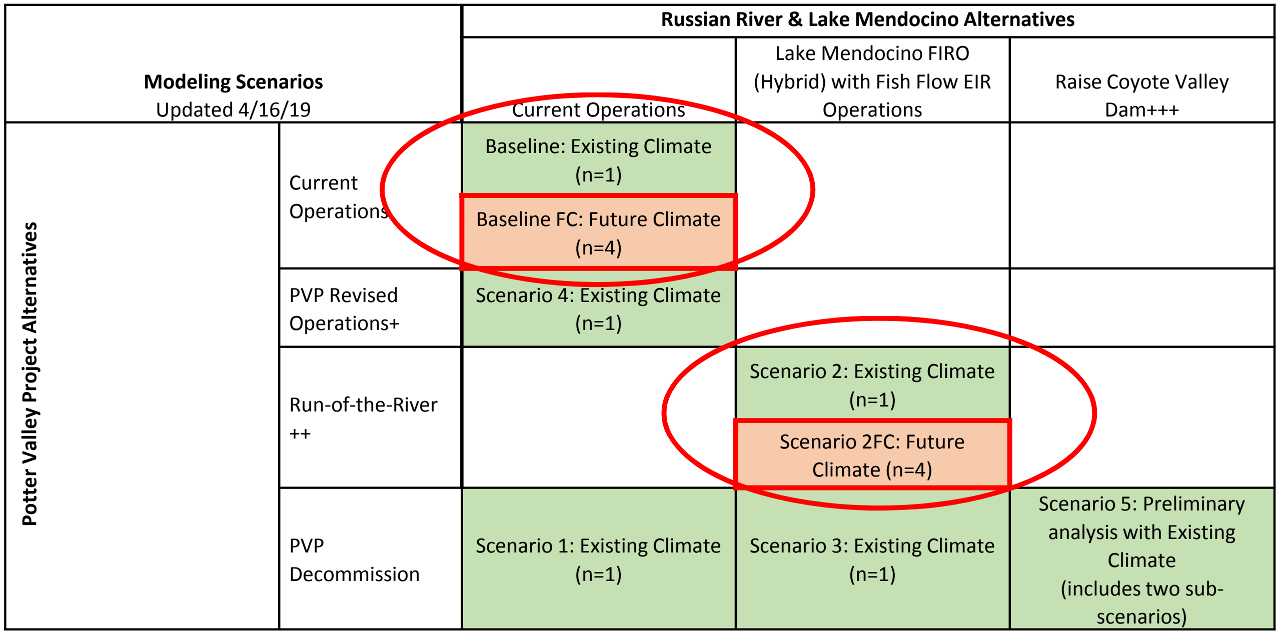
Future Climate Scenarios

Water Supply Ad Hoc Work Group
5/22/2019



Modeling Scenarios Updated 4/16/19		**Russian River & Lake Mendocino Alternatives**		
		Current Operations	Lake Mendocino FIRO (Hybrid) with Fish Flow EIR Operations	Raise Coyote Valley Dam+++
Potter Valley Project Alternatives	Current Operations	Baseline: Existing Climate (n=1) Baseline FC: Future Climate (n=4)		
	PVP Revised Operations+	Scenario 4: Existing Climate (n=1)		
	Run-of-the-River ++		Scenario 2: Existing Climate (n=1) Scenario 2FC: Future Climate (n=4)	
	PVP Decommission	Scenario 1: Existing Climate (n=1)	Scenario 3: Existing Climate (n=1)	Scenario 5: Preliminary analysis with Existing Climate (includes two sub-scenarios)

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Analyzing future climate scenarios

- Scenario 1-4 comparisons with historical hydrology used to compare different reservoir model operations
- Future climate scenario comparisons: develop a better understanding of robustness of model operations with range of future hydrology and system projections (demands, etc.)
- Baseline and Scenario 2 (Run of the River) were selected because the model operations varied significantly

Presentation Outline

- Future Climate Data (what it and why we chose it)
- Basin Characterization Model
- Comparison of future hydrology inflows into systems
- Comparison of future hydrology on operations
- Key Take Aways

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Future Climate Scenarios Data Generation

