Climate Variability Impact Studies in the Treasure Valley region

PI: V. Sridhar PhD PE DWRE, Assistant Professor

Team Members: Xin Jin, Postdoc

Civil Engineering, Boise State University, Boise, ID 83725

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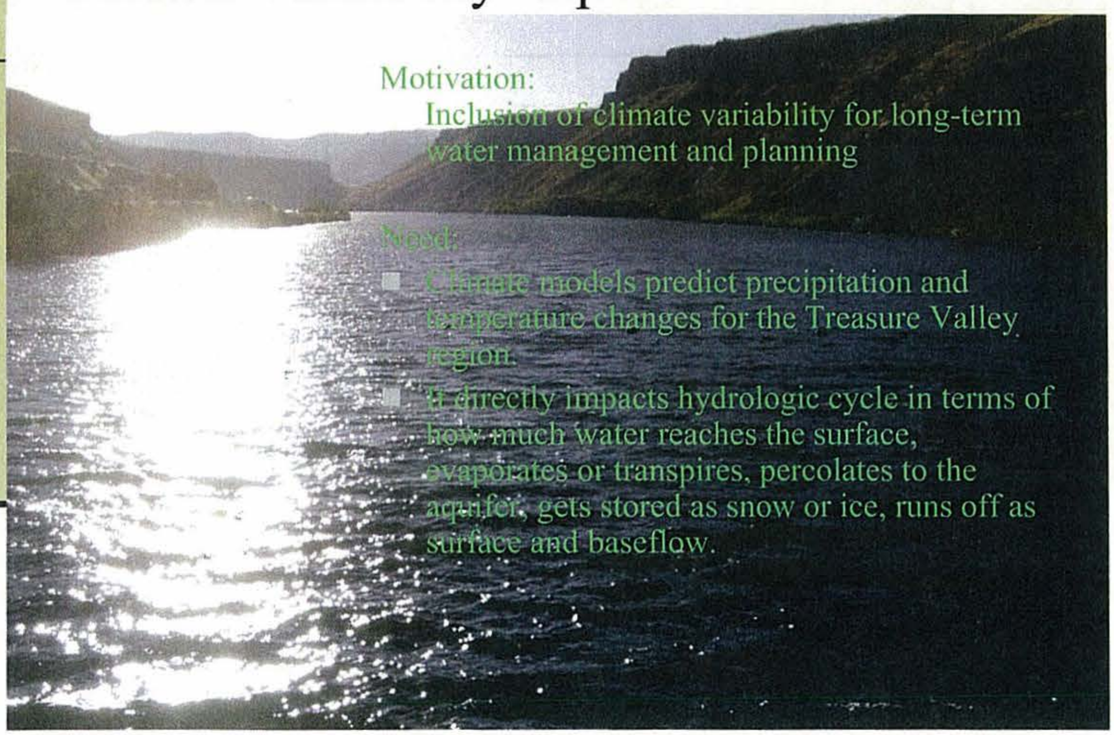
Climate Variability Impact



Motivation:

Inclusion of climate variability for long-term water management and planning

Need:

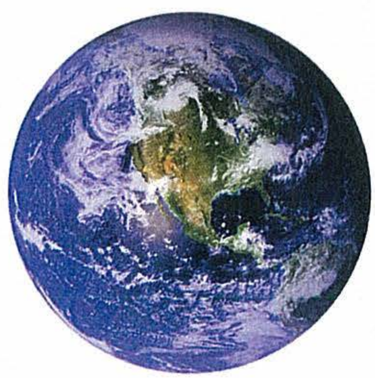
- Climate models predict precipitation and temperature changes for the Treasure Valley region.
- It directly impacts hydrologic cycle in terms of how much water reaches the surface, evaporates or transpires, percolates to the aquifer, gets stored as snow or ice, runs off as surface and baseflow.

Scope of the work

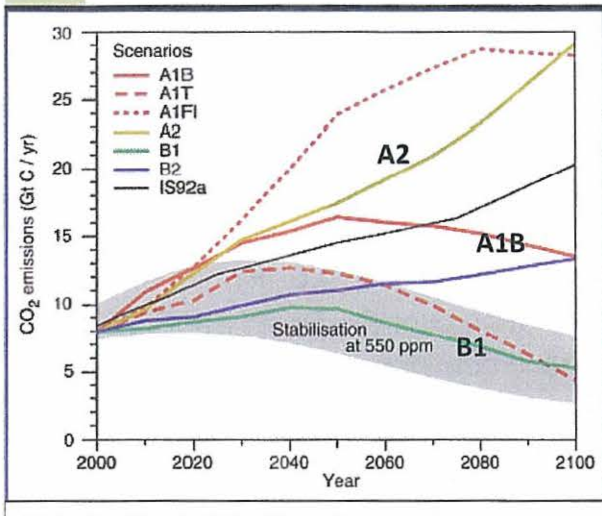
- Review of literature to understand changes in regional temperature and precipitation can impact the hydrology and water supply in the Treasure Valley basin
- Identify atleast three potential climate change scenarios from a suite of climate models and provide the rationale behind the choice of climate data and model
- Using Soil Water Assessment Tool (SWAT) to describe and quantify the possible impact of climate change on the water supply –for the Treasure Valley- amount of rainfall, timing and magnitude of snowmelt, interannual variability assessment in the streamflow and other water balance components including evapotranspiration, soil moisture and recharge.

Intergovernmental Panel on Climate Change (IPCC)

- The leading body for the assessment of climate change
- Established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO)
- Provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences (*www.**ipcc**.ch/*).



IPCC Special Report on Emission Scenarios (SRES)



IPCC, 2007

http://www.ipcc-data.org/guidelines/TGICA_guidance_sdciaa_v2_final.pdf

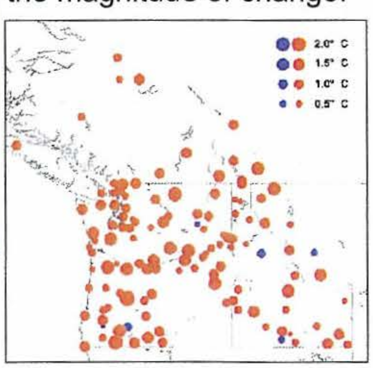
Table 2. The six SRES illustrative scenarios and the stabilisation scenarios (parts per million CO_2) they most resemble (based on Swart *et al.*, 2002).

SRES illustrative scenario	Description of emissions	Surrogate stabilisation scenario
A1FI	High end of SRES range	Does not stabilise
A1B	Intermediate case	750 ppm
A1T	Intermediate/low case	650 ppm
A2	High case	Does not stabilise
B1	Low end of SRES range	550 ppm
B2	Intermediate/low case	650 ppm

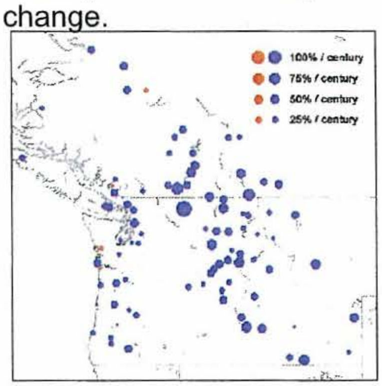
Background: PNW

Source: Climate Impacts Group, UW; http://cses.washington.edu/cig/pnwc/pnwc.shtml

20th century trends in average annual temperature (1920-2000). Increases (decreases) are indicated with red (blue) dots. The size of the dot corresponds to the magnitude of change.



20th century trends in average annual precipitation (1920-2000). Increases (decreases) are indicated with red (blue) dots. The size of the dot corresponds to the magnitude of change.



Warming is expected to continue as a result of climate change, with a likely warming rate of about 0.5°F/decade. While future changes in precipitation are less certain, overall, precipitation is projected to increase in the PNW.

