Applying the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM), an integrated hydrologic model of California's Central Valley, to assess local and regional impacts of conjunctive use projects

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IWFM source code, executables and documentation are freely available. Search for "IWFM" with Google or go to: http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM

Introduction

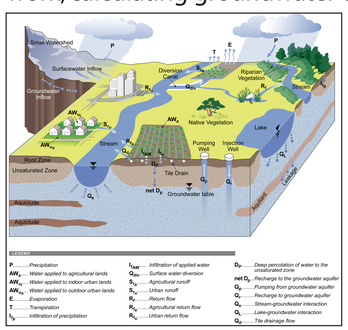
Integrated hydrologic modelling programs like IWFM combine land-surface processes, surface water flow, and unsaturated and saturated groundwater flow in a single unified application. The direct linkage of multiple processes within a single application has many benefits, including:

- Internal calculation of inter-process flows speeds model development and reduces errors;
- Less pre-processing of input data sets;
- No need to link multiple process-level models, often with different temporal scales;
- Robust model calibration - each parameter is constrained by several types of observations;
- Rapid model adaptation to evaluate the effects of complex scenarios on multiple processes.

Some of the advantages of integrated watershed-scale applications are demonstrated by applying the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) to assess local and regional impacts of a conjunctive use project.

Integrated Water Flow Model (IWFM)

C2VSIM was developed using the IWFM application. IWFM is a data-driven integrated hydrologic model that couples a 3-D finite element groundwater flow process with 1-D land surface, stream flow, lake flow and vertical unsaturated-zone flow processes. The groundwater flow process can simulate pumping wells, injection wells, tile drains and land subsidence. The land-surface process uses distributed soil properties, land use, crop acreage, precipitation rates and evapotranspiration rates are used to dynamically calculate water demands, runoff to streams and deep percolation through the unsaturated zone. The surface water flow and lake processes route flows through the stream and lake network, calculating groundwater-surface water interactions and inflows from runoff, and allocating available stream flows to meet specified deliveries and flows to bypasses. Surface water diversion and groundwater pumping rates can be specified or calculated at run-time.

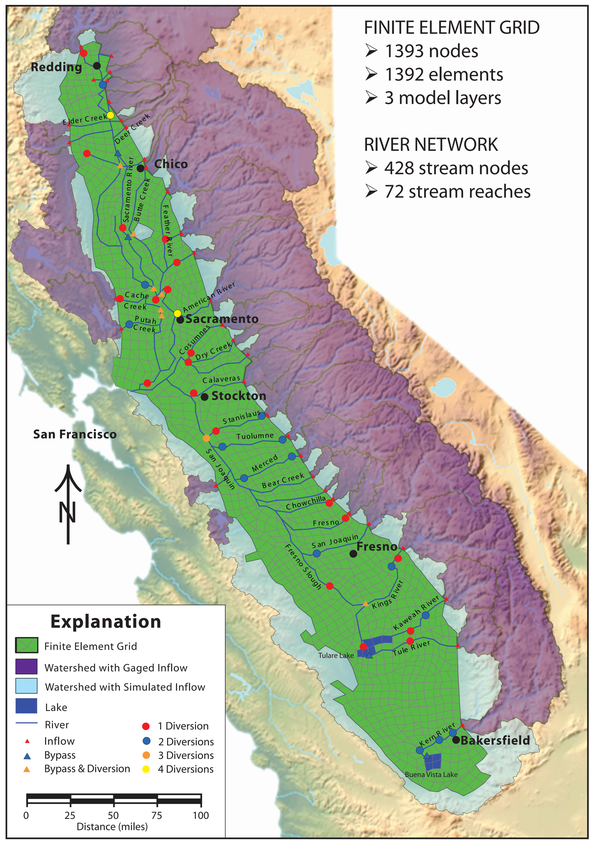


C2VSIM

C2VSIM simulates land-surface, groundwater and surface water flow processes in the alluvial portion of California's Central Valley, an area of approximately 20,000 mi^2. The model was calibrated for water years 1972-2003 (10/71-9/03) with a monthly time step.

A calibrated integrated hydrologic flow model can provide robust estimates of important water resources properties. These include groundwater pumping rates, changes in groundwater storage, and groundwater-surface water flows. The model can also be used for a variety of purposes, including assessing the impacts of human-induced and natural changes in land use, surface water flows and groundwater pumping on the Central Valley's streams and aquifers. Model applications include simulating the impacts of long-term changes in regional surface water availability, and assessing regional-scale impacts of increasing groundwater pumping while reducing surface water diversions.

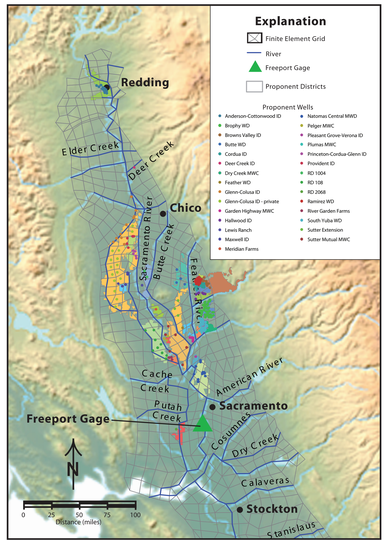
C2VSIM Model Framework



Conjunctive Use Simulation

C2VSIM was recently used to evaluate the effects of a conjunctive use project on river flows, by simulating project operation for the historical period 1972-2003. In years with low rainfall, 188 TAF of groundwater was pumped in lieu of surface water diversions, which increased river flows at Freeport, CA. In "wet" years, the aquifer was allowed to recover. The IWFM application automatically reduces surface water diversions when groundwater is pumped. The model simulated project effects on land-surface processes, aquifer storage, groundwater-surface water flows, and river flows.