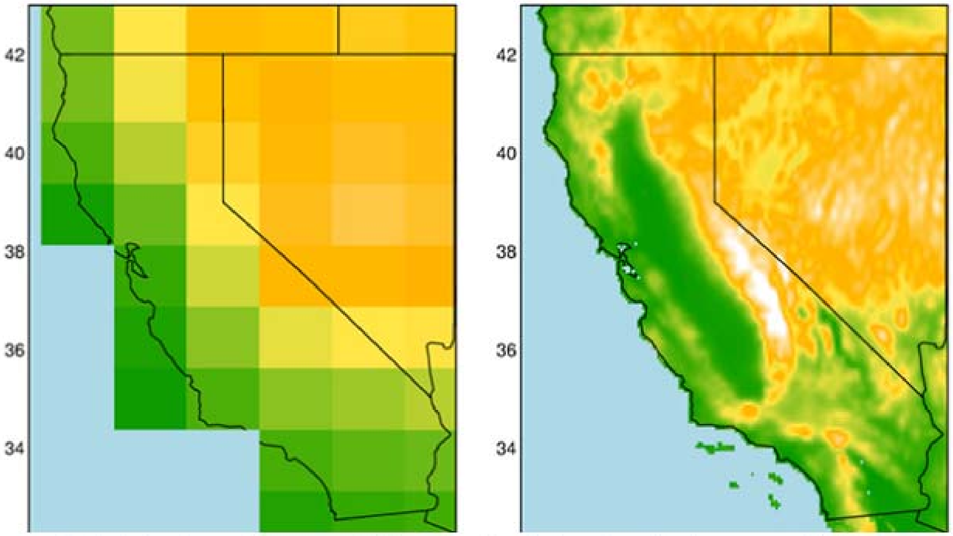
Global Circulation Model
ACCESS-1.0
CanESM2
CCSM4
CESM1-BGC
CMCC-CMS
CNRM-CM5
GFDL-CM3
HadGEM2-CC
HadGEM2-ES
MIROC5

CA DWR Perspectives and Guidance for Climate Change Analysis

Take a representative subset

- HadGEM2-ES “warm/dry” model
- CanESM2, the “average” model
- CNRM-CM5, the “cool/wet” model
- MIROC5, most unlike the other three models

- 20 future climate scenarios generated
  - IPCC 5th Assessment - 10 General Circulation Models (GCMs) selected by California Department of Water Resources Climate Change Technical Advisory Group
  - Representative Concentration Pathway (RCP) 4.5 and 8.5 GHG Emission Scenarios
- Localized Constructed Analogs (LOCA) downscaled precipitation and temperatures (6 km resolution)



Global climate model representation of California elevations (left) compared to LOCA

https://casc.usgs.gov/new-high-res-LOCA-climate-projections

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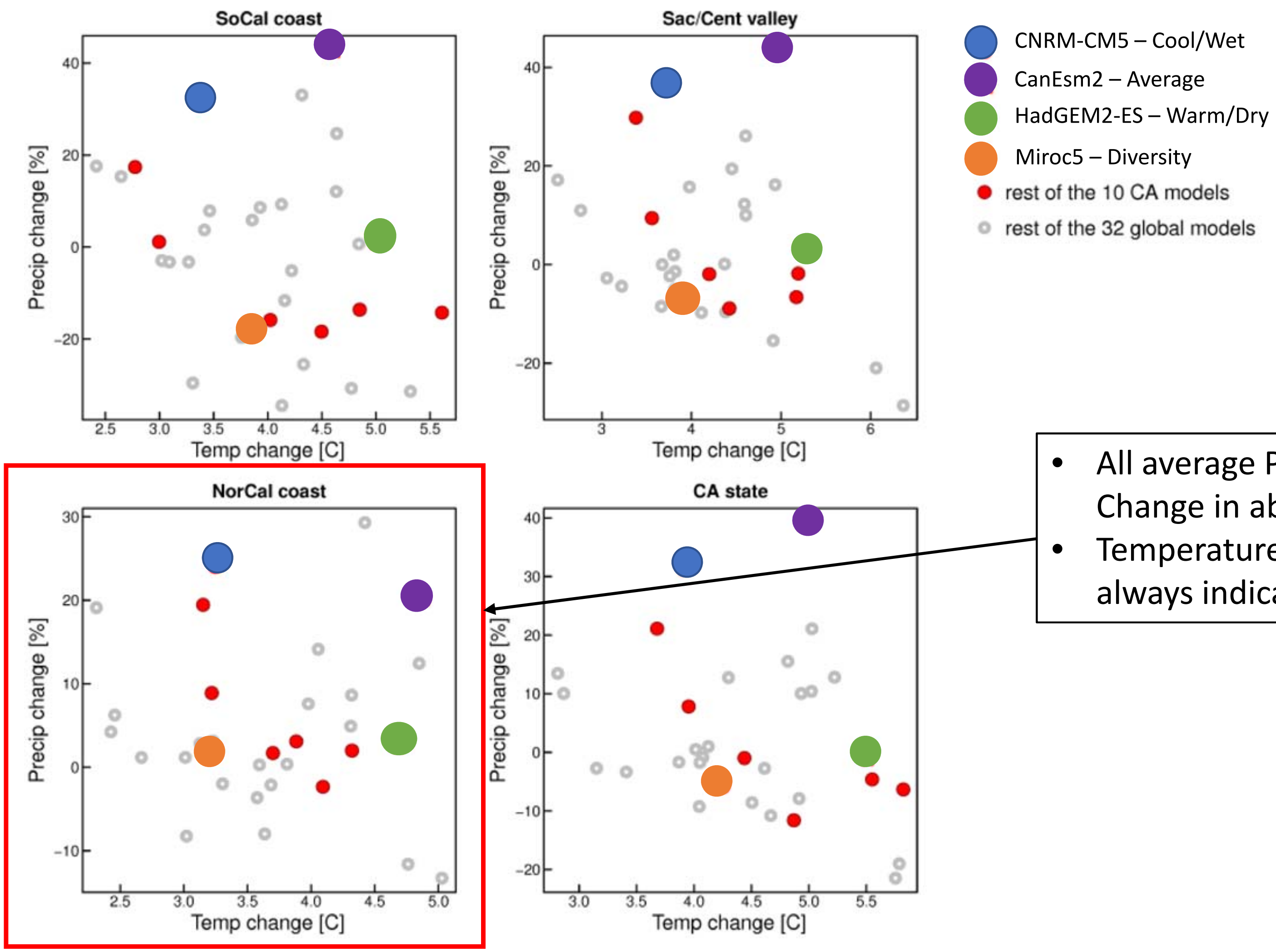

