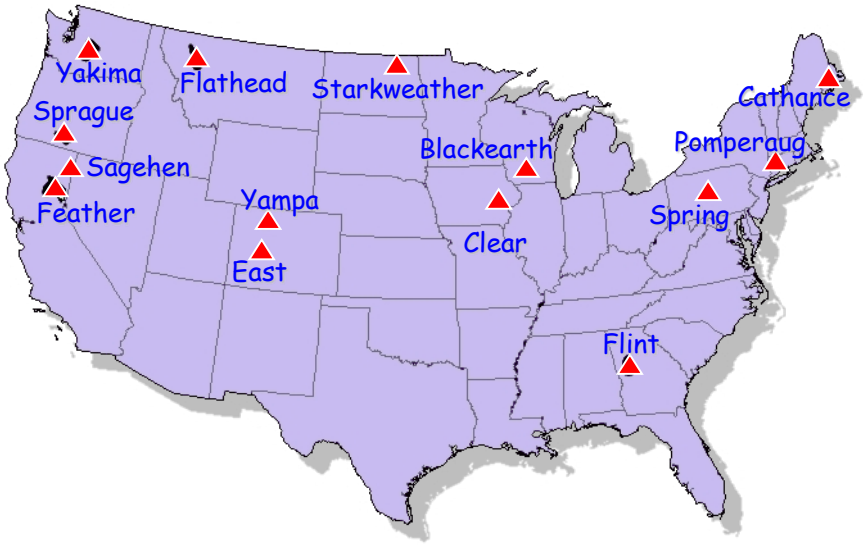
Either can use an effective change for all months or

a change that varies by month

USGS

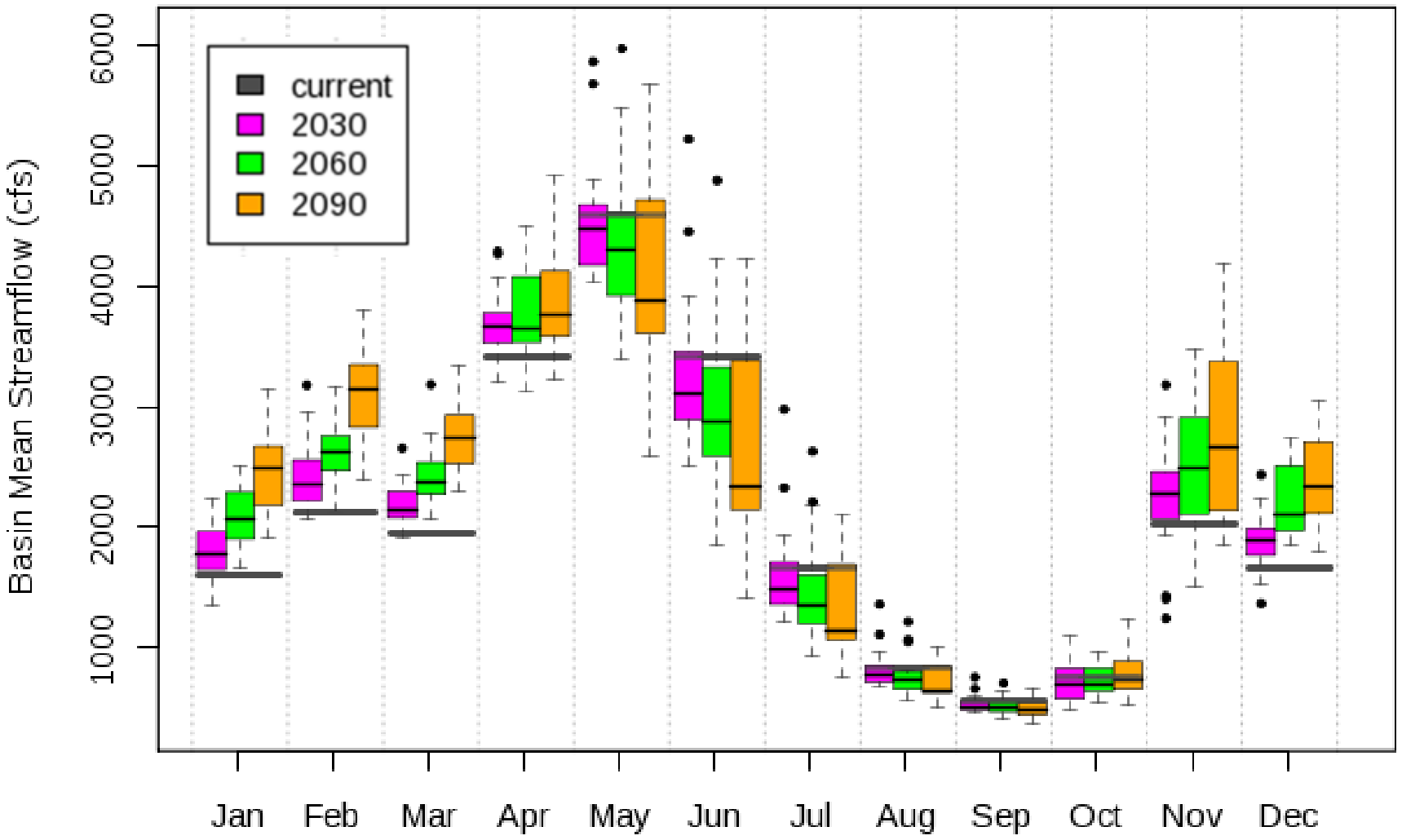
Integrated watershed scale response to global change in selected basins across the United States

Lauren Hay and Steven Markstrom (NRP/CR)



David Bjerklie (WSC/CT), Katherine Chase (WSC/MT),
Robert Dudley (WSC/ME), John Fulton (WSC/PA),
Randy Hunt (WSC/WI), Anne Jeton (WSC/NV),
Kathryn Koczot (WSC/CA, Mark Mastin (WSC/WA),
Richard Niswonger (WSC/NV), John Risley (WSC/OR),
Kevin Vining (WSC/ND), and John Walker (WSC/WI)

USGS



EXAMPLE: GCM time-varying output modifying current climate

USGS

From Hay and Mastin, USGS, 2008

EXAMPLE:
Look at temperature increase at some point in time and modify current climate

CASE: 2°C 1981-2005

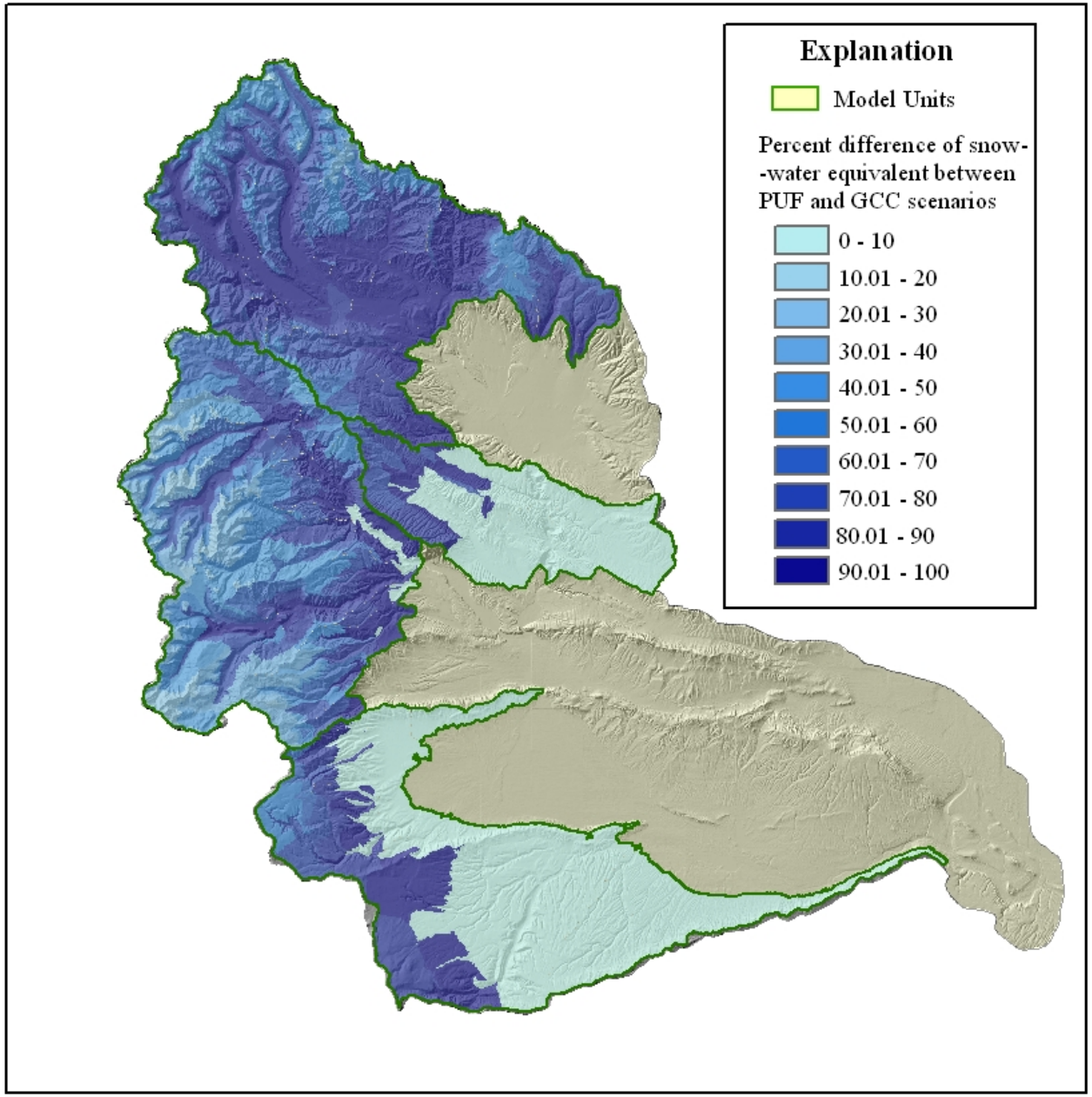
59% DECREASE

=

1.1 MILLION

ACRE-FEET

USGS



MASTIN, USGS, 2008

CASE:
2°C

BASE:
1981-2005

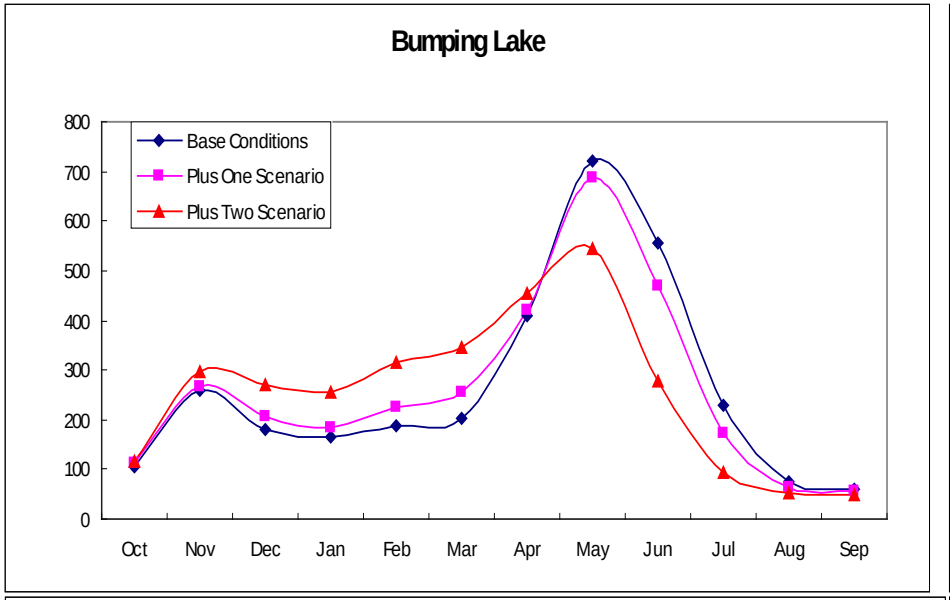
Rimrock Lake Inflow	-2.51
Bumping Lake Inflow	-2.66
Little Naches River	1.56
American River	-1.08
Rock Creek	-2.04
Milk Creek	-0.54
Lost Creek	-1.89
Gold Creek	-1.03
Devil Creek	-2.33
Swamp Creek	-1.69
Naches River near Naches	-1.24
Ahtanum Creek	-13.53
North Fork Cowiche Creek	-13.83
South Fork Cowiche Creek	-12.42
Cle Elum Lake Inflow	-8.25
Teanaway River at Mouth	-6.28
Keechelus Lake Inflow	-7.52
Kachess Lake Inflow	-7.59
Cabin Creek	-6.81
Swauk Creek	-13.45
Taneum Creek	-14.73
Manashtash Creek	-20.83
Naneum Creek	-9.70
Little Creek	-9.03
Wilson Creek	-9.52
Coleman Creek	-15.56
Cooke Creek	-16.39
Yakima River at Horlick	-8.10
Wenas Creek	-10.62
Umptanum Creek	-18.63
Satus Creek	-24.37
Toppenish Creek	-24.54

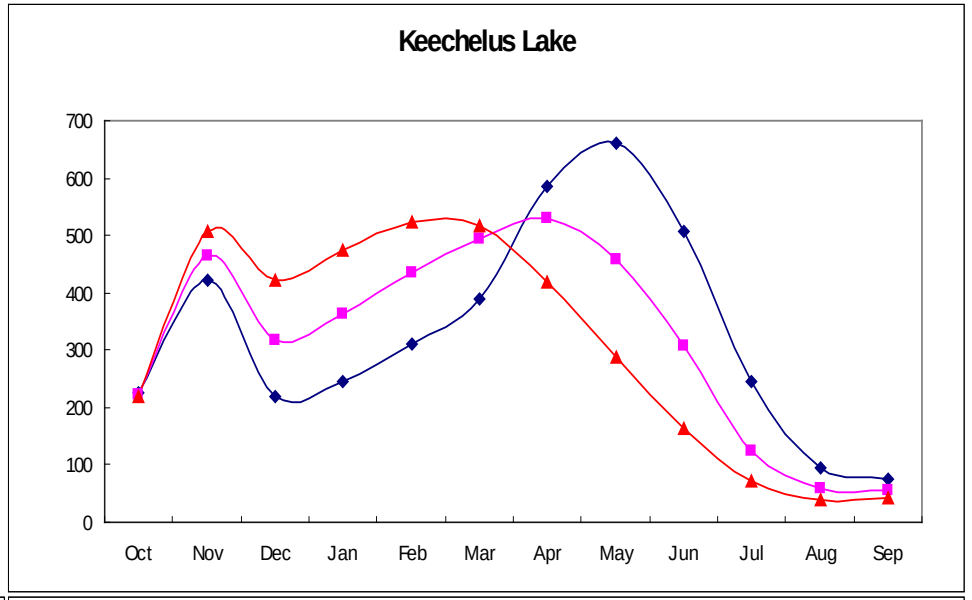
CHANGE FROM BASE:

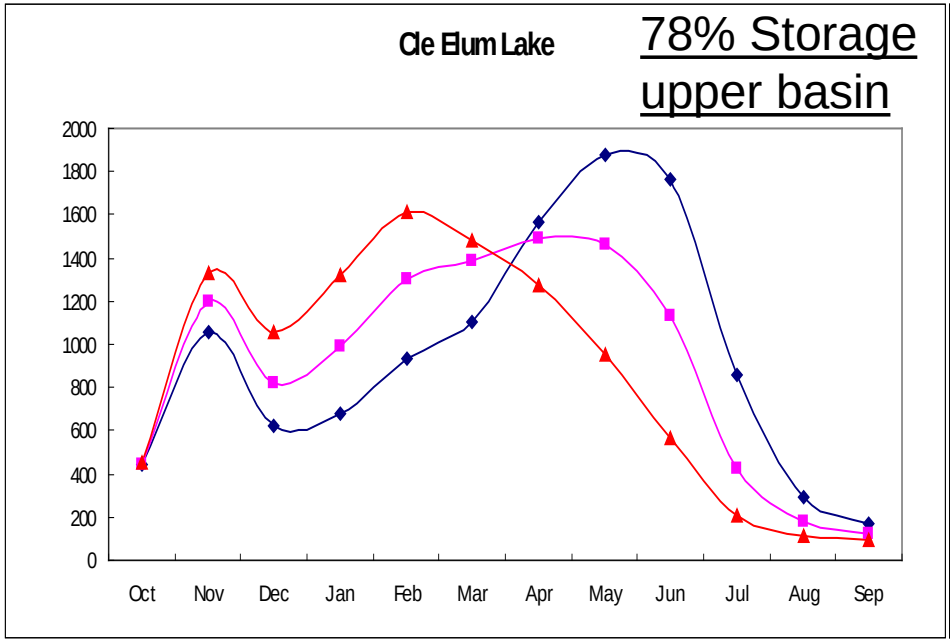
Mean Annual Discharge

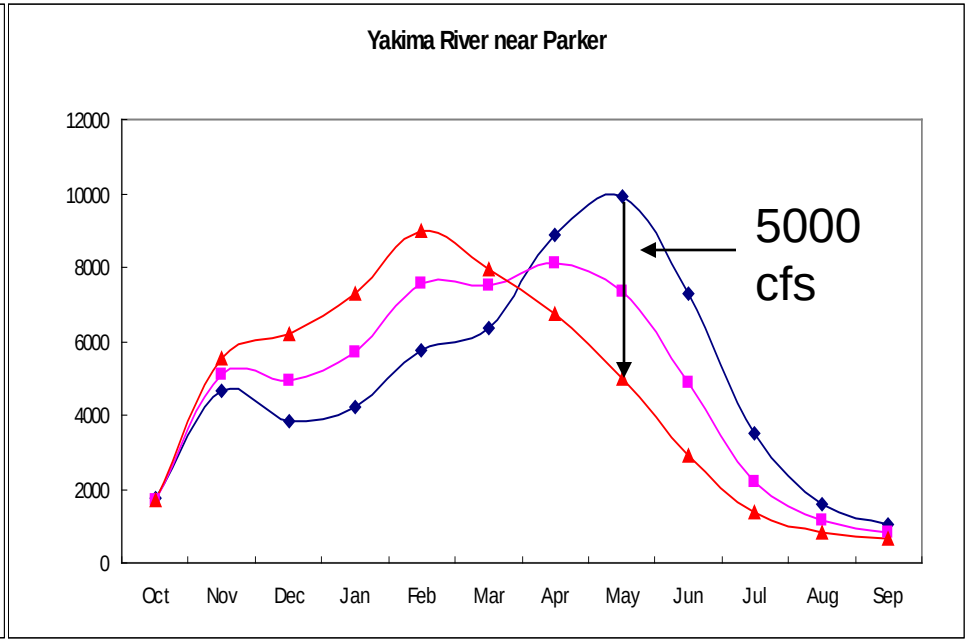
Less than 3% Change
6 - 8% Change
8 - 11% Change
Greater than 12% Change

