California Water Ledger

How a blockchain ledger can contribute to the reduction of economic inefficiencies California's water market.

This report presents an overview of California's water market and associated elements. We realize that the market operates well below its optimal point and is limited by the lack of a structured information system. We propose the development of a blockchain-based mechanism to achieve economic, environmental, and social gains from efficient water.

Background

Water in California has been central to the development of the state throughout its history. Southern California, a region with sprawling cities and a population of 23 million would cease to exist at all without the provision of the resource. The Central Valley, often nicknamed the "Salad Bowl of the World", supports a $84 billion dollar agricultural industry- the foundations of which are fully dependent on the state's technonatural infrastructure[1]. Yet California is known to suffer from a lack of rainfall, creating a mercurial relationship between California and its water. [2]

California has built a rich political history related to water management. At the highest level, Article 10 of the Californian Constitution (CA Const. Art. 10, §2) defines an usufructuary right to water. Water departments, agricultural entities, and other stakeholders are emitted the *right to use* water but cannot claim physical ownership. The Constitution outlines the state as a trustee to manage the water supply and resides to delegate water rights through a system of entitlements.

Entitlements & Allocation[3]

Water is allocated through a combination of quantitative and historical calculations. Here we summarize the entitlements at the lowest level.

<u>Riparian</u>- The right to divert from a natural flow adjacent to a parcel. These quantities are variable and dependent on environmental conditions to ensure equal provision to all stakeholders of the watercourse.

<u>Appropriative:</u> Individuals who have been granted appropriative rights may not have land parcels adjacent to the stream or river. The individual who claims such rights may divert water from its original source. These permits may be granted by the State Water Resource Control Board and a permit holder must specify the duration, purpose, and type of diversion. These rights hold a rule of priority so the most junior allocations must be the first to curtail their diversion in times of scarcity.[4]

<u>Groundwater:</u> Any landowner in California has the right to extract groundwater from the land underlying their property. As specified by the Supreme Court of California in 1903, this prevents unregulated and unlimited pumping of

[1] Carroll, Patrick. "Water and Technoscientific State Formation in California." Social Studies of Science, vol. 42, no. 4, June 2012, pp. 489–516., doi:10.1177/0306312712437977.
[2] Fd d "Drought in California." *California | Drought.gov*, 20 Oct. 2018, www.drought.gov/drought/states/california.
[3] United States, Congress, "Background and Recent History of Water Transfers in California ." *Background and Recent History of Water Transfers in California* , 2015.
[4] "Appropriative Rights." *Water Education Foundation*, 2015, www.watereducation.org/aquapedia/appropriative-rights.

