

26th Annual Groundwater Resources Association Annual Meeting

2017: Time for Collaboration and Innovation Toward Sustainable
Management of Groundwater for Quality and Supply

Recalculation of Sustainable Yield for the Chino Basin

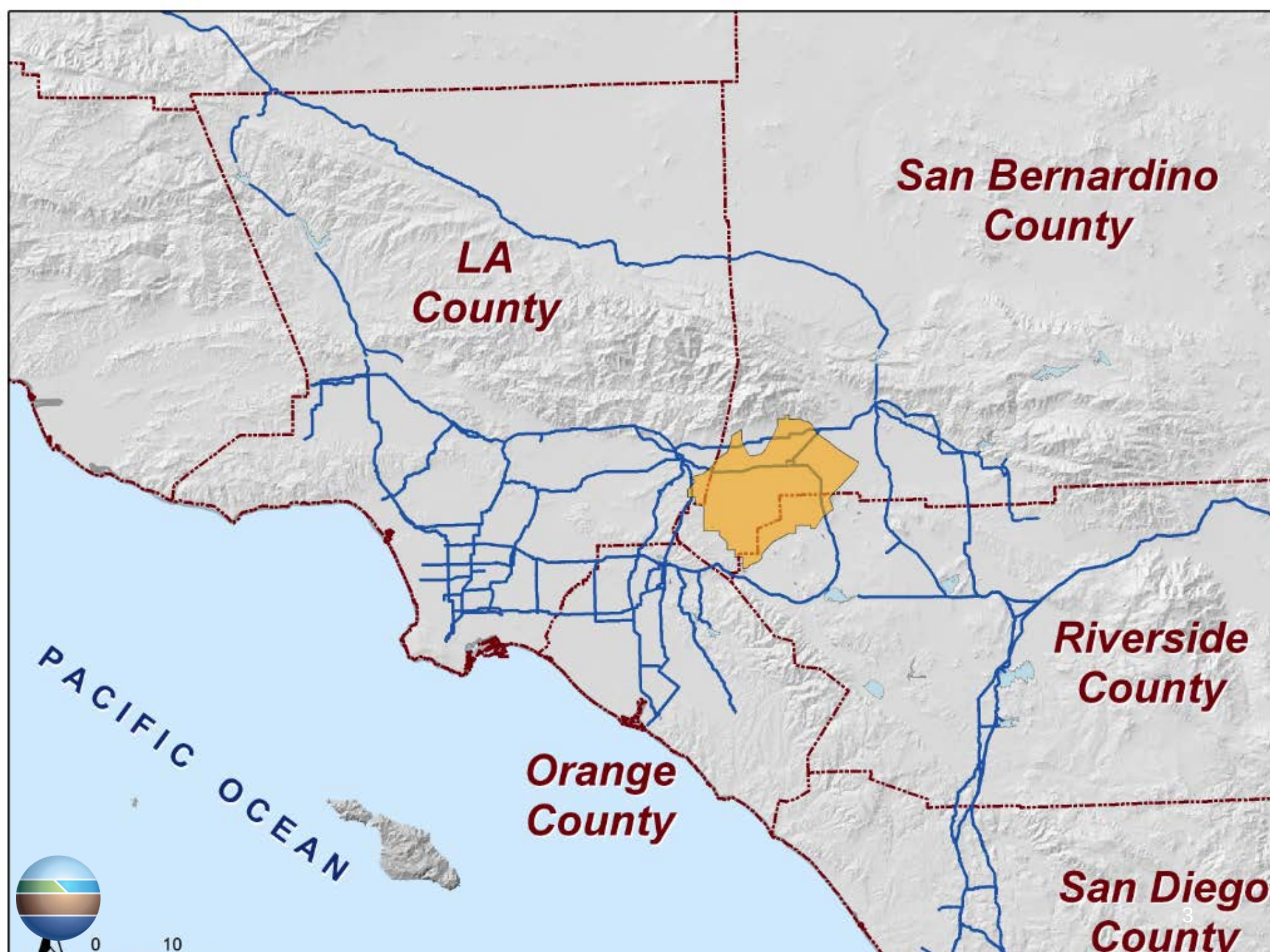
Mark Wildermuth
October 3, 2017



Special thanks to

- GRA for allowing me the opportunity to make this presentation
- Chino Basin Watermaster for the opportunity to serve it and its stakeholders
- Watermaster staff, legal counsel and my colleagues at WEI for their collaboration and support





**LA
County**

**San Bernardino
County**

**Riverside
County**

**Orange
County**

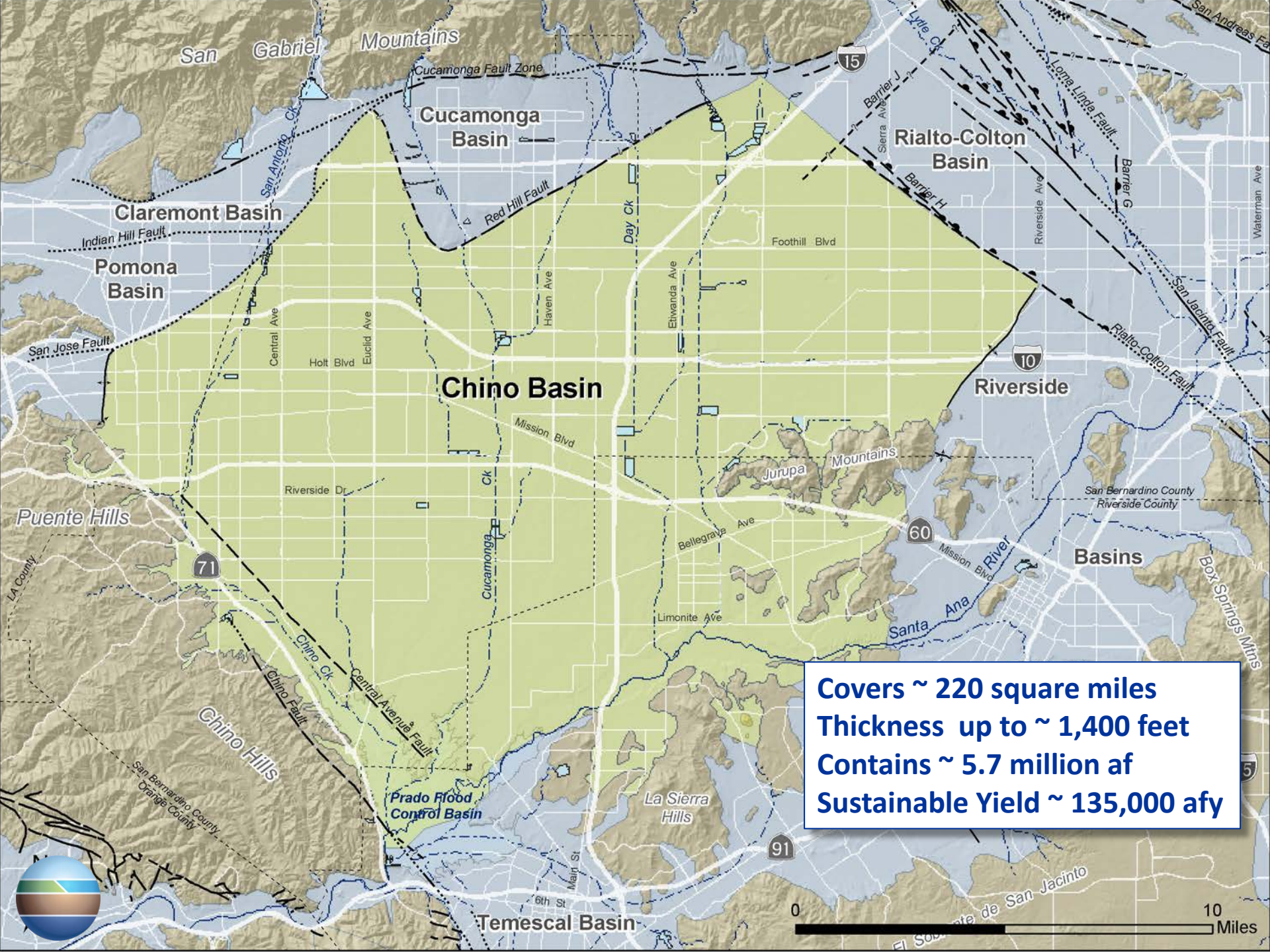
**San Diego
County**

PACIFIC OCEAN



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Chino Basin

Covers ~ 220 square miles
Thickness up to ~ 1,400 feet
Contains ~ 5.7 million af
Sustainable Yield ~ 135,000 afy

Adjudication and the physical solution

- Groundwater pumpers initiated a lawsuit in 1975 to adjudicate pumping and storage rights – not water quality
- Lawsuit resolved in 1978 through a stipulated agreement (Judgment) that allocated fixed pumping rights among the parties
- Pumping by a party in excess of their rights requires replacement
- Total pumping rights allocated to the parties equaled the safe yield of 140,000 afy
- Court retains jurisdiction and, with the exception of pumping rights, can change the terms of the stipulated agreement



Safe yield definition in the Chino Basin stipulated agreement

“The long-term average annual quantity of ground water (excluding replenishment or stored water but including return flow to the Basin from use of replenishment or stored water) which can be produced from the Basin under cultural conditions of a particular year without causing an undesirable result.”

(Restated Judgment, ¶ 4.(x).)



William J. Carroll's estimate of safe yield adopted in the 1978 Stipulated Agreement

Base period 1965 to 1974

Hydrologic Component	Annual Average (afy)
Inflows to the basin	
Precipitation and surface inflow	47,500
Imported water used for irrigation	7,000
Groundwater used for irrigation	61,700
Artificial recharge	3,900
Sewage recharge	18,200
Subsurface inflow	7,000
Total inflow	<u>145,300</u>
Outflows from the basin	
Subsurface outflow	7,200
Extractions	180,000
Total outflow	<u>187,200</u>
Average annual change in storage	-40,000
Safe Yield = Extractions + average annual change in storage	<u>140,000</u>



Approach to calculating safe yield for the 2011 through 2020 period

- Develop water budget table for 2011 through 2050 inclusive of all significant recharge and discharge terms
- Estimate annual net recharge as:
$$\text{Net recharge} = \text{groundwater pumping} + \text{change in storage} - \text{supplemental water recharge}$$
- Safe yield defined as the average net recharge for 2011 through 2020
- By 2020, update models and planning assumptions, repeat process for period 2021 through 2030