USGS







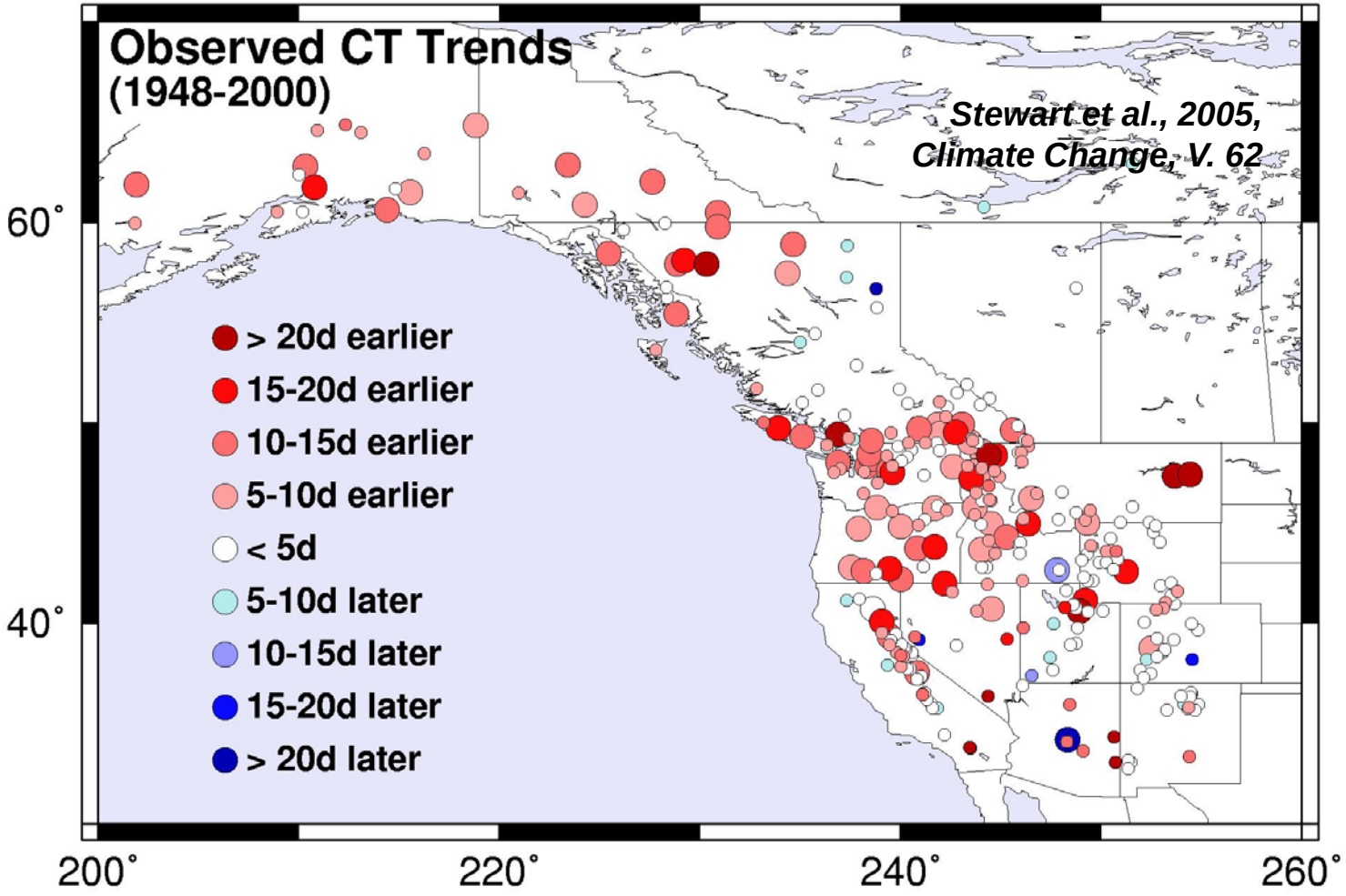


SENSITIVITY OF RESERVOIR INFLOW AND RESULTING STREAMFLOW TO 1°C AND 2°C WARMING

USGS

Mastin, USGS, 2008

…to be added to historical trends already being observed in the region.

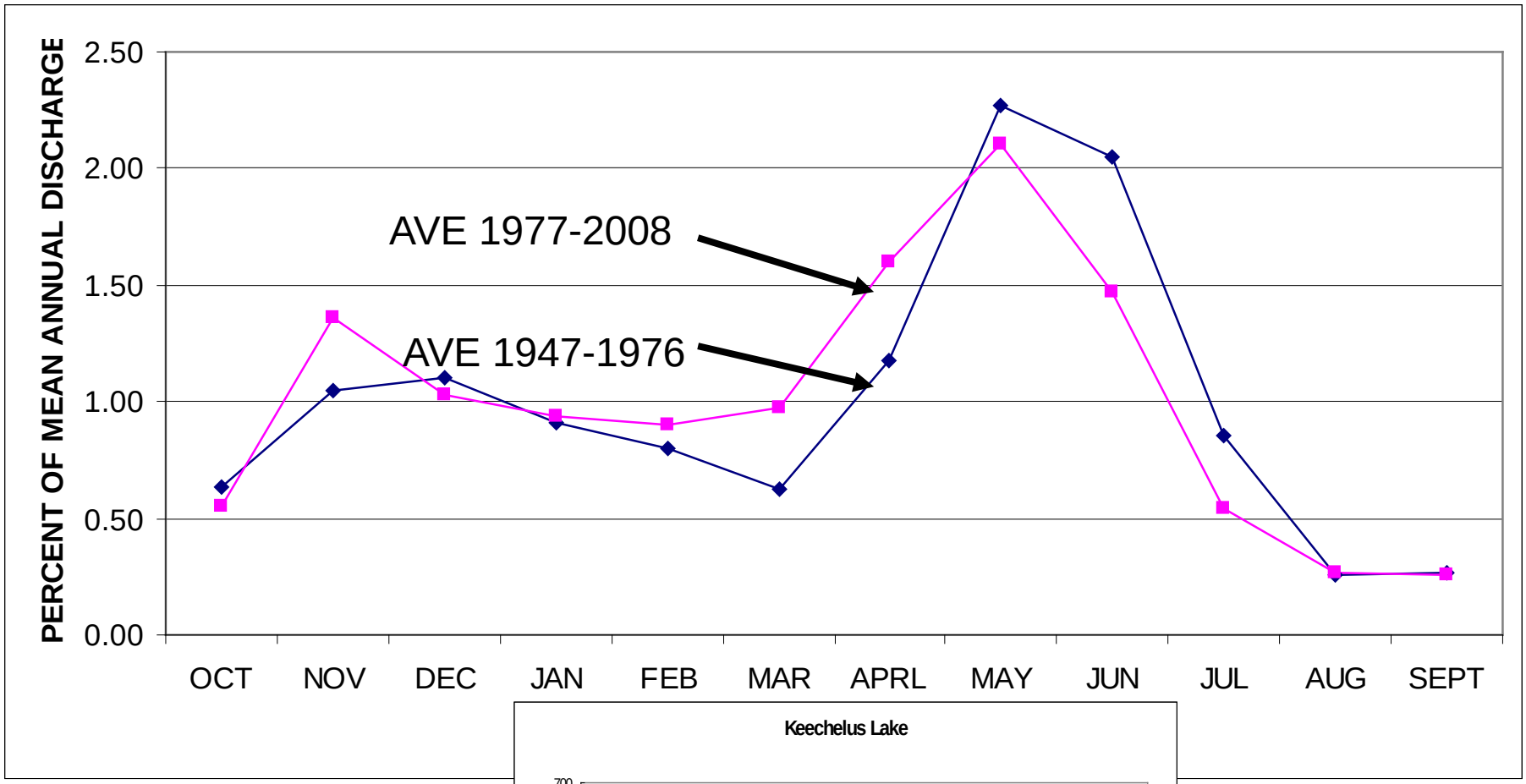


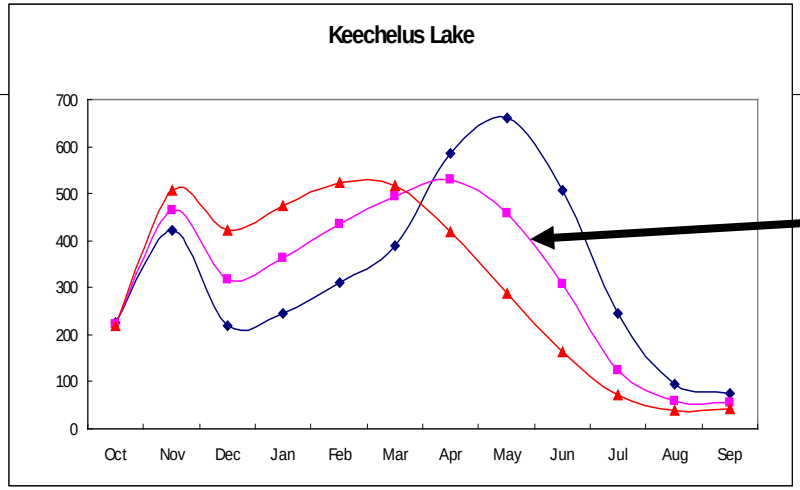
Lets Look at What is Already Occurring In the Basin

THIS EARLIER RUNOFF CAN BE SEEN BY COMPARING AVERAGE HYDROGRAPHS FOR THE 1947-1976 PERIOD TO THE POST-1976 PERIOD

THE 1976-1977 CHANGE REPRESENTS A REGIONAL SHIFT IN HYDROCLIMATE REGIMES: POST-1976 HYDROGRAPHS DISPLAY A SUBDUED VERSION OF THE PROJECTED GLOBAL CHANGES

Yakima River at Martin (Inflow to Keechelus Lake)



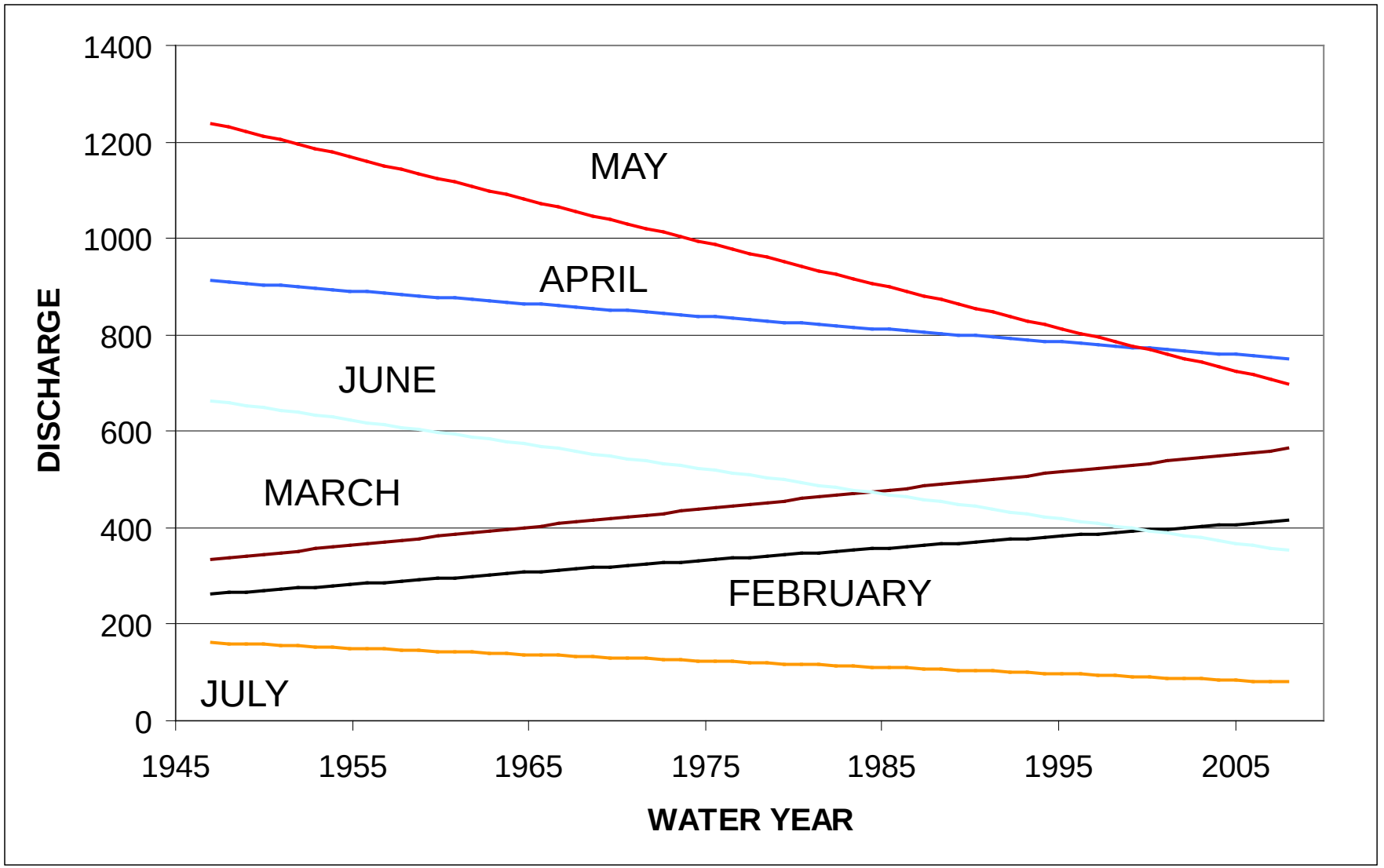


REMEMBER THE 1°C WARMING

USGS

TEANAWAY RIVER

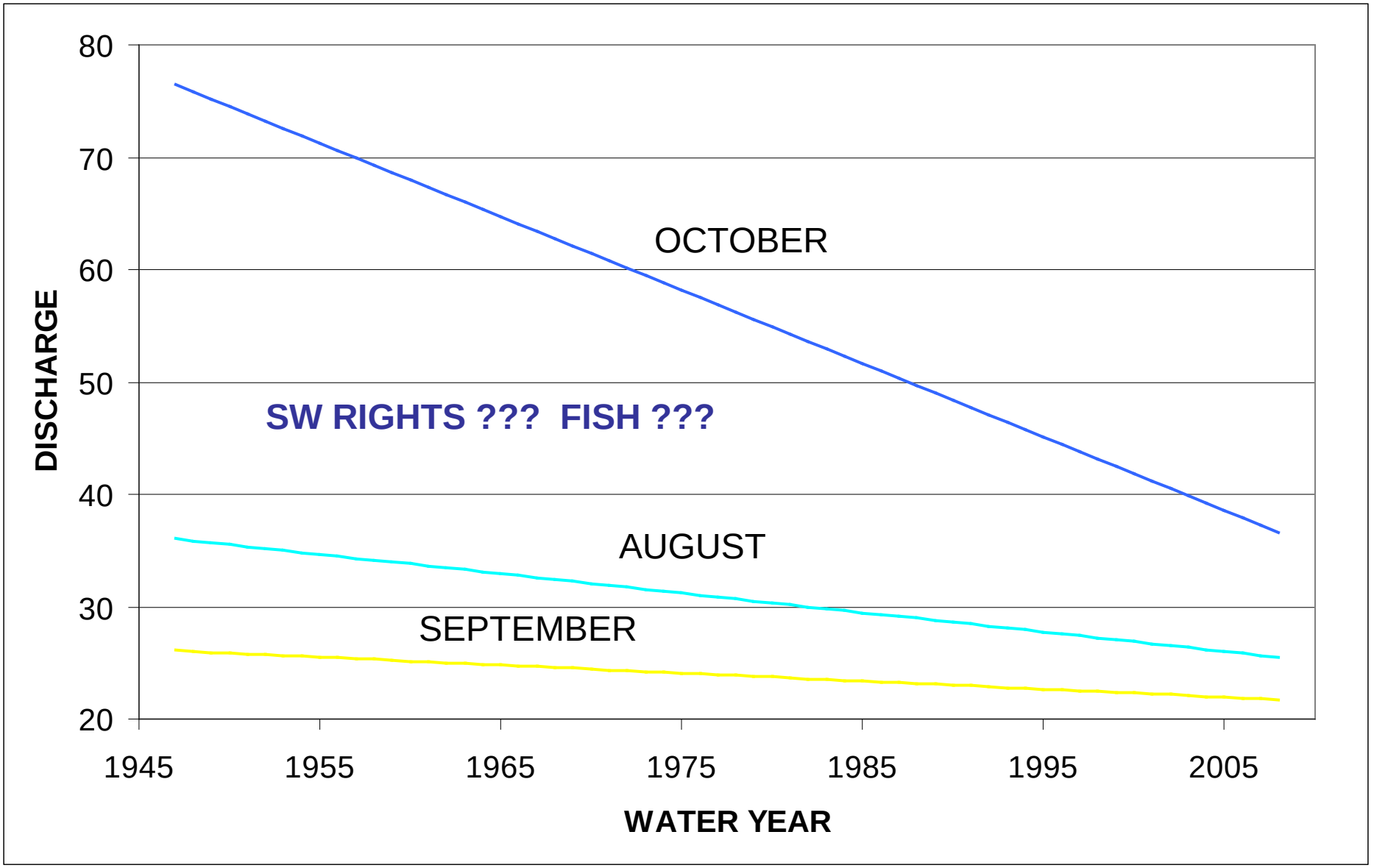
NOTE: APRIL 1-WATER RIGHT FOR 1ST IRRIGATION