Literature Summary

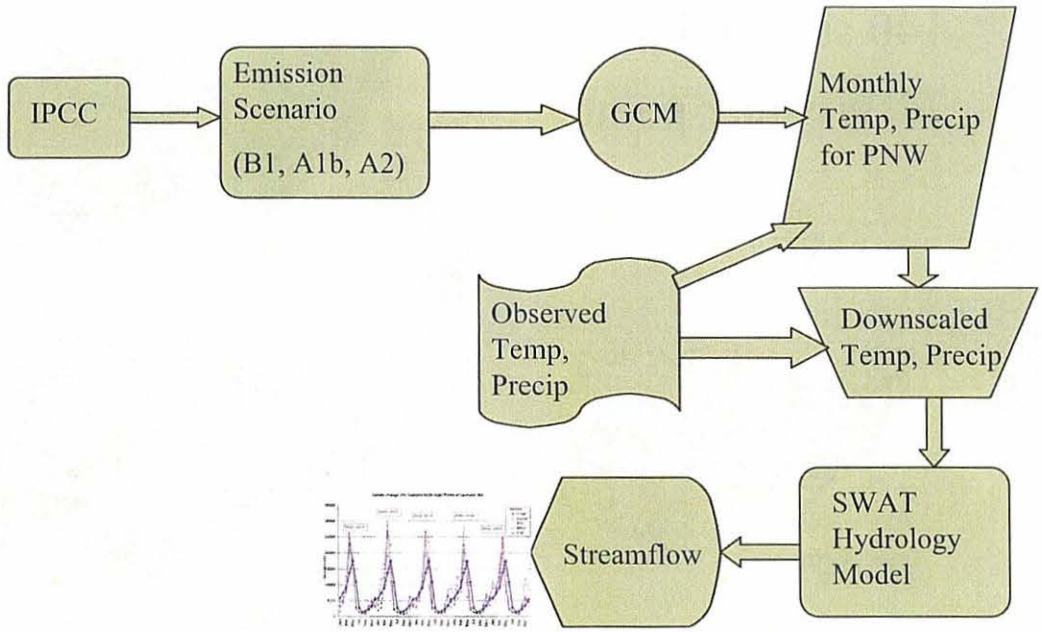
- Most GCMs reproduce key features (Mote and Salathe, 2009)
  - observed PNW climate including the sharp contrast between wet winters and dry summers
  - the 20th century warming of about 0.8°C (4.6 °F)
  - the mean atmospheric circulation over the North Pacific.
  - Hence, we can expect to have confidence in their projected changes in future climate.
- For the SRES scenarios examined here, all models produce annual mean warming of at least 0.1°C (3.3 °F)

Choice of Global Climate Models

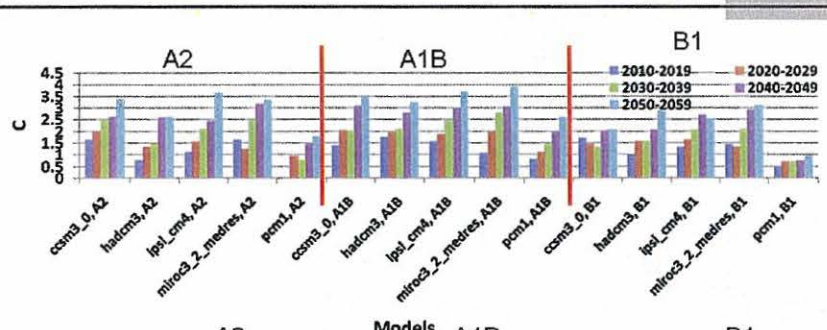
- CCSM3 (National Center for Atmospheric Research, USA)
- HADCM3 (Hadley Centre for Climate Prediction and Research/ Met Office, UK)
- IPSL-CM4 (Institut Pierre Simon Laplace, France)
- MIROC3.2 (medres)(Center for Climate System Research, Univ. of Tokyo, National Institute for Environmental Studies, and Frontier Research Center for Global Change, Japan)
- PCM (National Center for Atmospheric Research, USA)

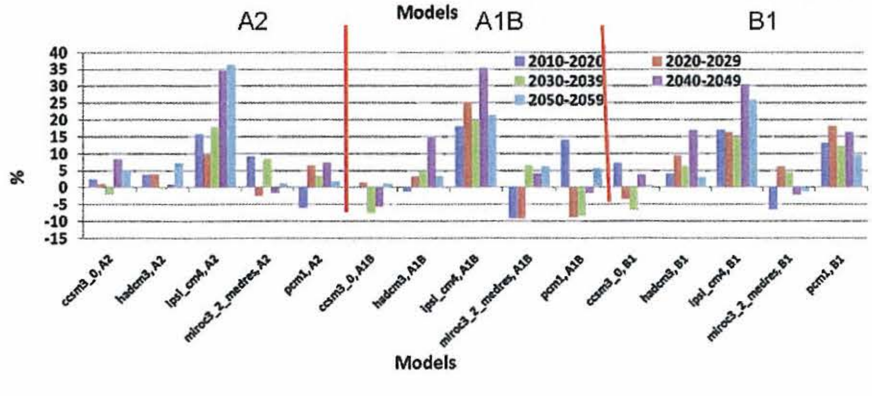
Climate Model Downscaling Approach:

Steps to obtain precipitation and temperature data from global climate models to drive the hydrology model at the local scale