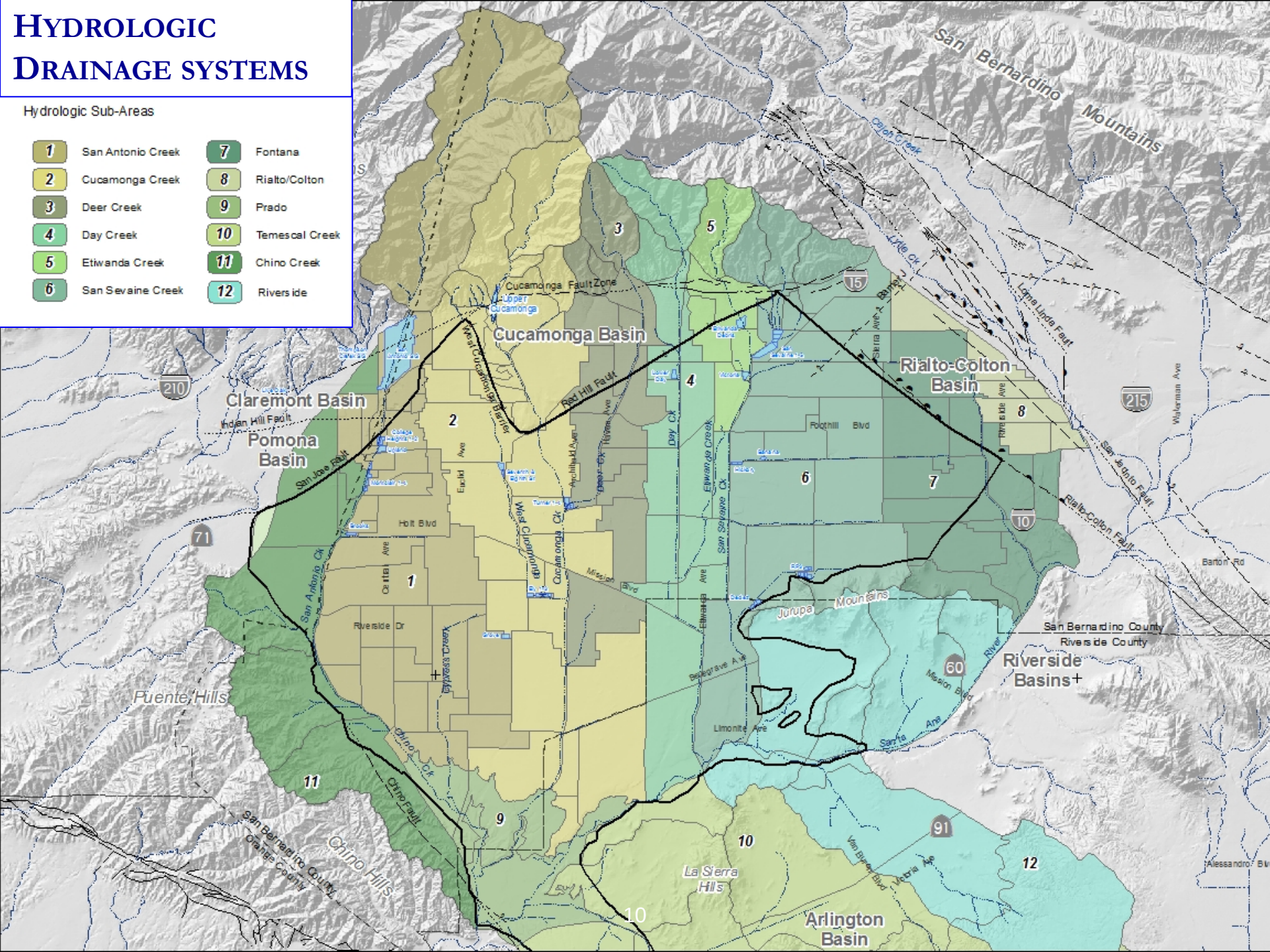
Assumption and execution of approach

- Build, integrate and calibrate surface and ground water models
- Construct future hydrology based on present and expected future cultural conditions and watershed/groundwater management
- Use surface and ground water models to estimate future recharge and discharge components, change in storage and net recharge – the water budget table