USGS

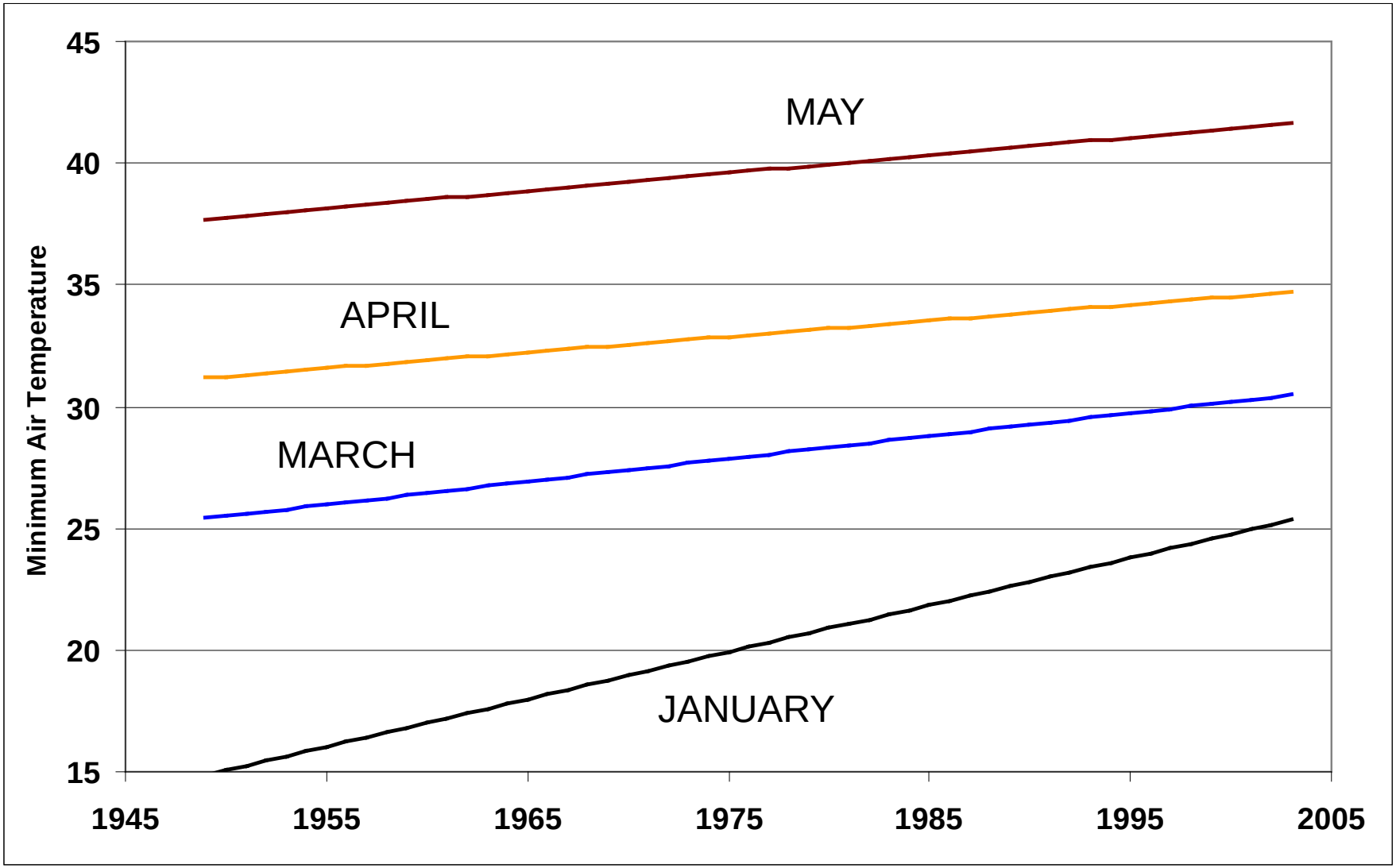
Mean Annual = 350 ft^3/s, D.A. 170 square miles

IRRIGATION SEASON EXTENDS THROUGH OCTOBER



USGS **TEANAWAY RIVER:** **Drought year: 08/28/2005 7.32 ft^3/s**

Monthly Minimum Air Temperature, Cle Elum



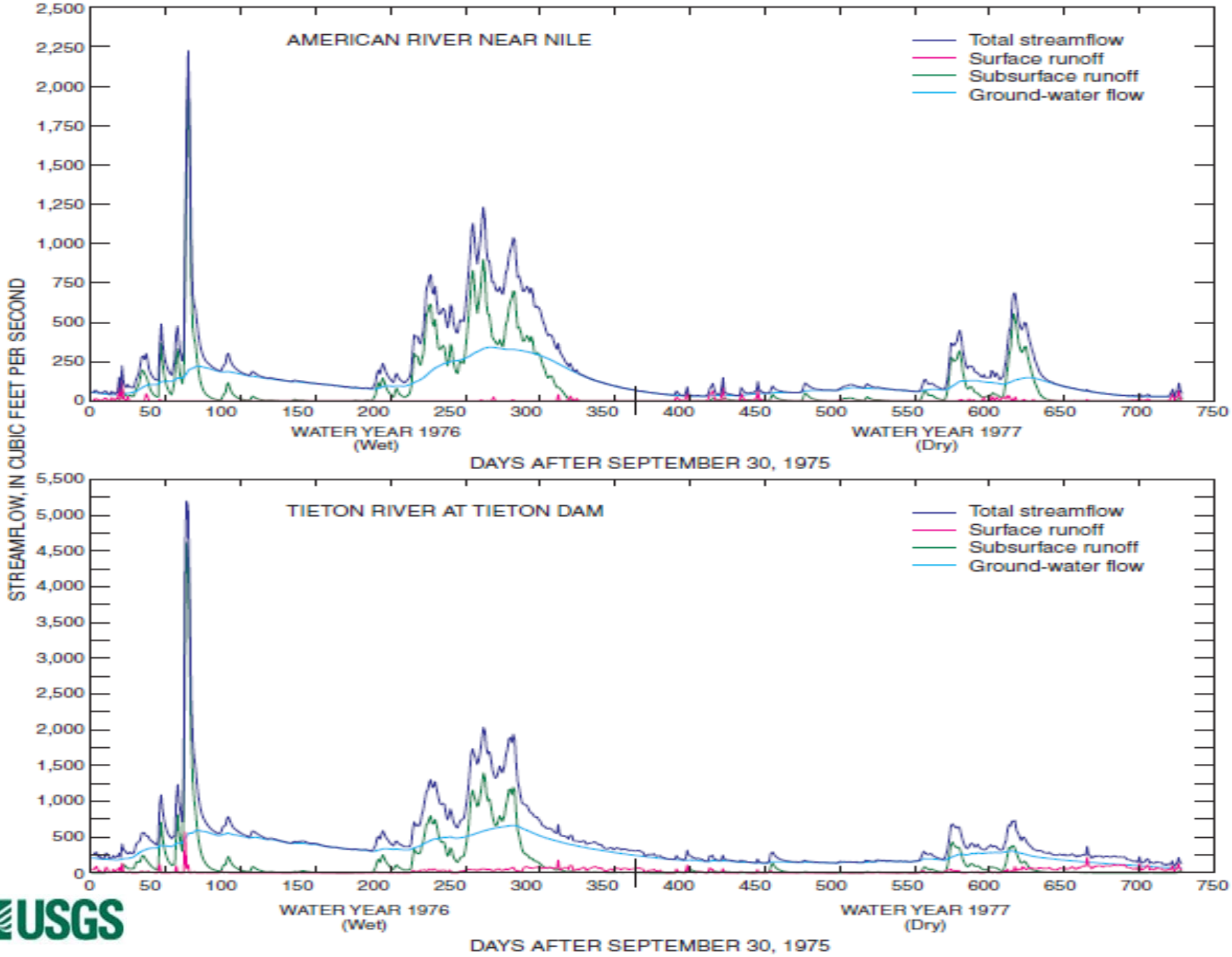
USGS

GLACIER THICKNESS CHANGE, 1970-2004

USGS

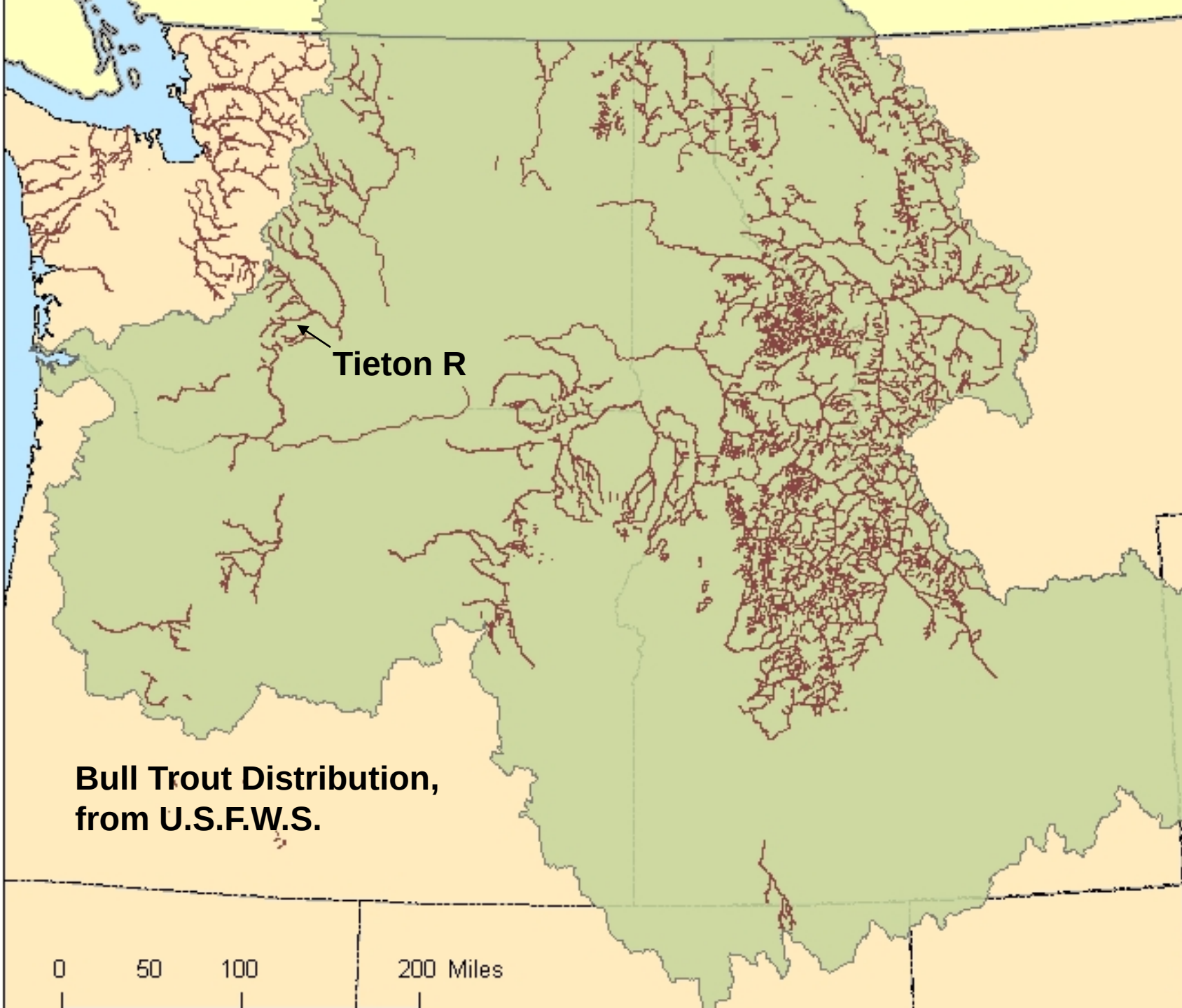
10 MILLION CUBIC METERS OF WATER LOST FROM THE GOAT ROCKS GLACIERS

(Bidlake, 2007)


AMERICAN RIVER NEAR NILE
Total streamflow
Surface runoff
Subsurface runoff
Ground-water flow
STREAMFLOW, IN CUBIC FEET PER SECOND
2,500
2,250
2,000
1,750
1,500
1,250
1,000
750
500
250
0
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750
WATER YEAR 1976
(Wet)
WATER YEAR 1977
(Dry)
DAYS AFTER SEPTEMBER 30, 1975
TIETON RIVER AT TIETON DAM
Total streamflow
Surface runoff
Subsurface runoff
Ground-water flow
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750
WATER YEAR 1976
(Wet)
WATER YEAR 1977
(Dry)
DAYS AFTER SEPTEMBER 30, 1975
USGS

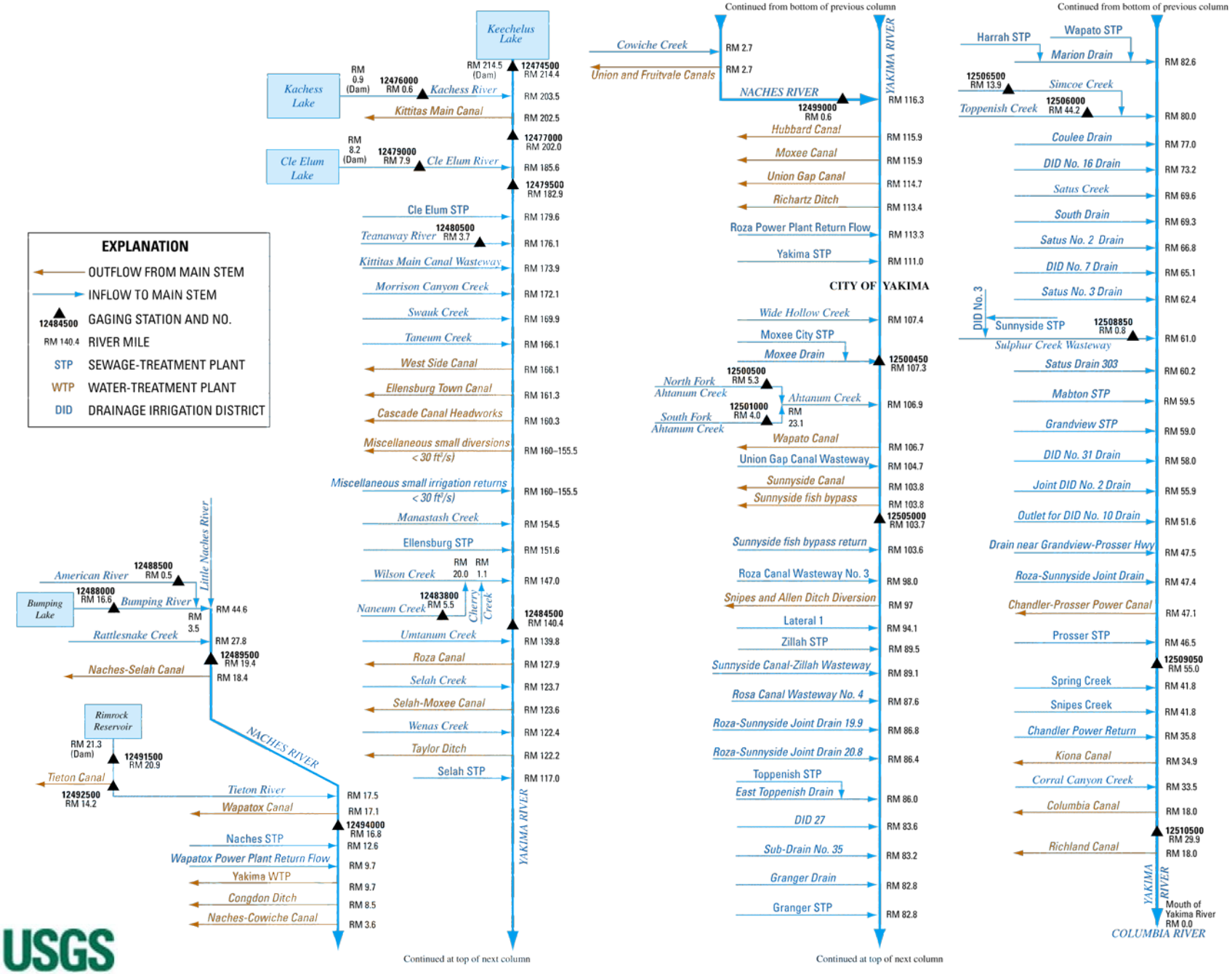
SNOWMELT IS A MAJOR COMPONENT OF SPATIALLY DISTRIBUTED GROUNDWATER RECHARGE -- 30-70% OF MELT