Downscaled GCM Precipitation and Temperature for the Boise River Basin

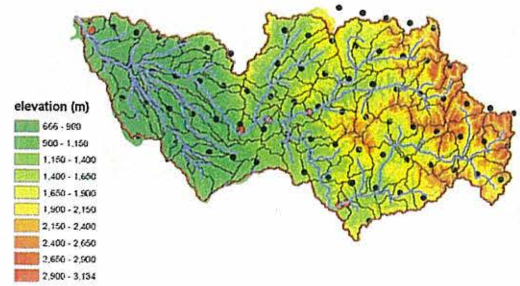


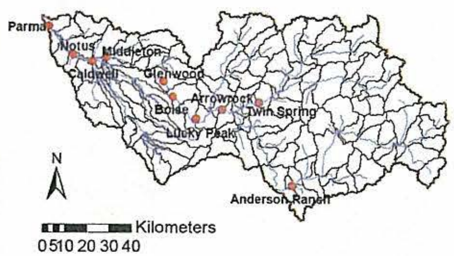


Boise River Watershed

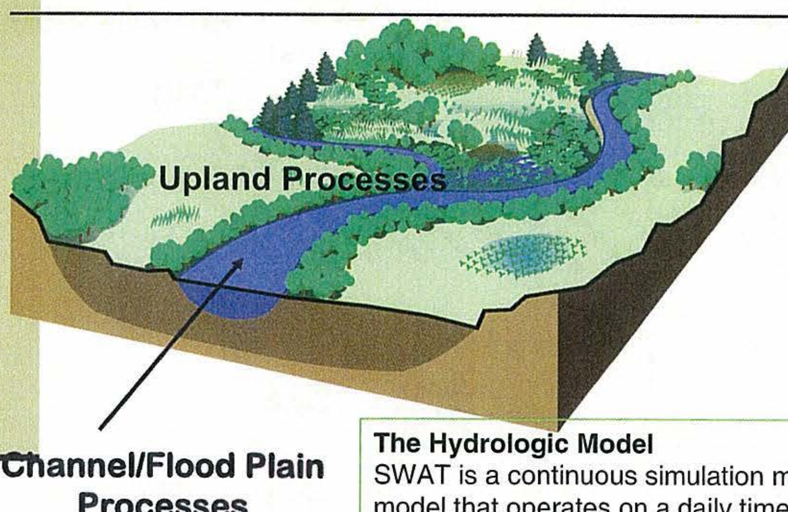
140 sub-basins

74 Weather points





SWAT Watershed System

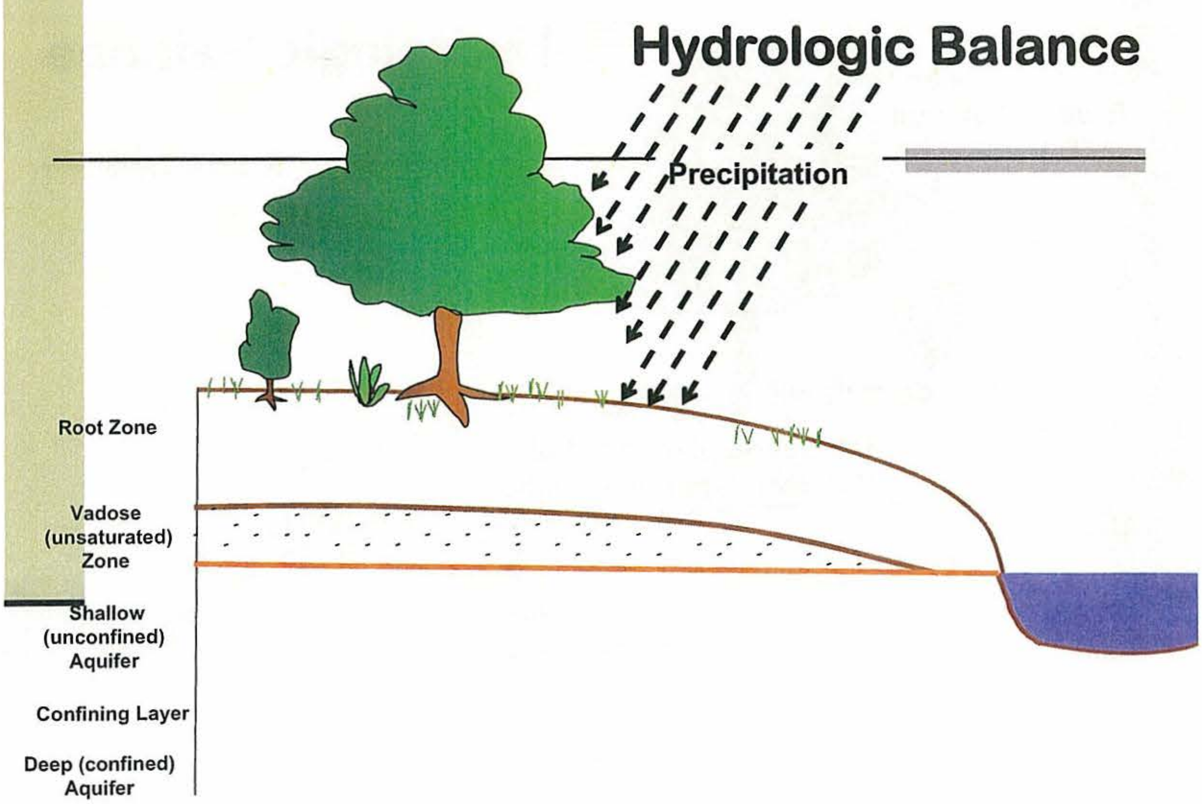


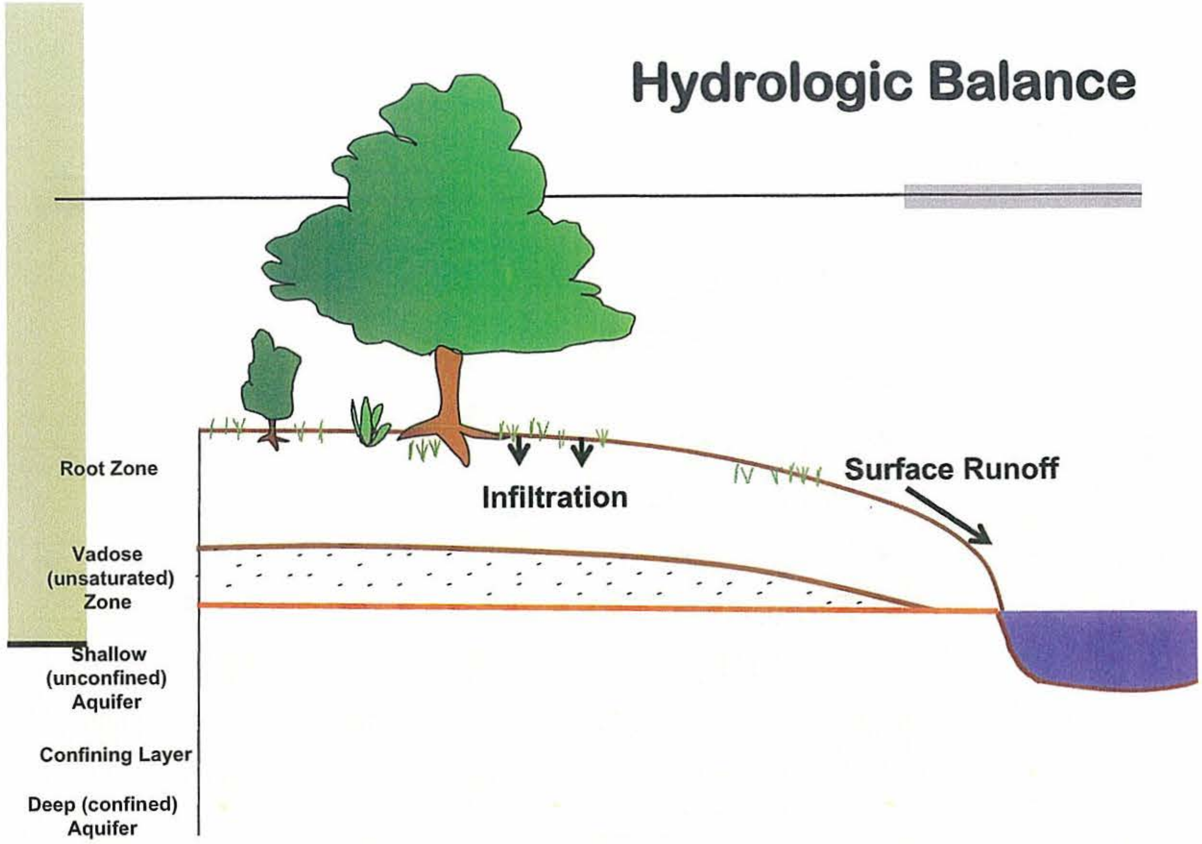
The Hydrologic Model
SWAT is a continuous simulation macroscale hydrologic model that operates on a daily time step and is designed to predict the impacts of land management on the water yield of large ungaged watersheds. The input requirements of the model are data describing a basin's weather, soil properties, topography, vegetation, and land management practices.

Upland Processes

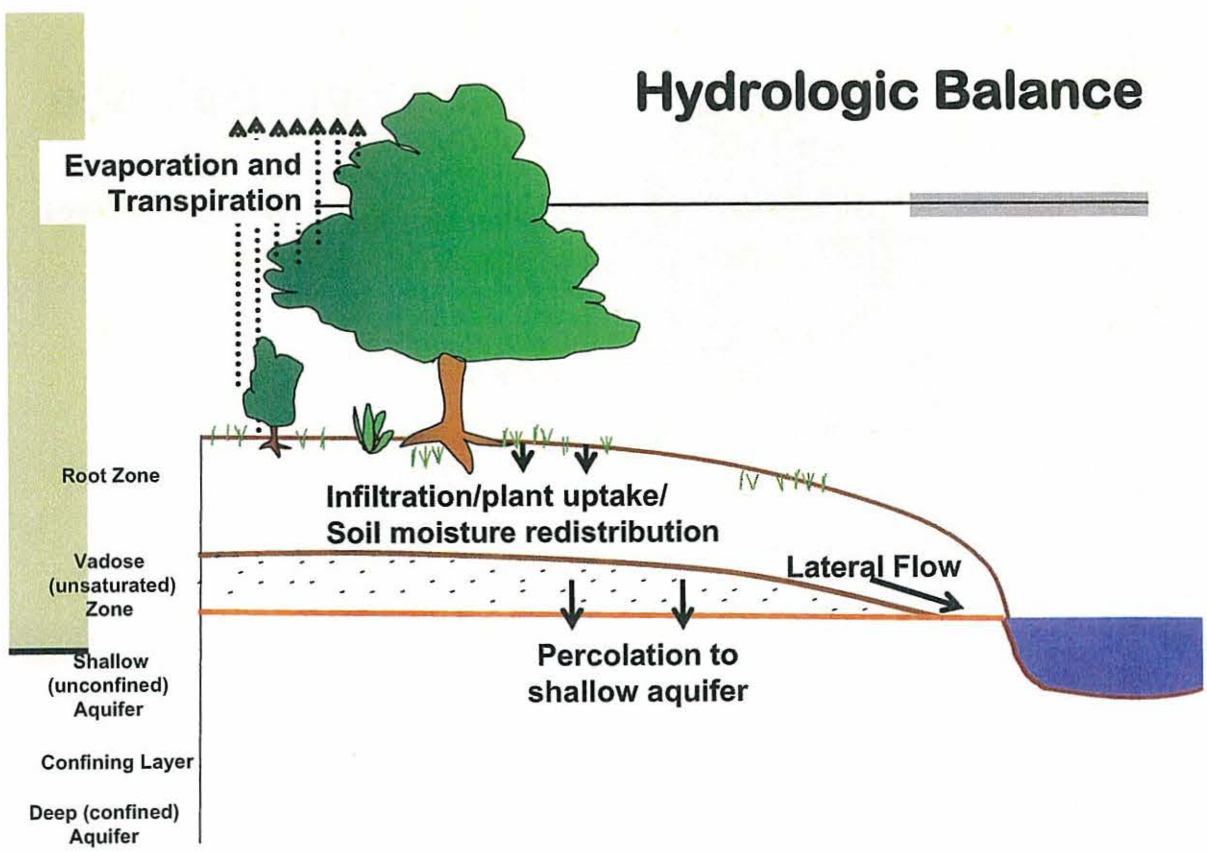
- Weather
- Hydrology
- Sedimentation
- Plant Growth
- Nutrient Cycling
- Pesticide Dynamics
- Management
- Bacteria