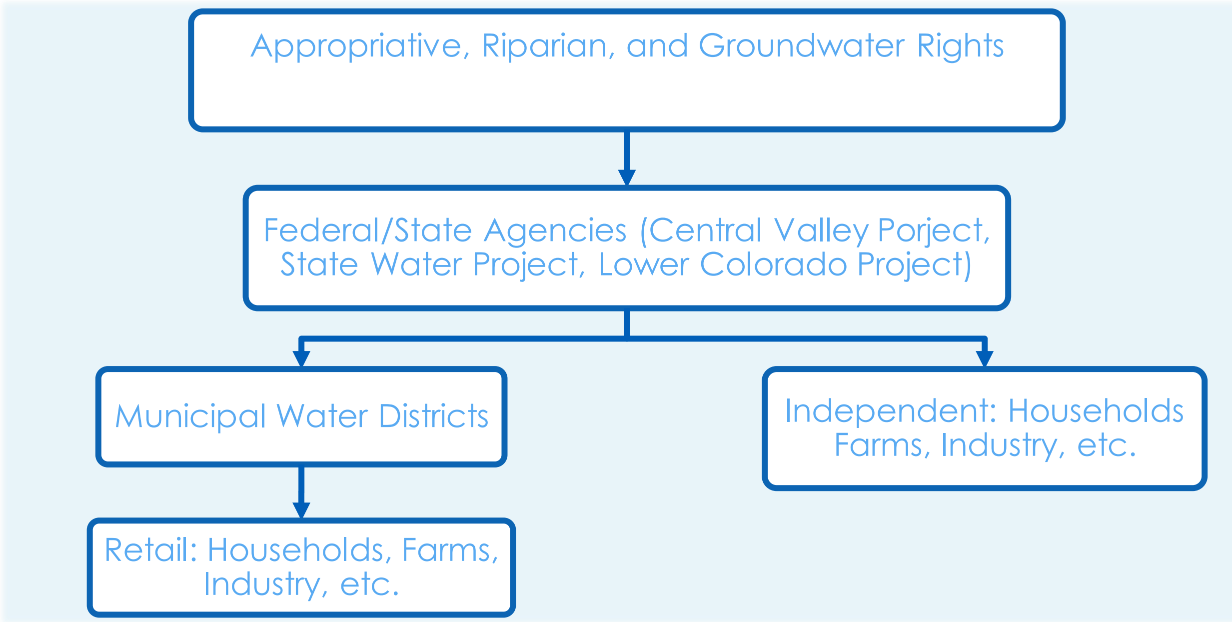

Figure 1: This diagram presents the structure in which entitlements are granted. The root of this structure represents the overall allocation which is then broken down through agencies and markets.

groundwater. The correlative rights of overlying landowners to the groundwater are quantified only when a basin is formally adjudicated.

Transfers

Over the last 40 years, California has experimented with a "water market" through which water entitlements can be bought and sold between both private and public users. The market has become a useful function of water allocation in California. 2 million acre-feet are transferred annually and this helps adjust allocations in reaction to droughts and long-term demographic shifts.

Water transfers are negotiated through contracts that fall into two categories:

1. Permanent sale of water rights
2. Intra-year leases in which sellers transfer a set quantity of water (without relinquishing their entitlement)

These transfers take a handful of parameters into consideration: quantity, duration, price, payment terms, delivery data, delivery pathway, and buyer destination.[5]

The Water Market

From an economic perspective we realize that the market operates well below any optimal equilibrium. The annual transfer volume can be estimated through an

[5] "Technical Information for Preparing Water Transfer Proposals." California Deparment of Water Resources and Bureau of Reclamation, Mid-Pacific Region. Dec. 2015. Information for Parties Preparing Proposals for Water Transfers Requiring Department of Water Resources or Bureau of Reclamation Approval

optimization problem. As we will notice, there are a variety of factors contributing to the market inefficiencies. Each transaction involves a handful of different stakeholders who induce high costs of information, access, and time burden to conduct a transactions. These trades involve a convoluted overhead regulation process that is overseen by the same agencies that issue entitlements.

One clear impediment to smooth market function is the lack of a central structure or database of transfers (seriously, no agency maintains such records!)[6]. The creation of a central database is recommended in a variety of policy papers and journals but has yet to materialize.

A Blockchain Organization for Water Management

Given the distributed nature of the state's agriculture[7], water delivery, and oversight, we can look towards distributed ledger technology to store and maintain data related to water markets. A properly configured blockchain can solve issues that stem from the shared oversight duties between regulatory agencies and private stakeholders.

Projects such as groundwater banking-- where a group of individuals maintains a "groundwater bank" by re-injecting water into the aquifer in wet years—suffer from mismanagement of the operate without a supported "collective-good".[8] A decentralized monitoring network can coordinate stakeholders and regulate groundwater banking by ensuring transparency and equity in the management of the resource.

Evidence

Much of my investigation into this topic has been based on two market studies. The first is a paper from MIT economist Nick Hagerty which analyses a proprietary dataset published by WestWater Research to model prices and transactions throughout the state. The analysis is compelling because it quantifies the ineffectiveness of today's market. [9]

The second paper is written by Ellen Hanak and Elizabeth Stryjewski from the Public Policy Institute of California (PPIC). This piece includes information on the regulations, structure, and trends in water marketing. [10]

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[6] Escriva-Bou, Alvar, et al. "Accounting for California Water." *California Journal of Politics and Policy*, vol. 8, no. 3, 2016, doi:10.5070/p2cjpp8331935.
[7] workshop.caltech.edu/caH2O/presentations/jhall.pdf

[8] "Groundwater Banking." *Water Education Foundation*, Aquapedia, www.watereducation.org/aquapedia/groundwater-banking.
[9] Hagarty, Nick. "Liquid Constrained in California: Estimating the Potential Gains from Water Markets." *Massachusetts Institute of Technology*, 12 Nov. 2017, economics.mit.edu/files/14178.

