"Still Wrong, but Sometimes Useful": Adventures with CALVIN

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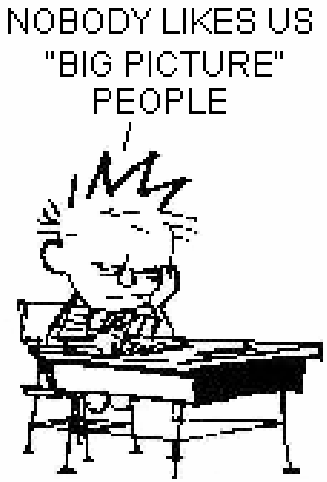

http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/

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More Thanks

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Agencies who gave us data and helped us better understand it: Dozens of people who went out of their way

Advisory Committee, chaired by Anthony Saracino for their aid in helping us communicate our approach and results

$till More Thank$

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Henry Vaux's connections

CALFED – Mark Cowin

CEC – Guido Franco

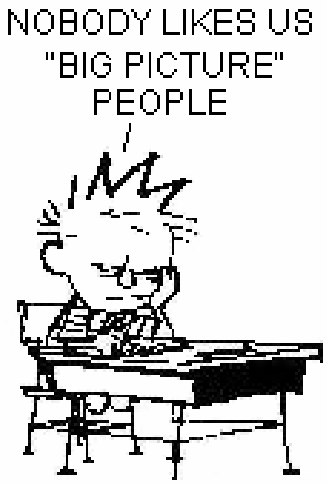
USBR

CALEPA – Ricardo Martinez

PPIC

TNC

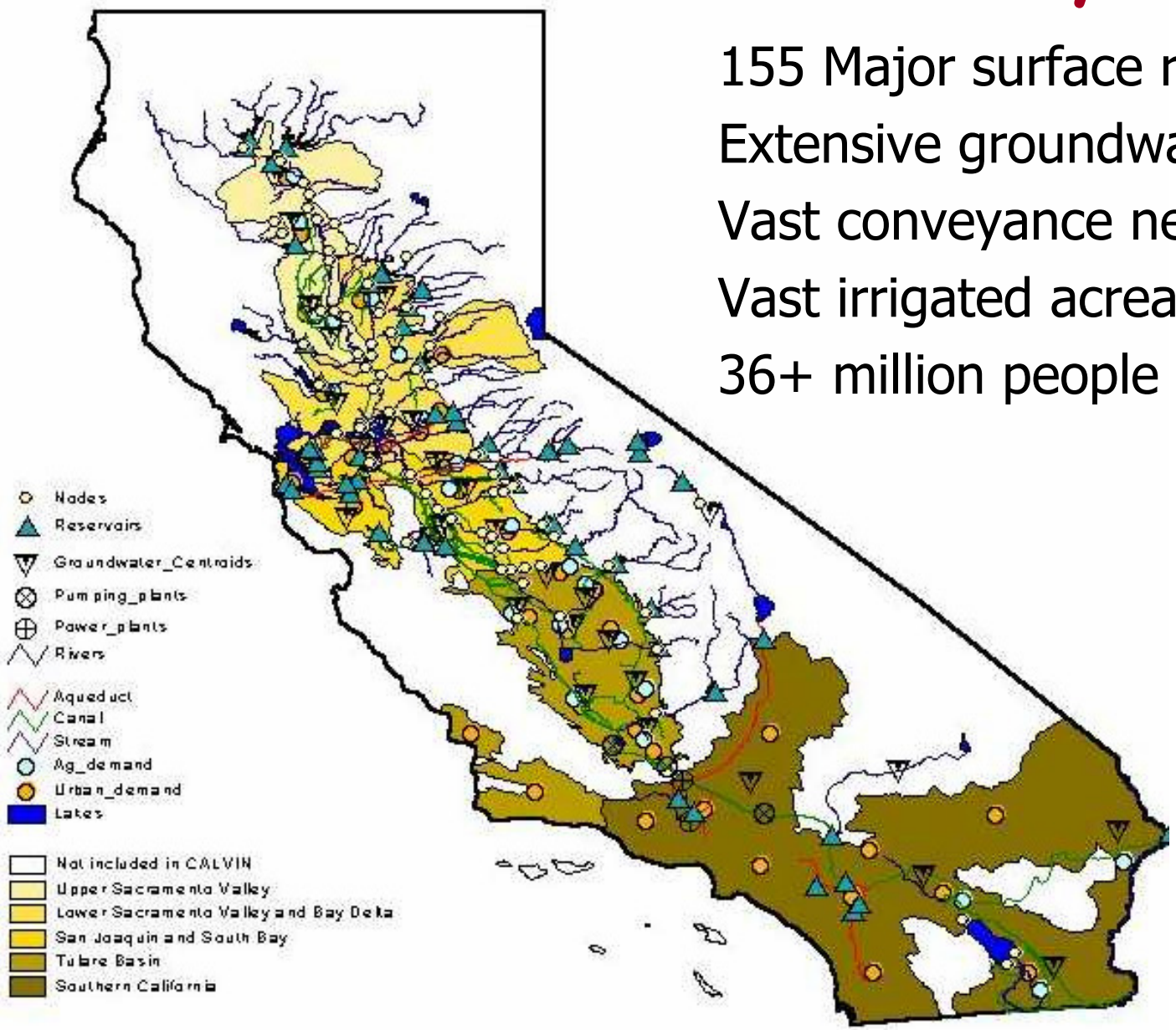
What is CALVIN?