- All average Precipitation Change in above 0%
- Temperature change always indicates warmer

RCP 8.5 at the end of the century (2070-2099)

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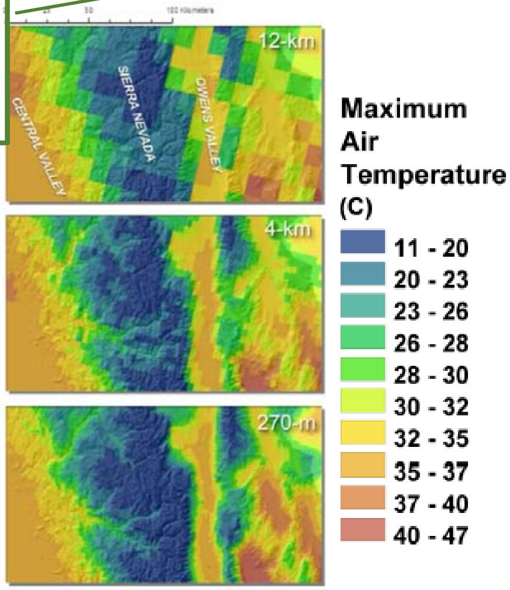
http://www.climateassessment.ca.gov/techreports/docs/20180827-Projections_CCCA4-CEC-2018-006.pdf

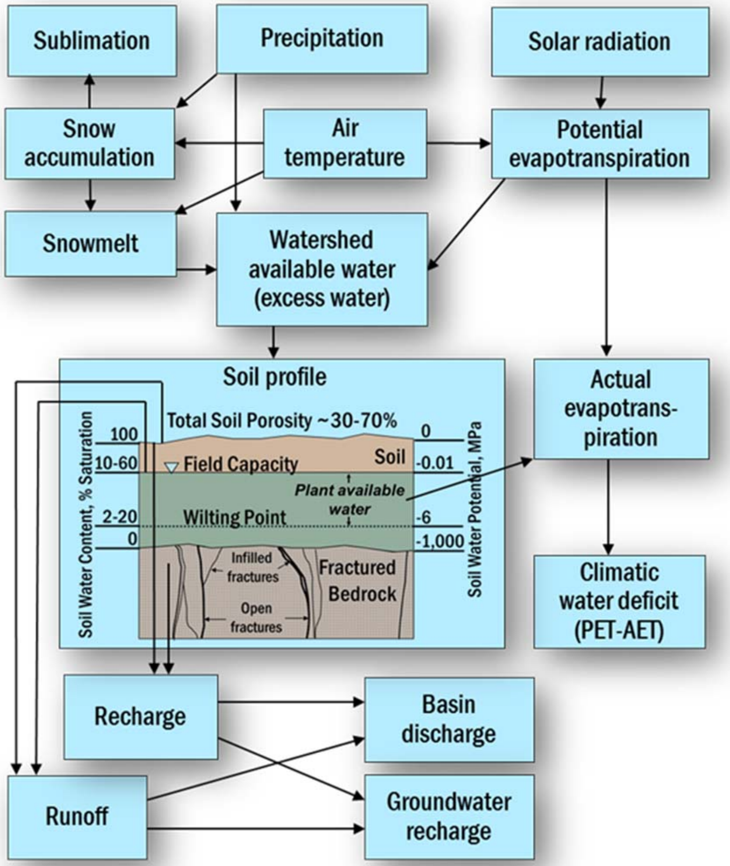
Getting the Flows - USGS Basin Characterization Model

- ➢ Gridded Hydrologic Model developed by the USGS
- ➢ Further downscales LOCA datasets to 270 meter resolution
- ➢ Unimpaired streamflow and evapotranspiration calculated daily from 1950 to 2099

- Climate change forcings applied starting 2006
- Future model years: 2006-2099



Flint and Flint: Downscaling future climate scenarios to fine scales for hydrologic and ecological modeling and analysis. Ecological Processes 2012 1:1.