Hydrologic Balance

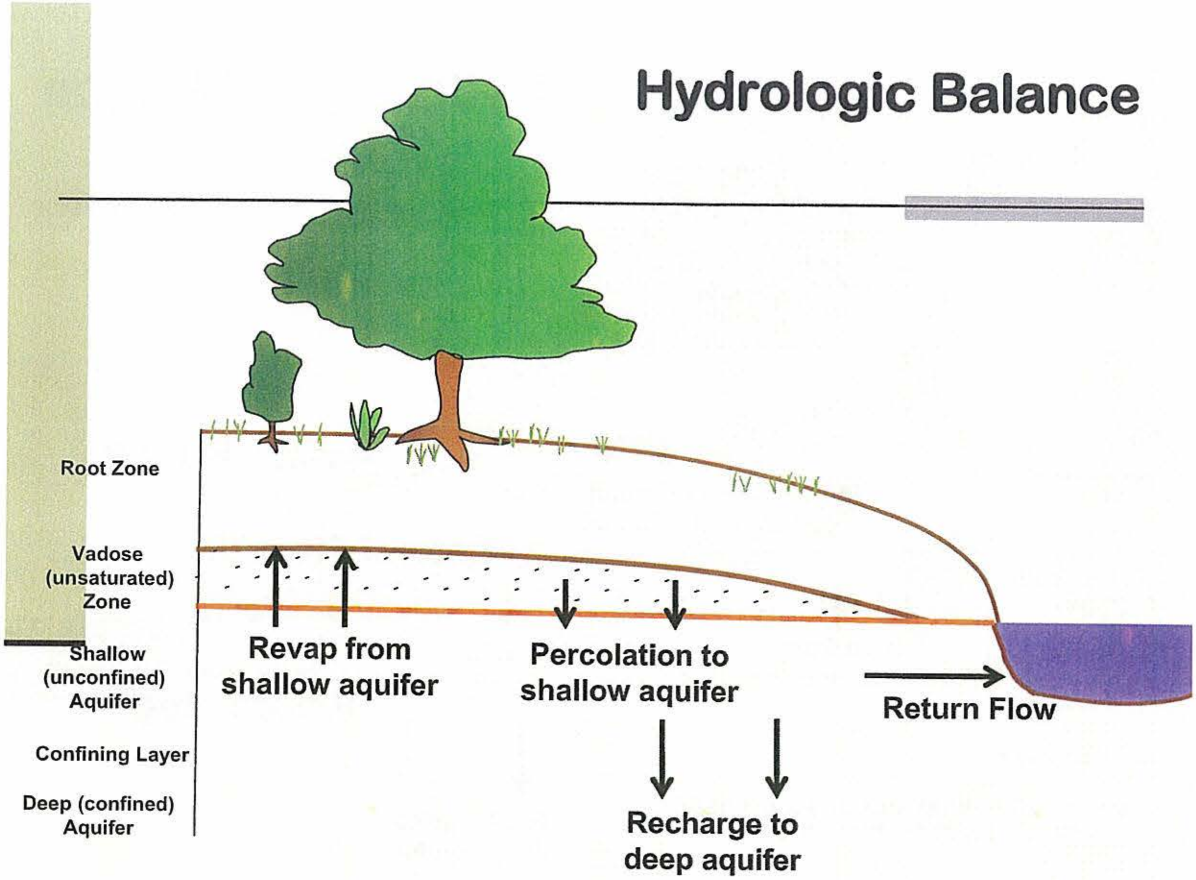


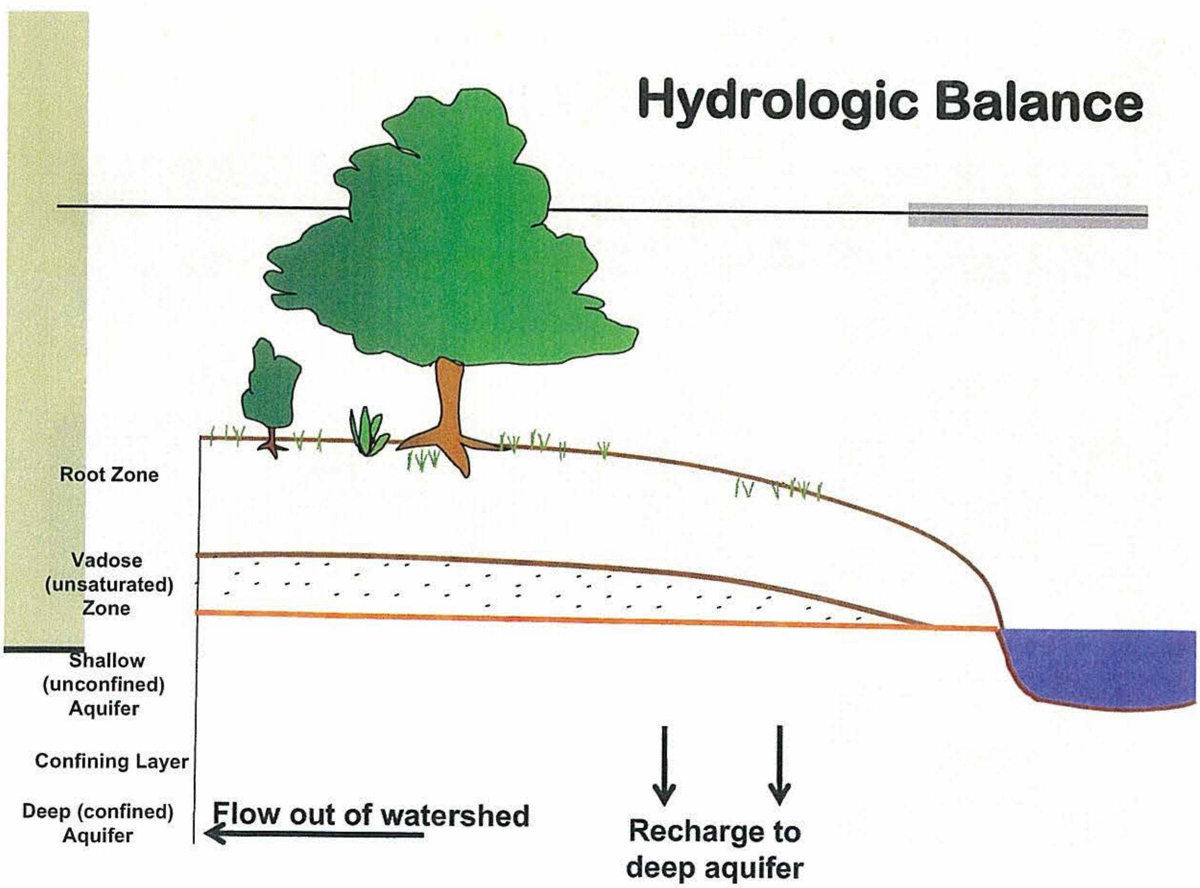


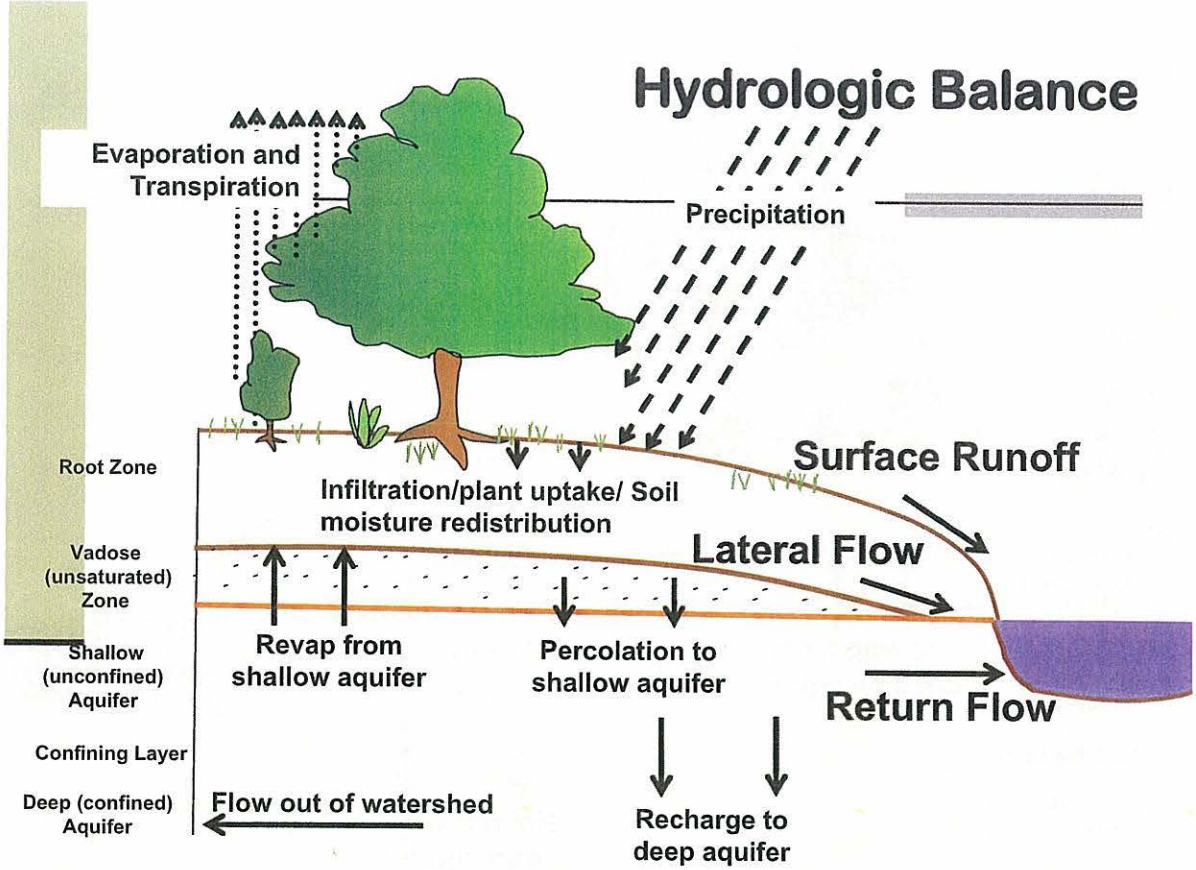
Hydrologic Balance
Root Zone
Infiltration
Surface Runoff
Vadose
(unsaturated)
Zone
Shallow
(unconfined)
Aquifer
Confining Layer
Deep (confined)
Aquifer



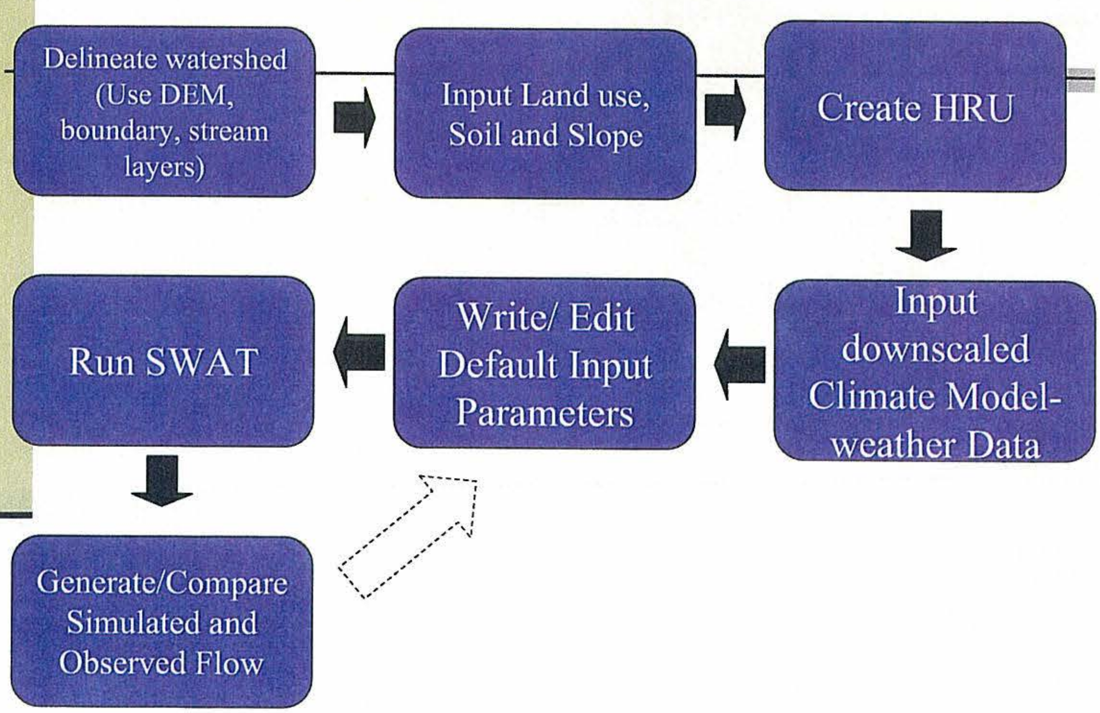
Hydrologic Balance
Evaporation and
Transpiration
Root Zone
Infiltration/plant uptake/
Soil moisture redistribution
Vadose
(unsaturated)
Zone
Lateral Flow
Percolation to
shallow aquifer
Shallow
(unconfined)
Aquifer
Confining Layer
Deep (confined)
Aquifer


Hydrologic Balance
Root Zone
Vadose
(unsaturated)