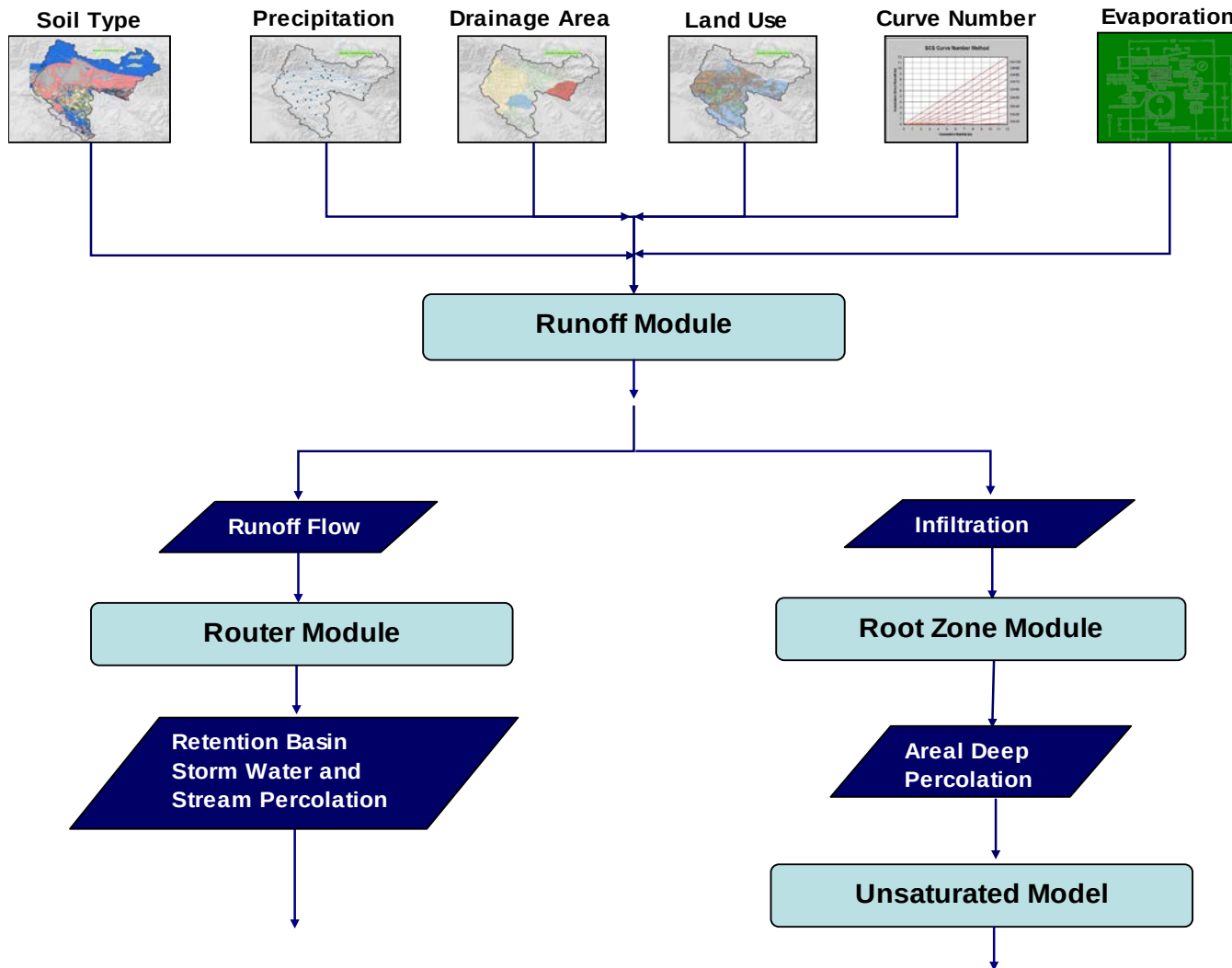
HYDROLOGIC DRAINAGE SYSTEMS

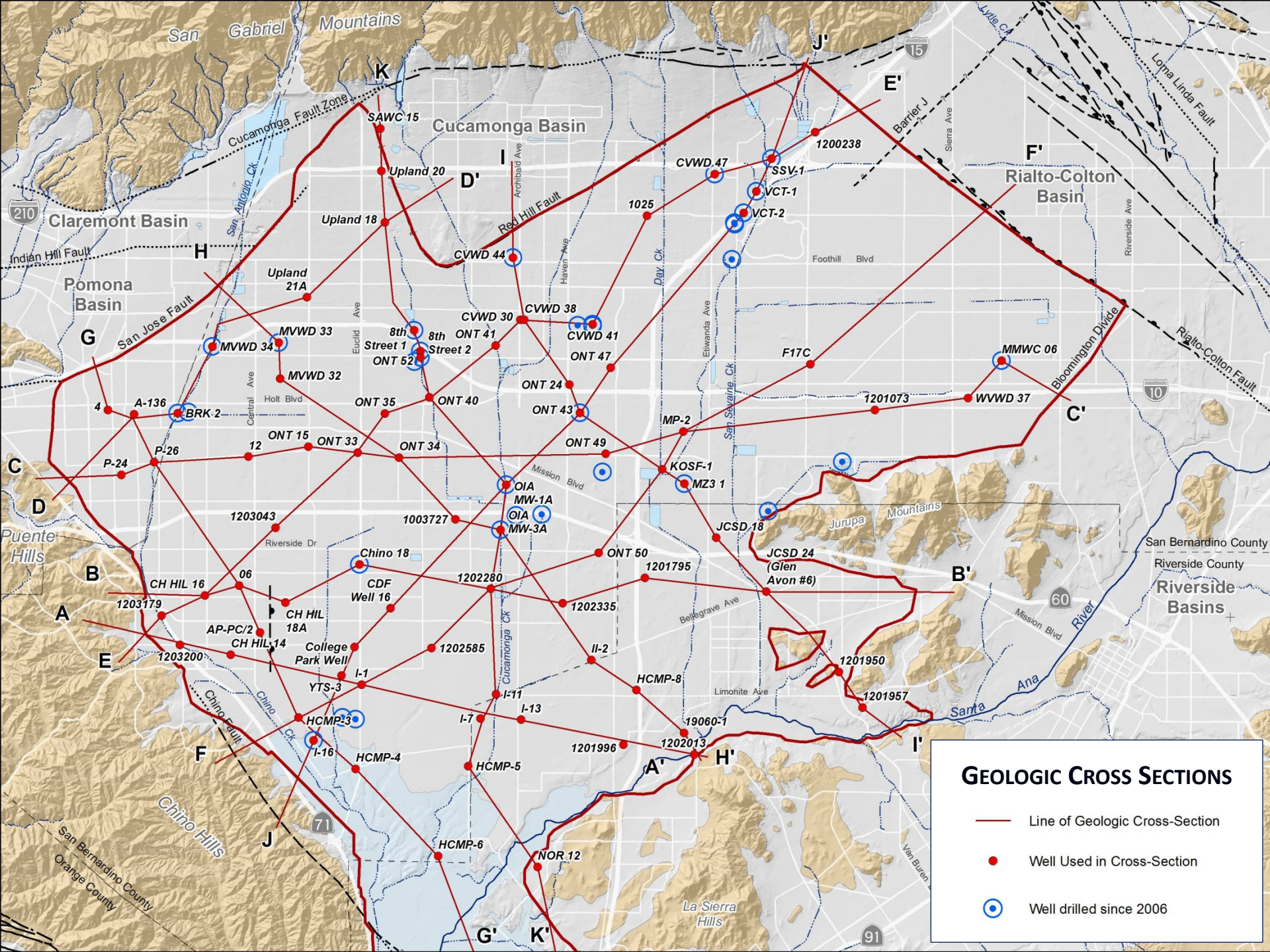
Hydrologic Sub-Areas

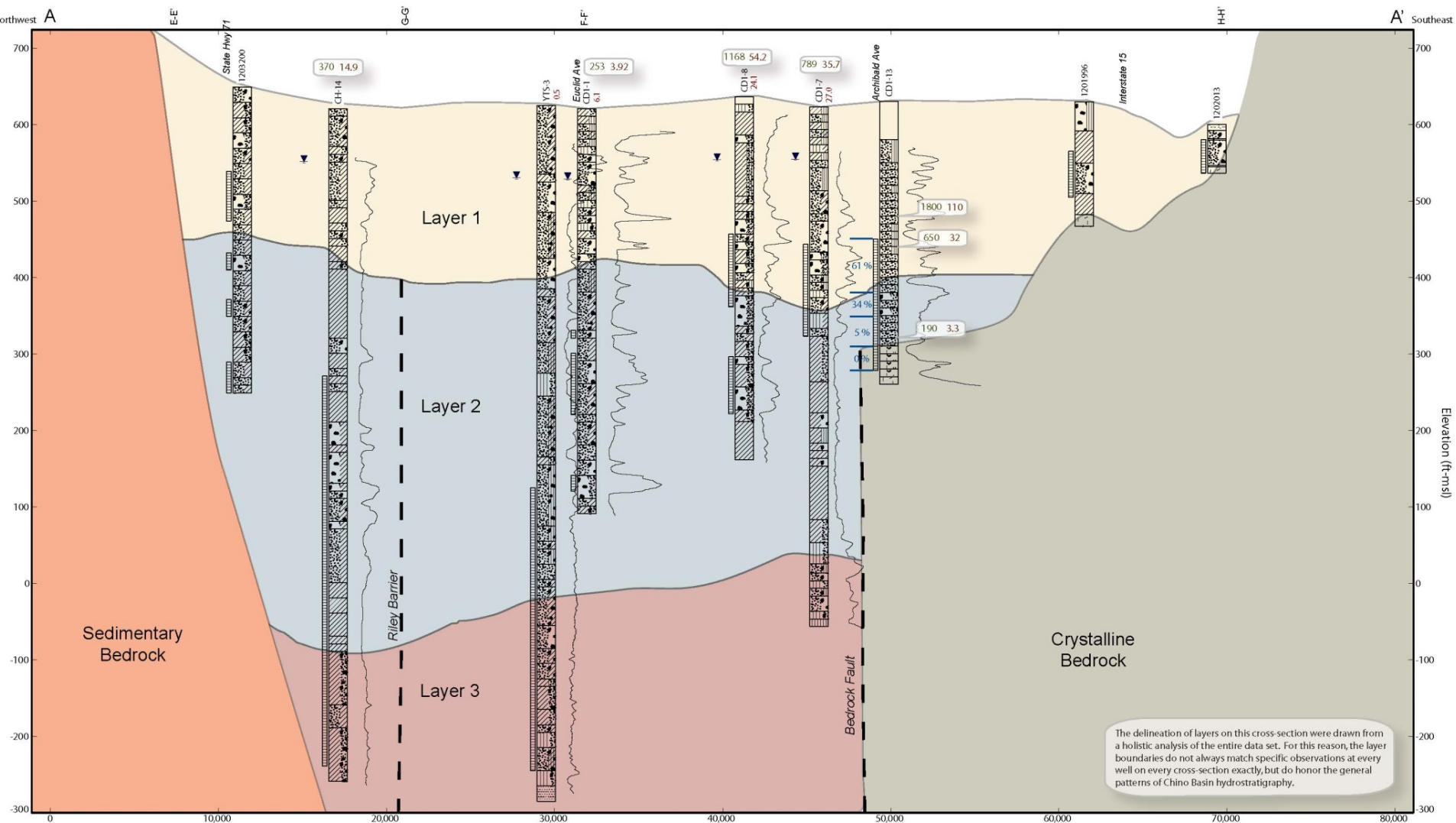
- | | | | |
|---|-------------------|----|----------------|
| 1 | San Antonio Creek | 7 | Fontana |
| 2 | Cucamonga Creek | 8 | Rialto/Colton |
| 3 | Deer Creek | 9 | Prado |
| 4 | Day Creek | 10 | Temescal Creek |
| 5 | Etiwanda Creek | 11 | Chino Creek |
| 6 | San Sevaine Creek | 12 | Riverside |