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https://ca.water.usgs.gov/projects/reg_hydro/basin-characterization-model.html

Comparison of Simulated Historical Hydrology (WY1911-WY2017) and Future Hydrology (CY2006-CY2099) on System Inflows

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Summary of Inflows from Four Climate Change Scenarios: **Annual Comparison**

Current Operations (Baseline)	**Baseline**	**CanEsm2**		**CNRMCM**		**Hadgem**		**Miroc**		**Range Across the four Climate Change Scenarios**
		Future Climate	*Percent Change from Baseline*	*Future Climate*	*Percent Change from Baseline*	*Future Climate*	*Percent Change from Baseline*	*Future Climate*	*Percent Change from Baseline*	*Percent Change from Baseline*
Lake Pillsbury Average Annual Inflow (ac-ft)	411,870	501,241	22%	535,029	30%	473,917	15%	448,302	9%	9% to 30%
Lake Pillsbury Minimum Water Year Inflow (ac-ft)	30,447	30,879	1%	37,032	22%	40,574	33%	51,718	70%	1% to 70%
Lake Mendocino Average Annual Inflow (ac-ft)	173,380	216,335	25%	216,202	25%	180,177	4%	169,438	-2%	-2% to 25%
Lake Mendocino Minimum Water Year Inflow (ac-ft)	21,099	24,145	14%	27,575	31%	9,086	-57%	30,952	47%	-57% to 47%

- Average Annual Inflow into Lake Pillsbury always higher than baseline for all four scenarios
- Average Annual Inflow into Lake Mendocino varies depending on climate scenario
    - Hadgem and Miroc are lower are average, but not much
    - CanEsm2 and CNRMCM are a lot higher on average

Run-of-the-River (Scenario 2)	**Scenario 2**	**CanEsm2**		**CNRMCM**		**Hadgem**		**Miroc**		**Range Across the four Climate Change Scenarios**
		Run of River Future Climate	*Percent Change from Baseline*	*Run of River Future Climate*	*Percent Change from Baseline*	*Run of River Future Climate*	*Percent Change from Baseline*	*Run of River Future Climate*	*Percent Change from Baseline*	*Percent Change from Baseline*
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Lake Mendocino Average Annual Inflow (ac-ft)	178,999	224,370	25%	225,832	26%	186,954	4%	177,184	-1%	-1% to 26%
Lake Mendocino Minimum Water Year Inflow (ac-ft)	12,933	23,753	84%	17,231	33%	8,220	-36%	22,688	75%	-36% to 84%

- Run of the River shows a similar pattern on annual inflows

<u>Annual Comparison shows an increase inflow into Lake Pillsbury and Increase or small decrease in Lake Mendocino (includes tunnel diversions)</u>

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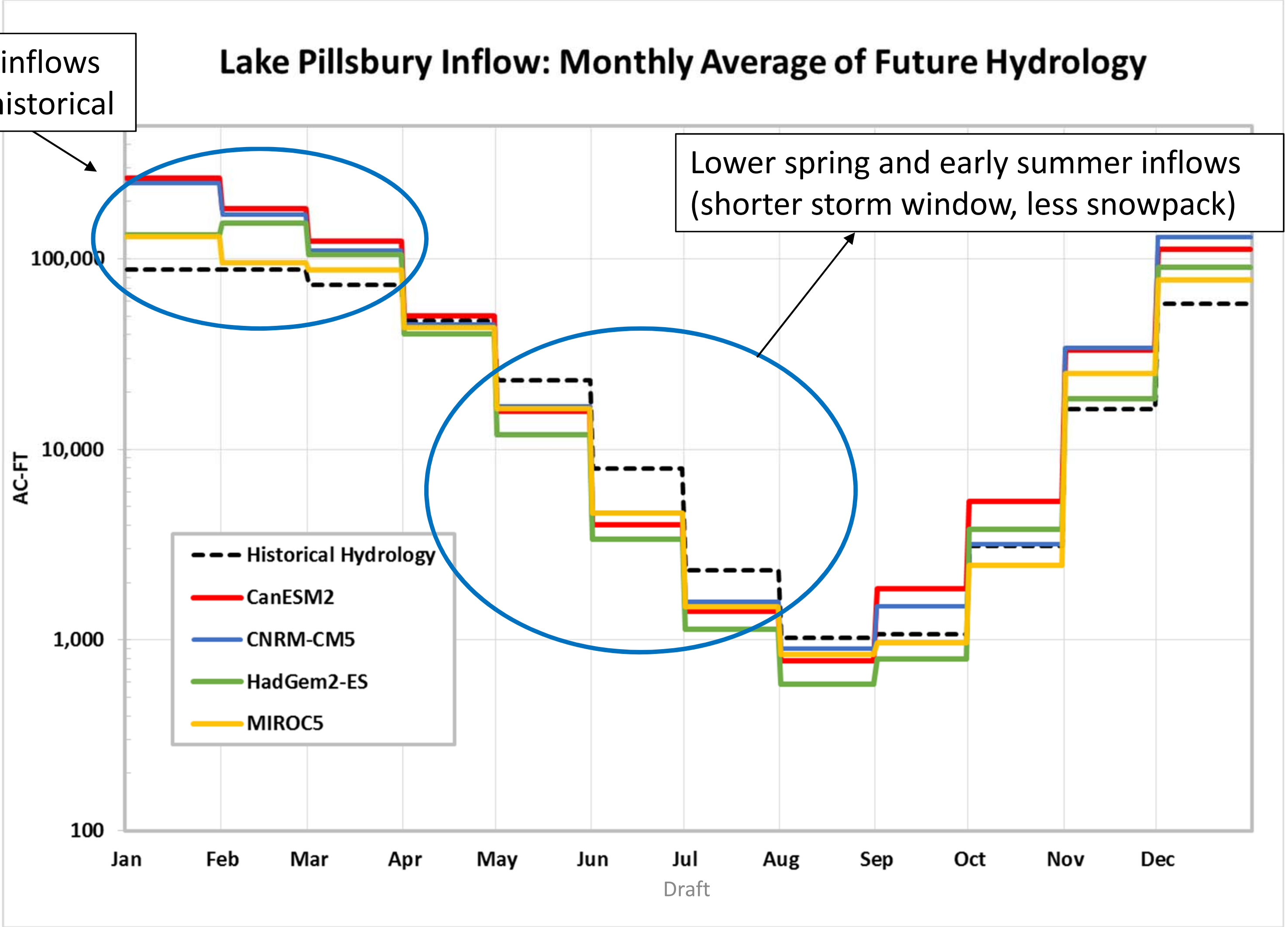
Need Seasonal Comparison of Inflows