Zone
Shallow
(unconfined)
Aquifer
Confining Layer
Deep (confined)
Aquifer
Revap from
shallow aquifer
Percolation to
shallow aquifer
Return Flow
Recharge to
deep aquifer

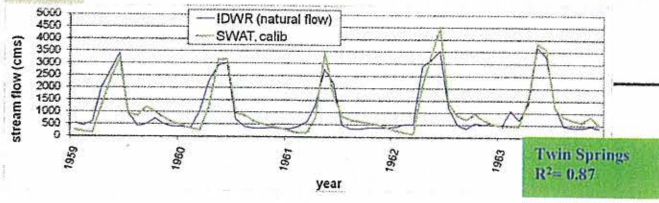

Hydrologic Balance
Root Zone
Vadose
(unsaturated)
Zone
Shallow
(unconfined)
Aquifer
Confining Layer
Deep (confined)
Aquifer
Flow out of watershed
Recharge to
deep aquifer

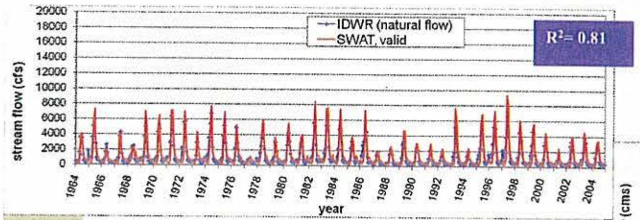


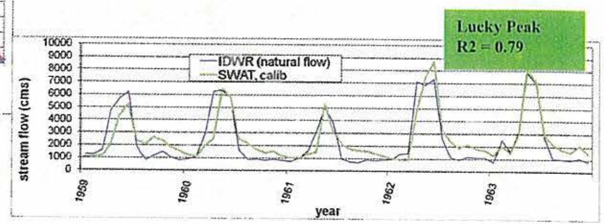
SWAT Model Setup SWAT Setup

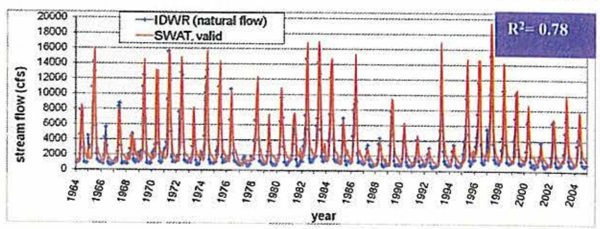


Sequential Uncertainty Fitting (Sufi2) Calibration/Validation Result (Twin Springs and Lucky Peak)









