A Wholesale Market for Water that Prices Hydrological, Environmental, and Political Constraints

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Hydrology and Water Trading

Hydrology of water re-charge and water flow implies that injecting an acre-foot now may not be equivalent to withdrawing an acre-foot later at the same location

- Same statement applies to an injection at one location and withdrawal at another location at the same time

Injections and withdrawals at different points in time and/or different locations can also have adverse environmental impacts

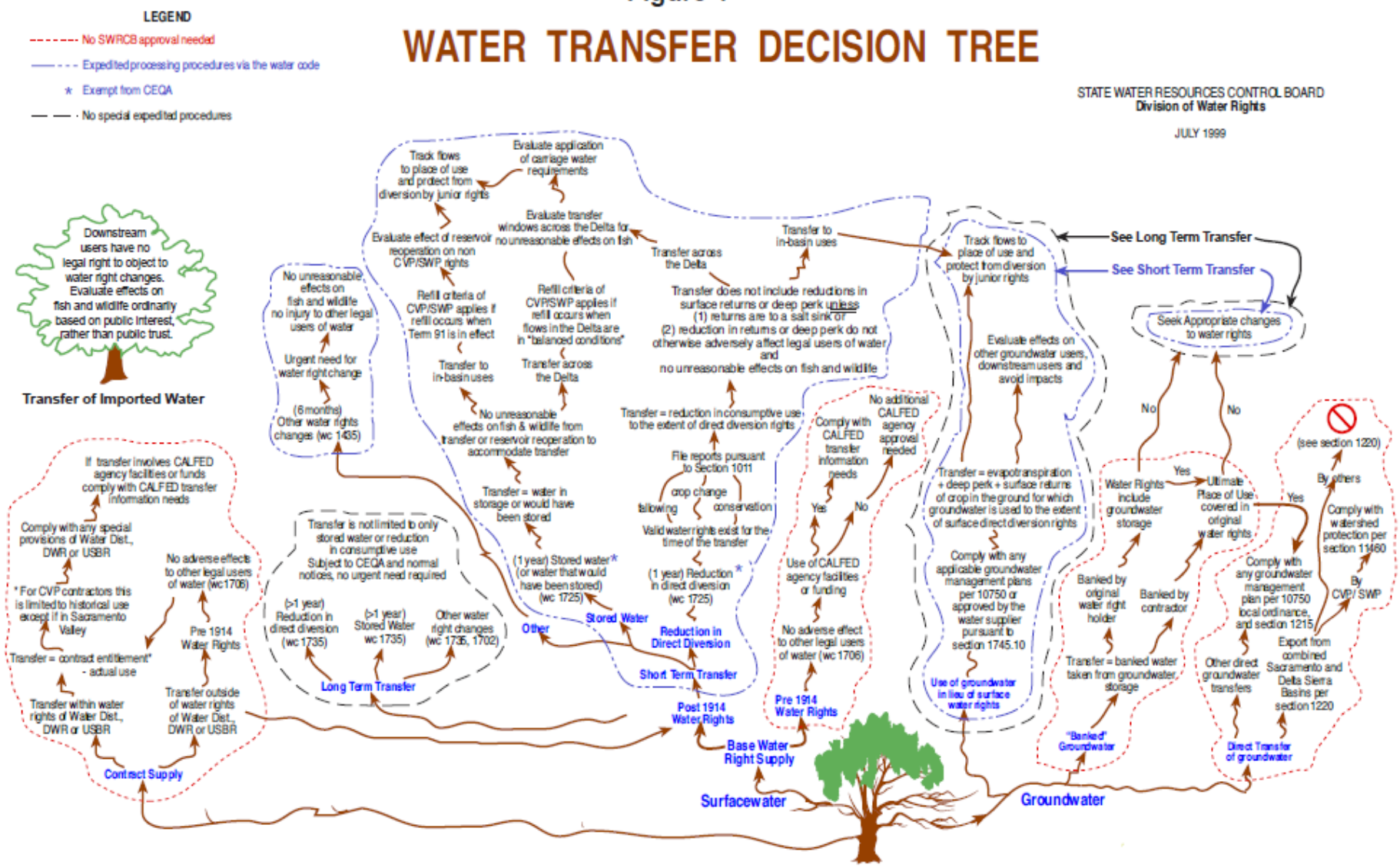
- Harm to fish and wildlife, agriculture, water recreation