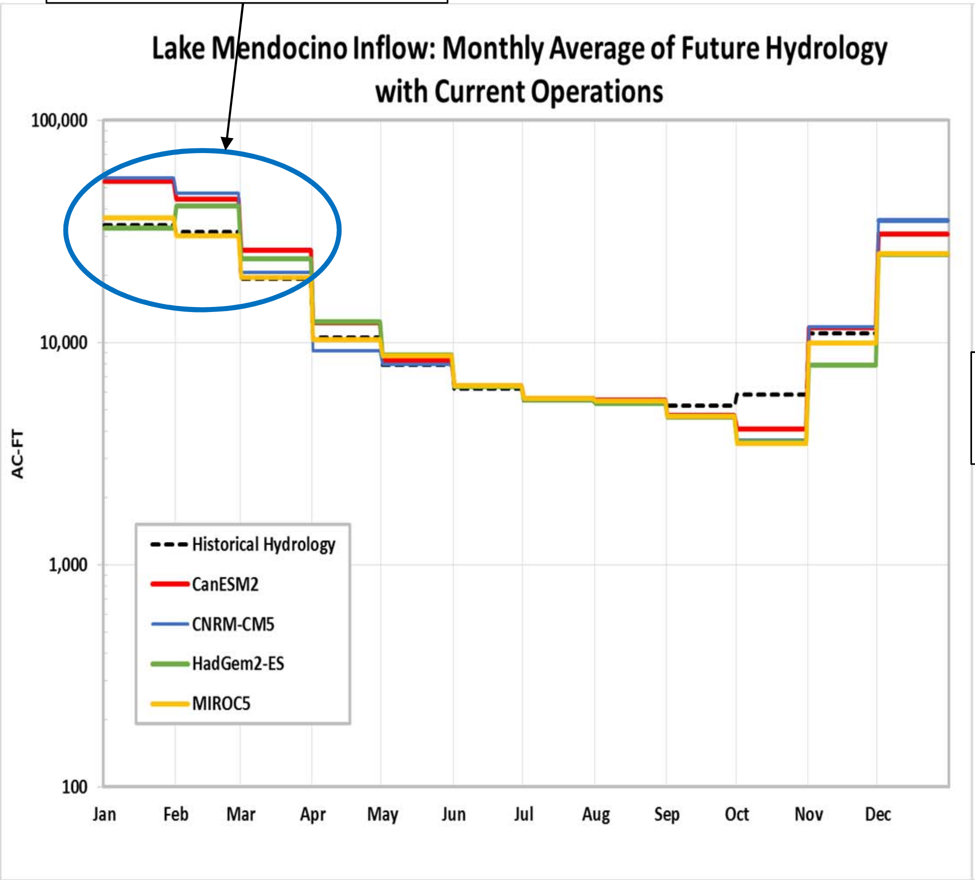


Higher winter inflows compared to historical

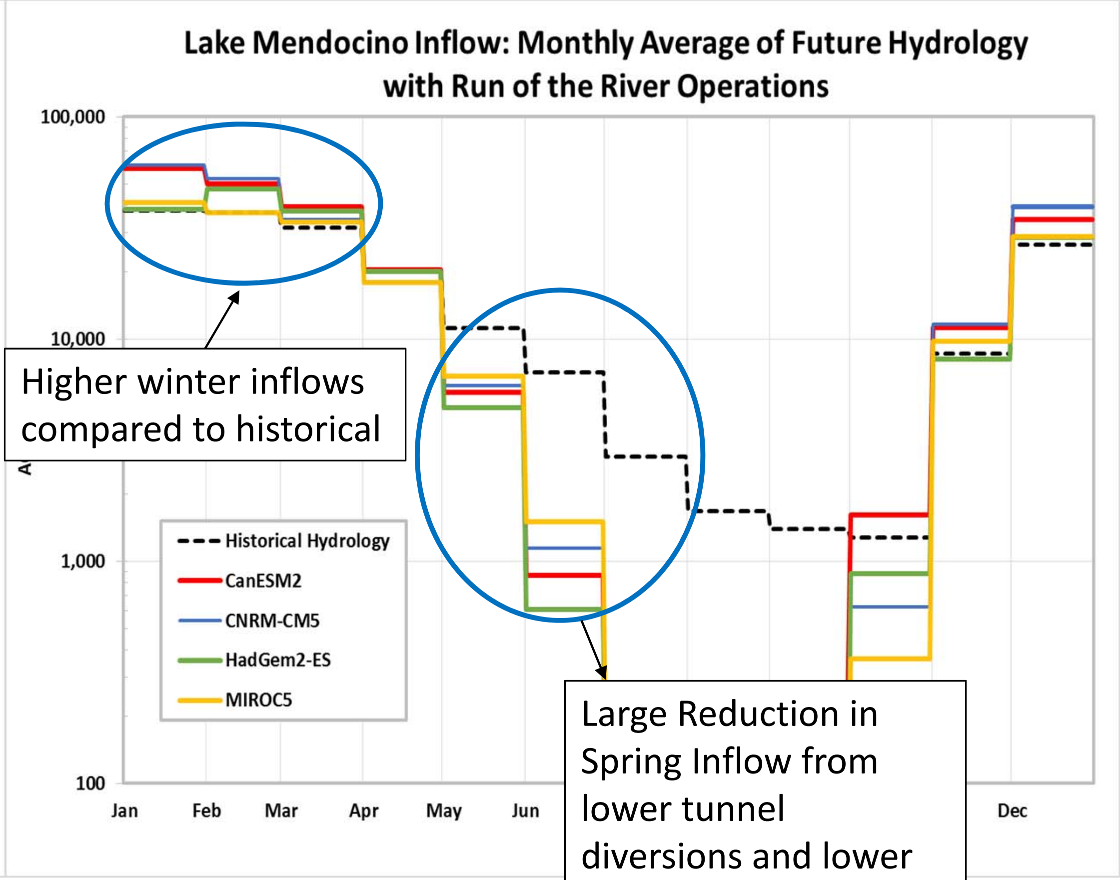
Lower spring and early summer inflows (shorter storm window, less snowpack)

Need Seasonal Comparison of Inflows

Higher winter inflows compared to historical



Lake Mendocino Inflow: Monthly Average of Future Hydrology with Current Operations



Lake Mendocino Inflow: Monthly Average of Future Hydrology with Run of the River Operations

Higher winter inflows compared to historical

Large Reduction in Spring Inflow from lower tunnel diversions and lower unimpaired flows

Comparison of Simulated Historical Hydrology and Future Hydrology on Reservoir Operations

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Future Reservoir Model Assumptions

- Lake Mendocino and Lake Pillsbury Storage Capacity
  - Sedimentation up to 2050 (held constant throughout simulation)
    - Lake Mendocino loses ~5,000 ac-ft of capacity
    - Lake Pillsbury loses ~6,000 ac-ft of capacity
- Upper Russian River Demand Projections
  - 2050 Projection (held constant throughout simulation)
    - Takes into account potential agricultural growth, change in evapotranspiration, population growth
    - ~20% Increase in total Upper Russian River Demand
- PVID contract amount (Baseline) and pumpback (Run of the River) are assumed the same as historical model runs