Provides Cold Water for Later Discharge to Streams and Prevents Winter Icing


Tieton R
Bull Trout Distribution,
from U.S.F.W.S.
0
50
100
200 Miles

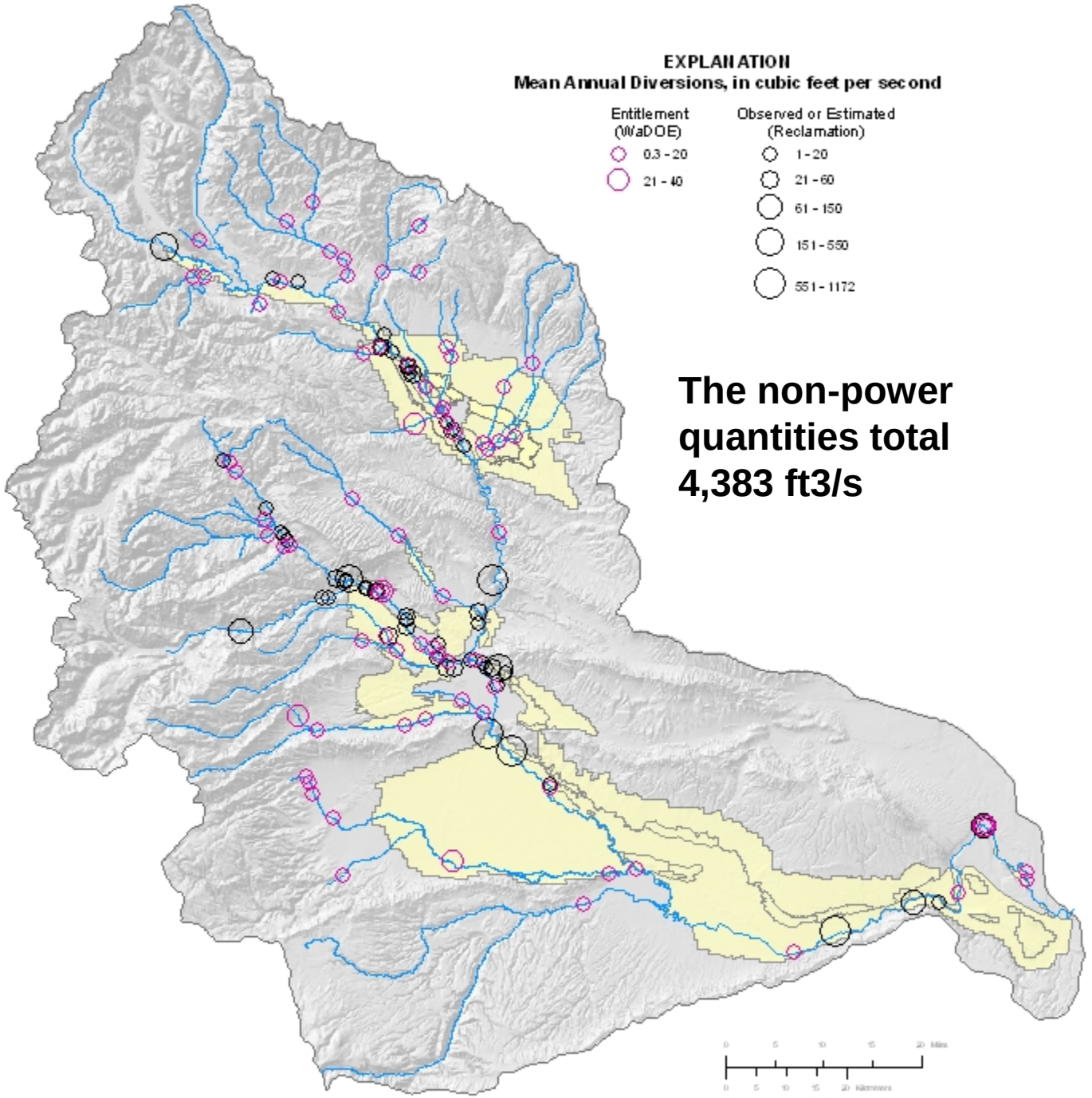
SOME FACTORS AFFECTING WATER MANAGEMENT IN THE BASIN

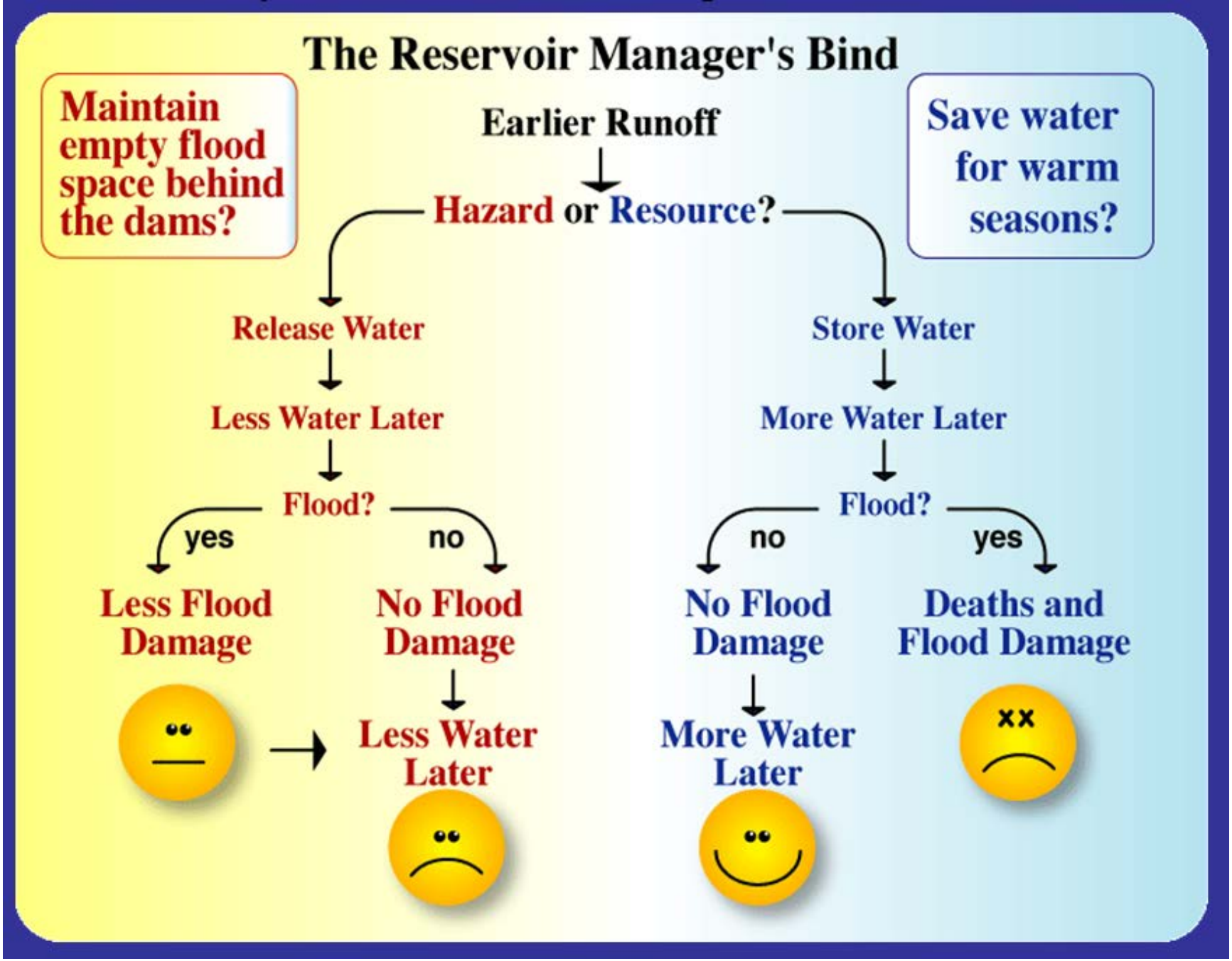
- SENIOR RIGHTS, including Tribal Rights
- JANUARY 31, 1945 CONSENT DECREE
- 1980 FEDERAL CIRCUIT COURT DECISION TO PROTECT INCUBATING SPRING CHINOOK EGGS AND ALEVINS IN THE UPPER YAKIMA RIVER BASIN
- TITLE XII INSTREAM FLOWS (10/31/94) (SUNNYSIDE AND PROSSER DAMS)


EXPLANATION
OUTFLOW FROM MAIN STEM
INFLOW TO MAIN STEM
12484500 GAGING STATION AND NO.
RM 140.4 RIVER MILE
STP SEWAGE-TREATMENT PLANT
WTP WATER-TREATMENT PLANT
DID DRAINAGE IRRIGATION DISTRICT
Keechelus Lake
RM 214.5 (Dam)
12474500 RM 214.4
Kachess Lake
RM 0.9 (Dam)
12476000 RM 0.6
Kachess River
RM 203.5
Kittitas Main Canal
RM 202.5
12477000 RM 202.0
Cle Elum Lake
RM 8.2 (Dam)
12479000 RM 7.9
Cle Elum River
RM 185.6
12479500 RM 182.9
Cle Elum STP
RM 179.6
Teanaway River
12480500 RM 3.7
RM 176.1
Kittitas Main Canal Wasteway
RM 173.9
Morrison Canyon Creek
RM 172.1
Swauk Creek
RM 169.9
Taneum Creek
RM 166.1
West Side Canal
RM 166.1
Ellensburg Town Canal
RM 161.3
Cascade Canal Headworks
RM 160.3
Miscellaneous small diversions < 30 ft³/s)
RM 160–155.5
Miscellaneous small irrigation returns < 30 ft³/s)
RM 160–155.5
Manastash Creek
RM 154.5
Ellensburg STP
RM 151.6
Wilson Creek
RM 20.0
RM 1.1
RM 147.0
Cherry Creek
Naneum Creek
12483800 RM 5.5
12484500 RM 140.4
Umtanum Creek
RM 139.8
Roza Canal
RM 127.9
Selah Creek
RM 123.7
Selah-Moxee Canal
RM 123.6
Wenas Creek
RM 122.4
Taylor Ditch
RM 122.2
Selah STP
RM 117.0
YAKIMA RIVER
Continued at top of next column
Little Naches River
American River
12488500 RM 0.5
Bumping Lake
12488000 RM 16.6
Bumping River
RM 44.6
RM 3.5
Rattlesnake Creek
RM 27.8
12489500 RM 19.4
Naches-Selah Canal
RM 18.4
Rimrock Reservoir
RM 21.3 (Dam)
12491500 RM 20.9
Tieton Canal
12492500 RM 14.2
NACHES RIVER
Tieton River
RM 17.5
Wapatox Canal
RM 17.1
12494000 RM 16.8
Naches STP
RM 12.6
Wapatox Power Plant Return Flow
RM 9.7
Yakima WTP
RM 9.7
Congdon Ditch
RM 8.5
Naches-Cowiche Canal
RM 3.6
Continued from bottom of previous column
Cowiche Creek
RM 2.7
Union and Fruitvale Canals
RM 2.7
NACHES RIVER
12499000 RM 0.6
RM 116.3
YAKIMA RIVER
Hubbard Canal
RM 115.9
Moxee Canal
RM 115.9
Union Gap Canal
RM 114.7
Richartz Ditch
RM 113.4
Roza Power Plant Return Flow
RM 113.3
Yakima STP
RM 111.0
CITY OF YAKIMA
Wide Hollow Creek
RM 107.4
Moxee City STP
Moxee Drain
12500450 RM 107.3
North Fork Ahtanum Creek
12500500 RM 5.3
Ahtanum Creek
RM 106.9
South Fork Ahtanum Creek
12501000 RM 4.0
RM 23.1
Wapato Canal
RM 106.7
Union Gap Canal Wasteway
RM 104.7
Sunnyside Canal
RM 103.8
Sunnyside fish bypass
RM 103.8
12505000 RM 103.7
Sunnyside fish bypass return
RM 103.6
Roza Canal Wasteway No. 3
RM 98.0
Snipes and Allen Ditch Diversion
RM 97
Lateral 1
RM 94.1
Zillah STP
RM 89.5
Sunnyside Canal-Zillah Wasteway
RM 89.1
Rosa Canal Wasteway No. 4
RM 87.6
Roza-Sunnyside Joint Drain 19.9
RM 86.8
Roza-Sunnyside Joint Drain 20.8
RM 86.4
Toppenish STP
East Toppenish Drain
RM 86.0
DID 27
RM 83.6
Sub-Drain No. 35
RM 83.2
Granger Drain
RM 82.8
Granger STP
RM 82.8
Continued at top of next column
Continued from bottom of previous column
Harrah STP
Wapato STP
Marion Drain
RM 82.6
12506500 RM 13.9
Simcoe Creek
Toppenish Creek
12506000 RM 44.2
RM 80.0
Coulee Drain
RM 77.0
DID No. 16 Drain
RM 73.2
Satus Creek
RM 69.6
South Drain
RM 69.3
Satus No. 2 Drain
RM 66.8
DID No. 7 Drain
RM 65.1
Satus No. 3 Drain
RM 62.4
DID No. 3
Sunnyside STP
12508850 RM 0.8
RM 61.0
Sulphur Creek Wasteway
Satus Drain 303
RM 60.2
Mabton STP
RM 59.5
Grandview STP
RM 59.0
DID No. 31 Drain
RM 58.0
Joint DID No. 2 Drain
RM 55.9
Outlet for DID No. 10 Drain
RM 51.6
Drain near Grandview-Prosser Hwy
RM 47.5
Roza-Sunnyside Joint Drain
RM 47.4
Chandler-Prosser Power Canal
RM 47.1
Prosser STP
RM 46.5
12509050 RM 55.0
Spring Creek
RM 41.8
Snipes Creek
RM 41.8
Chandler Power Return
RM 35.8
Kiona Canal
RM 34.9
Corral Canyon Creek
RM 33.5
Columbia Canal
RM 18.0
12510500 RM 29.9
Richland Canal
RM 18.0
YAKIMA RIVER
Mouth of Yakima River RM 0.0
COLUMBIA RIVER
USGS

RECLAMATION OPERATES THE RESERVOIRS TO MEET MOST OF THE ENTITLEMENTS

What are the Entitlements and What about Operations – Back to EARLIER RUNOFF AND Then onto PRORATING