Water transfer can adversely impact the ability of other water rights holders to exercise their water rights

Water trades typically occur on a bilateral basis

- *Two parties wishing to trade water must address hydrological, environmental impacts and 3rd party effects through a lawyer-intensive administrative process*

Figure 1



Source: "A Guide to Water Transfers," SWRCB

Electricity and Water Parallels

Electricity Supply Industry re-structuring offers several important lessons for design of wholesale water markets

1) Create Independent System Operator (ISO) for major California water storage and delivery network
2) Use multi-settlement locational marginal pricing (LMP) markets to set prices and schedule deliveries from storage and delivery network

Historically, wholesale electricity trading looked a lot like wholesale water trading

1) Only bilateral transactions that occurred did not harm ability of existing owners of transmission infrastructure to deliver their energy
2) Limited volume of transactions and typically only those that benefitted incumbent vertically integrated utilities
3) Mansur. E.T. and White M.W, (2012) "Market Organization and Efficiency in Electricity Markets" documents enormous increase in trading volume for same physical transmission network that results from establishing a formal wholesale market with LMP pricing

Physics and Electricity Trading

Underlying physics of electricity flows implies that injecting 1 MWh at one location may not allow withdrawal of 1 MWh at another location

1) Transmission network constraints
2) Transmission losses
3) Inertia of generation units
4) Ramp rates of generation units

Failure to account for all physical operating constraints in wholesale market pricing mechanism has led to substantial market inefficiencies

Particularly in the US, which has significantly less transmission capacity to major load centers than other industrialized countries and in regions with a larger share of intermittent renewable generation resources

Analogous logic is likely to apply to a wholesale water market

1) Physical infrastructure constraints on flows
2) Underground hydrological constraints on flows
3) Storage constraints
4) Water losses in man-made and natural water infrastructure

Market Solution for Electricity

Electricity industry handles operation of transmission network with many suppliers and demanders using an independent system operator (ISO)

1) All market participants have equal access to transmission network according to rules approved by relevant regulatory authority (Federal Energy Regulatory Commission [FERC])
2) These market rules or tariff are developed through a stakeholder process
3) All physically feasible trades are allowed subject to tariff

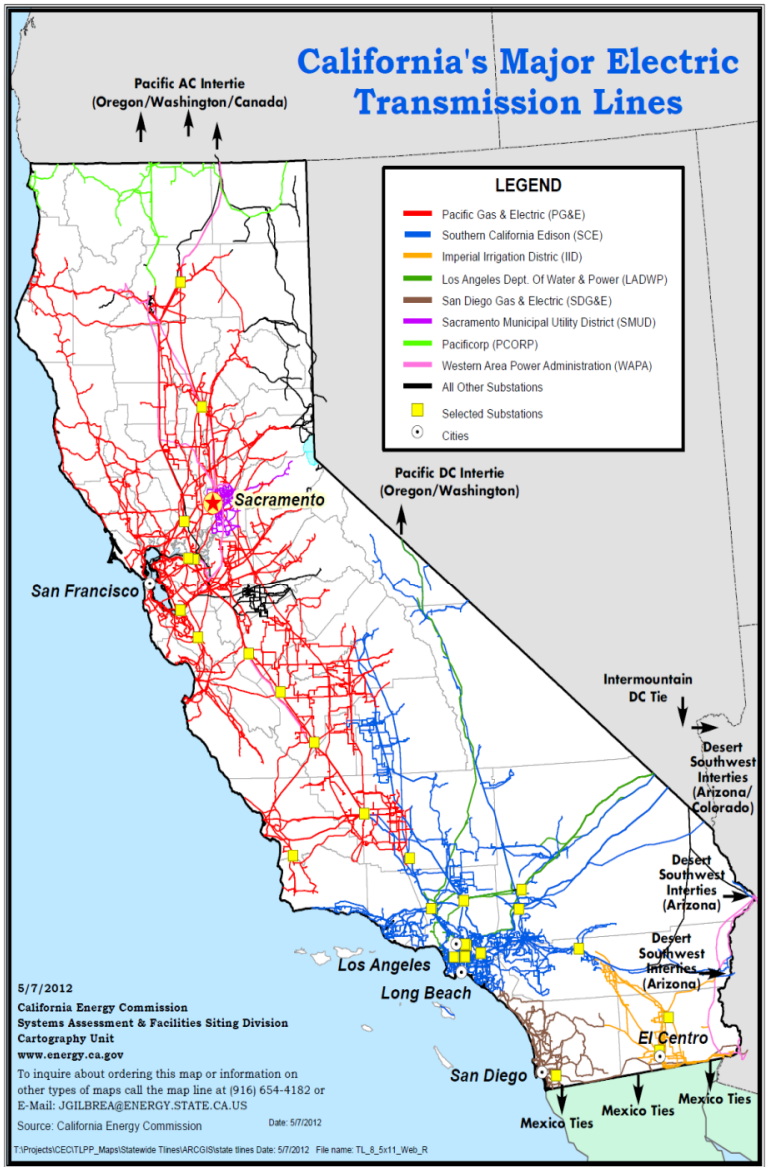
Which locational offers and bids are accepted depends on configuration of transmission network and other relevant operating constraints on transmission network and generation units