Conjunctive Use Project Well Locations



Sacramento River Index

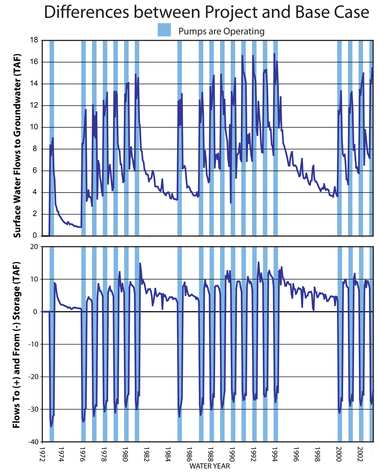
Water Year	Index Value	Index Yr-type	Project Status
1972	7.29	BN	OFF*
1973	8.58	AN	ON
1974	12.99	W	OFF
1975	9.35	W	OFF
1976	5.29	C	ON
1977	3.11	C	ON
1978	8.65	AN	ON
1979	6.67	BN	ON
1980	9.04	AN	ON
1981	6.21	D	ON
1982	12.76	W	OFF
1983	15.29	W	OFF
1984	10	W	OFF
1985	6.47	D	ON
1986	9.96	W	OFF
1987	5.86	D	ON
1988	4.65	C	ON
1989	6.13	D	ON
1990	4.81	C	ON
1991	4.21	C	ON
1992	4.06	C	ON
1993	8.54	AN	ON
1994	5.02	C	ON
1995	12.89	W	OFF
1996	10.26	W	OFF
1997	10.82	W	OFF
1998	13.31	W	OFF
1999	9.8	W	OFF
2000	8.94	AN	ON
2001	5.76	D	ON
2002	6.35	D	ON
2003	8.21	AN	ON
2004	7.51	BN	ON
2005	8.49	AN	ON
2006	13.13	W	OFF

* First year off for 'spin-up'

Index	Description	Status
W	Wet	OFF
AN	Above Normal	ON
BN	Below Normal	ON
D	Dry	ON
C	Critical	ON

Simulation Results

Differences between Project and Base Case

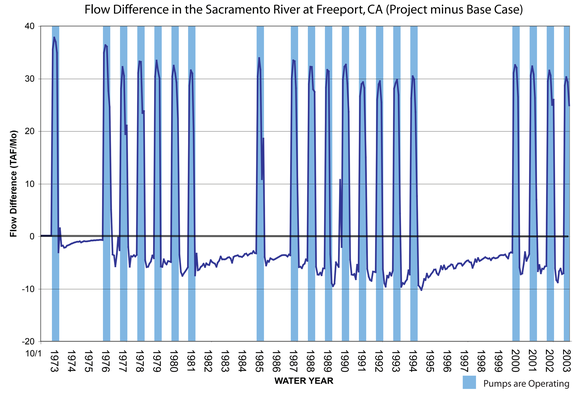


Surface water flows to groundwater were significantly changed by the project. Pumped groundwater was derived from both storage and a reduction in discharges to streams. Storage replenishment took several years, reducing discharges to streams during this time.

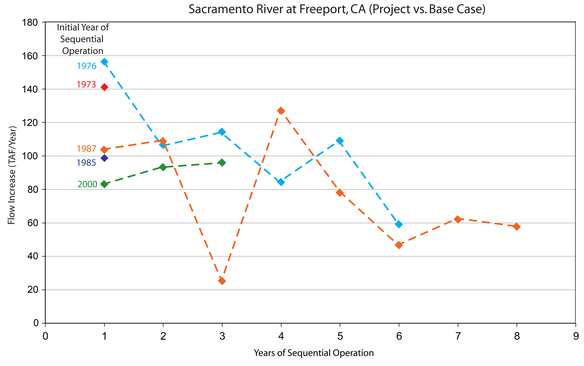
Conjunctive Use Results

Simulation results show that groundwater discharges to streams declined through time as aquifer storage was depleted. When the project operateed several years in a row, project benefits significantly decreased. In each year of project operation, 188 TAF of groundwater were pumped, with an equal amount of water left in the river system.

Flow Difference in the Sacramento River at Freeport, CA (Project minus Base Case)



Increase in River Flow vs. Years of Sequential Operation
Sacramento River at Freeport, CA (Project vs. Base Case)



Conclusions

- Integrated hydrologic models like C2VSIM can be used to evaluate the complex regional-scale effects of water management projects.
- On average, 68% of project water reached Freeport (ranged between 42% and 85%).
- Groundwater withdrawals affected groundwater discharges to rivers, reducing total project yields.
- Project yields decline significantly with each successive year of project operation.
- Simulations can be used to analyze alternative operating scenarios.