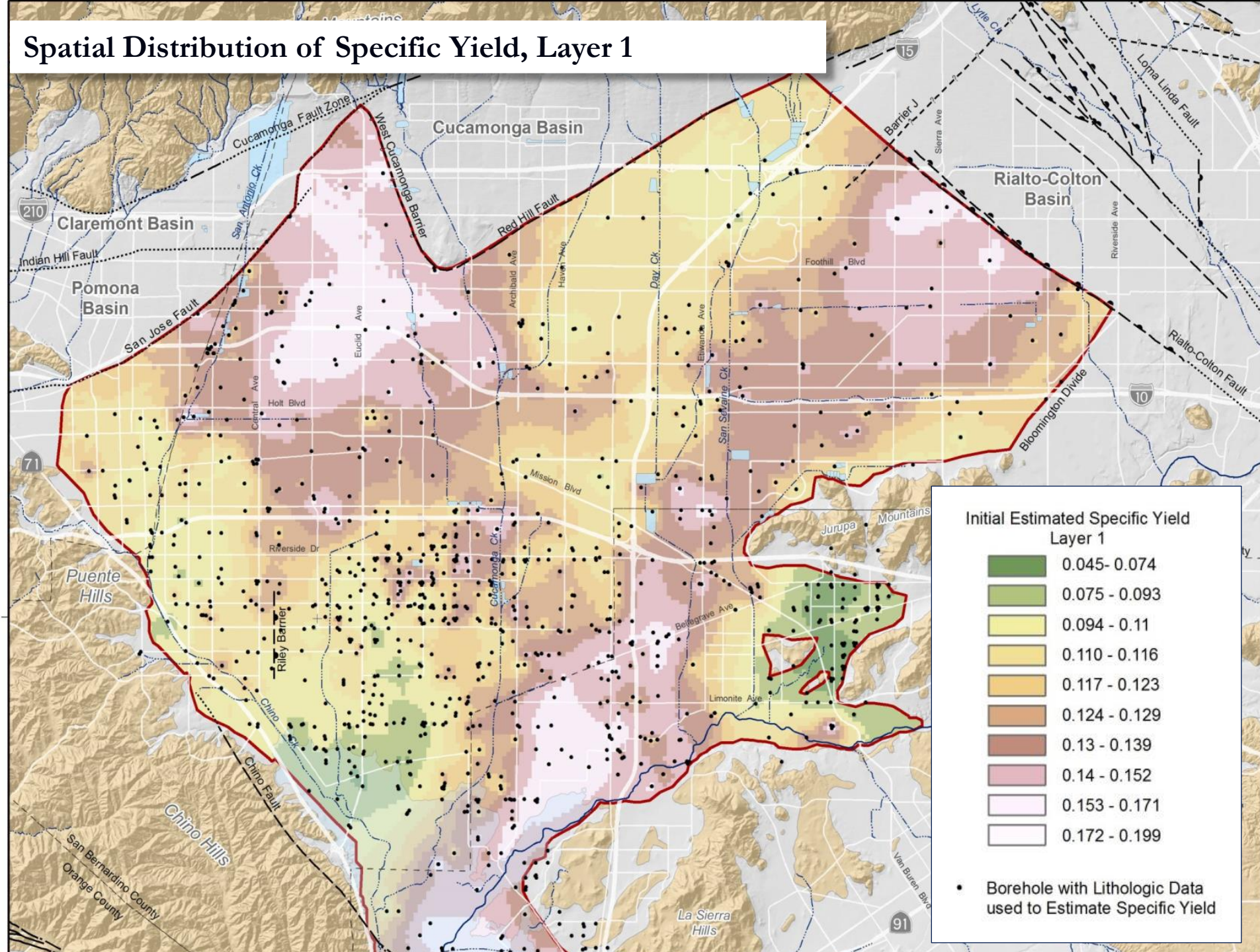
R4 Surface Water Model Organization



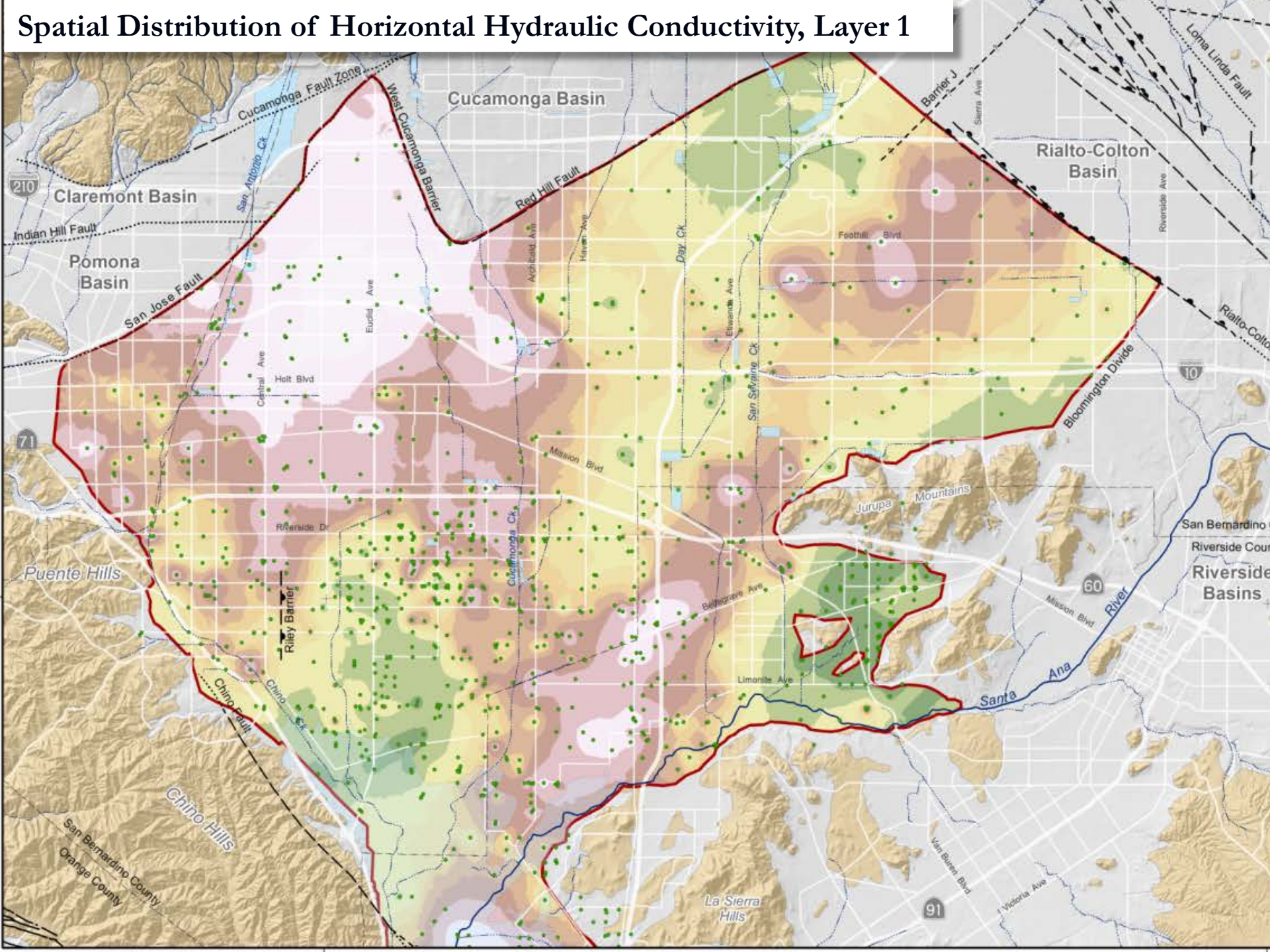




Spatial Distribution of Specific Yield, Layer 1



Spatial Distribution of Horizontal Hydraulic Conductivity, Layer 1



Spatial Distribution of Wells Used in Calibration

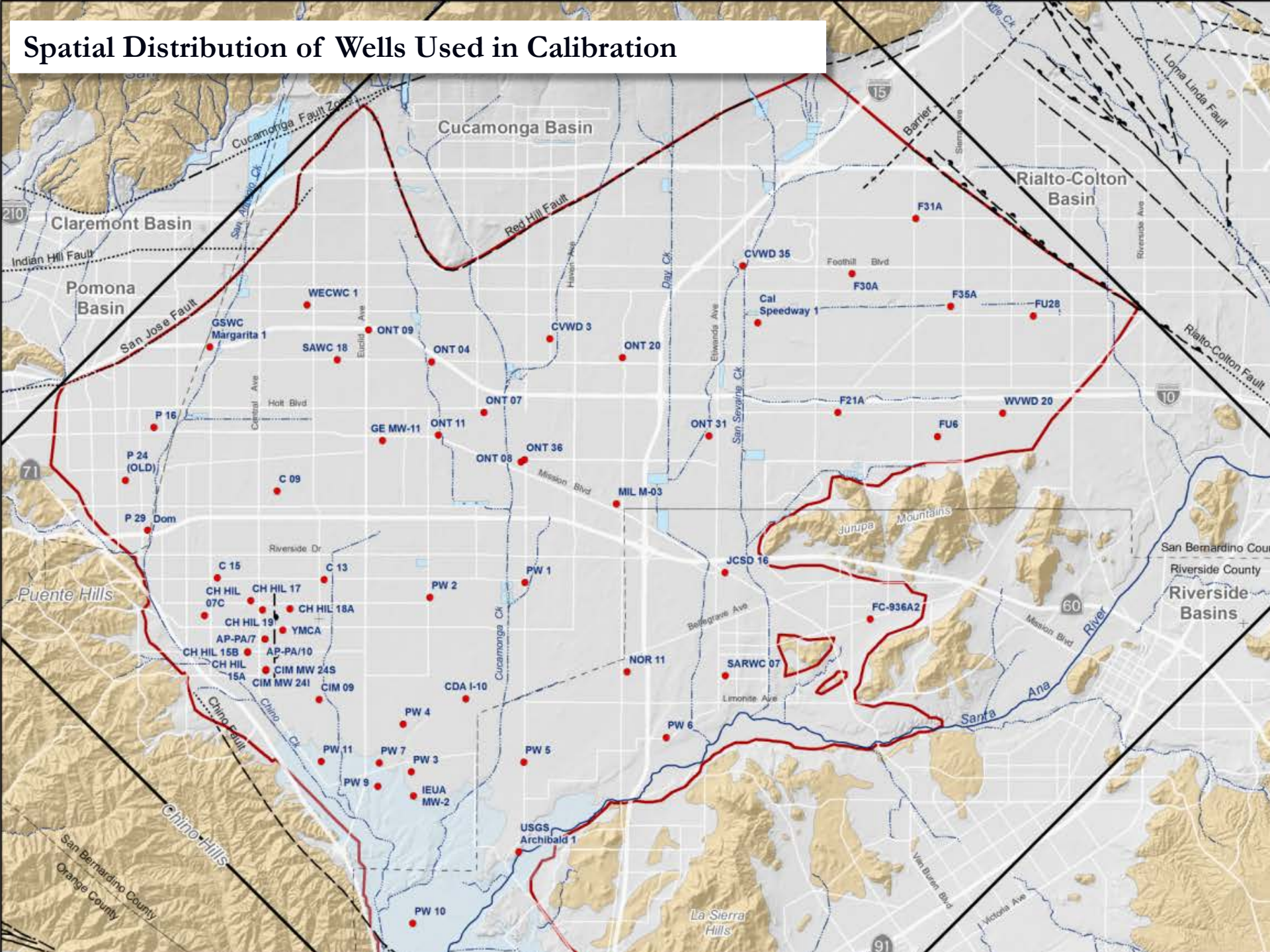


Figure E-1

Comparison of Simulated and Measured Water Levels in the Wells of Chino Basin

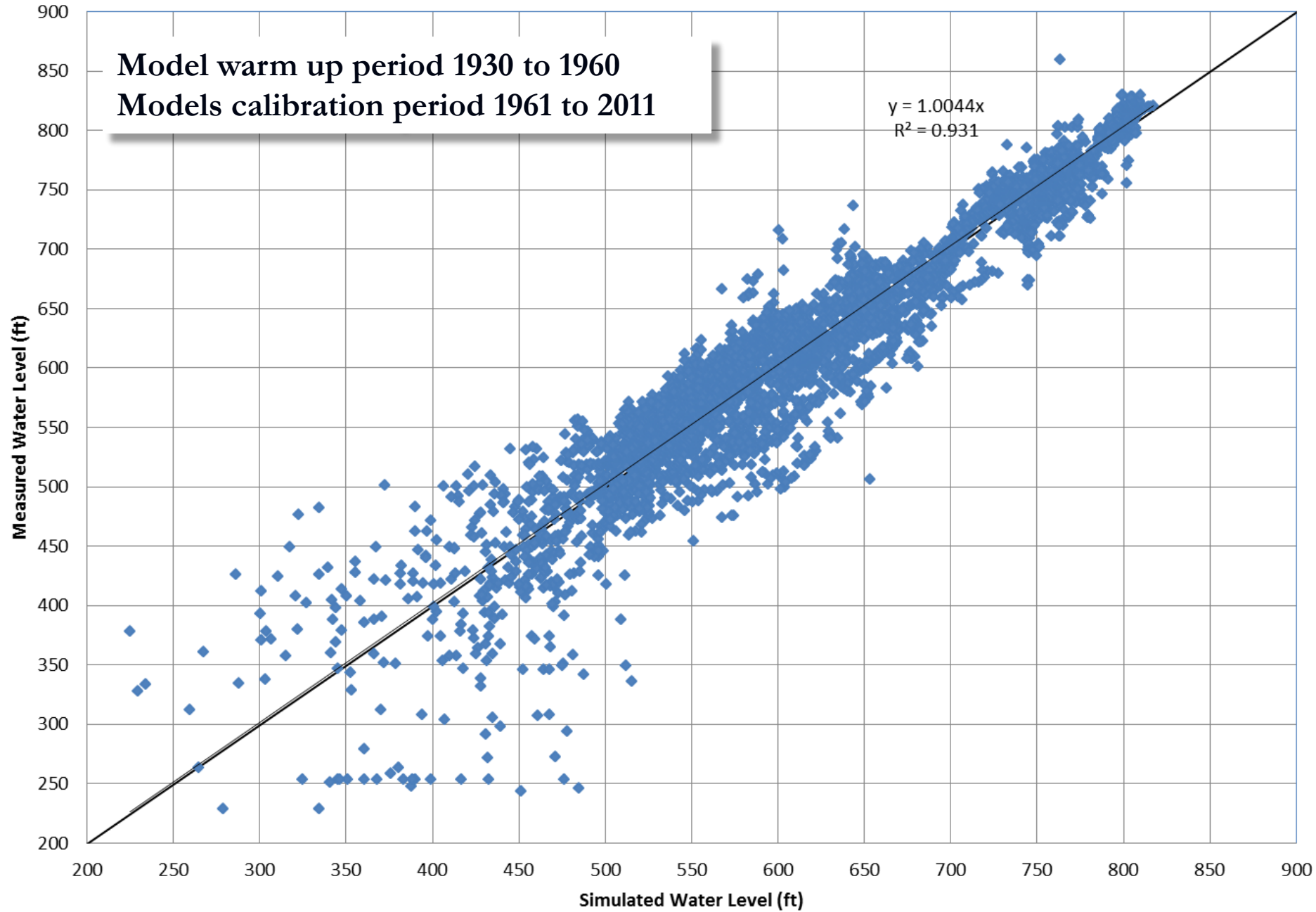
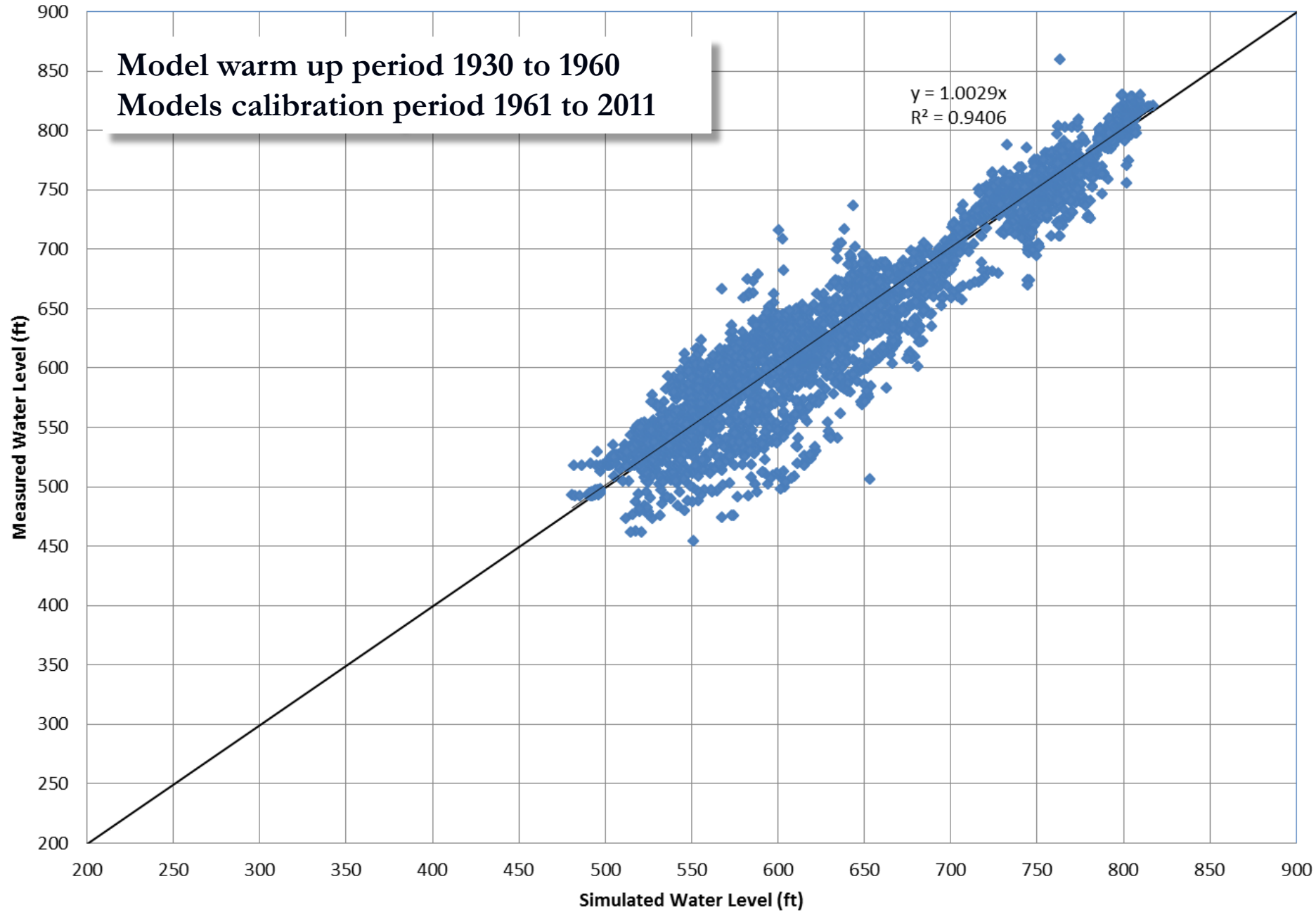
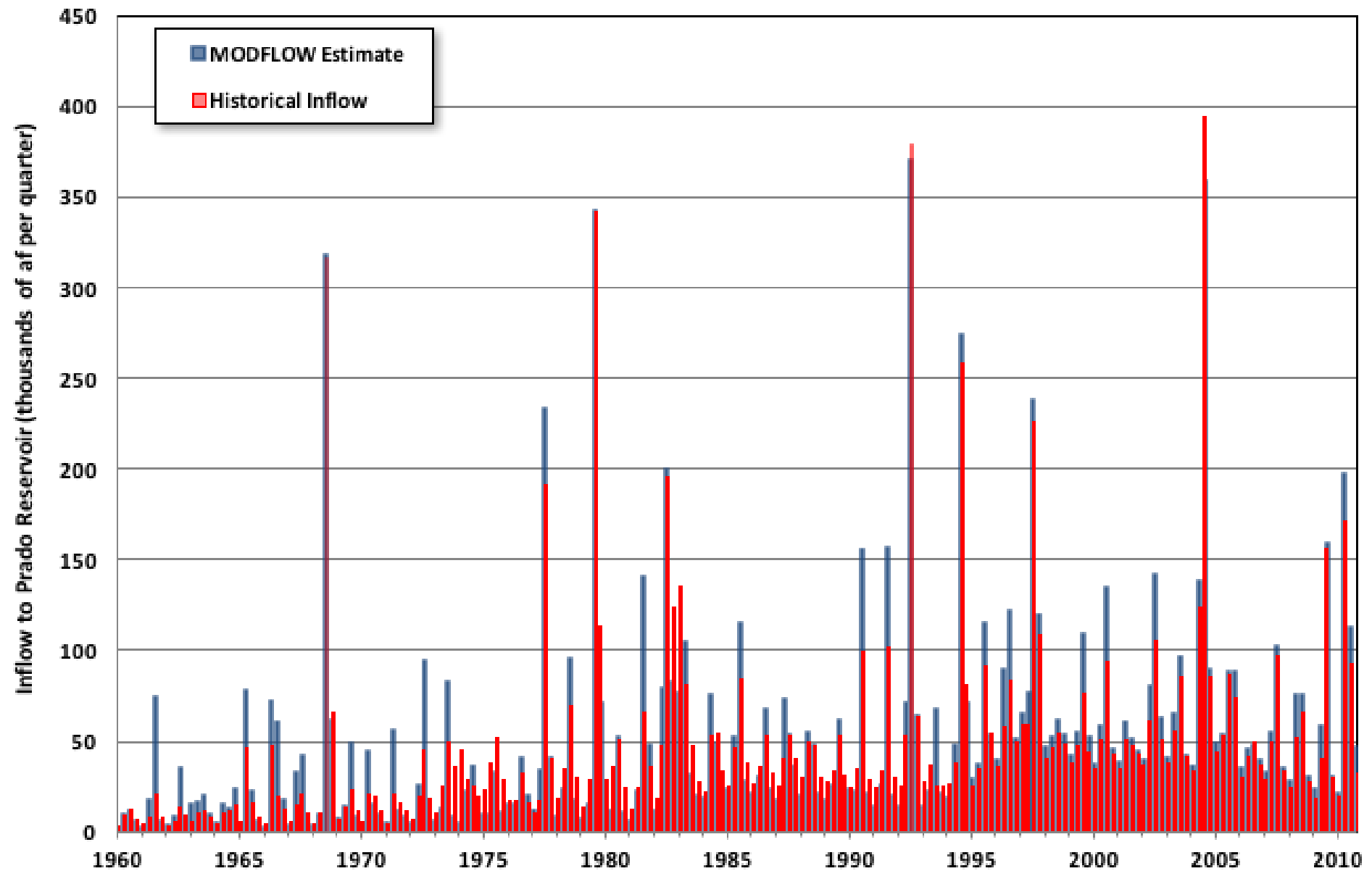