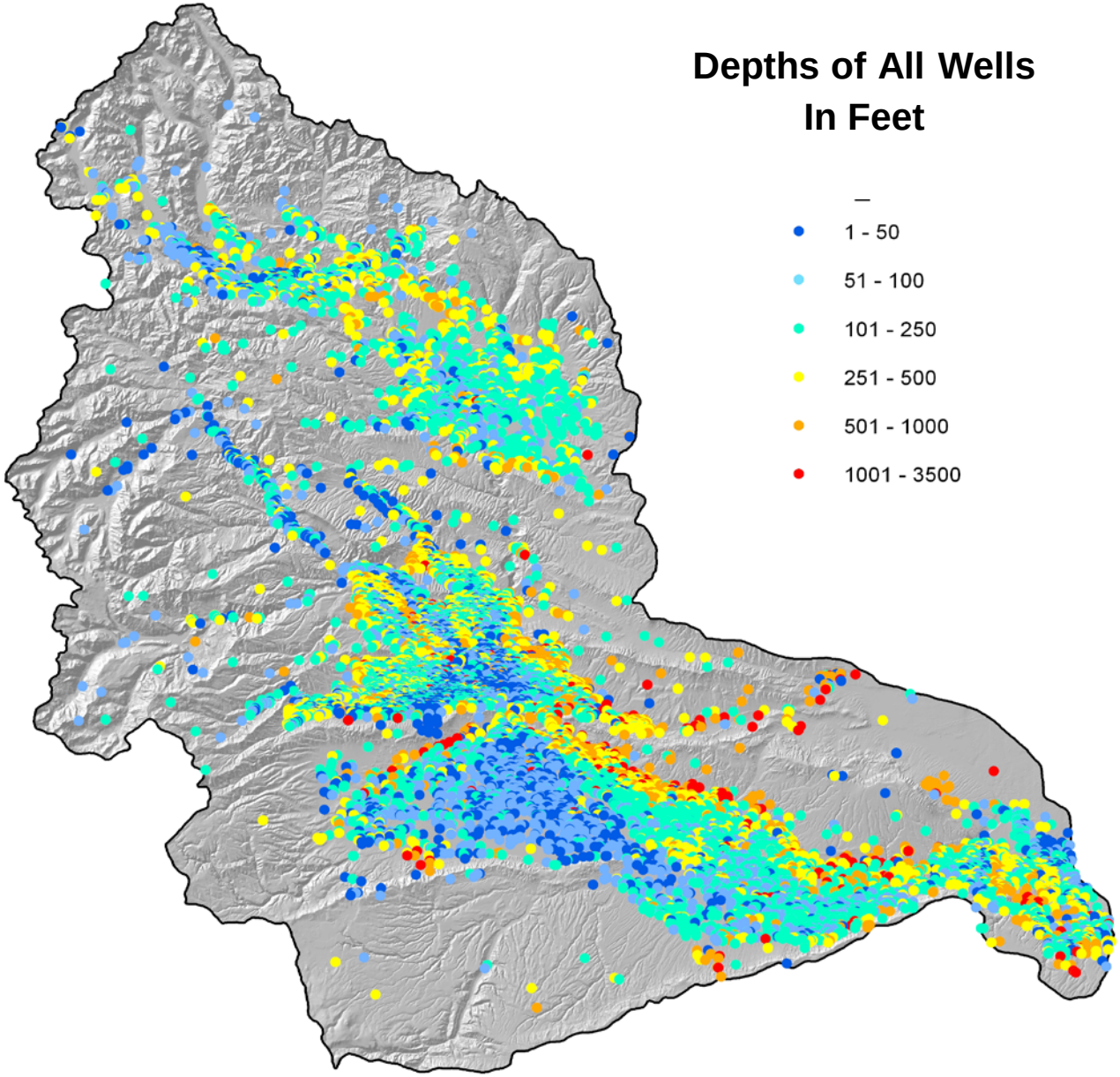

EXPLANATION
Mean Annual Diversions, in cubic feet per second
Entitlement (WaDOE)
0.3 - 20
21 - 40
Observed or Estimated (Reclamation)
1 - 20
21 - 60
61 - 150
151 - 550
551 - 1172
The non-power quantities total 4,383 ft3/s



From Mike Dettinger, USGS

PRORATING

- Occurs for Post-1905 SW Rights
- Prorating has ranged from 37% TO 88% (adjusted throughout year)
- Above PARKER: 1.3 Million AF of 2.5 MAF of Entitlements is Proratable
- 1% TO 100% of a District's Entitlement


Depths of All Wells
In Feet
1 - 50
51 - 100
101 - 250
251 - 500
501 - 1000
1001 - 3500

USGS

GROUNDWATER RIGHTS

	No. of certificates and permits	Instantaneous (gal/min)	Annual (acre-ft)	Irrigated area (acres)
Certificates	**2,575**	**720,683**	**422,040**	**101,371**
Permits	**299**	**230,623**	**107,191**	**28,199**

Note: about 25% of Irrigation Rights are Standby/Reserve Rights

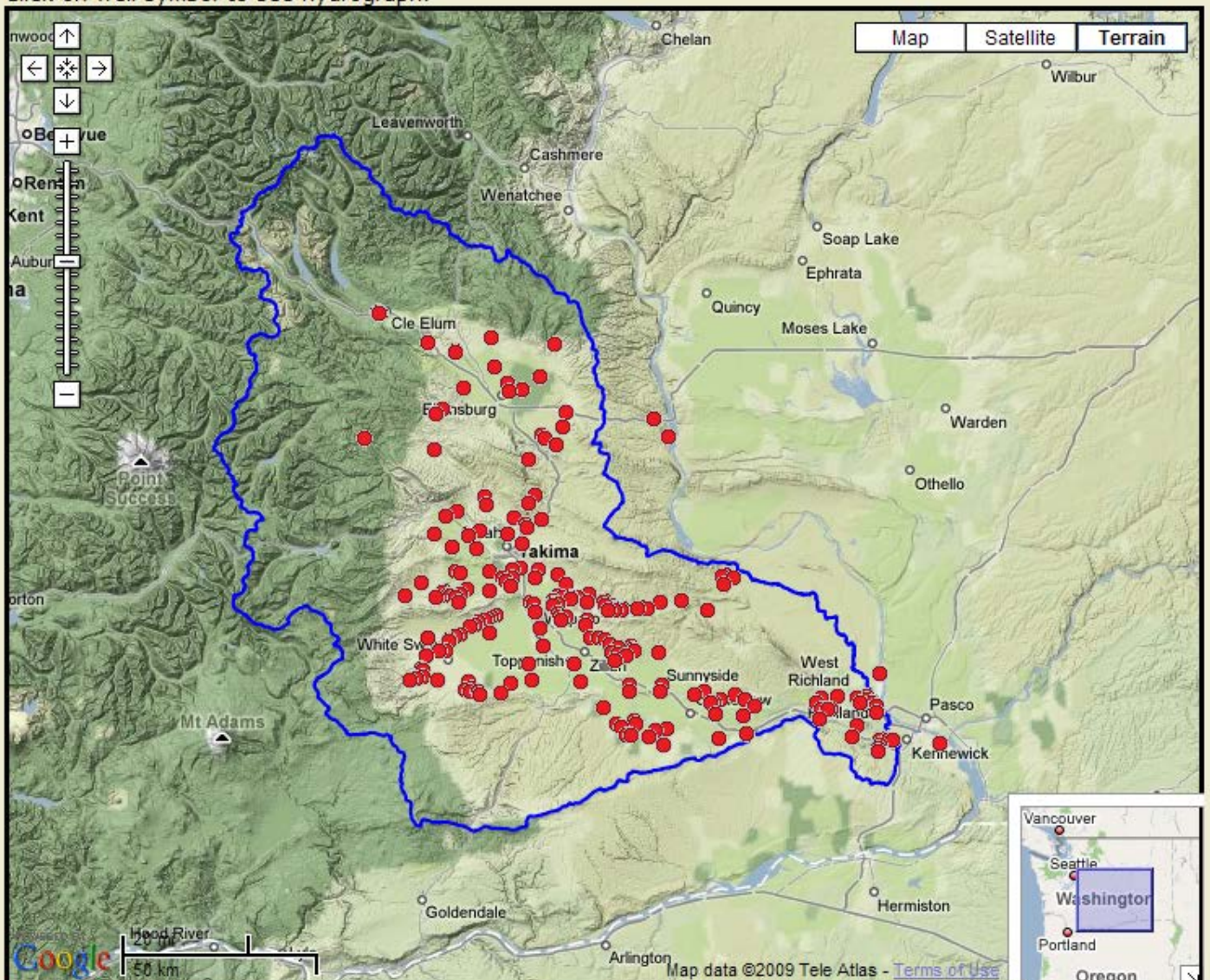
USGS

WHAT HAPPENS IN PRORATING YEARS?

Yakima Ground Water Sites - Hydrographs

Back to DS 343

Click on well symbol to see hydrograph.

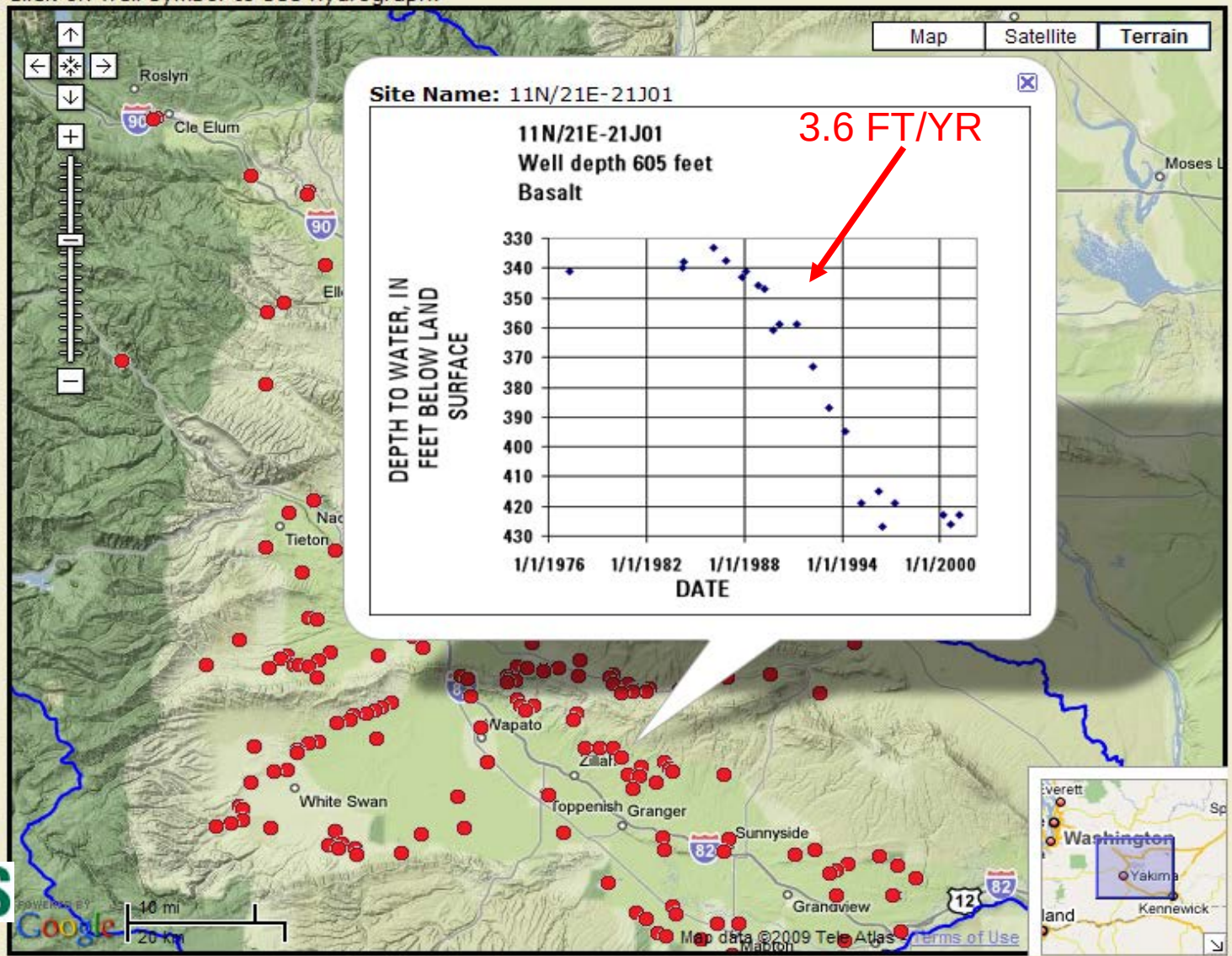


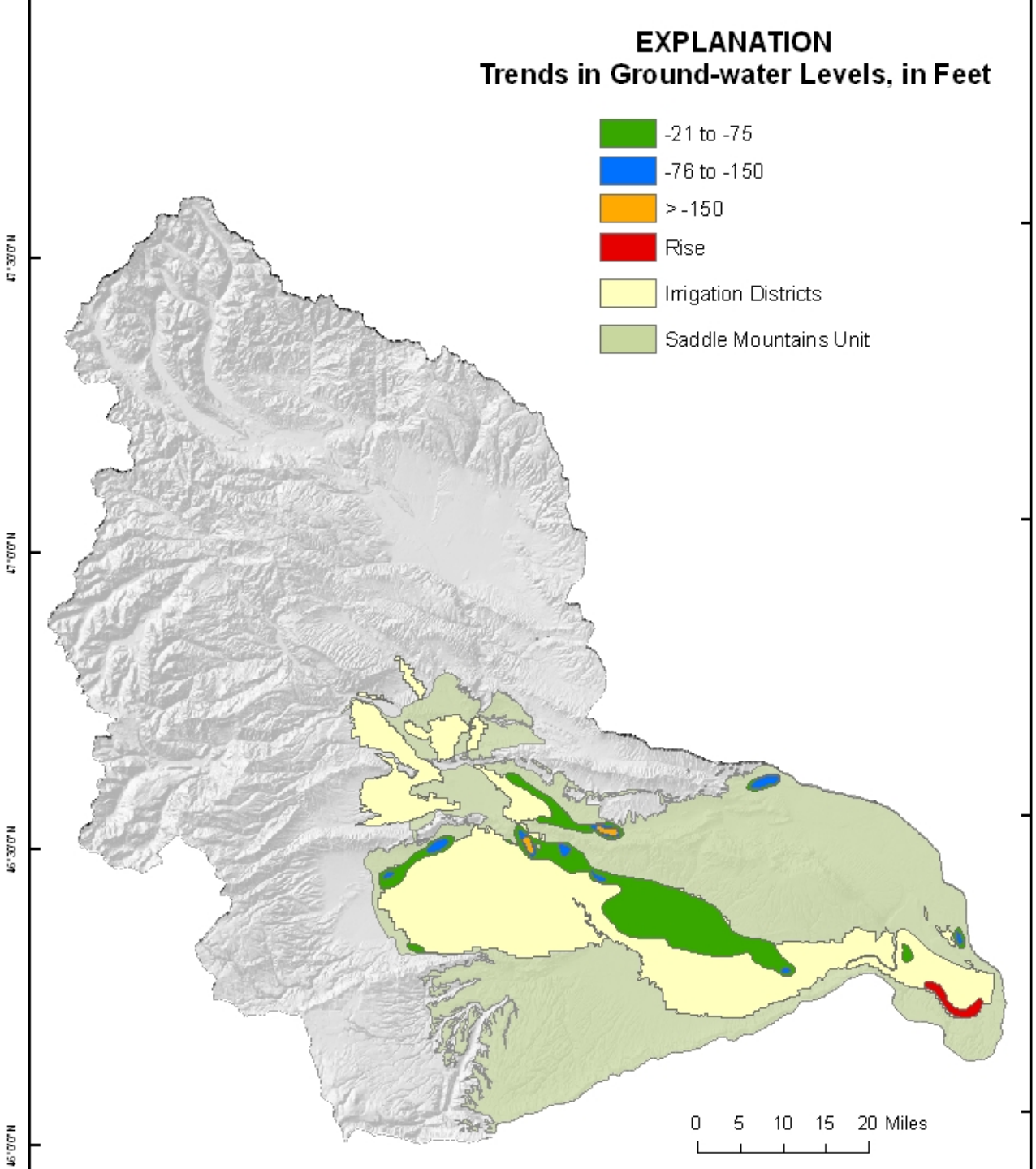
USGS

Yakima Ground Water Sites - Hydrographs

Back to DS 343

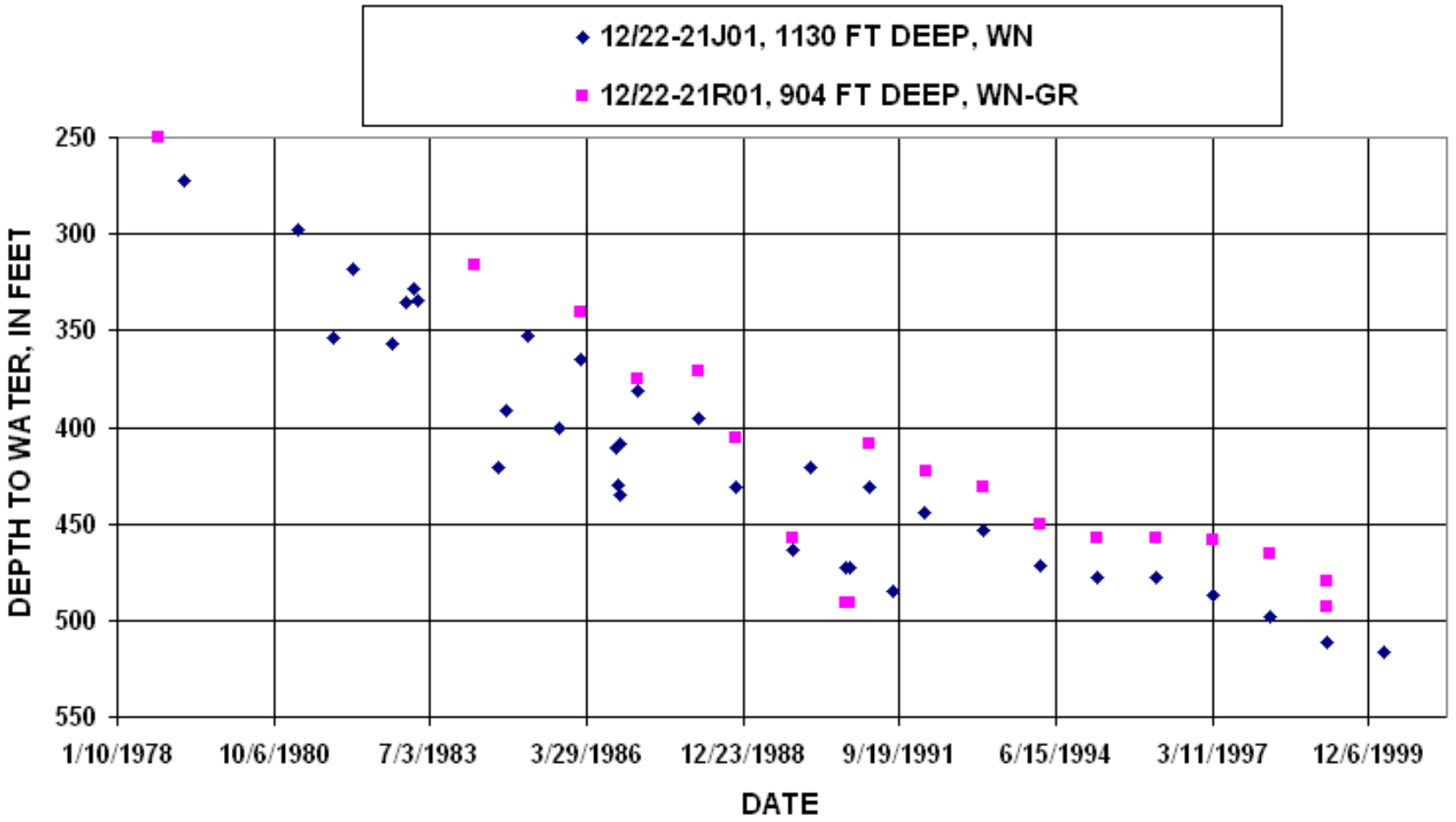
Click on well symbol to see hydrograph.