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Eel River Comparison

Lake Pillsbury storage is drawn down lower and depleted more often

Current Operations (Baseline)	Baseline	CanEsm2		CNRMCM		Hadgem		Miroc		Range Across the four Climate Change Scenarios
		Future Climate	*Change from*	*Future Climate*	*Change from*	*Future Climate*	*Change from*	*Future Climate*	*Change from*	*Change from Baseline*
Average Low Point of Lake Pillsbury Annual Storage (March-February) (ac-ft)	24,829	15,967	-36%	16,157	-35%	15,075	-39%	16,896	-32%	-39% to -32%
Number of Years Lake Pillsbury Depleted at Any Time During the Year (yrs)	5	15	200%	10	100%	17	240%	10	100%	100% to 240%
Below Cape Horn Dam Average June-September flows (cfs)	43	38	-11%	40	-7%	33	-22%	33	-24%	-24% to -7%
Below Cape Horn Dam Average October-December flows (cfs)	373	825	121%	940	152%	566	52%	538	44%	44% to 152%

Higher flows in the winter and lower in summer

Run-of-the-River (Scenario 2)	Scenario 2	CanEsm2		CNRMCM		Hadgem		Miroc		Range Across the four Climate Change Scenarios
		River Future	*Change from*	*River Future*	*Change from*	*River Future*	*Change from*	*River Future*	*Change from*	*Change from Baseline*
Below Cape Horn Dam Average June-September flows (cfs)	35	33	-5%	33	-6%	25	-28%	29	-17%	-28% to -5%
Below Cape Horn Dam Average October-December flows (cfs)	436	908	108%	1,024	135%	644	48%	613	41%	41% to 135%