Figure E-1

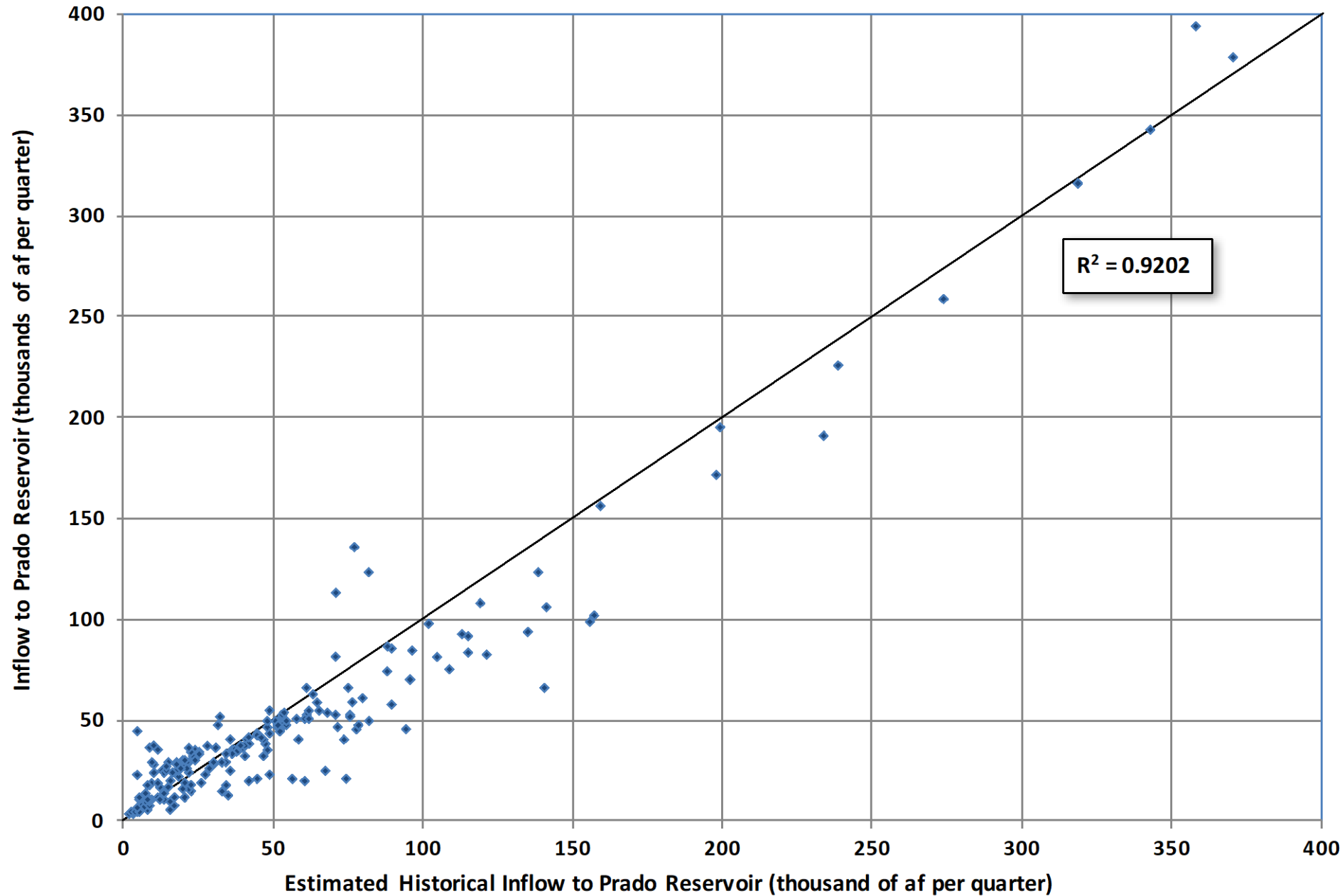
Comparison of Simulated and Measured Water Levels in the Wells of Chino Basin



Comparison of MODFLOW-Estimated Santa Ana River Inflow to Historical Prado Reservoir Inflow



Comparison of MODFLOW-Estimated Santa Ana River Inflow to Historical Prado Reservoir Inflow