ISO must maintain supply and demand balance at all locations in the transmission network at all horizons to delivery

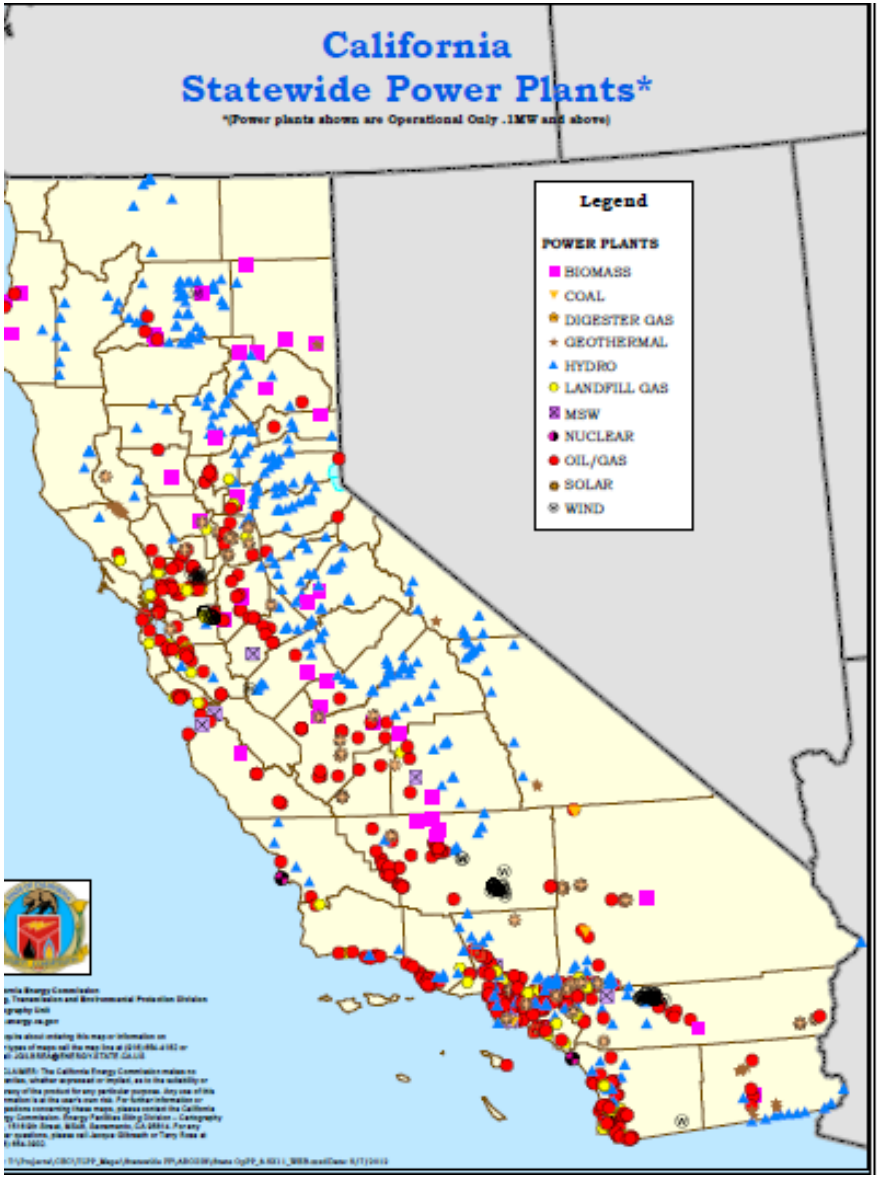
Multiple forward markets operate before actual production and consumption occurs (multi-settlement)