- Entire inter-tied California water system
- Surface and groundwater systems
- Supply and demand management options
- Economics-driven engineering optimization model
  - Economic Values for Agricultural, Urban, & Hydropower Uses
  - Flow Constraints for Environmental Uses
- Prescribes monthly system operation over a 72-year representative hydrology

Forces quantitative understanding of the system

California's Water System



155 Major surface reservoirs

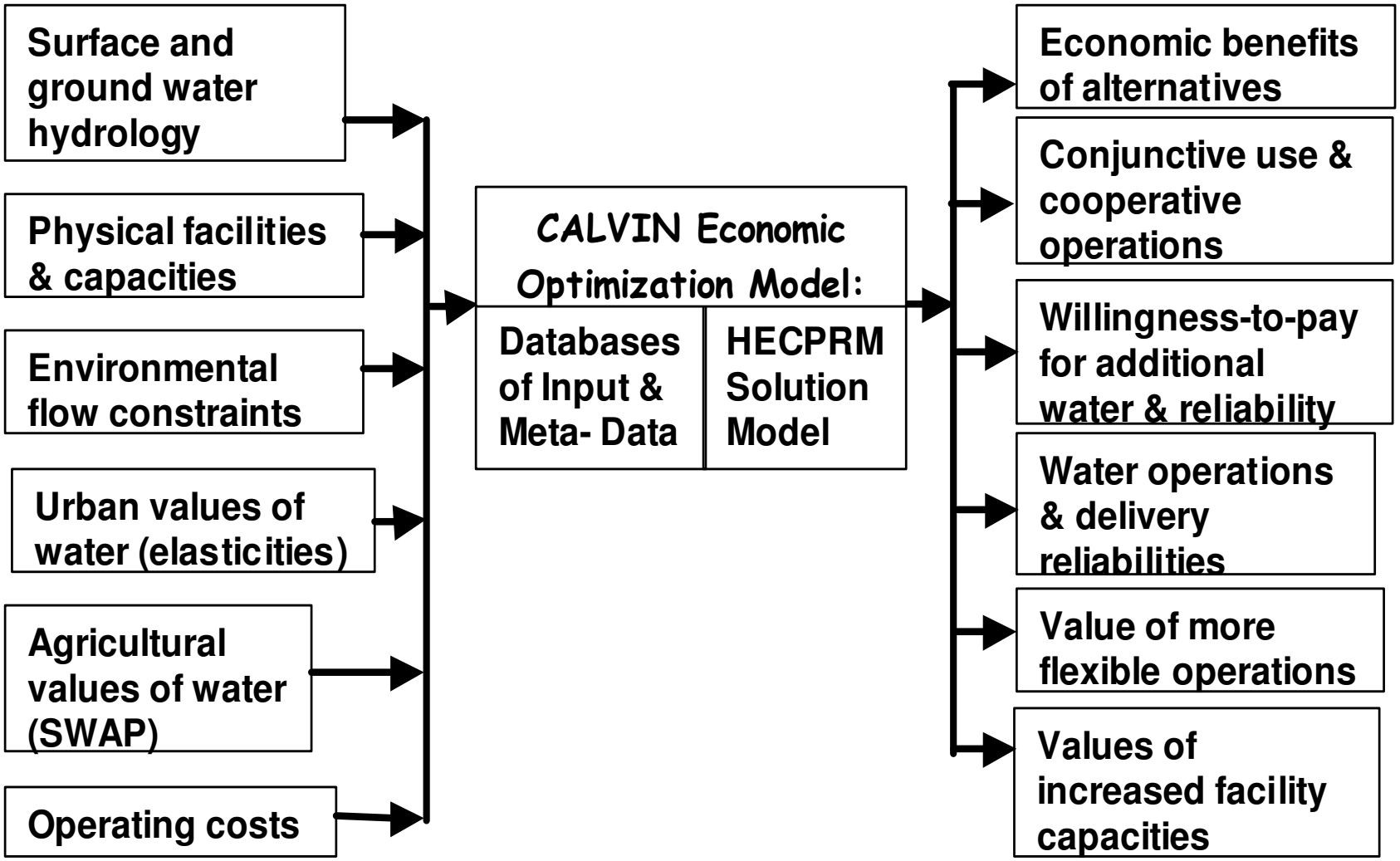
Extensive groundwater

Vast conveyance network

Vast irrigated acreage

36+ million people

Data Flow for the CALVIN Model



Network Flow Optimization

Minimize:

(1) $Z = \Sigma\Sigma\, c_{ij}\, X_{ij}$, X_{ij} is flow from node i to node j

Subject to:

(2) $\Sigma\, X_{ji} = \Sigma\, a_{ij}\, X_{ij} + b_j$ for all nodes j

(3) $X_{ij} \leq u_{ij}$ for all arcs

(4) $X_{ij} \geq l_{ij}$ for all arcs

c_{ij} = economic costs (ag. or urban)