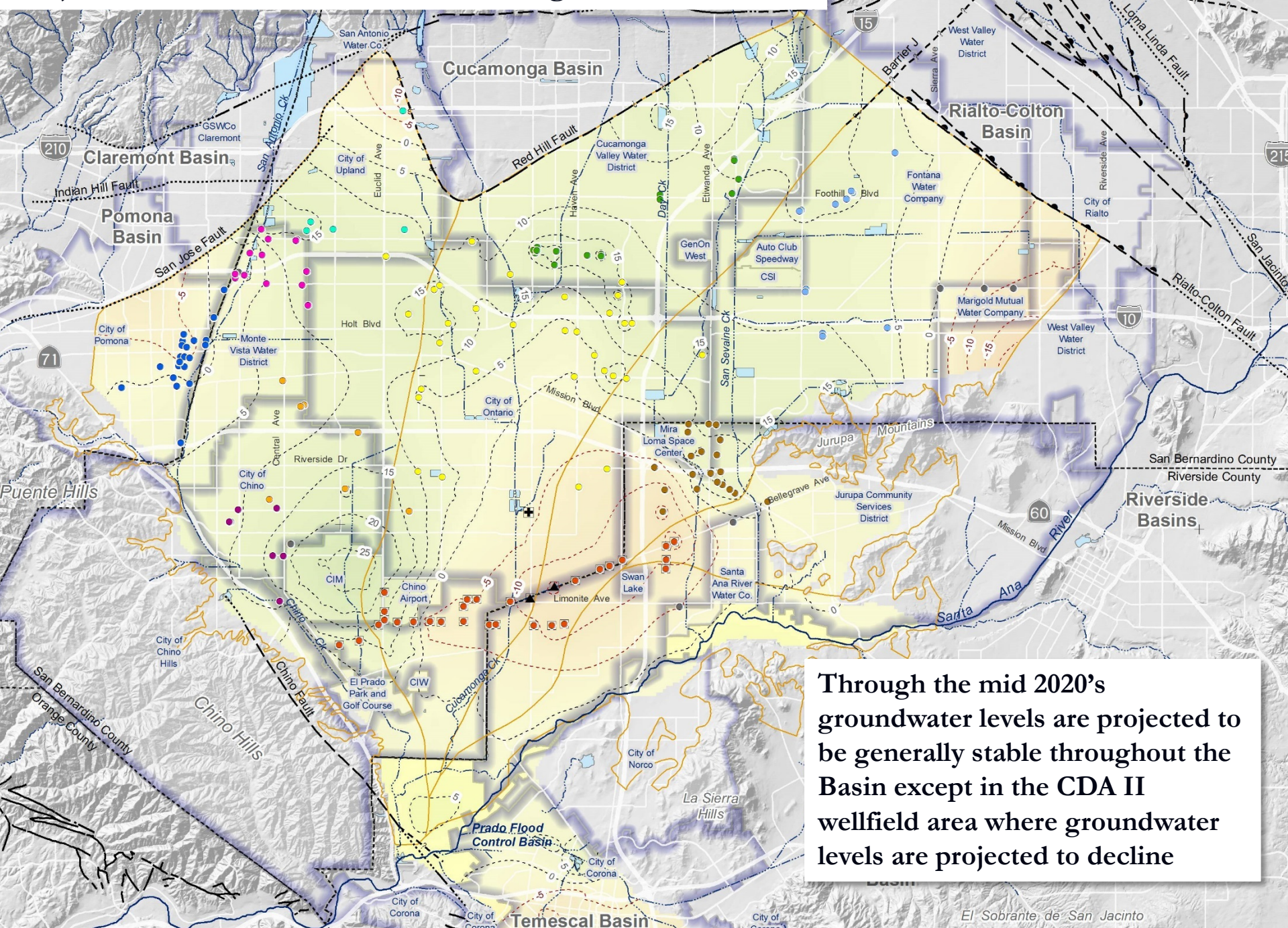


Assumption and execution of approach

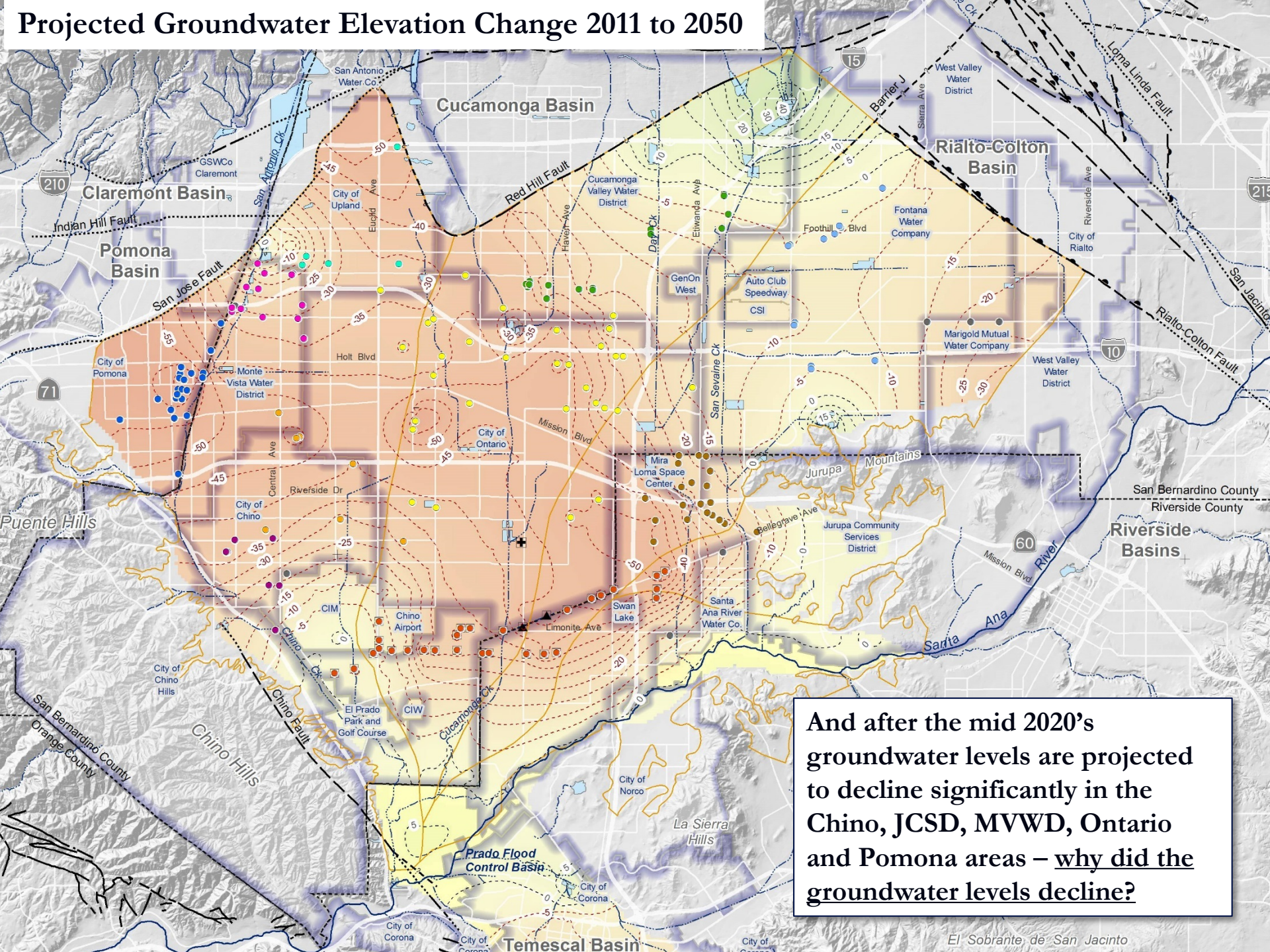
- Construct future hydrology
 - Collect future land use, stormwater management, irrigation management, water supply plans and other planning information to define future hydrology
 - Use surface and ground water models to estimate future recharge and discharge components, change in storage and net recharge – the projected water budget table