Day-ahead forward market and real-time imbalance market and each respects best estimate of network operating constraints to determine accepted bids and offers

Parallel Networks—Electricity and Water



Parallel Resources—Electricity and Water



Locational Marginal Pricing Market

Producers submit offer (willingness to supply) curves at their location
Consumer submit bid (willingness to demand) curves at their location

Market operator computes prices for each location that account for

1) Natural and physical network constraints
2) Storage constraints
3) Lossses in natural and physical networks
4) Environmental constraints

All producers and consumers have equal access to use of natural (above and below-ground) and man-made water network

1) Producers allocated access based on their offer prices
2) Consumers allocated access based on their bid prices

Market operator sets locational marginal prices that maximize value of feasible trades (sum of consumer surplus and producer surplus)

Multi-Settlement Market

Can run LMP market as various horizons to delivery

1) Run forward market for delivery six months in advance
2) Use market operator's best estimate of configuration of network

Market mechanism determines firm financial commitments that can be bought and sold in subsequent forward markets

Purchase 100 acre-ft of water at location A six months in advance for $200/acre-ft

In three-month ahead market sell 10 acre-ft back at $300/acre-ft

Run forward market at various horizons to clearing date

Market participants trade firm financial commitments subject market operator's best estimate of network configuration

Clear any remaining imbalances between final withdrawals and injections and forward market schedules at real-time price

Application to Water Markets

Run market for water injections and withdrawals over space and time accounting for man-made and natural hydrological network constraints, environmental constraints, and political constraints

Stakeholders agree to a tariff specifying all relevant operating constraints and market rules for a given "water transmission and storage network"

- All feasible trades can occur subject to market rules

Run markets at pre-specified horizons to delivery (multi-settlement) to allow market participants to adjust their final positions in forward markets as closely as possible to real-time injections and withdrawals

Market prices vary over space for each time horizon to delivery

- Potentially a different price set at each location at a given point of time in the future

Current Research

Derive mathematical model of actual water network to implement LMP pricing market

California has a number of water banks, which are essentially small water markets, typically within a single water basin

Use data from water bank to illustrate potential increase in volume of feasible trades and economic benefits from implementing LMP pricing relative to current water allocation mechanism

- Model hydrology of water system
- Environmental constraints
- Political constraints

Compare set of trades and prices that actually occurred with set of feasible trades and prices that result from applying LMP pricing mechanism and modeling all relevant operating constraints

Conclusions from Research on LMP Wholesale Market for Water

Market mechanisms facilitated by ISO can manage increasing water scarcity at least cost

1) Captures economies to scale in transactions costs for water trading by concentrating them in up-front tariff-setting process and then amortizing them over all physically feasible transactions rather than paying for each bilateral transaction

Eliminates large spatial wholesale water price differences except when there is a hydrological, environmental, legal constraint that is binding

Allows market mechanisms to be run over large geographic areas and long time horizons into future

LMP is being successfully used to deliver benefits in other markets

Wolak, F.A. (2011) "Measuring the Benefits of Greater Spatial Granularity in Short-Term Pricing in Wholesale Electricity Markets, *American Economic Review*, May, 247-252.

An LMP market has the potential to deliver even proportionally greater benefits in water sector

Thank you for your attention.
Questions/Comments?

Background papers available at http://www.stanford.edu/~wolak