[10] *Hanak, Ellen, and Elizabeth Styjewski. "California's Water Market, By the Numbers: Update 2012." Public Policy Institute of California, Nov. 2012.*

Market Overview

Two distinct features of California's modern water market are high price dispersion and low transaction volume, relative to the water districts or consumers that *should* have an economic incentive to participate in transactions. Water is a homogeneous commodity in this market and is associated with high transaction costs. The transaction costs stem from regulatory reviews and the cost of conveyance while other factors such as a lack of accessible market information and 'search difficulty' are also significant contributors. Transaction costs are location pair-specific and each transaction is unique from a policy perspective.

Transaction Components

Administrative Costs- There is no single contract or central exchange for water transfers. Buyers and sellers match primarily through word of mouth or through their social network. These costs are substantial in both explicit (legal costs) and implicit (opportunity cost and burden).

Physical transaction costs- Water transfers are logistically intensive as a result of pumping and conveyance through the state's infrastructure. The physical trajectory of a transfer can introduce a range of additional transaction costs. These extra costs are estimated as "wheeling charges", however these estimates are known to be inaccurate.

Regulatory Costs- Three agencies The California State Water Resources Control Board (SWRCB), California's Department of Water Resources (DWR), and U.S. Bureau of Reclamation (USBR)] subject transfers to regulatory review if the water involved falls under their jurisdiction. The transfer review process involved the following:

1. Sellers must compile historical records that prove their legal entitlement and capacity to transfer the water involved in the transaction
2. Estimate the consumptive use (water not returned to the system, transpiration/evaporation)
3. Monitor the transactions and verify that sellers do not consume the water after making a sale (no double spend)
4. Verify that the transfer meets all specific regulatory requirements and limitations, both on the state and federal level (both federal and state law prohibit certain transfers that do significant environmental damage or harm other stakeholders)
5. Schedule the transfer and circumnavigate the infrastructure's capacity constraints.

These regulatory costs are substantial and present a pure loss in terms of economic welfare.

Due to this friction, we can observe large discrepancies in the marginal valuation of water by region, as shown in in Figure 2.

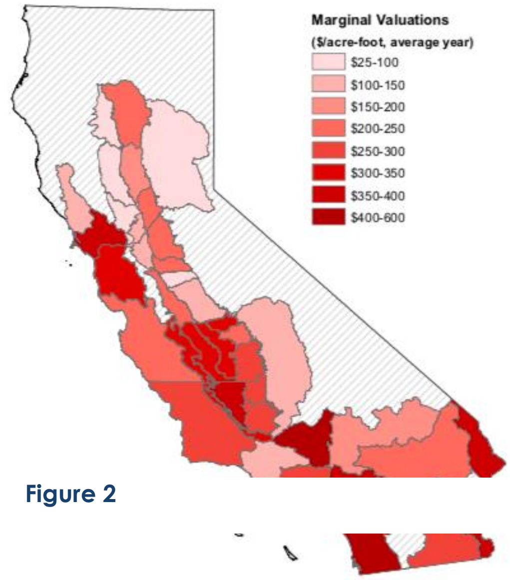

Figure 2

Gains from Coordination

Hagerty's analysis of the water market seeks to simulate the outcomes of transfers in systems where transaction costs are reduced and water is efficiently allocated through increased transaction volumes.

Hagerty makes two relevant estimates relating to potential gains from increased trade. <u>If all regions traded as much water as today's highest exporting (17.5% of water),</u> the quantity traded would increase by a factor of 6 and a consumer surplus gain of $481 million (from $146 million today). There are a number of layers to this optimization problem but the assumptions made by Hagerty seem reasonable.