EXPLANATION
Trends in Ground-water Levels, in Feet
-21 to -75
-76 to -150
> -150
Rise
Irrigation Districts
Saddle Mountains Unit
0 5 10 15 20 Miles

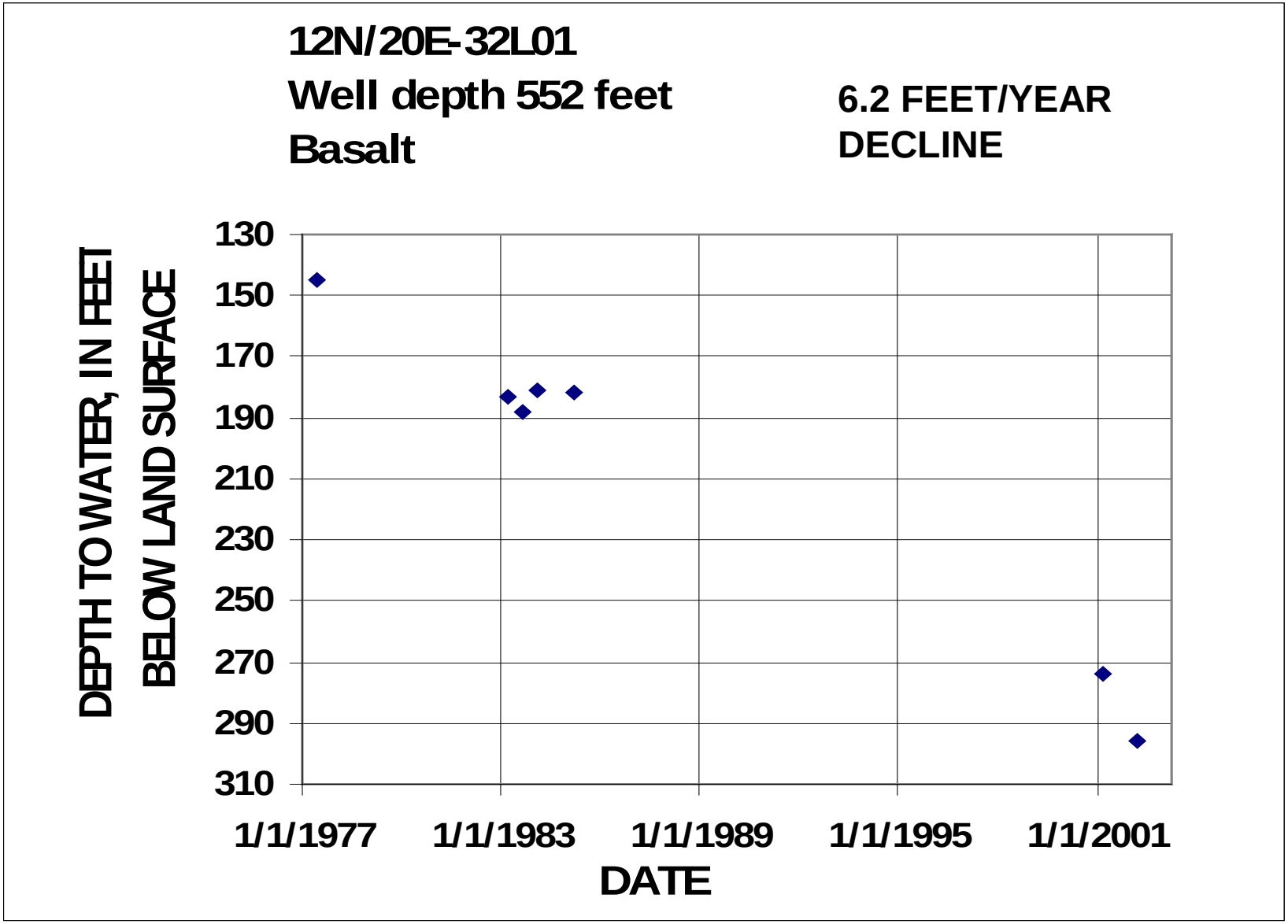
USGS

What Is Currently Happening To Groundwater Storage Due to Pumpage in Areas Outside of Irrigation Districts?



11 FEET/YEAR DECLINE

USGS


12N/20E-32L01
Well depth 552 feet
Basalt
6.2 FEET/YEAR
DECLINE
DEPTH TO WATER, IN FEET
BELOW LAND SURFACE
130
150
170
190
210
230
250
270
290
310
1/1/1977
1/1/1983
1/1/1989
1/1/1995
1/1/2001
DATE

MANY BELIEVE GROUND WATER WILL SUPPLEMENT SURFACE-WATER SUPPLIES IN A WARMING WORLD BECAUSE GROUNDWATER IS ‘BUFFERED’ AGAINST A WARMING CLIMATE

SIMPLE EXAMPLES OF WARMING AFFECTS ON CROPS IN THE YAKIMA RIVER BASIN

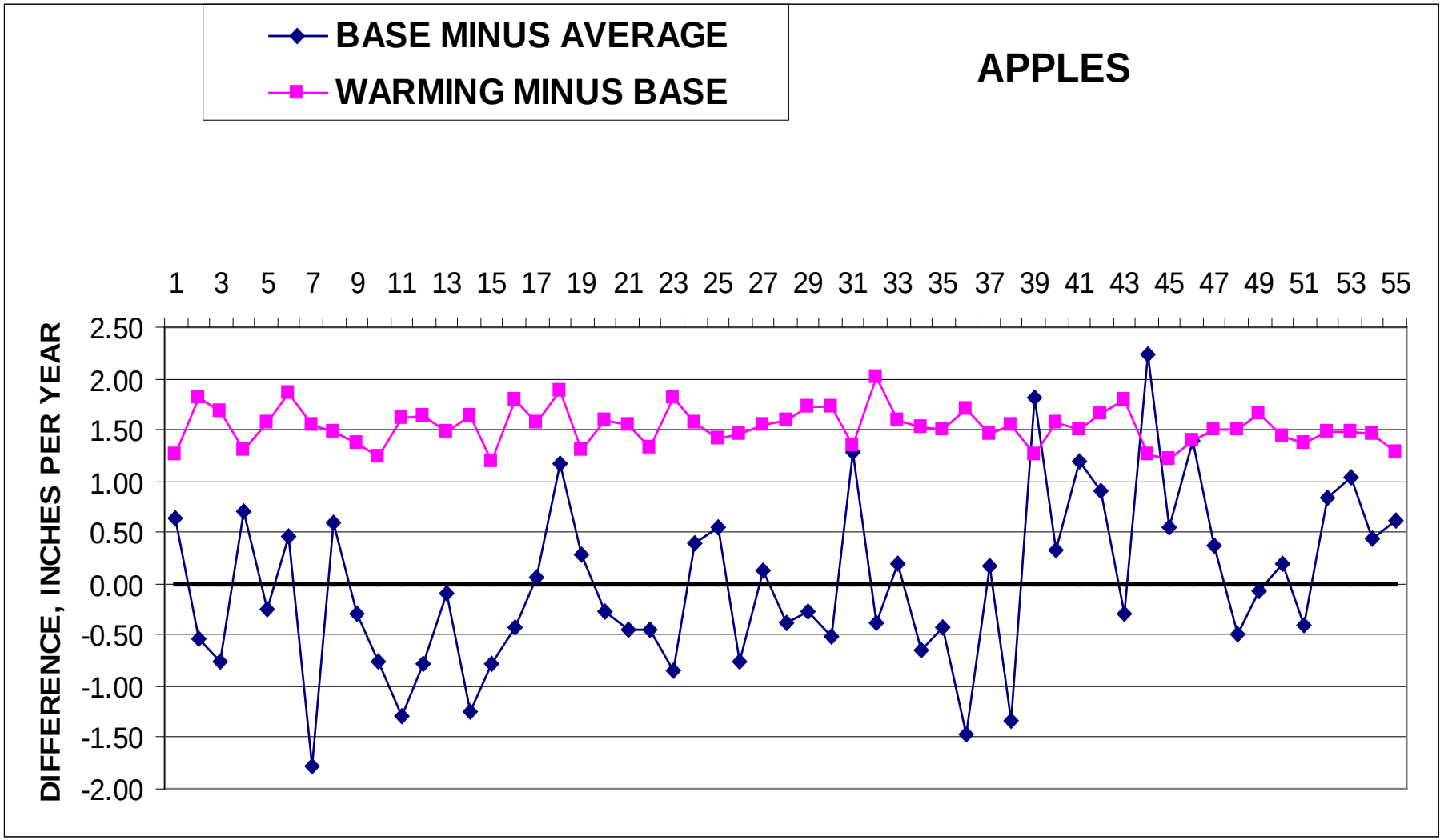
- CALCULATIONS FOR SUNNYSIDE, WA
- ASSUME A 3 DEGREE FAHRENHEIT WARMING
- LOOK AT CHANGES IN CROP-WATER USE
- ASSUMES APRIL 1 START IRRIGATION
- DAILY VALUES WATER-YEARS 1949-2003
- IRRIGATION RATE SAME FOR ALL YEARS

USGS

GENERAL ASPECTS

- MEAN ANNUAL POTENTIAL EVAPOTRANSPIRTATION INCREASED BY ABOUT 4.3 INCHES
- FOR IRRIGATED LANDS, INCREASE IN EVAPORATIVE DEMAND IS ABOUT EQUIVALENT TO 180,000 ACRE-FT (BETWEEN KEECHELUS AND RIMROCK STORAGE CAPACITIES)