Similar change as above

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Russian River Comparison

Lake Mendocino storage a little lower compared to baseline

Current Operations (Baseline)	Baseline	CanEsm2		CNRMCM		Hadgem		Miroc		Range Across the four Climate Change Scenarios
		Future Climate	*Change from*	*Future Climate*	*Change from*	*Future Climate*	*Change from*	*Future Climate*	*Change from*	*Percent Change from Baseline*
Average Low Point of Annual Storage (March-February) (ac-ft)	45,034	40,807	-9%	38,636	-14%	40,702	-10%	42,536	-6%	-14% to -6%
Number of Years Lake Mendocino Depleted at Any Time During the Year (yrs)	1	2	100%	1	0%	1	0%	2	100%	0% to 100%
Russian River at Cloverdale Average June-September flows (cfs)	147	146	-1%	145	-1%	145	-1%	140	-5%	-5% to -1%
Russian River at Healdsburg Average October-December flows (cfs)	1,075	1,560	45%	1,654	54%	1,026	-5%	1,052	-2%	-5% to 54%

Similar summer flows, larger range of winter flows

Run-of-the-River (Scenario 2)	Scenario 2	CanEsm2		CNRMCM		Hadgem		Miroc		Range Across the four Climate Change Scenarios
		River Future	*Change from*	*River Future*	*Change from*	*River Future*	*Change from*	*River Future*	*Change from*	*Percent Change from Baseline*
Average Low Point of Annual Storage (March-February) (ac-ft)	45,088	30,414	-33%	31,650	-30%	29,622	-34%	31,034	-31%	-34% to -30%
Number of Years Below Minimum Storage at Any Time During the Year (reservoir depletion) (yrs)	1	5	400%	1	0%	2	100%	4	300%	0% to 400%
Russian River at Cloverdale Average June-September flows (cfs)	132	127	-4%	128	-3%	128	-3%	126	-5%	-5% to -3%
Russian River at Healdsburg Average October-December flows (cfs)	1,009	1,487	47%	1,597	58%	956	-5%	983	-3%	-5% to 58%

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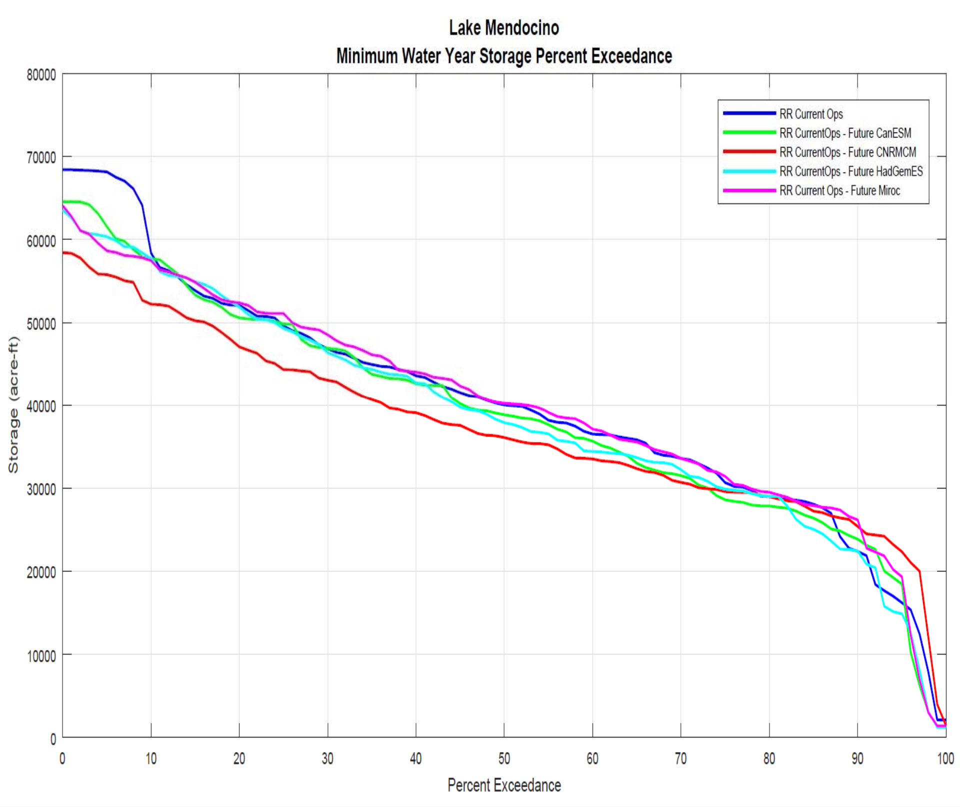
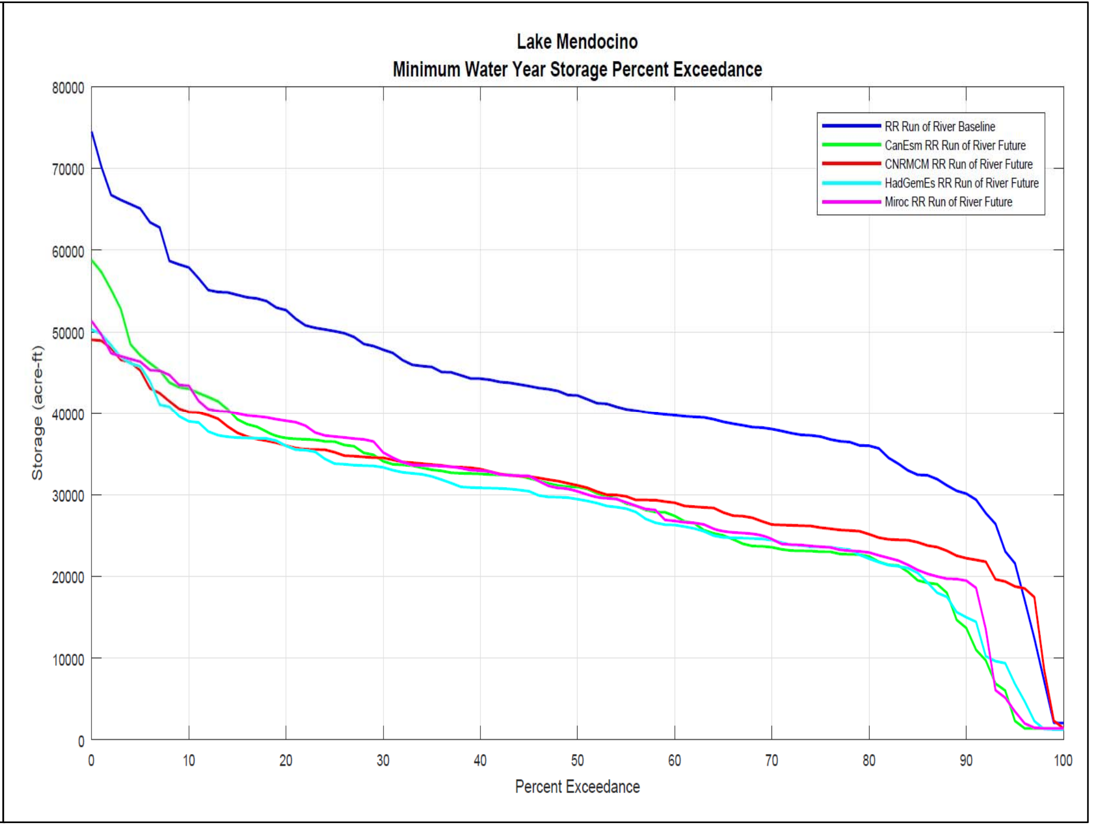
Lake Mendocino storage end of year is lower, but is depleted only a few years more often