b_j = external inflows to node j

a_{ij} = gains/losses on flows in arc

u_{ij} = upper bound on arc

l_{ij} = lower bound on arc

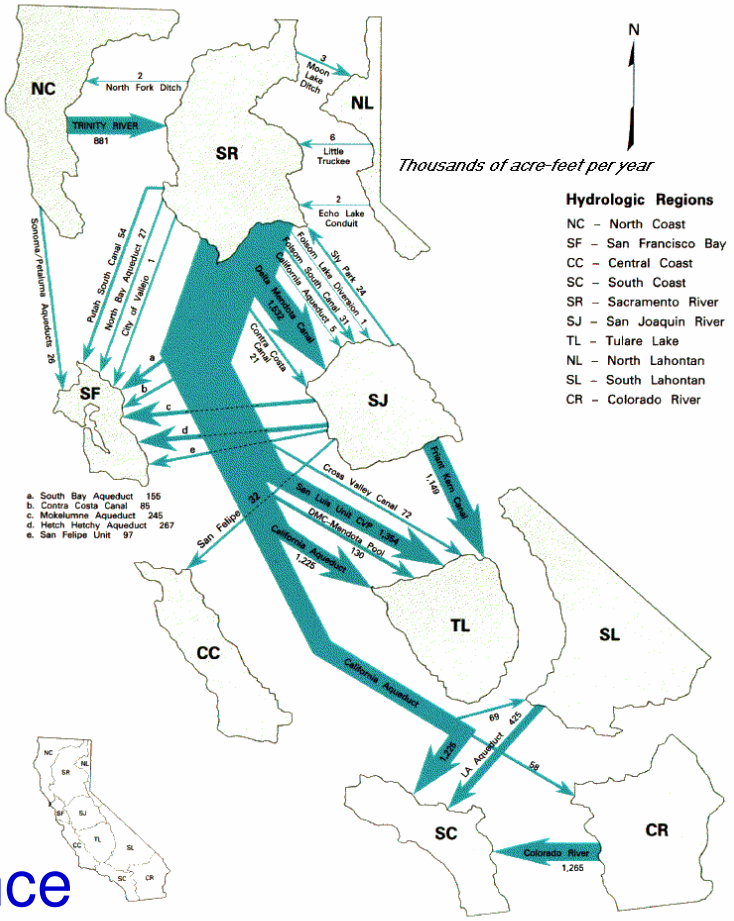
Local & Statewide Activities

Local Activities:

- Groundwater use and recharge
- Surface reservoir operations
- Local water markets and exchanges
- Water use efficiency improvements
- Wastewater reuse
- Desalination

Statewide Activities:

- Inter-regional water conveyance
- Surface reservoir operations
- Water conservation incentives
- Groundwater banking and recharge
- Water market support and conveyance
- Wastewater reuse subsidies



Integrating the mix of responses is important.

Purposes of CALVIN

Economic-engineering optimization of regional and California-wide water supply

User targets:

- Research
- Student education
- Educate California water modeling community:
  - Databases and documentation,
  - Large-scale optimization,
  - Integrated water management,
  - Integrating economics and engineering,
  - Trouble-making?

Applications of CALVIN

- Regional and statewide water markets & values of new facilities (2001)
- Conjunctive use in S. California (2002)
- Restoring Hetch Hetchy (2003)
- Climate warming & adaptation (2003, 2005, now)
- Paleodrought (2005)
- Groundwater overdraft (2006)
- Baja California & Colorado R. Delta (2006 - now)
- Delta water supply impacts (2002, 2007- now)
- Sacramento Valley Conjunctive Use (now)

Proof of concept for innovations

Major Innovations

1) Integrated modeling of integrated systems
   - Surface and ground water
   - Supply and demand
   - Wide range of water management options
   - Economics, engineering, and hydrology
   - Local, regional, and statewide scales
2) Data bases of California's water system
3) Planned integrated modeling
4) Optimization

Does it work? 2001 Predictions

1. Water market transfers
   - IID – San Diego transfers ($800M/yr)
   - Kern–Castaic transfers (~$100M/yr)
   - Sacramento Valley to South transfers
2. CCWD-EBMUD inter-tie
3. No major new surface storage
4. More conjunctive use development
5. CRA conjunctive use fails (2003)

Limitations

- Chapter 5 of 2001 report, on web
- Data problems
- Limits of network flow formulation
- Too smart: perfect hydrologic foresight
- Lack of companion simulation model
- Not finished (interface, data, software, …)

Big models are never finished …

…unless they stop being used.

- Software and interface (GIS and schematic)
- Data
- Companion simulation model
- Foresight
- Groundwater levels and pumping
- Demand variation with wet years
- More water quality effects

Lesson taught by CALVIN

1. Integrated modeling is possible
2. Integrated modeling produces more insightful results
3. Documentation is possible
4. System data bases are possible

Some reflections

Model development worked because:

- We didn't know it could not be done
- Students earnestly made it better
- Nobody took us seriously, politically
- We modeled for insights, not numbers
- Malice of forethought on integrated method, theory, data management and documentation
- Integrated simplicity
- We enjoyed working hard together

Where to go from here?

It is odd for the Forum to give an award to a 7 year old model.

Most 7 year old models should be about ready for retirement, and this is in some ways true for CALVIN.

So we should think about what should come after CALVIN…

Can do better than CALVIN

Final Thoughts

"All models are wrong, but some are useful." – G.E.P. Box

"They can because they think they can." – Virgil