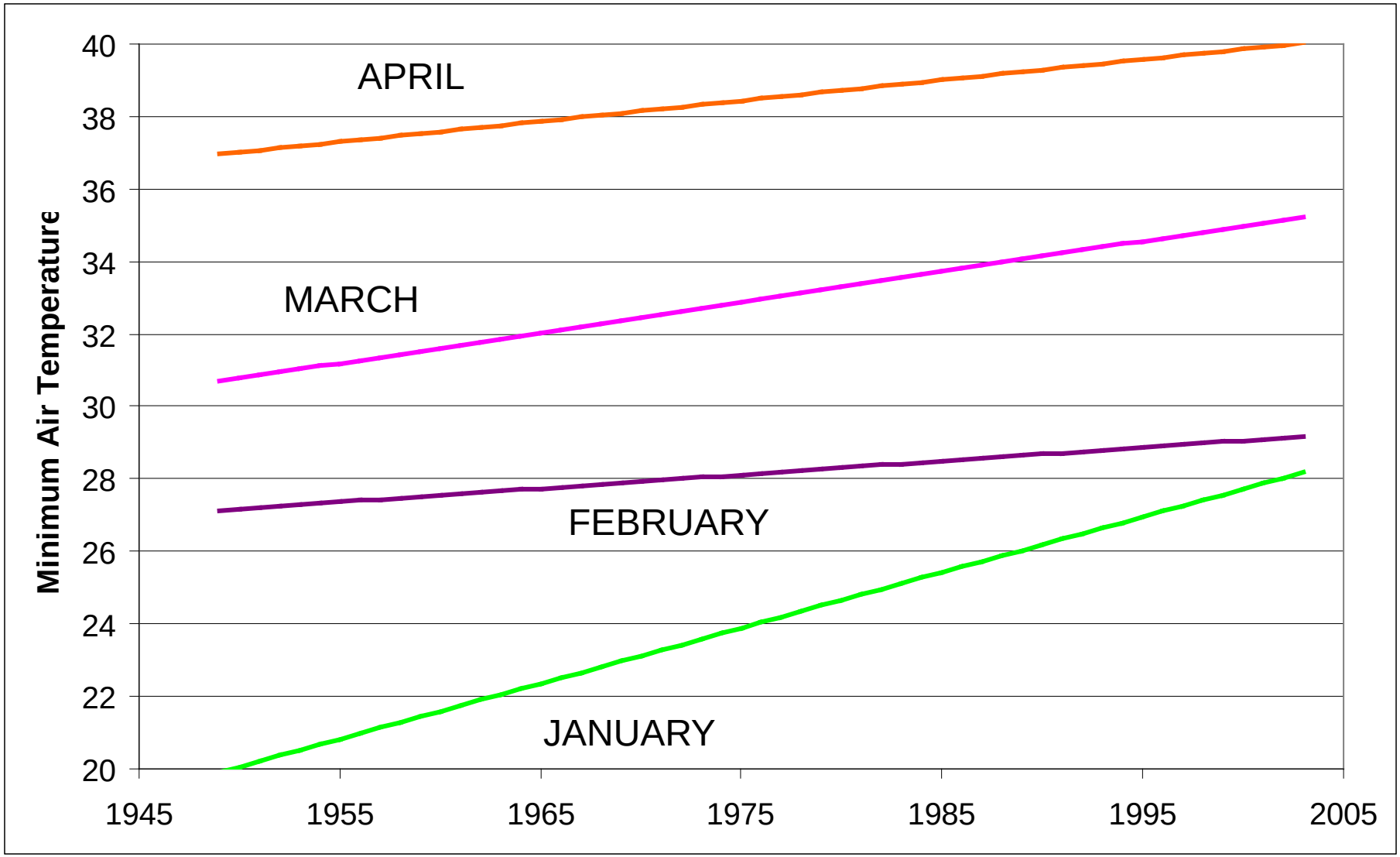
USGS



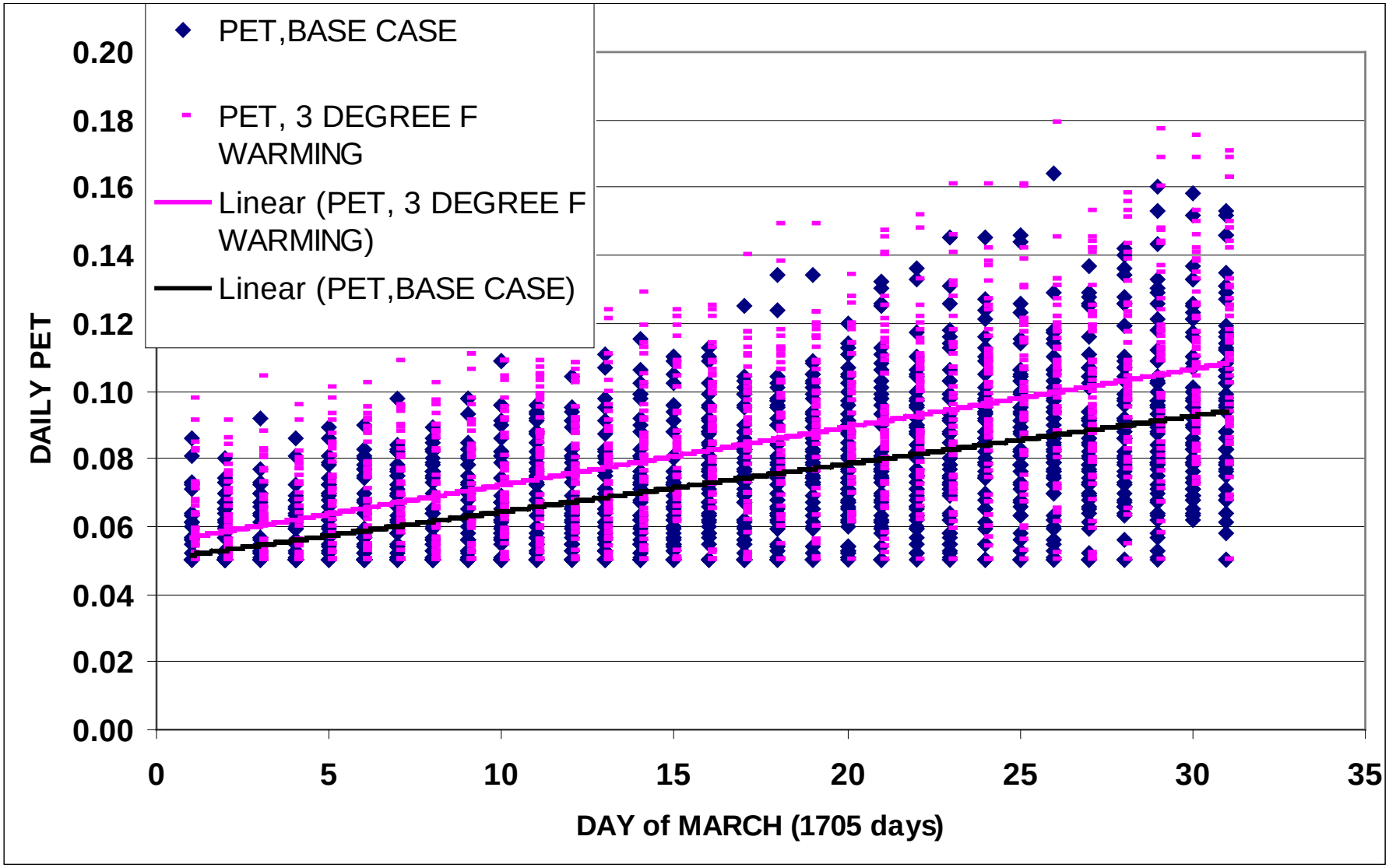
USGS

WATER YEARS: 1949-2003

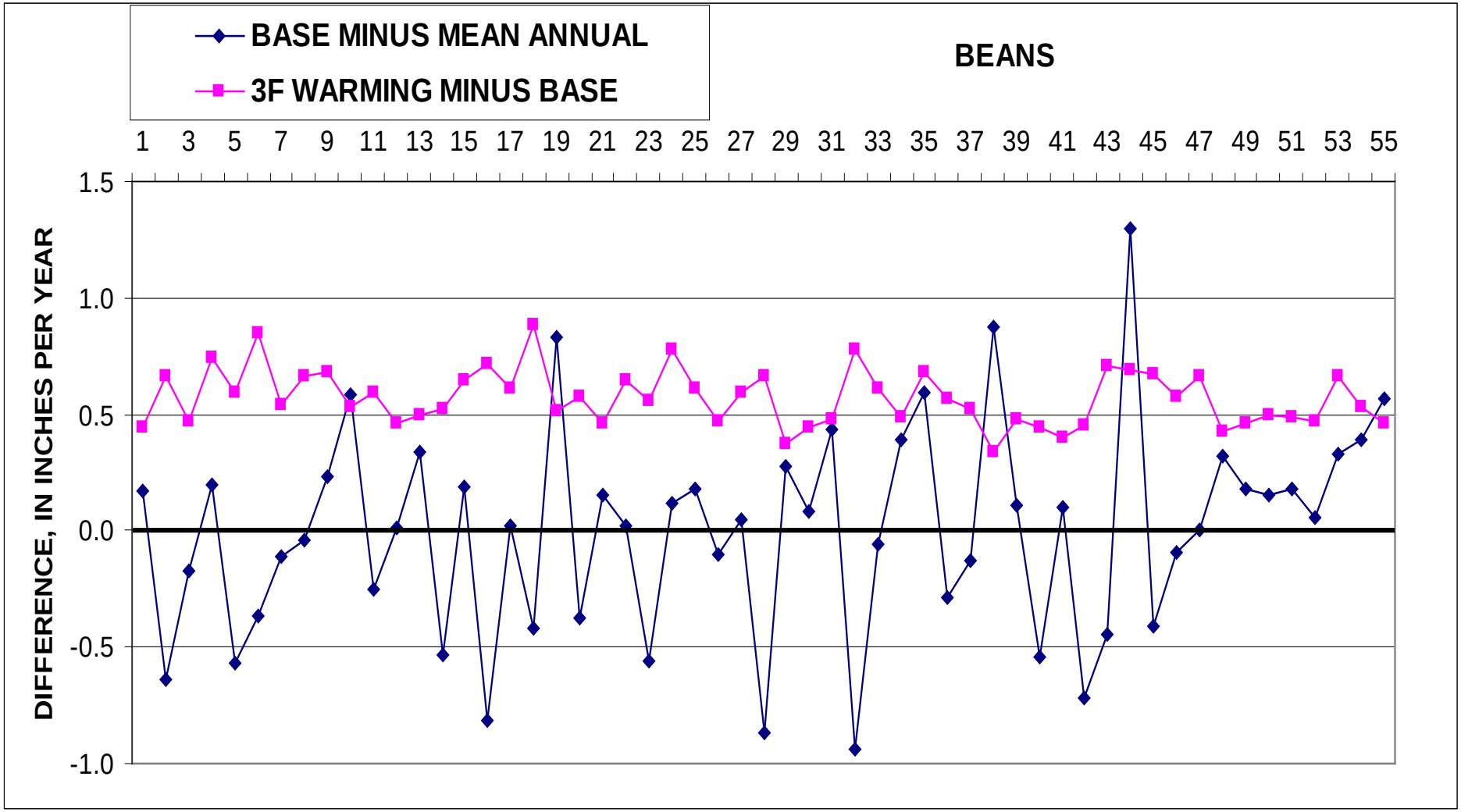
Monthly Minimum Air Temperature, Sunnyside



USGS


PET,BASE CASE
PET, 3 DEGREE F WARMING
Linear (PET, 3 DEGREE F WARMING)
Linear (PET,BASE CASE)
DAILY PET
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
5
10
15
20
25
30
35
DAY of MARCH (1705 days)

USGS


BASE MINUS MEAN ANNUAL
3F WARMING MINUS BASE
BEANS
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55
1.5
1.0
0.5
0.0
-0.5
-1.0
DIFFERENCE, IN INCHES PER YEAR

USGS

- Results vary by soil type (119 categories for lower basin)
- Results very dependent on irrigation method
- Much to gain by improvement in irrigation methods and (?) conveyance systems
- If all croplands > 2.5 ft of demand switched to < 2.5 ft, a reduction in total demand of ~500,000 acre-feet per year may be possible

USGS

IMPORTANCE OF SW & GW RETURN FLOWS

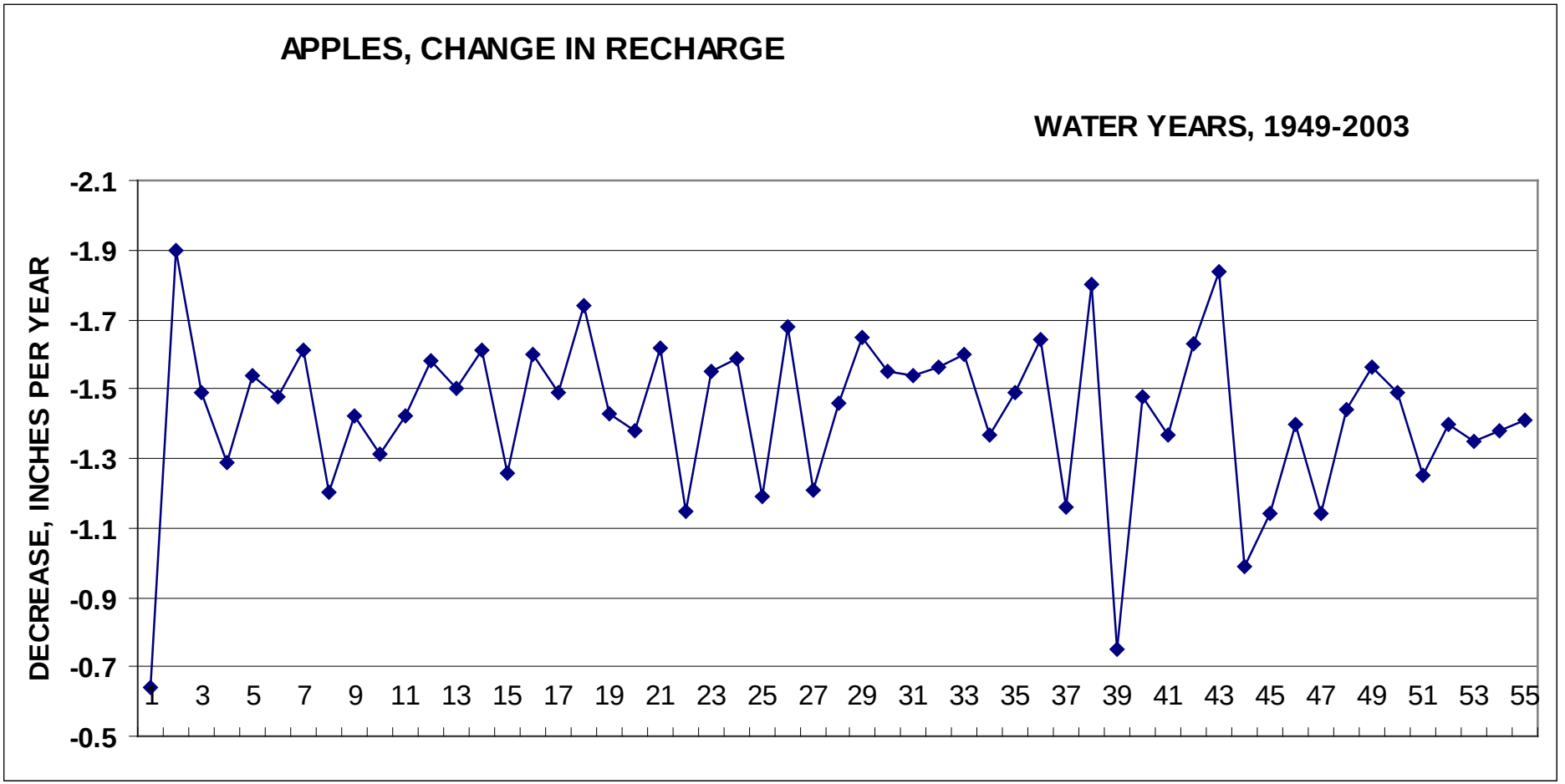
EXAMPLE:

AUGUST 15, 2001 VALUES IN CUBIC FEET PER SECOND

YAKIMA RIVER AT PARKER	357	
CHANDLER POWER CANAL	479	
YAKIMA RIVER AT PROSSER	308	GAIN OF 430
YAKIMA RIVER AT KIONA	1,033	GAIN OF 449
KENNEWICK CANAL	203	

USGS

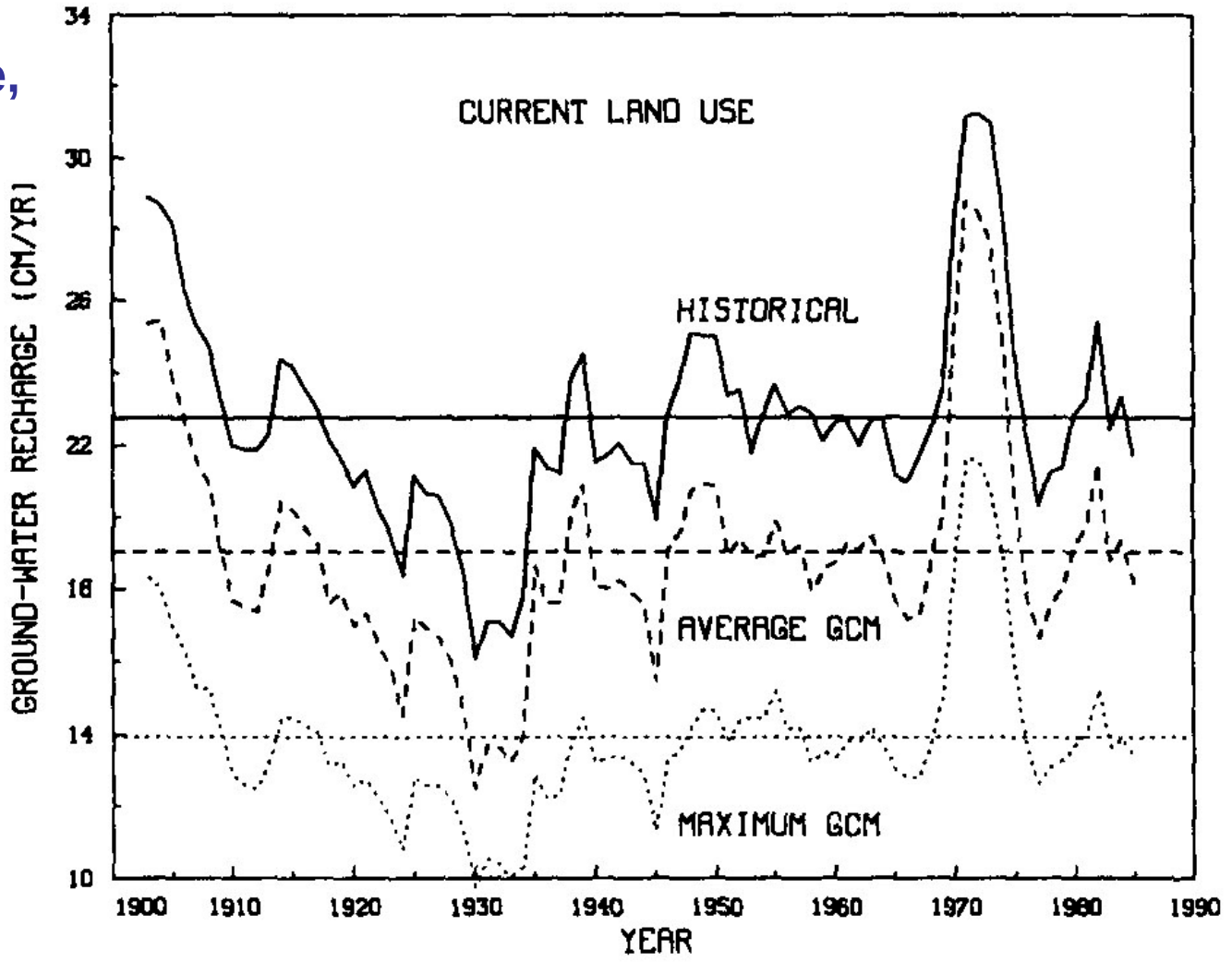
MEAN ANNUAL REDUCTION IN RECHARGE OF ABOUT **20 PERCENT** WITH A 3 DEGREE FARHENHEIT WARMING



USGS

93 ft^3/s reduction in mean recharge, about equal to total pumpage for irrigation from the basin-fill deposits in 2001