Table 7-6																				
Water Budget for Chino Basin (2011-2050)																				
Scenario 5A																				
(acre-ft)																				
End of Fiscal Year	Recharge										Discharge							Recharge minus Discharge	Annual Net Recharge	Ten-Year Average net Recharge
	I*	I	R	I	I	I	I	I	R		I	I	I	R	R	R				
	Subsurface Boundary Inflow, Chino Hills, Six Basins, Cucamonga Basin and Rialto Basin	Subsurface Boundary Inflow from Bloomington Divide	Subsurface Inflow From Temescal Basin	Deep Infiltration of Precipitation and Applied Water	Streambed Infiltration from Santa Ana River Tributaries	Storm Water Recharge in Basins	Recycled Water Recharge	Imported Water Recharge	Streambed Infiltration in the Santa Ana River	Subtotal Recharge	CDA Pumping	Overlying Non Ag and Appropriative Pools Production	Overlying Agricultural Pool Production	ET	GW Discharge to Streams	Subsurface Discharge to Temescal Basin	Subtotal Discharge			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
2011	23,077	13,658	6,750	81,096	1,308	16,985	7,743	9,466	34,347	194,431	29,043	98,922	21,021	18,190	18,358	2,899	188,433	5,997	137,775	130,286
2012	19,106	8,153	5,892	91,059	1,081	9,271	8,634	22,560	38,444	204,199	28,411	96,725	22,407	18,060	17,440	3,520	186,563	17,636	133,985	131,408
2013	19,106	8,153	4,949	90,236	1,084	5,271	10,479	0	39,746	179,023	27,098	110,918	23,950	18,024	17,260	3,946	201,196	-22,173	129,314	131,440
2014	19,106	8,153	5,432	91,466	1,087	12,000	9,300	3,996	38,934	189,473	31,440	105,212	21,950	18,118	17,987	4,070	198,778	-9,304	136,002	132,514
2015	19,106	8,153	5,953	91,550	1,089	12,000	14,500	3,996	37,760	194,108	32,289	106,595	19,125	18,214	18,715	4,013	198,951	-4,843	134,670	132,791
2016	19,106	8,153	6,122	95,445	1,092	12,000	14,500	3,996	36,855	197,270	37,500	108,125	16,300	18,266	19,272	3,924	203,387	-6,117	137,312	133,255
2017	19,106	8,153	6,233	96,220	1,095	12,000	14,500	3,996	36,776	198,079	39,767	109,655	13,475	18,267	19,231	3,881	204,275	-6,196	138,205	134,798
2018	19,106	8,153	6,310	96,705	1,098	12,000	16,900	3,996	36,048	200,316	39,767	111,184	10,650	18,287	19,428	3,862	203,178	-2,862	137,844	135,414
2019	19,106	8,153	6,365	95,553	1,101	12,000	16,900	3,996	35,467	198,641	39,767	112,714	7,825	18,323	19,760	3,855	202,244	-3,603	135,808	135,749
2020	19,106	8,153	6,405	94,200	1,104	12,000	16,900	3,996	34,878	196,741	39,767	114,244	5,000	18,358	20,120	3,851	201,341	-4,600	133,516	135,443
2021	19,106	8,153	6,410	92,631	1,106	12,000	16,900	3,996	34,770	195,073	39,767	116,444	5,000	18,357	20,189	3,854	203,612	-8,540	131,776	134,843
2022	19,106	8,153	6,403	91,884	1,109	12,000	18,700	3,996	34,787	196,139	39,767	118,644	5,000	18,342	20,133	3,860	205,746	-9,608	131,108	134,555
2023	19,106	8,153	6,393	93,273	1,112	12,000	18,700	3,996	34,671	197,404	39,767	120,844	5,000	18,316	19,872	3,869	207,609	-10,264	132,651	134,889
2024	19,106	8,153	6,378	93,509	1,115	12,000	18,700	3,996	34,824	197,781	39,767	123,044	5,000	18,303	19,717	3,878	209,708	-11,928	133,187	134,608
2025	19,106	8,153	6,361	94,353	1,118	12,000	18,700	3,996	34,992	198,778	39,767	125,244	5,000	18,290	19,564	3,887	211,752	-12,974	134,341	134,575
2026	19,106	8,153	6,345	94,889	1,121	12,000	18,700	3,996	35,164	199,475	39,767	127,367	5,000	18,276	19,405	3,896	213,711	-14,236	135,202	134,364
2027	19,106	8,153	6,329	94,717	1,124	12,000	18,700	3,996	35,355	199,479	39,767	129,489	5,000	18,262	19,234	3,905	215,658	-16,179	135,381	134,081
2028	19,106	8,153	6,315	94,652	1,126	12,000	18,700	3,996	35,523	199,571	39,767	131,612	5,000	18,247	19,079	3,912	217,618	-18,047	135,637	133,861
2029	19,106	8,153	6,301	95,291	1,129	12,000	18,700	3,996	35,727	200,403	39,767	133,735	5,000	18,231	18,898	3,920	219,550	-19,147	136,659	133,946
2030	19,106	8,153	6,286	95,381	1,132	12,000	18,700	3,996	35,961	200,715	39,767	135,857	5,000	18,213	18,699	3,929	221,465	-20,750	137,179	134,312
2031	19,106	8,153	6,274	96,029	1,132	12,000	18,700	0	36,203	197,597	39,767	137,838	5,000	18,193	18,482	3,934	223,215	-25,618	138,288	134,963
2032	19,106	8,153	6,263	94,944	1,132	12,000	18,700	0	36,428	196,726	39,767	139,820	5,000	18,172	18,269	3,938	224,967	-28,241	137,646	135,617
2033	19,106	8,153	6,252	95,236	1,132	12,000	18,700	0	36,700	197,279	39,767	141,801	5,000	18,149	18,015	3,944	226,676	-29,397	138,471	136,199
2034	19,106	8,153	6,242	96,292	1,132	12,000	18,700	0	36,996	198,621	39,767	143,782	5,000	18,124	17,746	3,948	228,367	-29,746	140,103	136,891
2035	19,106	8,153	6,232	96,476	1,132	12,000	18,700	0	37,318	199,117	39,767	145,763	5,000	18,097	17,492	3,953	230,072	-30,954	140,876	137,544
2036	19,106	8,153	6,222	96,794	1,132	12,000	18,700	0	37,700	199,807	39,767	145,763	5,000	18,069	17,248	3,957	229,805	-29,997	141,833	138,207
2037	19,106	8,153	6,215	96,137	1,132	12,000	18,700	0	38,080	199,523	39,767	145,763	5,000	18,041	17,027	3,960	229,559	-30,036	141,795	138,849
2038	19,106	8,153	6,205	95,400	1,132	12,000	18,700	0	38,468	199,164	39,767	145,763	5,000	18,014	16,808	3,966	229,318	-30,154	141,676	139,453
2039	19,106	8,153	6,197	95,022	1,132	12,000	18,700	0	38,850	199,159	39,767	145,763	5,000	17,987	16,605	3,970	229,092	-29,933	141,898	139,977
2040	19,106	8,153	6,191	94,503	1,132	12,000	18,700	0	39,207	198,993	39,767	145,763	5,000	17,962	16,431	3,972	228,895	-29,902	141,928	140,451
2041	19,106	8,153	6,185	94,044	1,132	12,000	18,700	0	39,547	198,867	39,767	145,763	5,000	17,938	16,275	3,975	228,719	-29,852	141,978	140,821
2042	19,106	8,153	6,179	93,678	1,132	12,000	18,700	0	39,911	198,859	39,767	145,763	5,000	17,914	16,099	3,978	228,522	-29,662	142,168	141,273
2043	19,106	8,153	6,174	93,144	1,132	12,000	18,700	0	40,232	198,641	39,767	145,763	5,000	17,892	15,948	3,981	228,351	-29,710	142,120	141,638
2044	19,106	8,153	6,168	92,707	1,132	12,000	18,700	0	40,494	198,461	39,767	145,763	5,000	17,873	15,827	3,984	228,214	-29,753	142,077	141,835
2045	19,106	8,153	6,164	92,038	1,132	12,000	18,700	15,271	40,727	213,291	39,767	145,763	5,000	17,856	15,728	3,985	228,100	-14,809	141,751	141,923
2046	19,106	8,153	6,159	91,738	1,132	12,000	18,700	30,291	40,962	228,241	39,767	145,763	5,000	17,840	15,625	3,988	227,984	258	141,797	141,919
2047	19,106	8,153	6,155	91,657	1,132	12,000	18,700	30,291	41,149	228,343	39,767	145,763	5,000	17,827	15,551	3,990	227,899	444	141,984	141,938
2048	19,106	8,153	6,150	91,506	1,132	12,000	18,700	30,291	41,305	228,343	39,767	145,763	5,000	17,816	15,490	3,992	227,828	515	142,055	141,976
2049	19,106	8,153	6,147	91,385	1,132	12,000	18,700	30,291	41,421	228,335	39,767	145,763	5,000	17,808	15,442	3,993	227,774	561	142,101	141,996
2050	19,106	8,153	6,143	91,158	1,132	12,000	18,700	30,291	41,495	228,177	39,767	145,763	5,000	17,803	15,411	3,995	227,739	438	141,978	142,001
Statistics for the Period 2011 through 2050																				
Total	768,211	331,625	247,849	3,743,997	44,973	475,527	689,556	266,683	1,504,224	8,072,646	1,537,873	5,232,026	311,703	724,318	713,882	156,131	8,675,933	-603,287	5,522,076	5,472,600
Total (%)	10%	4%	3%	46%	1%	6%	9%	3%	19%	100%	18%	60%	4%	8%	8%	2%	100%			
Average	19,205	8,291	6,196	93,600	1,124	11,888	17,239	6,667	37,606	201,816	38,447	130,801	7,793	18,108	17,847	3,903	216,898	-15,082	138,052	136,815
Median	19,106	8,153	6,227	94,276	1,132	12,000	18,700	3,996	37,157	198,863	39,767	136,848	5,000	18,137	18,001	3,945	222,340	-14,523	138,024	135,530
Maximum	23,077	13,658	6,750	96,794	1,308	16,985	18,700	30,291	41,495	228,343	39,767	145,763	23,950	18,358	20,189	4,070	230,072	17,636	142,168	142,001
Minimum	19,106	8,153	4,949	81,096	1,081	5,271	7,743	0	34,347	179,023	27,098	96,725	5,000	17,803	15,411	2,899	186,563	-30,954	129,314	130,286

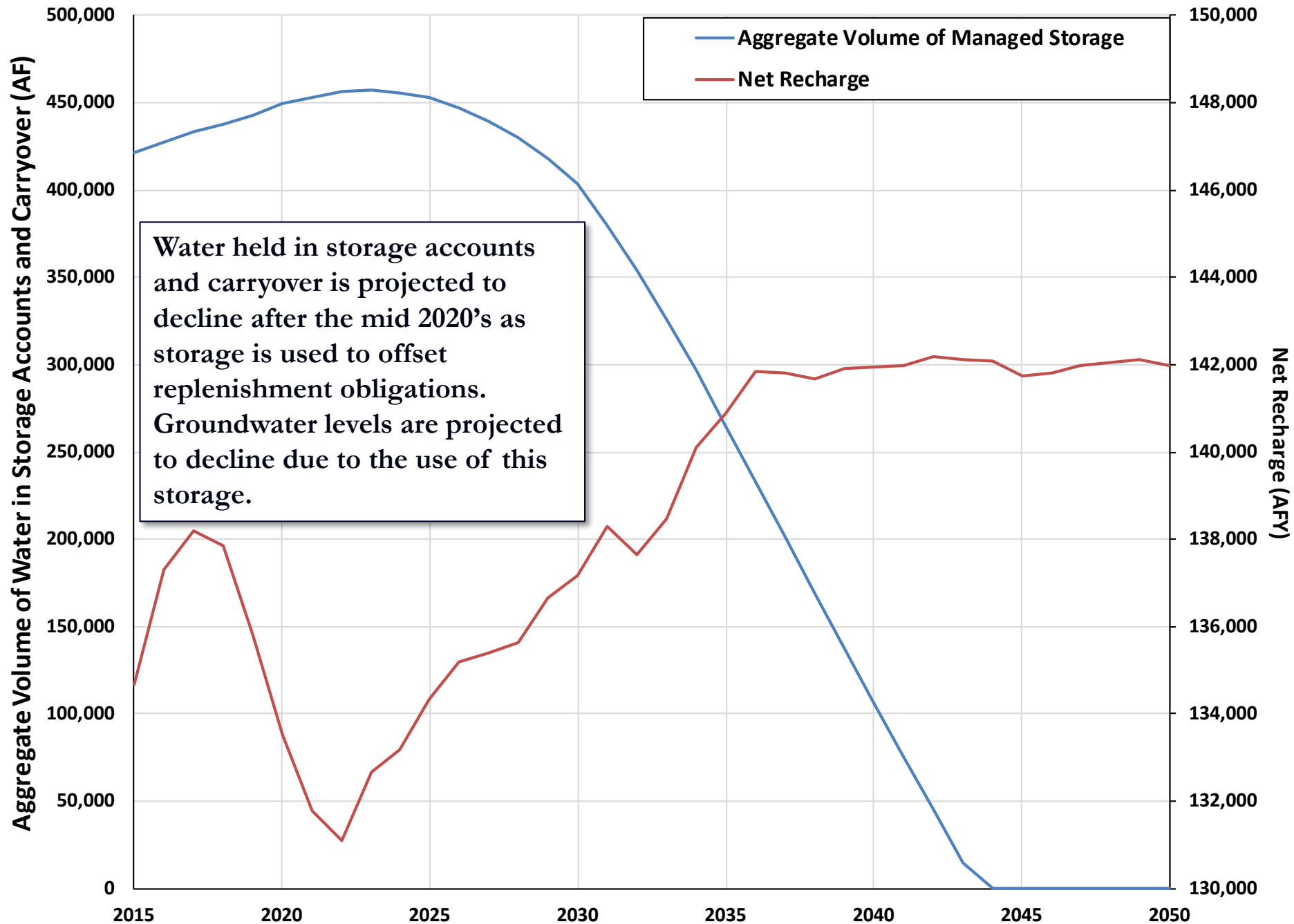
Projected Groundwater Elevation Change 2011 to 2020