SWAT Calibration Parameters (Lucky Peak, Arrowrock, Twin Springs and Anderson Ranch)

Parameter name	Parameter definition:Parma	low bound	up bound	imet	Calibration Sites: Lucky Peak	Arrowrock	Twin Springs	Anderson Ranch	scale level
Canmx	Maximum canopy storage (mm)	0.816	9.802	v	4.344	3.109	2.508	8.351	hru
Cn2	Initial SCS CN II value	-34.77	37.44	r	-32.5	-21	-32.9	-21.68	hru
Alpha_Bf	baseflow alpha factor (days)	0	1	v					hru
Epco	Plant uptake compensation factor	-50	50	r					hru
Esco	Soil evaporation compensation factor	0.95	1	v	Default Parameters				hru
Gw_Delay	Groundwater delay (days)	0	192.3	v					hru
Gw_Revap	Groundwater revap coefficient	0.02	0.2	v					hru
Revapmn	Threshold water depth in the shallow aquifer for "revap" (mm)	0.01	500	v					hru
Gwqmn	Threshold water depth in the shallow aquifer for flow (mm)	0	673	v	572.2	422.3	535.5	75.5	hru
Rchrg_Dp	Deep aquifer percolation fraction	0	1	v	0.488	0.89	0.364	0.272	hru
Ch_K2	channel effective hydraulic conductivity (mm/hr)	3.8	80.8	v	19.8	72.3	51.01	34.2	subbasin
Sol_Awc	Available water capacity (mm H2O/mm soil)	-50	50	r	8.9	16.9	12.38	13.9	hru
Sol_K	Saturated hydraulic conductivity (mm/hr)	12.5	37.5	r					hru
Surlag	surface runoff lag time (days)	0	10	v	1.446				basin
Timp	Snow pack temperature lag factor	0.001	1	v	0.0063				basin
Smtmp	snow melt base temperature (C)	1.8	5.5	v	4.1				basin
	note: for imet, v - replacement, r - multiplying initial value by value (in percentage)								

SWAT Calibration Parameters
(Parma)

Parameter name	Parameter definition	low bound	up bound	imet	Parma Calibration values	scale level
Canmx	Maximum canopy storage (mm)	0.816	9.802	v	1.705	hru
Cn2	Initial SCS CN II value	-34.77	37.44	r	23.6	hru
Alpha_Bf	baseflow alpha factor (days)	0	1	v	0.0601	hru
Epco	Plant uptake compensation factor	-50	50	r	9.46	hru
Esco	Soil evaporation compensation factor	0.95	1	v	0.962	hru
Gw_Delay	Groundwater delay (days)	0	192.3	v	173.2	hru
Gw_Revap	Groundwater revap coefficient	0.02	0.2	v	0.191	hru
Revapmn	Threshold water depth in the shallow aquifer for "revap" (mm)	0.01	500	v	3.66	hru
Gwqmn	Threshold water depth in the shallow aquifer for flow (mm)	0	673	v	643.9	hru
Rchrg_Dp	Deep aquifer percolation fraction	0	1	v	0.252	hru
Ch_K2	channel effective hydraulic conductivity (mm/hr)	3.8	80.8	v	13.36	subbasin
Sol_Awc	Available water capacity (mm H2O/mm soil)	-50	50	r	-28.88	hru
Sol_K	Saturated hydraulic conductivity (mm/hr)	12.5	37.5	r	36.73	hru
Surlag	surface runoff lag time (days)	0	10	v	1.446	basin
Timp	Snow pack temperature lag factor	0.001	1	v	0.0063	basin
Smtmp	snow melt base temperature (C)	1.8	5.5	v	4.1	basin
	note: for imet, v - replacement, r - multiplying initial value by value (in percentage)					

SWAT Performance

Subbasin		r^2	NSE
Parma	calibrated (1959 - 1963)	0.81	0.75
	validated (1964 - 2004)	0.82	0.80
Lucky Peak	calibrated (1959 - 1963)	0.79	0.78
	validated (1964 - 2004)	0.78	0.73
Arrow Rock	calibrated (1959 - 1963)	0.75	0.75
	validated (1964 - 2004)	0.77	0.70
Twin Spring	calibrated (1959 - 1963)	0.87	0.85
	validated (1964 - 2004)	0.81	0.65
Anderson Ranch	calibrated (1959 - 1963)	0.87	0.70
	validated (1964 - 2004)	0.83	0.64

Future Temperature and Precipitation Trends

A2

		P (%)	T (C°)
2010-2019	ccsm3_0	2.49	1.63
	hadcm3	3.60	0.76
	ipsl_cm4	15.71	1.11
	miroc3_2_medres	9.09	1.64
	pcm1	-6.02	0.02
2020-2029	ccsm3_0	0.93	1.98
	hadcm3	3.76	1.35
	ipsl_cm4	9.72	1.53
	miroc3_2_medres	-2.33	1.24
	pcm1	6.36	0.93
2030-2039	ccsm3_0	-1.82	2.47
	hadcm3	-0.47	1.48
	ipsl_cm4	17.66	2.11
	miroc3_2_medres	8.23	2.47
	pcm1	3.33	0.77
2040-2049	ccsm3_0	8.22	2.63
	hadcm3	0.85	2.59
	ipsl_cm4	34.37	2.43
	miroc3_2_medres	-1.64	3.17
	pcm1	7.15	1.47
2050-2059	ccsm3_0	4.89	3.37
	hadcm3	7.00	2.61
	ipsl_cm4	36.28	3.61
	miroc3_2_medres	1.00	3.34
	pcm1	1.69	1.77

A1B

		P (%)	T (C°)
2010-2019	ccsm3_0	0.18	1.38
	hadcm3	-1.19	1.76
	ipsl_cm4	17.89	1.56
	miroc3_2_medres	-9.11	1.07
	pcm1	14.12	0.79
2020-2029	ccsm3_0	1.45	2.05
	hadcm3	3.20	1.96
	ipsl_cm4	25.16	1.85
	miroc3_2_medres	-9.06	1.98
	pcm1	-8.81	1.10
2030-2039	ccsm3_0	-7.66	2.02
	hadcm3	4.58	2.10
	ipsl_cm4	19.82	2.48
	miroc3_2_medres	6.40	2.78
	pcm1	-8.50	1.45
2040-2049	ccsm3_0	-5.62	3.08
	hadcm3	14.86	2.80
	ipsl_cm4	35.15	2.99
	miroc3_2_medres	4.06	3.06
	pcm1	-1.59	1.95
2050-2059	ccsm3_0	1.06	3.44
	hadcm3	3.15	3.22
	ipsl_cm4	21.28	3.70
	miroc3_2_medres	6.05	3.91
	pcm1	5.49	2.59

B1

		P (%)	T (C°)
2010-2019	ccsm3_0	7.02	1.690
	hadcm3	3.79	1.005
	ipsl_cm4	16.97	1.321
	miroc3_2_medres	-6.58	1.418
	pcm1	13.15	0.484
2020-2029	ccsm3_0	-3.45	1.470
	hadcm3	9.17	1.567
	ipsl_cm4	16.28	1.645
	miroc3_2_medres	6.10	1.345
	pcm1	18.17	0.699
2030-2039	ccsm3_0	-6.72	1.302
	hadcm3	6.21	1.587
	ipsl_cm4	14.66	2.063
	miroc3_2_medres	4.37	2.101
	pcm1	12.15	0.696
2040-2049	ccsm3_0	3.62	2.003
	hadcm3	16.88	2.067
	ipsl_cm4	30.49	2.702
	miroc3_2_medres	-2.24	2.907
	pcm1	16.28	0.747
2050-2059	ccsm3_0	0.46	2.068
	hadcm3	2.89	2.865
	ipsl_cm4	25.75	2.542
	miroc3_2_medres	-1.17	3.092
	pcm1	9.28	0.949