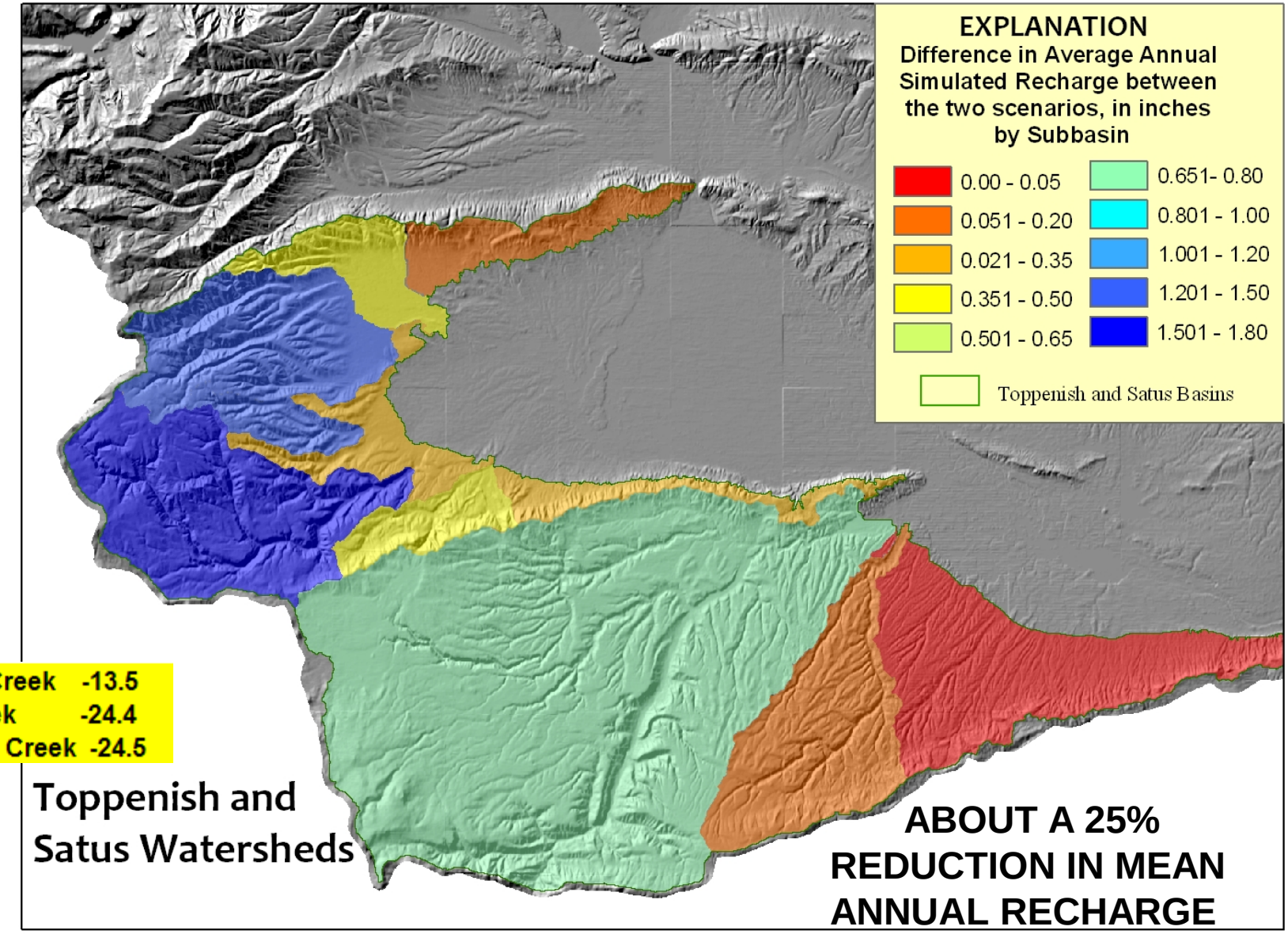
ASSUMES IRRIGATION STARTS APRIL 1



FIVE-YEAR MOVING AVERAGES OF GROUNDWATER RECHARGE

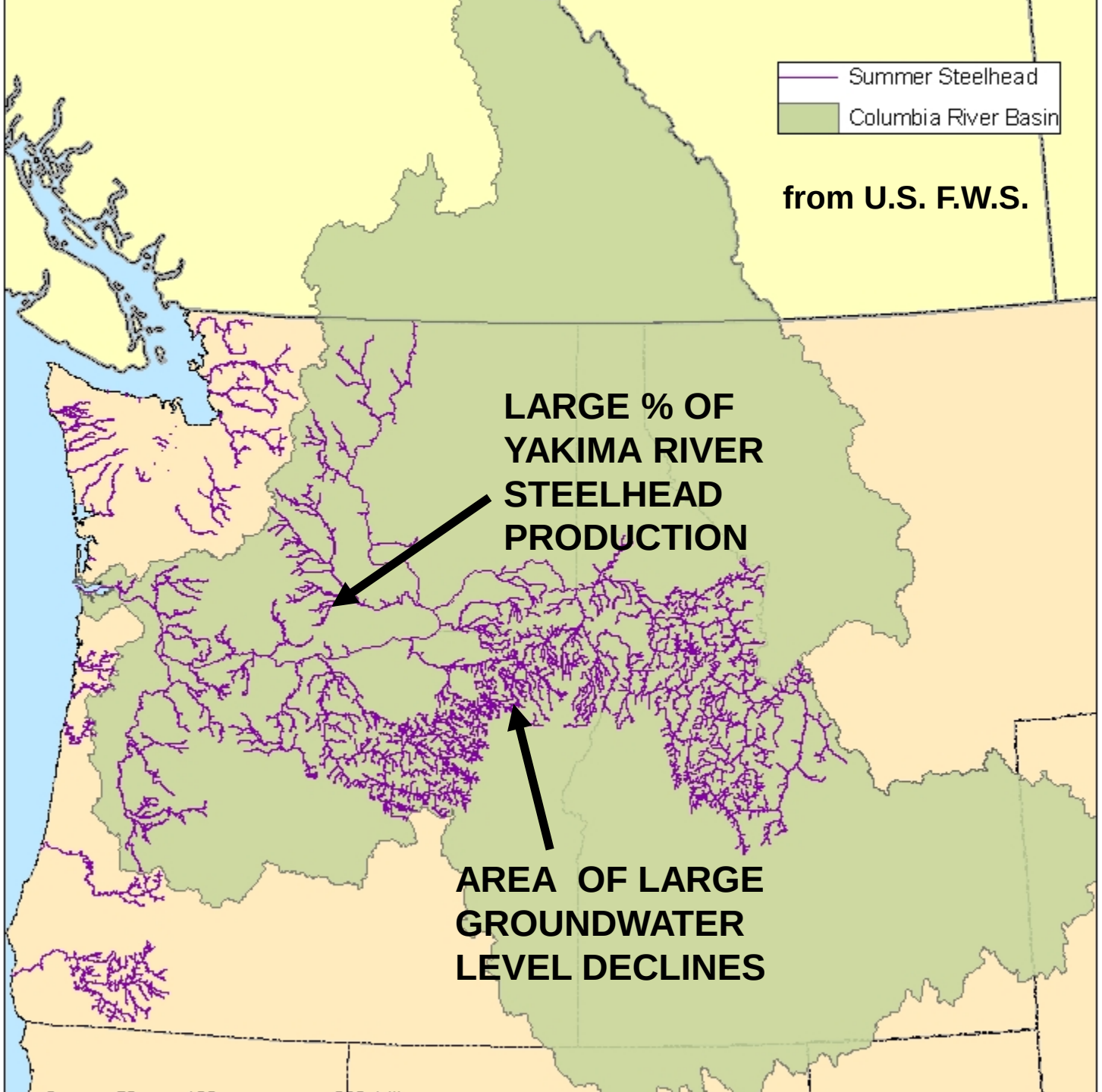
USGS

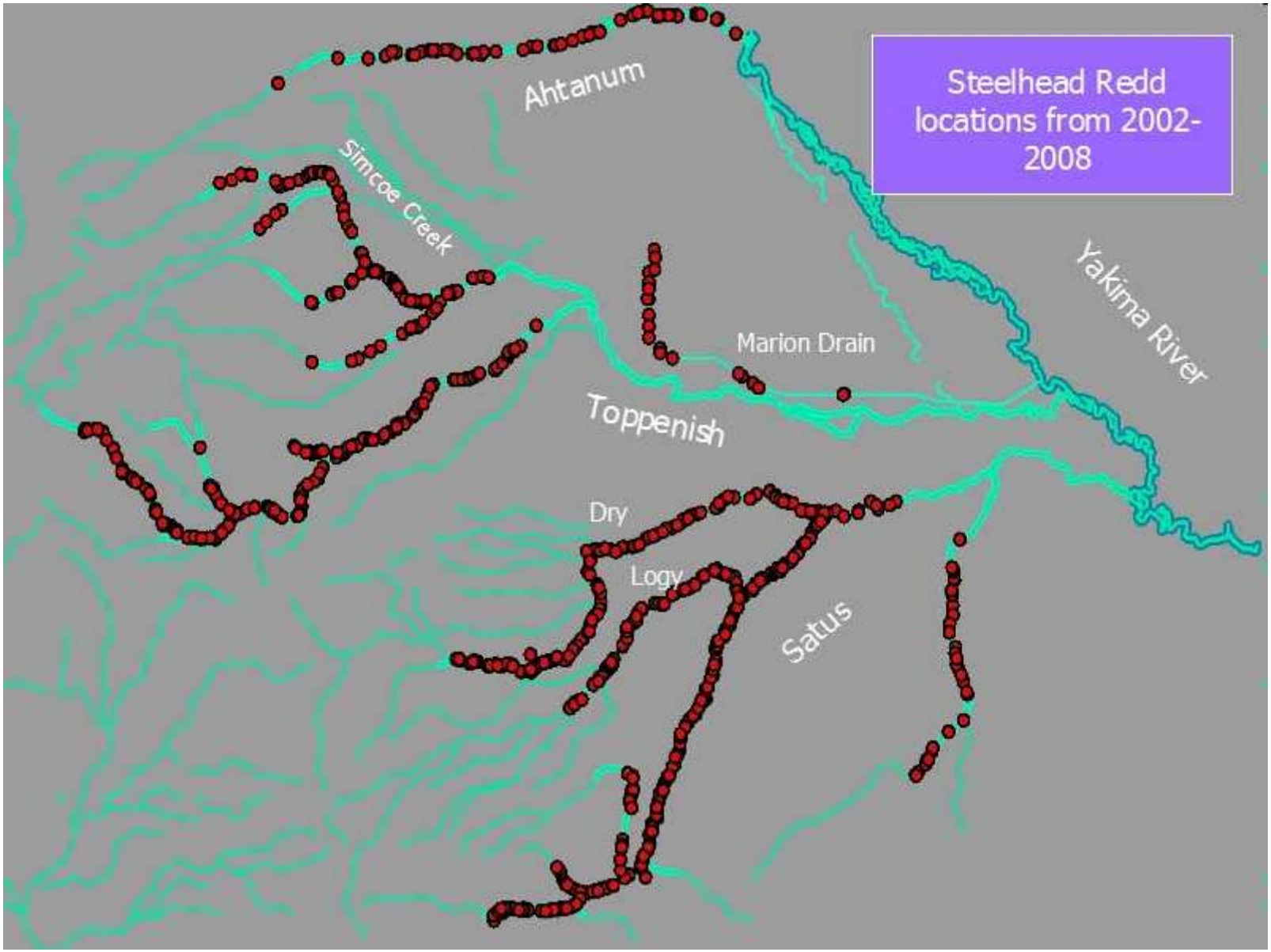
Vaccaro, 1992, JGR



USGS

SENSITIVITY OF 2 °C INCREASE ON RECHARGE, YAKIMA RIVER BASIN


Summer Steelhead
Columbia River Basin
from U.S. F.W.S.
LARGE % OF YAKIMA RIVER STEELHEAD PRODUCTION
AREA OF LARGE GROUNDWATER LEVEL DECLINES



From Yakima Nation Fisheries, 2009

SOME ENVIRONMENTAL ASPECTS OF POTENTIAL DECREASED GROUNDWATER RECHARGE-DISCHARGE

IMPACTS ON:

SPAWNING AREAS

REFUGIA DURING SALMONID MIGRATION (DECREASED CONNECTIONS)

REARING AREAS (LESS)

SLOW VELOCITY--SHALLOW WATER AREAS (MORE DEWATERING)

CREATION OF MIGRATORY BARRIERS

RECRUITMENT OF BLACK COTTONWOODS

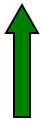
LOSS OF RIPARIAN HABITAT

ALGAL AND INVERTABRATE COMMUNITY STRUCTURE

USGS

DECREASING SNOWPACK

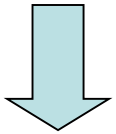
EARLIER (& LESS) RUNOFF



ELEVATION OF SNOW TRANSITION ZONE

INCREASED ET

INCREASED PUMPAGE



DECREASED RECHARGE

WARMER RECHARGE

DECREASED GROUNDWATER DISCHARGE
LOWER BASEFLOWS
DECLINING GROUNDWATER LEVELS

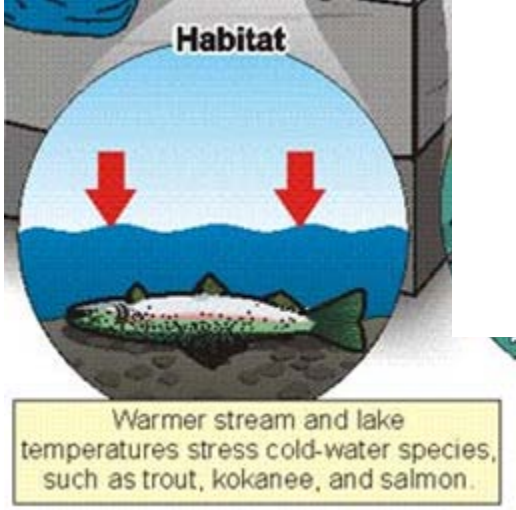
VULNERABILITIES

USGS

Water Supply

- RESERVOIR OPERATIONS
- LESS UNREGULATED RUNOFF APRIL-SEPTEMBER=>STORAGE CONTROL DATE
- DECREASED TOTAL STREAMFLOW IN VARIOUS SMALL BASINS-DIVERSIONS, FISH
- GROUNDWATER LEVELS/STORAGE
- JUNIOR/SENIOR WATER-RIGHTS

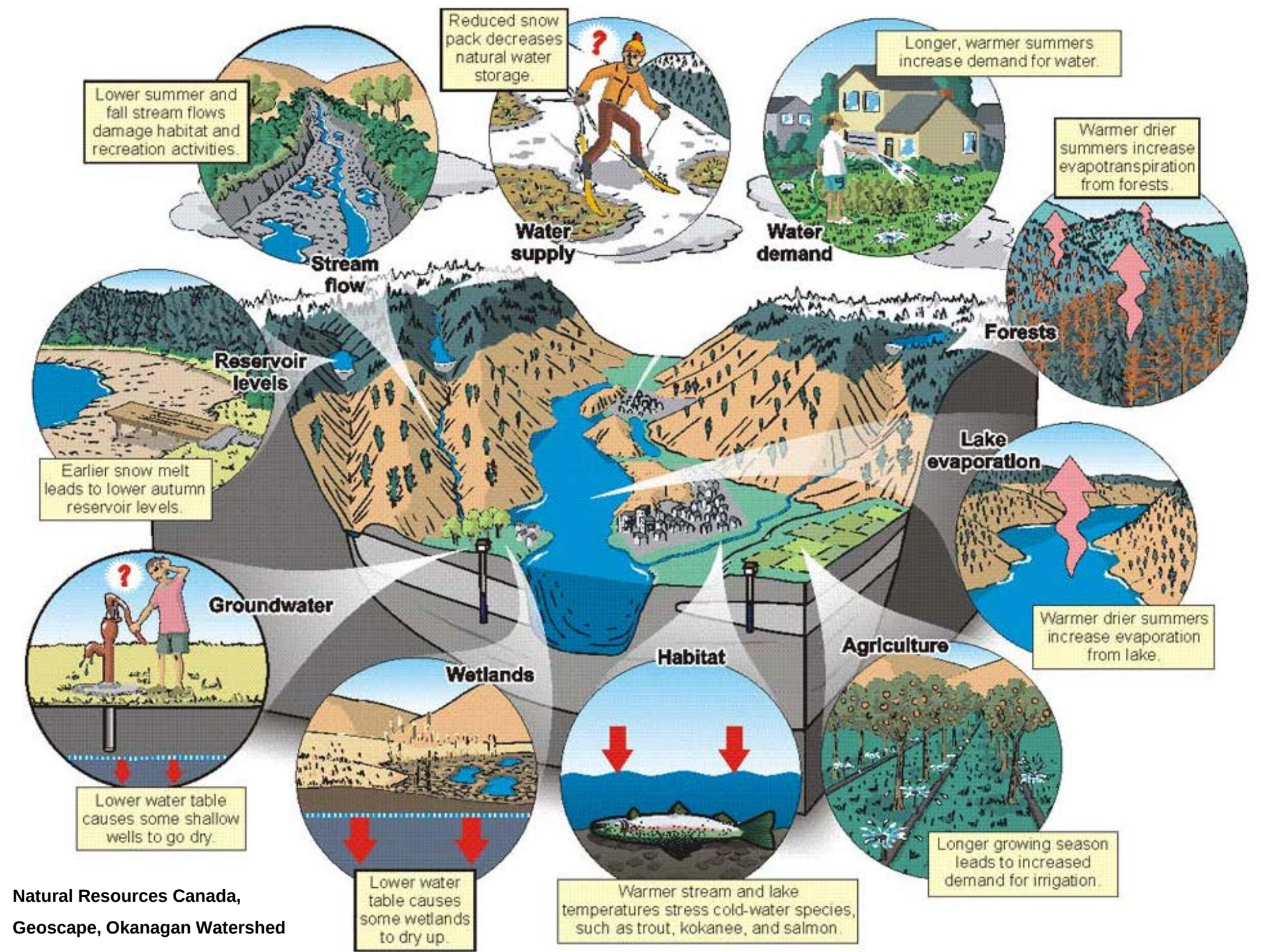
Fish



- SPAWNING SITES
- STREAMFLOW TEMPERATURE
- THERMAL REFUGIA
- INCREASED ENERGY EXPENDITURES
- DIEASE
- INCREASE PREDATATION
- BULL TROUT, STEELHEAD, COHO—FRAGMENTATION, ETC.

Other

- PLANT STRESS-Native and Perennial crops
- ALGAL COMMUNITY STRUCTURE
- INVERTEBRATE COMMUNITY STRUCTURE
- INCREASED PLANT INFESTATIONS



Natural Resources Canada,

Geoscape, Okanagan Watershed