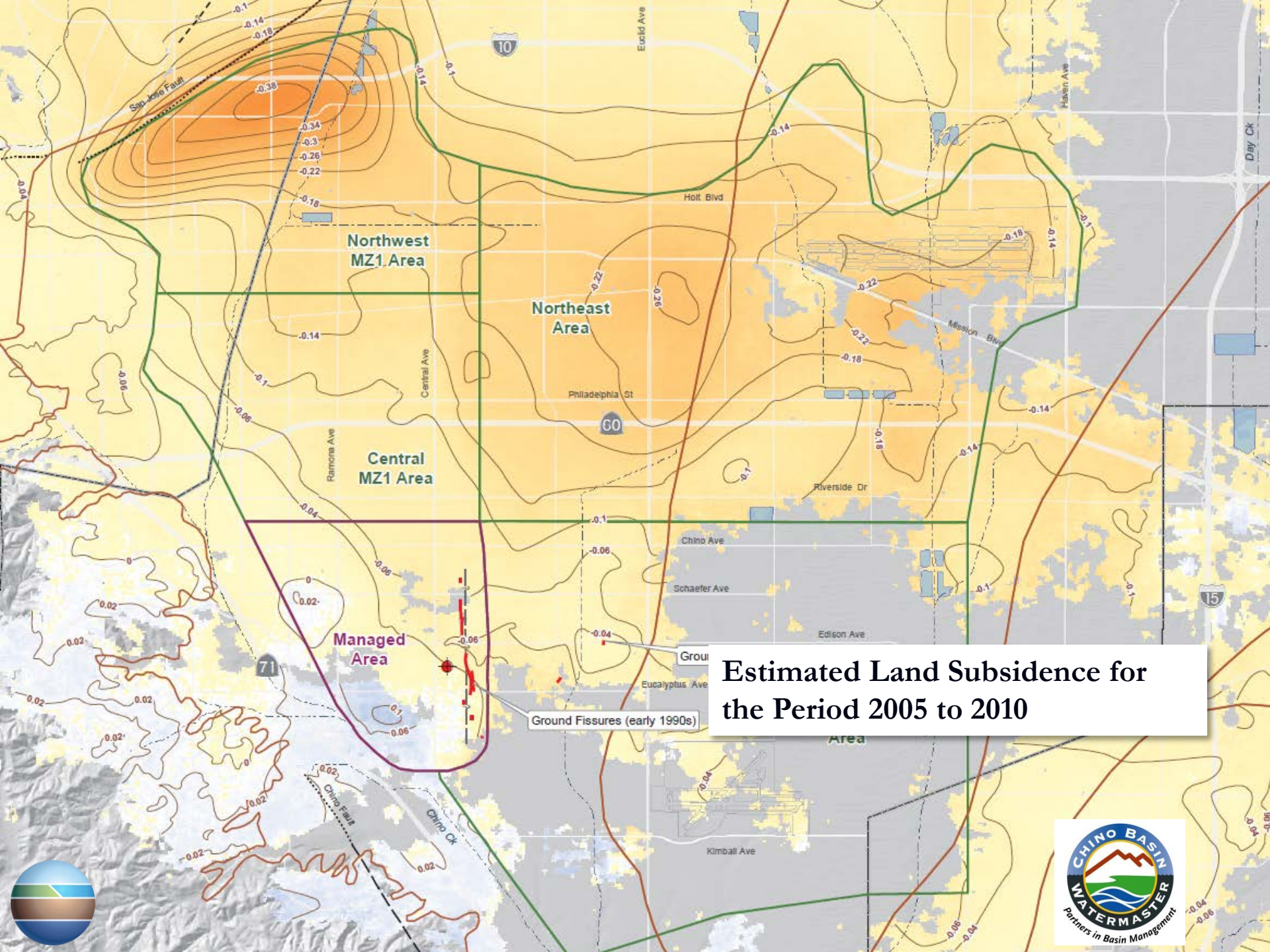


Projected Groundwater Elevation Change 2011 to 2050



And after the mid 2020's groundwater levels are projected to decline significantly in the Chino, JCS, MVWD, Ontario and Pomona areas – why did the groundwater levels decline?

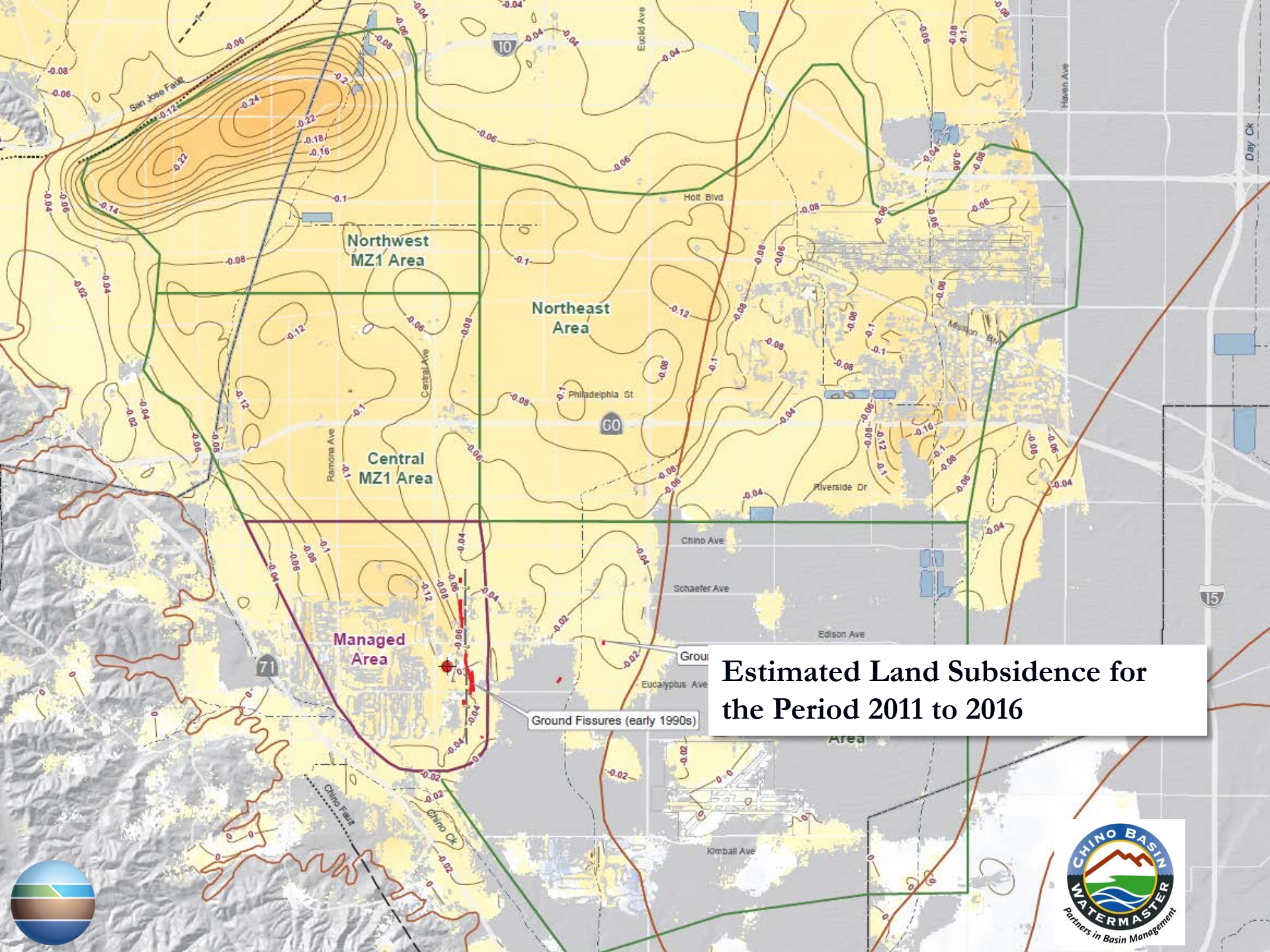




**Estimated Land Subsidence for
the Period 2005 to 2010**

Ground Fissures (early 1990s)





Northwest
MZ1 Area

Northeast
Area

Central
MZ1 Area

Managed
Area

Estimated Land Subsidence for
the Period 2011 to 2016

Ground Fissures (early 1990s)



SGMA definition of sustainability

- The maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result.

SGMA definition of undesirable results

- One or more of the following effects caused by groundwater conditions occurring throughout the basin:
 1. **Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon**
 2. Significant and unreasonable reduction of groundwater storage
 3. Significant and unreasonable seawater intrusion
 4. Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies
 5. **Significant and unreasonable land subsidence that substantially interferes with surface land uses**
 6. Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water

Chino Basin sustainable yield

- Watermaster will recalculate safe yield in 2020 consistent with the SGMA concept of sustainable yield
- Watermaster is currently developing management plans to
 - Ensure sustainable pumping
 - Manage ongoing land subsidence and not to create new land subsidence
 - Not degrade riparian habitat in Prado Reservoir area

What we learned and can share

- The Chino Basin Watermaster has invested in monitoring and model development since 1998 and since 2000 has been actively implementing its Optimum Basin Management Program (OBMP)
- Through monitoring and modeling the parties to the stipulated agreement:
 - Have learned how the groundwater basin responds to their individual and aggregate groundwater management choices
 - Made better choices
 - Have worked together to develop new groundwater management strategies to prevent undesirable results
- Groundwater management achieving sustainability requires:
 - Commitment for constant improvement in monitoring and modeling and analytical tools
 - Periodic reviews of the current management plan to ensure metrics and milestones are achieved



Questions

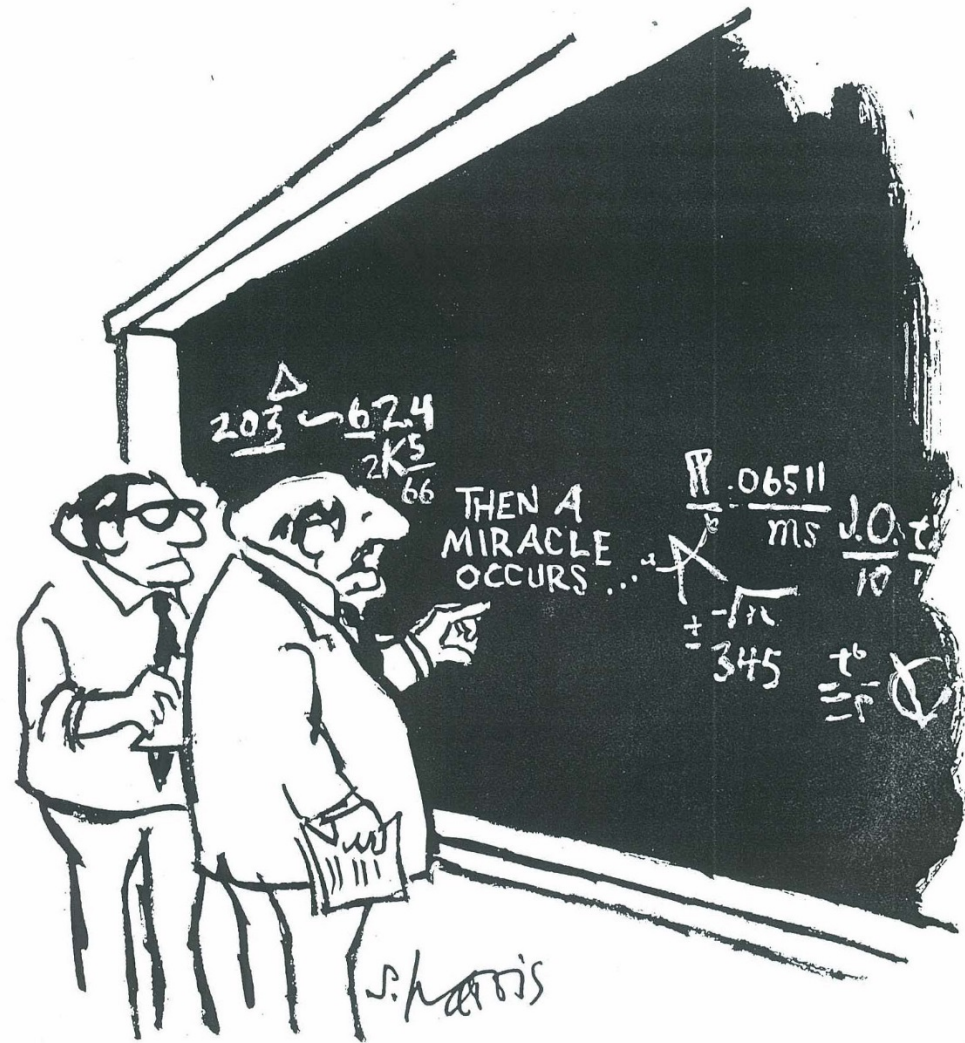
Contact me at:

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2013 Chino Basin Model
Update and Recalculation of
the Safe Yield Pursuant to the
Peace Agreement can be
viewed here:

http://www.cbwm.org/rep_engineering.htm



"I THINK YOU SHOULD BE MORE
EXPLICIT HERE IN STEP TWO."

S. Harris



End