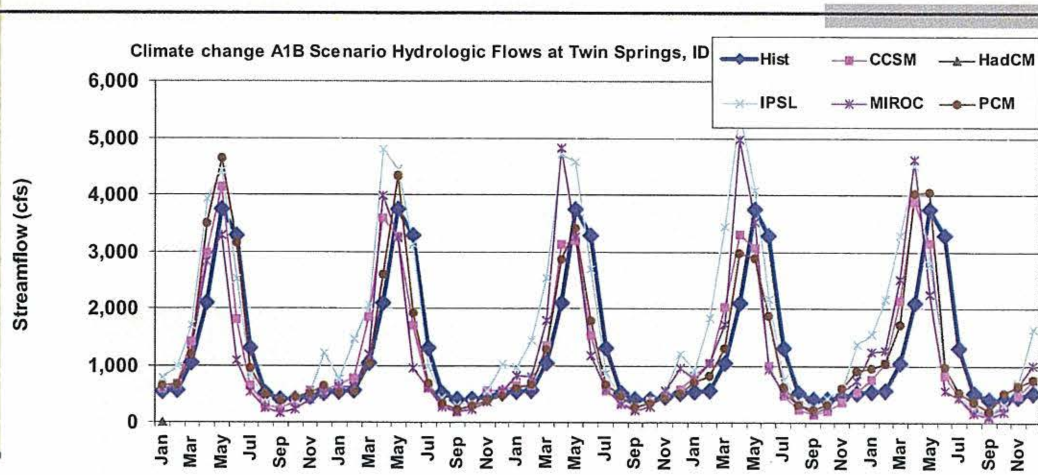
Future Flow Trends in the Boise River Basin

	Change (cfs)		
Scenario	Peak flow Min	Peak flow Max	Peak flow Avg
A2	-1223	4117	621
A1B	-1693	3285	300
B1	-1366	3917	436
	Low flow Min	Low flow Max	Low flow Avg
A2	-622	195	-281
A1B	-662	77	-303
B1	-607	336	-328

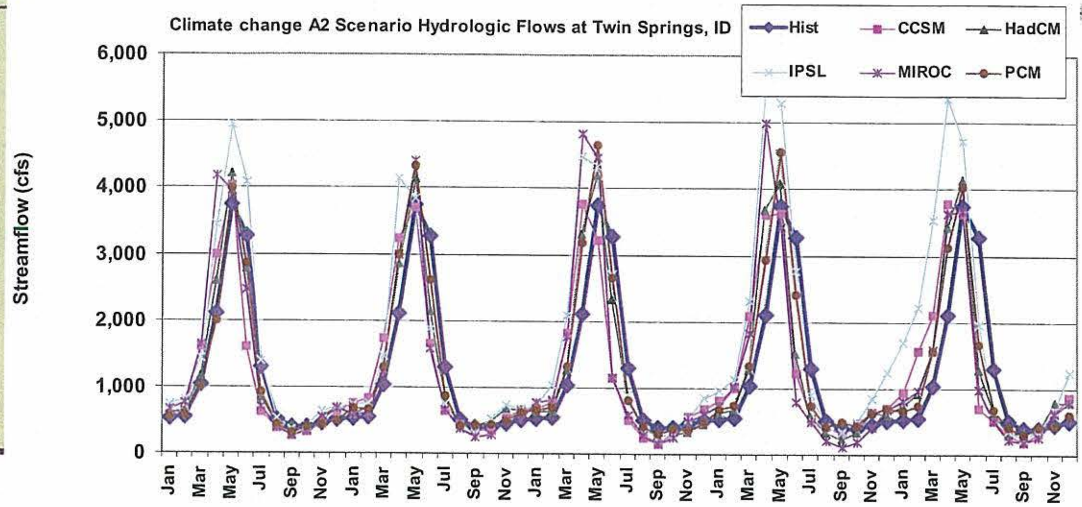
Future Volume Trends in the Boise River Basin

	Change in flow volume (ac-ft)		
Decade	A2	A1B	B1
2010-2019	200738	97195	184812
2020-2029	72193	78271	382690
2030-2039	191419	101483	174700
2040-2049	276108	218825	358348
2050-2059	269021	106963	226368
Average	201896	120547	265384
		Overall Avg	195942

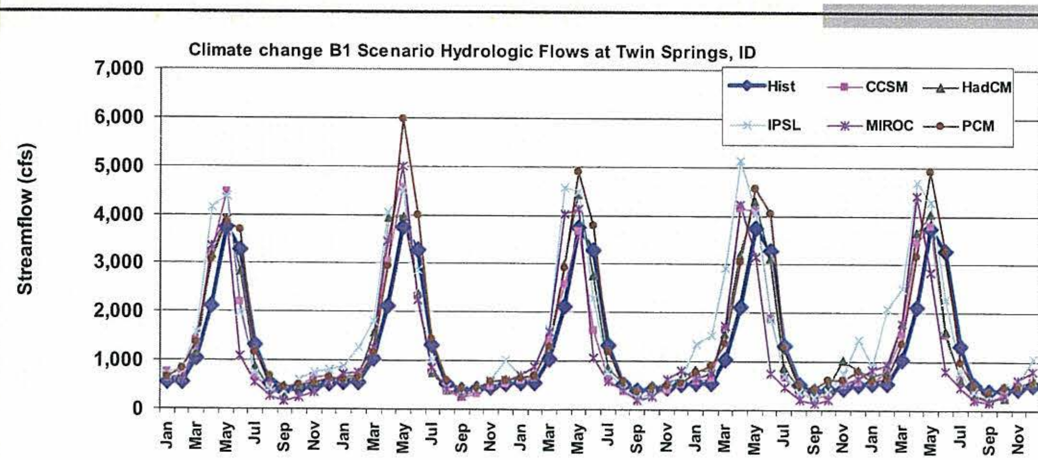
Projected Streamflow – Twin Springs (A1B, 2010-2059)



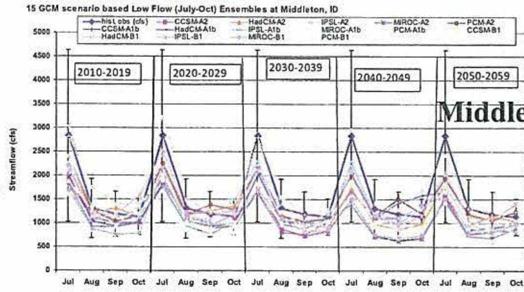
Projected Streamflow – Twin Springs (A2, 2010-2059)



Projected Streamflow – Twin Springs (B1, 2010-2059)