Lake Mendocino Storage Exceedances





PVID Comparison

Annual tunnel diversions are a little lower

Current Operations (Baseline)	**Baseline**	**CanEsm2**		**CNRMCM**		**Hadgem**		**Miroc**		**Range Across the four Climate Change Scenarios**
		Future Climate	*Percent Change from Baseline*	*Future Climate*	*Percent Change from Baseline*	*Future Climate*	*Percent Change from Baseline*	*Future Climate*	*Percent Change from Baseline*	*Percent Change from Baseline*
Diverted to Potter Valley via Tunnel (E-16) Average Water Year Volumes (ac-ft)	78,077	71,993	-8%	72,269	-7%	69,925	-10%	72,756	-7%	-10% to -7%
Number of years May-Oct PVID delivery less than 15,140 (ac-ft)	2	2	0%	1	-50%	3	50%	4	100%	-50% to 100%

Tunnel diversions during irrigation season similar

Run-of-the-River (Scenario 2)	**Scenario 2**	**CanEsm2**		**CNRMCM**		**Hadgem**		**Miroc**		**Range Across the four Climate Change Scenarios**
		Run of River Future Climate	*Percent Change from Baseline*	*Run of River Future Climate*	*Percent Change from Baseline*	*Run of River Future Climate*	*Percent Change from Baseline*	*Run of River Future Climate*	*Percent Change from Baseline*	*Percent Change from Baseline*
Diverted to Potter Valley via Tunnel (E-16) Average Water Year Volumes (ac-ft)	82,785	75,164	-9%	77,913	-6%	72,302	-13%	76,980	-7%	-13% to -6%
Number of years May-Oct PVID delivery less than 15,140 (ac-ft)	2	6	200%	1	-50%	4	100%	4	100%	-50% to 200%

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Key Takeaways

- On average: wetter winters/drier springs and summer
- Future climate scenarios have similar impacts to Current Operations and Run of the River Operations to flows
  - Slightly reduced summer flows on Eel River and Russian River
  - Greatly increased winter time flows on Eel River and Russian River
- Future climate scenarios have large impact on Lake Pillsbury water supply reliability (depleted more often) for Current Operations
- Run of the River future climate scenario results in much lower Lake Mendocino storage than Current Operations because of reduction in spring tunnel diversions

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