The second estimate is <u>the gains made by relaxing all non-physical transaction costs</u>. Hagerty estimates that volume traded would increase to 7.58 million acre feet with a consumer surplus of $1.05 billion. This estimate may include some unrealistic assumptions and thus we should reiterate that there are just estimates. However, we can still use this data to guide us in

Hanak and Stryjewski make similar claims from a policy perspective. The researchers have ____ stagnation in the market and identify "the transaction costs for parties wishing to engage in trading" as a significant handicap.

Blockchain for Water (WaterChain)

Building a central platform to conduct these transactions will have significant effects on the market. More so, the decentralization of the respective data and sensors allows the platform to contribute to the growing ecosystem of blockchain projects that animate the physical world.[11]

WaterChain will operate on a token system that supports the deployment of smart contracts to facilitate water transfers.

[11] Tapscott, Don. *Blockchain Revolution*. Portfolio Penguin, 2016.

Components

Store historical data

At the lowest level, WaterChain will act as immutable record of water ownership that can be referenced by each stakeholder in the transfer. The different legal agencies may operate on and reference the ledger.

P2P transactions

Using a front-end interface, two individuals can create a contract that stores the conditions of the transfer (quantity, price, origin, destination, etc.). Upon agreement, the contract will be attached to the blockchain to reflect ownership changes and disperse associated funds.

Compliance/Governance

While these transaction occur between two individuals, WaterChain will facilitate compliance to environmental regulations. Watershed regulations that seek to prevent negative externalities from transfers can be turned into conditional statements on smart contracts. The smart contracts cannot be executed should the contract outline any regulatory violation *before* the transaction occurs. A system for appeals can be constructed using oracles linked to existing judicial agencies.

Facilitate the Transfer

WaterChain can communicate with physical infrastructure to facilitate and verify transactions. Pumps can be monitored to ensure that the water is transferred in full before funds are dispersed. Transactions can be taxed or subsidized when they trigger specified delivery pathways. As we renovate our existing public infrastructure, we want to prepare physical infrastructure to engage in an autonomous and coordinated manner. In this case, we enable communication between the state's existing hydrological tools to create a system of "smart pumps". In an analysis titled "Accounting for California's Water", five PPIC researchers recommend an interconnected system of monitors and sensors to provide a real-time flow data for water managers, water rights-holders, and consumers. [12]

Groundwater Banking

Between the "dry-years" 2007 and 2010, groundwater banking operations helped make 1.9maf of water available. The PPIC believes that banking will be required to expand to "help secure water supply reliability in California, particularly as the Sierra snowpack diminishes with a warming climate". [13]

As with the general market, we can quantify inefficiencies and suggest management solutions. Given the "communal" nature of groundwater banking, we are interested

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[13] Rott, Nathan. "California's Near-Record Snowpack Is Melting Into Raging Rivers." *NPR*, NPR, 3 July 2017, www.npr.org/2017/07/03/534877196/californias-near-record-snowpack-is-melting-into-raging-rivers.

again in applying a decentralized ledger to tailor policy in specific fashion and resolve coordination issues that stem from distrust in today's system.

Conclusion

With an outline of the losses derived from market inefficiencies like a lack of coordination and information gaps, we can conceptualize a blockchain that can automate coordination and introduce a more transparent overview of water in California. There are a diversity of components of associated with creating regulatory blockchain system that range from codifying law (turning environmental regulation into logic statements) to the seamless integration of machines and IoT devices.

One of the long term goals of this project is to increase the equity of water distribution in California. At the present moment, "owning" water as a citizen is a complex proposition, yet every citizen holds an interest in the management of the resource. In a decentralized system, this principle becomes much easier to realize. Re-envisioning water rights has opportunity to democratize water rights and further sustain the principles laid out in the Californian Constitution.

WaterChain seeks to truly modernize California's infrastructure and prepare for future innovation in resource management. As we continue to forecast decentralization trends in socioeconomic sectors, it is my hope that WaterChain will contribute to this growing ecosystem of information, data-sharing, and digital governance.

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