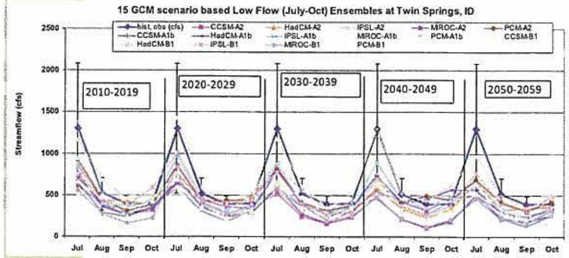


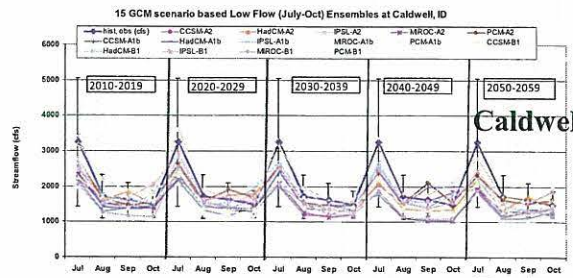
Low Flows



Middleton

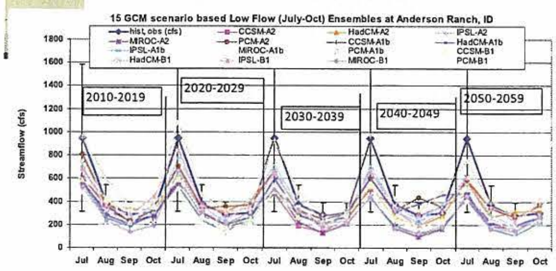
Twin Springs



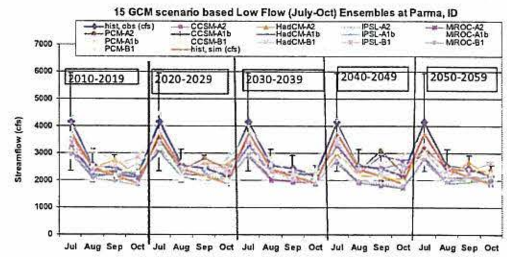


Caldwell

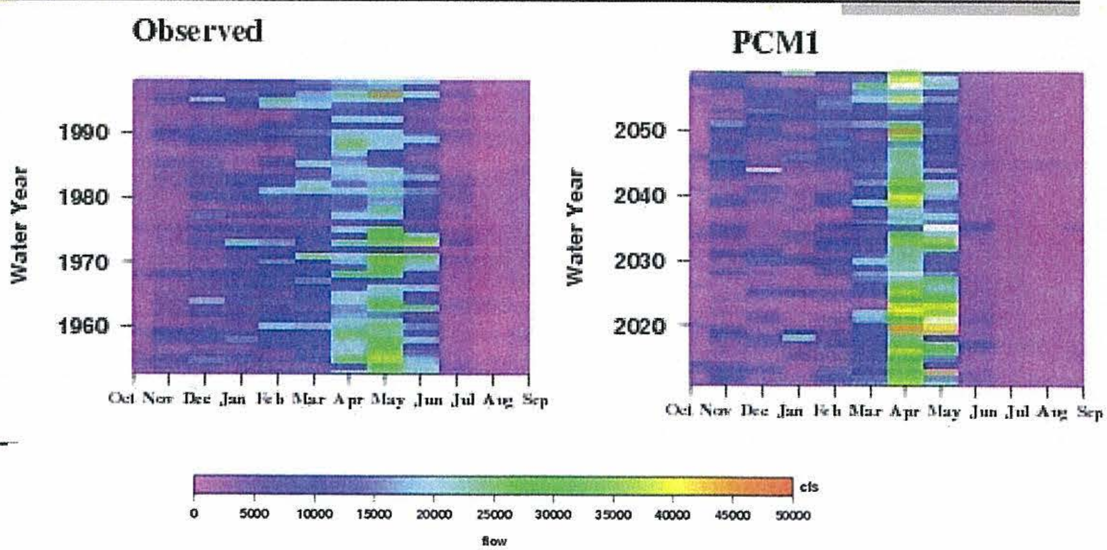
Anderson Ranch



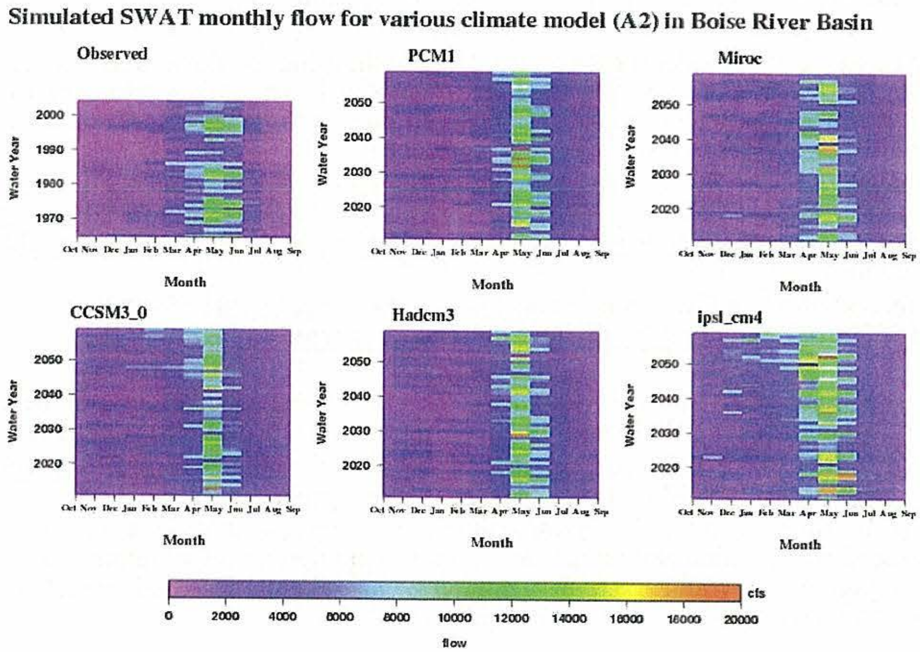
Parma



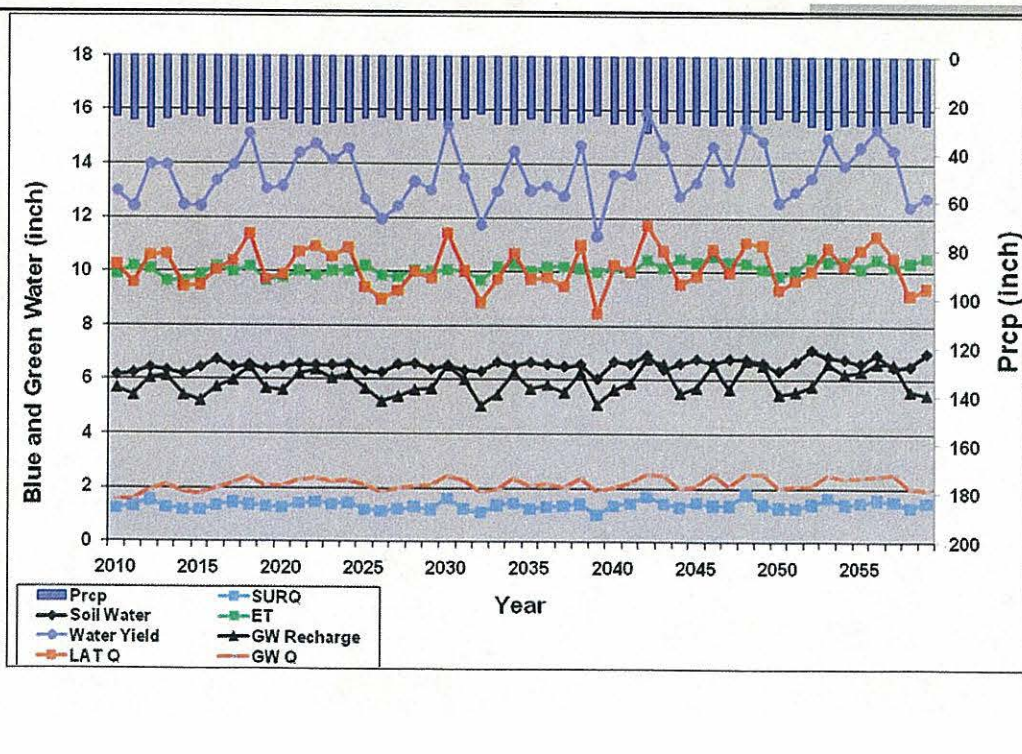
Future Flows Time Map – Lucky Peak



Time Map – Lucky Peak, A2



Annual water balance components



Summary

- For the Treasure Valley region, changes in precipitation ranged between -3.8 % and 36%. Changes in temperature are expected to be between 0.02 and 3.9 °C.
- We calibrated the model for the Boise River basin using the flows from Parma, Lucky Peak, Arrowrock, Twin Springs and Anderson Ranch. This calibration exercise resulted in 16 parameters adjusted for various processes within the basin including snowmelt, vegetation, groundwater and surface runoff.
- On average, in the Boise River basin the peak flows (March through June) are expected to increase by 4117 cfs (A2), 3285 cfs (A1B) and 3917 cfs (B1). **Thus, the high flows in the future will probably be higher than historic high flows. The peak flows will be earlier.**
- In general, the low flow averages declined in the future by 281 cfs (A2), 303 cfs (A1B) and 328 cfs (B1). **Notably, the low flows are expected to be lower than historic low flows**.
- Translation of flows into volumes (integrating area under the hydrograph) the increase in flow volumes are 201896 ac-ft (A2), 120547 ac-ft (A1B) and 265384 ac-ft (B1).
- The overall average when combining all of these flow volumes results in **increasing flow volume by 195942 ac-ft over the next five decades**.
- There are some uncertainties in our estimates and that can be attributed to GCM-produced precipitation and temperature, model parameters and structure (for instance reach gain or loss, residence time of aquifer recharge) and measured regulated flow, computed natural flow and its year-to-year variability.